CANADA
DEPARTMENT OF MINES AND RESOURCES

MINES AND GEOLOGY BRANCH
BUREAU OF GEOLOGY AND TOPOGRAPHY

GEOLOGICAL SURVEY
MEMOIR 248

TAKU RIVER MAP-AREA, BRITISH COLUMBIA

BY

F. A. Kerr
(Compiled by H. C. Cooke)

OTTAWA
EDMOND CLOUTIER, C.M.G., B.A., L.Ph.,
KING'S PRINTER AND CONTROLLER OF STATIONERY
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View northeasterly up Taku River Valley from below the junction of Tulsequah River (on the left) and Stuhini Creek (on the right). The village of Tulsequah lies on the west bank of Taku River a short distance above the junction of the three streams. (Page 3.)

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PREFACE

The Taku River area was mapped geologically by the late Forrest A. Kerr of the Geological Survey in the field season of 1932. The work completed a series of investigations in northwestern British Columbia, commenced by Dr. Kerr in 1926. Preliminary accounts of these investigations have beeen published in the Summary Reports of the Geological Survey for 1926, 1928, 1929, and 1930, and recently a Memoir, No. 246, has been issued on Dr. Kerr's work in the lower Stikine and western Iskut River areas.

Though a preliminary geological map of the Taku River area has been available for some time, Dr. Kerr's death, in 1938, and subsequent events of the war years, have delayed publication of the report. The present memoir has been compiled by H. C. Cooke of the Geological Survey from original manuscript submitted by Dr. Kerr. In this compilation Dr. Cooke believes that he has correctly stated Dr. Kerr's facts and conclusions, though it is, of course, impossible now to verify this. Further, at all points in the report where statements occur such as "writer believes", "it is the writer's view", etc., the writer is Dr. Kerr.

The report deals with the geological and economic features of a rugged and physically difficult area in the northern Coast Mountains, in which several promising prospects have been discovered, and one mine, the Polaris-Taku, brought into production. A more recent (1938) account of this property, by D. C. Sharpstone, Consulting Engineer and Geologist for the Company, is included in the present volume.

GEORGE HANSON,
Chief Geologist, Geological Survey

OTTAWA, June 25, 1947

Taku River Map-Area, British Columbia

CHAPTER I

INTRODUCTION

LOCATION AND ACCESSIBILITY

Taku River area[1] lies in the Atlin mining division of northern British Columbia from north latitude 58° 30′ to 59°, and from west longitude 133° to 134°. Most of it is drained by Taku River and its tributaries (*See* Figure 1).

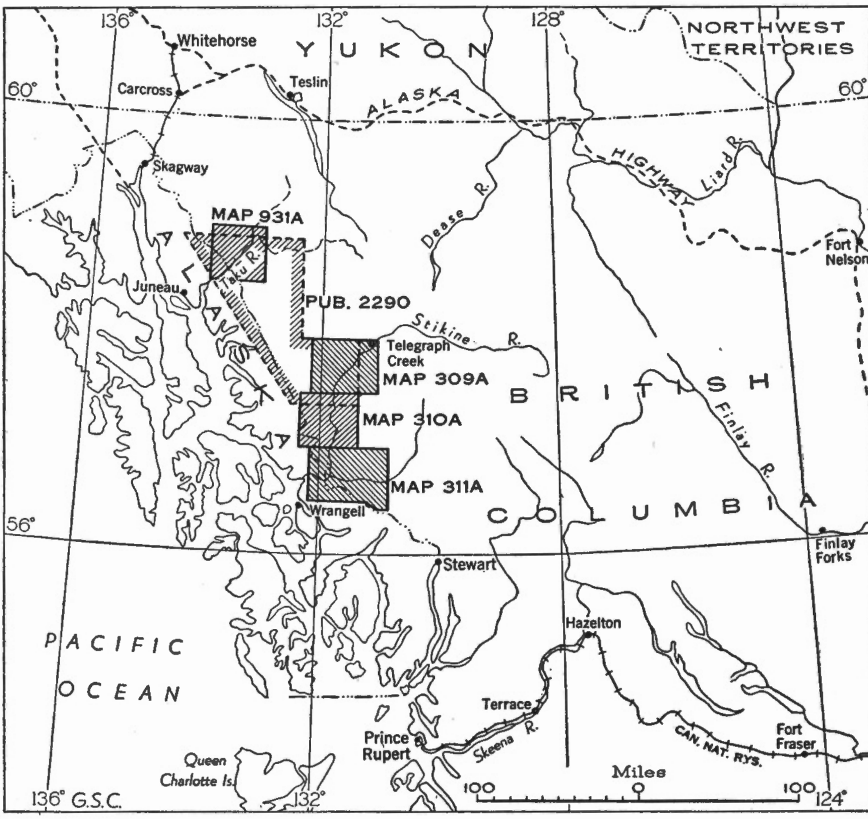

Figure 1. Index map showing position of Taku River (Map 931A) and Stikine River map-areas (Maps 309A, 310A, and 311A); and of exploratory survey (Pub. No. 2290) by F. A. Kerr in 1930, between Stikine and Taku Rivers.

The lower 20 miles of Taku River flows through Alaska. The mouth of the river is about 30 miles from Juneau, the capital of Alaska, and the usual route to that place is by way of Taku Inlet and Gastineau Channel. Boats from Seattle or Vancouver call at Juneau every few days in summer, and about

[1] Taku River area should not be confused with Taku Lake or Taku Arm, a part of Tagish Lake. The latter lies to the northwest of Taku River area, and in a different drainage system.

weekly in winter. Almost any type of boat can make the trip from Juneau to the Taku in fine weather, that is, during most of the summer; but in stormy weather only very seaworthy craft can travel. From 1929 to 1932 a fairly regular service was maintained by the United Transportation Company and its successor the Taku Trading Company, whose boats ascended the river as far as Tulsequah, 26 miles above the mouth, a trip requiring 5 to 10 hours.

Tulsequah, the first permanent settlement in the area, grew up in the late twenties, partly as a result of mining developments to be described later, and partly as an airport. For some reason Taku Valley remains free of fog and clouds for much more of the year than other valleys that extend into the interior of the province, and this fact, coupled with its direct course through the Coast Mountains and its low altitude, makes it by far the best aeroplane route from the Pacific coast into northern British Columbia and Yukon. The valley has thus become established as the chief air route from the coast, and most planes stop at Tulsequah for gasoline and other supplies. A fairly long and wide straight stretch of river here enables planes to land, and air conditions are favourable as the wind always blows either directly up or down the river. Unfortunately, the settlement and docks are about 1,000 feet from the river, up a narrow slough. This makes for some difficulty in turning planes, and would not be satisfactory for planes of unusually wide wing spread, which might have to tie up in the main river. Much level ground at Tulsequah should, however, permit ready construction of landing fields.

Taku River area may also be entered from the north. Starting from Skagway on the coast, one may travel by the White Pass and Yukon Route Railway to Carcross, and thence by lake steamer to Atlin. From Atlin an automobile road leads 25 miles to O'Donnel River, whence a good trail, constantly used by the natives, extends 25 miles south to Canoe Landing on Nakina River beyond the limits of the map-area. From this point one may travel either by the river, or by trail that follows it as far as Inklin.

From the south, a good pack trail leads into the area from Telegraph Creek, which is 150 miles up Stikine River and is reached by river boat from Wrangell. The route involves about 125 miles of overland travel. Both this route and the preceding one are considerably longer and more costly than the direct route up Taku River, but are preferable where access for pack-horses and large quantities of supplies is required to work the upper parts of the drainage basin.

Within the map-area itself, travel is by the larger streams and by trails, which are fairly numerous. Many of them are merely game trails that have been blazed and slightly improved.

The rivers are extremely swift and dangerous. Currents attain in places a speed of 10 or even 15 miles an hour; snags and bars are numerous; and channels are crooked and constantly changing. Waters are turbid, so that obstructions can be detected only by the appearance of the surface. Consequently, successful navigation demands considerable experience, and special boats of shallow draft and high engine power. A strongly built, flat-bottom boat, about 24 feet long and with considerable beam, fitted with a 20-horsepower outboard motor, is more or less standard equipment. The boat should carry a lifting device to raise the motor vertically, so that it can operate in water shallower than normal. Such a boat is not too large for man-handling, which is essential at times.

If large quantities of supplies are to be moved, it is best to utilize the services of the established transportation companies. They have facilities for moving men and supplies to any point on navigable waterways.

The season for navigation lasts from the breakup of the ice, usually in April though occasionally later, to some time between mid-October and the first of December. Very mild winters have been known during which the Taku has remained open; usually, however, by the first of January the rivers are completely frozen, and travel is then by dog team.

PRINCIPAL STREAMS

Taku River. The name Taku is applied only to the lower 50 miles of the stream below the junction of Nakina and Inklin Rivers (*See* Plate I). Below Tulsequah fairly large, shallow-draft boats can navigate it without difficulty except at very low stages of water. Above Tulsequah the river can always be travelled by small boats of the type previously described, though at low water it may not be possible to use the engine in places where the river is split into many channels. Larger boats can probably navigate this section when water conditions are favourable.

The river is generally very low directly after the ice goes out in the spring. As the weather becomes warmer, the water rises, and reaches a maximum height some time between late June and the middle of July. During this period navigation is not good, because of the swift current, the abundant drift, the continually shifting bars, and the poorly defined channels. Moderately high water is maintained during July and August, and conditions for navigation are then at their best. Early in September, with shorter days and colder nights, the river level drops, and navigation may become very difficult for a few weeks. In late September and October the autumn rains supply an abundance of water, and the river rises to its July levels. About the middle of October snow begins to gather on the mountain tops, and river levels fall again. Navigation by large boats is then discontinued, though small craft may be used until about December 1.

At flood times the river moves immense volumes of sand and gravel down stream. Islands are eroded away, trees are torn down to be lodged on some bar, and new bars are formed. With each such obstruction, the course of the river is changed. However, at such times the water is deep almost everywhere, so that beyond avoiding snags and other obstructions navigation is not too difficult. As the water begins to fall, the stream finds itself greatly overloaded, so that it is continually aggrading its bed, forming new bars, and breaking out into new channels. The navigator then finds himself compelled to search out a new route on every trip. At low water the river becomes comparatively clear, few new bars are formed, and the river begins to cut into its bed and to become established in well-defined channels. With its decreased force, however, it has not the power to cut away the coarser gravels, so that bad riffles become fairly numerous. At this stage it is probably least dangerous, for although obstructions are most numerous the current is slacker and they are not so great a menace.

Other Streams. On the other streams of the area the general conditions are similar to those described for the Taku. Most of them can be ascended for relatively few miles and, in general, their smaller volume of water renders navigation impossible by large boats, and more difficult by small ones. Further, local rains, or sudden changes of temperature causing variations in the rate at which the glaciers melt, may raise river levels by several feet in a single night, thus endangering moored boats or supplies cached below high water mark.

Nakina River is navigable by small boats with outboard motors as far as Canoe Landing. This point, which lies north of the limits of the map-area, is at the junction of the Nakina with a large tributary, the Sloko.

Inklin River was ascended from its junction with the Nakina to the Sutlahine, a distance of 20 miles. The river is confined to one channel for the lower 12 miles, the upper 4 of which are in a deep narrow canyon that at high water is dangerous or even impassable. Above the canyon the river, though not confined to one channel, is not badly split, but it is swift and snags are numerous. The Inklin is reported to be navigable to the mouth of the Sheslay, 20 miles above its junction with the Sutlahine.

Tulsequah River, which enters the Taku at Tulsequah (*See* Plate I) has its source in a glacier (Plate II) about 12 miles above its mouth, and its water comes largely from the melting ice. It flows over an unusually wide gravel base with a rather steep gradient, so that the stream is swift and continually changing its course. It can be travelled, with considerable difficulty and danger, for some 8 miles to the Tulsequah Chief landing. Prior to 1932 it was possible to navigate to within 1½ miles of the glacier, but during the summer of that year the river broke out of its channel to cut through a wooded area into what had been the channel of Shazah Creek, and most of it now follows this course. A curious development is taking place concurrently. Tulsequah Valley is filling faster than that of the Shazah, and thus tends to dam the latter at its mouth. As a result, the Shazah is becoming lake-like above its mouth, and eventually a large lake may be formed.

At intervals of every few years Tulsequah Lake, a body of water about 3 miles long and 500 feet deep, breaks out to discharge completely beneath the glacier and causes a great flood to sweep down the valley. This is known to have taken place in 1910, 1929, and 1932. The flood of 1932 was observed by the writer, and has been elsewhere described (23[1]) and in this report page 16.

TRAILS AND OTHER ROUTES OF TRAVEL

Aside from the few streams mentioned, all travel within the area is on foot. The wide valley flats of the large rivers, except in limited parts of the northeastern section of the map-area, are almost impenetrable jungles of alder, willow, devil's club, and other bushes, and have numerous sloughs, beaver lakes, and swamps. They should be avoided unless gravel bars, dry channels, or bear trails can be found. On the lower slopes, those that carry the thickest growth of evergreens are the most easily traversed; lighter green slopes that appear smooth from a distance are apt to be tangles of brush. On such slopes, small streams not deeply entrenched, gullies where the snow lingers most of the summer, and spurs or ridges are commonly the best routes of travel. Above 3,000 feet the wide glaciated valleys are easily travelled. Above timber-line travel is in most places relatively easy, but precipitous and unscalable slopes may be encountered, particularly southwest of Mount Lester Jones. In general, travel in Taku district is probably about as difficult as the worst in Canada.

In the Tulsequah area, a trail follows the east side of Tulsequah River from Tulsequah to the Tulsequah Chief prospect; this trail formerly continued across Shazah Creek and up to the glacier. With the change in the course of the river, previously mentioned, this route above the Tulsequah Chief is now very difficult, and the west side of the river, where travel is entirely over open gravel bars, is better, though longer. Travel is good on the glacier for the first 6 miles, particularly on the southwest side; the remainder is more crevassed, but it can be travelled to its head by devious routes. Nine miles from the foot a low pass

[1] Numbers in brackets are those of references in the bibliography at the end of Chapter I.

leads to Atlin Lake 20 miles distant. It would be easy to enter the northwestern part of the district by this pass and thus avoid the long and difficult trip over the glacier.

In 1932 a good trail followed the east side of Shazah Creek to the first canyon, about 4 miles above the Tulsequah Chief landing. Above this point there is much brush, and travel is very difficult. From the head of Shazah Creek a low wide pass at elevation of about 3,000 feet leads to the head of Tahi Creek, a tributary of Sloko River. The creek occupies a wide, well-wooded valley trending northeast away from the mountains.

Across the Tulsequah, a trail follows the north side of Wilms Creek to the camp of the Silver Bird claims. Above this a poor blazed trail continues for about a mile, then crosses the creek and follows the south side to the glacier.

Another trail branches from the Wilms Creek trail where it first leaves the Tulsequah flat and goes north along the hillside to near the Whitewater camp. A second branch leaves the Wilms Creek trail about a mile below Bacon Creek and extends south for about a mile along the base of Mount Strong. A third branch follows the north side of Bacon Creek to the glacier at its head.

Two trails to Whitewater Mountain leave Tulsequah River and pass the Whitewater and Silver Queen prospects, respectively.

To reach the Sittakanay section, a trail leaves Taku River about half a mile below the International Boundary and crosses the flats to where the valley enters the mountains. Above this travel is easy only at low water, when, by frequently wading the river, one may keep to the gravel base. At other times it is very difficult, as it is necessary to take to the hillsides in many places, and these are thick tangles of brush. One might also reach the head of the valley by Wright River, which is navigable, and by travelling across Wright Glacier.

A good trail leads up Stuhini Creek from opposite Tulsequah to where the valley swings to the northeast. Poor trails continue beyond that point on both sides. By that on the south side the head of the valley can be readily reached; nothing is known of the other. From the head of the Stuhini several possible routes lead to the Sutlahine, but no low passes. A tributary of the Stuhini affords a low and easily travelled pass to the head of a tributary of King Salmon Creek, and thereby to the head of Zohini Creek. By ascending a creek locally known as "Granite", about 9 miles up the Stuhini, a high pass to Morepat Creek is reached.

A trail up Ericksen Mountain starts at the slough that joins the main river about 1¼ miles above Tulsequah; it begins at a camp-site 2 miles from the entrance of the slough, which is navigable at high water, whereas at low water the upper quarter mile is practically dry. The trail follows the spur of the mountain to timber-line. A second trail leads up Ericksen Creek from its mouth.

On the other side of the Taku, a trail leads from Yellow Bluff Point to the base of Metzgar Mountain.

A very good trail leaves Taku River about half a mile above Zohini Creek, and follows the creek to its head, crossing in places. From the head, through a low easily travelled pass, a tributary of King Salmon Creek can easily be reached.

A good trail starts from a camp-site on a slough near the mouth of Red Cap Creek, and follows the south side of the creek to the lake. From that point the upper part of the valley and the mountains to the northeast are easily reached.

There is no trail up Shustahini Valley, and extensive cutting would be necessary to make one. A trail that follows the slough above the mouth of the creek for a short distance leads to the base of Shustahini Mountain, and the main chimney, entered from the northeast side and about 500 feet from the base, affords a good route to the top. By cutting across the spur at an elevation of about 3,300 feet the upper part of Honakta Creek is easily reached. This valley can be travelled readily to its head, and through a low pass the valleys of Tahi and Shazah Creeks are accessible. The upland areas northeast of this can be traversed without serious difficulties.

Travel up Takwahoni Creek is fairly easy by a trail that branches off the main game trail along the Taku.

King Salmon Valley has many game trails, from which one route has been chosen and somewhat improved. It starts from a cabin about a mile below the valley, and goes north to cross the stream at a very high bluff. As most of the trees suitable for bridges at this point have been cut, it is better to leave Taku River by a poorly blazed trail that starts directly opposite the point of King Salmon Mountain. This trail leads to the well-marked trail first mentioned on the north side of the creek. It follows this side for about a mile, then crosses, and in another mile enters a series of meadows that lie close to the base of the mountain. These are followed for nearly 2 miles, nearly to the prominent rock point of King Salmon Mountain. The blazed trail then turns north out of the meadows to the stream half a mile away. It follows the south side to just above the first south fork, crosses to the north side, and continues to a point just above the third south fork. Here it crosses again, and continues to King Salmon Lake. Travel northeast of King Salmon Valley is in general comparatively easy.

As navigation on Nakina River is difficult, a trail follows the river from Inklin to Canoe Landing at the mouth of Sloko River. The trail is good near Inklin, but becomes increasingly poorer to the north, and cannot be used by horses.

HISTORY OF MINING AND PROSPECTING

Prior to 1929 no settlement in Taku River district was large enough to warrant the presence of a federal or provincial official. Prospectors' licences were difficult to obtain, and claims could not be easily filed. Hence, little is known of operations in the district before that date.

In 1875 the annual report of the Minister of Mines for British Columbia mentions discoveries of gold on "Tacoo" River. In 1882 the gold commissioner of the Cassiar district "guessed" that a small production of placer gold was made in the "Takoo" district. Dawson (6) mentions Taku River in his report of 1888. During the Klondike rush of 1897-98 and later years the Taku was a route of entry to the interior, and many prospectors halted or abandoned their journey to prospect in the district. Subsequent to this rush prospecting was intermittent, but probably, from 1912 on at least, some work was done in the district each year.

Lode deposits were probably discovered early in the history of the district, because some of them, such as the Tulsequah Chief, Ericksen-Ashby, and others, outcrop so prominently that they could hardly be missed. Knowledge of the Tulsequah Chief, at least, is reported to date back to 1910 or 1912.

The official record of mining and prospecting in the district begins in 1923, when George A. Clothier, resident engineer for the northwest district of British Columbia, visited it. In that year the Tulsequah Chief, staked earlier by W. Kirkham of Juneau, was optioned by the Alaska Juneau Gold Mining Company, which drove an adit in an unsuccessful search for ore and then abandoned its operations. Five years later, in 1928, a syndicate represented by W. A. Eaton and Dan J. Williams found impressive widths of mixed sulphides; and in 1929 the United Eastern Mining Company optioned the property and carried on efficient and aggressive development.

