CANADA
DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA
MEMOIR 299

WHITESAIL LAKE MAP-AREA
BRITISH COLUMBIA

By
S. Duffell

THE QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1959

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Panoramic view of the mountains at the head of Tahtsa Lake. The Alcan tunnel pierces the mountain just to the right of the centre of the picture. Topography typical of the Coast Mountains.

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PREFACE

The study of the Whitesail Lake map-area was started as part of a systematic program. During the course of the work, however, the area came into unexpected prominence on account of the various projects resulting from the power developments of the Aluminum Company of Canada. New exploration was done on the known mineral deposits and active prospecting led to the discovery of others. Not only, therefore, is geological information of timely importance made available by this work, but much information was gained from outcrops that have since been buried beneath the rising waters of the flooded areas. Data from these outcrops may never again be available.

The mapping clearly showed that the Coast Mountains, by many still considered to be composed mainly of granitic rocks rarely good hosts for mineral deposits, are actually underlain by extensive areas of non-granitic rocks known to contain important orebodies. The Coast Mountains therefore contain areas well worth prospecting, and although prospecting is difficult it is by no means impossible with the aid of modern facilities.

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

OTTAWA, May 31, 1957

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Chapter I

INTRODUCTION

Whitesail Lake map-area lies in west-central British Columbia between latitudes 53° and 54° north, and longitudes 126° and 128° west, and has an area of about 5,650 square miles.

The presence of lead-zinc-silver deposits on Mount Sweeney has long been known, and the discovery of gold-bearing quartz veins and tungsten deposits on Lindquist Peak in 1943 and 1944 created so much interest that mapping of the whole area was undertaken to provide a modern base map and to complete mapping the geology. Although part of the area was previously mapped geologically in a reconnaissance manner, much of the two-degree quadrangle had never been mapped. Lying as it does along the eastern margin of the Coast Mountains, the area is favourably situated for the occurrence of mineral deposits. In 1946 the Royal Canadian Air Force photographed the area and in 1947 both topographical and geological survey parties commenced work. Geological field work was continued by the author each field season until completed in 1952.

Owing to the unfavourable economic position of gold in 1947, exploration of the gold-bearing veins on Lindquist Peak stopped and little prospecting was done in the area in 1947 and 1948. Interest was rekindled when preliminary surveys of the Aluminum Company of Canada, relative to their projected smelter at Kitimat, were made during 1948-50, and it was further stimulated by the Aluminum Company's decision, early in 1951, to proceed with the Kitimat project. Accordingly the Emerald Glacier property on Mount Sweeney pushed forward active development and attained a small production of lead, zinc and silver. This interest in prospecting continued through 1952, resulting in the discovery of new gold and copper deposits and a re-examination of some of the known properties in the area, including the gold and tungsten showings on Lindquist Peak.

The development of the hydro-electric possibilities of the area by the Aluminum Company of Canada reached full momentum in 1952. The greater part of the storage basin for this development lies within the boundaries of the map-area and the whole economy of the area is thus directly affected. Parts of the map-area adjacent to the lake system were flooded by the raised lake levels, and many excellent outcrops made inaccessible.

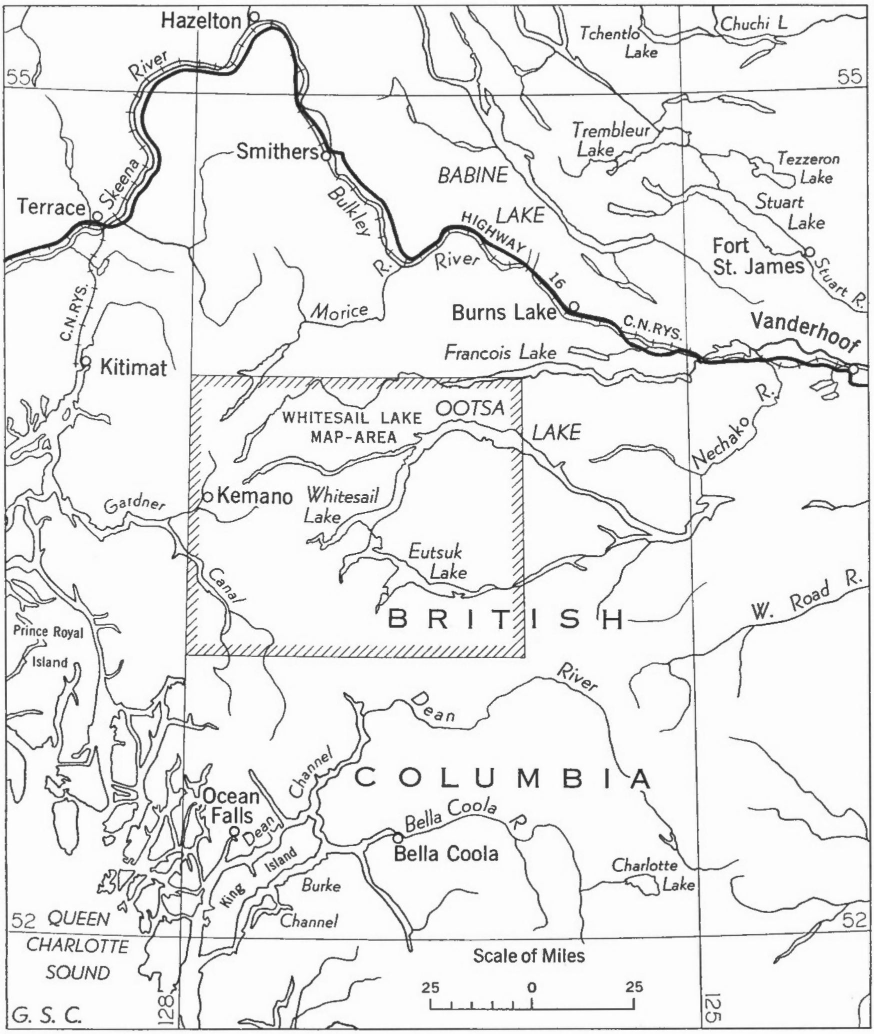

Figure 1. Index map of west-central British Columbia, showing position of Whitesail Lake map-area.

Location and Accessibility

The northern boundary of the area coincides with the western end of Francois Lake, which lies 15 miles south of the town of Burns Lake on the Jasper—Prince Rupert line of the Canadian National Railways. Except for the rugged northwest and southwest corners, most of the map-area lies within the boundaries of Tweedsmuir Provincial Park, an area of lakes and snow-capped peaks preserved in its natural state for its beauty and tourist attraction. Consequently, there are no towns or villages within the map-area, the only settled parts being along the north shore of Ootsa Lake and between there and Francois Lake. The settlement of Ootsa Lake provides general-store facilities but the main business centre for the area is Burns Lake, 45 miles by road north from Ootsa Lake. The town of Burns Lake provides all normal facilities for communication and commerce, including banks, telephone and telegraph services, government offices, Royal Canadian Mounted Police, hospital, rail service, charter aircraft service, excellent general and grocery stores, hardware stores, and service for all makes of cars and trucks. During 1952 business on the railway increased to such an extent that it was necessary to augment the train service from thrice weekly to daily except Sunday.

Only in the inhabited northeast corner of the area are there any roads. Ootsa Lake is connected to Burns Lake by a good gravel road that is passable all year round. As Burns Lake is on the main British Columbia highway system the area may be reached by car from all points. Good gravel roads extend along the north shores of both Ootsa and Francois Lakes and these are connected by a road from Wistaria to Nadina River at the head of Francois Lake. Another good road serves the settlers along the south shore of Francois Lake, between Grassy Plains and Isaac Lake. Numerous farm and logging roads have been built by the inhabitants from the main road system, which is kept open the year round. The provincial government operates a car ferry across Francois Lake during the open-water season. In winter, travel to Burns Lake must be made via Wistaria and around the head of Francois Lake.

In 1951 the Aluminum Company of Canada constructed an all-weather gravel highway from Francois Lake to Tahtsa Lake, thus facilitating travel in a formerly inaccessible area. This distance can now be covered by car in 3 to 4 hours, whereas it previously took a week's tedious travel by pack-train. The Aluminum Company also constructed service roads up Kemano River and Horetzky Creek valleys. The remainder of the area is devoid of roads, and trails are few.

During the water-resources surveys of 1928 to 1938 numerous trails were cut in the area but these are now for the most part obliterated. Trails usable while the field work was being done were mainly those of prospectors and guides. J. W. McNeill, a guide who lived at Ootsa Lake, cut a trail from the foot of the lake to Blanchet Lake and maintained a trail up Wells Creek to Mount Wells. B. R. Harrison, a guide who lived at Wistaria, maintained a good trail from Ootsa Lake opposite Wistaria to Mount Wells, Tweedsmuir Peak, Glatheli Lake, Michel Peak, and Goodrich Lake. These trails were used mainly for hunting parties but were excellent means of access to the plateau area between Ootsa and Eutsuk Lakes known as the 'Circle'.

A good trail ascends the northwest shoulder of Chikamin Mountain, servicing the various mineral showings there, and an excellent trail leads to Deer Horn mine on Lindquist Peak. Recently a road was constructed from Lindquist Lake to the property.

From Copps cabin on Tahtsa River just above the confluence of Kasalka Creek an excellent trail leads to the mineral showings on Swing Peak. Trappers' trails used mainly in winter were encountered in most valleys but were of little use during the summer season.

The main means of transportation in Tweedsmuir Park prior to the flooding was by open river and lake boat and outboard motor. The river boats used by the inhabitants were 20 to 35 feet in length and of narrow beam. They were commonly propelled by outboard motors of 22 or 25 horsepower. Whitesail River was not difficult to navigate, but Tahtsa River, particularly in its upper 8 to 10 miles, required experienced river men with knowledge of the channels. Both rivers were fast and tortuous towards their heads. In August and September, during the period of low water, they were shallow and difficult to navigate. With the raised water level travel on these rivers will be easier and it will be possible to use much larger boats.

All parts of the area between Eutsuk, Whitesail, and Ootsa Lakes may be reached by pack-train with relative ease. Pack-trains were used also in those parts of the area south of Eutsuk Lake and east of Pondosy Lake, between Nadina Lake and Newcombe Lake, and on the north side of the Tahtsa Range.

Much of the area may be reached by aircraft from Burns Lake where Pacific Western Airways maintains a base. The party was landed on Kitlope, Ear, Kimsquit, Tesla, and Morice Lakes.

Population and Industries

Previous to the commencement of the Alcan project in this part of British Columbia about 150 people were living in the area. Most of them lived in the northeast corner in the settlements of Ootsa Lake and Wistaria. As the work on the project progressed the population increased, but this was only temporary as those living along the shores of Ootsa Lake were forced to move due to flooding of the lake. The Aluminum Company of Canada, however, compensated each property owner for loss of land, buildings, and livelihood.

Of recent years logging has been of prime importance and many residents are employed in cutting and hauling timber, particularly during the winter months. A few make their entire income from farming and nearly all operate small farms part-time. Cattle raising is the main agricultural enterprise though some grains are grown and grasses are raised for their seed. The climate is favourable for raising root vegetables and good crops are common. The long distance from suitable markets, however, prevents the industry from being profitable.

The outfitting and guiding of hunting and fishing parties represents a major source of income for a large proportion of the residents. The proximity of Tweedsmuir Park, an area of rugged mountains and beautiful rivers and lakes where fish and game abound, makes this occupation a natural and important one in the region. Moose, goat, deer, and bear, both grizzly and black, are plentiful. Caribou, once present in great herds in the plateau country between Eutsuk and Ootsa Lakes, have now declined to such an extent that they are protected. Their decline is attributed to the increased number of wolves rather than to the greed of the hunter. Canada geese and duck gather in flocks by the hundreds along the shores and marshes of Sinclair and Ootsa Lakes in the autumn of the year. The more common varieties of grouse are plentiful in most wooded areas. Fishing is excellent in all of the lakes, rainbow trout being the main catch.

Prospecting and mining have played an important part in the economic life of the area. Lead, zinc, silver, gold, copper and tungsten have been found. Three of the properties have had considerable exploration work done on them and one property attained some production during 1951 and 1952.

Trapping has always been a basic part-time occupation of the inhabitants, and residents hold trap lines, though they do not use them every year. Beaver, mink, muskrat, martin, fisher, otter, fox, and lynx have all been trapped for their fur.

Climate

The climate of the Whitesail Lake map-area varies greatly, precipitation, for example, being much greater on the western border than at Wistaria or Ootsa Lake. Wistaria is the only place where weather records have been kept for any lengthy period, so information on the climate of the area as a whole is meagre.

Average precipitation at Wistaria over a 25-year period to 1950 was 18.02 inches, the heaviest precipitation being in November and December. Kitimat on the coast just west of the area records an average precipitation over a 15-year period to 1927 of 88.98 inches. In the mountains at the head of the large lakes the precipitation is still greater, with snowfalls up to 50 feet. Some of this snow remains throughout the summer giving rise to numerous alpine and cirque glaciers.

At Wistaria frost occurs in practically every month of the year. From the records examined, only June and July were frost free and then not every year. Warmest months are June, July and August which average about 56 degrees Fahrenheit; coldest months are December, January and February which average 18 degrees Fahrenheit. High temperatures in summer are 80 to 85 degrees and low temperatures in winter are 40 to 50 degrees below zero. The climate in the eastern part of the area is typical of the plateau region of British Columbia but the southwestern and western parts have a coast climate.

Previous Work

The first explorer to enter the region was Alexander Mackenzie who, on his famous journey in 1793 from the Peace River to the coast at Bentinck Arm, passed just south of the area. In the summer of 1874 James Richardson of the Geological Survey of Canada and Charles Horetzky on behalf of the Canadian Pacific Railway, explored Gardner Canal as far as Kemano Bay and proceeded up Kemano River for a distance of some 25 miles. They also explored Kitimat Arm, and Richardson described the flat-lying, heavily timbered land along Kitimat River. In 1875 G. M. Dawson traversed the country between Fraser River and the Coast Mountains from Bella Coola valley to Francois Lake. This trip included a visit to the Nechako River and canyon, now the site of the Kenney Dam which blocks the eastward flow of the Nechako River. He also visited Francois Lake and described the rock outcrops and general country along both shores. Assistants were sent to gather rock specimens from Ootsa Lake to the south. In 1905 William Fleet Robertson, provincial mineralogist for British Columbia, briefly visited Francois and Ootsa Lakes on a trip from Quesnel to Hazelton along the old 'Telegraph' trail.

Settlers began to inhabit the shores of Ootsa Lake in the first decade of the century. By 1914 and 1915 there was considerable interest in the mineral showings on Mount Sweeney and Sibola Peak and in 1916 John D. Galloway of the British Columbia Department of Mines made a reconnaissance trip south from the Grand Trunk Railway to Bella Coola, along the eastern boundary of the Coast Range. He left Houston on the railway and visited Mount Sweeney and Sibola Peak, examining the mineral claims there. He also reported on the rocks along Ootsa Lake, Tahtsa River, Whitesail River, Whitesail Lake, and Eutsuk Lake, refitting himself at Ootsa for the remainder of his journey to Bella Coola. As a packer on this trip Galloway hired Barney Mulvaney who was still a prominent character in the country during the period of the survey. At Ootsa Lake he hired James Morgan, a pioneer rancher along the lake whose son and daughter still reside in the district.

In 1920 R. W. Brock, of the Geological Survey of Canada, spent the summer studying the rocks along Ootsa, Whitesail, and Eutsuk Lakes. In 1924 and 1925 the work of the Geological Survey was continued by J. R. Marshall who mapped a large part of the area, and in 1935 by M. S. Hedley who mapped the area north of Tahtsa River to the head of Tahtsa Lake. In 1945, S. Holland of the British Columbia Department of Mines reported on the properties in the area. The work on which this report is based was done during the field seasons of 1947-52.

Acknowledgments

The residents of the area extended many courtesies to the writer and his men. They freely gave information and advice on travel through the country, as well as permission to use cabins along the main travel routes. The Harrison family of Wistaria and the McNeill family of Ootsa Lake generously gave assistance in transportation of equipment and supplies, and were keenly interested in the welfare of the parties and the progress of the work. Mr. A. Pelletier and Mr. N. Pratt of the Ootsa Lake general store made every effort to obtain necessary supplies and helped immeasureably by the extra efforts they put forth. The officers and engineers of the Aluminum Company of Canada extended hospitality and many kindnesses to the party.

Efficient assistance was rendered in the field by H. W. Tipper, J. A. Roddick, J. E. Reesor, J. R. Woodcock, J. K. Eccles, and numerous other summer student assistants. R. V. Morris, N. Erhorn, L. Aslin and C. Bennett rendered efficient service as packers during the course of the work.

Chapter II

PHYSICAL FEATURES

Physiography

Two main physiographic subdivisions of the Canadian Cordillera, namely, the Pacific Ranges of the Coast Mountains and the Nechako Plateau, are represented in Whitesail Lake map-area. The transition zone between these two main subdivisions is also well represented.

The rugged granitic mountains at the heads of the long lakes and the mountains bordering the Kimsquit River valley form the eastern edge of the Coast Mountains. On the other hand the rolling country along the eastern border of the map-area is well within the Nechako Plateau region. The intervening part, including the large lakes, comprises the transition zone between the two main subdivisions. This lake system is one of the few of its kind along the whole eastern boundary of the Coast Mountains and is very similar to the long narrow fiords on the western side.

Coast Mountains

Southwest of the heads of the large lakes, the Pacific Ranges of the Coast Mountains rise in a series of sharp crested ridges and lofty peaks separated by a network of deeply incised valleys. Relief at Ear Lake immediately west of the divide is between 5,000 and 5,500 feet, whereas relief on the eastern slope of this line of hills is 3,000 to 3,500 feet. Except for Tsaydaychuz Peak 9,085 feet and Salient Mountain 7,981 feet, the peaks near the heads of the lakes are mostly about 7,000 feet being slightly higher in the southern part of the area and slightly lower towards the northwest (*see* Plate II B). These peaks form the divide between coast drainage and drainage eastward through Nechako River to Fraser River and through Morice River to Skeena River. They are composed largely of granitoid rocks particularly on their western slopes but contain significant amounts of metamorphosed sedimentary and volcanic rocks.

For at least half of their extent in the map-area this line of mountains is bounded on the west by the deeply incised valley of Kimsquit River almost 2,000 feet lower than the valley floors on the opposite or eastern slope of the divide. This valley trends northwest and is longitudinal with respect to the Coast Mountains. West and southwest of Kimsquit Valley the mountains are composed almost entirely of granitoid rocks. The peaks in this part are not as high as those to the east but the terrain is more rugged and the relief greater. The valleys are much more deeply incised and drainage is well established, all major valleys being eroded to about the same level.

Kemano and Kitlope River valleys are also longitudinal valleys, carrying drainage to the Gardner Canal from the western slope of this same line of hills. These longitudinal valleys form the trunk drainage arteries in this part of the Coast Mountains, and a series of tributary, transverse valleys, trending generally northeast, form a rectangular pattern with the longitudinal lineaments. The transverse valleys and lineaments cross the divide and are marked on the eastern slope by the long narrow lakes that characterize the area. They are also apparent in the fiord system farther west on the coast.

Transitional Zone

East of the height of land the character and composition of the mountains change perceptibly. The rocks are mainly volcanic and sedimentary types, cut by local stocks and cupolas of granitoid rocks. The sedimentary and volcanic rocks are commonly highly metamorphosed. Main valleys are 2,000 to 2,500 feet higher than on the western side of the divide and yet the mountains are only slightly higher. The relief therefore is not so great or the terrain so rugged. The main ranges, such as Chikamin, Whitesail, Tahtsa, Kasalka, and Sibola, trend northeasterly transverse to the general trend of the Coast Mountains. They are parallel to, and separated by, the transverse valleys occupied by the long narrow lakes and each is characterized near its western extremity by a main peak just over 7,000 feet high, and towards its eastern end by a plateau-like area 4,500 to 5,000 feet high that merges into the general configuration of the main plateau area. It is proposed to refer to these as 'Transitional Ranges'.

The sedimentary and volcanic rocks composing the transitional ranges trend northwesterly parallel with the trend of the Coast Mountains rather than with the direction of the transverse valleys. Therefore, it appears that these valleys are a result of erosional forces rather than orogenic factors. Erosion, at least in its initial stage, did follow joints or fractures in the batholithic rocks that are part of the regional fracture system. As erosion continued the valleys were widened and deepened leaving highland areas between them. There is some evidence that these valleys were well established by early Tertiary time and that they were main ice channels during

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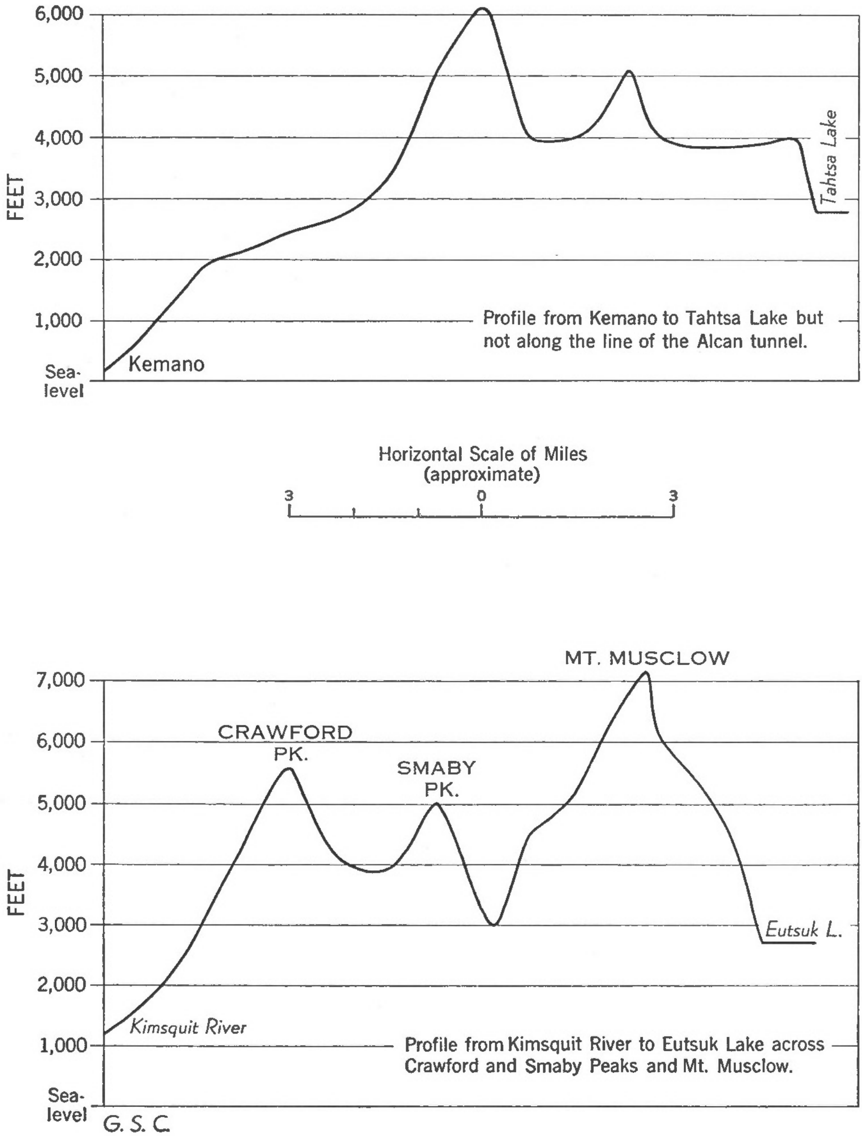

Figure 2. ***Profiles from southwest to northeast across the drainage divide along the eastern side of the Coast Mountains in Whitesail Lake area. The profiles show the difference in elevation between the major valley bottoms on the southwest side of the divide and the large lakes on the northeast side.***

the Pleistocene period. The lakes at the heads of these valleys in the eastern flanks of the Coast Mountains have their outlets in typical plateau country and therefore traverse the zone of transition between Coast Mountain and Plateau topography.

Nechako Plateau

That part of the area east and northeast of the lake system belongs properly to the Interior Plateau region and in particular to the Nechako Plateau. The general level of this plateau varies between 3,000 and 4,000 feet with hills to 5,000 feet and occasional peaks to 7,000 feet. Much of the plateau is mantled with till and is spotted with hundreds of lakes and open wet meadows. In this part of the plateau the streams are not large or deeply incised and most have a gentle gradient. Main streams are relatively shallow, often too much so for navigation during low-water period. Forest cover is lodgepole pine and poplar with numerous open grassy areas.

The highest area in the plateau region is the range of hills near its western border that includes Chef Ridge, Michel Peak, Tweedsmuir Peak, and Mount Wells, all over 7,000 feet in elevation. Lowest valleys are those of Francois Lake 2,346 feet and Ootsa Lake 2,666 feet in elevation.

Mosquito Hills and Shelford Hills form two prominent high areas in the western part of the plateau, but reach an elevation of 5,000 feet only at one point in the Shelford Hills. Except for the higher parts of the 7,000-foot mountains mentioned previously, all summits in the plateau are forested. Only a small part, probably less than one-quarter, of the map-area may properly be included in the plateau region.

Drainage and Drainage History

Three main watersheds lie within the map-area; the Nechako basin, a Skeena drainage, and a western watershed.

The Nechako basin covers most of the area and includes Eutsuk, Whitesail, Troitsa, Tahtsa and Ootsa Lakes which form a large part of the storage basin for the power development of the Aluminum Company of Canada. Francois Lake and its tributaries are also included in this basin. Drainage is via Nechako River to Fraser River.

Nanika, Kidprice, and Morice Lakes are separated from the Nechako basin by a low divide and drain eastward via Morice River to the Skeena drainage.

West of the main divide, drainage is by trunk streams in deeply incised valleys of the Kimsquit, Kitlope, and Kemano Rivers. These trunk streams are fed by countless mountain torrents cascading from the high peaks, down steep-sided mountains, through narrow ravines and canyons, to the floors of these deep valleys.

The series of long, narrow, subparallel lakes along the eastern slope of the Coast Mountains is the most striking drainage feature of the area. Large lakes occur elsewhere along the eastern slope of these mountains but nowhere are they as numerous as in Whitesail Lake map-area. Altogether there are eight valleys that form major lake basins, all of which flow eastward. The elevation of the lakes in these valleys varies from 2,614 to 3,100 feet. As Upper Cretaceous and Tertiary rocks were deposited in these valleys it seems most probable they originated in Cretaceous time. During Pleistocene time these valleys formed avenues of egress for the ice flowing off the core of the Coast Mountains. These ice streams excavated most deeply near the mountains, thus forming the lake basins as we know them today. Post-Pleistocene uplift has been recorded along the deep fiords but any such uplift in this area has not been sufficient to erase the lake basins. One important factor in their preservation is that no westward-flowing stream on the opposite side of the mountains has eroded headward sufficiently to capture any of the drainage feeding these lakes. If, for instance, a tributary of Gamsby River had eroded headward sufficiently to capture Whitesail Lake, possibly both Whitesail and Eutsuk Lakes would now drain westward.

Aluminum Company of Canada Power Development

The power development of the Aluminum Company of Canada has changed the flow of the large lakes in this area from east to west and made available over 1,600,000 horsepower. This has been a great step forward for British Columbia and for this part of the province in particular. The roads built during construction give access to parts of the area hitherto isolated and the growth of the city of Kitimat will bring many people into the general region.

As early as 1930 and 1931 the Water Rights Branch of the Province of British Columbia had information indicating that the lakes draining eastward through the Nechako River could be made to flow westward by damming the eastward flow and cutting a tunnel through the mountains to the coast. Two alternative diversions were considered each of which would develop only part of the lake system. One from Eutsuk Lake to Kimsquit River was calculated to give upwards of 600,000 horsepower, and one from Tahtsa Lake to Kemano River was calculated to give upwards of

500,000 horsepower. For some 20 years no action was taken because of lack of suitable markets for such large amounts of electrical power. After World War II, the Aluminum Company of Canada was in search of a suitable location for the erection of a new production plant requiring large amounts of power, and the British Columbia government interested this Company in the possibilities of the province. Many sites were investigated both in British Columbia and elsewhere before the decision was reached to locate the plant at Kitimat and the powerhouse at Kemano. The project finally agreed upon had all the requirements necessary; sufficient power at low cost, a harbour suitable the year round, and space for smelter and townsite. The project was expanded from that originally envisaged by the Water Rights Branch of British Columbia to embrace the whole chain of lakes in the system, thus giving a potential of 1,695,000 horsepower when fully developed.

Preliminary surveys were conducted by the Aluminum Company from 1948-50, and actual construction commenced in the spring of 1951. A dam, known as the Kenney Dam, 325 feet high and 1,500 feet long was built just above the canyon of the Nechako River. It was completed in the autumn of 1952, and the basin began filling in November of that year. The dam was named after the Honourable E. T. Kenney, Minister of Lands and Forests in the British Columbia government during the period of construction, who was largely responsible for interesting the Aluminum Company in the possibilities of the project site. The dam contains the waters of Eutsuk, Whitesail, Tahtsa, Troitsa and Ootsa Lakes which lie inside the area, and Tetachuck, Natalkuz, Intata, Euchu and Chelaslie Lakes east of the area, to a working level of 2,800 feet elevation. The artificial lake formed by the dam on the Nechako River is calculated to cover an area of 335 square miles and be 135 feet higher than the old level of Ootsa Lake. When required the waters of Nanika and Kidprice Lakes may be made to flow into the storage basin by placing a dam at the outlet of Kidprice Lake and cutting a tunnel from Nanika Lake to Tahtsa Lake.

A tunnel 25 feet in diameter and about 10 miles in length was driven through the mountains between the head of the Tahtsa Lake and Kemano River (*see* Frontispiece). Through this tunnel the waters of the artificial lake now flow westward towards Kemano River. The course of the tunnel runs roughly along the north side of Horetzky Creek. Some delay in the driving of the tunnel, particularly in the eastern end, was caused by unexpected broken ground conditions, resulting in the necessity of supporting a much larger proportion of the tunnel than was first estimated.

The power-plant is located underground in huge chambers excavated in Mount DuBose. Perhaps the most difficult of the various integrated projects was the design and construction of the 50-mile long, high tension power-line from the generating plant at Kemano, across rugged Coast Mountains to Kitimat where the smelter and townsite are located.

The whole project was divided into several smaller projects all of which were completed on a schedule that permitted the production of aluminum by the autumn of 1954.

Surveying and engineering were under the direction of B.C. International Engineers, and Morrison Knudsen Company of Boise, Idaho, U.S.A. were contractors for the dam, power-line and tunnel. Though the power potential of the fully developed project is 1,695,000 horsepower, the initial installation was for a capacity of 425,000 horsepower. Additional installations can be made when required.

These great man-made alterations in the drainage and topography of the area will undoubtedly bring changes to the life and character of the region. Many of the feeding and nesting grounds of the wild game and birds were flooded, necessitating an adjustment on their part, and of course all those people living within the area were forced to move. It is within the realm of possibility that industries based on either mineral or forest products will locate on the shores of the vast lake produced by this project. Flooding in some areas widened the waterways considerably, but where the channels were confined between steep mountains there has been little change.

The salmon do not run in this basin and there has been no damage to the fishing industry; in fact a lake so large could support a small inland freshwater fishing industry if stocked with the proper fish. Transportation is much easier and it is possible to use larger and more comfortable vessels. However, all the changes this project will bring to the area cannot be assessed at this time.

The field work on which the geology of this report is based was completed before the flooding, the geology was therefore mapped down to the old shorelines. This information is shown on the accompanying map and the new position of the water level indicated.

Glaciation

Features due to glaciation are widespread in Whitesail Lake map-area and glacial debris is everywhere. All of this part of British Columbia was at some time covered by ice. Even today alpine glaciation is active in the higher mountains and nearly every peak of 7,000 feet has its cirque glacier or ice-cap. Commonly a peak may have two or three small cirque glaciers giving it a horn-like appearance. The largest ice-field entirely within the area is about 9 miles long by 3 miles wide. It lies south of Seel Lake and supplies several small ice tongues and one prominent valley glacier. West of the headwaters of Morice Lake is another large ice-field, only part of which lies within the map-area. The cirques on higher peaks of the Transitional Ranges, such as Chikamin Mountain and Troitsa Peak, contain small glaciers, but towards the eastern and lower ends of these ranges, at an elevation of about 5,000 feet, some cirques on the north side of the range are ice free. Evidently alpine glaciation was formerly more extensive. This is borne out by many instances of terminal and lateral moraines well in advance of their present ice lobes, and such structures as hanging valleys, truncated spurs, and U-shaped valleys.

Drift is abundant in the valleys and covers the plateau areas. The bulk of the material is fluvioglacial in origin, particularly along the present drainage channels, and consists mainly of silt, sand, and gravel. In one part of Tahtsa River, about 8 miles below Kasalka Creek, the banks of the former stream were red and blue varved clay.

Alluvial fans are common, particularly in the mountains where streams from alpine glaciers enter lakes at the bottom of steep-sided mountains. In several instances such fans were observed to have dammed the lake completely or left only a narrow channel (*see* Plate III). Much of this material is ultimately carried downstream by rivers such as the Tahtsa and Whitesail and accumulates as deltaic deposits at the heads of the large lakes (*see* Plate IV).

Ridges and Grooves

Perhaps the most prominent and striking glacial feature of the area is the system of parallel, drumlin-like ridges and intervening grooves seen so clearly in the air photographs (*see* Plate V). These ridges and grooves mark the direction of the last ice advance in this part of British Columbia. The general direction of the markings, which is north 50 to 80 degrees east, agrees very closely with that of glacial striae measured on rock surfaces. Valleys in some instances have influenced the direction of ice flow and in such cases a change in the direction of the ridges may be noted. The direction of many valleys is closely aligned with the principal direction of ice flow so that the amount of influence the valleys exerted is difficult to assess. There is no doubt that in the early stages they were the main channels of ice flow and probably contained the ice until it became of sufficient thickness to override the valley walls.

These ridges and grooves appear to be best developed where the ice pushed uphill. This is well illustrated on the west slope of Chef Ridge where the ice pushing upwards out of the valley of Eutsuk and Whitesail Lakes rode over the top of the mountain. The markings there show identical trends on both sides of flat-topped Wells Gray Peak suggesting that the ice rode over the top of the peak without change in direction. To do this the ice must have reached a thickness of at least 4,400 feet.

In timbered country the ridges are characterized by a good growth of lodgepole pine and at timber-line by stunted spruce and juniper. Most of the adjoining depressions are marked by a long narrow lake or wet meadow. Many of the lakes in the plateau area are pointed towards the east, or in the direction of ice flow.

The size and shape of the ridges vary considerably. They may be long and narrow, between 1 mile and 2 miles in length and a few hundred feet wide, or they may be oval in shape from ½ to ¾ mile long and ¼ mile wide. Commonly they are ¾ to 1 mile in length and less than 1,000 feet wide. Height may be as much as 50 feet, but is commonly less. These compare with the drumlins observed by Armstrong (1949, p. 12)[1] in the Fort St. James map-area.

Many of the ridges show crag-and-tail effect with the tail towards the east, and rock outcrops at the crag end. Where no rock outcrops Armstrong and Tipper (1948, p. 293) suggested that the hard core causing the ice to ride upwards was a frozen mass of till with softer material on the sides.

The ridges are composed largely of fairly well-rounded pebbles and boulders in a grey to light brown or sandy clay, and may in places contain some outwash material.

For the origin of such ridges and grooves Armstrong and Tipper postulated the presence of an earlier till plain over which the final advance of the ice proceeded. However, Gravenor (1953, p. 679) considered only one advance necessary and that such drumlins may be due to both destructional and constructional processes. According to Gravenor, it is not necessary to have a previous ice advance and consequent till layer. The advancing ice itself might have a layer or load of till in front of it, particularly if the advance is slow. The ice would then ride over this till and fashion the drumlin-like ridges. In areas where the overburden is deep, on the other hand, the ice might erode the drift into the drumlinoid shapes. In the Whitesail Lake area similar forms were commonly the result of constructional processes. The advancing ice has ridden up and over a rock outcrop or

[1] Dates in parentheses are those of references cited at the end of this report.

frozen till, depositing debris on the opposite side to form a ridge. The proportion of constructional to destructional types is not known but it is believed that the destructional or erosional types predominate in the plains or flat areas and the constructional types in the mountains or hilly areas.

As the direction of the glacial striae, measured on bedrock, and that of the drift ridges conform completely with the picture as set up by Armstrong and Tipper for north-central British Columbia and the Nechako Plain, there appears to be no doubt that the ice accumulated on the northwest-trending Coast Mountains. From its gathering ground on the crest of these mountains it flowed off them more or less at right angles thus moving initially in a northeast to east direction. All easterly trending valleys would, in the first stages of ice encroachment, be natural routes of travel. Later, when the ice completely filled the valleys, it would continue to flow across the high plateau and mountain ridges along its original direction because of the momentum already established. At its maximum this ice flowed onto the Nechako Plain.

Depletion of this ice mass left no visible recessional or terminal moraines and it is probable that the final stages were depleted by stagnation.

Eskers are not as prevalent in the Whitesail Lake map-area as they are farther east, but some were noted in the valleys east of the Quanchus Range and in Tetachuck Lake. One string of small islands towards the head of Tetachuck Lake are composed of drift material and all belong to a partly submerged esker running down the lake depression. Eskers were also noted in the Chelaslie River valley west of Chief Louis Lake. One long esker, composed almost entirely of well-rounded granitic boulders, was observed east of Nutli Lake.

Near Twinkle Lake on the Francois Lake–Tahtsa Lake road, fill for road construction was taken from a nearby esker, a partial cross-section of which is shown in Plate II A. The partial section measured 15 feet in height and consisted of crossbedded sand and gravel in layers up to 4 feet thick. The largest boulder noted was 6 inches in diameter and the boulders were subrounded to subangular, about 25 per cent of the whole being well rounded. A ½-inch layer of blue clay occurred 12 feet from the top of the cut.

Summary and Conclusions

The conditions described above for Whitesail Lake map-area occur also in the Nechako map-area to the east and continue east and northeast into the area described by Armstrong (1949, pp. 8-17). Therefore, at least in this part of British Columbia, the evidence indicates clearly that the ice accumulated first on the crest of the Coast Mountains. When the accumulation reached sufficient proportions the ice flowed off these northwesterly trending mountains in an initial northeasterly direction. Any easterly or northeasterly trending valley would naturally provide an excellent channel for ice movement. As the process continued the ice grew thicker, filled the valleys, and finally flowed over the top. To do so the ice must have reached a thickness of around 4,500 feet finally moving as far east as the Nechako Plain (Armstrong, 1949, p. 8) and merging with ice from other gathering grounds. It would appear that this ice advance was alpine and piedmont glaciation on a grand scale.

Chapter III

GENERAL GEOLOGY

The geological history of the map-area, as expressed by the bedrock formations, began in Mesozoic time. Except for a few small areas of post-Oligocene basalt and some probable early Tertiary rhyolites, all other rocks belong to the Mesozoic era and largely to the Jurassic period.

Upper Triassic breccia, tuff, flows and sedimentary rock outcrop in the northeast corner of the map-area and may be correlated with the Takla group, as may some green andesites along the eastern border in the vicinity of Tetachuck Lake.

Metamorphosed volcanic and sedimentary rocks of mainly Middle Jurassic age underlie by far the greater part of the area. No Upper or Lower Jurassic beds were defined by fossils but volcanic rocks of these epochs may occur.

Most of the sedimentary and volcanic rocks may be correlated with the Hazelton group. No Cretaceous rocks included with the Hazelton group in other areas were observed in Whitesail Lake area, though some do occur immediately north of the north boundary near Anzac Lake.

The relationship of the Takla and Hazelton groups has never been very clear. However, Tipper (1955), working in Nechako River map-area to the east of Whitesail Lake area, found an erosional unconformity at the base of the Middle Jurassic. This unconformity is expressed by an abundance of chert pebble conglomerate and coarse clastic material which outcrop only in the northeast corner of Whitesail Lake map-area. This unconformity which Tipper followed down the whole western side of Nechako River map-area forms a logical horizon, in this part of the country, for the separation of the Takla and Hazelton groups. In Whitesail Lake area, as no known Upper Jurassic rocks are present and the Lower Jurassic strata are, according to the above principle, included with the Takla group, the Hazelton group is confined to rocks of Middle Jurassic age.

Late Lower Cretaceous, fossiliferous shale, arkose, greywacke, and volcanic rock, equivalent to the Haida formation of the Queen Charlotte Islands, occur on Swing Peak and Laventie Mountain. These rocks outcrop along the south shore of Tahtsa Lake but were not found on the north shore. The relationship between these rocks and those of the Hazelton group is certainly nonconformable and they may be in fault contact.

The plutonic rocks of the Coast Intrusions, which form the second largest group of rocks within the map-area, intrude rocks of the Hazelton group and to some extent the late Cretaceous rocks mentioned above. The

Coast Intrusions include many varieties of granitic and dioritic rocks. Commonly these intrusions have metamorphosed the volcanic and sedimentary rocks in contact with them, particularly in the region of the main mass which occupies a large part of the southwest corner of the area. As the dominant rock group of the area is of Middle Jurassic age and all except two small stocks cut only Middle Jurassic rocks there is little evidence indicating the relative ages of the various granitic types. Rarely were two types found in contact. The late Lower Cretaceous rocks mentioned above are cut by two small stocks included with the Coast Intrusions indicating that at least some of the intrusive bodies were emplaced in post-Jurassic time.

A series of flows, mainly acidic, but including some andesite, basalt, tuff, and minor sedimentary rocks of continental character outcrops along Whitesail River and Ootsa Lake. Freshwater shells and poorly preserved plant remains suggest this series to be Upper Cretaceous or later in age and, though it has been considerably deformed, it was not found to be invaded by the Coast Intrusions. Beds of this series are in unconformable contact with the Hazelton group and in places have a coarse conglomerate at the base. The localities where these features were observed are now flooded by the Aluminum Company of Canada's project.

Lying unconformably above these acidic rocks and in places directly on old granitic surfaces are undisturbed (Oligocene) or later basaltic lavas, which have their greatest extent in the vicinity of Chef Ridge. These rocks are fresh looking and easily recognized by their undisturbed condition.

Thick accumulations of till, fluvioglacial material and alluvium occur along the main valleys and in the plateau region along the eastern boundary.

Mineral deposits occur mainly along the eastern boundary of the main mass of Coast Intrusions, with gold, silver, lead, zinc, copper, and tungsten minerals having been found. The showings, though persistent in length, have been too narrow to work, but it is possible, now that the area has become more accessible, that some will become economic.

Structurally the area is one of gentle folding which locally becomes intense, the structure of each range appears to be controlled by the granitic intrusion that forms the core of the highest peak and rarely do structures continue from one range to another.

Faults are particularly common along the contact of the main mass of Coast Intrusions and may be found to a lesser extent near more or less isolated cupolas. In the vicinity of Tesla Lake the pattern appears to have been block faulting. No major faults were mapped but faulting on a major scale may have been responsible for the valleys of the large lakes, possibly in early Cretaceous time.

Table of Formations

Era	Period or epoch	Group or formation	Lithology
Cenozoic	Pleistocene and Recent		Till, gravel, sand, clay, alluvium
	UNCONFORMITY		
	Oligocene or later		Basalt, tuff; gabbro dyke
UNCONFORMITY			
Mesozoic or Cenozoic	Upper Cretaceous to Oligocene	Ootsa Lake group	Rhyolite, dacite, andesite, basalt; breccia, tuff; minor conglomerate
NOT IN CONTACT			
Mesozoic	Lower Cretaceous		Argillite, arkose, breccia, tuff, andesite, basalt
	NONCONFORMITY, POSSIBLY FAULT CONTACT, WITH HAZELTON GROUP, INTRUSIVE CONTACT WITH PART OF COAST INTRUSIONS		
	Upper Jurassic (?) and later	Coast Intrusions	Granodiorite, diorite, granite, quartz diorite, syenite, quartz monzonite, monzonite, gabbro
	INTRUSIVE CONTACT		
	Middle Jurassic (mainly)	Hazelton group	Breccia, tuff, andesite, dacite, rhyolite, basalt; argillite, greywacke, chert, conglomerate; minor limestone
	UNCONFORMITY BETWEEN LOWER JURASSIC ROCKS AND HAZELTON GROUP FAULT CONTACT BETWEEN UPPER TRIASSIC ROCKS AND HAZELTON GROUP		
	Lower Jurassic and Upper Triassic	Takla group	Breccia, tuff, andesite, argillite
	Jurassic and older	Metamorphic complex; largely Hazelton group but may include older rocks; cut by Coast Intrusions	Greenstone, amphibolite, phyllite, schist, gneiss, recrystallized limestone; undifferentiated minor granite and diorite

Undifferentiated Metamorphic Rocks

Along parts of the eastern contact of the main mass of Coast Intrusions metamorphism and metasomatism have progressed to the stage where the original composition of the rocks has been largely destroyed. Many of these metamorphic rocks may be correlated with the Hazelton group and recognizable Hazelton group rocks can be followed into them. Rocks other than Hazelton group are also included. Detailed mapping near the head of Tahtsa Lake by R. A. Stuart (1955) of the British Columbia Department of Mines indicates that metamorphosed layered rocks of the Hazelton group unconformably overlie an older metamorphic sequence containing dykes and cupolas of an altered granite. These metamorphic rocks are cut by bosses, stocks, cupolas, and dykes of granitic and dioritic material associated with the Coast Intrusions.

Some of the larger bodies of Coast Intrusions have been mapped separately, but in the scale of mapping on which this report is based it was not possible to separate all bodies of the various rock units or types in this part of the area.

The largest area of these metamorphic rocks extends from Nanika and Tahtsa Lakes southward across Gamsby River to Kimsquit Lake where it pinches out. Smaller areas are present on Morice and Nanika Lakes, which are on strike with the large area to the south but are separated from it by an eastward bulge in the batholithic rocks. A small area of similar metamorphic rocks occurs on Mount Musclow at the head of Eutsuk Lake.

The metamorphic rocks of this map-unit are in contact with the main mass of Coast Intrusions and have undergone considerable physical deformation. In the vicinity of the Kemano tunnel, Stuart (1955) indicated the presence of a large, south-plunging anticline. Layered rocks of the complex are characterized by intricate crumpling and contortion. Migmatic folding and injection are common and are well exposed near Siffleur Lake. Excavations at the eastern end of the Kemano tunnel exposed numerous closely spaced fractures and small faults which contained soft gouge. Many of the contacts between altered granite and wall-rocks, exposed in the tunnel, were marked by gouge. West of Morice Lake minute fractures in volcanic rocks are marked by the development of granitic material, probably due to hydrothermal alteration as indicated by the ever present epidote.

Dioritized volcanic rock, greenstone, amphibolite, recrystallized limestone, skarn, and phyllite, as well as schists in which the prime mineral may be hornblende, biotite, chlorite, or carbonate, are found in this metamorphic complex. Numerous dykes and small cupolas of granitic and dioritic material are also included (*see* Plate VI A). Hornblende, epidote, and chlorite are common minerals. Hornblende is particularly abundant where the original rock was of volcanic origin and in some instances it comprises the whole rock. Epidote is widespread and chlorite is ever present as an alteration product of ferromagnesian minerals. Commonly greenstones or metamorphosed lava flows have become coarse grained and dioritic in character, resembling intrusive diorite. Some limestones have recrystallized without the production of skarn, but others have produced wide bands containing typical skarn minerals.

The range in age of the various rocks comprising this complex is not definitely known. Most of the rocks are in part correlative with the Hazelton group, but the possibility that some may be as early as Palæozoic must be entertained. Recent work by the author in the Terrace area to the northwest has shown the presence of Palæozoic rocks in metamorphosed zones similarly related to the main mass of Coast Intrusions.

Copper, lead, zinc, gold and silver have been reported from quartz veins, in the areas of these metamorphic rocks that are readily accessible. Much of the main belt of these rocks, however, covers rugged country, difficult of access, along the crest of the Coast Mountains and any mapping or prospecting done so far must be regarded largely as reconnaissance. Some mineral deposits have been found in the main belt, copper and gold being the principal economic elements, but, generally speaking, the belt has not been prospected.

Takla Group

The Takla group was defined by Armstrong (1946, Map 844A) as a series of volcanic and lesser sedimentary rocks about 5,000 feet thick which range in age from Upper Triassic to Upper Jurassic. Tipper (unpublished report), however, pointed out that the original locality from which the group was named and described contained fossils of only Upper Triassic and Lower Jurassic age and that the component of Upper Jurassic age is the result of work by Lord (1948, pp. 19-25) in McConnell Creek map-area. There, Lord included with the Takla group, as an upper member, certain Middle and Upper Jurassic strata. Though he distinguished between the Upper Triassic—Lower Jurassic beds and the Middle Jurassic—Upper Jurassic beds he included them all with the Takla group. Based on this information Armstrong extended the Takla group to include Upper Jurassic strata even though the highest beds in the type locality are of Lower Jurassic age.

This extension of the Takla group to include Middle and Upper Jurassic strata caused some confusion with the Hazelton group, which is itself composed largely of Jurassic rocks. It might be noted here that fossils collected from the Middle Jurassic, Hazelton group rocks of the Whitesail Lake area, were similar to those collected by Lord from the Middle Jurassic strata of the McConnell Creek area.

The discovery by Tipper (1955) in Nechako River map-area of an erosional break between the Lower and Middle Jurassic beds provides a definite marker as a basis of separation between the Takla and Hazelton groups. In Nechako River area the base of the Middle Jurassic beds is a medium to coarse conglomerate, commonly containing numerous chert pebbles. Tipper believed this to be a shoreline deposit with the landmass to the east. He was able to follow this zone of coarse clastics down the length of Nechako River map-area, along its western border. It outcrops only in the northeast corner of Whitesail Lake map-area, where it swings westward from its northerly trend in Nechako River area. Tipper considered this erosional break to be the logical horizon for the division between the Takla and Hazelton groups, at least in the Nechako River area, and this line of demarcation applies equally well to Whitesail Lake area. Therefore, in Whitesail Lake area, the boundary between the two groups is placed at the close of the Lower Jurassic, and the Takla group will be restricted to Upper Triassic and Lower Jurassic strata.

Distribution

Outcrops in Whitesail Lake map-area that have been correlated with the Takla group occur only along the eastern boundary of the map-area, and are westward extensions of much larger areas of similar rock occurring in Nechako map-area. In Whitesail Lake map-area rocks of this group form a prominent hill in the northeast corner, about 7 miles north of Ootsa Lake, which is used by the British Columbia Forest Service as a lookout station, known as Verdun. There an upfaulted block brings these older rocks to the surface over an area of about 6 square miles adjacent to the eastern boundary of the map-area.

Farther south, near the east end of Eutsuk Lake and the west end of Tetachuck Lake, a series of massive green andesites with some minor limestone, tuff and breccia is present, which has been included with the Takla group. These rocks occur both north and south of the lakes and underlie an area of about 100 square miles.

Certain greenstones at the northeast end of Troitsa Lake and on Kasalka Butte and Huckleberry Mountain may belong to the Takla group but, due to lack of definite evidence and the possibility they may be lowermost Middle Jurassic, they have been included with the Hazelton group.

Lithology

Upper Triassic Rocks on Verdun Hill

The rocks composing Verdun hill consist of andesitic and basaltic flows, greenish grey to red andesitic breccia and tuff, fine-grained green to grey fossiliferous greywacke, and dark argillite. The whole assemblage has undergone metamorphism, and chlorite and epidote are common secondary minerals. The flow rocks are slightly porphyritic with prominent feldspar laths up to ½ inch in length. Thin sections show the feldspars and ferromagnesian minerals to be broken down with the production of zoisite, sericite, calcite, chlorite, magnetite, and epidote. Both pyroxene and amphibole are present as primary minerals. Feldspars are rarely zoned. Feldspar laths in the groundmass show flow structure around the larger phenocrysts.

The fragmental nature of the breccias is best observed on a weathered surface where the fragment boundaries are accentuated. Commonly on a fresh surface it is difficult to distinguish fragment from matrix. Fragments vary in colour from greenish grey to brown and red, and in size from a fraction of an inch to 10 inches, most fragments are from ½ inch to 1½ inches across. The matrix consists of fragments of tuff size but of the same material as the larger fragments.