Reports of these operations drew prospectors into the district, and in May 1929 V. Manville discovered the Big Bull mineralized zone, on which the Alaska Juneau Gold Mining Company acquired a working option. The later discovery of the Ericksen-Ashby and other deposits contributed further to the favourable publicity given to the area.

Tulsequah, the first permanent settlement, now became established. Prospectors continued to increase in numbers during 1929 and 1930, but with the advent of government officials and customs duties the free and easy passage from Alaska to British Columbia ended, and this caused a considerable lessening of activity. Interest in the district was still further decreased by the failure of the United Eastern Mining Company, in 1930, to resume work on the Tulsequah Chief, and by the later action of the Alaska Juneau Gold Mining Company in dropping its option on the Big Bull claims. However, Tulsequah had been established, and the fairly regular service between it and Juneau continued. In 1931 active development began on the Whitewater claims (afterwards the Polaris-Taku mine) by the N. A. Timmins Company, and in 1932 Tulsequah airport began to be much used by companies in search of placer gold.

SETTLEMENT

The one settlement, Tulsequah, is situated on Taku River at the first point above Tulsequah River high enough to escape the Tulsequah floods (*See* Plate I, frontispiece). Its site was selected to lie at the junction of four main routes of travel, and it has the further advantage of being a good landing place for aeroplanes going to or from the interior. Its disadvantages are that the site is not sufficiently high to avoid occasional flooding, and the slough on which the landing is placed is narrow.

The population in 1932 consisted of fifteen to twenty-five more or less permanent inhabitants. A store and post office were operated during the summers, and mail, freight, and passenger services were maintained from about May 1 to October 15. During the winters connections with Juneau were irregular. A government official was in residence for customs, immigration, clearance of boats and aeroplanes, registration of mining claims, and so on.

Above Tulsequah one farm was permanently occupied in 1932, and several widely scattered cabins were used intermittently by prospectors and trappers. At the junction of the Nakina and Inklin several families of Indians were usually to be found, and three cabins in fairly good condition were formerly used as a trading post. Substantial buildings had been erected at the Big Bull, Tulsequah Chief, and Whitewater prospects.

Until recent years the only industry of the district was some trapping by the natives, but of late the chief activity has been prospecting and development work. During 1932 the use of Tulsequah as an aeroplane base has added considerably to the income of the inhabitants.

WATER POWER

Much water power could be developed in the district. Many large streams such as Kwashona, Zohini, and Red Cap Creeks enter the main valleys over cascades or falls, and others such as the Stuhini have falls along their courses. Wide glaciated valleys afford in many places suitable storage basins that could be utilized to regulate the usual seasonal fluctuations in volume.

CLIMATE

Taku district extends from the heart of the Coast Mountains, a wet belt, to the Stikine Plateau, a dry belt, so that all gradations of climate are found in it. The moisture-laden winds that sweep in from the warm Pacific Ocean are forced upward by the Coast Mountains, and, thus chilled, precipitate their moisture there. Precipitation along the Alaskan coast, accordingly, ranges from 75 to 150 inches yearly, and the average snowfall may be as much as 114 inches. Beyond the axis of the range, precipitation is somewhat less but still heavy as far as the eastern limit of the high mountains—in Taku River area about as far as Mount Lester Jones. Farther northeast the elevation decreases rapidly, and with it a corresponding decrease in rainfall; a traveller on his way upstream will commonly pass from cloudy wet weather into bright sunshine a few miles below King Salmon Creek. From there the amount of rainfall decreases gradually to the Stikine Plateau at the northern edge of the map-area, where the annual precipitation averages about 10 inches, including a snowfall of about 50 inches.

Temperatures at the coast are relatively high. The winter months, December, January, and February, average 23 to 27 degrees; there is little sub-zero weather, and on many days the thermometer is above freezing point. Around Tulsequah winter temperatures average considerably lower, and have a greater range. Toward the interior the winter temperatures become increasingly severe, to where, on the Stikine Plateau, they range down to 50 degrees below zero and rarely rise above zero. In spite of this, the clear days and dry snow of the interior make much better travelling than the wet snow of the mountains.

Around Tulsequah snow accumulates on the flats to a depth of 10 feet, and probably more at higher levels. The flats do not begin to clear until about the end of April, and it is the end of June to the middle of July before most of the slopes up to timber-line are free of it. Above timber-line more or less snow may fall at any time during the summer. The most favourable working month is August. July is an uncertain month, usually with much cloudy, wet, and cold weather; and the rainy season normally begins early in September, after which there are few days without heavy rain.

Work in the area should, therefore, be arranged so as to spend the first and last parts of the season in the dryer belt northwest of King Salmon Creek, where work can commence early in May and continue under favourable conditions until mid-October, and to confine work in the wet belt to August and part of July.

During the summer the wind in Taku Valley almost invariably blows upstream. The greatest velocity is generally attained in the eastern part of the mountains, and during the afternoon. At nights, except in stormy weather, it usually dies. Before gasoline engines came into common use, these winds made it possible to ascend the river with sails, even against the swiftest currents. In the winter the direction of the winds is reversed, and at times they blow so strongly out of Taku Inlet that coastwise steamers are held up. About the middle of October the wind alternates, blowing sometimes up and sometimes down the valley. These winds are purely a valley phenomenon; the air around the mountains, even directly above the valley, may be still or moving in an entirely different direction.

VEGETATION AND AGRICULTURE

Three more or less distinct belts of vegetation in the map-area correspond to the climatic belts. In the wet belt, southwest of King Salmon Valley, the valley flats, where not stream-washed, are a veritable jungle in which large cottonwoods and evergreens rise above a tangle of devil's club, alders, willows, cranberry, huckleberry, and other bushes. The lower slopes, where conditions are favourable, are clothed with mature growths of spruce, hemlock, and fir, very little of which has suffered from fire due to the wet climate. Where the evergreens are sparse, by reason of snow slides or other factors, a terrible tangle of the shrubs previously mentioned results. Timber-line (*See* Plate III) is rarely above an elevation of 3,000 feet, though in a few favoured places it extends to 4,500 feet. Many of the larger glaciated valleys above 2,000 feet have little timber, and are mainly clothed with a dense growth of alders.

Between King Salmon Creek and the Inklin the valley flats carry more large trees and much less brush, so that on the whole they can be easily travelled. Mature forests of evergreens cover the slopes to an elevation of 4,500 and in places to 5,000 feet, but large areas have been burned, making travel difficult. Dry areas such as the tops of knobs on southern slopes are relatively open or even bare, though pines, poplars, birches, maples, etc., are abundant.

Still less vegetation clothes the interior plateau. The valley flats are fairly open, and timber is abundant only on northern exposures and other sheltered places. Trees on the whole are much smaller. Pines, poplars, birches, and maples occupy the drier parts, and spruce and hemlock the wetter. Great upland expanses and even lower slopes may be merely grassy.

Western hemlock is the most common tree of the map-area, forming 50 to 75 per cent of the total number. Sitka spruce is almost as abundant in many places, and attains diameters of 5 to 6 feet. Englemann spruce is found in the higher parts, and in some places fairly well down the slopes. Alpine fir is relatively uncommon. Cedars were noted in one locality on Sittakanay River, and larch near the canyon on Shazah Creek. Lodgepole pine are present on the rocky spurs upriver from Yellow Bluff, and are abundant above the flats northeast of King Salmon Creek. Cottonwoods are numerous along the river flats. They grow larger than any other tree, and remarkably quickly.

Possible agricultural land is limited to the valley flats above flood levels. The common hardy vegetables grow fairly well at Tulsequah, and even better at Inklin where there is more sunshine. There are probably some areas of good farm land around King Salmon Creek.

Certain parts of the wet belt support a luxuriant growth of small fruits. These include salmonberries, huckleberries, wild strawberries, serviceberries, thimbleberries, raspberries, black cap, soapallali, red and black currant, high bush cranberry, elderberry, gooseberry, and various small bush mountain berries.

GAME AND FISH

Game is much scarcer in Taku Valley than in other parts of northern British Columbia. Moose were formerly fairly abundant, but have been mostly killed or driven away. Mountain goats may be encountered on most of the mountains, but few bands of more than ten were seen. There are no mountain sheep, except possibly in the extreme northeast. Less than half a dozen grizzly or brown bears were seen during the summer's field work whereas that number might easily be seen in one day in other parts of the Coast Mountains. Porcupine, marmots, and wolves are rare, but coyotes are more common. Geese and ducks are found along the rivers in the autumn in fair numbers. Grouse and ptarmigan were seen in all parts of the map-area, and are fairly abundant in the northeastern part. Fur-bearing animals include the beaver, mink, muskrat, fox, marten, weasel, fisher, lynx, marmot, wolverine, wolf, and coyote.

In the late summer and autumn salmon are abundant in the Taku and the lower parts of its tributaries. Cut-throat and Dolly Varden trout occur in the river and are abundant in the clear streams and lakes. Small trout are numerous in some of the streams, even in the upper reaches inaccessible from the main river.

ACKNOWLEDGMENTS

The writer mapped Taku River area in 1932, but also visited it for brief periods in 1929 and 1930. In 1932 he was efficiently assisted by Alex and J. Y. Smith. Both in that year and during earlier visits he received a most cordial welcome, and much help, from the residents of the area and from the officials of the Taku Trading Company, the United Eastern Mining Company, the Alaska Juneau Gold Mining Company, and the N. A. Timmins Corporation. All of these most generously made available to him the data and reports on their properties. The co-operation and assistance of B. D. Stewart, Federal Mine Inspector and representative in Juneau of the United States Geological Survey, were also deeply appreciated. Mr. Stewart had made a geological survey of most of the area adjacent to Taku River in Alaska, and discussion of the problems of the area with him was, therefore, most helpful.

PREVIOUS WORK

Geological Work. Very little geological work had been done in Taku River area prior to that undertaken by the writer. In 1892, C. W. Hayes, who had made a track survey of the river, gave in the National Geographic Magazine (8) some observations on the rocks along his route. In 1925, W. E. Cockfield, in making an exploratory survey between Atlin and Telegraph Creek, mapped the geology as far southwest as the junction of Nakina and Inklin Rivers (4). The Annual Reports of the Minister of Mines for British Columbia from 1923 onward contain considerable information, especially a publication by J. D. Mandy (23).

Considerable work has been done in nearby districts closely related to Taku River area. This includes the work of J. C. Gwillim and D. D. Cairnes in Atlin district, that of the writer in Stikine River area (*See* Figure 1), Buddington and Chapin's summary of the work of American geologists along the coast of Alaska, and B.D. Stewart's unpublished work on the Alaskan areas immediately adjacent to the International Boundary. The writer's work in 1930 between Stikine and Taku Rivers links together most of the work on the Canadian side of the boundary from Atlin district to Unuk River.

Topographical Work. Vancouver's maps of the west coast show Taku Inlet but not the river. It appears first, so far as known, on a United States coastal survey map of 1869. C. W. Hayes in 1891 made a track survey of the river. In 1892 N. B. Gauvreau, P.L.S., did further surveying and provided data shown on Dawson's and other maps. In 1906-7 the International Boundary was accurately located by a system of triangulation that also fixed many points in Taku area. Topographical work done at the same time was published in 1923 as a map on a scale of 1 to 250,000—Sheet No. 8 of Cape Muzon to Mount St. Elias series. It shows the topography of a considerable part of Taku River area, and its geographic relation to Atlin and other neighbouring districts. Photographs taken at this time are a valuable record of the extent of glaciers. In 1929 àerial photographs of Taku Valley near the International Boundary were taken by the Alaska Aerial Survey Expedition of the United States Navy Department. In 1930 the Canadian Geological Survey published the Atlin sheet on a scale of 1 inch to 8 miles; it shows all the geographical and geological information, available at that time, of a large area north of latitude 58 degrees in western British Columbia and Yukon. In 1930, R. Bartlett mapped topographically all of Taku district that is readily accessible and took a third valuable series of photographs. Subsequently, J. A. Macdonald compiled Bartlett's data and those of the International Boundary surveys to produce the base used for the geological map that accompanies this report.

FIELD WORK

In the single field season of 1932 it was impossible to cover in any detail an area as large and as difficult as the Taku River area. To map it even sketchily it was necessary to make trips yielding the maximum amount of information from direct examination, and then, from good vantage points, to extend the boundaries as far and as well as possible by long distance observation. Probably not more than 1 per cent of the total length of geological contacts shown on the map was actually examined; about 25 per cent was seen at ranges of 100 feet to 20 miles. Such contacts are shown on the map in full line, but it is obvious that they are not, therefore, accurately located.

The nature of the weather had also a pronounced effect on the accuracy of the mapping. The section along Taku River from King Salmon to Ericksen Creek was covered in July, when it was almost continuously cloudy, foggy, or rainy, and the results obtained from long-distance observations under these unfavourable conditions must be considered poor. In August, when splendid weather prevailed, the Tulsequah River section and the Taku near Tulsequah were explored. The results on these sections are, therefore, considered good, except around Whitewater Mountain where the light was poor. The Wilms Creek and Sittakanay Creek sections were examined in a more or less continuous downpour, with correspondingly unsatisfactory results. In the northwest part of the area the weather was as a rule moderately clear, and the results of long-distance observations were about normal.

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CHAPTER II

GENERAL CHARACTER OF THE DISTRICT

PHYSIOGRAPHY

Northern British Columbia is made up of three main physiographic units, a central plateau belt, flanked on the southwest by the Coast Mountains and on the east by the Cassiar-Omineca Ranges. Taku River area lies mainly in the Coast Mountain belt, with its northeast corner in the central plateau.

The Coast Mountains, at the coast, rise in abrupt slopes to form well-rounded, fairly heavily forested mountains about 4,000 feet high. Farther northeast the elevations of the summits rise to the International Boundary, which follows the main axis of the range. Along this main axis heights range from 6,000 to 10,000 feet; slopes are steep, in places almost vertical, and culminate in sharp, needle-like peaks and saw-toothed ridges (*See* Plate II). Northeastward from the main axis levels drop off abruptly into a deep, synclinal valley that divides the Coast Mountains into two ranges. In places this valley is a deep narrow cleft, with its base only a few hundred feet above sea-level, and great peaks rising on either side. In other places the base may be 2,500 feet or more above sea-level, and may be bounded by abrupt slopes that rise to rounded, well-glaciated mountains 4,000 to 5,000 feet high. The trench has been eroded in a belt of softer rocks that lies between masses of batholithic rocks; in Taku area it is represented by the valleys of Tulsequah and Stuhini Rivers (*See* Map 931A, in pocket).

Northeast of the trench is the remaining section of the Coast Mountains, which is also very rugged, though peaks are for the most part somewhat lower than in the main section. It is also more irregular, being pierced by wide, well glaciated valleys, though in the Taku River area this characteristic is somewhat less pronounced than elsewhere. On their northeast side, these mountains drop away toward the Stikine Plateau (*See* Plate V), which has a general elevation of about 4,000 feet. The uplands in this mountainous section are gently sloping, but below them the valley walls are relatively abrupt. These features suggest that the mountains have been carved from uplifted parts of the plateau, the boundary of which, in the map-area, is defined by Inklin River Valley.

The upland surface of Stikine Plateau is nearly flat, with only a few hundred feet of relief and a general elevation of about 4,000 feet. However, on it, though not within the map-area, are some erosion remnants, volcanic cones, and raised lava platforms, which may rise as much as 2,000 feet above the general surface and thus detract from the plateau appearance. Also, the great valleys of Taku and Stikine Rivers are deeply incised into it.

The general structure of the southwestern part of the plateau is that of a synclinorium, and the rocks are mostly younger than those exposed in the Coast Mountains. Though small intrusive masses are known to occur, no large ones have been reported. The upland surface bevels the upturned edges of all strata regardless of their hardness, so that it would appear to be an uplifted peneplain.

Throughout the Coast Mountains snow and ice blanket extensive areas and send long tongues of ice down the valleys. The main axis of the range northwest of Taku River is occupied by a great ice-field about 25 miles wide, most of which lies in Alaskan territory. Southeast of the river the average width of the corresponding ice-field is only about 10 miles. Tongues of ice reaching down from these fields occupy parts of Tulsequah and Stuhini Valleys. In the Coast Mountains north of these valleys ice is less abundant, and almost none appears in the section north of Shustahini and King Salmon Creeks.

The Coast Mountains are remarkable for their extreme ruggedness. From the wide, gravel-filled bottoms of the main valleys slopes rise very steeply (Plate III) to the high peaks, many of which have almost vertical cliffs. Great talus piles of fallen debris blanket the mountain sides over vertical distances of hundreds of feet. Cirques and hanging valleys are abundant. Streams that occupy them fall picturesquely over the lips of these hanging valleys, and in most instances have cut canyons into them.

The scenic beauty of the Coast Mountains, as displayed along Taku Valley, is superb (*See* Plate I). The valley is so straight that from certain vantage points a panoramic view of nearly the whole cross-section can be had. From the broad low valley the lofty peaks of the main axis rise sharply in rugged grandeur. Great glaciers wind their way down them from the ice-fields at the summit to the sea or the main valley. Hundreds of smaller glaciers occupy the cirques or hanging valleys, or cling to precipitous slopes. From them foaming torrents cascade down the mountain sides, in places dropping vertically for more than 1,000 feet.

DRAINAGE

Taku River cuts directly across the trend of the Coast Mountains, and thus appears to be an antecedent stream, one that existed before uplift began and was able to maintain its course as uplift proceeded. Its tributaries are mostly streams that parallel the general northwest trend of the mountain system; and their tributaries, in turn, have normal dendritic patterns.

The courses of all the streams are well adjusted to the structure and composition of the underlying rocks. Many of them occupy synclines, and all of them are established in courses involving a minimum of cutting of batholithic intrusions. Quite possibly streams that originally crossed such intrusive rocks were unable to maintain themselves against the uplift of the mountain belt.

Taku and Stikine Rivers together share the drainage of the Stikine Plateau. They are now separated mainly by Level Mountain, a huge volcanic cone of Tertiary age, with extensive lava plateaux. It is probable that the extrusion of this lava altered to some extent the proportions of the drainage tributary to each river, but the actual effect is not known.

The valleys of the larger streams display many peculiarities. Thus, Nakina Valley (*See* Plate V) maintains the size and characteristics of Taku Valley, and would appear to be a normal continuation of it. It is wide, and has a gravel-filled base that averages more than half a mile in width. In spite of this, it carries a much smaller volume of water than the Inklin, which, except for some 3 miles from the mouth, is in a narrow valley much of it canyon-like. Taku Valley widens into a great, basin-like area southeast of Sinwa Mountain, and the lower part of King Salmon Valley is also abnormally wide (Plate IV). Between King Salmon and Tulsequah Valleys that of the Taku displays high rock spurs that jut out into it, with deep, steep-walled embayments between them. At the confluence of the Tulsequah and Stuhini is a flat area of more than 16 square miles (*See* Plate I). Below it the Taku is a normal glaciated valley widening gradually to 2½ miles at the International Boundary. All these peculiarities are believed due to glaciation. It will be shown that at times glaciers moved up Taku Valley, at other times down it; and the differing strength and extent of these movements could account for the erosional peculiarities mentioned. It is also possible, of course, that both Tertiary volcanism and later glaciation may have caused variations in the volumes of water, particularly of Nakina and Inklin Rivers.

Taku River falls about 240 feet in its length of 60 miles, an average of 4 feet a mile. The Tulsequah is much steeper, with an average gradient of 15 feet a mile in the lower 10 miles, and more in the upper 2 miles.

ICE-FIELDS AND GLACIERS

Within the map-area are parts of three large ice-fields. The most extensive of these is the one northwest of Taku River along the axis of the Coast Mountains. It has an average width of about 25 miles, and an area, probably, of more than 1,300 square miles, of which about one-fourth is in British Columbia. The ice-field lies mainly between 3,000 and 6,000 feet above sea-level. Numerous rocky peaks rise above the ice, and the ice surface itself has considerable local relief, rising near the peaks and falling towards the main outlets. Extensive areas are unbroken by crevasses, but other parts display these evidences of movement.

A much smaller ice-field, southeast of Taku River and also along the main axis of the range, supplies the Wright and Sittakanay Glaciers. It is about 10 miles wide, but only about 16 miles long, as the range is again interrupted, some 32 miles from the Taku, by the transmontane valley of Whiting River.

A third ice-field lies in the high area north of Tulsequah River. Its size is not known, but it may extend as far as Upper Sloko River, some 25 miles away. As it lies well to the northeast of the main axis, so that precipitation is much lighter, its lower boundaries probably lie considerably above those of the axial field, at about 4,000 feet.

The glaciers of Taku Inlet and the lower part of the river have been described by many authors (25). They were photographed and mapped by the International Boundary Survey of 1906 to 1910, and in 1929 magnificent aerial photographs were taken of the more important glaciers by the United States Topographical Survey. In 1930 R. Bartlett of the Topographical Division of the Canadian Geological Survey took further photographs (*See* Plates II to VI).

The large glaciers of the district come from the major ice-fields. They have lengths up to 18 miles, and in their lower reaches are as much as 1½ miles wide. Their thicknesses range from some 50 feet, near their lowermost ends, to several hundred feet—probably 800 or more—within a distance of a few miles. The surface gradient is rarely as low as 50 feet to the mile, and is usually much steeper. The three major glaciers of the district are Tulsequah, Wright, and Sittakanay.

Besides the major glaciers there are innumerable smaller ones that range in size down to ice patches too small to move. They occur wherever the annual accumulation exceeds loss by run-off or evaporation, some on flat surfaces and others on slopes so steep that it is difficult to understand why they do not slide off. Northern slopes, and places to which quantities of snow slide, are the most likely to develop them. They are most abundant in the western part of the map-area, and decrease in numbers toward the east.

The evidences for glacial advances and recessions during the last few hundred years is less complete in this district than in Stikine River district; but such evidence as is available points to a similar history. Following the period of general glaciation, the land stood some 600 feet lower than now, relative to sea-level, for mud-like delta deposits carrying Quaternary sea shells underlie the present Tulsequah Glacier. These deposits are known from chunks of the frozen mud carried out from beneath the glacier by the floods later described. Such delta deposits must have formed after the main period of glaciation, as otherwise they would have been destroyed. Besides these delta deposits, marine beaches are exposed along the lower part of Taku Valley, at a considerable height above sea-level.

Fifteen to twenty feet below the base of the ice, at the end of Tulsequah Glacier, alder stumps and moss were observed. They seem to have grown on the delta above described, presumably after uplift had carried it above sea-level. Their presence demands the conclusion that the climate then was considerably warmer than now, a conclusion in accordance with evidence from many other parts of the world.

Of the interval that followed, probably a few thousand years, there is no record in Taku River district. The evidence only indicates that a few hundred years ago the climate was much colder than now, for moraines of the Tulsequah glacier extend more than three-quarters of a mile below the present terminus; and others at the mouth of the valley may have been formed during the same advance. At a point 1,000 feet from the present terminus there is a terminal moraine 100 feet high, where the ice must have stood for many years. Photographs taken in 1910 show that the glacier then terminated at or near this moraine, so that since that time (to 1930) it has been retreating at a rate of about 50 feet a year. This retreat has been steady as no important moraine has formed.

Other glaciers, such as the Wright and Mount Lester Jones, also show evidence of rapid retreat in the last 20 years.

TERRACES

Above King Salmon Creek terraces are almost continuous on both sides of Taku Valley. At Inklin there are six major, and some minor, terraces; the lowest major terrace is just above high water level, and the others stand 40, 140, 180, 250, and 280 feet higher. Opposite King Salmon Creek are two well-defined terraces at elevations of 330 and 450 feet. This extensive development of terraces along the upper reaches of Taku River may have been caused by the ponding of Taku Valley by ice from the axial range, or by morainal dams.

Northwest of Tulsequah terraces occur at elevations of 300, 450, and 500 feet. They appear to be in part delta deposits of marine or lacustrine origin. In Tulsequah Valley there are terraces between 200 and 600 feet in elevation; in Zohini Valley distinct terraces appear at elevations of 330, 500, and 550 feet; and terraces believed to be lateral moraines are well developed along Tulsequah, Wright, and other valleys.

TULSEQUAH FLOODS

Periodically great floods sweep down Tulsequah Valley, covering the flats from side to side and lasting about 6 days. They are very destructive, and are a serious menace to persons travelling the river or to operations along the base of the valley. The author and his party were fortunate enough to witness one of these floods in 1932.

The floods are caused by the sudden draining of Tulsequah Lake through a channel beneath Tulsequah Glacier. Though they may occur at any time, they do so usually only once a year, in late summer or early autumn—probably because melting and ice movement are greatest then.

Tulsequah Lake occupies a valley gouged out by a tributary of Tulsequah Glacier. During the recent period of glacial retreat, this tributary retreated some 4 miles up the valley, leaving an empty basin the base of which was estimated as 600 feet above sea-level at its lower end, and 800 feet at its upper end. As the surface of Tulsequah Glacier at the lower end of the tributary valley is about 1,425 feet above sea-level, that glacier has pushed up the tributary valley a distance of nearly a mile. Drainage from the ice masses above and below is ponded in the valley between to form Tulsequah Lake. Its surface is normally about 1,300 feet above sea-level, and there would appear to be some outlet for the water when this level is reached, for a single, well-defined shoreline has been developed. Thus the lake has a depth of 600 to 700 feet at its lower end, and some 200 feet less at the upper. Its surface is covered with thousands of floating bergs broken off from the ends of the glaciers.

Periodically this water finds a channel into the main stream that flows beneath Tulsequah Glacier and discharges into it until the lake is empty or nearly so. When the level of the lake is low, the floating bergs would be washed into the outlet, become lodged there, and presumably block it. However, whatever the cause, the outlet becomes very thoroughly blocked, and water accumulates again, filling the basin.

The floods start with a moderately large volume of water, which continues to increase for about 6 days, until the lake is drained or the channel blocked. This suggests that the channel is at first moderately large, and increases in size as discharge goes on. Further, in recent years at least, the discharge has always come from about the same place at the end of Tulsequah Glacier, about one-quarter mile west of the nunatak or rock island at the glacier front. This fact would seem to point to a fairly well-maintained channel beneath Tulsequah Glacier, even though at normal times the amount of water flowing from it is not great.

Normally, Tulsequah River, even at high stages, covers only about one-seventh of its mile-wide gravel flat, sprawling over it in many ever-changing channels. On August 18, 1932, it was noticed, from the top of a mountain, that the river covered about half of its flat, and a speedy effort was at once made to report on the phenomenon. The rise continued steadily until the morning of August 21, by which time the river covered the valley from rock wall to rock wall, and was thus a mile wide. Where the water had been 1 to 2 feet deep it was now 5 to 6 feet, with a current of 10 to 15 miles an hour. The flood waters shot from an aperture about 75 feet wide and 50 feet high, partly in the ice and partly in the gravel below. Its force, where it emerged, was tremendous, and it rolled down the valley in a series of huge combers, sweeping with it blocks of ice 20 feet in diameter and huge boulders. Farther down great numbers of mature trees were swept away, and the river was charged with great cottonwoods up to 100 feet in length, which were carried down to crash into others or to lodge on bars and create temporary dams. The water was loaded with silt and sand, so much so that deposits up to 6 inches in thickness were formed on wooded flats that had been covered for only a day by slow-flowing water. Above the junction of Tulsequah and Taku Rivers the waters of the latter were backed up for miles, and at Tulsequah village the river rose many feet above normal high-water levels.

The flood waters started to fall on the morning of August 21, and for 10 hours continued to drop at the rate of about an inch an hour. Thereafter the fall was still more rapid, so that by the following morning a normal level was once more reached. The valley, however, was a picture of destruction. Old channels were completely gone, and new channels up to 15 feet deep had been cut in the coarsest gravels. Forested islands had completely disappeared, and great piles of logs and newly uprooted trees were scattered everywhere. Ice cakes were strewn around, and many of them had been partly or almost completely buried, to create pot-holes as they melted.

The site of Tulsequah Lake was now a deep and awful chasm, its bottom piled with enormous blocks of ice that creaked, cracked, and groaned in terrifying fashion as they settled.

The erosion, transportation, and deposition effected by one such flood is probably greater than could be accomplished by the normal flow of the river during many years. The influence of such floods in aggrading Tulsequah and Taku Valleys and in building the Taku delta has been tremendous. Tulsequah Valley has, in fact, been aggraded so fast that its tributary, the Shazah, has been almost ponded, so that meanders and swamps have been formed there. However, during the flood of 1932 the Tulsequah broke out of its own channel into the lower Shazah Valley, so that henceforth its own waters will help to maintain the Shazah channel.

CHAPTER III

GENERAL GEOLOGY

GENERAL STATEMENT

Owing to its relative lack of intrusive masses, the structure of Taku River area is simple as compared with other parts of the Coast Mountains. Further, Taku Valley, cutting across these mountains almost at right angles, affords two well exposed structure sections of them over a vertical range of 8,000 feet. Above an elevation of 2,000 feet, in particular, are tremendous areas of almost unweathered rock free of vegetation. Below this elevation, talus and other unconsolidated materials obscure much of the exposures, and valley bottoms are, of course, mainly filled with gravels and other recent deposits.

The map-area lies along the eastern edge of the core of batholithic rocks that extends throughout the length of the Coast Mountains. These rocks cross the International Boundary for short distances both northwest and southeast of Taku River, but mostly lie entirely in Alaska. Smaller batholithic masses are found northeast of Tulsequah-Stuhini Valley, but are fewer and of less variety than in other parts of the Coast Mountains.

Toward the axis of the Coast Mountains the structure of the non-batholithic rocks is irregular, and the rocks themselves are much recrystallized and altered. Apparently this is due to the repeated deformations during Mesozoic time. Along the northeastern flank of the mountains the folds become more regular and open, with northwesterly trends, and the rocks become increasingly less altered.

The formations of the map-area, so far as determined by the work of 1932, are listed in the following table.

TABLE OF FORMATIONS

Surficial Formations

Age	Formation, series, or group name	Characteristics	Thickness
Quaternary		Alluvium, talus and glacial drift	Feet 750
		Unconformity	
Upper Cretaceous (not mapped)		Lava, tuff?, conglomerate?, etc.	2,000
		Unconformity	
Lower Cretaceous?	Inklin group	Dominantly tuff and greywacke; argillite, sandstone, lava, conglomerate, and limestone; volcanics; diopside and hornblende albite-oligoclase dacite	18,000

TABLE OF FORMATIONS—*Con.*

Surficial Formations—Con.

Age	Formation, series, or group name	Characteristics	Thickness
			Feet
Unconformity?			
Jurassic?	Yonakina group	Dominantly argillite; sandstone, tuff, conglomerate, greywacke, lava, and limestone; volcanics; oligoclase dacite with rare albite-oligoclase andesite	13,000
	Sinwa group	Limestone; rare lenses of sandstone and argillite; some basal sandstone and tiny seams of coal	2,500
Unconformity			
Upper Lower Jurassic	Takwahoni group	Dominantly argillite, conglomerate, sandstone, arkose, and greywacke; tuff and lava; volcanics; hornblende and biotite andesine dacite	5,000
Unconformity			
Upper Triassic	Honakta group	Limestone, possibly some chert and other materials	1,000
	Unconformity		
	Stuhini group	Tuff, greywacke, argillite, sandstone, and conglomerate	500
		Dominantly conglomerate, greywacke, and tuffs with some lava breccias and limestone; volcanics; andesite, mainly with oligoclase, some albite and andesine; basal conglomerate	2,000–4,500
		Unconformity?	
		Dominantly lava with much tuff; some breccia, conglomerate, greywacke; andesite, mainly oligoclase, some albite and andesine; basal conglomerate	5,000
	Unconformity		
	King Salmon group	Dominantly argillite and quartzite, with tuff, greywacke, conglomerate, lava, breccia, and limestone; augite-oligoclase (rarely albite) andesite	2,500±
		Dominantly tuff with some greywacke, lava, argillite, conglomerate, breccia, and quartzite; augite-oligoclase (rarely albite) andesite	3,000±

TABLE OF FORMATIONS—*Con.*

Surficial Formations—Con.

Age	Formation, series, or group name	Characteristics	Thickness
			Feet
		Unconformity	
Permian?		**Limestone, in places altered to silica and silicates; some chert**	**500±**
		Unconformity	
Pre-Permian		Quartz-mica-amphibole-chlorite schists, quartzite, argillite, and slate; mainly sedimentary in origin but in part may be volcanic (andesitic?); local highly crystalline schists and gneiss	5,000+

Intrusive Rocks

Late Lower Cretaceous or early Upper Cretaceous	Quartz monzonite
Lower Cretaceous?	Biotite-andesine granodiorite
Upper Jurassic or early Lower Cretaceous	Biotite-oligoclase-andesine granodiorite
Jurassic?	Hornblende-andesine granodiorite

PALÆOZOIC

Rocks here considered as Palæozoic are confined to the near-axial part of the Coast Mountains. At the extreme south edge of the map-area they are limited to a couple of narrow bands lying within 3 miles of the International Boundary, but farther northwest they are found throughout a belt 8 to 10 miles wide.

All these rocks are too greatly deformed for fossils to have been preserved in them, but they so closely resemble similar beds in the Stikine River area (21) both lithologically and in their relations to Mesozoic strata, that the writer makes the correlation with confidence. As in Stikine River area, the group consists of grey, well-bedded, sheared sedimentary, with some interbedded volcanic, rocks capped by a massive limestone that is mainly pure white calcium carbonate. It is considered to be of Permian age, as in Stikine River area. Both above and below, it is in contact with different rock types, and these relationships are believed to indicate unconformities. Unfortunately, the limestone band is not everywhere present between the Palæozoic and Mesozoic strata, and this, partly because of the exploratory character of the work and partly because of the intricacy of the structure, has undoubtedly resulted in imperfect mapping.

More detailed work will undoubtedly show many small anticlinal areas of Palæozoic strata within areas here mapped as Mesozoic, and small synclines of Mesozoic rocks in areas here mapped as Palæozoic.

PRE-PERMIAN

As in Stikine River district, the pre-Permian rocks are mostly schists, alteration products of rather siliceous sediments. The extremely altered products, consisting of gneisses and coarsely crystalline schists, which were found in Stikine River area close to the main axis of the Coast Mountains, are almost absent in Taku River area, and if not destroyed by igneous intrusions must be largely confined to the Alaskan side of the International Boundary.

The original rocks that were converted into the schists were dominantly quartzites and siliceous argillites. Some chert beds are present, but no conglomerate or other coarse sediments. Some limestone and volcanic rock may have formed part of the succession, but without more detailed study it is impossible to know definitely whether these beds are conformable parts of the series or infolded bits of the overlying Permian and Mesozoic formations. Certainly, in many places volcanic beds that seem to be interbedded with the pre-Permian rocks are abundant near contacts with the Mesozoic formations, but may be almost or entirely absent farther away. On the other hand, all the rocks have been so much metamorphosed that schists of igneous origin may be present but not distinguishable as such.

The amount of metamorphism undergone was, of course, dependent on the original character of the rock. Fairly pure quartzites or cherts are not greatly altered as a rule, but softer rocks are completely converted into schists. The common types now found are biotite schists, sericite schists, and hornblende schists. Chlorite schists are not common, and where they do occur appear to represent sheared volcanic rocks, and may include feeders of the Mesozoic flows. The hornblende schists, in part at least, appear to be the result of alteration of calcareous sediments. The schists consist of biotite, sericite, or hornblende with quartz, and with or without feldspar. Magnetite, pyrite, carbonates, and carbon or graphite, are minor constituents. Some schists consist almost entirely of pyriboles—brown hornblende, actinolite or tremolite, and pyroxenes.

Most of the rocks are dark grey, though certain beds such as the purer quartzites and cherts are light grey or even white. Dark quartzites may weather to quite light grey tints. Much of the rock carries pyrite, the weathering of which gives rise to brown iron oxide stains. From a distance, good exposures appear either dark grey or dark brown, a feature that distinguishes them readily from the green tints of the Mesozoic volcanic rocks.

Throughout the pre-Permian strata there is an abundance of silica in the form of veins, irregular masses, or cement for breccia. Gash veins of quartz are found everywhere, some of them of good size; and bedded quartz veins are common. In places chalcedony takes the place of the normal mineral. Some of the quartz veins have evidently formed from mineralizing solutions.

No subdivision of the pre-Permian rocks was found possible, and the absence of both conglomerates and fossils, together with similarities in lithology throughout, make it seem doubtful that any will be possible. The pre-Permian age assigned to them is based entirely on their similarity, in composition and stratigraphic relations, to rocks in the Stikine River area. Their likeness to these, and to others in the Alaskan area (1), suggests that they are probably Carboniferous, with possibly some Devonian and Silurian. At the same time it should be mentioned that similar rocks to the northwest have been assigned by D. D.

Cairnes (3) to the Mount Stevens group of pre-Devonian age, and others by W. E. Cockfield (5) to the Yukon group of questionable Precambrian age.

No accurate estimate of the thickness of these rocks can be made, but the exposed sections indicate that several thousand feet may be represented.

PERMIAN

The rocks here classed as Permian are light grey limestones, grading in places to dark grey, in others to buff. The limestone is, in the main, fairly pure, crystalline calcium carbonate. In a few places soft argillaceous or tuffaceous bands were noted in it, in others the limestone contains bands and irregular masses of chert or quartzite, or is silicified, especially near contacts. On this account the writer considers that the silica has been carried in by solutions passing through the adjacent siliceous sediments.

The limestones form a band that is nowhere more than 500 feet thick, and in places is much thinner or altogether absent. Its usual stratigraphic position is between the pre-Permian and the Mesozoic volcanic rocks, but small synclines of it may be found entirely surrounded by pre-Permian rocks, or small anticlinal masses surrounded by Mesozoic rocks. It is probably more widespread than the map indicates, as it was not mapped much beyond the range of actual observation. The greatest observed exposures are on the west side of Shazah Creek where the limb of a syncline corresponds roughly to the mountain slope, and between Wright and Sittakanay Glaciers. The latter section was not visited, but could be identified from a distance.

The limestone band overlies a variety of pre-Permian rocks. In places these are entirely soft mica schists, in others largely quartzites, quartz schists, or cherty beds. The writer interprets these variations as indicating that the pre-Permian was somewhat folded, and the folds truncated, before the Permian limestone was deposited.

No fossils were found in this formation in Taku River area, but its likeness, in lithology and stratigraphic position, to a similar formation in Stikine River district, whose age is fairly well fixed, justifies its correlation. It is also similar to a group in Dease Lake area (11) and to one in the Alaskan area (1), both of which have been determined as Permian.

The widespread distribution of the limestone, its purity, and the absence of conglomerates or other clastic sediments, suggest deposition in a wide trough bordered by low-lying lands. This trough may have included the Stikine, Taku, and Dease Lake areas, and extended westward throughout much of southern Alaska, and perhaps into southern Yukon. However, the presence of shallow-water faunas in many places would suggest that submergence of this area was not deep.

MESOZOIC

TRIASSIC

In the northeastern part of the map-area the Triassic rocks are separable, on fairly good evidence, into three groups, the lower or King Salmon group, a middle or Stuhini group, and an upper limestone formation, the Honakta formation. The King Salmon and Stuhini groups are largely of volcanic origin, and as both display wide variations along the strike, they are not readily separable lithologically. The King Salmon folds plunge northwest to disappear beneath the Stuhini beds, and the assemblage also thins in this direction as if it had been subjected to erosion before the Stuhini was deposited. If it reappears again to the west, it was not recognized owing to its lithologic resemblance to the Stuhini. Consequently, the rocks mapped as Stuhini in the western part of the map-area must be considered as possibly including some beds of the King Salmon group.

They may also include some volcanic rocks of both pre-Permian and post-Triassic ages. In other words, west of the most westerly outcrops of the King Salmon group all the fine-textured igneous rocks observed have been mapped as Stuhini, and some of them are probably intrusive necks, dykes, or stocks. Some of these, about which there is considerable doubt, are described later in a separate section of this report (page 27).