The tuffs interbedded with the breccias are hard, dense, fine-grained, red to green rocks with banding as fine as $\frac{1}{16}$ inch. The fossiliferous greywackes or water-lain tuffs are fine-grained, grey to grey-green rocks, thinly bedded, with minor bands of chert and narrow partings of argillite.

Rocks near Eutsuk and Tetachuck Lakes

Rocks in the vicinity of Eutsuk and Tetachuck Lakes assigned to the Takla group are massive, green, andesite and basalt flows and minor argillite and limestone. The flow rocks, which form the greater part of the group, are similar to those described from Verdun hill. Some impure, narrow limestone beds and minor argillites occur between the flows. Some of the flows contain sufficient pyrite to present a rusty appearance on the weathered surface.

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Structural Relations

The rocks on Verdun hill form an upfaulted block in which the beds strike south 65 to 75 degrees east and dip 25 to 75 degrees to the north. Faulting is evident along the southern boundary of the assemblage where the rocks are sheared in a direction north 75 to 90 degrees east and in which the plane of shearing dips 45 to 85 degrees south. Relations at the other boundaries are obscured by overburden. To the north the rock surface descends into a heavily timbered depression. About a mile west of the hill a fine conglomerate considered to be part of the Hazelton group occurs in small outcrops. No contact between the two rock types was observed.

The rocks of the Takla group near Eutsuk Lake are separated from the main belt of Hazelton group rocks by a wide drift-filled valley, which runs southeast from Connelly Bay on Eutsuk Lake. The rocks on each side are perceptibly different, strongly indicating the possibility of a fault down the valley. If this is the case then it is possible that there also the two groups are in fault contact.

The massive andesites in this locality are cut by stocks of the Coast Intrusions. The contacts are commonly sharp with silicification of the flow rocks restricted to a narrow rim close to the contact. Commonly the flows are traversed by joints having more or less random attitudes.

Age

Only in the rocks composing Verdun hill were any fossils found that were diagnostic as to age. There some of the tuff and argillite contained large numbers of the pelecypod *Halobia* which, according to F. H. McLearn of the Geological Survey, designates an Upper Triassic age. No fossils or structural evidence as to age were found in the rocks around Eutsuk Lake, but Tipper (1955) found that, farther east in the Nechako area, these rocks were structurally older than those of the Hazelton group and that fossils collected in them near Bryan Arm on Tetachuck Lake were most probably of early Jurassic age.

Correlation

In Whitesail Lake map-area rocks included with the Takla group are lithologically and stratigraphically similar to the Takla rocks in the type area at Takla Lake and those that are so widespread in Fort St. James, McConnell Creek, Aiken Lake and Manson Creek map-areas. Elsewhere in British Columbia are many groups of rocks that are at least in part correlative with the Takla group, such as the Vancouver group of Vancouver Island and the Nicola group of southern British Columbia. Armstrong (1949, pp. 58-62) gives a complete list of these groups west of the Rocky Mountains. Commonly they are unfossiliferous and because of this character some Takla group rocks may have been included with the Hazelton group.

Hazelton Group

The name Hazelton group was applied in 1909 to a series of interbedded marine and continental sedimentary and volcanic rocks that underlie a large part of west-central British Columbia, east of the Coast Mountains. These rocks are mainly of Jurassic age but appear in places to grade upwards into Lower Cretaceous strata, particularly where the beds are of continental origin. Many workers have investigated these rocks in various parts of central British Columbia, but to date it has not been possible to define their upper and lower limits, or the proportion of volcanic and sedimentary strata. These strata vary from place to place and a section at one locality will be greatly different from that at another. The Lower Middle Jurassic (Bajocian) succession of sedimentary strata provides a widespread horizon marker that is easily identified by its abundant fossil content. This unit is commonly underlain and overlain conformably by volcanic rocks. Volcanic rocks of the group are characterized by a high proportion of tuff and breccia. Flows are mainly andesitic or basaltic but more acid varieties do occur. Overall the volcanic rocks are dominantly andesitic in character. Greywackes form a large proportion of the Bajocian sedimentary rocks, commonly formed of tuffaceous material derived either from the erosion of earlier tuff beds or by original deposition of tuffaceous material in water. Less common than the greywackes are dark argillites and light grey-green chert. No limestone beds were observed but some of the sedimentary strata are high in calcium.

As the rocks of the group are mainly of Jurassic age they are intruded by the Coast Intrusions, which has caused some dislocation and a general metamorphism that has given rise to the formation of epidote. This pistachio-green mineral is very common in all rocks of the group and is particularly abundant in contact zones.

History

The term 'Hazelton Group' was first used by W. W. Leach (1910) to include the sedimentary rocks found near the town of Hazelton and the porphyritic tuff, breccia, and flows that occur in the Telkwa River valley. The volcanic rocks had previously been referred to the 'Porphyrite group' of Dawson (1875-76, p. 250) a term descriptive of their porphyritic texture. Leach in his work followed these volcanic rocks northward into the Hazelton area where they gave place to sedimentary strata. It was, therefore, clear that the descriptive term 'Porphyrite group' was not generally applicable and Leach dropped it in favour of the non-descriptive term, Hazelton group.

Shales and sandstones near the top of the group are partly fossiliferous, and on the basis of fossils collected the group was assigned an Upper Jurassic or Lower Cretaceous age.

Lying above the Hazelton group rocks as outlined by Leach in the Hazelton and Telkwa area and commonly occurring in small patches folded in with the underlying Hazelton rocks, is a series of coal-bearing conglomerate, coarse sandstone, thin shaly sandstone and nodular shale. Fossil plants from these beds were determined by Leach (1910, p. 64) to be equivalent to the Lower Cretaceous about the horizon of the Kootenai series. The boundary between the two series of rocks was not a definite but an arbitrary one (Leach, 1911, p. 93). The Hazelton group as described by Leach did not include the coal-bearing beds, which were placed in the Skeena series.

Subsequent workers extended the area of Hazelton rocks both south and north of the town of Hazelton, most fossil collections being made from Middle and Upper Jurassic sedimentary beds. Some workers found no unconformity at the base of the Skeena series and included it in the Hazelton group; others found an unconformity and regarded the two as separate units. Thus the upper limit of the Hazelton group was left in some doubt. The lower limit was not defined by Leach, and Hanson (1925*b*, p. 41 A), in the Portland Canal area, believed that the group included some Triassic rocks.

Hanson (1935, p. 5) reviewed the Hazelton problem as it stood at that time and said:

> There is in the west central part of the province a series of rocks, the parts of which are in the main conformable, consisting mainly of volcanic rocks and clastic sediments lying between Palæozoic sediments and the Skeena series, and for which it is desirable to retain the name Hazelton group. The group can in many places be divided into parts but in general very few of the rocks contain fossils of diagnostic value, and therefore their age can be stated only in general terms. Fossils found in the Portland Canal area indicated that the rocks were, in part at least, of Jurassic age.

More recent work has been done by Armstrong (1944*a, b*) in the Smithers and Hazelton areas, and of the Hazelton group he stated (1944*a*):

> The Hazelton group consists of an apparently conformable succession, possibly 10,000 feet thick, of interbedded sedimentary and volcanic rocks ranging in age from pre-Middle Jurassic to Lower Cretaceous and including what have

been called Hazelton group and Skeena formation or series. In the vicinity of Hudson Bay Mountain near Smithers it has been subdivided into five units largely on the basis of two sedimentary divisions.

These units are:

Lower Cretaceous or Later	Volcanic rocks
Upper Jurassic and Lower Cretaceous	Sedimentary rocks containing (*a*) Upper Jurassic fauna (*b*) Blairmore flora
Middle or Upper Jurassic	Volcanic rocks
Middle Jurassic	Sedimentary rocks (marine); Middle Jurassic fauna
Lower Jurassic	Volcanic rocks

Some confusion exists in these areas with respect to the dating of the higher sedimentary beds, and with regard to the upper sedimentary division Armstrong (1944*a*) stated: "The Upper Jurassic and Lower Cretaceous sedimentary division is composed of at least 5,000 feet of interbedded continental and marine strata containing fossil shells and plants. The shell collections are all of Upper Jurassic or possibly very early Lower Cretaceous age. The plants represent two distinct flora correlated provisionally with the Kootenai and Lower Blairmore of Alberta and presumably of Lower Cretaceous age. In Glacier Gulch, however, fossil shells of Upper Jurassic or very early Cretaceous age were collected from a bed 300 feet stratigraphically above a bed containing fossil plants of Blairmore age." This discrepancy may be due to faulting not detected at the time the fossils were collected (E. D. Kindle, personal communication). Armstrong further concluded that no satisfactory stratigraphic division can be made between the Hazelton group and the Skeena series, and that continental strata comparable with the Skeena rocks appear at various horizons within the Hazelton group.

The Hazelton group then at that time consisted of a more or less conformable series of volcanic and sedimentary rocks (both marine and continental), extending from a horizon in the Lower Jurassic to early Lower Cretaceous time—probably Kootenai or Blairmore.

Work in Whitesail Lake map-area did not add substantially to the knowledge of the limits of this complex group. No definite Upper Jurassic or Lower Cretaceous marine beds, like those associated with the Hazelton group elsewhere, were found. Volcanic rocks in abundance overlie, conformably, Lower Middle Jurassic fossiliferous marine strata over a large part of Whitesail Lake map-area. Some of these volcanic rocks may reach up into the Upper Jurassic. No Lower Cretaceous fossils equivalent to those found elsewhere in the Hazelton group were found in the area, though they do occur just north of it.

Only in the northeast corner of the map-area is the possible base of the group exposed and there it consists of a chert pebble conglomerate that Tipper (1955) believed to be the base of the Middle Jurassic. This conglomerate bed, which Tipper followed down the western edge of Nechako River map-area, is believed to be a shoreline deposit and to represent an unconformity separating the Takla group rocks of Upper Triassic and Lower Jurassic age from Hazelton group strata of Middle Jurassic and later age. As stated previously, this break was used also in the Whitesail Lake area to separate the Hazelton and Takla groups along the eastern boundary. However, farther west in the map-area no similar conglomerate was observed and it may be that, in the deeper part of the basin, sedimentation was continuous and no break occurred. There would therefore be no definite horizon on which to separate the two groups and some Lower Jurassic rocks may possibly be included with the Hazelton group. This is the situation near the west end of the Whitesail Range and Troitsa Lake where the Hazelton group as mapped may include some Lower Jurassic volcanic rocks, and also in other areas where no definite break has been determined between Lower and Middle Jurassic. Though Tipper pointed to a logical stratigraphic horizon that may be used as the base of the Hazelton group, at least in Nechako and part of Whitesail Lake areas, it is restricted in the sense that it is of a local nature and as yet is not applicable to the group as a whole. Future work may prove the presence of this unconformity in other areas of these rocks, thus widening its application. It would seem then that where the age of strata can be determined the base of the Hazelton group should coincide with the base of the Middle Jurassic, and that no Middle Jurassic strata should be included with the Takla group.

Distribution

In Whitesail Lake map-area rocks attributed to the Hazelton group are by far the most common. The principal belt of these rocks lies adjacent to the eastern contact of the main body of the Coast Intrusions, and traverses the area in a northwesterly direction. These rocks constitute the strata on Pattullo, Chikamin, Whitesail, Sibola, and Tahtsa ranges and those unnamed ranges along Nanika and Morice Lakes. Most of them are of Middle Jurassic age, as indicated by fossil evidence. The possibility that some Takla group volcanic rocks of Lower Jurassic age have been mapped with the Hazelton group around the north end of Troitsa Lake, on Kasalka Range, and along Tahtsa River near Huckleberry Mountain has been mentioned previously. On the western slope of Troitsa Peak, fossils of lowest Middle Jurassic age were collected from sedimentary strata interbedded with rhyolite flows. These strata are underlain conformably by a thick series of volcanic rocks the base of which was not seen, or at least not recognized. These volcanic rocks may be Middle Jurassic in age or may be in part of Lower Jurassic age and belong to the Takla group. In this report, however, because there is no definite evidence that they are Lower Jurassic, they have been included with the Hazelton group.

In Smithers map-area to the north, the Hazelton group contains strata of Upper Jurassic or Lower Cretaceous age as well as some continental strata that are correlative with the Kootenai and Blairmore formations of Alberta (Armstrong, 1944*a*). These Cretaceous continental beds do not extend southward into Whitesail Lake area but terminate at its northern boundary. The Lower Cretaceous beds occurring on Swing Peak and Laventie Mountain are marine strata and are not correlative with the Hazelton group but with the Haida formation of the Queen Charlotte Islands.

Lithology

In Whitesail Lake map-area the Hazelton group consists of at least 11,500 feet of interbedded volcanic and sedimentary rocks. This assemblage may in places be roughly divided into a lower, mainly volcanic division; a middle, mainly marine sedimentary division; and an upper, dominantly volcanic division. Boundaries between these divisions are arbitrary and cannot be followed across the area as a whole. For this reason the group was mapped as a single unit. The three divisions vary in thickness and composition along strike, so that a section in one locality may bear no resemblance to a section in another. The two volcanic divisions are similar in general character and are not always separable. The lower division is characterized by a larger proportion of massive green and purple andesite, generally duller colours, and contains a larger proportion of sedimentary material than the upper volcanic division. The base of the lower division was not observed but the thickness of this division is probably not less than 3,000 feet.

Lying above the lower volcanic division on Chikamin Range, along Tahtsa River, and on Troitsa Peak is a succession of sedimentary rocks, with minor interbedded tuffs and flows, which yield marine fossils of Middle Jurassic age. The section on Chikamin Range exposes about 2,500 feet of tuffaceous greywacke, black argillite, grey-green tuff, impure limestone, thin-bedded chert, and minor andesitic flows. At the east end of Nadina Lake a section of similar rocks yielding similar fossils is also about 2,500 feet thick. Fossils of the same age were found along Tahtsa River, on Tweedsmuir Peak, Michel Peak, and on Nadedikus Mountain.

Overlying these sedimentary beds on Chikamin Mountain and along Eutsuk Lake is a thick series of volcanic flows, tuffs, and breccias of the upper volcanic division. These are well exposed on the west end of Chikamin Range, on Key Mountain and on Mount Preston, where they are folded into a syncline representing about 6,000 feet of bedded volcanic rocks.

In the Hazelton group the most common and characteristic rock types are volcanic breccia and tuff. These rocks are typically red and green but may be brown, grey, or purple. The breccia or coarse tuff is distinctive and commonly spectacular. Fragments consist largely of volcanic rocks, but include minor amounts of sedimentary and plutonic material. Towards the western end of Chikamin Range occurs a breccia that contains numerous fragments of diorite and granodiorite along with the usual volcanic material. This breccia bed conformably overlies Middle Jurassic sedimentary beds on the mountain. Fragments range in size from that of fine ash to blocks a foot or more across, but most are ¼ to ½ inch in longest dimension. The matrix of these pyroclastic rocks is similar to that of the fragments but more finely comminuted. Rarely do such rocks contain carbonaceous material. Commonly the tuff may be termed lithic but crystal, lapilli, and cindery varieties also occur.

On Chikamin Mountain water-lain tuffs contain layers and clusters of circular particles that are probably lapilli. These particles were found just above the tunnel on the Garner No. 1 and Marie claim in a hard siliceous tuff bed that contained Middle Jurassic fossils. The particles vary in size up to ½ inch in diameter and are greenish grey, but weather a distinctive light grey. In hand specimen they show a crude concentric structure which is not apparent in thin section. Under the microscope, these particles are seen to be much finer grained than the remainder of the rock, and except for minor microlites of feldspar are dark grey under crossed nicols. Similar structures were found in a very fine-grained, maroon ash or tuff on the eastern slope of Core Mountain. They are, however, more oval shaped and are about ½ inch in longest diameter. The outer rim of the lapilli or small bombs is glassy but the centre is extremely fine-grained, stony material. Some of the glassy outer rims of the lapilli have been broken as if they had rolled or been broken on landing.

Lithic tuff and breccia contain fragments of sedimentary, volcanic, and plutonic rocks with diorite and granodiorite fragments abundant in some beds. Dark grey to black argillaceous fragments are not as common as andesitic volcanic fragments. One cindery variety from the east end of Sibola Range consists of dark and light grey and brown, rounded to subrounded fragments cemented together by fine ash.

A breccia from the south slope of Tweedsmuir Peak is a hard, dense, greenish grey rock containing fragments of black argillite, reddish feldspar porphyry, and purple, green, and grey volcanic rocks cemented together by light, fine-grained material of the same kind.

A red tuff from the west side of Morice Lake is composed largely of particles of purple, red, and dark grey andesitic volcanic material more than ¼ inch across. Under the microscope a few small phenocrysts of plagioclase appear clear but the remainder is clouded by alteration products. Many of the tuff beds are banded, a characteristic that is emphasized on a weathered surface. A typical example of these tuffs is exposed on the east slope of Sibola Peak where they are composed of light grey and maroon bands, varying in thickness from $\frac{1}{16}$ to ½ inch.

Fragmental rocks of the types described above form most of the Hazelton group. Flows and sedimentary strata follow in order of abundance. The larger fragments of the breccia are commonly angular but may be subangular to subrounded. The presence of feldspars that occur as phenocrysts, commonly ⅛ to ¼ inch in length, but in places as much as ½ inch, is typical of both the fragmental types and the flows. This characteristic is more common in the lavas and was largely responsible for Dawson (1875-76, 1876) applying the name 'Porphyrite' to the group.

Most lava flows of the Hazelton group are of andesitic and basaltic composition, rhyolites and dacites being much less common. The more basic lavas are purple, brownish red, red, brown, grey, greenish grey, and less commonly dark grey and black. The more acidic varieties are lighter in colour. The andesites and basalts, as mentioned previously, display white or light coloured phenocrysts of feldspar in a microcrystalline groundmass. The groundmass commonly exhibits flow structure around the phenocrysts. The intermediate and basic lavas are medium-grained, normal rocks in flows up to 50 feet thick commonly well layered. Amygdaloidal and vesicular types though not common do occur. Many of the andesites are now typical greenstones with an almost dioritic texture. These rocks are characterized by the usual feldspar (andesine) phenocrysts and short blocky crystals of hornblende and a pyroxene, probably augite. Rhyolites are subordinate in amount but are present in both the lower and upper volcanic divisions. They may be cream, white, light green, or light purple. They are fine grained in texture, but some show a few quartz grains or feldspar phenocrysts in a microcrystalline groundmass of quartz and feldspar. Magnetite and biotite are minor constituents. Dacite lavas are present in the group but rare.

A section across part of the upper volcanic sequence exposed west of Newcombe Lake illustrates the fragmental nature of the group and to some extent the thickness of individual members.

Description	Thickness (feet)
Top of section	
Siliceous grey tuff	1.0
Banded (½" to 2") soft maroon tuff	7.0
Massive coarse breccia, fragments to walnut size	35.0
Banded (½" to 2") maroon tuff	15.0
Medium-grained maroon tuff	25.0
Rhyolite breccia	2.0
Maroon to grey banded tuff	2.0
Gap	50.0
Coarse red breccia	250.0
Massive grey breccia, fragments to walnut size	50.0
Reddish grey tuff	3.0
Red andesitic flow	5.0
Dense, fine-grained, red-grey breccia	2.5
Pink rhyolite tuff	8.0
Pink tuff with 1-inch laminations	3.0
Red porphyritic flow	6.0
Red-grey tuff	3.0
Red tuff (⅛" to ½" laminations)	2.0
Red andesite flow	4.0
Grey-red tuff	2.5
Hard dense rhyolitic tuff	3.5
Hard siliceous red tuff	2.0
Hard siliceous red tuff	.2
Fine maroon tuff	.25
Hard siliceous red tuff	.25
Hard siliceous grey tuff	.75
Grey-green weathering, breccia fragments up to 2 inches by ¾ inch	100.00
Bottom of section	

Sedimentary rocks of the Hazelton group include fine-grained, dark argillite, greywacke, thin-bedded, grey-green chert, and minor conglomerate and impure limestone. The argillites, though commonly black, may be limonite brown or rarely green, and occur in beds from 1 inch to 15 feet thick. Greywackes are common and are composed largely of tuffaceous material, that probably came from the erosion of older tuffs but may include some original pyroclastic material deposited in the basin of sedimentation. The greywackes are commonly grey-green but may be maroon, red, or brown.

Grey-green, thin-banded chert, commonly in beds less than 1 foot thick, occurs in the uppermost 500 feet of Chikamin Mountain as well as along the north shore of Eutsuk Lake and on Tableland Mountain. No pure limestones were observed but beds with a high percentage of carbonate are not uncommon. Conglomerates are rare except for the basal Hazelton beds in the northeast corner of the map-area described above.

The following short partial sections across well-exposed parts of the sedimentary beds on Chikamin Mountain indicate the fine banding and relative proportions of the sedimentary rock types. The first section is from a cut above the adit on the Garner No. 1 and Marie claim on the northwest side of Chikamin Mountain.

Description	Thickness (inches)
Top of section	
Dark argillite	5
Light grey greywacke	60
Dark argillite	3
Greywacke	1
Light grey, dense argillite	2
Dark grey argillite	2
Grey arkose	1
Black argillite	3
Grey-green chert	12
Black argillite	12

In another cut 230 feet above this, the following section was measured.

Description	Thickness (inches)
Light grey chert	4
Dark grey argillite	15
Light grey chert	6
Dense black argillite	24
Light grey chert	12
Dark grey greywacke	18
Dark chert	36
Light grey siliceous tuff	60
Bottom of section	

Metamorphism

The proximity of the main mass of Coast Intrusions and the widespread injection of granitic material have caused much alteration of the Hazelton group within the area.

Epidote and chlorite are common alteration products, imparting a general green coloration, particularly to the altered volcanic rocks. In other places amphibole is developed to the extent of forming most of the rock. This development of amphibole is dominant near the main batholithic masses, particularly near the heads of Morice and Tahtsa Lakes. Commonly near contacts with granitic masses, rocks of the Hazelton group have been altered to schists and gneisses and hybrid types intermediate in character between regular volcanic rocks and typical granitic rocks. Feldspathic material developed along minute fractures in volcanic rocks, commonly bordered by an alteration rim of epidote. The rocks of this zone appear to be more siliceous than is normal for the Hazelton group.

Where the Hazelton group rocks contain limy members adjacent to tongues and cupolas of granitic rocks it is common for contact metamorphism to have produced skarn zones of significant extent. Thus on the mountain east of Sandifer Lake, a skarn zone at least 400 feet long and 60 feet wide contains well-developed crystals of epidote, specular hematite, garnet, a little chalcopyrite and minor bismuthinite. Except for the bismuthinite similar mineralization and alteration were observed alongside the intrusion on Chikamin Range. Where argillites of the group are in close contact with granitic masses they have in places been altered to andalusite schists. An example of this alteration is exposed on Lindquist Peak on the property of Deer Horn Mines Limited.

Environment of Deposition

The preponderance of volcanic material, particularly of the fragmental variety, together with marine sediments as expressed by the argillites, greywackes, and reworked volcanic material, suggests that rocks of this group were deposited in a shallow sea within a region of volcanic activity. Rocks composing the Hazelton group together with associated batholithic rocks typify those found in eugeosynclinal conditions as outlined by Kay and the whole map-area is included in Kay's *Fraser Eugeosynclinal* (Kay, 1947).

Of the sediments in geosynclines Kay (1951, pp. 85-86) said, in part,

> ..., rocks in eugeosynclines pass on the one hand into lavas, tuffs, and coarser fragmental rocks, and the derivatives of the weathering of volcanic islands, and on the other hand into terrigenous sediments eroded from tectonic lands.

> Margins of seas gained conglomerates of hundreds of thousands of feet, some with plutonic pebbles suggesting erosion of exposed intrusive rocks. Water depths tended to increase rapidly and the lands were immature, for sediments are poorly sorted, have graded bedding and slump structures, and are dominantly of the greywacke suite. The greywackes often have feldspathic constituents, particularly sodic plagioclase; being derived from volcanic sources, they are virtually limited to eugeosynclines.

The similarity of the above description to the rocks as they occur in Whitesail Lake map-area indicates eugeosynclinal conditions for the deposition of the Hazelton group. According to Tipper (unpublished thesis) the chert pebble conglomerate present in the northeast corner of Whitesail Lake map-area and the western part of Nechako map-area contains pebbles of the Topley Intrusions of pre-Middle Jurassic age, as well as pebbles and cobbles of Cache Creek rocks of late Palæozoic age. This conglomerate Tipper believed to be a shoreline deposit, the material of which was derived from a landmass to the north and northeast. To the west and southwest in Whitesail Lake map-area the basin of sedimentation deepened but was interrupted by the presence of volcanic masses or active volcanoes. No definite Mesozoic volcanoes were recognized during the progress of the work but the great mass of fragmental material present indicates that in Jurassic time active volcanism was dominant.

Structural Relations

Internal Structure

The structure of the Hazelton group in Whitesail Lake map-area is one of moderate folds with occasional sharp crenulations. Hedley (1935) gave an apt description of the overall structure as that of a comparatively flat-lying blanket warped into open folds. Commonly these folds are of small dimension and extend along the strike for only a short distance. The fold structures on any one range of hills are restricted, in the main, to that range. Axes of the folds strike commonly northwest but some diverge from this direction. Near the main mass of the Coast Intrusions the rocks parallel the contact and the structures trend northwesterly. East of the main contact the group is cut by numerous stocks, cupolas and small batholiths that locally disrupt and dislocate the older rocks. The strata commonly conform to the contact with these plutons, thus where several such plutons occur close to one another the structures are small and discontinuous and some of them diverge from the general northwesterly trend. Commonly in such cases a shallow synclinal structure or basin is found between the plutons. Each mountain range has its core of plutonic rock that has dislocated the Hazelton group rocks near it, thus the structures on one range are rarely continuous with those of an adjacent range. Angles of dip are in the order of 30-50 degrees and rarely exceed 60 degrees.

A number of small fold structures are indicated by the mapping, but as stated above they are not persistent along the strike.

Between Tahtsa and Nanika Lakes there is a sharp anticline and complementary syncline, the axes of which trend northwesterly. The north slope of the Sibola Range is a fairly wide synclinal structure, the axis of which strikes north, but the structures on this mountain are interrupted, warped, and broken by the pluton that forms the core of the range.