King Salmon Group

The King Salmon group is exposed in three anticlines in the central part of the map-area. Only the northeastern of these, along Shustahini and King Salmon Valleys, is sufficiently deeply truncated to afford a fairly complete section, but even in it the base is not exposed. The anticlines appear to plunge both southeast and northwest, and hence the King Salmon strata are probably covered by younger rocks in both directions. In a few places, as on Manville and Whitewater Mountains, the basal part of what has been mapped as Stuhini is better bedded than usual in that group, and more careful study may place these beds in the King Salmon group.

In a general way, the stratigraphic succession within the group seems to comprise several hundred feet of basal, massive lavas, with local beds of coarse breccia conglomerates, overlain by some 2,500 feet of volcanic rocks, mainly tuffs and breccias, with an increasing proportion of normal sediments toward the top, and succeeded by 1,500 to 2,500 feet of argillite and quartzite, with much interbedded volcanic material, which in places is largely restricted to bands of moderate thickness. At the extreme top, in several localities, are lenses of light grey limestone, or the beds carry numerous nodules or masses of limestone; and so many pebbles of limestone occur in the basal conglomerate of the overlying Stuhini group as to suggest that the limestone member was once widespread, but was mainly removed by erosion before the Stuhini was laid down.

An outstanding characteristic of the King Salmon group, enabling it to be easily distinguished from the overlying Stuhini beds, is its well-marked banding. Though present throughout the group, it is especially marked in the upper sedimentary part. Black sedimentary bands alternate with grey or brown bands of tuff, lava, or breccia, whose relative hardness as compared with the sedimentary strata emphasizes the effect, for weathering and erosion have worn numerous draws and gullies on the softer beds.

As a whole, the King Salmon group is more rapidly weathered by atmospheric agencies than the surrounding rocks, and hence occupies relatively lower positions.

The lavas of the group, from the few thin sections examined, are mainly oligoclase andesites at the lower horizons, grading upward into albite andesites with an increased content of augite. At the upper horizons augite forms large, black to bottle-green crystals and fragments. These lavas have undergone considerable alteration to the usual secondary products. They are usually dark green, though in places light grey, brown, black, or mottled. Single flows up to 50 feet thick were commonly seen, and massive sections of much greater thickness may also have been single flows. Thick flows near the terminus of Lester Jones Glacier have pillows 1 to 3 feet in diameter; the glacier has gouged out the softer, dark grey cement between the green pillows and left them standing out in relief. Some flows maintain their thickness for considerable distances, others pinch out quickly.

Both flow and explosive breccias are present, but only in moderate amount. Those that carry fragments with the large augite crystals previously mentioned are very striking in appearance. In the upper members of the group, fragments of argillite, quartzite, and limestone may accompany the lava fragments, and the matrix may be almost entirely slaty or sandy. Such beds are really coarse conglomerates. Many of the boulders are well rounded and up to 1 foot in diameter. In the lower horizons of the group the breccias or conglomerates consist almost wholly of volcanic materials.

The most abundant rocks, particularly at the lower horizons, are fine-grained, well-bedded tuffs. They are commonly dark green, though light greys are common, and browns, blacks, reds, and purples are also to be found. They are usually dense, hard, tough rocks, and the beds are mostly thin.

In the upper part of the group, as mentioned, normal clastic sediments predominate. They include argillites, quartzites, and sandstones, with other beds gradational into tuffs and breccias. Most of the beds are dark grey to black, though some of the quartzites have lighter tints. At the uppermost horizons there are nodules and lenses of dark grey to light grey limestone. The argillites and limestones in places contain marine fossils. It is quite possible that these sedimentary beds are merely a local development, and that farther along the strike they may give place to lavas, breccias, and tuffs.

Both the individual sections exposed, and the total thickness of the group, vary greatly from place to place. Some of these differences may be due to irregularities in the depositional surfaces created by the volcanic extrusions. Others are undoubtedly due to the proximity or otherwise of volcanic vents, near which great thicknesses of lavas and tuffs might be expected. Much of the difference is due, however, to erosion before the overlying Stuhini group was deposited. On Jeanne Mountain, for example, the contact between the two groups was observed to cut across some 2,500 feet of the older strata; and the entire absence of the lower group at the lower contact of the Stuhini group in Ericksen Creek Valley suggests that at depth below Jeanne Mountain the whole of the King Salmon group has been eroded away.

The King Salmon group has not anywhere been recognized in contact with the older Palæozoic rocks, but the metamorphism of the latter has been so much greater than that of the King Salmon rocks that it may reasonably be concluded that the two are unconformable.

Four collections of rather poorly preserved fossils were made from the limbs of the northeastern anticline. They have been definitely identified as Triassic in age, and probably Upper Triassic. More careful collecting will have to be done, however, before results of real value are obtained. The fossils include ammonites and other marine forms, indicating that the area was largely covered by the sea, although volcanic peaks may have risen above the surface.

Stuhini Group

The Stuhini group is so called because it is well displayed along Stuhini River. Its distribution is indicated on the accompanying map. Unlike the King Salmon folds, the Stuhini folds have a general plunge to the southeast, so that the rocks underlie wide areas of the eastern part of the map-area but in the west appear as scattered outcrops that occupy the higher peaks and local synclines in the underlying Palæozoic rocks.

In the eastern part of the map-area, the Stuhini group is well bounded by formations stratigraphically above and below it, so that its composition and succession can be determined with confidence, except that in places, perhaps, some remnants of the underlying King Salmon group may have been mapped with it. In the western part of the map-area, where overlying beds were not found, no such confidence exists. It was necessary, in mapping, particularly in this rapid exploratory work, to consider as Stuhini any dark, relatively fine-grained igneous rock that was encountered. Though probably most of them do belong to the Stuhini group, there can be no certainty of this, and in fact some are almost certainly fine-grained intrusive rocks, and others may be lavas interbedded with the pre-Permian sediments. At the end of this section (page 27) some of the more doubtful varieties are discussed.

The base of the Stuhini group in many places, though not invariably, is a coarse conglomerate. Above this is a lower volcanic division, consisting of massive lavas with tuffs almost indistinguishable from them in appearance, because the bedding is not apparent except under unusually favourable conditions. These lavas and tuffs are extraordinarily resistant to erosion, and form the peaks of many of the highest mountains of the map-area. Above them, in turn, is a thick succession of tuffs, breccias, greywackes, and conglomerates, with many lenses of limestone. A fourth division, at the top, includes argillites and sandstone, but its extent within the map-area is limited, and its thickness is only a few hundred feet. It may have been extensively removed by erosion.

The basal conglomerate has been studied in several places. On Jeanne Mountain it is a thick band, containing mainly boulders of lava, a few of sedimentary rocks, and occasionally one with a coarse texture suggesting a plutonic origin. On Manville Mountain, though the conglomerate rests on Palæozoic rocks most of the boulders are lavas, and resemble those of the King Salmon group. On Tulsequah River above the Banker prospect the basal member is a breccia-conglomerate with fragments up to 6 inches in diameter of the underlying Palæozoic quartzites and other sedimentary rocks. On Mount Eaton the basal conglomerate has pebbles of the underlying limestone and other Palæozoic strata as well as rounded and angular volcanic detritus in a soft, sheared, calcareous matrix. Southwest of King Salmon Valley the conglomerate is massive, and made up largely of rocks of the King Salmon group. The same is true at the base of the series on Shustahini Mountain.

The lower volcanic division is made up largely of dark green andesites, though some are grey, black, brown, or purple. Oligoclase, less commonly andesine, is the usual feldspar, though a few rocks that carry albite were encountered. The proportion of feldspar is large, and that of the dark constituents relatively low. Phenocrysts or large fragments of feldspar up to ½ inch in length are abundant in all the rocks, and the groundmasses consist mainly of small feldspar laths. Phenocrysts of pyroxene are rare. In rare instances enough quartz may be present to warrant classifying the rock as a dacite. The presence of orthoclase was determined in only a few specimens. Chlorite is fairly abundant in the groundmass, and magnetite and pyrite are common accessories. Secondary minerals are common, particularly in the western part of the area where much of the rock has been altered to chlorite, epidote, zoisite, sericite, carbonates, and so on. Amygdules are rarely found in these lavas.

Interbedded with the lavas are fine tuffs not readily distinguishable from the flows because of their very massive character and the difficulty of distinguishing bedding except on unusually fresh, clean surfaces. Some coarse breccia, both flow and explosive, is present but not common. In the eastern part of the map-area, however, the proportion of tuffs and breccias is much greater than in the western part.

In the eastern part of the area, as well, much ordinary sedimentary material is admixed with the tuffaceous, so that gradations exist from purely pyroclastic rocks to normal sediments. Thus it is not uncommon to find sandstone-like rocks composed of grains of lava in limy, sandy, or clayey matrices. In addition, some normal shales and sandstones are present, and some small lenses of light grey to dark grey limestone. Two of these, on Honakta Mountain, carry an abundance of fossil corals.

The lower volcanic division ranges in thickness from nil to about 3,000 feet, or possibly more in places. Whether these variations are due to original irregularities in deposition, to the existence of an unconformity between it and the overlying clastic part of the group, or possibly to both causes, is not yet known.

The third division of the Stuhini group consists mainly of well-bedded clastic rocks—greywackes, conglomerates, and breccias—with some interbedded tuffs and limestone lenses. It is best represented in the eastern part of the map-area, especially on Shustahini and Honakta Mountains and Mount Lester Jones. The two divisions, though fairly well defined in some sections are not well marked in others; and it is possible that some of the sedimentary materials described in the last paragraph but one may belong to the third division of the group. On Honakta Mountain the boundary between the two divisions follows approximately the course of Honakta Creek. East of Taku River all the rocks mapped are considered to belong to the sedimentary division, though parts are as massive as the lower volcanic division. On Chuunk Mountain coarse clastic rocks with interbedded limestones are abundant and are included with the sedimentary division. Along King Salmon Valley, above a massive breccia and conglomerate section that is considered to belong to the lower volcanic section, are several thousand feet of bedded greywackes, tuffs, sandstones, and argillites.

West of Taku River the thickness of the sedimentary division probably exceeds 2,000 feet; east of the river it may range from 3,500 to 4,500 feet.

The Stuhini group, as described in the section on the King Salmon group, lies with pronounced unconformity on that group. Its relations to the Palæozoic rocks are undoubtedly unconformable also, but owing to contortion and shearing along the contact the unconformity is not readily established by direct observation. The Palæozoic rocks are, however, much more deformed than the Stuhini rocks.

Three sets of joints cut the Stuhini rocks, one striking north and dipping steeply west, one slightly north of east and nearly vertical, and one nearly horizontal. On the river face of the spur of Mount Jeanne some strange forms resembling buildings 100 feet or more in height are due to breakage along these joints, leaving great vertical flat-topped columns.

Fossils of Upper Triassic age have been collected from limestone beds on Honakta Mountain and from argillites near the mouth of Lester Jones Creek where it joins King Salmon Creek.

Rocks Doubtfully Stuhini

Mainly in the southwestern part of the map-area, various rocks that have been mapped as Stuhini are doubtfully members of this group. Their compositions do not correspond to those of the known Stuhini rocks; many of them have textures more characteristic of intrusive bodies, and still others are more highly metamorphosed than known Stuhini types.

On the mountain southwest of the terminus of Tulsequah Glacier a specimen was taken of a dark green rock of medium grain. Under the microscope it proved to be nearly 58 per cent cordierite with uniform extinction over large areas. Included in it is a large amount of hornblende and lesser quantities of biotite, quartz, diopside, titanite, apatite, magnetite, etc. All the minerals are fresh.

Rock much like this in appearance constitutes almost all the boulders of the high moraines along the southwest side of Tulsequah Glacier, other than those of Palæozoic or granitic rocks. The abundance of such material suggests that it is extensively exposed north of Tulsequah Lake.

At the head of Bacon Creek two general rock types are exposed. One comprises green, grey, and white bands that may have been interbedded volcanic and sedimentary rocks, but are now metamorphosed to schists and gneisses. They may be part of the pre-Permian succession. A second rock was massive and unsheared, and appeared quite fresh. In thin section it showed phenocrysts of acid andesine, in a matrix about 60 per cent plagioclase, 25 per cent hornblende, and 10 per cent biotite. The composition and appearance suggest that it is a hypabyssal rock of post-Triassic age.

In Wilms Creek Valley, near the southern end of the spur of Whitewater Mountain, there is a highly sheared, coarse-textured, dark green rock. It is composed largely of orthoclase, with quartz, muscovite, chlorite, calcite, and other minerals. It may be a sheared granite, but is unlike any other Coast Range intrusive rock and is probably much older.

Many other unusual rocks, some apparently intrusive, others definitely volcanic, were observed southwest of Tulsequah Valley, and to a lesser extent northeast of it. The area would repay more detailed examination.

Honakta Formation

The Honakta formation is mainly a massive, fine-grained limestone, grey to dark brown on fresh surfaces, and weathering light grey to buff. It is cut by stringers of crystalline calcite. In places east of Taku River dark grey to red cherty bands seem to be present at or near the upper part of the formation. The limestone has a cleaner, purer appearance than the limestone bands in the Stuhini group beneath. Locally karst topography is developed on it.

Stratigraphically, the limestone appears between the Stuhini formation below and the Jurassic Takwahoni group above. Its contact with the Stuhini group was not well exposed at any point where crossed, but the thickness of the group below the limestone varies considerably, and the limestone is in contact with various members of the group. Both features suggest an unconformity, a suggestion strengthened by the thickness and purity of the limestone, which indicates that an important change in conditions of deposition took place between Stuhini and Honakta times.

The thickness of the Honakta formation varies greatly. Just west of Taku River it ranges from 200 to 300 feet, but farther northwest it is more than 600 feet thick, and east of Taku River the thickness may be as much as 1,000 feet. Between the Stuhini and Takwahoni groups in King Salmon Valley, however, no limestone was seen, though this may be due to the fact that for a width of 1,000 feet along this contact there are no exposures, so that the Honakta might be present there as a narrow band; but this is not believed to be true, as the limestone was not seen on the hills to the southeast. Likewise, no limestone is present below the Jurassic of Zohini Valley.

The overlying Jurassic conglomerates contain many boulders of limestone, and this, coupled with the wide variations in the thickness of the limestone, is believed to indicate that the Jurassic measures overlie the limestone with erosional unconformity.

Fossils collected in one locality in the limestone were assigned to the Triassic. At another place to the northwest, many large bivalves up to 4 inches in length were noted. Otherwise no fossils of any value were observed.

Correlation of the Triassic Groups

To review, the Triassic rocks of Taku River district consist of the Lower King Salmon volcanic rocks, the Upper King Salmon sediments, the Lower Stuhini volcanic rocks, the Upper Stuhini clastic rocks, with an upper section of finer sediments, and the Honakta limestones.

In the Alaskan area (1, p. 131) a division of volcanic rocks rests on the Permian, and hence may be equivalent to the Lower King Salmon. Another division of volcanic rocks rests unconformably on Upper Triassic sediments. These, therefore, could correspond to the Lower Stuhini and Upper King Salmon groups respectively.

In Stikine River district, though only two groups of Upper Triassic rocks were mapped, five divisions were recognized. These were: (1) a basal series of argillites, quartzites, and tuffs in isolated masses in the east; and a group of dominantly volcanic rocks (2), separated by an unconformity from an overlying group of conglomerates and greywackes (3), overlain, in turn, by clastic sediments (4), and capped by limestones (5). The correspondence between this section and that of Taku River district is remarkable. The lowest beds of the Stikine area correspond to the Upper King Salmon, the next to the Lower Stuhini, the third with the Upper Stuhini, the fourth to the uppermost part of the Upper Stuhini, and the fifth to the Honakta.

JURASSIC

The Jurassic and Lower Cretaceous rocks of the map-area comprise the Takwahoni group of clastic rocks with some limestones and volcanic rocks; the Sinwa formation of, mainly, limestones; the Yonakina group, very like the Takwahoni; and the Inklin group composed mainly of volcanic rocks. The aggregate thickness of this assemblage is great; the components display rapid variations in composition along the strike; the groups are separated from one another by important unconformities; and local unconformities are found within the groups. Though some fossils were found, both the fossil collections and the amount of study it was possible to devote to these rocks in the field were far from adequate. The present classification and subdivision is, therefore, offered merely as a preliminary effort. More detailed examination, and particularly more careful collection of fossils, will be required before the succession can be correctly determined.

The lithography of many of the post-Triassic rocks is practically identical with that of the Triassic rocks, both in hand specimen and even under the microscope. In seeking for criteria by which they can be distinguished with certainty only three were found. Granite pebbles, usually in abundance, are found in the post-Triassic conglomerates, whereas they are very rare in the Triassic conglomerates. Grains of quartz derived both from the disintegration of granites and from the dacites extruded in post-Triassic time are found, often in abundance, in the post-Triassic clastic rocks, but are rare or absent in the Triassic formations. Finally, fossil leaves or carbonized wood are common in the post-Triassic rocks, but were not seen in the Triassic beds.

The conditions that prevailed during the Triassic period seem to have continued during Jurassic and Lower Cretaceous time. The area toward the axis of the Coast Mountains, to the southwest, was undergoing successive uplifts, accompanied by volcanism and possibly by the intrusion of batholiths, while the area to the northeast remained a site of deposition, and was possibly sinking. These conclusions are indicated by the more numerous and greater unconformities to the southwest, which decrease in importance to the northeast; by the greater thicknesses of conglomerate to the southwest; and by the larger proportion of volcanic debris that those conglomerates contain.

The northeastern part of the map-area seems to have experienced some volcanic activity at rather frequent intervals, but no major period of extrusion until Lower Cretaceous (?) time. The minor extrusions were, however, probably merely the marginal phases of the greater extrusions to the southwest.

As the map shows, the Jurassic and lower Cretaceous rocks are found on Niagara Mountain and Zohini Valley; on Tuskwa Mountain, where a small body is completely surrounded by quartz monzonite, north of King Salmon Valley, and west of Tahi Creek on the flanks of Mount Dirome. The following table lists briefly the succession in each of these sections, and the correlations used by the writer.

Correlation Table

Age	Group or formation	Description of sections (measurements in feet)			
		Taku-Nakina-Inklin section	*Zohini Valley section*	*Tuskwa section*	*Taki Valley section*
Lower Cretaceous	Inklin group	Clastic rocks predominate, but considerable amounts of dacitic tuffs also present. Thick beds of limestone and conglomerate. Boulders in conglomerate include quartz diorite for first time. 10,000±	Dacitic lavas mainly, some tuffs.................... 1,300±		
		Dacitic flows and tuffs constitute basal band about 1,000 feet thick. Above this conglomerates, sandstones, and argillites alternate with bands in which volcanic rocks are dominant. . 8,000±	Dacitic tuffs mainly.......................... 800–1,500±		
	Unconformity?				
Jurassic(?)	Yonakina group	Argillites dominant, with subordinate amounts of sandstone and dacitic tuffs. Two thick horizons of coarse conglomerate, one at or near base, the other near top of section.............. 3,000±			
		Dacitic lavas and tuffs dominant, with subordinate amounts of argillite and quartzite........... 4,500±			
		Unconformity			
		Argillites dominant, with much sandstone and a good deal of limestone locally in discontinuous lenses. Andesitic flows and tuffs present throughout, but in small amounts, increasing toward top................. 5,500±			
	Sinwa formation	Limestone exclusively, except for two lenses (?) of non-calcareous sediments and some basal coal and sandstone............... 2,500±			
	Unconformity				

Lower Jurassic	Takwahoni group	Dominant rocks of upper part are argillites, with much sandstone, some limestone, some dacitic lavas and tuffs, and thick lenses of coarse conglomerate. Boulders in conglomerate include both Triassic and Jurassic lavas, andesine granodiorites, and other granitic types. Basal part mainly sandstones and shales, but with rapid and extreme variations in lithology along the strike 5,000±	Southwest limb	Northeast limb	Argillite, quartzite, some small-pebble conglomerate....500± Possible unconformity	Well-bedded rocks only partly examined, but like those in Taku section, with some tuff.................4,000±
			Argillites and fine-grained quartzites...........2,000±			
			Massive basal conglomerate (300–400) overlain by lens of argillite and then by some 3,000 feet of conglomerate like that in Taku section. Minor unconformities	Mainly conglomerate like that in Taku section, with a little interbedded tuff and finer clastic rocks.........2,000±	Mainly conglomerate like that in Taku section............500± Unconformity	Basal part massive conglomerates like those in Taku section.................500±
			Argillite and arenaceous argillite exclusively, in thin lenses at Taku River, thickening to southeast...........1,000	Argillite with some sandstone occurs near Taku River, pinches out to east.....300±	Argillites and quartzites 300–500	
Triassic	Triassic	Limestones overlying upper part of Stuhini group.	Stuhini and King Salmon groups.			Limestone of unknown age unconformably overlying the lower division of the Stuhini group.