Smoke Mountain is an open synclinal structure striking north 65 degrees east which is at right angles to the common northwesterly trend. West of Anzac Lake another small synclinal trough lies between two plutonic masses. This structure also strikes in a northeasterly direction. The attitude indicates that the stocks and bosses outcrop on anticlinal structures in this part of the area.

Attitudes in the Shelford Hills indicate the rocks there to be warped into gentle northwesterly trending folds. The western end of the Mosquito Hills is represented by a small anticline the axis of which strikes northeasterly.

The attitudes on Whitesail Range do not clearly indicate any definite structure, the beds altering in strike and dip within short distances.

On Chikamin Range the beds west of the peak form the southwestern limb of an anticlinal structure that is interrupted to the east by granitic and dioritic intrusions forming the core of the range. This western limb of the structure is fractured near the intrusion the fracturing expressing itself in narrow continuous breaks which in places contain lead-zinc minerals. Near the head of Whitesail Lake the beds strike northwesterly and dip away from the main batholithic contact.

The northwestern slope of Key Mountain contains a small synclinal structure the axis of which trends northwesterly.

The beds on Mount Preston dip 40 degrees to the southwest, and those on Mount Pondosy dip 50 degrees to the northeast, indicating a synclinal structure whose axis lies along the valley between Tesla Lake and Pondosy Bay.

In the Quanchus Range in the eastern part of the map-area the rocks are again disturbed by intrusions and the structures are mostly local. Where observed on the western slopes of Mount Wells and Tweedsmuir Peak the beds dip away from the plutonic mass. In this case the dip is westerly.

Faults

In the Hazelton group rocks of Whitesail Lake area, the lack of distinctive marker beds, the general similarity of the various rock types, and the discontinuous character of the strata make recognition and extension of faults difficult. As a result relatively few have been mapped though it is believed faults are common within the group. Faults were recognized at the head of Whitesail Lake, on Whitesail Range and Tahtsa Range, on Lindquist Peak, and at the head of Tesla Lake.

On Core Mountain a distinctive fault is marked by a small stream that flows from the lake on the mountain top. Rocks in the stream bed are highly sheared and pyritized. The fault strikes north 40 degrees east almost parallel with the direction of Whitesail Lake, and the dip of the shearing is vertical. In part, the north wall of this fault consists of a small gabbro mass that forms part of the hill. The fault crosses a small red granite body where it is marked by two narrow ponds, and it may continue southwest across the head of Whitesail Lake.

The large quartz veins in the Hazelton group rocks on Lindquist Peak are crossed by a series of north-striking faults that offset the vein as much as 900 feet in some instances.

On Mount Sweeney the strata are marked by gouge seams between the beds and are offset by transverse faults across them. The sedimentary beds towards the west end of Whitesail Range were probably brought to the surface by faults and the crushed zones near the granite contacts on this range suggest other faults.

To the south in the vicinity of Tesla Lake faults were observed trending both parallel with and transverse to the batholithic contact and most of the topographic features in this region are a result of fault patterns.

The Aluminum Company of Canada's tunnel driven westward from the head of Tahtsa Lake ran through several thousand feet of broken ground. There the volcanic rocks had been intruded by a swarm of small red granite bodies and dykes. The contacts of each of these bodies were marked by a seam of gouge, indicating movement. The whole area in this vicinity is apparently much shattered. Although no major structural faults were identified the long narrow lakes characteristic of the area are due to fractures in the main body of Coast Intrusions and adjacent Hazelton rocks. These lakes accord with the transverse fracture system of the Coast Intrusions and are probably due to the same structural conditions responsible for the fiords of the British Columbia coast.

Most of the faults in the Hazelton group described above are adjacent to the main contact with the Coast Intrusions, and it is probable that faults are exceedingly common close to this contact throughout its length within the map-area.

External Structural Relations

The Hazelton group rocks are in faulted contact with rocks of the older Takla group in the northeast corner of the map-area. Elsewhere in the vicinity the Hazelton group is in erosional contact with the Takla group. South of Eutsuk Lake, Hazelton group and Takla group rocks outcrop on opposite sides of a wide, southeasterly trending valley that may be the locus of a fault.

To the west of Kasalka Butte, upper Lower Cretaceous marine beds are in contact with greenstones of the Hazelton group. The actual contact was not seen due to overburden and snow, but it is certainly non-conformable and may be faulted.

On Mosquito Hills rocks of the Hazelton group are overlain unconformably by basalt flows of Tertiary age. Elsewhere along Ootsa Lake and on the flanks of Mount Wells rhyolites and basalts of Upper Cretaceous or Tertiary age unconformably overlie volcanic rocks of the Hazelton group. Near Goodrich Lake flat-lying Miocene basalts overlie disturbed sedimentary and volcanic rocks of the Hazelton group.

All main intrusive bodies in the map-area are younger than the Hazelton group. Some of the contacts are faulted, others are typically intrusive and sharp, still others are gradational and do not suggest crosscutting characteristics. Due to the large amount of intrusive material affecting them, the Hazelton group rocks are generally metamorphosed and not uncommonly have reached a high stage of alteration.

Age

Fossil remains of marine invertebrates are common in the middle division of the Hazelton group. The remains are poorly preserved, and good specimens are difficult to obtain. Fossils were found in argillite, greywacke, impure limestone, and tuff. Pelecypods and brachiopods are common but belemnites or their remains are present wherever sedimentary rocks occur. The fossils collected are all confined to the Bajocian (Middle Jurassic) and no fossils of definite Lower Jurassic or Upper Jurassic affinities were found, though it is possible beds belonging to these epochs are present.

Fossil remains were found at numerous localities but those giving best results were along Tahtsa River, near the east end of Nadina Lake and, on Troitsa Peak, and Chikamin Range. Fossils were also found on Tweedsmuir Peak, Mount Sweeney, Nadedikus Mountain, and Holmes Ridge.

H. Frebold and J. A. Jeletzky of the Palæontological section of the Geological Survey of Canada identified the fossil collections and commented on their age and stratigraphic significance.

Collections made in the area are as follows:

Northwest ridge of Troitsa Peak

Catalogue No. 13754. H. Frebold
- *Tmetoceras regleyi* Dumortier
- *"Polymorphites"* cf. *senescens* Buckman
- *Pleuromya* sp. A
- *Arca* sp.
- Indeterminable gastropods

Age: Lower Bajocian (early Middle Jurassic)

Catalogue No. 13753. H. Frebold
- *Tmetoceras regleyi* Dumortier
- *Pleuromya* sp. A
- *Trigonia* sp. indet.
- *"Rhynchonella"* sp. indet.
- Gastropods indet.

Age: Lower Bajocian (early Middle Jurassic)

Catalogue No. 13758. H. Frebold
- *Tmetoceras regleyi* Dumortier
- Poorly preserved pelecypods (*Pleuromya*?) and gastropods
- *Discinia* sp.

Age: Lower Bajocian (early Middle Jurassic)

Frebold (1951, p. 20) remarked that *Tmetoceras regleyi* Dumortier has hitherto been unknown in Canada and that it represents an early Bajocian horizon. Its stratigraphic position is older than that of the widespread Lower Yakoun fauna (*Stephanoceras* and *Chondroceras*) of British Columbia and its equivalents in the Fernie group of Alberta, but younger than faunas with *Harpoceras, Fanninoceras,* and *Dactylioceras* (found at various places in British Columbia and Alberta) which, as stated by McLearn, belong to the Toarcian. As stated previously, this bed is not the bottom of the Troitsa section but is underlain by volcanic rocks some of which may possibly reach into the Lower Jurassic.

On Chikamin Range the sedimentary strata are slightly younger in age and belong to the Middle Bajocian. Fossil collections from these strata contained numerous belemnite casts and fragments.

Chikamin Mountain just above adit on Garner No. 1 and Marie claim

Catalogue No. 16071. H. Frebold
Stephanoceras sp.
Trigonia sp.
Pecten sp.
Age: Middle Bajocian (early Middle Jurassic)

Southwest side of Chikamin Mountain about elevation 5,500 feet

Catalogue No. 17194. J. A. Jeletzky
Indeterminable ammonoids. (*Stephanoceras* sp. indet.)
Belemnoids (similar to *Nannobelus*)

Fossil Canyon

The canyon of a small creek flowing into Tahtsa River from the north about 6 miles below the confluence with Sibola Creek proved to be a very good locality. The creek cuts across the strata at a slight angle and exposures are good. The fossils have suffered some deformation from pressure exerted during folding of the beds and are not generally well preserved, but are abundant and relatively easy to collect. Collections were made from four separate localities in the canyon, all within ½ mile above the mouth of the creek. In order ascending the creek the collections were as follows:

Catalogue No. 13759. H. Frebold
Ammonites sp. indet. (*Stephanoceras*)
"*Terebratula*" sp. indet.
Trigonia sp.
Pinna sp.
Other pelecypods
Age: Probably Middle Bajocian (early Middle Jurassic)

Catalogue No. 13760. H. Frebold
Stephanoceras cf. *caamanoi* McLearn (poorly preserved fragment)
Ammonites sp. indet.
Trigonia cf. *dawsoni* Whiteaves
Trigonia sp.
Pinna sp.
Age: Middle Jurassic

Catalogue No. 13761. H. Frebold

"Terebratula" sp. indet.

Pinna sp.

Other poorly preserved pelecypods

Age: Probably Middle Jurassic

Catalogue No. 13762. H. Frebold

Stephanoceras n. sp.

Trigonia sp. indet.

Other badly preserved pelecypods. Some indeterminable gastropods

Age: Probably Middle Bajocian (early Middle Jurassic)

Several collections were made from localities along the north shore of Tahtsa River, some close to the river, others north of it. These contained fossils similar to those already mentioned.

North shore of Tahtsa River about ½ mile east of Fossil Canyon

This locality is flooded now that the storage basin of the Kitimat development has been filled.

Catalogue No. 13752. H. Frebold

Indeterminable ammonites

"Terebratula" apparently the same form as in catalogue Nos. 13759, 13761 and 13755

Some poorly preserved pelecypods

Age: Probably Middle Jurassic

North shore Tahtsa River 1 mile east of Fossil Canyon

Catalogue No. 13749. H. Frebold

Stephanoceras sp. indet.

Pinna sp.

Other poorly preserved pelecypods

Age: Probably Middle Bajocian (early Middle Jurassic)

Tahtsa River 2 miles east of Sibola Creek

Catalogue No. 13757. H. Frebold

"Rhynconella" sp.

Age: Probably Middle Jurassic

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Whitesail Lake Map-Area

2 miles north of Tahtsa River, 5 miles east of Sibola Creek

Catalogue No. 13756. H. Frebold
Trigonia sp.
"*Rhynconella*" sp.
Age: Probably Middle Jurassic

1½ miles east of Fossil Canyon, 1 mile north of Tahtsa River

Catalogue No. 13747. H. Frebold
Ammonites indet. (of Middle Jurassic affinities)
Belemnites
? *Pinna* indet.
? *Trigonia* indet.
Other poorly preserved pelecypods
Age: Probably Middle Jurassic

Tahtsa River 2 miles west of Mosquito Hills

Catalogue No. 13755. H. Frebold
Ammonites sp. indet.
Trigonia (common; some specimens similar to *Trigonia ferrieri* McLearn)
Other poorly preserved pelecypods
"*Terebratula*" sp. indet. (apparently the same form as in catalogue Nos. 13751, 13761 and 13759)
Age: Probably Middle Jurassic

½ mile east of 13755

Catalogue No. 13751. H. Frebold
"*Terebratula*" sp. indet. (same form as in 13755)
Age: Same as collection 13755

2 miles south of Nadina Lake

Catalogue No. 18279. H. Frebold
Stephanoceras?
Trigonia sp. indet.
Age: Probably Middle Jurassic

Two collections were made just west of the north end of the Mosquito Hills about 3 miles north of Tahtsa River.

3 miles north of Tahtsa River about 12 miles up from Sinclair Lake

Catalogue No. 18277. H. Frebold
Ammonites gen. and sp. indet. (*Stephanoceras*?)
Belemnites sp. indet.
Trigonia sp. indet.
Other indet. pelecypods
Gastropods indet.
"*Rhynchonella*" sp. indet.
Corals
Age: Probably Middle Bajocian (early Middle Jurassic)

1 mile south of 18277

Catalogue No. 18278. H. Frebold
Belemnopsis sp. indet.
Trigonia sp. indet.
Other poorly preserved pelecypods
"*Rhynchonella*" sp. indet.
Age: Probably Middle Jurassic

Fossils were found at several localities on the southwest and west side of Tweedsmuir Peak but only two collections were made.

3 miles southwest of Tweedsmuir Peak

Catalogue No. 18281. J. A. Jeletzky
Belemnites sp. indet.
Age: Probably Jurassic

At this locality belemnites were very prolific and a fairly large collection was made but none of the specimens was well enough preserved for diagnostic identification.

3 miles west of the west end of Glatheli Lake

Catalogue No. 18282. H. Frebold
Belemnites sp. indet.
Poorly preserved pelecypods (among others *Trigonia* sp. indet.)
Age: Probably Middle Jurassic

Fossils similar to those detailed above were found on Holmes Ridge in the southeastern part of the map-area but their preservation was so poor that positive identification or dating other than 'Jurassic' could not be made.

Though many of the forms collected were poorly preserved and indeterminate, the evidence is sufficient to substantiate the age of the bulk of the rocks included with the Hazelton group in Whitesail Lake map-area as the Lower and Middle Bajocian stage of the Middle Jurassic. The volcanic rocks overlying the Middle Jurassic sedimentary division may include some Upper Jurassic strata but there is no definite evidence for this.

Correlation

Sedimentary and volcanic rocks included with the Hazelton group by workers in other parts of central British Columbia range in age from Lower Jurassic to Lower Cretaceous. In the Whitesail Lake area, rocks comprising the Hazelton group are largely of Middle Jurassic age and thus may be correlated with other Middle Jurassic sedimentary and volcanic rocks in central and southern British Columbia.

In central British Columbia sedimentary rocks of Middle Jurassic age containing fossils similar to those found in the Whitesail Lake map-area have been reported from Nechako, Hudson Bay Mountain, Smithers, and McConnell Creek map-areas. In the Queen Charlotte Islands the lower part of the Yakoun formation is considered to be equivalent in age on the basis of *Stephanoceras*. In southern British Columbia, Middle Jurassic sedimentary beds have been reported from the southwest part of the Hope area, at Ashcroft, and from the Tyaughton Lake area. Frebold (1953) in his correlation chart of the Jurassic formations of Canada, clearly shows with which formations the Middle Jurassic rocks of Whitesail Lake map-area may be correlated.

In the McConnell Creek map-area, Lord (1948) included the Middle Jurassic sedimentary strata in the upper division of the Takla group. Many of the fossil forms present in the Whitesail Lake rocks are also present in the McConnell Creek strata. The similar fossil groups, together with the very similar lithology, suggest that the rocks of the two areas are not only of the same age but were deposited under similar conditions.

The volcanic rocks of Whitesail Lake map-area included with the Hazelton group, particularly those above the sedimentary division, are a southern extension of the so called 'Porphyrite' rocks included by Leach (1910) in his original description of the Hazelton group. Similar volcanic rocks are found in Nechako, Smithers, Fort St. James, Houston, and Terrace map-areas.

Coast Intrusions

Subsequent to the deposition of the Hazelton group, emplacement of plutonic rocks was widespread throughout the map-area, particularly in the west half. The period of emplacement persisted at least till the end of the Cretaceous era, and though no plutonic rocks of Tertiary age were recognized in the area, post-Upper Cretaceous plutonic rocks occur on Nadina Mountain (Lang, 1942) just to the north.

Mapping showed that the southwestern one-third of the map-area is underlain by plutonic rocks of the Coast Intrusions. In addition to this main mass, and to the east and northeast of it, many stocks, bosses, and cupolas, commonly possessing no particular characteristic other than a general similarity to the main mass are present. Several of these plutons are, however, sufficiently distinctive to be described as separate groups or individuals. For descriptive purposes the Coast Intrusions have been divided into the following units.

Main mass	(8)[1]
Quanchus intrusions	(7)
Diorite	(4)
Gabbro	(3)
Red granite	(6)
Red syenite	(5)
Mount Bolom stock	(10)
Swing Peak stock	(9)

Commonly the plutons are separated from one another and only in one instance were different types found, in contact. However, all are in contact with the Hazelton group rocks and two of the plutons were found in contact with the Lower Cretaceous rocks on Swing Peak and Laventie Mountain.

The term Coast Intrusions was used by Rice (1947, p. 33) to include those plutonic rocks which occur largely in the Coast Range but may be present outside that physiographic province. They comprise a distinctive suite of rocks including granodiorite, granite, quartz diorite, diorite, quartz monzonite, monzonite, and related rocks. In southern British Columbia they may be separated from an intrusive suite that is less acidic and is characterized by reddish syenites that locally contain sufficient quartz to be classed as a granite. This latter suite overlaps the Coast Intrusions in time sequence and is perhaps a little younger. No general term has been given to these

[1] Number in brackets is that of the unit in the map-legend.

quartz-deficient rocks but in southern British Columbia they include such bodies as the Otter granite in Princeton area (Rice, 1947) and the Coryell batholith in Nelson area (H. W. Little, personal communication). In central British Columbia the granitic rocks are most commonly associated with the Coast Intrusions and though some bodies similar to the less quartzose suite have been noted, there is no clear separation. In Whitesail Lake map-area the granitic rocks undoubtedly belong to the Coast Intrusions. Only in one small group (map-unit 5) is the quartz sufficiently deficient to question its inclusion with the regular Coast Intrusions. Though this intrusion resembles the quartz-deficient suite of southern British Columbia, its correlation with that suite is doubtful. It has, therefore, been included with the regular Coast Intrusions but is described under a separate heading.

Lithology

Main Mass (8). The plutonic rocks included under map-unit 8 comprise all the granitic rocks in the southwest corner of the area, as well as related stocks and bosses on Sibola and Chikamin Ranges and in the region of Morice, Anzac and Tagetochlain Lakes. Also included are two small cupolas in the Shelford Hills.

These rocks, mainly granodiorite, granite, diorite, and quartz diorite, are light to dark grey, but may be red or flesh coloured near their contact with Hazelton group rocks.

In the vicinity of Kitlope Lake, well within the main mass and distant from any contact, the rock is a light grey, medium- to coarse-grained, fresh granodiorite. Orthoclase is commonly less than 30 per cent of the total feldspar and the plagioclase is oligoclase about An_{15}. Quartz, which comprises about 35 per cent of the rock, is clear and occurs as relatively large anhedrons. Rarely is there quartz-feldspar intergrowth. The ferromagnesian mineral is commonly biotite, less commonly hornblende. Biotite is present in fine flakes or well-developed books; hornblende as euhedral crystals or anhedral feathery masses. Foliation is not common but does occur in the vicinity of faults and shears.

Southwest of Surel Lake and between there and Seel Lake, the plutonic rock is a coarse-grained hornblende granite containing large, well-developed phenocrysts of orthoclase and interstitial greyish white oligoclase and colourless quartz. Near Ear Lake the feldspars of this granite are red, due to contained particles of hematite. The hornblende is a green pleochroic variety. In thin section the specimens show strain shadows in the quartz anhedrons and the feldspars are so clouded that identification is difficult. The rock as a whole appears to have suffered alteration by percolating solutions. On the east side of Sias Mountain the orthoclase phenocrysts of this hornblende granite are up to 1 inch long. Thin sections of this rock also show the feldspars to be clouded and the hornblende altered to chlorite and magnetite.

South of Musclow Lake the plutonic rock is a medium-grained, dark grey granodiorite consisting of 65 per cent andesine An_{32}, 20 per cent hornblende and minor biotite, and 10 to 12 per cent quartz, the remainder accessory minerals.

Between Tahtsa and Nanika Lakes red granite, grey quartz diorite, and dark granodiorite are present. Tsah Mountain is composed largely of a red hornblende granite that shows evidence of alteration by deuteric action and is similar to the rock between Surel and Lindquist Lakes.

On Redslide Mountain the plutonic rock is a medium-grained hornblende-biotite granite, in which the feldspars have a slightly pink colour. In thin section all minerals but quartz appear to have suffered deuteric alteration. Near Anzac Lake and Tableland Mountain the stocks are a medium- to fine-grained pink granite. In thin section, the feldspars and ferromagnesian minerals are seen to be altered.

The plutonic rock composing the stock on Sibola Peak is a dark grey hornblende-biotite granodiorite. Diorite and a light coloured granite outcrop on Chikamin Range but a large part of the pluton is covered by the cirque glacier on the peak.

The plutons in the vicinity of Tagetochlain Lake and Nadina River differ from the regular Coast Intrusions in that they are porphyritic. The feldspar, which is oligoclase, occurs in phenocrysts up to ¼ inch by ½ inch in size in a groundmass of fine-grained quartz, plagioclase, and hornblende. Hornblende of the common variety may also occur as phenocrysts. These rocks may be classed as porphyritic diorites.

The granodiorite in the vicinity of Kitlope Lake had suffered less alteration than the plutonic rocks observed elsewhere in the main mass. In localities close to the contact with the Hazelton group the plutonic rocks are commonly red or pink and invariably altered. In some of these cases the red colour was due to the inclusion of hematite particles in the feldspars. Commonly the feldspars are altered to zoisite and sericite, and the hornblende is altered to chlorite and magnetite.

Quanchus Intrusions (7). The Quanchus intrusions underlie a large part of the high plateau between Eutsuk and Ootsa Lakes. They form the core of the Quanchus Range, Michel Peak, Chef Ridge, and the southern slope of Eutsuk Peak. They also outcrop along the shore of Eutsuk Lake towards its eastern end, and near Detna Lake and Watut Mountain. The largest of these intrusions, which Marshall (1926, p. 151) named the Quanchus batholith, underlies Mount Wells and Tweedsmuir Peak.

The main rock type composing the intrusions is an even textured, pink to grey granite consisting largely of quartz, orthoclase, oligoclase, hornblende, and biotite with accessory minerals magnetite, apatite, and zircon. The proportions of these minerals vary from place to place and pluton to pluton. Oligoclase, which is commonly 5 to 10 per cent of the rock, is much subordinate in amount to orthoclase, but may increase to the point where the rock becomes a quartz monzonite. Quartz, both clear and smoky, varies between 20 and 50 per cent but may be less in some localities, and there the composition approaches that of a syenite. Hornblende and biotite are present in about equal amounts and make up from 5 to 10 per cent of the rock. Accessory minerals do not form over 3 per cent. The two small plutons near Detna Lake and Watut Mountain are quartz diorite. The plagioclase is andesine An_{35}, with hornblende the dominant ferromagnesian mineral. Though these two plutons differ in composition from the others, they are so similar in their main characteristics that they have been included with the Quanchus intrusions. The quartz on Mount Wells is difficult to see in the hand specimen and the rock looks very much like a syenite, but in thin section the rock is seen to contain about 35 per cent quartz. Near Chef Ridge and along Eutsuk Lake the granite is composed almost entirely of orthoclase and quartz in about equal amounts, with biotite the ferromagnesian mineral when any is present. The orthoclase, commonly in phenocrysts, is pink on a fresh surface but weathers white, and the bare hills and ridges composed of this granite are very conspicuous.

Throughout the whole mass quartz-orthoclase intergrowths are common. The feldspars are altered with the resultant production of kaolin and sericite. Quartz, commonly clear, is smoky in the granites along the shore of Eutsuk Lake and on Chef Ridge.

Though the rock is commonly medium grained it may be fine or coarse grained or porphyritic. Where it is porphyritic the phenocrysts are orthoclase.

Diorite (4). Several promontories on Eutsuk Lake are composed of diorite which also outcrops on the southeast side of Chikamin Range, on Lady Susan Island, and south of Redfish Lake. The diorite outcropping on Eutsuk Peak is probably also correlative. This diorite occurs in small widely separated plutons, none over 5 square miles in area, and except for the one on Eutsuk Peak all occur along the shore of the lake.

In hand specimen it is a dark grey, medium-grained holocrystalline rock composed essentially of plagioclase, hornblende, augite, and accessory magnetite and chlorite. In thin section it is seen to consist of about 75 per cent of slightly zoned andesine An_{44} occurring in well-developed laths. Anhedral hornblende and augite form the remainder of the rock. Quartz is rare, having been noted in only one specimen. Alteration has progressed slightly and the plagioclase is altered along minute fractures in the laths. Chlorite and magnetite are seen to occur as secondary minerals after hornblende.

Gabbro (3). Three small plutons of gabbro were noted at widely separated localities within the map-area. One of these forms a distinct hill just north of the settlement of Ootsa Lake close to the eastern boundary of the area. Locally this is known as Bennett's hill, and was formerly used by the Provincial Forestry Department as a lookout station. A second stock of gabbro outcrops in the Tahtsa Range west of the granodiorite mass on Sibola Range. On Core Mountain a small pluton about 1,000 feet in diameter is of similar composition to that in the Tahtsa Range.

The pluton of Bennett's hill, a few acres in area, is composed of a dark weathering, greenish grey, medium- to coarse-grained, massive rock containing feldspar laths up to $\frac{3}{8}$ inch long. Commonly the rock is medium grained, but on top of the hill it becomes coarse grained and shows well-developed phenocrysts of plagioclase with some hornblende and augite. Where the rock is medium grained, feldspars are dominant and ferromagnesian minerals poorly developed.

A thin section of a medium-grained phase of the rock showed it to consist of about 90 per cent plagioclase, labradorite An_{62}, pale purplish brown augite and pale yellowish green chlorite. The chlorite formed as an alteration product of the augite. The feldspars show slight alteration to kaolinite along minute fractures. The rock as a whole is fresh and the minerals are relatively unaltered.

Joints, in a direction south 35 degrees east, are prominent.

The stock on Tahtsa Range covers an area of 3 to 4 square miles and occurs on the crest of the range. It is a fine- to medium-grained, dark grey rock, which, in hand specimens, closely resembles many of the diorites associated with the main mass of Coast Intrusions. Ferromagnesian minerals form about 30 per cent of the rock. In thin section it was seen to consist of 60 to 65 per cent plagioclase, labradorite An_{53}, 30 to 35 per cent hornblende, and 5 per cent magnetite.

The small pluton on Core Mountain is of similar character and feldspar composition to that on Tahtsa Range. A thin section of the rock shows a few grains of euhedral apatite not seen in the Tahtsa Range specimen.

Red Granite (6). A large part of the southeastern slope of Whitesail Range is underlain by a medium-grained, pink to red granite. Similar granite outcrops on the east shore of Whitesail Lake and in small cupolas along Tahtsa River in the vicinity of the Mosquito Hills. All contacts seen of the body on the east shore of Whitesail Lake proved to be faults, as did some of the contacts on Whitesail Range. The exposures on Whitesail Lake and Tahtsa River are covered by the waters of the Aluminum Company's project.

Similar rock of coarser grain was observed along Bone Creek on the southern slope of Key Mountain.

On Whitesail Range the rock is a fresh looking, medium-grained, red to pink granite consisting mainly of anhedral quartz, pink orthoclase, minor oligoclase, biotite, and hornblende, and a few specks of magnetite. Quartz, which is commonly about 20 per cent of the rock, may in some localities be reduced to 10 per cent or less and the rock becomes syenitic. Orthoclase, the dominant feldspar, is pink in colour and anhedral in form. Quartz-orthoclase intergrowths are common. Oligoclase is present in minor amounts. The feldspars show slight alteration to kaolin but the quartz is unchanged and commonly occurs as distinct clear eyes.

On Tahtsa River the rock contains less quartz, none being seen in the hand specimen. In thin section the rock is similar to that on the Whitesail Range, except that quartz has decreased in favour of plagioclase and apatite is present as an accessory; ferromagnesian minerals are scarce. The rock approaches a granodiorite in composition.

On Key Mountain the rock is a pink to red, coarse-grained, porphyritic hornblende granite. In hand specimen it is seen to consist of large, not uncommonly euhedral, orthoclase, large anhedral quartz grains with interstitial plagioclase, and large hornblende phenocrysts. The rock is commonly coarse grained and locally may become pegmatitic. Feldspar phenocrysts up to ¾ inch in size were noted. The plagioclase is slightly zoned and all the feldspars are altered.

Red Syenite (5). Between Wahla Lake and Eutsuk Lake, on Oppy Lake, Nadedikus Mountain, and Two Bear Hill there are stocks and bosses of a red plutonic rock that is mainly syenitic in character, but locally contains sufficient quartz to be termed a granite or quartz monzonite. It is essentially a red, fine- to medium-grained rock that in hand specimen shows phenocrysts of pink orthoclase, minor oligoclase, rare quartz, and fine needles of hornblende. Under the microscope the rock is seen to consist of about 65 per cent cloudy orthoclase, 25 per cent oligoclase, 5 per cent quartz, and 5 per cent hornblende and magnetite. Graphic intergrowths of quartz and orthoclase are common and the general character of the rock is similar to that of the red granite described above except that it contains much less quartz.

Mount Bolom Stock (10). A large part of Mount Bolom is underlain by a light coloured, medium- to fine-grained, porphyritic granite that cuts the late Lower Cretaceous rocks on Laventie Mountain and Swing Peak. It is composed of phenocrysts of cloudy orthoclase in a finer groundmass of plagioclase and quartz with a little biotite and hornblende. Under the microscope, the quartz, which comprises about 15 per cent of the rock, is clear. The orthoclase is cloudy and commonly in slight graphic intergrowths with the quartz.

Swing Peak Stock (9). A light coloured, porphyritic, plutonic rock that outcrops on Swing Peak may be associated with the mass on Mount Bolom. It weathers light brown to rusty, and is composed of phenocrysts of feldspar, biotite, and hornblende, in a light grey groundmass.

Structural Relations and Age

Contacts of the Coast Intrusions with older rocks may be either clear-cut intrusive, gradational through a metamorphic zone, or faulted. Adjacent to the main mass there is commonly a metamorphic zone containing rocks of a 'hybrid' character. This metamorphic zone is irregular in size, shape, and continuity. It may be interrupted by a tongue of batholithic rock, or be present as an embayment in the edge of the batholith. Such zones are mixtures of batholithic material, older volcanic and sedimentary rocks, and intermediate or hybrid types that have some of the characteristics of each of the main components. Small plutons, cupolas, and dykes of batholithic material may cut these hybrid rocks, but commonly the beds are not greatly disturbed and the contact is a zone rather than a sharply defined line.

The above contact relations differ from those associated with the small plutons occurring some distance away from the main mass. The contacts of these bodies are sharper and better defined, metamorphism is not so great; 'hybrid' types are present in minor amounts. Commonly the older rocks are more disturbed than is the case near the main mass. These relations hold true on Sibola Range and Chikamin Range and on other similar stocks. On the ridge north of Fenton Lake the granitic rock–Hazelton group contact is sharp and well defined. The Hazelton group rocks near the contact are metamorphosed but still easily recognizable as volcanic and sedimentary types whose attitudes conform approximately to that of the granitic contact. At several localities on Mount Wells and Michel Peak granitic dykes were observed extending from the main pluton into the older rocks. Similar relations were observed associated with the stock on Swing Peak.

Faulted contacts are probably more common than indicated on the map. They were observed, particularly, associated with the main mass of the Coast Intrusions south of Tesla Lake and at several localities on Whitesail Lake and Whitesail Range. At the head of Tahtsa Lake swarms of red granite dykes cut the metamorphosed rocks. The contacts on these dykes are commonly filled with gouge, indicating faulted conditions.

Fractures and joint systems are common in the intrusions of the map-area. The main joint or fracture pattern of the main mass of the Coast Intrusions is exemplified by the longitudinal and transverse valleys of the Coast Mountains. Locally there are joint and fracture patterns that differ from the major system but the common direction is south 60 degrees east, which is close to that of the longitudinal valleys of the main mass.

The plutonic rocks included under the heading Coast Intrusions are not all of the same age but are composed of rocks of several periods of emplacement. Relations between the plutonic rocks and the volcanic and sedimentary rocks indicate to some extent the limits in which the period of emplacement must fall.

Evidence of granitic emplacement early in the Mesozoic era is indicated by the fragments composing a volcanic breccia on Chikamin Range. This breccia immediately overlies Middle Jurassic sedimentary beds and contains fragments and boulders of granitic material up to a foot in diameter. As it is probable that this breccia, like the underlying beds, is of Middle Jurassic age, the granitic plutons from which the fragments originated must have been emplaced in pre-Middle Jurassic time. Stuart (1955) indicated that granitic dykes and cupolas, included with the greenstone complex at the head of Tahtsa Lake, are overlain unconformably by rocks equivalent to the Hazelton group. The evidence, therefore, strongly indicates that some plutonic rocks were emplaced prior to the deposition of the Hazelton group. As the Hazelton group is itself cut by many types of plutonic rocks there is no doubt that much of the plutonic suite was emplaced after the deposition of the Hazelton group.

The upper limit of the period of emplacement, as indicated by the available evidence, is in early Tertiary time prior to the deposition of the Miocene basalts. Within the map-area all of the main plutons are younger than the Hazelton group and at least two, those on Mount Bolom and Swing Peak, are younger than Lower Cretaceous, as they cut rocks of that age on Swing Peak and Laventie Mountain. It is possible that other plutons, not in contact with these Cretaceous rocks, are of the same age. On Nadina Mountain just north of the map-area Lang (1940) found a red granite cutting definite Upper Cretaceous strata and it is possible that some of the small plutons near the north boundary of the area belong to this period of emplacement. Unfortunately within the map-area no granitic rocks were found in contact with rocks of probable Upper Cretaceous age, such as those along Ootsa Lake. The Miocene basalts on Mount Wells and Chef Ridge are, however, undisturbed and lie directly on the eroded surface of granitic rocks of the Quanchus intrusions, which indicate that the period of emplacement of plutonic rocks had ended prior to the deposition of the Miocene flows.

Evidence within the map-area therefore indicates that emplacement of the plutonic rocks included with the Coast Intrusions occurred over a period extending from pre-Middle Jurassic time to some time in the early Tertiary prior to the deposition of the Miocene flows. The bulk of the plutonic rocks were most probably emplaced during the Cretaceous period.

It was not possible to separate or divide the various plutonic masses into relative ages as few of the major plutons are in contact. The two stocks that cut the upper Lower Cretaceous rocks are presumed to be the youngest but others, not in contact with the Lower Cretaceous rocks, may be of the same age. Only in two instances was one plutonic rock seen to cut another. At Kitlope Lake the predominant grey granodiorite is cut by narrow dykes of a red coarse-grained granite, and at the head of Tahtsa Lake the granitic dykes and cupolas included with the greenstone complex are cut by a light grey quartz diorite that enters the area from the west.

Mode of Emplacement

In Whitesail Lake map-area ample evidence exists to support each of the two main theories for the emplacement of plutonic rock, and it is probable that both processes were active in the emplacement of the Coast Intrusions. A zone of metamorphic and hybrid rocks is present along the border of the 'main mass', in which various stages of alteration of the older volcanic and sedimentary rocks to granitic material may be noted. These zones may of course be mainly places of border assimilation, but metasomatic replacement of original material by granitic material has taken place.

In the vicinity of the smaller plutons, removed from the main contact, the zone of metamorphism is much narrower and hybrid rocks are less abundant; contacts are sharp and the disturbance of older rocks is greater. It would appear that the plutonic rock in these instances was emplaced as a magma forcing its way into the older rocks rather than as a quiet replacement.

Some of the contacts along the 'main mass' are faults, and probably the contacts of some of the outlying bodies are also faults, although no evidence was observed to show that whole bodies have been faulted into place.

Lower Cretaceous Rocks (11)

A series of interbedded black shales and fawn to grey sandstones and arkoses occurs on Swing Peak and Laventie Mountain, which is lithologically and palæontologically similar to the Haida formation of the Queen Charlotte Islands. Overlying these sedimentary strata is a series of volcanic rocks, but whether the contact is conformable or unconformable is not definitely known. However, the two series appear to be conformable and the similarity of their attitudes and relationship to the intrusive rocks suggest they are a single unit. They have, therefore, been mapped together.

Distribution

Rocks included in this group occur only in one locality, mainly on Swing Peak and Laventie Mountain. They extend westward from the small creek immediately west of Kasalka Butte along the whole length of Swing Peak ridge. They underlie all of Laventie Mountain and outcrop along the south shore of Tahtsa Lake as far west as Laventie Creek. They were not observed on Mount Baptiste but occupy the northern extremity of Mount Bolom. No other rocks with a similar fossil content were noted elsewhere in the area but a small patch of sandstone on Tahtsa Range was similar lithologically. Except for fossil content these rocks are very similar to parts of the Hazelton group and have been mapped with that group in the past (Marshall, 1925, p. 48). Other small isolated patches may have been included with the Hazelton group in the present mapping.

Lithology

The lower half of the group consists entirely of sedimentary rocks of marine origin. Dark grey to black fossiliferous mudstones are conspicuous near the base, occurring in beds 75 to 100 feet thick. Minor thin beds of grey to fawn arkose separate the mudstones in this part of the sequence. Higher in the sequence the arenaceous material increases and the mudstones are interbedded with more and more sandstone and arkose. Still higher in the sequence several hundred feet of arkosic sandstone are present. This sandstone is fawn to grey, fine grained, and well stratified in beds 2 inches to 2 feet thick. It commonly weathers a rusty yellow and contains a few fragmentary plant remains.

The sedimentary strata on Swing Peak are at least 2,000 feet thick at the east end. They thicken towards the west end of the ridge where they may reach a thickness of 3,000 feet.

The volcanic rocks overlying the sedimentary sequence consist of red, green, and brown breccia and tuff and grey, brown, and black andesitic and basaltic lava flows. The fragments of the pyroclastic rocks range in size from 1 mm. to as much as 6 or 7 inches. Some of the flows are porphyritic with phenocrysts of plagioclase and hornblende in a fine-grained, purple groundmass. Others are amygdaloidal and some show the characteristics of a flow breccia. The volcanic part of the group has a thickness of about 2,000 feet and covers the central part of the ridge of Swing Peak.

Structural Relations

All strata on Laventie Mountain and Swing Peak have a general easterly strike and southerly dip. The dip ranges from 12 to 15 degrees at the eastern end of the ridge to as high as 65 degrees farther west, but is commonly under 30 degrees. The strike varies from north 40 degrees west to north 80 degrees west, except where local structures cause a deviation from the general trend.

Both the sedimentary and volcanic sequences are intruded by the stock of purple feldspar porphyry underlying a part of the eastern end of the Swing Peak ridge. The whole sequence is also cut by fine-grained porphyritic and dioritic dykes, and the granitic rocks of the Mount Bolom stock.

The contact of the sedimentary rocks with the underlying Hazelton group was not observed, though much time and effort was spent in searching for it. The eastern contact of the group lies close to a small stream along which there appears to have been some movement and it may be that this contact is a faulted one. The Hazelton rocks east of the contact have a decidedly different trend and composition and if the contact is not faulted it is certainly not conformable. The Cretaceous rocks outcrop along the south shore of Tahtsa Lake but were not observed on the north shore. The contact there may also be a fault that lies under the lake.

Age and Correlation

The mudstones of the Lower Cretaceous series, which are conspicuous near the base, contain marine invertebrate fossils that definitely establish the rocks as belonging to the Albian stage of the Lower Cretaceous epoch.

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Fossils were collected from the canyon of the small creek just west of Kasalka Butte near the eastern contact of the series. Two collections were made from this locality, referred to as Slate Creek, one in 1951 and the other in 1952. These collections were studied and all identifications made by J. A. Jeletzky of the Geological Survey. The forms identified are:

Catalogue No. 19756, collected 1951

Sonneratia (*Sonneratia*) ex gr. *kitchini* Spath
Sonneratia (*Cleoniceras*) ex aff. *pereziana* (Whiteaves)
Sonneratia sensu lato spp. indet.
irregular echinoids from the family
Spatangidae Wright, probably belong to the genus
Toxaster Agassiz
Metahamites ? sp. indet.
Pecten spp. indet.
Yoldia ? sp. indet.
Lima sp. indet.

The 1952 collection did not include any different forms and is therefore not listed here.

Jeletzky reported on the collection as follows:

> The ammonoid genus *Sonneratia* Bayle is accepted in the broad sense of F. Roman ("Les ammonites Jurassique et Crétacées", Paris, 1938).
>
> The genus *Sonneratia* even in the broad sense adhered to in this report is an exclusively Lower Albian genus, at least in the present state of our knowledge. The same applies to its subgenus *Cleoniceras*. Therefore a Lower Albian stage (latest stage of the Lower Cretaceous series) is indicated.
>
> The individual *Sonneratia* forms show strong affinities with those of the Haida formation of Queen Charlotte Islands, and the collections from Swing Peak are believed to be equivalent in age to the lower part of that formation. In addition to *Sonneratia* (*Cleoniceras*) ex aff. *pereziana* (Whiteaves) the Swing Peak collection contains several *Sonneratia* forms probably identical with or closely related to as yet undescribed forms from the Haida formation in collections of the Geological Survey. Coarsely ribbed forms of *Sonneratia* (*Sonneratia*) ex gr. *kitchini* Spath are also represented in these collections.
>
> Some forms of *Sonneratia* in the Swing Peak collections appear to be closely allied with *Sonneratia* ex gr. *mulleri-perinismithi-stantoni,* which were recently referred to the genus *Lemuroceras* Spath, and to *Cleoniceras* ex gr. *modestum* Anderson characteristic of the Huling beds of the Californian Horsetown group. *Sonneratia* (*"Pseudosonneratia"*) ex gr. *sakalava* Collignon and *Sonneratia* (*Cleoniceras*) *besairiei* Collignon of the Madagascar Albian rocks seem also to be comparable with some Swing Peak *Sonneratia.*
>
> All of the above mentioned forms of *Sonneratia* related to those in the Swing Peak collection are generally believed to be of early Albian age. The *Sonneratia* fauna collected from Swing Peak was at the time the only definite record of early

Albian marine rocks on the mainland of British Columbia. Since then, however, an early Albian form of *Beudanticeras* cf. *breweri* Anderson has been found in a collection made by J. Usher from the Dewdney Creek formation in Princeton map-area in southern British Columbia. Another index fossil of the Lower Albian stage, *Douvilleiceras* ex gr. *mammillatum* (Schlotheim), was seen in a collection of C. H. Crickmay from the Bridge River area, also in southern British Columbia. There it apparently occurs in the upper part of the Eldorado group. These widely scattered occurrences of Lower Albian fossils suggest that the Haida sea may have covered considerable parts of southern, central and northern British Columbia.

In southern British Columbia two groups of rocks have been referred to the Albian stage of the Lower Cretaceous epoch. These are the Kingsvale and Pasayten groups which occur in Ashcroft, Princeton and Hope map-areas. The Pasayten group, which is mainly sedimentary rocks of continental origin, does contain minor volcanic rocks, mainly tuffs. Age determination was made on fossil leaves. The Kingsvale group resembles the assemblage on Swing Peak very closely with one notable difference. The sedimentary rocks at the base of the Kingsvale are continental in origin. The volcanic assemblage in both cases is very similar though it may be thicker in the Kingsvale group.

The presence of volcanic rocks of similar age in such widely separated parts of British Columbia would indicate widespread volcanism towards the close of the Albian stage of the Lower Cretaceous epoch.

Ootsa Lake Group (12)

A series of mainly acid flows with minor amounts of basalt, andesite, tuff, breccia, and rare conglomerate occurs in widely scattered patches in the northeast quarter of the map-area. These rocks form the rhyolite bluffs and ridges along Ootsa Lake and Whitesail River and many of the small hills east of Mount Wells and Tweedsmuir and Michel Peaks. On Ootsa Lake east of the map-area freshwater shells and fossil leaves of probable Upper Cretaceous age were found in a conglomerate bed near the base of the group. In Nechako River area to the east fossil leaves were found by H. W. Tipper that are of probable Upper Oligocene age. As these rocks are extensively developed along and adjacent to the shores of Ootsa Lake the term Ootsa Lake group is proposed for them.

Flooding of the Ootsa Lake-Whitesail Lake drainage basin for the Aluminum Company of Canada's Kitimat project covered much of this group, particularly the excellent outcrops along the former shores of Ootsa Lake. Many of the beaches along the old shore of Ootsa Lake were composed of rhyolite talus and were a distinctive feature of the country. Critical exposures covered by the flooding include the basal conglomerate of the group at the eastern end of Whitesail Lake, the bedded tuffs near Streatham, and the fossil locality at Chief Louis Bay east of the map-area.

Distribution

This group occurs in relatively small patches in the eastern and northeastern part of the map-area, but was not encountered in the western half of the area. The outcrops are concentrated mainly along and adjacent to the Ootsa Lake drainage basin from as far west as the mouth of Whitesail Lake. They underlie a large proportion of the ridge between Ootsa and Francois Lakes and extend across Francois Lake a short distance northward. They are very prevalent in Nechako River area to the east where they have been studied in some detail by H. W. Tipper of the Geological Survey. In Whitesail Lake map-area some of the largest and best exposed areas of these rocks are in the vicinity of Ghitezli, Thletelban, Chief Louis, and Uduk Lakes lying east of the Quanchus Range. Small areas of these rocks were found in the valley of Tetachuck Lake.

Lithology

Sedimentary rocks are not common in the group but on the east side of Whitesail Lake about 1 mile from the mouth are two relatively small outcrops of a very coarse conglomerate composed of roundstones of Hazelton group rocks in an arenaceous matrix. The stones, mostly greenish grey, range from cobble size to well-rounded boulders as much as 3 feet in longest dimension. The matrix is a coarse, grey-green sand.

Between 2 and 3 miles north of Wistaria landing is a band of conglomerate in which the pebbles consist of subangular to well-rounded fragments of red andesite, vesicular basalt, and dense black basalt. To the north the stones increase in size up to 6 inches in diameter.

Basalts are well represented towards the base of the group and some are amygdaloidal. They are dark grey to black, and are commonly marked by the development of very large labradorite phenocrysts up to 1 inch in length and ½ inch wide. The amygdaloidal varieties are less common than the massive types. Amygdules are most commonly chalcedonic quartz. One flow on the former shore of Ootsa Lake between Ootsa landing and Streatham contains thousands of chalcedonic amygdules of pea size. Commonly these amygdules weather away from the basalt and cover the outcrop as loose particles. Most of the amygdules are hollow but many are solid. One of the local inhabitants had several of the solid variety polished and buffed into small ornamental stones.

A thin section of a basalt flow, containing the large phenocrysts of plagioclase, showed little else than the euhedral forms of labradorite An_{53} in a microcrystalline groundmass of feldspar laths, magnetite, and interstitial glass. Olivine and apatite are present as accessory minerals. Calcite and limonite have formed as secondary minerals. The feldspar laths of the groundmass show distinct flowage around the large porphyritic feldspars.

Andesites are about as common as basalts and are generally light grey, purple, or black. The porphyritic feldspars are not as large as in the basalt flows. The islands in Ootsa Lake opposite Streatham were found to be composed almost entirely of andesitic flows that exhibited a crude columnar structure. These islands have been completely covered by the flooding of the lake.

A thin section of a purple andesite flow from the south shore of Ootsa Lake near these islands showed phenocrysts of plagioclase An_{35} and a lesser number composed of altered hornblende in a groundmass of feldspar laths and magnetite. In this also the feldspars of the groundmass showed distinct flow structure around the phenocrysts.

Rhyolite flows are perhaps the most distinctive rock types of the group. They outcrop along the hills bordering Ootsa Lake and commonly form distinctive ridges and knolls. Much of the road metal used on the old Ootsa landing-Wistaria road was broken rhyolite from nearby outcrops. The rocks are white to creamy white, light brown and, rarely, light pink. They are hard, dense, fine-grained rocks, in part porphyritic containing small phenocrysts of quartz and feldspar. The phenocrysts are commonly orthoclase or oligoclase and the groundmass consists of quartz, feldspar, and partly devitrified glass. Ferromagnesian minerals are rare, but a few crystals of hornblende do occur. Intergrowths of quartz and orthoclase are common. Spherulitic structures are common in the flows along Ootsa Lake, some of the spherulites being up to ½ inch in diameter. Perlites and perlitic rhyolites occur in similar rocks near Francois Lake north and east of the map-area, but were not seen within its boundaries.

It is believed that the perlitic flows associated with the group outside the map-area are stratigraphically higher in the group and are therefore slightly younger than the flows along Ootsa Lake.

The individual rhyolite flows vary greatly in thickness. They may be as little as 2 feet or as much as 100 feet, but most are 35 to 50 feet thick.

In addition to flows, tuff and breccia are also present. Near Streatham on the north shore of Ootsa Lake a section about 70 feet thick exposed thinly bedded tuff and breccia with individual beds ranging from ½ inch to 1 foot in thickness. The general colour of the rocks is greyish white to flesh. The larger fragments of the breccia, which are commonly basalt, are angular to subangular; the smaller fragments, also largely basaltic, are rounded to subrounded. Sorting is poor with little or no gradation between fine and coarse fragments. One thin bed of finely laminated, light grey rhyolitic tuff is composed of fragments less than 1 mm. across in a devitrified glassy groundmass.

West of the head of Ootsa Lake are several small hills or knolls composed of rocks of this group. One of these hills, locally known as the 'Jap Hat', is composed of white to pinkish white, rhyolite breccia, with fragments up to 4 inches and an average size of ½ inch. In several places the rock has been carbonatized and pyritized and commonly the feldspars are kaolinized. There is no apparent flow structure though there is a slight lineation of the quartz in the larger fragments.

The conglomerate on Whitesail Lake appears to be the basal bed of the group. It is overlain by a black fragmental rock that has been highly altered. This in turn is succeeded by thin basalt and rhyolitic flows. In the vicinity of Francois and Tchesinkut Lakes, Armstrong (1949, pp. 68-74) divided the rocks here included in the Ootsa Lake group into three divisions, namely, Upper Cretaceous or younger, Eocene or Oligocene sedimentary rocks, and Eocene or Oligocene volcanic rocks. Tipper (personal communication), in Nechako River area where rocks of the group are more abundant and better exposed, divided them into a lower dominantly basaltic and andesitic division and an upper dominantly acidic volcanic unit. His two divisions, which are based on lithological composition, are equivalent to Armstrong's three divisions, which were based on fossil collections. In Whitesail Lake area, although it is recognized that basalts and andesites are more abundant near the base of the group, as a unit the group is dominantly rhyolitic and there did not seem to be sufficient basic material present in any part to make a definite subdivision. No fossils were collected from this group in the map-area and no subdivisions could be made on this basis. The rocks therefore were not subdivided, but were treated as a single unit equivalent to Armstrong's three and Tipper's two subdivisions.

The thickness of the group is uncertain and varies from place to place. Armstrong indicated an aggregate thickness for his three divisions of about 3,000 feet. Tipper (personal communication), in Nechako area, suggested a thickness for the two subdivisions of at least 1,500 feet. In Whitesail Lake map-area the discontinuous and unstratified nature of the outcrops makes it difficult to attain any accurate figure for the thickness of the group. However, the few attitudes observed in the area of these rocks near the foot of Whitesail Lake indicate a thickness of about 3,000 feet.

Structural Relations

Rocks of the Ootsa Lake group have been moderately disturbed, with dips up to 55 degrees, although dips of 35 to 40 degrees are most common. The rocks of the group near the mouth of Whitesail Lake are folded into a shallow open syncline plunging to the northwest. Near the head of Ootsa Lake available attitudes indicate a sharp anticlinal structure the axis of which strikes west. Near Streatham the group is faulted by a northwest-trending fault, which has caused shearing and slickensiding in the rhyolites exposed along the shore of the lake.

The relationship of this group of rocks to those of the Hazelton group is one of erosional unconformity as evidenced by the basal conglomerate on Whitesail Lake. Granitic intrusions were not found in the group, nor does the adjacent Quanchus batholith appear to have intruded or altered the rocks. No definite contact between rocks of the group and the Quanchus batholith was seen, though much time was spent searching for one.

Near the head of Ootsa Lake rocks of the group are very close to the batholith but show no sign of metamorphism. It is, however, possible that the contact there is a faulted one.

The two small islands at the head of Ootsa Lake are cut by black basalt dykes which strike north 45 degrees west and dip 50 degrees to the northeast.

At several localities in the map-area the acid flows of this group are overlain by flat-lying basalts of post-Oligocene age.