Fossils collected from several localities in the Takwahoni group northeast of King Salmon Creek have fixed its age fairly well as upper Lower Jurassic. Fossils determined as probably the same age were collected from the Zohini section, below the top of the conglomerate horizon, and others possibly of Lower Jurassic age from above the conglomerate. These determinations indicate a fairly good correlation between the rocks of Niagara Mountain and those north of King Salmon Creek.

Takwahoni Group

The various local assemblages of rocks here included with the Takwahoni group differ somewhat in lithology, and that in Zohini Valley displays some unconformities, which, though possibly present elsewhere, were not detected. It seems best, therefore, to describe these sections individually.

Takwahoni-King Salmon Section. In this section the succession is most nearly complete. The basal member is extremely variable. Though generally a sandstone, shale or calcareous shale, it may pass within short distances along the strike into conglomerate or into rocks of volcanic origin. As all the rocks appear to have been laid down in the sea such rapid variations are puzzling. If the shore to the southwest was a mountain range the changes from fine- to coarse-grained sediments might be due to proximity to the mouths of rivers; and the changes to volcanic rocks to the proximity of a vent.

Throughout the remainder of the succession the dominant rocks are argillites and sandy argillites with much sandstone. The argillites are thin-bedded, dark grey to brown rocks, and the sandstones are usually brown. Many of them are calcareous. Conglomerate is locally abundant as thick lenses. It carries well-rounded pebbles and boulders, mostly less than 6 inches in diameter, but a few up to 1 foot. The boulders include granitic types in abundance, volcanic rocks similar to those of the underlying Triassic groups, and others resembling the Jurassic lavas. The granitic boulders are mostly andesine granodiorite, though other types are also present.

Besides these principal types, limestones and volcanic rocks are present in smaller quantity. The limestones are mostly impure, dark grey to black varieties, and are largely crystalline. The volcanic rocks are dacites, with much quartz. They include both tuffs and lavas, with tuffs probably in excess. Most of them are green, but some are grey and brown. Their feldspar ranges from oligoclase to andesine; ferromagnesian minerals are mostly hornblende and biotite, rarely pyroxene.

No important unconformities were found within this section, but some of the thick beds of coarse conglomerate may mark intervals of erosion.

The thickness of the section appears to have a wide range. At the head of Takwahoni Valley, which was observed only from a distance, it appears to be 750 feet or less. Four miles down the valley it may exceed 5,000 feet, and is probably about as great east of the Taku. The original thickness may have been much greater, as an unknown amount was eroded before the next series was laid down. Probably this unconformity accounts for the variation in thickness from place to place.

Good collections of marine fossils were made in eight localities. One from the upper half of the section just east of Taku River was dated as Upper Lias by F. H. McLearn of the Geological Survey. Others from lower in the section were dated Lower Jurassic. The fossils included leaves, carbonized wood, and thin lenses of coal from the basal horizons, and ammonites and brachiopods at higher stratigraphic levels. Though the fossils suggest that the whole succession falls into the Lower Jurassic, it should be noted that there are considerable thicknesses of strata, with some conglomerate beds, both above the highest and below the lowest points where marine fossils were obtained.

Tahi Valley Section. At the southeastern end of the Tahi Valley section the Takwahoni series is composed almost entirely of massive, coarse conglomerate. It constitutes the base of the group at this point, lying with a gentle northwest dip on Stuhini and Honakta rocks that strike northwest and dip vertically. The conglomerate is composed of well-rounded boulders up to 6 inches in diameter in a sandy or arkosic matrix. The boulders are mainly of granitic rocks, probably andesine granodiorite, with an abundance of volcanic types.

Looking north to Mount Dirome it can be seen that the conglomeratic basal section has a thickness of some 500 feet and is overlain by brown weathering, bedded rocks with a total thickness, possibly, of more than 4,000 feet. In the southeastern corner of the area a downfaulted block displays some of these overlying beds. They include brown and grey sandstones, in part calcareous, hard arkoses, argillites, and hard green and grey tuffs. Marine fossils were collected, but have not yielded any diagnostic information.

Zohini Valley Section. In this section the rocks classified as Takwahoni fall into at least three distinct divisions, as shown in the table, page 31. The general structure of this section is that of a syncline plunging east-southeast, with its central part overlain by a body of the Inklin group of rocks. The parts northeast and southwest of the Inklin group are termed the northeastern and southwestern limbs of the syncline, respectively. As previously mentioned, the Takwahoni strata in this section overlie the Triassic rocks with marked unconformity. An angular discordance of 30 degrees and more is clearly visible for a distance of more than 2,000 feet.

On the northeast limb of the syncline, the basal member of the series is 100 to 200 feet of well-bedded and hard, black to dark grey argillite and slate, with a little quartzite. To the east this band pinches out. At the west end of the syncline at the foot of Mount Jeanne, the band is again missing, but higher on the slope a lens of it appears. Beyond the bend in the contact it appears again and seems to thicken eastward, as on the two spurs jutting southward, and crossing Morepat Valley, thick bands of similar sediments were seen and are believed to be the same. If so, the band has a thickness there of at least 500 and possibly as much as 1,500 feet. On Mount Jeanne some sandstone, some pebbly rock, and some volcanic materials are interbedded with the argillites. Fossils collected at the base of the cliff on Mount Jeanne, and believed to have come from this band, were determined to be of later Lower Jurassic age.

Above the argillite band is a thick conglomerate division that rests with slight unconformity on the argillite and in places truncates it completely to rest on Triassic rocks. On the northeast limb of the syncline, toward the east end, the conglomerate constitutes almost all of the exposed band of Takwahoni rocks, but toward the west end, where it is underlain by the argillite, most of it was eroded before the Inklin group was deposited on it, so that the thickness there is less than 400 feet. At the west end of the syncline, north of Zohini Creek, the lowest bed of conglomerate is 500 feet or more in thickness, above which lie some 1,500 feet of beds in which conglomerate is dominant.

On the southwest limb of the syncline the lowest bed of conglomerate is 300 to 400 feet thick. It is succeeded by a lens of argillite, and then by more conglomerate. In some places conglomerate beds may be seen cutting across the bedding of finer sediments, and it is thought possible that such relations may indicate minor unconformities within the group. If so, the parts of the group may differ quite widely in age. To the east, on this limb, the thickness of conglomerates appears to be maintained or even increased.

The conglomerates carry an abundance of well-rounded boulders up to 1 foot in diameter. Unlike the conglomerates previously described, however, most of the boulders are the dacitic volcanic rocks characteristic of the Jurassic. Granitic types, such as syenodiorite, oligoclase granodiorite, and andesine granodiorite, are also present, however, and increase proportionately in the higher parts of the group. The conglomerate is hard and well cemented, so that boulders do not weather out readily. The matrix is greywacke in the lower parts, becoming arkosic in the higher beds; and it has a considerable content of volcanic ash throughout.

Above the conglomerates, at the west end of the syncline north of Zohini Creek, appear bands of well-bedded argillites and quartzites, with a considerable amount of tuffs. They constitute the uppermost division of the Takwahoni group in this area, and may have a total thickness of about 1,000 feet. They are all fine-grained, dark grey to black rocks. They do not appear on the northeast limb of the syncline, presumably because removed by erosion before the Inklin group was laid down; but on the southwest limb they appear to have a thickness of about 2,000 feet. Similar beds were found at the top of the Takwahoni series on Mount Headman.

Fossils were found in one place only, in the rocks of the uppermost division in Zohini Valley, but were merely dated as Jurassic.

Tuskwa Mountain Section. The Takwahoni rocks of Tuskwa Mountain are surrounded by quartz monzonite, and appear to be identical with those on the other side of Taku River. The basal division, 300 to 500 feet thick, consists of well-bedded, hard, dark grey argillites and quartzites. Resting on these, and clearly truncating the bedding, is the conglomerate division, which is similar to that on the other side of the river. Unlike it, however, this conglomerate division is only about 500 feet thick. It is made up of conglomerates interbanded with some argillite, quartzite, arkose, and probably some tuff. The uppermost division consists of well-bedded, dark grey argillites and quartzites, with some interbedded tuff and some small-pebble conglomerate. These rocks are much contorted, but appear to be several hundred feet in thickness.

If these rocks are the equivalent of the uppermost division on the east side of the river, as the writer is inclined to believe, then the thinness of the underlying conglomerate division suggests a possible unconformity between it and the uppermost division.

General Considerations. It may be noted: (1) that the conglomerates of the southern areas of Takwahoni group are both thicker and coarser than in the areas farther north; (2) that their content of Jurassic volcanic rocks is larger than farther north; and (3) that local unconformities seem present, but are absent farther north, or at least were not recognized there. As previously mentioned, these facts suggest that farther to the southwest uplift was occurring intermittently accompanied by vigorous erosion and by volcanic extrusions.

Sinwa Formation

The Sinwa formation is, in the main, a fairly pure limestone of a dark brown colour, weathering light grey (*See* Plate VI). The basal beds were seen only in one place, at the creek that crosses the base on Sinwa Mountain. There a massive, brown sandstone is overlain by 1 foot of fine-grained, brown sandstone with several interbeds of coal and chert up to $\frac{1}{4}$ inch thick. The latter is overlain by 3 or 4 feet of partly silicified, massive limestone, which carries much carbon. The limestone above, for 10 feet, is massive and contains some carbon. All these basal beds are considered to belong to the Sinwa formation. Their relation to the Takwahoni beds was hidden.

The overlying limestones, which constitute the bulk of the formation, are as a whole well bedded, though some of the beds are thick. The rock carries some bitumen. In a few places lenses of brown weathering sediments appear to be included, but these were seen only from a distance and their true relations are uncertain. Poorly preserved fossils were noted in a number of places, and two collections, mainly brachiopods, were made, but proved to be of no value in fixing the age.

The band as mapped is 1½ to 2½ miles wide and about 13 miles long. It is known, however, to extend across Tahi Valley to Mount Haney, a distance of more than 6 miles, and can be seen to extend at least 5 miles eastward beyond the area mapped, on a bearing of east 28 degrees south, so that its known length is about 25 miles.

The formation has a thickness of about 2,500 feet at Taku Valley, and may be greater elsewhere. The apparent narrowness of the band at Taku River is due to a steepening of the dip, and to the fact that there is less relief. Much of the widening on Sinwa Mountain is due to the northeast dip. The limestone is more resistant to erosion than the overlying or underlying rocks, so that streams tend to shift down the dip on the upper surface.

On Sinwa Mountain (*See* Plate VI) the underlying Takwahoni rocks appear to be deformed by minor folds, which seem to be truncated by the Sinwa formation. However, as mentioned, no actual contact was seen. At its upper contact, the Sinwa formation seems to grade into the overlying Yonakina group through the appearance of clastic sediments that are interbedded with the limestones, and rapidly increase in proportion to them.

Yonakina Group

Knowledge of the Yonakina group is mainly based on a section across the east end of Yonakina Mountain. Hence, it is not known whether the subdivision about to be described is widespread or local. On that mountain, however, the group appears to fall definitely into three divisions. The lowest of these consists largely of sediments with much limestone; in the middle division volcanic rocks are dominant; and the uppermost division, again, comprises mainly sediments with important amounts of conglomerate.

About 2 miles west of Taku River the basal division of the group extends from Sinwa Creek to the top of the first knob on Yonakina Mountain. The rocks are mainly argillites, many of which are sandy, limy, or tuffaceous. Some sandstone is present, but is usually argillaceous and there are several bands of limestone 5 to 20 feet thick. Some of the limestone is light brown and weathers grey, other parts are black; much of it is sandy or clayey. Some chert is also present.

Near Taku River volcanic rocks outcrop just above the Sinwa limestone, and other bands of volcanic rocks are interbedded with the argillites and limestones higher up. These strike more northerly than the Sinwa-Yonakina contact, and seem to disappear less than 2,000 feet from the river.

East of Taku River, likewise, volcanic rocks are interbedded with argillites, sandstones, and limestones directly above the Sinwa limestone. One broad band of limestone can be seen, on a cliff face on Shana Mountain, to pinch out in a long point. The volcanic rocks include both flows and tuffs, and are mainly dark green. Their relative amount is small. One specimen examined proved to be andesite, with a few small phenocrysts of albite-oligoclase. It is thus less siliceous than most of the Jurassic flows.

The middle division of the group is fairly well displayed on the knobs at the east end of Yonakina Mountain. It is composed dominantly of volcanic rocks of dacitic composition with large phenocrysts or fragments of quartz and oligoclase (An_5). They are dark grey to green, fine-grained rocks. Both lavas and tuffs are present. Some breccias, containing fragments of limestone as well as lava, were also seen. This feature may indicate that the volcanic vent was not far away, and if so this volcanic division may be a purely local development.

The sediments of the middle division, which are present in subordinate amount, are much the same as those in the lowest division.

The upper division of the group consists mainly of argillite, well bedded and dark grey to black, with subordinate amounts of sandstone and volcanic rocks. Well down in the division, however, and possibly basal to it, is a coarse conglomerate with boulders up to 6 inches in diameter. The boulders are of granitic rocks, like those in the Takwahoni conglomerates but more weathered, volcanic rocks, and limestones similar to those of the Sinwa formation. Near the top of the division is another and possibly slightly coarser conglomerate, as a few boulders up to 2 feet in diameter were observed. This conglomerate forms two or more thick beds. Its boulders include granitic rocks, like those of the lower conglomerate, but fresher. Others are of argillites and volcanic rocks, and of limestone that may have been derived from both the Sinwa and Honakta formations.

Few volcanic rocks appear in the uppermost division, and they occur at considerable intervals. They are dacites, with large phenocrysts of quartz and oligoclase (An_{10}). No beds of true limestone were seen, but some of the rocks are calcareous.

General Considerations. The fine-grained, argillitic sediments of the two lower divisions of the Yonakina group indicate more thorough weathering at the sources of the sediments than in Takwahoni or Triassic times. Stable conditions, with deep weathering and not very active erosion, are thus indicated during their period of deposition. The appearance of the lower conglomerate of the upper division must indicate uplift to the southwest, with more rapid erosion, and the well-weathered nature of its granite boulders supports the previous contention that the preceding time was one of quiet, deep weathering. The appearance of possible Sinwa limestones among the boulders suggests that the uplift brought this formation under erosion, and perhaps even parts of the lower divisions of the Yonakina group.

The character of the upper conglomerate indicates still further uplift to the southwest. The very large boulders must have been moved by rapid mountain streams, and the comparative freshness of the granite boulders shows that the weathered materials were now completely removed, and that erosion was very active. The abundance of limestone and argillite detritus also points to rapid erosion of the Sinwa formation, and probably of the lower parts of the Yonakina group. The lower conglomerate, therefore, appears to mark the presence of an unconformity or disconformity, the upper conglomerate probably of another.

The thickness of the three divisions of the Yonakina group, in the section examined, is estimated at about 5,500 feet for the lowest, 4,500 feet for the middle, and 3,000 feet for the upper division.

LOWER CRETACEOUS (?)

Inklin Group

The Inklin group is found in the northeastern corner of the map-area, and in a much smaller area in Zohini Valley. The former area has been studied only by traverses extending some 2 miles or so from Nakina and Inklin Valleys, so that it is imperfectly known. The contact of the group with the Yonakina has not been studied anywhere, and is established entirely on a lithological basis, the change from rocks almost exclusively sedimentary to others dominantly volcanic. The position of the indicated contact west of Nakina River is very uncertain.

In the northeastern area the Inklin group has been broken into two divisions, a lower, about 8,000 feet thick, consisting mainly of volcanic rocks, and an upper, about 10,000 feet thick, in which volcanic and sedimentary types are about equal in amount. No break between the two divisions was found.

The base of the lower division, where studied, comprises about 1,000 feet of tuffs and lavas, with little or no clastic sediment. On these lie some 3,000 feet of strata mainly volcanic in origin, but containing some conglomerate, greywacke, and a little argillite and limestone. Then follows a band nearly 1,500 feet thick, with considerable conglomerate, especially at the base, and the remainder mainly sandstone and argillite. The remaining 2,500 feet comprise, first a band mainly of volcanic rocks, then one largely sedimentary, and finally another band in which volcanic types are dominant. The lower division thus appears to begin with an outbreak of intense volcanism, which was renewed at intervals separated by long periods of comparative quiet and sedimentation.

The basal part of the upper division is about 2,000 feet thick, and consists mainly of sedimentary rocks. Argillites and sandstones with some limestones are followed by a thick band of limestone, and then by more clastic rocks, including much conglomerate. The succeeding 6,000 feet comprise interbedded tuffs, argillites, greywackes, and conglomerates. Structural conditions to the north suggest that above these there may be as much as 2,000 feet more of similar beds.

The conglomerates of the group carry boulders up to 6 or 8 inches in diameter. Boulders of granitic materials and limestone are abundant. Conglomerates near the base of the upper division were seen to carry some boulders of quartz diorite, a type not previously noted. The upper conglomerates also carry many fragments of massive volcanic rocks. Thus the materials of the conglomerates were derived from many horizons and widely distributed points. They suggest that disturbed conditions prevailed over wide areas, and probably that successive uplifts occurred to the southwest.

The volcanic rocks are all dacitic in composition. Quartz is abundant, feldspar ranges in composition from albite to oligoclase, and diopside or hornblende is usually present in large grains. Fine-grained, bedded tuffs predominate, but coarser types with sandy or breccia textures are also fairly common. Limestone fragments or nodules are abundant in some of the latter types. Colours are mostly green, but some are grey.

Limestones are most abundant above the base of the upper division. They range from fairly light grey to black, and many are argillaceous. One band about 200 feet wide was noted. No fossils were found in them.

In the Zohini section all the rocks are volcanic. At the base are 800 to 1,500 feet of well-bedded volcanic rocks, on which rest some 1,300 feet of massive types. Both the considerable range in the thickness of the lower division, and the fact that the bedding of the upper part appears, in places, oblique to that of the lower, support the conclusion that a vent was probably nearby, or else that the two divisions are separated by an unconformity. The group definitely overlies the Takwahoni rocks with marked unconformity, though actual discordances of attitude, where observed, are slight.

The lower division of the Zohini section is composed predominantly of tuffs, the upper division probably largely lavas. All the rocks are the dacitic types previously described, though one contained enough orthoclase to warrant its classification as a rhyodacite.

No fossils were found in the Inklin group, and those obtained from the underlying Jurassic (?) strata were in general so unsatisfactory as to make reliable correlation with other districts impossible. Correlation on a basis of lithology alone is even more impracticable, by reason of the rapid variations along strike, even within the map-area.

UPPER CRETACEOUS (?)[1]

On the tops of Mount Dirome and Mount Haney there were observed from a distance gently dipping beds that truncate the underlying Jurassic and Lower Cretaceous (?) rocks with marked unconformity. Whereas the pre-Upper Cretaceous formations are everywhere considerably folded, and even vertical dips not uncommon, these rocks have dips that rarely exceed 30 degrees. Other peaks to the north and northeast of Mount Haney appear to be capped by similar relatively flat beds. The relations here to those in Stikine River district, where gently folded Upper Cretaceous rocks rest on more highly deformed older beds, are so similar as to suggest that these slightly deformed beds are probably also of Upper Cretaceous age.

On Mount Dirome, about 100 feet below the southern knob, nearly horizontal, light grey beds suggest the sandstone or well-washed conglomerate of the Stikine Upper Cretaceous. Above these are massive, dark brownish grey rocks that may be conglomerate or, less probably, lavas. The total thickness is about 1,000 feet.