Age

No fossils were found in rocks of this group within the map-area but relationships with older and younger rocks indicate a period of deposition extending from the late Cretaceous to Oligocene. East of the map-area, at Chief Louis Bay on Ootsa Lake, H. W. Tipper found both fossil leaves and freshwater pelecypods and gastropods in sandstone and conglomerate beds near the base of the group.

W. A. Bell of the Geological Survey examined the plant collection and reports:

> Most of the plant remains are too fragmentary to be of value. The few complete or nearly complete leaves show, at best, only the primary and secondary nervation and hence even a generic identification is open to question. With this reservation the leaves are referred to the following.
>
> *Alnus* sp.
> *Rhamnites marginatus* ? (Lesquereux)
> *Spirodela* ? *scutatata* ? Dawson
>
> The doubtful nature of the above identifications precludes any confident conclusion on precise age represented. So far as the evidence goes a late Upper Cretaceous or Paleocene age is considered probable.

E. T. Tozer of the Palæontological Division of the Geological Survey examined the shells in the collection and reports:

Catalogue No. 17180

> *Unionid* genus indet.
> *Sphaerium* sp. (cf. *S. heskethense* Warren)
> *Lioplacodes* sp. (cf. *L. sanctamariensis* (Russell))
>
> Although this faunule is very rich in individuals it is poor in species and consequently a satisfactory comparison with other faunas cannot be made. No significance can be attached to the unionid but some of the sphaeriids have the prominent posteriorly placed umbones characteristic of the Edmonton (Upper Cretaceous) species *S. heskethense* Warren. The *Lioplacodes* is closer to *L. sanctamariensis* (Russell), a contemporary of *S. heskethense,* than to any other described species. Although the faunule does not permit an unequivocal correlation an Upper Cretaceous age is suggested.

Near Tchesinkut Lake, Armstrong (1949, p. 70) collected fossil leaves from rocks included under the general heading of the group which indicated an Upper Cretaceous or later age. On the road north of Francois Lake, he (1949, p. 73) collected fossil leaves from rocks belonging to this group that were of Upper Eocene or Oligocene age.

In Nechako map-area north of Intata Lake, Tipper collected plant remains from a rhyolite tuff at or near the top of the group. W. A. Bell who studied the collection correlated them with the flora of the Kitsilano formation of probable late Oligocene age.

This information along with the structural relations of the group indicates that the period of deposition lasted from some time in the Upper Cretaceous probably to late Oligocene time.

Correlation

Rocks of similar age and composition to those of the Ootsa Lake group are present in several parts of British Columbia, particularly east of and parallel with the Coast Mountains.

In the vicinity of Whitesail Lake area rocks of the group have been found in Nechako River map-area to the east (Tipper, 1955), Fort St. James map-area (Armstrong, 1949), and Houston map-area (Lang, 1940) to the north. Tipper (personal communication) finds similar rhyolites in Anahim Lake map-area to the southeast.

In southern British Columbia the Kamloops and Princeton groups, which include sedimentary and volcanic rocks of Tertiary age, may be in part correlative. The Kitsilano group, though in part correlative in age, is largely of sedimentary composition. In the Chilcotin area and east of Taseko Lake rhyolites and conglomerates occur (Logie, 1929, p. 253) that may be of similar age.

In McConnell Creek map-area of north-central British Columbia the Sustut group (Lord, 1948, p. 34) of Upper Cretaceous and Paleocene age may be correlative. Though the Sustut group is composed largely of continental sedimentary rocks it does contain some beds of dacitic tuff.

Oligocene or Later Volcanic Rocks

The youngest consolidated rocks in the map-area are relatively flat-lying basaltic flows and related tuff and breccia that overlie unconformably the Ootsa Lake group. Associated with these rocks is a fresh-looking gabbro dyke that may be an intrusive phase of the basalts. No fossils were found in these rocks but they are similar to other basalts present in adjacent areas that are considered to be late Oligocene or younger in age. In Fort St. James and Nechako River map-areas similar rocks are referred to as the Endako group.

Distribution

The largest exposures of these rocks in the area are around Fenton Lake and the southwest shoulder of Chef Ridge. Near the headwaters of St. Thomas River they form a distinct escarpment about 800 feet high. In the northeast corner of the map-area they are widespread and form the southward extension of a large area of similar rocks in the Houston area to the north. They occur on the Mosquito Hills, the eastern tip of Whitesail Range, and as numerous small outliers east of the Quanchus Range. On the north shore of Eutsuk

Lake, east of Sand Cabin Bay, are four conical shaped hills composed entirely of basalt. Two of the small islands near the north end of Pondosy Lake are composed of rocks that, on the basis of their composition and fresh appearance, are included in this group though no other similar rocks are in the vicinity. The flat-lying basalts occur as caps or remnants of caps on most of the mountains east of the Coast Mountains and it is probable that they covered a much wider area later denuded by erosion. Such rocks are very prevalent in Nechako River area to the east and Anahim Lake map-area to the southeast. A gabbro dyke, exposed in the northeast corner of the area near Tatalrose, may be an intrusive phase of the basalts.

Lithology

Flows of the group are commonly fine-grained, dark grey to black basalts and andesites. Where they are porphyritic they may exhibit feldspar phenocrysts up to 1 inch in size. They may be massive, vesicular, or amygdaloidal with the amygdules most commonly of chalcedonic quartz although calcite and stilbite also occur. Olivine is present in some of the flows on Chef Ridge but is not a common constituent.

Under the microscope a typical basalt from the Mosquito Hills shows a few small broken and resorbed plagioclase phenocrysts in a very fine-grained groundmass of feldspar microlites, magnetite, and interstitial glass. Limonite is present as a secondary product. Hematite may replace magnetite as an accessory mineral.

Flows from the height of land between Francois and Ootsa Lakes are commonly very fine grained. They show few phenocrysts of feldspar, the whole being a mass of feldspar microlites and magnetite in a glassy groundmass. Flows from Chef Ridge are medium grained and commonly not porphyritic. Augite is abundant and olivine is present in minor amounts in some flows.

Tuff and breccia comprise a small proportion of the group and on the east end of Whitesail Range a soft, white ash bed occurs between two basalt flows.

Near the foot of Pondosy Lake is a group of small islands, two of which are composed of rocks included with this group. One of the islands is composed entirely of volcanic agglomerate. The rock is composed of fragments and blocks of Hazelton group rocks and minor amounts of intrusive rocks embedded in a matrix of red volcanic tuff. The fragments are rounded to angular and vary from pea size up to 10 inches in diameter, with no indication of sorting. Commonly a cluster of small fragments is wedged between the larger ones. The matrix consists of angular fragments of feldspar, quartz, and basaltic material.

Previous workers included all the islands in this vicinity with the Tertiary rocks. The writer, after careful examination, concluded that the rocks in this general area, with perhaps the exception of the two islands mentioned above, are more characteristic of the Hazelton group than of the younger rocks.

The gabbro dyke in the northeast corner of the map-area is a light grey porphyritic rock with phenocrysts of labradorite An_{56} in a fine-grained groundmass of plagioclase, biotite, and subordinate augite.

Internal Structure

Rocks of this group are relatively undisturbed and thus are commonly flat lying. On Mosquito Hills the flows have a gentle southerly dip of 25 degrees at a contact between two flows. The white ash bed between the flows on Whitesail Range dips 35 degrees southeast. Angles of dip, measured on columnar structures on Chef Ridge, are as high as 40 degrees at one place, though most flows in this region are flat lying. Many of the dips may be due to initial inclination for it seems most probable that these rocks were extruded over a terrain of at least moderate relief as they are found undisturbed both on plateau regions above timber-line and in valley bottoms. On the north shore of Eutsuk Lake east of Sand Cabin Bay the four buttes or hills mentioned above rise to as much as 1,000 feet above the general level of the valley bottom and are aligned in a direction south 45 degrees east. These four structures resemble volcanic plugs and were most probably sources for some of the basaltic material.

External Relations

Flow rocks of Oligocene or later age overlie unconformably all other consolidated rocks in the map-area. On Mosquito Hills and the eastern end of Whitesail Range they overlie the Hazelton group rocks with an angular unconformity. On Mount Wells and Chef Ridge they overlie batholithic rocks. They have themselves been deeply eroded during Pleistocene time and now occur merely as remnants of a much wider and thicker cover.

Chapter IV

ALCAN TAHTSA LAKE-KEMANO TUNNEL

Much has been written about the Aluminum Company of Canada's tunnel from Tahtsa Lake to Kemano River, which lies just within the western boundary of the map-area. The tunnel, about 10 miles in length and 20 to 25 feet in diameter, carries water from Tahtsa Lake at the head of the Nechako storage basin, westward through the mountains forming the divide, to the powerhouse at the Kemano River. The powerhouse chamber, excavated in Mount DuBose at the western end of the tunnel, is about 2,600 feet below the level of Tahtsa Lake when the storage basin is full. The whole scheme was an ambitious undertaking requiring much precise engineering and careful planning. Most of the papers written about this project are of a popular nature but many have also dealt with the engineering and logistic problems involved. We shall give here a brief background of the project and an outline of the geology in the vicinity of the tunnel, as well as mention the geological and geophysical work carried out during the construction period.

As the field work for the 4-mile mapping of Whitesail Lake area was completed more than a year before the completion of the tunnel, the writer did not have an opportunity to examine more than a small part of the tunnel excavations. Detail mapping of the tunnel and the surface geology was done by Mr. R. Stuart (1955) of the British Columbia Department of Mines. Dr. Alexander Smith spent some time examining special structures in the granitic rocks, and Dr. A. D. Misener, head of the Department of Physics of the University of Western Ontario, carried out thermal conductivity and heat flow measurements along the length of the tunnel.

Early in 1951 when the Aluminum Company of Canada decided to proceed with the whole Kitimat project, the construction of the tunnel and powerhouse presented an important and difficult operation. Before mining could start docks, roads, camps, mining plants, and communication lines had to be constructed. The general plan for construction of the tunnel was to work from both ends, and from the middle both ways. During the spring and summer of 1951 docks were built at Kemano Bay on Gardner Canal, and roads were constructed up Kemano River and Horetzky Creek, and from the head of Francois Lake to the outlet of Tahtsa Lake. Boats and barges were constructed at Ootsa Lake and hauled to Tahtsa Lake for the transportation of personnel and material. Camps and mining plants were established at West Tahtsa (*see* Frontispiece), near the head of Horetzky Creek, and at the west end of the tunnel at Kemano River. Actual mining commenced in October of 1951 and was completed December 2, 1953. Concrete lining and guniting of the tunnel, where required, and installation of machinery and equipment were accomplished by July of 1954, and power was first generated in that month.

Prior to 1951 little was known of the geological conditions along the line of the tunnel, except that some metamorphosed volcanic rocks were intersected by granite at the east end. It was expected that the greater part of the tunnel would be entirely within granitic rocks of the Coast Intrusions. Early in the season of 1951, the writer made several traverses from the head of Tahtsa Lake westward towards the mountains on either side of Horetzky Creek. Those traverses indicated that the volcanic and sedimentary rocks at the head of Tahtsa Lake extended much farther west than was previously believed and that they were intruded by tongues and cupolas of granitic rocks. The tunnel provided a 10-mile cross-section through the contact zone of the main body of Coast Intrusions with the older volcanic and sedimentary rocks, and afforded an excellent opportunity for detailed study and research on the mode of emplacement of the batholithic rocks and their contact relations with the older rocks.

During the early months of 1952, through the efforts of Dr. H. C. Gunning of the University of British Columbia, the National Advisory Committee on Research in the Geological Sciences, the Geological Survey of Canada, the British Columbia Department of Mines, and the Aluminum Company of Canada, agreed that a program of study should be carried out on the tunnel, and that for the season of 1952 Mr. Roy Stuart of the British Columbia Department and the writer should examine the available excavations to September of that year. The writer examined approximately 4,000 feet of tunnel at the Tahtsa Lake end and Mr. Stuart, who spent the whole season on the project, examined the excavations at Kemano and Horetzky and carried out detail mapping on the surface on a scale of ½ mile to the inch. A start was also made on temperature and heat flow measurements along the tunnel. During 1953 and 1954 Stuart mapped 180 square miles in the vicinity of the tunnel on a scale of 1 inch to ½ mile, and completed mapping of underground excavations on a scale of 1 inch to 50 feet. During 1954 Dr. Smith completed the studies of special structures in the granitic rocks and during the same year thermal conductivity measurements were completed. Final reports on these studies will be published in the near future.

The Aluminum Company of Canada was most cooperative and helpful during the progress of these studies.

Detail mapping by Stuart (1955, p. 108) indicated that the volcanic-sedimentary assemblage in the vicinity of the tunnel is divisible into two groups, a lower greenstone complex composed of metamorphosed andesites and tuffs, now mainly greenstones and amphibolites, cut by granitic dykes and cupolas; and an upper layered series consisting of quartzite, andesite tuff, schist, and limestone (*see* Figure 3). These greenstones are intruded, near Tahtsa Lake, by dyke swarms and cupolas of coarse red granite. This granite contains many inclusions of the older rocks and is itself cut by many dark green to black basaltic dykes. The actual boundaries of this type of

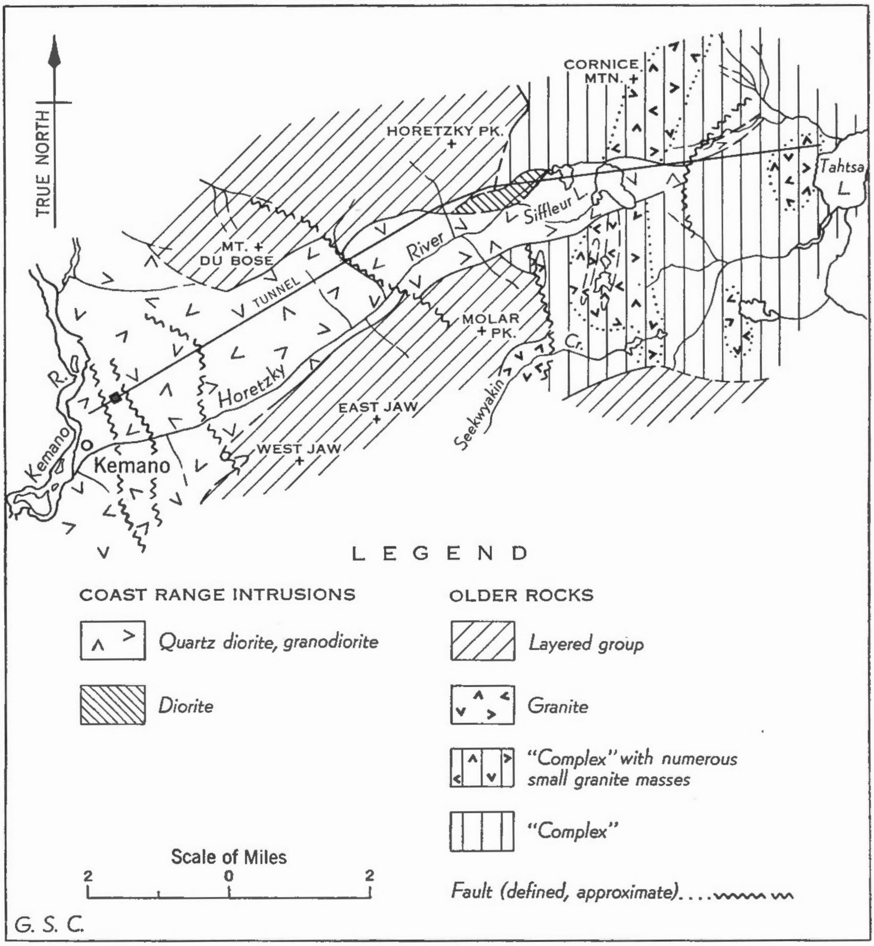

Figure 3. Map showing surface geology along the line of the Alcan Tunnel, B.C. (After R. A. Stuart, 1955.)

rock is difficult to determine. Occupying Horetzky Creek below timber-line and underlying Siffleur Lake and its immediate vicinity is a tongue of grey quartz diorite and granodiorite that is younger than the red granite dykes.

This grey granodiorite which is more than 1½ miles wide at Siffleur Lake narrows perceptibly east of the lake and pinches out before reaching Tahtsa Lake. These intrusions have caused a good deal of shearing and fracturing of the older rocks, a condition that presented some difficulties in the construction of the tunnel. The granodiorite itself is not fractured and little difficulty was experienced in driving the tunnel through it.

That part of the tunnel examined by the writer at the Tahtsa Lake end in 1952 was entirely within the greenstone complex. At the portal and for about 3,000 feet along the tunnel the greenstones are cut by dykes and cupolas of red granite. This granite is itself cut by narrow dark green to black basaltic dykes. Much of the granite is sheared and broken and traversed by numerous faults. Each granite-greenstone contact is marked by a mud seam or filled with rock gouge. The numerous cross-cutting faults are also gouge-filled. This broken condition made overbreaking in the tunnel a serious problem at the Tahtsa Lake end and much timbering and rock support were required. Guniting of the walls proved satisfactory in some cases in preventing rock spall along the tunnel walls. In some cases the strike of the faults was the same as that of the tunnel direction. Where this was encountered timber or steel supports were necessary.

At Horetzky Creek the line of the tunnel ran close to the contact of the quartz diorite-granodiorite tongue with the layered series, and much broken ground was encountered in this section. Support was accomplished by lining the tunnel with cement and guniting the walls.

At the western end the big powerhouse excavations are mainly in granodiorite and quartz diorite which proved to be a much more massive rock. A few faults close to the walls caused a weakening of the structure, in some instances, but broken conditions there were much less severe than in the layered sequence and greenstone complex.

All the powerhouse excavations and the main tunnel inverts are in the granodiorite-quartz diorite mass. Of the 53,050 feet of tunnel (R. A. Stuart, personal communication) 28,025 feet are in the granodiorite-quartz diorite, 7,800 feet are in the younger layered complex and 17,225 feet are in the greenstone complex. Lining and support in the tunnel were as follows: (Mathias, 1954, p. 1400) "The main tunnel invert was concrete full length and concrete lining was placed in the 15,422 feet that required steel supports while driving, or was unreliable. The equivalent of about 20,000 feet of tunnel received gunite to protect against the unravelling of the live, but broken, rock which contained fine seams filled with clay or with decomposed rock. The remainder of the tunnel was left without lining, but some permanent rock bolting was done to tie exposed blocky, but sound rock, deep into the walls and arch of the tunnel."

The ultimate plan to bring the whole Kitimat scheme to full capacity of 1,695,000 horsepower (Wolcott, 1954, p. 1385) requires the construction of a second tunnel from Tahtsa Lake to Kemano, the construction of a dam at the outlet of Kidprice Lake and a tunnel between Nanika and Tahtsa Lakes. The Nanika-Kidprice drainage will then flow into Tahtsa Lake and augment the storage in the basin. The powerhouse at Kemano will have to be extended and additional generating equipment installed. The engineering and geological experience and information gained in the construction of the first tunnel will be of advantage in the construction of the second. Geological conditions between Nanika Lake and Tahtsa Lake are similar to those encountered in the tunnel between Tahtsa and Kemano, therefore, records kept on the first phase of the project should be very useful in the construction of the later phase.

Chapter V

ECONOMIC GEOLOGY

The Whitesail Lake map-area includes about 85 miles of the mineralized eastern contact zone of the main mass of Coast Intrusions. Though much of this zone traverses country very difficult of access, prospecting has been carried out in it since early in the century, mainly by individual prospectors working on their own but also by mining companies with regular prospecting teams. Mineral deposits found by these prospectors include galena-sphalerite veins, gold-quartz veins, copper-bearing contact metamorphic deposits, copper-bearing veins, and scheelite deposits. No coal of consequence has been found and no non-metallic mineral deposits have been reported.

Several of the deposits received underground development. The Emerald Glacier property on Mount Sweeney produced a total of 4,566 tons of lead-zinc ore during 1951 and 1952. Extensive exploration of the area was not practicable in the past as known deposits were not of sufficient size to warrant the large expenditures necessary to build roads and power-plants so far from available sources of supply. The completion of the Aluminum Company of Canada's project in the area will no doubt favourably affect prospecting and mining. In fact already, under the impact of this project, the Emerald Glacier property reached production and interest was renewed in the Harrison group on Lindquist Peak. Because of the flooding and consequent deepening of the channels, transportation will be easier on the waterways. The new roads constructed by the Aluminum Company provide much easier transportation to the known mineralized areas.

History

The first record of claims staked for mineral in the area is reported in the 1906 volume of the Minister of Mines Report for the province of British Columbia. It is stated there (p. H68) that, during that year, Messrs. Daking and Pocklington of Victoria staked the Pintledanne group on what was called Pintledanne Creek. This creek flows into the Kemano River from the northeast about 8 miles from Gardner Canal, and probably flows down the valley that forms the low pass near the south end of Sandifer Lake. The claims were located about 2 miles from Kemano River and 2,000 feet above it. The ore minerals consisted of chalcopyrite, bornite, and molybdenite in a wide quartz vein in granitic rock.

In 1913 'Kid' Price found, first, placer gold then lode gold in narrow quartz veins on Sibola Creek and Sibola Peak. The news of this find caused a rush of prospectors to Mount Sweeney and Sibola Peak in 1914. The narrow veins were subsequently proved to be of low grade.

About the same time or a little earlier prospectors were busy on Whitesail Lake and the 'Cariboo Group' (now Mentor group) on the south shore of the lake near Zinc Bay was staked by Messrs. Harrison and Michelson. Mr. Harrison settled at Wistaria till 1952 when he was compensated for his property by the Aluminum Company. He and his sons have prospected the Whitesail and Eutsuk Lakes country during the years between 1914 and the present and have made numerous discoveries, the most important of which have been the gold and scheelite deposits on Lindquist Peak.

Prospecting continued in a desultory manner during and following World War I. However, it gained impetus between 1923 and 1930 when there was much activity in the area. Copper was found on Tesla Mountain, and the Emerald lead-zinc vein on Mount Sweeney was developed by the Consolidated Mining and Smelting Company of Canada. There was also some underground development of the showings on Swing Peak and Chikamin Mountain.

From 1930 through the depression years and the early years of World War II prospecting and development were at a very low ebb. The discovery by the Harrison brothers of gold and tungsten in promising quantities on Lindquist Peak in 1943 created intense interest during the next three years. The area was covered by prospectors and prospecting teams sent out by major exploration companies, and an intensive diamond-drilling campaign was carried out on the gold veins on Lindquist Peak. The depressed state of the gold mining industry in 1947 had an ill effect on prospecting in the area and there was little if any serious work that year. Interest by the Aluminum Company in the power potential of the area combined with increased prices for base metals brought activity to the point where the Emerald Glacier property on Mount Sweeney produced ore in 1951 and 1952. At this time Deer Horn Mines Limited was formed to explore further and to develop the gold and tungsten deposits on Lindquist Peak. Underground and surface explorations were carried out each year till November 1955 when all operations ceased. During 1952 interest was again shown in the copper deposits on Tesla Mountain and an entirely new gold find was made, known as the Smith-Nash group, in the country west of Sandifer Lake.

Classification

The mineral deposits of Whitesail Lake map-area may be classified as:

1. Non-metallic deposits
2. Metalliferous deposits
   A. Placer
   B. Lode

Non-Metallic Deposits

In Whitesail Lake map-area to date no non-metallic deposits of consequence have been found. Due to widespread glaciation and stream action sand and gravel are common and there is a plentiful supply of these materials in stream valleys, lake shores, and drumlin-like drift ridges for such purposes as road building and cement work. Though rhyolite flows are plentiful, so far none of the perlitic varieties like those present northeast of the area on Francois Lake has been discovered.

The presence of coal on Wells Creek has been reported by residents of the area but five separate excursions up the creek in search of this coal proved unsuccessful. A few fragments of lignitic material were found as float in the creek but none was found in place.

Metalliferous Deposits

Placer Deposits

The only record of placer activity in the area is that of 'Kid' Price on Sibola Creek. Price found a few colours by panning which led him to discover gold in narrow quartz veins. The creek flowing into Tahtsa River from the east end of the Whitesail Range is referred to by some of the residents as 'Placer' Creek and is reported to have yielded a few colours. No placer claims are at present staked in the area and there is no evidence of old placer workings.

Lode Deposits

Most of the deposits of the area can be included under this heading and may be divided on the basis of their chief mineral content as follows:

1. Lead-zinc deposits
2. Gold deposits
3. Copper deposits
4. Tungsten deposits.

The lead-zinc deposits are narrow quartz veins occurring as fracture or shear-zone fillings and are present on Mount Sweeney and Chikamin Range close to small stocks of granitic rock; and on Swing Peak in fractures in a porphyritic diorite. The relationships on Swing Peak date this mineralization as post-Lower Cretaceous, and it is probable that the similar mineralization on Chikamin Range and Mount Sweeney is of the same age.

Gold is common in most deposits but those noted mainly for their gold content are large quartz veins close to the contact with the main mass of Coast Intrusions and may be either in the dioritic or metamorphic rocks. Gold also occurs in narrow veins in Hazelton group rocks on Sibola Peak and Huckleberry Mountain as well as at several other places in the area, but the veins are too small and too low grade to be economic.

Copper and tungsten have been found in contact-metamorphic zones but copper is also present in veins and shear zones.

Description of Properties

Lead-Zinc Deposits

Mount Sweeney

Emerald Glacier Group (3)[1]

References: B.C. Minister of Mines, Ann. Repts.: 1916, pp. 164-165; 1919, pp. 104, 105; 1929, pp. 183, 184; 1945, p. 68; 1950, p. 101; 1951, p. 117; 1952, pp. 97, 143; Geol. Surv., Canada, Sum. Rept. 1924, pt. A, pp. 56, 57 (1925); Map 367A; Hedley, 1942, pp. 158, 159.

The Emerald Glacier group situated on the south side of Mount Sweeney about 6 miles from Tahtsa River, was first staked in 1915 by W. J. Sweeney and associates. It has received more active exploration to date than any other property in the area. In 1917 and again in 1919 it was optioned to J. Cronin of Prince Rupert, who drove a drift adit 125 feet along the vein zone at an elevation of 6,385 feet, known as the 6,400-foot level (*see* Figure 4). Work was resumed by the Consolidated Mining and Smelting Company of Canada Limited between 1928 and early 1931, during which period the original adit was extended and two more adits driven, one at elevation 5,989 feet, known as the 6,000-foot level, and the other at 5,418 feet elevation, known as the 5,400-foot level. Results from this work were disappointing and no further interest was shown in the property until 1949 when Emerald Glacier Mines

[1]Numbers in parentheses are those used on the accompanying map to indicate the location of the property.

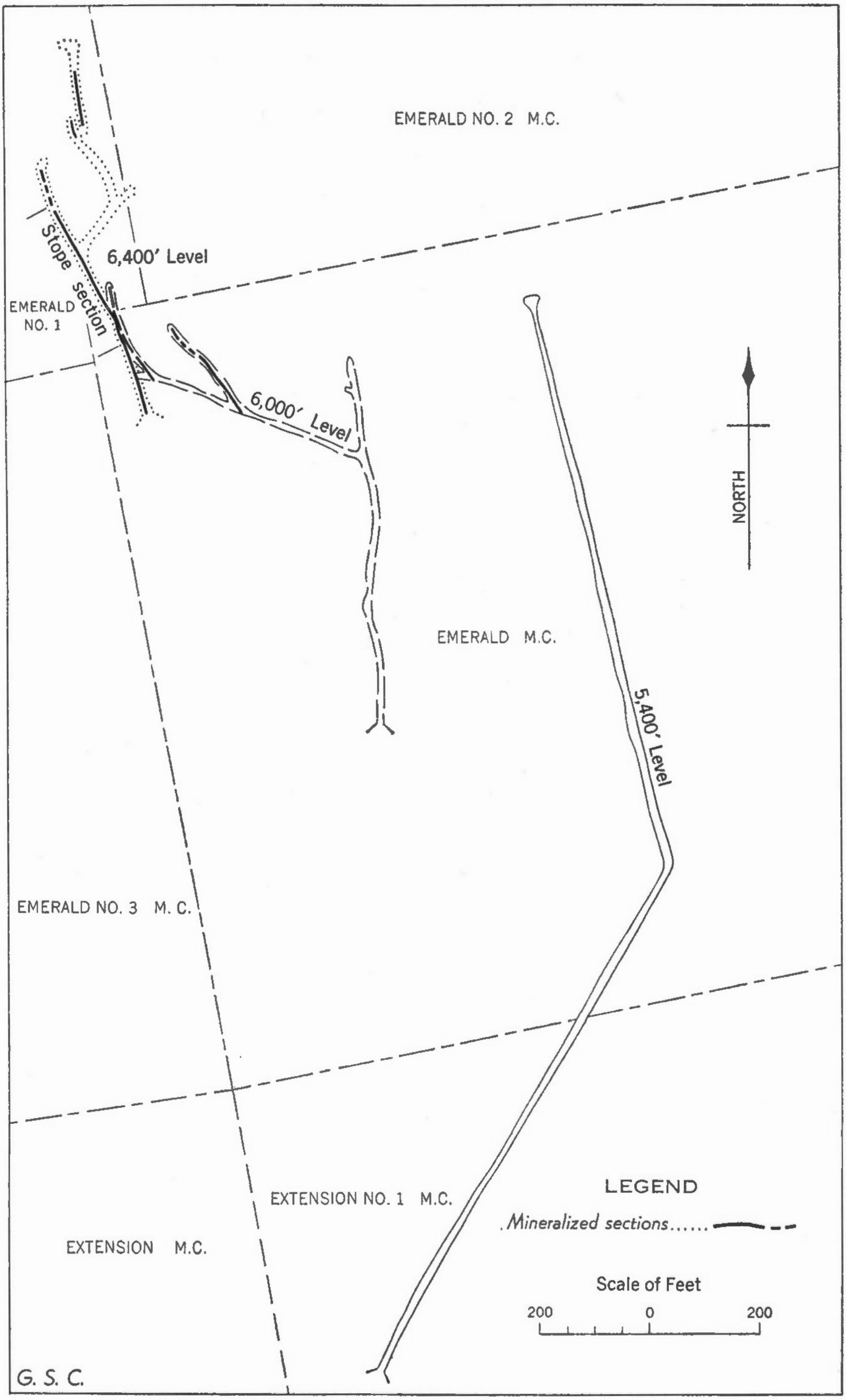

Figure 4. **Plan of underground workings, Emerald Glacier Mines Ltd., B.C.**

Limited was formed to take it over. Late in 1950 and early 1951 the company completed a rough winter road from the head of Francois Lake to the property, brought in machinery and supplies, and made ready for mining operations during the summer of 1951. This work coincided with the decision by the Aluminum Company of Canada to proceed with their power development of the area, and in May 1951 the Aluminum Company assumed responsibility for the completion and maintenance of the road, which would also serve their operations on Tahtsa Lake.

The ore on the Emerald Glacier property is vein quartz in a shear zone up to 20 feet wide in which occur lenses of solid sulphides up to 5 feet wide but averaging 2½ to 3 feet in width. The zone has been traced on the surface for at least 1,000 feet. It strikes north 5 degrees west and dips easterly at 50 to 70 degrees. The host rocks are volcanic and sedimentary rocks of the Hazelton group that have been disturbed by the emplacement of the granitic stock on Sibola Mountain.

The vein matter is concentrated along the foot-wall of the sheared zone which is marked by much gouge. Ore minerals consist of massive sphalerite and galena with minor chalcopyrite in a gangue of quartz, minor calcite, and wall-rock.

The shear zone in which the vein occurs lies along a sharp monoclinal crumple in the Hazelton group strata. West of the crumple the beds are fairly flat lying but in the vicinity of the vein they dip eastward up to 70 degrees, flattening east of the crumple to dips of 20 to 25 degrees eastward. That movement has taken place along the bedding planes where the beds flattened out east of the vein is shown by the 1 inch to 2 inches of gouge between the beds in this vicinity. A short distance farther to the east the beds are offset by a north-south fault that is marked by a stream channel.

The vein is strongest in the upper adit or at the crest of the crumple. It narrows perceptibly with depth and probably dissipates where the beds flatten out to the east. Only narrow veins were intersected on the intermediate level and none at all in the lowest adit. It is probable that the lowest adit was driven well below the main shear structure.

Development work by the Emerald Glacier Company included the building of roads to the 6,400-foot level and the construction of a permanent camp at 5,100-foot elevation (*see* Plate VI B). Underground and surface diamond drilling amounted to 4,366 feet and underground drifts and crosscuts totalled 1,448 feet. A raise from the 6,400-foot level to surface is 150 feet long. A stope was opened on the 6,400-foot level for a distance of 280 feet. A total of 4,566 tons of ore from development work and the stope yielded 37 ounces of gold, 55,179 ounces of silver, 1,118,809 pounds of lead and

1,050,240 pounds of zinc. Vein widths in the stope section varied from 1½ to 5 feet but averaged about 2½ feet. Much of the exploration and drilling underground was on the 6,000-foot level in search of the downward continuation of the vein. Two narrow veins were developed both west of the original adit on this level. A crosscut, driven north 70 degrees west from a point 498 feet from the portal, intersected the first vein at 240 feet and the second at 410 feet. Strike of the veins is north 30 to 35 degrees west with steep dips to the east. Widths vary from .7 foot to 2.3 feet but average 1.5 feet. These veins have been opened to the north for distances of 170 and 200 feet, respectively. Mineralization is similar to that on the 6,400-foot level with perhaps a higher percentage of zinc.

Operations at the property ceased in November of 1952 and the mine has been inactive since.

Tahtsa Range

Lead Empire Group (1)

References: W. H. Patmore, 1949; Western Miner, vol. 22, No. 2, pp. 39-42; Can. Mining J., vol. 72, No. 4, p. 226; B.C. Minister of Mines, Ann. Repts.: 1951, p. 118; 1952, p. 97.

The Lead Empire Group is situated on the northwest slope of the Tahtsa Range close to the plutonic stock in the centre of the range. The claims were staked by W. H. Patmore in 1948 and 1951 and cover a number of narrow quartz veins and shear zones associated with the basic diorite or gabbro stock in the core of the Tahtsa Range. The veins and shear zones contain lead-zinc minerals with a small gold and silver content. The veins occur in both the plutonic rocks and rocks of the Hazelton group. The claims are very difficult of access and are free from snow only for a short period each year.

Some work was done during the period July to October in each of the years 1951 and 1952. Much of the effort was expended on trail cutting and cabin construction but some stripping and trenching were accomplished. The property was not visited by the writer as the work in that part of the map-area was completed prior to the work on the claims.

The trail to the claims, which is about 21 miles long, leaves the Tahtsa Lake road near Twinkle Lake. It is understood a cabin was constructed on the trail about 5 miles from the property. During 1952, six men were employed between July 9 and September 14 working on trails and open-cuts. No subsequent work has been done.

Tahtsa Range Occurrence (2)

On the southeast flank of the Tahtsa Range stock there occurs a number of narrow quartz stringers containing pyrite, chalcopyrite, galena, specular hematite and some gold. These veins are near the head of the north fork of the east branch of the creek flowing from the western end of Rhine Ridge. The fractures and veins occur both in the stock and the Hazelton group rocks close to the contact. Strike is north 40 degrees east and dip is vertical. The stringers filling the fractures are only 2 to 3 inches wide and discontinuous.

Swing Peak

Captain Group (5)

References: B.C. Minister of Mines, Ann. Repts.: 1927, pp. 154-155; 1929, p. 184; 1945, pp. 67, 68.

This group of six claims, situated on the northeast slope of Swing Peak, was previously known as the Swannell group. It is owned by C. McNeill of Ootsa landing and G. Young of Vancouver.

The main showing is a shear zone that strikes nearly north and dips steeply to the east. This zone crosses both the lavas and the fine-grained porphyritic intrusive rock that comprise this part of Swing Peak. In 1929 and 1930, Tahtsa Mining Company drove an adit 383 feet long at an elevation of 4,985 feet. This adit intersected and explored the shear zone 100 feet below its most prominent surface showing. Little work other than surface prospecting has been done since.

The rocks on Swing Peak have been cut by a fine-grained porphyritic diorite that has been fractured and faulted in a north-south direction. Most of the fractures are narrow but a few reach a width of over 3 feet. They dip steeply to the east and are commonly marked by gouge. Some of these fractures are mineralized with galena, sphalerite, pyrite, arsenopyrite, and tetrahedrite in a gangue of quartz, minor calcite, and wall-rock.

The main mineral showing is on a persistent shear zone that strikes north and dips 85 degrees to the east. A drift from the crosscut adit was driven on this zone and all mining was entirely within the porphyritic diorite. Several minor fractures were intersected in the crosscut; evidence of mineralization was encountered 273 feet from the portal. At this point the adit intersected a fracture containing 6 to 18 inches of gouge and a mineralized seam from 1 inch to 4 inches wide on the hanging-wall that continued for 65 feet. A picked sample of ore from this seam yielded, on assay, 12.40 per cent lead, 5.42 per cent zinc, 63.07 ounces silver a ton, and a trace of gold.

About 150 feet below the adit, on the northerly extension of the shear zone, there occurs a mineralized lens 20 feet long and 1 foot to 2 feet wide where the shear zone is 3 feet wide. No work has been done on this showing but an assay of the mineralized section gave 22.4 per cent lead, 9.50 per cent zinc, 25 ounces of silver and 0.005 ounce of gold a ton.

About 750 feet southwest of the adit are two narrow mineralized stringers about 4 feet apart striking north 25 degrees west, dipping 75 degrees to the northeast, and with similar mineralization to that in the adit. About 500 feet to the southeast on the strike of these stringers, an open-cut exposes a similarly mineralized vein 6 to 7 inches wide.

No work has been done on the property since 1950.

Chikamin Mountain

Lead-zinc properties situated on Chikamin Mountain include the Mentor group, Roosevelt group, Garner No. 1 and Marie group, Dads Special and Rainy and Gold Coin groups. These groups extend from the shore of Whitesail Lake across to the south side of the mountain a distance of 3 to 3½ miles laterally. Most of the claims belong to the Harrison family, formerly of Wistaria, who have prospected this mountain since early in the century. Their efforts have uncovered and partly developed several narrow veins carrying galena, sphalerite, chalcopyrite, arsenopyrite, gold and silver. Little has been done in the way of development since 1945 when Privateer Mines drilled several holes on the Roosevelt and Dads Special groups.

The rocks forming the western slope of the mountain in the vicinity of the deposits consist of interbedded siliceous tuffs, greywackes, argillites, and breccias and flows of the Hazelton group. Fossils collected from these rocks indicate a lower Middle Jurassic age. These interbedded volcanic and sedimentary rocks have been folded into an anticline whose axis strikes north 45 degrees west. The beds strike north 15 to 30 degrees west and dip 20 to 30 degrees southwest. Fractures approximately parallel with the axis of the fold have allowed access to galena-sphalerite-bearing solutions that have deposited their load in the open fissures. Comb structures, vugs, and banding are common characteristics of the veins, which strike north 45 to 50 degrees west and dip up to 70 degrees to the southwest. The veins vary in size from 1 inch to 2 feet but average less than 1 foot. The veins though narrow are persistent, one being traced for over 2,000 feet.

The contained minerals vary from showing to showing but commonly consist of galena, sphalerite, pyrite, and chalcopyrite in a gangue of quartz, minor calcite, and wall-rock. Other minerals present in minor amounts are arsenopyrite, ruby silver, stibnite, and lollingite. High values in gold and silver have been reported, though gold is rarely seen.

The anticlinal structure is cut by a stock of granodiorite, and porphyritic and dioritic sills are interbedded with the sedimentary and volcanic rocks. None of the properties has any record of production but several of the showings have undergone some underground development.

Mentor Group (11)

References: Geol. Surv., Canada, Sum. Rept. 1924, pt. A, pp. 52, 53 (1925); B.C. Minister of Mines, Ann Repts.: 1926, p. 146; 1927, p. 155; 1945, pp. 68, 69.

This group of two claims along the south shore of Whitesail Lake in Zinc Bay at the foot of Chikamin Mountain was formerly known as the Cariboo group. In 1916 it was explored by a Prince Rupert syndicate, which drove an adit along a shear zone striking north 25 degrees west and dipping 75 degrees northeast. The zone, consisting of sheared rock, with a few irregular stringers of quartz and calcite, is mineralized with sphalerite, galena, pyrite and chalcopyrite. An assay of the best ore encountered at that time gave: gold, trace; silver, 0.8 ounce a ton; copper, 0.5 per cent; and zinc, 32 per cent.

The adit followed the foot-wall of the shear zone for 50 feet, then turned at right angles to cut across the formation. These workings were caved when the showing was visited in 1949, but an assay of a sample of ore taken from the vein near the portal gave: lead, 10.2 per cent; zinc, 13.74 per cent; gold, 0.02 ounce a ton; and silver, 3.26 ounces a ton.

About 800 feet west of the adit an open-cut exposes two parallel veins about 3 feet apart and 10 to 12 inches wide. They strike north 15 degrees west and dip vertically. The wall-rock is silicified and heavily pyritized for several feet on either side of the veins. A sample of ore from these veins assayed: lead, *nil;* zinc, 28.51 per cent; gold, 0.01 ounce a ton; and silver, 0.82 ounce a ton.

In 1950 some new trenches exposed sphalerite mineralization about 500 feet south of the tunnels on the shore. All workings on these claims were flooded when the level of Whitesail Lake was raised.

Roosevelt Group (13)

References: Geol. Surv., Canada, Sum. Rept. 1924, pt. A, pp. 53, 54 (1925); B.C. Minister of Mines, Ann. Repts.: 1926, pp. 146, 147; 1945, p. 69.

This group of eight claims approximately 1,100 feet above the level of Whitesail Lake is reached by the well-graded trail that services the properties on this part of Chikamin Mountain. This trail starts from a deep bay 3 miles west of Zinc Bay and continues up the mountain to the Garner No. 1 and Marie claim and the old Ruby adit, a total distance of about 3 miles. At about 1½ miles up the trail a branch to the right leads to a small creek on which occurs the original showing on the Roosevelt group. Alongside the creek a short adit was driven southwesterly for 37 feet where it intersected a shear zone containing a quartz stringer 8 to 9 inches wide. Strike of the shear is south 30 degrees east. The underground development followed this shear for 40 feet. From this point a crosscut was driven for 25 feet. Minerals present in the vein are pyrite, galena, sphalerite, and arsenopyrite. A sample taken across 8 inches, by S. Holland of the British Columbia Department of Mines, in 1945, assayed: gold, .29 ounce a ton; silver, 17.9 ounces a ton, lead 14.3 per cent; and zinc, 15.8 per cent.

In 1945 Privateer Mines Limited did about 500 feet of diamond drilling in three holes directed to intersect the southward extension of the shear zone. The results of this drilling are not known.

When the writer visited the property in 1949 the adit portal was caved and access was not possible. The rock in which the shear occurs is a red-green breccia. About 5 tons of mineralized material were found in front of the adit. A sample of this material assayed: gold, .04 ounce a ton; silver, 14.38 ounces a ton; lead, 14.0 per cent; and zinc, 31.6 per cent. Gangue consists of quartz and calcite and metallic minerals present were galena, sphalerite, arsenopyrite, pyrite, and chalcopyrite. Comb structures in the quartz suggest fissure filling.

Dads Special (12)

Reference: B.C. Minister of Mines, Ann. Rept. 1945, p. 69.

About a mile up the Chikamin Mountain trail and 900 feet above the lake an outcrop of rusty weathering tuffs and breccias is exposed in a small creek, 300 feet east of the trail. A ½-inch stringer of galena and ¼-inch stringer of sphalerite that strike south 45 degrees east and dip vertically occur in the creek bottom. This occurrence was covered by a group of four claims owned by A. Ritz of Wistaria.

Garner No. 1 and Marie (14)

References: Geol. Surv., Canada, Sum. Rept. 1924, pt. A, pp. 54, 55 (1925); B.C. Minister of Mines, Ann. Rept. 1935, p. A24.

The well-graded trail up Chikamin Mountain from the deep bay in Whitesail Lake leads to a cabin just at timber-line, 1,750 feet above the lake. From there a trail leads to the old Nickel Plate or Ruby adit on the Garner claim 900 feet above the cabin. The adit, 118 feet long, was driven on a narrow quartz vein that strikes north 45 degrees west, dips vertically, and carries galena, sphalerite, pyrite, chalcopyrite, and tetrahedrite. The quartz shows both banded and comb structures, which are evidences of fissure filling. In 1939 B. T. O'Grady of the British Columbia Department of Mines sampled the vein in the adit. The results gave an average assay of 0.036 ounce gold, and 14.4 ounces silver a ton, 0.9 per cent copper, 7.4 per cent lead, and 8.7 per cent zinc. A sample of the vein taken by the writer in 1949 gave 0.04 ounce gold, 14.38 ounces silver a ton, 18.40 per cent lead, and 6.61 per cent zinc.

About 700 feet higher on the mountain and on the strike of the vein, an open-cut exposes four stringers, each 1 inch to 3 inches wide, within a zone of 30 inches. A picked sample from this showing assayed 0.06 ounce gold, and 71.06 ounces silver a ton, 16.4 per cent lead, and 7.54 per cent zinc. Some ruby silver noted in this showing probably accounts for the high silver assay.

Rainy and Gold Coin (15)

Reference: B.C. Minister of Mines, Ann. Rept. 1945, p. A69.

These claims are on the south side of Chikamin Mountain just below the summit. An adit about 25 feet long, known as the California, and some open-cuts expose vein matter for a length of about 50 feet. The adit is driven on a shear zone containing two narrow quartz stringers, 1 inch and 6 inches wide, respectively, and about 6 feet apart. They strike north 20 degrees west and dip 70 degrees southwest. The portal of the adit was caved at the time of the visit, but the dump revealed about 5 tons of sorted vein material. A selected sample of this material assayed: gold, 0.01 ounce a ton; silver, 119.06 ounces a ton; lead, 12 per cent; zinc, 3 per cent; and copper, 0.50 per cent.

East of this adit and a little lower on the mountain a shear zone that strikes north 40 degrees east and dips vertically is exposed for about 100 feet. The zone is about 2 feet wide and contains some quartz with which the minerals galena, arsenopyrite, and lollingite are associated.

Surel Occurrence (20)

A traverse up the stream that enters Surel Lake on the south side about 1½ miles from the outlet encountered some narrow quartz veins mineralized with pyrite, sphalerite, molybdenite, and chalcopyrite. The veins are about 3 inches wide. An assay of a selected sample yielded: lead, trace; zinc, 9.92 per cent; copper, 0.08 per cent; gold 0.02 ounce, and silver 0.64 ounce a ton.

Gold Deposits

Gold is present in most of the mineral occurrences in the area and has been reported particularly from narrow quartz veins on Sibola and Huckleberry Mountains and from the veins on Chikamin Range. The main occurrences however are the wide quartz veins on the property of Deer Horn Mines Limited and the Smith-Nash group west of Sandifer Lake.

Deer Horn Mines Limited (17)

References: B.C. Minister of Mines, Ann. Repts.: 1944, pp. 175-177; 1945, pp. 71-72; 1952, p. 98; 1953, p. 94; 1954, pp. 95-96; 1955, pp. 25-27; Western Miner, vol. 26, No. 8, p. 94.

This property of twenty-eight claims and one fraction was held by the Harrison brothers of Wistaria until 1951 when it was taken over by Deer Horn Mines Limited. The property lies on the southeastern slope of Lindquist Peak, astride the contact between the main mass of Coast Intrusions and the metamorphosed Hazelton group rocks. A wide quartz vein outcrops in the batholithic rocks near the contact and dips gently northward towards the sedimentary and volcanic rocks of the Hazelton group. This quartz vein, though displaced by north-trending faults, may be followed westward across the property for about 2,600 feet. Metallic minerals in the vein are mainly pyrite, galena, sphalerite, chalcopyrite, and telluride minerals, hessite and altaite. Gold is rarely present in the free state and only as a residual mineral in cavities and veinlets; it is most commonly intimately associated with hessite and may be present as rare disseminations in other minerals such as pyrite (Warren, 1947).

Pioneer Gold Mines Limited developed these claims from 1944 to 1946. A good pack-trail was built from the head of Whitesail Lake to the property, and camps were established both at Whitesail Lake and at timber-line below the showings. Some surface work and a total of 12,540 feet of diamond drilling explored the vein. The drilling indicated that the vein dipped gently north towards the Hazelton group rocks and that there is a slope distance of 150 feet in the granitic rocks before the contact is reached. Indications are that the vein breaks into stringers at the contact which dips south at about 55 degrees. Exploration of the contact zone by diamond drilling showed mineralization across vein widths of 2 to 4 feet.

Assay returns on samples taken along the vein varied considerably in gold and silver content. This is most probably due to the abundance or scarcity of hessite.

Because of the faulted nature of the vein it is broken into a number of individual sections. The following values for eight sections were taken from a 1946 company report.

Section	Length	Width	Gold	Silver
No.	Feet	Feet	Ounces	Ounces
1A	50	3.0	0.16	1.6
1B	25	4.3	0.217	1.6
2	One hole	2.2	0.02	0.4
3	150	7.5	0.228	3.62
4	270	7.8	0.295	5.6
5A	80	19.0	0.18	4.3
5B	270	10.7	0.294	8.2
6	128	6.0	0.19	7.27
7	90	17.3	0.06	1.8
8	90	10.0	0.21	9.15

Pioneer Gold Mines Limited dropped the option in 1946 and little further work was done until 1951 when the property was taken over by Deer Horn Mines Limited. In 1952 a small crew of men worked at the property all summer clearing out trenches, re-examining diamond drill core, and locating road grade from Lindquist Lake to the showings as well as generally re-checking values on the property. Further preparations for active development were carried out during 1953. It is reported (*Western Miner,* August 1953) that a "1,075-foot section of the exposed vein returned assays of 0.255 ounce gold and 6.3 ounces silver a ton over an average width of 9.5 feet. Diamond drilling on this structure indicated a developed length of 600 feet with an average width of 11.2 feet and grade of 0.283 ounce gold and 8.3 ounces silver a ton. Depth of this structure appears limited to 200 feet where a junction with the contact zone occurs. This . . . zone has been developed to a limited extent by diamond drilling with results indicating a length of 725 feet, average width of 8.7 feet and a grade of 0.407 ounce gold and 12.24 ounces silver per ton."

Underground development began late in 1954 and continued till November 1955 when operations were suspended. During that period the Company reports it completed 1,822 feet of drifting, 113 feet of raising, 3,075 feet of underground drilling, and 2,997 feet of surface diamond drilling.

The property includes, besides the gold-silver deposit, a scheelite-bearing metamorphic zone that will be described later under a separate heading. (*See* map *in pocket,* Figure 6.)

Lam and Old Timer Groups (16)

Reference: B.C. Minister of Mines, Ann. Rept. 1945, p. 72.

The Lam group of four mineral claims to the southwest, and the Old Timer group of six claims to the west of Deer Horn Mines are also on Lindquist Peak. The showings on these groups were not seen, but little work has been done on them. The Lam group is underlain by a dioritic phase of the Coast Intrusions, whose contact with the Hazelton group cuts across the Old Timer group.

Surel Lake Group (21)

Reference: B.C. Minister of Mines, Ann. Rept. 1945, pp. 72, 73.

The Surel Lake group of claims was staked by J. J. Hepson in 1945 near the falls on Surel Creek. It is also near the contact of the Coast Intrusions with Hazelton group rocks. The showings were not seen, but it is reported that the vein is 1 foot to 2 feet wide, that it is exposed for 50 feet, and that it carries some gold.

Core (10) and Shirley Groups

Reference: B.C. Minister of Mines, Ann. Rept. 1945, p. 70.

The Core group of twelve claims, staked in 1944 by Fred Paulig and Orald Harrison of Wistaria, covers a gabbro outcrop on the south slope of Core Mountain, and the Shirley group of eight claims lies between the Core group and the entrance to Little Whitesail Lake. The Consolidated Mining and Smelting Company of Canada Limited had a base camp in a protected bay on the Core group, and did a little trenching. No veins were uncovered, but it is reported that some heavily pyritized material carried a little gold.