On Mount Haney are several clearly defined massive bands of dark brown rock that thin gradually and are almost certainly lava flows. Between them are lighter coloured bands that may be sandstone, tuff, or conglomerate. Angling across the series are dark brown bands that are undoubtedly dykes. In the upper part of the series the beds are thinner, and the dark brown bands more numerous. The entire section is 1,500 to 2,000 feet thick. On the westerly peak, the top 500 feet or so is more massive and resembles the rock on Mount Dirome. Thus the lower beds on Mount Haney may be absent on Mount Dirome.

These relations, coupled with those observed in the Stikine River area, indicate that important deformation occurred at the close of Lower Cretaceous (?) time, and was followed by long-continued erosion and approximate peneplanation. In Upper Cretaceous time there must have been further upwarp of the Coast Mountains area, the resulting active erosion giving rise to the Upper Cretaceous sediments along the northeast flank. Obviously, too, the upwarp was accompanied by volcanism.

CENOZOIC

QUATERNARY GLACIATION

In northern British Columbia, a glacial epoch was presumably initiated with alpine glaciation, such as exists at present, and proceeded, as ice accumulated, to what may be termed an intense alpine stage, then to the mountain

[1] Not shown on accompanying map.

ice-sheet stage, and finally to a continental ice-sheet stage. At the close of the epoch, when the ice began to waste away, these stages would be repeated but in reverse order. If more than one glacial epoch occurred, all the stages would be repeated.

During the alpine stage, as at present, glaciers are largely confined to the valleys, and their movement follows the direction of the drainage, down the valleys. In the intense alpine stage, after much more ice has accumulated, all the valleys are completely blocked by ice, and movement is outward from somé more or less central divide. In some places, therefore, as in upper Taku Valley, movement in this stage would be in the opposite direction to what it was in the alpine stage. In the mountain ice-sheet stage the Coast and Cassiar Mountains were completely covered by ice-sheets that moved away from the axis of each, in northeast and southwest directions. In the continental ice-sheet stage northern British Columbia was completely covered with ice, and from its centre in the high area between the Stikine, Taku, Yukon, and Liard drainage systems movement was outward in all directions, though controlled to some extent by the underlying topography. This simplest type of sequence may have been complicated in many ways, as for instance by repeated alternations of two or more stages.

In the continental ice-sheet stage, ice must have moved westward across Taku area to the Pacific. No good evidence of such movement was found, however, as was the case in the Stikine River area, although the mountains appear to have been completely submerged by ice as far up as observations were made, about 7,000 feet, and some topographic features suggest a westward movement. Such movement was probably not great, however, partly because Taku River district is relatively near the great outlet to the north, over the Teslin-Atlin Plateau, and partly because such a movement would be opposed, except in maximum stages, by the normal tendency to movement away from the axis of the Coast Mountains, which is near the coast.

In the mountain ice-sheet stage, movement in Taku River district would be northeastward, away from the main axis of the Coast Mountains. Evidence of such movement is conclusive. The topographic forms of many higher mountains in the northeastern part of the range strongly suggest that they have been completely overriden by ice-sheets moving northeast. High on the mountains in the northeastern part of the area there are numerous boulders, up to 10 feet in diameter, of rocks found only in the central part of these mountains, boulders that must have been carried there by a northeastward-moving sheet of ice thick enough to cover the intervening mountains.

Certain features such as the size and character of Nakina Valley and of other valleys beyond the limits of the map-area imply that they were carved by northeastward moving ice. As the glaciers of the next stage are not believed to have extended much beyond the Inklin-Nakina junction, it seems best to relate these features to the mountain ice-sheet stage.

During intense alpine stages all the valleys of the Coast Mountains were completely blocked by ice, and movement in them was outward from some more or less central divide. On Taku River, the divide is supposed to have been between Red Cap Creek and Tulsequah River, though it may have shifted back and forth in this section. The peculiar form of this part of Taku Valley is believed due to this relation.

From this central divide, whether correctly located by the writer or not, ice must have flowed *up* Taku Valley to a point where the glaciers disappeared by wastage. That it did so is indicated by abundant evidence. Not only is there much drift from the Coast Mountains in the upper part of the valley, but various topographic details around the confluence of Nakina and Inklin Rivers so indicate. The valley of the Inklin, for some 3 miles from its mouth, has a typical U-shape and is much wider than above. As no glacier flowed *down* Inklin Valley, these topographic features must have been formed by ice pushing up from the main Taku Valley. Further, the northeast walls of both Nakina and Inklin Valleys, in this neighbourhood, are very steep and smooth as compared with the opposite sides; and the valley spurs of tributaries entering these streams are deeply eroded and well rounded on the upstream side, much less so on the downstream side. Such features, the writer contends, could have been formed only by glaciers moving up the valleys.

It is interesting to note that at least one example of such movement can still be seen. Some 50 miles southeast of the map-area Sawyer Glacier bifurcates, part moving out to Tracey Arm while part moves up the valley to enter the valley of the south branch of Whiting River.

The wide flat at the mouth of King Salmon Creek was probably formed, in the writer's opinion, by the efforts of Taku Valley glacier to branch here and push up King Salmon Valley. Once formed, this flat and that in Taku Valley just north of it would permit a glacier coming up Taku Valley to spread out, with consequent loss of forward motion. The writer believes that during many periods of advance the ice may not have gone farther up the valley than this flat; and that the decreased width of Taku Valley above the wide flat area is thus explained.

The blocking of Taku Valley by a glacier would pond the drainage above, forming lakes; and though it is possible that channels beneath the ice may have been formed at intervals and have permitted the water to escape, at other times there appears to have been flooding extensive enough to force the water to escape through the large valleys that trend northwest into the Yukon. The great development of terraces in Taku and Nakina Valleys above King Salmon Creek is attributed to such ponding.

That valley glaciers, even at times of most intense glaciation, did not extend up Nakina Valley beyond the mouth of Sloko River, is indicated by the observations of C. W. Hayes (8). He found the upper valleys of the Nakina filled with drift containing numerous boulders of a peculiar granite containing large porphyritic crystals of black hornblende. The source of this rock, he found, was in a range of hills about halfway between the head of navigation on the Nakina and Teslin Valley. Ice movement in this district must, therefore, have been northwest, and it is probable that there may have been some overflow into upper Nakina Valley.

The alpine stage of glaciation is represented by present conditions, in which ice-fields occupy the higher parts of the higher ranges, and glaciers from them flow down the valleys, following for the most part the direction of normal drainage.

QUATERNARY DEPOSITS

All Quaternary deposits of the map-area are unconsolidated. They include materials of marine, glacial, fluvial, lacustrine, and volcanic origin, together with talus and landslide deposits. The greatest deposits are those filling the valleys of the main rivers.

At the close of the Glacial period the land surface stood several hundred feet lower than at present, relative to sea-level, as indicated by the presence of beds containing marine shells beneath the present end of Tulsequah Glacier. The sea must then have extended up Taku Valley to or above the confluence of Nakina and Inklin Rivers; and the lower ends of the Tulsequah and other large tributary valleys would be well below sea-level. In these estuaries the rivers must have at once begun building deltas, so that the bottoms of all these streams are undoubtedly filled with marine delta deposits. As the land rose and brought the surfaces of the deltas above water, the rivers probably removed some of the accumulated deltaic material and laid down fluviatile deposits, mainly sands and gravels, upon the parts left. Delta building, of course, continued in the parts below sea-level, and is still rapidly going on in Taku Inlet.

These processes were interrupted at least once, possibly more than once, by advances of the valley glaciers. These glaciers seem to have overridden the frozen deposits below without greatly eroding them, and formed their own moraines, so that some morainal material is undoubtedly interbedded with the marine and fluviatile beds.

Lakes formed in places. Some of them, such as Tulsequah Lake, resulted from the ponding of water behind glaciers, others, like the lake in front of Twin Glacier, at the head of Taku Inlet, were formed by the extension of the delta in such a way as to impound a body of water. Still another type seems to be now in process of formation at the mouth of Shazah Creek, where the Tulsequah is aggrading its bed so rapidly as to dam the creek at its mouth. In all such lakes deposits have formed or are forming.

The writer estimates that the rock base of Taku Valley is at least 200 feet below the present surface at Inklin, and at least 600 feet near the mouth of the river. As the valley is wide, the amounts of unconsolidated materials it must contain are very large.

Marine Deposits. No deposits definitely determinable as marine have been observed within the map-area, but in 1930, below the foot of Tulsequah Glacier, piles of mud and sand containing marine fossils were found. It was concluded that these materials had been carried out from beneath the glacier, as frozen lumps, by the flood of 1929. The conclusion was confirmed when it was found that the flood of 1932 had brought out lumps of similar material, still frozen. In 1932 the depth to which the frozen gravels and muds were cut into by the flood was measured, and determined to be 15 to 20 feet. Presumably, therefore, the marine deposits lie within this distance below the present under surface of the glacier. The material containing the marine fossils is mud and fine sand, such as could be formed in a delta deposit. It differs sharply from the coarse sands and gravels laid down above it by the river.

The fossils collected from the muds were referred to C. H. Crickmay, who identified them as follows:

FORAMINIFERA

Polystomella umbilicatula Williamson

PELECYPODA

Leda fossa var. *sculpta* Dall
Yoldia thraciaeformis Storer
Macoma calcarea Gmelin

Crickmay further states, "This assemblage is, of course, strictly marine, and of cold water aspect, i.e., Aleutian. The foraminifer is a living North Atlantic species. The pelecypods are common today on the southern Alaskan coast, which is roughly the centre of their geographic range. The fauna is, no doubt, fairly recent."

Certain other deposits of the area may be marine. They include terraces of fairly fine-grained materials that lie 450 to 500 feet above sea-level, to the northwest of Tulsequah. They appear to be well bedded and to dip down Taku River, as delta beds formed in that valley would do. Somewhat similar benches were seen in Tulsequah Valley between 300 and 600 feet above sea-level. Below Wright Glacier in Alaska there are benches 100 to 300 feet above sea-level, which may be marine beaches.

Fluvial Deposits. Fluvial deposits are forming in the valleys of the main rivers. Streams from beneath the glaciers carry out great loads, most of which are dropped as soon as the streams have a chance to spread out. In many places such deposits are built up many feet above the foot of the glacier. Tributaries, on account of their steep gradients, carry down great amounts of debris, which are dumped as alluvial fans in the main valleys. That these processes are actually resulting in a general aggradation of the beds of the main streams is evident in many places. Above Yellow Bluff, for instance, river level during much of the summer is now well above flats clothed with fairly old trees. These have been killed, and accumulation of sand and silt around them is proceeding fairly rapidly. That similar processes have been active for some time is evident wherever new channels are cut in the river flats. There it can be seen that layers of vegetation are interbedded with the sands and gravels.

Lake Deposits. Although no large deposits of lacustrine origin have been recognized within the map-area, several small ones were found. On Nakina River lake clays are exposed for long distances, below considerable thicknesses of gravel. On King Salmon Creek, 800 feet above the limestone bluff, 8 to 10 feet of bedded clay with no pebbles was noted. The extensive terraces along the upper valleys to the northeast, and fine materials over wide areas higher up, undoubtedly were formed in lakes. It is believed that at times very large lakes existed in front of the ice barrier to the southwest, and had their outlet to the north into the drainage basin of the Yukon.

Glacial Deposits. Glacial drift is found in all sections of the map-area, in varying thicknesses. Moraines occur along the walls and less commonly in the bases of practically all valleys. Extensive terraces along the Upper Taku and its tributaries were formed by the last intense alpine stage. Deposits of the mountain ice-sheet stage are widely scattered over the mountainous area in the northeast.

Present-day valley glaciers were observed merely to ride over the frozen unconsolidated materials below as if they were solid rock, without either building up or eroding their beds to any great extent. Their main deposits are, therefore, their terminal moraines and outwash plains.

Talus and Landslide Deposits. These are of considerable size in Taku River area, on account of the many steep slopes. Along the main valleys, in places, talus extends up the slopes for more than 2,500 feet. Many talus heaps must have thicknesses of several hundred feet. Similarly, there are large deposits due to landslides and snowslides.

Tufa. On the southwest side of King Salmon Valley, at the base of the mountain west of King Salmon Mountain, there are thick and extensive beds of calcareous tufa. They have been formed by a large number of springs, and extend for some distance along the mountain side. Moss grows upon the tufa and is encrusted by it.

INTRUSIVE ROCKS

In Stikine district the batholithic rocks of the Coast Mountains were found to include some nine more or less distinct types ranging in age from early Triassic to late Lower Cretaceous or early Upper Cretaceous, and in composition from diorite to quartz monzonite. In Taku district the intrusive bodies are much fewer, and none of Triassic age was recognized. However, boulders of intrusive rocks similar in composition to those of the Triassic intrusion of Stikine district are numerous in the various Jurassic conglomerates; hence it is possible either that such intrusions once existed in Taku River district but have now been completely removed by erosion, or that they formerly were present on the Alaskan side of the International Boundary, and have been destroyed by the intrusion of younger batholiths. The intrusive rocks appearing actually within Taku map-area are biotite-oligoclase-andesine granodiorite and hornblende-andesine granodiorite along the main axis of the Coast Mountains, masses of quartz monzonite that lie northeast of that axis, and a small body of biotite-andesine granodiorite and a small mass of diorite, both on Mount Lester Jones. Besides these, there are dykes of granodiorite and feldspar porphyry.

GRANITIC BOULDERS IN JURASSIC CONGLOMERATES

In the conglomerates of the Takwahoni group granitic boulders are abundant, and as no such boulders are present in the Triassic conglomerates it seems reasonable to conclude that they originate from batholiths just unroofed. Their likeness to Triassic batholithic rocks in the Stikine River area strongly suggests a Triassic age for them also.

Three rock types have been found, which may be termed oligoclase syenodiorite, oligoclase granodiorite, and andesine granodiorite. However, a rather wide variation in composition exists within each group, so that the separation is perhaps somewhat arbitrary, and a different classification of many specimens might be made.

All the specimens of oligoclase syenodiorite were gathered from the Takwahoni conglomerates of Zohini Valley. They are light grey to chalky in colour, medium textured, and fairly uniformly peppered with dark constituents. In most of them oligoclase (An_{13}) is the most abundant mineral, with much potash feldspar ranging up to 40 per cent in some specimens. No quartz is present, and dark minerals are chiefly hornblende, up to 10 per cent, with some pyroxene, biotite, and apatite. Considerable alteration to secondary minerals has taken place. No rock much resembling this was found in the Stikine areas.

Boulders of oligoclase granodiorite are widely distributed throughout all the conglomerates of the group, and probably in some younger ones. The rock ranges in grain from medium to very coarse. Acid plagioclase (An_{15}) forms 44 to 67 per cent; orthoclase 7 to 36 per cent, with an average of 15 to 18 per cent; quartz 9 to 20 per cent, though a single specimen showed 42 per cent; hornblende 2 to 12 per cent; altered biotite up to 4 per cent; and titanite and apatite are the common accessory minerals.

This rock is very similar in composition to the older oligoclase granodiorite of the Stikine River area. Its average composition is: oligoclase, 62 per cent; orthoclase, 11 per cent; quartz, 17 per cent; hornblende, 8 per cent; and biotite, 2 per cent.

Boulders of andesine granodiorite are also widely distributed in the conglomerates. The grain is coarser than in the two preceding groups, and the rock on the whole is remarkably fresh. In it plagioclase (An_{32}) ranges from 33 to 55 per cent; orthoclase, 7 to 43 per cent, averaging 27 per cent; quartz 8 to 28 per cent, averaging near the higher figure; biotite, rare to 7 per cent and averaging 2 per cent; and titanite, augite, magnetite, and apatite occur in minor quantities.

The writer suggests a correlation of this rock with the older hornblende-andesine granodiorite of the Stikine River area. Its average composition is: andesine, 60 per cent; orthoclase, 13 per cent; quartz, 17 per cent; hornblende, 8 per cent; and biotite, 2 per cent.

Boulders of the oligoclase and andesine granodiorites are also present in the Yonakina conglomerates.

GRANODIORITES INFERRED FROM MORAINIC DEBRIS

On Tulsequah and Bacon Glaciers there are fragments of schist with grey phenocrysts up to $1\frac{1}{2}$ inches in diameter, and apparently rounded by the shearing. This rock bears a marked resemblance to schists west of Chutine Lake, in Stikine River area, which are believed to be highly sheared varieties of the older hornblende granodiorite, of Triassic age. Further, the moraines contain unsheared blocks very similar to the unsheared parts of the Chutine Lake rocks. They are medium grained, with fairly large, grey to purple, phenocryst-like masses of orthoclase. Possibly, therefore, one or more masses of the older hornblende granodiorite are present in the upper Tulsequah drainage basin.

On Tulsequah Glacier there are also blocks of diorite and quartz diorite, some of which contain inclusions in all stages of assimilation. They bear some likeness to the quartz diorite of Stikine River area.

HORNBLENDE-ANDESINE GRANODIORITE

Hornblende-andesine granodiorite is believed to form two masses, one east and south of Tulsequah Lake, the other on Mount Strong and extending north to the head of Bacon Creek. However, these bodies have been incompletely studied, owing to difficulties of access, and it is, therefore, not improbable that other types may be represented in these areas. The presence, in moraines, of boulders of other types, as mentioned later, suggests that somewhere in this axial area such types must outcrop.

The hornblende-andesine granodiorite is a medium grey, massive rock of medium grain, with hornblende phenocrysts up to $\frac{1}{2}$ inch in length. The grain is usually maintained nearly to contacts with older rocks, where a chilled edge, generally less than 2 feet wide, is found. The composition is fairly uniform, and the constituents quite fresh, although, locally, weathering or other alteration has given rise to the usual decomposition products. The rock is fractured along several directions, leaving it slightly less massive in appearance than the biotite-oligoclase-andesine granodiorite next to be described. The areas underlain by it support little vegetation.

Eight specimens of the rock, examined under the microscope, gave the following results:

Mineral	Average Per cent	Range Per cent
Quartz	24	10–40
Orthoclase	9	0–15
Andesine	54	42–68
Hornblende	7	1–15
Biotite	5	1–9

The more important accessories are magnetite, titanite, and apatite. The andesine is strongly zoned, with cores An_{35-45} and rims An_{15}. Commonly many more or less calcic zones alternate.

In various places, as for instance near the contact northwest of Tulsequah Lake, darker types, both finer and coarser in grain than the normal rock, were observed. In part their contacts with the normal rock are sharp, in part gradational. They are thought to be earlier crystallization products of the same magma, possibly contaminated by dissolved country rock, here basic volcanic material. A single specimen, examined under the microscope, carried less quartz and orthoclase, and more andesine and basic constituents, than the normal rock.

The contacts of the batholithic masses are sharp, well defined, and gently curving. Few dykes run off from them, and those that do are mostly short. Inclusions of country rock are present almost everywhere, and in places abundant. Most of them are only a few inches in diameter, and appear to consist of volcanic, sedimentary, or intrusive material in various stages of assimilation. Pegmatite veins are rare, and those observed are small. They carry much pyrite in places, and seem to pass into thin veins of quartz and pyrite, or pyrite alone. The granodiorite itself carries considerable pyrite, and the older rocks close to contacts are in many places impregnated with pyrite. No evidence of differentiation was noted, even throughout the vertical range of several thousand feet; and there has been little metamorphic effect on the intruded rocks.

The northern mass has been barely unroofed, and its upper slopes have dips of only 20 to 35 degrees outward. The southern mass is more deeply cut, and its walls dip outward at about 45 degrees.

The batholiths are cut by two systems of joints. One set strikes north 45 to 70 degrees west and dips 50 degrees southwest to vertical. The strike of the other set is north 25 to 50 degrees east, the dip 60 to 70 degrees northwest. Considerable movement has taken place along the joints in some localities.

The hornblende-andesine granodiorite cuts Palæozoic rocks, and volcanic rocks here supposed to be Upper Triassic. It has considerable similarity to the younger hornblende-andesine granodiorite of the Stikine River area, which was dated tentatively as Jurassic. For these reasons it is here considered as probably Jurassic.

Though there is little direct evidence of this rock having had any mineralizing effect, beyond impregnating some contact zones with pyrite, the occurrence of various mineral deposits not too far from its contacts suggests a possible genetic relationship.