The south slope of Core Mountain is marked by a distinct fault that strikes northeast and dips vertically to steeply southeast. The fault is marked topographically by a narrow gorge occupied by a creek. A small mass of gabbro lies to the northwest of the fault, with broken and altered Hazelton group rocks to the southeast. Locally, the course of the fault is marked by much silicification and carbonatization of the wall-rocks and by the occurrence of much pyrite. Some pyrrhotite and chalcopyrite were also observed. Between the fault and the lake shore the Hazelton group rocks contain a little disseminated pyrite, pyrrhotite, and chalcopyrite.

Riverside Group (4)

Reference: B.C. Minister of Mines, Ann. Rept. 1945, pp. 65-67.

This group of four claims, staked by J. W. McNeill, J. Knox and the late G. Seel, all of Ootsa Lake, lies on the north side of Tahtsa River about 1½ miles below the junction with Kasalka Creek and close to Huckleberry Mountain. Dark green tuff, breccia, and flows of the Hazelton group, which constitute the strata on Huckleberry Mountain, also underlie the claims of this group. On Huckleberry Mountain and adjacent hills pyrite and arsenopyrite occur in narrow quartz veins and small patches of disseminated sulphides in the bedrock. The veins are commonly 1 inch to 6 inches and rarely up to a foot or more in width, and have an irregular strike. On the Riverside claims a quartz vein 2 to 5 inches wide, striking north 75 degrees east and dipping vertically to 85 degrees southeast, is exposed for 100 feet. The vein is mineralized with arsenopyrite, pyrite, chalcopyrite, and sphalerite, and it is reported that the highest assay gave 0.36 ounce gold a ton.

Smith-Nash Group (8)

Reference: B.C. Minister of Mines, Ann. Rept. 1952, p. 97.

In the late summer of 1952 George Smith and Fred Nash of Vancouver staked a group of fourteen claims and one fraction on the steep south slope of the southwest extension of Sandifer Peak. The claims cover several limonite stained quartz veins seen by the stakers while flying over the area. They subsequently hired a helicopter from nearby Kemano and landed near one of the veins, taking several samples of highly pyritized material. Assay returns on this material showed a gold content as high as 6 ounces in one sample. They later returned to the showings via Sandifer Lake and staked the fourteen claims.

As these claims are in a part of the area difficult to reach and were staked at the end of the writer's last season of field work, they were not visited. However, R. A. Stuart of the British Columbia Department of Mines, who was stationed at Kemano visited the showings with Smith and Nash and reported in the British Columbia Minister of Mines Annual Report for 1952, as follows:

> The veins are near the eastern contact of the Coast Range batholith on an anticlinal structure. The country rock on the east side of the group consists of interbedded greenstones and gneissic quartzites on the west; nearer the batholith it consists of granitic gneisses containing numerous pegmatite bands and dykes and occasional barren quartz veins.
>
> The only vein examined occupies a shear zone striking northwest and dipping southwest. It outcrops continuously between elevations 4,500 feet and 5,000 feet in a steep shear-controlled gulley on the northeasternmost claim of the group. At the top of the gulley the vein, which is here about 4 feet wide, disappears beneath talus on a small bench and could not be located in the bluffs above. At the 4,500 foot elevation the only place where the vein is accessible, it swells to a width of about 15 feet then pinches out abruptly. The sheared zone, about 8 feet in width, continues below the pinch-out of the quartz but flattens in dip and swings to a more easterly strike.
>
> The only visible metallic mineral is pyrite, which occurs as disseminated blebs and stringers in the quartz. Several stringers of massive granular pyrite from 2 to 6 inches wide occur on the hanging wall and footwall of the lowest seen part of the vein, and in the sheared zone below the quartz pinch-out. The sheared wall rock is only slightly mineralized.

The following type samples were taken by Stuart.

	Gold (ounces per ton)	Silver (ounces per ton)
1. Mineralized vein quartz	0.39	0.28
2. Massive pyrite from a 5-inch stringer	2.9	1.5
3. Sheared wall-rock	0.09	0.1

A sample of the highly pyritized material given to the writer by George Smith, one of the stakers, gave an assay of 3.14 ounces of gold a ton.

Some development work was done on the claims during 1953 but results were disappointing. The writer met Mr. Smith during the 1954 season and was told that only one vein was auriferous.

Ear Lake Occurrence (18)

Minor occurrences of mineralized quartz veins have been reported from Ear Lake and Kimsquit Lake. These are narrow quartz veins occurring in the metamorphic rocks. A sample of mineralized vein quartz from the west side of Ear Lake near the mouth, assayed: gold, 1.88 ounces a ton; silver, 14.90 ounces a ton, and copper 3.68 per cent.

Whitesail Range Occurrence (9)

At about 4,000 feet elevation on the south slope of Whitesail Range in the canyon of the middle tributary of the creek east of Cummins Creek, is a wide, sheared and silicified zone that is heavily mineralized with pyrite. The zone extends along the creek for 200 feet with shearing being parallel with the creek. A sample of pyrite assayed 0.005 ounce of gold a ton.

Copper Deposits

Chalcopyrite is a common constituent of many mineral occurrences in the area but no deposit has yet been found of sufficient size or grade to warrant development for its copper content alone.

Pintledanne Group (7)

Reference: B.C. Minister of Mines, Ann. Rept. 1906, p. 68.

This group of claims was the first to be recorded within the boundaries of the map-area. It was staked in the spring of 1906 by Messrs. Dakin and Pocklington of Victoria as a copper prospect. No work has been done on the showing, probably because of its isolated location. The writer did not see the occurrence but it is listed here as a matter of interest and as an occurrence of copper in the area. The following description is taken from the 1906 report of the Minister of Mines of British Columbia.

> The claims are reached from the north side of the Gardner Canal by following up the Kemano River to the mouth of Pintledanne Creek, a tributary flowing in from the north. There is an old Indian trail following up this creek and over the summit to Tahtsa Lake . . . This follows the north bank of the creek for a distance of about 2½ miles, when it crosses the creek to the south side and rapidly ascends the mountain, reaching at an altitude of about 2,000 feet, the claims in question. Pintledanne Creek runs through high granitic mountains, which rise on either side to an altitude of 4,000 feet. On the mountain on the left side of the creek, two miles from its junction with the Kemano River, is a large well defined quartz vein. This is easily seen where the vein crosses the

> gulches which run down the mountain side. The vein has an approximate width of 100 feet and crosses diagonally in a northeasterly direction, over the range a distance of several thousand feet. On this vein the Pintledanne group of claims has been staked. The vein was examined where it crossed the two gulches at an altitude of 2,000 feet above the Kemano River and at a distance from it of about 2 miles. The vein is well and strongly defined, with a frozen contact with the granite on the lower side and diabase on the upper side. The diabase dyke is of a later date than either the vein or the granite. The vein matter is rather sparsely mineralized with copper pyrites, bornite and molybdenite unevenly disseminated through the mass and it is doubtful with the present showing on the property, whether it would pay to work.

This description indicates that the vein in question is near those staked by Smith and Nash. The presence of two occurrences of large mineralized quartz veins in the vicinity of the western slope of Sandifer Peak indicates that this section of the map-area, though difficult of access, is good prospecting ground. Similar rocks extend southwards to Kimsquit Lake.

Sandifer Lake Occurrence (6)

On the mountain east of Sandifer Lake, near the headwaters of the west fork of Laventie Creek, chalcopyrite is sparsely distributed in a contact metamorphic zone about 400 feet long and 40 to 60 feet wide. This showing was staked during the summer of 1950 by C. McNeill of Ootsa Lake and G. A. Young of Vancouver. It occurs along the north contact of a small stock of granite, and consists of a mass of well-developed crystals of epidote and garnet, with chlorite and minor amounts of specular hematite, chalcopyrite, pyrite, and bismuthinite.

Chezko River (23, 24)

Reference: B.C. Minister of Mines, Ann. Rept. 1926, pp. 150-151.

In the canyon of Chezko River about 2 miles below the outlet of Tesla Lake, chalcopyrite occurs (24) in a rusty weathering shear zone of green andesite. The zone is 15 feet wide, strikes north 45 degrees west, and dips vertically. Midway along it is a 6-inch quartz vein containing chalcopyrite, hematite, pyrite, and galena. The zone is exposed for about 300 feet and about 60 feet down the wall of the canyon. A sample of the mineralized material assayed 0.02 ounce gold and 1.6 ounces silver a ton, and 3.59 per cent copper.

On the southeast slope of Two Bear Hill the writer's party discovered a mineralized zone (23) 3 to 4 feet wide that strikes north 50 degrees west.

The zone is exposed for 200 feet and contains quartz stringers mineralized with chalcopyrite, pyrite, and hematite. An assay of a grab sample of the mineralized material yielded a trace of gold and 7.9 per cent copper.

Tesla Mountain Occurrence (25)

Reference: B.C. Minister of Mines, Ann. Rept. 1926, pp. 149-150.

The occurrence of copper-bearing minerals on Tesla Mountain has been known for many years but because of their isolated location little work, other than prospecting, has been done on them. In 1926, Douglas Lay of the British Columbia Department of Mines made a special trip to visit claims staked there the previous year. He reported on three showings on the mountain all between 5,200 feet and 5,700 feet, and remarked that the actual showings of mineral were somewhat disappointing and that where the veins were wide the values were low, and where the values were high the veins were narrow.

No further interest was shown in these occurrences until 1952 when George Young, who held original claims on the mountain, and Andy Ostrem restaked some of the old claims as well as some new ground. There is no record of further activity on the claims.

A sample taken by Douglas Lay in 1926 across a 12-inch vein on G. A. Young's showing assayed 0.133 ounce gold a ton and 4.2 per cent copper.

Members of the writer's party made several traverses on Tesla Mountain in 1948 but none of the showings was seen.

Red Bird Mountain Occurrence (22)

References: B.C. Minister of Mines, Ann. Repts.: 1929, p. 185; 1945, p. 73.

Red Bird Mountain is on the south side of Eutsuk Lake between Mount Haven and Key Mountain. An occurrence of copper on this mountain was reported by B. R. Harrison and J. Worth in 1929 but no work of consequence has been done. The writer did not see the showings.

Surel Pass Occurrence (19)

On the west side of the creek flowing into the head of Surel Lake from Surel Pass, a quartz vein 1 foot to 2 feet wide has been exposed for 25 feet in diorite near its contact with the Hazelton group. The vein strikes north 80 degrees west and dips 42 degrees southwest. It is mineralized mainly by chalcopyrite and pyrite.

Tungsten Deposits

Tungsten has been noted in a number of localities close to the Hazelton group-batholith contact but most of the deposits are small, only one being worthy of mention.

Deer Horn Mines Limited (17)

This property, described under gold deposits, also includes a tungsten deposit of considerable size. During exploration of the gold deposit, scheelite, though not common, was noted in the core but the main deposit is separate from the gold occurrence and lies 800 to 1,000 feet west of the most westerly pit exposing the gold-bearing quartz vein. The scheelite occurrence extends northwesterly for at least a claim's length.

The part of the property on which the scheelite deposit occurs lies astride the contact between the main mass of the Coast Intrusions on the southwest, which there consist of granite, quartz diorite and diorite, and metamorphosed tuff, greywacke, shale, slate, and flows of the Hazelton group. The shale and slate contain andalusite, epidote, chlorite, and zoisite, and silicification is widespread in the volcanic rocks. Minor amounts of skarn are present, but none was noted near the scheelite occurrence. There, epidote, chlorite, and quartz, and some andalusite in the shale and slate are characteristic.

At the scheelite deposit the strike of the contact of the granitic rocks turns sharply from northwest to north for a short distance forming an embayment of the Hazelton group rocks. The general effect of contact metamorphism of the sediments in this embayment is more marked than elsewhere in the vicinity. The volcanic rocks particularly appear to have been minutely fractured and cut by a stockwork of quartz stringers that carry scheelite. The stringers vary in width from a fraction of an inch to 4 inches but are commonly 1 inch to 2 inches wide. About 500 feet east of the main showing volcanic rocks are cut by numerous stringers of quartz containing small amounts of scheelite, commonly along their borders. Two veins up to 2 feet wide, which also cut the volcanic rocks at this point, contain no scheelite. Assays of samples proved the average scheelite content of this occurrence to be much lower than that of the main deposit. In addition to the scheelite and quartz a few grains of pyrite and chalcopyrite were noted in the country rock and quartz stringers. These outcrops are above timberline and at most points are covered by talus that contains sufficient scheelite to give a spectacular appearance under ultraviolet light at night.

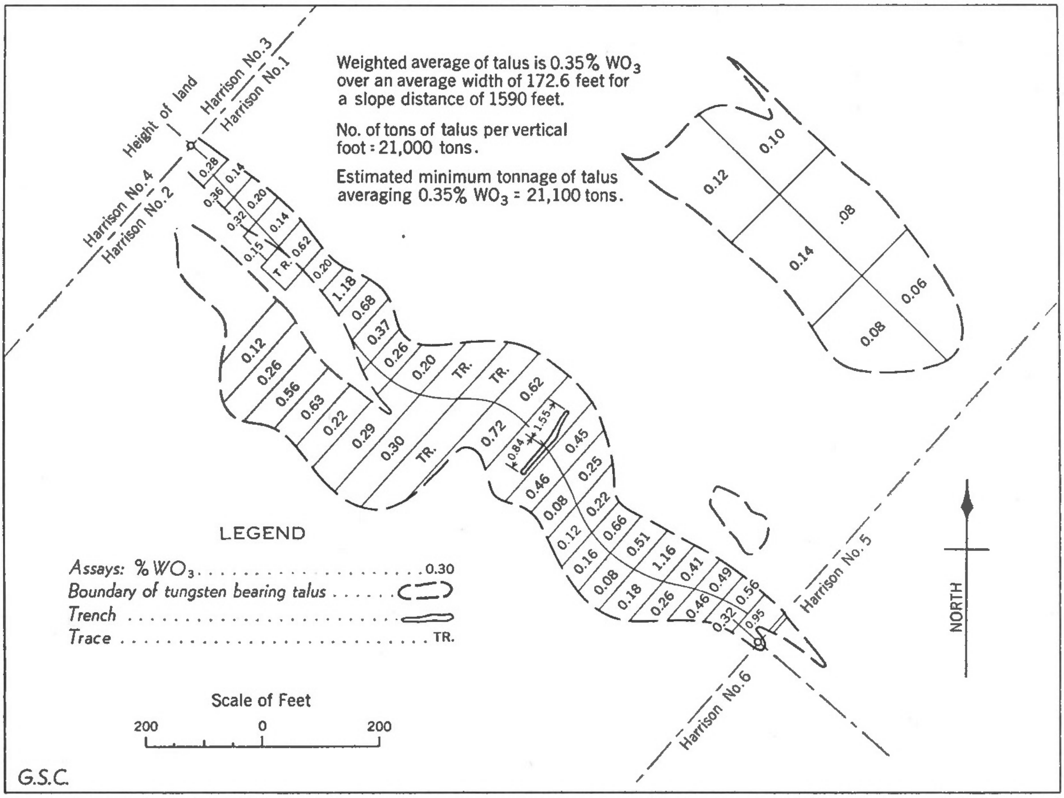

Figure 5. ***Plan and assays of the scheelite-bearing talus, Deer Horn mine, B.C. (From plans of the Deer Horn Mines, Ltd.)***

Although scheelite is present in all the rocks it occurs most commonly in quartz stringers where they are plentiful. In diorite the scheelite is in small grains whereas in volcanic rocks it may occur as crystals up to 1½ inches long. Little development work has been done so that the full extent and mode of occurrence is not known.

The main showing lies under a large talus deposit along the boundary between the Harrison No. 1 and No. 2 claims. In 1952 Deer Horn Mines Limited, under the direction of Jack Ross, outlined the scheelite-bearing area of this talus and systematically sampled it (*see* Figure 5). An open-cut had been made at one point where bedrock outcropped within the area of talus. This trench is 130 feet long and both ends are in scheelite-bearing talus. The known area of scheelite-bearing talus has a slope length of 1,590 feet and an average width of 172.6 feet. For each 1-foot average depth this area is estimated to contain 21,100 tons of tungsten-bearing talus. The scheelite-bearing talus area, for the purpose of estimating grade and tonnage, was divided into 48 rectangular sections 50 feet wide but of varying lengths. The weighted average assay of grab samples from these 48 rectangular areas gave 0.34 per cent WO_3. Bedrock samples taken from the trench gave 0.84 per cent over 60 feet at the west end and 1.55 per cent over 70 feet at the east end. As scheelite-bearing talus occurs for 800 feet slope distance above the trench the size of the source body of the scheelite-bearing blocks in this vicinity may be considerable. No diamond drilling or additional trenching has been done so that at present the size and tungsten content are unknown. The chance to prove a substantial body of tungsten ore at this locality, however, appears promising.

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A. *Crossbedding in esker on Tahtsa road near Twinkle Lake.*

Plate II

B. *Granite mountains at the head of Pondosy Lake. Note the broad U shape of the main valley and the glaciers in the cirque basins.*

G.S.C. 110066

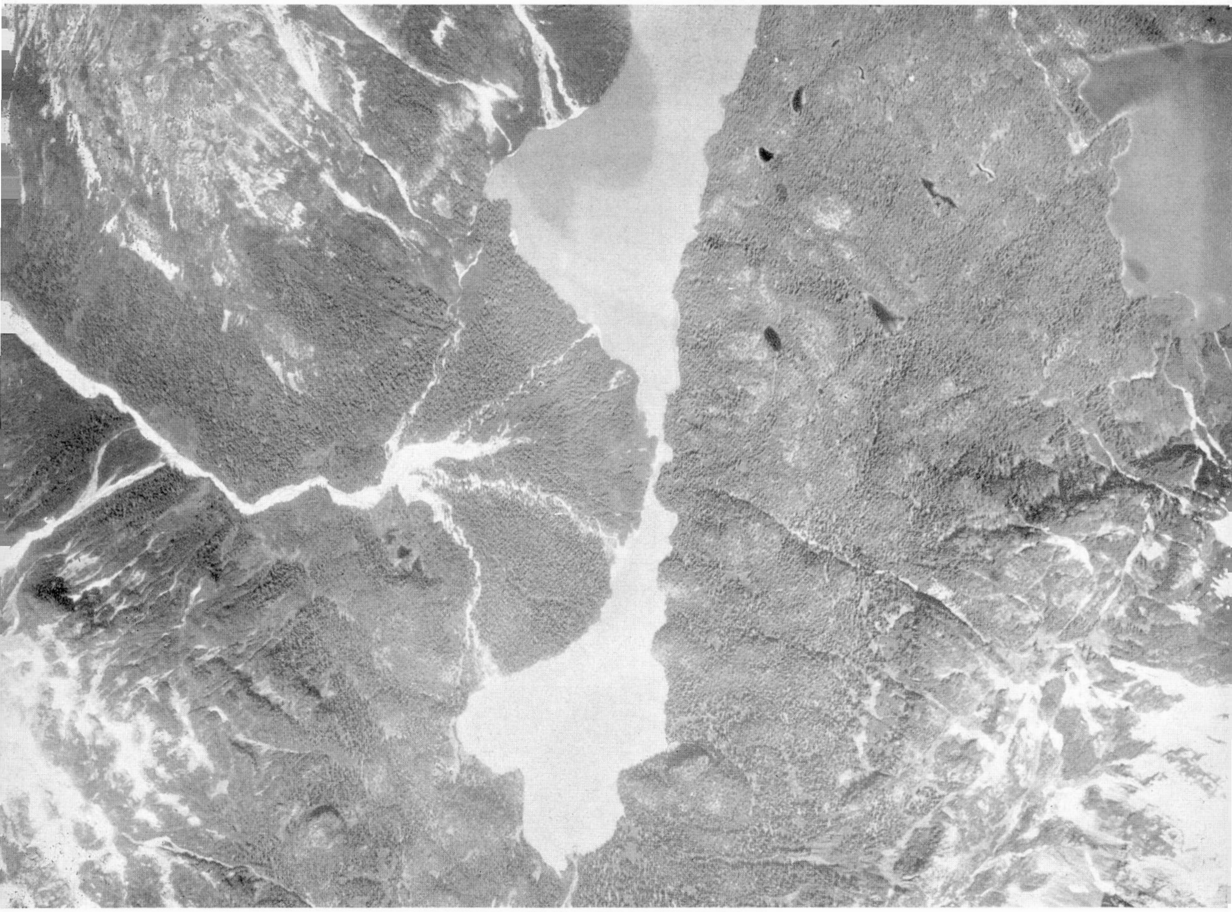

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Plate III *Alluvial fan in Blanket Lakes near head of Troitsa Lake. Stream causing the fan is coming from Mount Bolom to the west.*

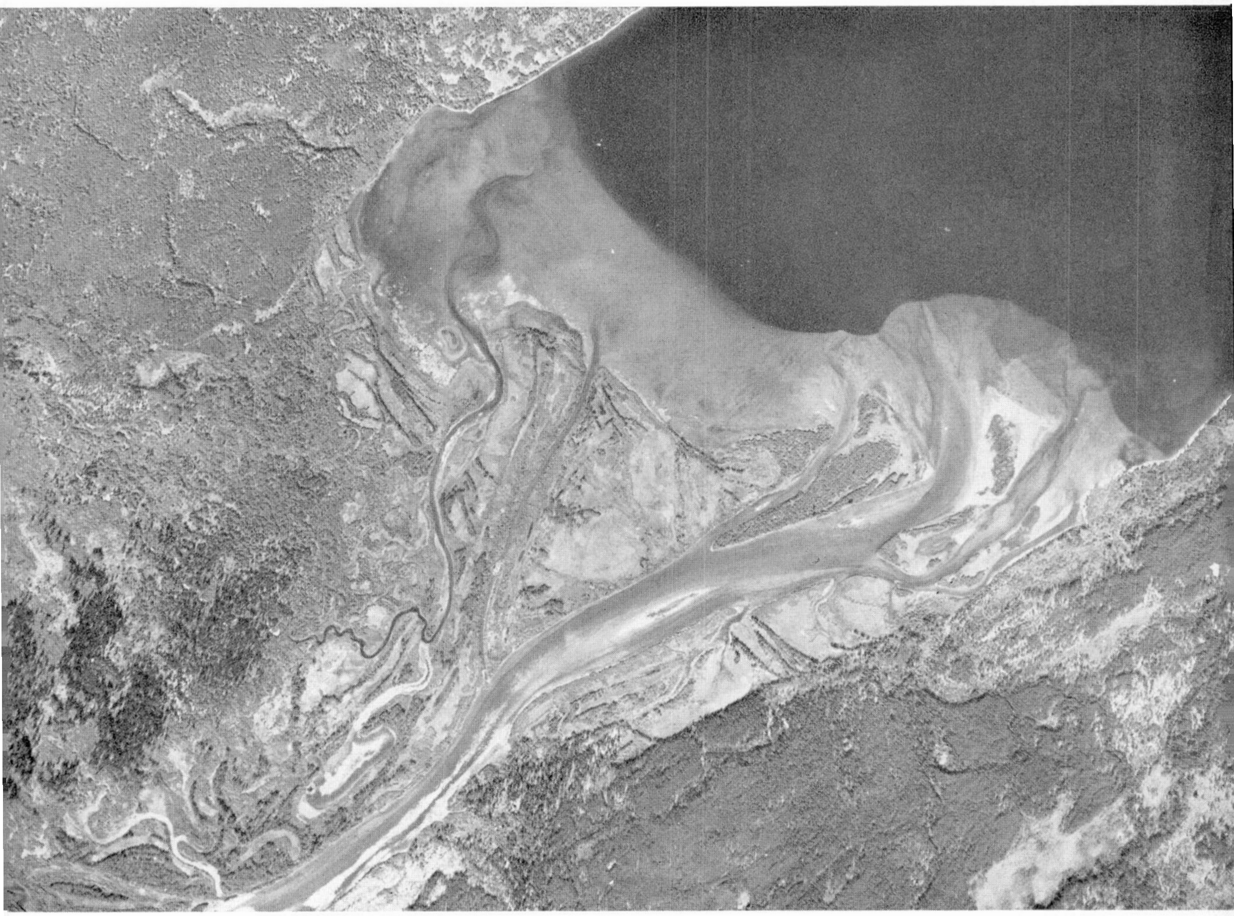

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Plate IV *Aerial view of the delta of Whitesail River at the head of Ootsa Lake, before flooding by the Kitimat project. This delta is now under 135 feet of water.*

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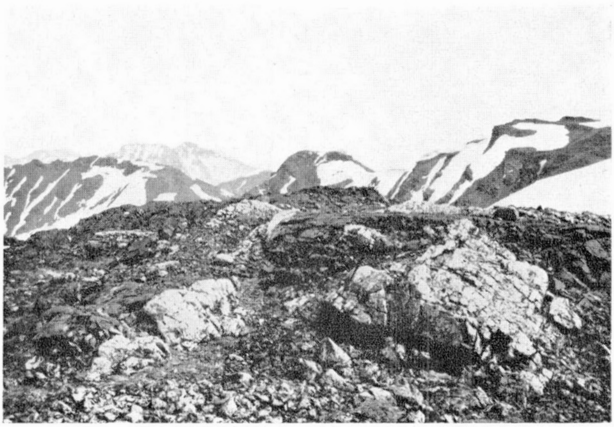
Plate V Aerial view of ridges and grooves near head of Ootsa Lake. Ice moved in the direction of the markings towards right of picture. Many ridges are composed of bedrock.



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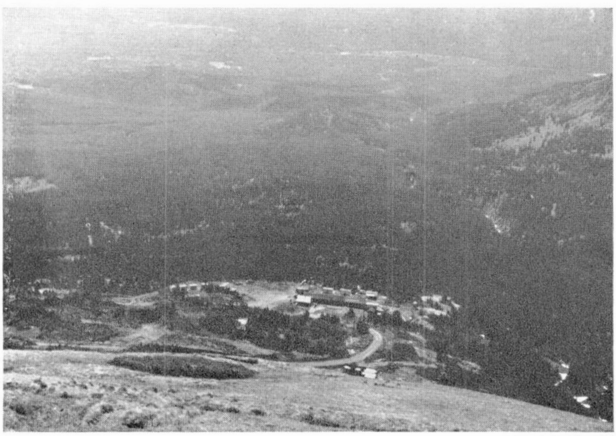
A. Granite dykes in metamorphic complex near head of Tahtsa Lake.

Plate VI

B. Emerald Glacier main camp buildings, elevation 5,100 feet. Tahtsa River valley in the background.



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