BIOTITE-OLIGOCLASE-ANDESINE GRANODIORITE

Biotite-oligoclase-andesine granodiorite forms a single mass to the southwest of Tulsequah Lake. Owing to difficulties of access it was not visited, and its distribution as mapped is the result of aeroplane observation.

This granodiorite is lighter grey than the hornblende-andesine granodiorite and is less jointed and hence more massive in appearance. It has sharp, well-defined contacts, and appears to cut the other. From aeroplane observation it seems to extend southward as far as Taku River at Devighne Point, 12 miles below the International Boundary; and a specimen taken there had the composition, oligoclase-andesine (An_{15-30}), 29 per cent; orthoclase, 18 per cent quartz, 50 per cent; and biotite, 3 per cent. The texture was coarse and granitic. The rock has a marked resemblance to the youngest biotite granodiorite of the Stikine River area, and is tentatively correlated with it, as probably Upper Jurassic or early Lower Cretaceous.

BIOTITE-ANDESINE GRANODIORITE

Biotite-andesine granodiorite forms a small mass in the valley of Red Cap Creek, west of the peak of Mount Lester Jones. Its boundaries as mapped are probably not accurate, as both the intrusive and the surrounding volcanic rocks are much rusted.

Where not rusted, the granodiorite is light grey and badly fractured, so that it does not present a massive appearance. It is medium to fine in grain, and locally carries phenocryst-like masses of orthoclase, or large crystals of hornblende. Contact phases are very fine in grain, and may carry phenocrysts of plagioclase and quartz, or biotite in long hexagonal prisms. Locally the rock is sheared and altered, but in the main it is fresh.

Thin sections show that it is made up of 15 to 35 per cent quartz, 15 to 25 per cent orthoclase, less than 50 per cent andesine (An_{20-35}), 3 to 9 per cent biotite, and 0 to 4 per cent hornblende.

Contacts are very irregular in most places, with many small dykes and sills up to a foot in width extending into the country rocks. The outer contacts appear to dip from 45 degrees to nearly vertical.

The marginal parts of the intrusion are impregnated with pyrite, and the surrounding volcanic rocks, for considerable distances, are similarly impregnated and otherwise altered. Mineral deposits are present in places, and there can be little doubt of the association of the granodiorite with the mineralization.

The intrusive mass cuts Jurassic rocks, and is considered also to be younger than the Inklin group of probable Lower Cretaceous age. If the latter assumption is correct, its age is probably Lower Cretaceous.

AUGITE-HORNBLENDE-BIOTITE-ANDESINE GRANODIORITE

The occurrence of a body of granodiorite at the crest of Mount Lester Jones was inferred from the observed presence of large numbers of boulders carried down by the ice and other agencies.

The granodiorite is a very fresh, massive rock, light grey to dark grey in colour, and of moderately coarse grain, though some fine-grained boulders were seen. Five thin sections showed it to consist dominantly of basic andesine, with rarely more than 5 per cent each of orthoclase and quartz. Ferromagnesian minerals average about 30 per cent. They include augite, hornblende, and biotite. In some specimens augite is the most abundant, even to the exclusion of hornblende; in others the opposite is true. Ilmenite is accessory.

Toward the eastern end of the body the boulders are impregnated with pyrite, and cut by stringers of it. The nearby volcanic rocks are similarly affected.

QUARTZ MONZONITE

The quartz monzonite masses of the map-area, the positions of which are shown on the accompanying map, are the most northerly representatives of a group of rocks that has been traced from Stikine River to Shazah Creek, a distance of more than 120 miles. For this distance the masses lie within a belt 15 to 25 miles wide that parallels the trend of the Coast Range. Most of them also lie to the northeast of the discontinuous trough that separates the main axial part of the range from the more or less subsidiary groups of mountains northeast of it. Besides the main masses outlined on the map there are many dykes that could not be mapped in the time available, though one of the largest, on Mount Ericksen, has been shown. The dykes north of Shazah Creek are believed to be of quartz monzonite.

The quartz monzonite is for the most part a coarse-grained granitic rock with a characteristic light yellow-brown to flesh colour that makes it easily identifiable even at distances of many miles. In many places it is decidedly massive, standing in the higher sections in magnificent angular peaks and ridges flanked with steep to vertical walls. At lower elevations it may present great rounded forms well preserved since glaciation. Usually it displays a well-developed, regular and angular topography because of its well-defined jointing. Higher slopes that are free of snow for considerable periods may show dark grey tints, due to the growth of moss.

The composition of the quartz monzonite is fairly uniform. Biotite averages about 5 per cent of the total, with a range of 2 to 6 per cent; and the other three main constituents, quartz, orthoclase, and plagioclase (An_{15-20}), are present in nearly equal proportions, ranging rarely more than 5 per cent above or below the average. Hornblende averages 1 per cent, though as much as 3 per cent was found in one specimen. Apatite, titanite, and magnetite are the most common accessories.

In the large masses the grain is equigranular and very coarse, up to $\frac{1}{5}$ inch. Near contacts, however, and in dykes, the texture is commonly porphyritic, with a fine- or moderately fine-grained groundmass. Any of the three principal minerals may form phenocrysts, but most of them are of plagioclase. Phenocrysts disappear, however, in chilled, very fine-grained contacts; hence it is clear that they developed after intrusion and not in the magma chamber beneath. Thin sections display some very interesting irregular intergrowths of quartz and orthoclase, or of orthoclase and plagioclase; in some dyke materials intergrowths of two kinds of plagioclase were also observed.

Contacts are well displayed on the mountain slopes, throughout vertical distances up to 7,000 feet. For the most part they are smoothly sinuous, though in places angular and serrate. Offshoots are rather rare, though in one place, at a contact of the southern mass, the older rocks are greatly shattered for a distance of some 2,000 feet from the main mass of monzonite, and the fractures filled with intrusive material.

Besides the great dyke crossing Mount Ericksen, dykes are numerous on Mount Stapler and near Shazah Creek. Many of them are less than 10 feet wide and can be traced a mile or more, thus suggesting that the magma, when introduced, was very mobile and probably under great pressure. In one specimen large quartz grains appear to have been fractured and re-cemented with orthoclase, as if there had been movement during crystallization.

Although inclusions can be seen almost everywhere, most of them are less than 2 inches in diameter. They appear to consist of partly assimilated volcanic or sedimentary materials.

The walls of the quartz monzonite masses dip steeply, from vertical to 45 degrees outward, though the average dip is probably nearer the higher figure. In places, even inward dips have been observed, but are probably of limited extent. The northeast wall of the Tuskwa Mountain mass maintains a nearly vertical dip throughout a vertical range of about 6,000 feet.

The quartz monzonite masses truncate the structures of the rocks they intrude in an extraordinary manner, as if punched through without otherwise disturbing them. They cut through synclines as readily as anticlines, so that in places through vertical distances of 6,000 feet dips are inward toward the intrusive mass. Strikes and dips may trend at any angle to the contact. In other places the intrusion has entered an anticline, and dips are away from it. It is, however, clearly apparent that the various structures were developed before the masses were injected, and that little or no upbowing was caused by the intrusion.

The quartz monzonite metamorphosed the older rocks very slightly. Contacts are everywhere sharp and clean, with no evidence of assimilation. Limestones may have been rendered somewhat more highly crystalline; and it is possible that at some contacts silicate minerals were developed as in the Stikine district, but none was actually seen.

The masses maintain a very uniform composition throughout a great vertical range, with no evidence of gravitative or other differentiation. Even pegmatites are extremely scarce. It would seem, therefore, that once the magmas attained their present positions crystallization must have been very rapid. Correspondingly, almost no mineralization is attributable to the intrusions. The only place where any evidence of mineralizing processes was seen was near the southern contact of the large southern mass. There the volcanic rocks are slightly altered, and carry a little pyrite.

The quartz monzonite is cut by two systems of fairly widely spaced, nearly straight joints that can be traced for several thousand feet. One system trends nearly north, with near-vertical dips; the other strikes northeast and has southeast dips of about 65 degrees.

In a few places faults were noted; in some others the rock has been sheared.

There is little evidence in Taku River district to date the time of intrusion, as the youngest rocks cut by the monzonite are Jurassic. Evidence obtained in the Stikine and Whiting River districts, however, justify placing it as late Lower or early Upper Cretaceous.

OTHER INTRUSIVE ROCKS

Mount Jeanne Dykes. High on Mount Jeanne are several light grey, granitic dykes, and in the valley on the northeast side there is much light grey, medium- to fine-grained, granitic debris. These probably indicate the presence, near the crest, of a small intrusive mass. The volcanic rocks of the neighbourhood are much altered and very rusty, and mineral deposits have been reported.

Feldspar Porphyry Sills. Several dykes or sills of oligoclase porphyry occur along the central part of the Shustahini-King Salmon anticline. The positions of the larger of these, one of which is more than 500 feet wide, have been indicated on the map, though the shorter ones shown may be considerably longer. Smaller dykes are also present in this area on the north slope of Mount Lester Jones and elsewhere. Northwest of the area contoured a sill follows the western contact of the King Salmon and Stuhini groups. These intrusions for the most part follow contacts between groups of sedimentary and volcanic rocks, but where the structure is complicated by minor folds they cut across the bedding.

On fresh surfaces the porphyry is grey, but weathered surfaces are generally buff or brown, due to rust, and may be pitted by the weathering out of large pyrite crystals. The rock carries phenocrysts of oligoclase (An_{13}) up to $\frac{1}{4}$ inch or even larger, in a fine, granular groundmass consisting mainly of oligoclase with some quartz and a little magnetite and pyrite. A few, small and scattered phenocrysts of quartz are usually present, and these become more numerous toward the northwest and are abundant in the sill in Tahi Valley.

Although the sills cut the structures in such a way as to indicate that they were intruded after much of the folding was completed, in places they have been twisted, sheared, and faulted, indicating that some movement took place after their injection.

The porphyries are everywhere impregnated with sulphides and appear to have caused similar impregnation of the country rocks. On King Salmon Mountain there are quartz-sulphide veins in the porphyry.

Mount Stapler Dyke. On the top of Mount Stapler, a conglomerate-like dyke somewhat resembles two that were seen in Stikine River district. It is about 18 inches wide, and cuts sharply across the bedding of the surrounding rocks. Approximately 90 per cent of it is made up of fragments, most of them well-rounded boulders of quartz monzonite, with a few of granodiorite and some angular pieces of Palæozoic rocks similar to that of the dyke walls. The matrix, which constitutes about 10 per cent of the rock, contains tiny fragments. It has not been studied under the microscope, so that its nature is not known.

CHAPTER IV

STRUCTURAL GEOLOGY

The structure of Taku River area has not been studied in detail. Only the broader features, as made evident by the distribution of the various formations, and the folds as observed in vertical sections, are here treated. A detailed study of the structure would require much time, far more than was at the writer's disposal.

As indicated in the discussion of the general geology, Taku River area, as part of the Coast Mountains, has been deformed intermittently and recurrently throughout all the early part of the Mesozoic era, to at least as late as Upper Cretaceous time. Uplift centred in the axial part of these mountains, which in Taku River area follows or lies southwest of the International Boundary. The recurrent uplifts, and the intervening periods of erosion, have given rise to numerous unconformities and discontinuities, greatly complicating both the succession and the structure.

In the broadest way, therefore, the Coast Mountains constitute a broad anticlinorium, the northeast flank of which falls away through a multitude of subordinate folds to the synclinorium of Stikine Plateau. The folds have been disturbed and deformed by the intrusion of the various batholithic rocks, excepting the quartz monzonite. During their intrusion these seem to have thrust the older strata upwards and to one side, creating local irregularities in the axial directions turning them as much as 90 degrees away from the general northwest trend.

In a general way, the folds in the northeastern part of the area are fairly open, with dips in general less than 60 degrees. Minor folds, also, are in general only moderately numerous, though local exceptions are found. Toward the southwest folding becomes closer and minor folds more numerous, presumably because successively older beds, which have suffered more periods of deformation, are exposed in this direction. A great many of these folds are overturned to the southwest, so that their axial planes dip northeast.

The first major fold recognized on the flank of the great anticlinorium is the great syncline occupied roughly by Tulsequah and Stuhini Valleys. It has a marked plunge to the southeast, which continues well beyond the area mapped. As a result, in the southeastern part of the map-area and beyond it, Palæozoic rocks are sparsely exposed or not at all, whereas to the northwest, they outcrop in increasingly greater amount, to where, in the upper part of Tulsequah Valley, Mesozoic rocks form only thin shells on the walls or tops of mountains, or occur as synclinal remnants. It may be noted that the batholith of hornblende-andesine granodiorite appears at the upper end of this long plunging syncline, and may be, in part at least, responsible for the plunge. Certainly it seems to have had some disturbing effect, for on the northeast side of Tulsequah Glacier the dips are mainly northwest and southeast, away from the exposures of the granodiorite.

Northwest of this syncline are several major folds, the positions of which are indicated on the map and may readily be determined from the distribution of the rocks. In this direction there appears to have been some upbowing or cross folding in the Taku Valley section, because the Zohini syncline plunges to the southeast, whereas the Mount Dirome syncline plunges to the northwest. This may indicate the presence, at depth, of some intrusive body that did not reach the surface.

Northwest of Tulsequah Lake a new and independent structure seems to be present, for the rocks of the Stuhini group there appear to lie in a syncline of considerable size that trends and plunges to the north.

Although the axes of the folds have a general northwesterly trend parallel with the axis of the range, they exhibit much irregularity. They are not straight, but commonly have gentle bends. Further, they are not parallel, so that they are apt to come together and merge, or several folds may fan out from one centre. A broad, gentle fold may pass, either along the strike or in vertical section, into one with steeply dipping or even overturned limbs. It is thus impossible to project the structure with any degree of accuracy far beyond the limits of actual observation.

By Upper Cretaceous time folding movements seem to have largely ceased, at least in the marginal parts of the Coast Mountains and beyond. The Upper Cretaceous strata of Stikine River district, and the supposedly Upper Cretaceous of Taku River district, are gently undulating with a low regional dip to the northeast.

Extensive major faulting has not been noted in the map-area. The largest observed faults did not appear to have displacements of more than 1,000 feet. They were detected mainly because they cut across the structures; strike faults would probably have been missed. However, it is probable that in an area where deformation has been so general faults are numerous and may be found by detailed work on areas with suitable horizon markers. Actually, in Shazah Valley and on Mount Stapler a great many were seen. Most of the observed faults are of the normal type, and in the writer's opinion may be of late Tertiary age and have formed during a period of extensive block faulting recognized in the Stikine River district.

All the rocks of the map-area examined are jointed. In the intrusive masses joint systems are well developed, and are more numerous in the older rocks. The best defined system throughout the area strikes slightly west of north but may swing to northeast, and dips 60 to 70 degrees west, on the average. Another well-developed system strikes north 35 to 70 degrees west, and dips 50 to 60 degrees southwest. In places nearly horizontal jointing is distinct.

CHAPTER V

HISTORICAL GEOLOGY

It is believed that during Palæozoic time there must have existed a land area west of the Alaskan islands that underwent periodic uplift. The products of its erosion formed near-shore deposits in Alaskan areas, and somewhat deeper water deposits in British Columbia areas. Volcanism and the development of batholiths took place within and near the positive area, and to a much smaller extent elsewhere, as in Taku River district.

During late Carboniferous time northern British Columbia was uplifted to some extent; erosion began, and an unknown thickness of strata was removed. Then downwarping permitted the sea to occupy the area once more, and during the Permian period conditions were favourable for deposition of almost pure limestone. Some of it, at least, is composed of the shells of shoal-water organisms.

The Palæozoic era closed with a moderate deformation and uplift, followed by a long period of erosion during which, in places, some 5,000 feet of strata at least were removed. Erosion may have continued throughout Lower and Middle Triassic times, as the next strata found in Taku River area are of Upper Triassic age; but the presence of boulders of volcanic rocks in the lowest beds exposed suggests that during this interval volcanic rocks may have been deposited, to be completely eroded away before the exisiting beds were formed. Some support is afforded to this hypothesis by observation of the later relations, which show that great thicknesses of the existing beds were in places removed before subsequent beds covered them.

The older measures of the King Salmon group indicate a period of pronounced volcanic activity. There were many vents, around which volcanic cones were built up. Much of the area appears to have been below sea-level, though possibly some of the cones rose above it. The relief of the area, the variations in the character of the materials extruded from the different vents, and the fact that the bulk of deposition was undoubtedly close to the vents, combined to cause great variations in the composition and thickness, even within short distances. Toward the close of King Salmon deposition volcanic activity diminished, sedimentation of completely weathered materials was widespread, and, eventually, conditions became favourable for the deposition of limestone.

King Salmon (early Upper Triassic?) time closed with deformation and uplift, which was most intense in the west, and several thousand feet of its strata were then removed by erosion. It is probable that within most of the map-area the beds were completely destroyed, because at all contacts with Palæozoic strata the Mesozoic rocks are those of the next overlying group, the Stuhini.

The Stuhini group represents, in general, a repetition of events such as characterized the accumulation of the King Salmon rocks. They opened with intense and widespread volcanic activity, and closed with deposition of more ordinary sediments, and even some limestones. The wide variations in the thickness of the volcanic part of the group suggest an interval or intervals of deformation and erosion.

During the time that included the deposition of the groups, batholiths were injected into the area of the Coast Mountains, as boulders of them appear in the earliest conglomerates of the overlying Jurassic rocks. It is probable that their injection accompanied such various uplifts and deformative movements as have been described, and that the forces causing these movements were also responsible for the volcanism and the batholithic intrusion.

Towards the end of Upper Triassic time stable conditions were once more established, and the Honakta limestones were deposited. The epoch closed with the uplift initiating the Jurassic period.

The interval of erosion thus initiated appears to have lasted through much of Lower Jurassic time, for the earliest fossils collected appear to characterize the upper part of that epoch. During this interval, much of the underlying Honakta limestone seems to have been eroded, and to the southwest, in the axial parts of the Coast Mountains, the Triassic batholiths were unroofed.

The oldest, Takwahoni group of Jurassic rocks displays features that, with the information available, are difficult if not impossible to explain. More detailed work, with careful collection of fossils, will be necessary to unravel the history satisfactorily. In Zohini Valley the oldest rocks are argillites with marine fossils, implying moderately deep water conditions. Lying with apparent unconformity on them are thick, coarse conglomerates, interstratified with some beds carrying marine fossils, a succession that can only be interpreted as indicating subaerial or shore conditions complicated at times by marine submergence. The rocks correlated with these farther north are again sandstones, argillites, and a little limestone, in which marine fossils have been found in several places; and these are again interbedded with great thicknesses of coarse conglomerate. Fluctuating conditions, and perhaps unconformities, seem required to explain the facts. There was also some volcanic activity during this epoch.

A long and remarkably stable period ensued, during which the thick Sinwa limestones were laid down. It ended as a result of changing conditions, caused perhaps by some uplift to the southwest, and the limestone was overlain by a thick series of argillitic beds, the lower division of the Yonakina group. Such beds imply the presence, to the southwest, of rather low-lying lands from which streams carried muds, the products of thorough weathering, into the sea. Some volcanoes also contributed lavas and ash to this group of strata.

The next episode, as revealed by the rock section examined, indicates a tremendous outbreak of volcanism, in which some 4,000 feet of beds, mainly lavas and tuffs, were deposited. As the ordinary clastic sediments accompanying the volcanic rocks are of the same argillitic nature as those directly below, it is considered possible that this was merely a local episode, and that farther along the strike these volcanic rocks may disappear.

The uppermost division of the Yonakina group records two pronounced uplifts of the area to the southwest. These uplifts involved the areas where the Sinwa limestones had been laid down, and brought them under erosion, so that they supplied boulders to the conglomerates of the uppermost division. The shorelines must, therefore, have lain close to the present positions of the lower contact.

Two coarse conglomerates in the upper Yonakina division correspond with the two uplifts that took place. They record periods of rapid erosion, during which all the well weathered materials developed in the areas to the southwest were removed, and unweathered rocks were exposed. Argillites above the conglomerate beds imply offshore conditions. There was a little volcanic activity.

During these late Jurassic intervals of deformation and uplift, it is probable that batholiths of quartz diorite were being injected into the axial part of the Coast Mountains in Alaska, because scattered boulders of it are found in the conglomerates of the overlying Inklin group.

Inklin time records another period of intense and widespread volcanic activity. Following the accumulation of a thick succession of mainly volcanic rocks volcanic activity became intermittent, and there were quiet intervals of considerable length during which normal sediments formed. The succession of events is, however, very imperfectly known, and as here outlined may include several groups of rocks separated by unconformities.

The last great deformative movement that involved the rocks of the map-area followed the deposition of the Inklin, supposedly Lower Cretaceous, rocks. It folded the Inklin beds into rather open folds, with dips up to 60 degrees on the flanks, and seems to have been accompanied by renewed upward movement of the axial part of the Coast Mountains, and by intrusion into it of the quartz monzonite batholiths. Erosion of this newly uplifted area gave rise to the presumably Upper Cretaceous sediments that were observed at a distance on Mounts Dirome and Haney. These strata are little disturbed.

The several periods of deformation affecting the formations of this area indicate a gradual migration to the northeast. Uplift, as we have seen, began in the axial part of the Coast Mountains and was accompanied by batholithic intrusion and volcanic activity. As time went on, the areas of uplift moved northeast, until by the end of Jurassic time the Sinwa limestones, and perhaps higher beds, were brought under erosion. Volcanic activity accompanied this migration, and in fact seems to have always been in advance of the uplift, so that the vents were in the sea and the materials discharged from them are intercalated with marine sediments. The injection of batholithic magmas likewise accompanied the uplift in its northeastward movement, and the youngest batholiths are those farthest to the northeast.

The total exposed thickness of Mesozoic strata laid down on the flank of the Coast Mountains anticline is of the order of 50,000 to 60,000 feet; and, though it cannot be said that such thicknesses will be found at any one place, it is probable that existing thicknesses amount to several miles. All these strata are interbedded with marine beds, and were, therefore, deposited either in the sea or near sea-level. The Stikine synclinorium must, therefore, have been a negative area that subsided as fast as new loads of sediment were deposited in it; and the total subsidence, therefore, must have been enormous. Possibly this continuing subsidence of the synclinal basin may have been, in part, the cause of the successive uplifts of the marginal parts, and of the northeastward migration of these uplifts.

The post-Inklin folding appears to have brought northern British Columbia finally and permanently above sea-level, for subsequent deposits, of Upper Cretaceous and Paleocene age, are all continental types. They seem to have been laid down as a belt, in places quite narrow, along the northeastern boundaries of the Coast Mountains; and great thicknesses are found in places. Such relations imply that during this period the area now occupied by these mountains was a range of hills or mountains, from which the drainage was to the northeast.

A long period of relative quiet seems to have followed, during which the entire area was gradually reduced to a surface of low relief that truncated all the folded rocks. The writer would not go so far as to say that the whole region was peneplaned; quite possibly hilly or mountainous areas still remained in what are now the Coast and Cassiar Mountains; but the manner in which the originally level surface of the Stikine Plateau can be seen to bend upward into the present Coast Mountains indicates clearly that much, if not all, of the present mountain area was formerly a part of the peneplain.

It must have been during this long period of erosion, which culminated in near-peneplanation, that streams working headward from the Pacific slope cut across the axis of the present mountain range, then very low, to capture the longer interior rivers and establish the present trans-range drainage ways. In so doing they established courses on the relatively easily eroded Palæozoic and Mesozoic strata, and avoided, to a large extent at least, the resistant batholithic rocks. Taku River district is an excellent example of this structural control, in that all the main valleys, including Taku Valley itself, are developed in the softer rocks.

No definite evidence has yet been obtained by which the events of the later Tertiary can be accurately dated. Most of the Tertiary rocks are volcanic, so that their exact age is uncertain. However, it seems reasonable to conclude that the development of the post-Paleocene peneplain required considerable time, and might, therefore, not be complete until fairly late in the Eocene. The establishment of the present course of Taku River, therefore, would probably date back to about the same time. During the remainder of Tertiary time there was gradual uplift of the peneplaned area, apparently without much accompanying deformation. It was raised as a block, with only slight warping, to form the present Stikine Plateau some 4,000 feet above sea-level; and the parts nearer the Pacific were differentially warped upward several thousand feet more to form the present Coast Mountains. During these uplifts, the Taku and other transmontane streams were able to cut down their beds as fast as uplift proceeded, and hence maintain their valleys. On Stikine Plateau they have cut broad valleys some 2,000 feet deep; in the mountain sections the valleys are, of course, much deeper. All this valley cutting was completed when glaciation began in Pleistocene time.

Elsewhere in British Columbia there is evidence that a first uplift of the Coast Mountains took place in late Eocene time, and that a second movement probably occurred during Pliocene time. The scanty evidence afforded by Taku River and the neighbouring districts does not conflict with these conclusions; and until better evidence is available they may be accepted tentatively.

CHAPTER VI

ECONOMIC GEOLOGY

Mineral deposits have been found in the contact zones of the Coast intrusions in many parts of western British Columbia. Taku River area, which comprises a considerable section of the eastern part of the Coast Mountains, also displays many mineralized areas. As yet they have not been explored to any great extent, but when this is done profitable deposits may well be found.

Field observations indicate that the biotite-andesine granodiorite, the hornblende-andesine granodiorite, the feldspar porphyry, and the diorite of Mount Lester Jones have mineralized the rocks they intrude, and their general neighbourhood should, therefore, be favourable prospecting ground. On the other hand, bodies of quartz monzonite and biotite-oligoclase-andesine granodiorite appear to have had little or no mineralizing effect.

The part of the map-area that observations indicated as most favourable for prospecting lies southwest of the Shustahini-King Salmon Valleys. Within this area, Tulsequah Valley is as yet the most attractive part, and most of the claims staked in the map-area are there. Debris on the north side of Tulsequah Glacier suggests that important mineral deposits may be found farther to the northwest. Little evidence of mineralization was seen on the upper slopes of Mount Strong, Mount Metzgar, or Mount Manville. Considerable alteration and mineralization was seen in many places along Stuhini Valley, mainly at low levels, and along Taku Valley between Stuhini and Sittakanay Rivers. On Ericksen Mountain, however, deposits extend well toward the top. Mineralized zones were found in many places on Mount Jeanne and throughout the section north of it into Zohini Valley. Yellow Bluff on Taku River displays a large area of volcanic rocks altered and impregnated with sulphides, but Chuunk Mountain and the ridge northeast of it are comparatively free of rusty areas. The section northwest of Mount Lester Jones to Taku Valley contains numerous veins and replacement deposits. Zones of mineralization are found along the anticline occupied by the feldspar porphyry dyke on King Salmon Mountain, and some small silver-lead deposits are reported in limestone in King Salmon Valley. Deposits of silver, lead, and gold have been reported from the Yeth Creek section.

Though some veins have been found, most of the deposits are the result of replacement. They fall into two main classes, those that can be related directly to the proximity of some igneous mass, and those than cannot. The only known example of the first type is the mineralized area surrounding the biotite-andesine granodiorite of Mount Lester Jones. Around this mass a shell of the volcanic rocks some 2,000 feet thick has been impregnated with sulphides.

Most of the replacement deposits, however, cannot be related to any igneous rock, but do have very definite associations. They fall into three general types: shear zone deposits, deposits in anticlines, and irregular masses.

Shear zone deposits lie in sheared zones that parallel the local structure and usually lie in or close to the axes of minor folds. All the better deposits of the area, including those on Ericksen Mountain and on both sides of Tulsequah Valley, appear to be of this type. The existing relations suggest that ore-bearing solutions, rising through the sheared zones, deposited their mineral contents when they encountered rocks susceptible to replacement. The pre-Permian sandy argillites, apparently, were not readily replaced, but both the Permian limestones and the Stuhini volcanic rocks were; consequently, most of such deposits are found immediately above the upper contact of the pre-Permian rocks. Deposition, when it began, appears to have been fairly rapid, and it may probably be expected that the mineralized masses will display no great width in directions normal to this contact.

Contacts of the Permian limestone with the Stuhini volcanic rocks have proved to be especially favourable for the formation of mineral deposits. In such places, it is often difficult to tell which rock has been replaced.

The Ericksen-Ashby, Potlatch, Tulsequah Chief, Manville, and many of the deposits on Whitewater Mountain, are examples of the shear-zone type.

The second type of deposit, found in anticlines, appears to have been formed by solutions that followed the bedding in their upward migration. Where the rock is susceptible to replacement—and replacement in places seems to have been encouraged either by fracturing at the anticlinal crest or by the presence of an impermeable overlying bed—a long, flat, narrow body of ore may result. The main showing of the Potlatch-Banker group is a replacement in limestone of this type, as are also some of the bands on Whitewater Mountain, and some of the limestone replacements on the Ericksen-Ashby claims.

The third type of deposit, the irregular mass, is not definitely related to structure. Apparently they were formed by solutions migrating along some fracture or other passageway, which, when they reached a rock suitable for replacement, at a suitable temperature, formed a deposit that has no visible relation to pre-existing structures. The big altered zone on Yellow Bluff is of this type, as are many zones along Stuhini Creek, in the Mount Lester Jones section, and elsewhere. Some isolated and irregular masses of limestone on the Ericksen-Ashby claims are partly replaced by mineral, and will perhaps fall into this group.

All replacement deposits in volcanic rocks are surrounded by a zone of altered materials, and many such altered zones may be seen that have no visible core of ore. The altered zones have light grey colours, and weather to rusty tints, instead of the dark greys or greens of the unaltered rocks. Many of them are small and lenticular in shape, others can be traced for more than a mile. Their outlines are irregular, and they maintain no uniformity in size or shape for any great distance. Though they follow local structure lines in a general way, they have no very definite trend or systematic arrangement.

The altered volcanic rocks, which are chiefly those of the Stuhini group, were mainly andesitic in composition, and included both lavas, breccias, and tuffs. These were first sheared along definite zones, or irregularly fractured. As might be expected, alteration along well-defined shear zones produced bodies of more regular shape and with more distinct walls than the others. In all instances, however, the altered rocks grade into the unaltered throughout a fairly wide zone.

Many specimens, most of them from the Tulsequah Chief property, were studied microscopically in an attempt to determine the course of the alteration. Unfortunately, these proved to vary so widely in composition that much more work, it is felt, will be needed to be certain of the facts. The following outline, therefore, must be considered merely a preliminary effort. Further study may alter the sequence of events as here outlined, and throw more light on their causes.

The andesites of the Stuhini group consist mainly of oligoclase feldspar, with some andesine, and minor quantities of pyroxene, chlorite, magnetite, and pyrite. The changes are believed to consist of the development in them of much chlorite, epidote, and calcite. In places this material appears further altered to almost pure chlorite; in others, quartz and white mica have been added to it. All variations in composition may be observed, from types that contain little quartz and mica to others in which these are dominant or the only minerals present. Further, some varieties consist largely of the mica, others largely of quartz.

The writer believes, though his data are not complete, that there was an intermediate stage during which albite oligoclase was introduced and in some parts formed large masses. The white mica was formed by alteration of this feldspar.

When these alterations had been completed, further shearing appears to have taken place, or perhaps shearing movement was more or less continuous during the alterations. Through the openings thus created, solutions carrying metals arose, and deposited their loads within the altered zones. Pyrite was the first mineral thus deposited, in massive shoots and disseminated grains. It was accompanied by fluorite and other gangue minerals, including quartz and albite. Then followed chalcopyrite, galena, and zinc blende, which replaced the pyrite and to some extent the other minerals.

On the Tulsequah Chief property, the next event was the injection of dykes of quartz albitite, which cut through the orebodies and across the pre-existing shearing at small angles. The composition of the dyke material is so similar to that of much rock in the altered zone that it is difficult to separate them in places, or to be sure that the dykes have not been similarly altered.

Some stringers of chalcopyrite and galena, and their gangue minerals, cut the dykes, so that either deposition of these minerals continued after the dykes were injected, or there was some rearrangement of the minerals previously deposited.

The final event of this succession appears to have been the injection of quartz, and possibly some albite, to form replacement veins, knots, or irregular masses.

TYPES OF DEPOSITS

The following types of deposits have been noted.

(1) *Pyrite Deposits.* Many of the altered zones in volcanic rocks appear to carry pyrite only. Some of these deposits are said to contain gold, but they have not been thoroughly tested.

(2) *Zinc-copper-lead Deposits.* These carry low to moderate values in gold and silver. The Tulsequah Chief, Manville, and Potlatch properties are examples.

(3) *Gold-antimony Deposits.* The principal minerals are arsenopyrite, which carries good values in gold, and pyrite. Some chalcopyrite and stibnite are present locally. The Whitewater and Silver Bird properties are of this type.

(4) *Antimony Deposits.* The chief minerals are pyrite and stibnite. The Surveyor and Council properties are examples.

(5) *Zinc-lead Deposits.* Pyrite, galena, sphalerite, and arsenopyrite are the chief minerals, with a little chalcopyrite in places. The Red Cap claims carry this type of deposit.

(6) *Lead-zinc-silver Deposits.* These are replacements of limestone by pyrite, sphalerite, and argentiferous galena. The Potlatch-Banker and Ericksen-Ashby are the chief representatives of this type.

(7) *Gold-bearing Veins.* In these pyrite and arsenopyrite are the chief sulphides, as on the Silver Bird claims.

(8) *Silver-lead-zinc Veins.* These occur on the Highland Boy.

(9) *Graphite Veins.* These have been reported on the Red Cap claims.

(10) *Coal.*

ZINC-COPPER-LEAD DEPOSITS

TULSEQUAH CHIEF

The Tulsequah Chief property, comprising twenty claims, is situated on the northeast side of Tulsequah Valley 7½ miles above the mouth of the river. The deposits were discovered about 1923. Intermittent work was done on them until 1929 when they were optioned by the United Eastern Mining Company of

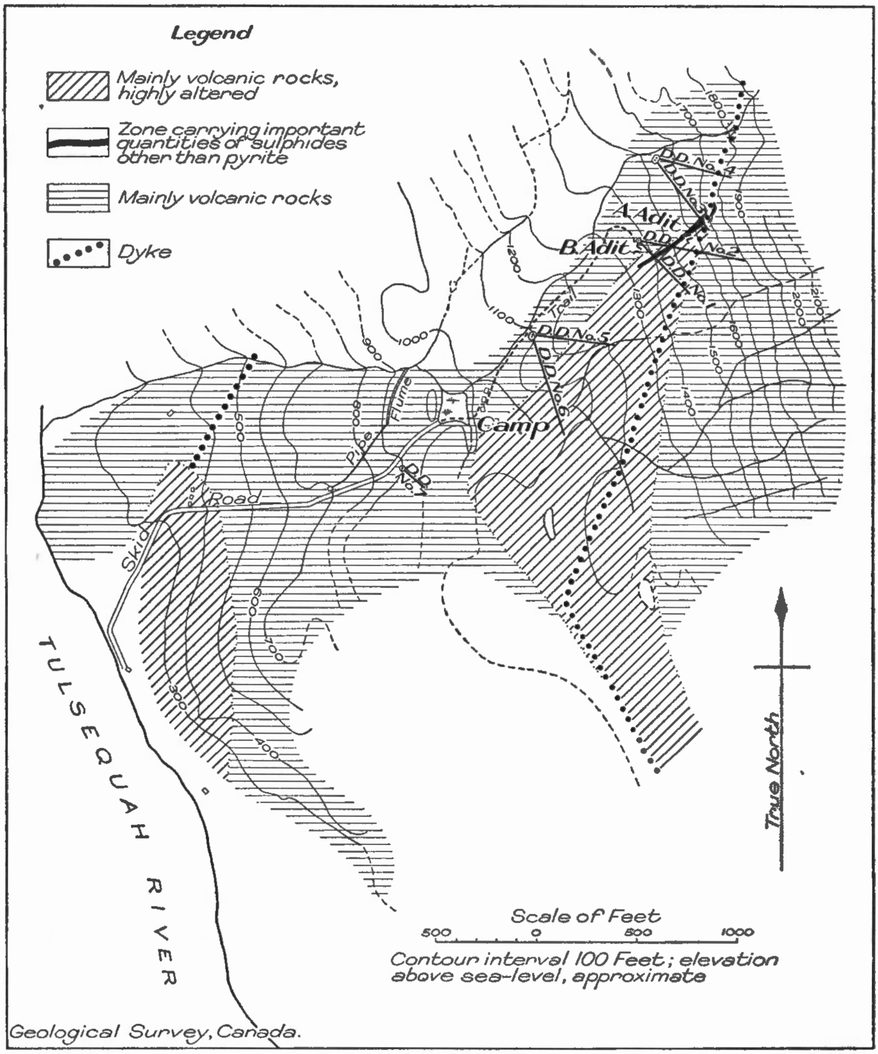


Figure 2. Area adjacent to Tulsequah Chief workings, Atlin mining division, B.C.

Los Angeles, which did considerable development work in that year, and in December incorporated the Taku Mining Company to take over the property. However, no further work was done in the next 3 years, and the total development up to 1932 consisted of two adits, seven diamond-drill holes, and several open-cuts.

There are two altered zones on the property. That on which all work has been concentrated is shown in Figures 2 and 3; the other, also shown in Figure 2, lies about 3,000 feet southwest of the workings, near Tulsequah River. Both zones are fairly well exposed.

The altered rocks are parts of the Stuhini group. Above the deposits, at an elevation of about 4,000 feet, is an anticlinal area of Palæozoic rocks (*See* Map 931A, in pocket); at the base of the mountain they appear again in another minor anticline; and at about 2,000 feet elevation another such area has been mapped. Others may be present that were not observed. Thus it is clear that the Stuhini rocks form only a relatively thin shell on the mountain side, although the actual thickness, in minor synclines, may be considerable. The anticlines mentioned plunge steeply to the south.

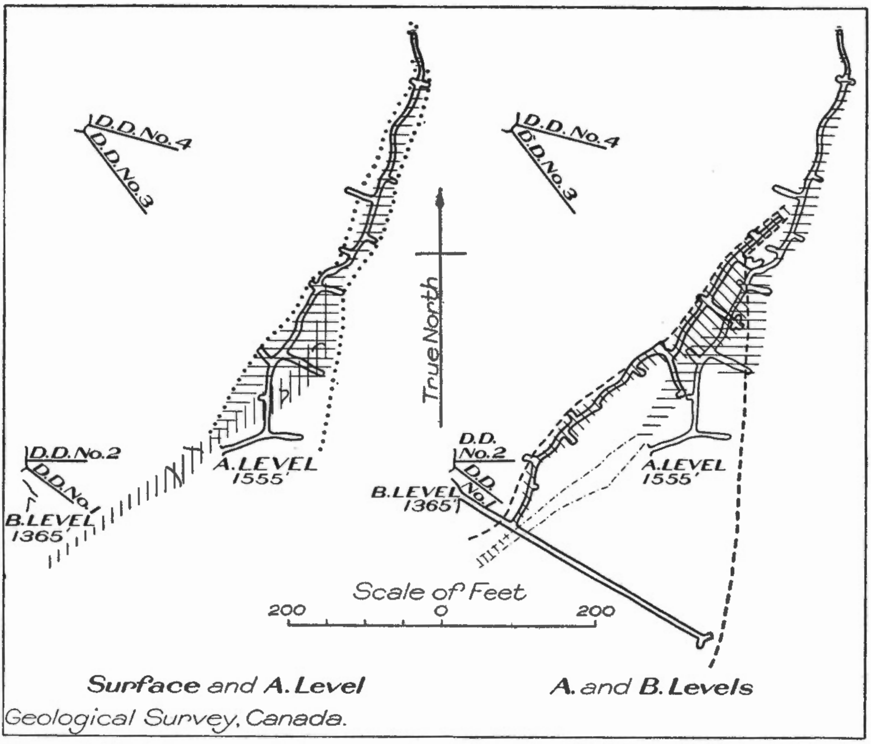


Figure 3. Workings of the Tulsequah Chief showing approximate extent of altered zone carrying important quantities of sulphides other than pyrite. (Zone on surface represented by pattern of vertical lines, on A level by pattern of horizontal lines, on B level by pattern of inclined lines; assumed limit of altered zone on A level by dotted line, on B level by pecked line; the dyke is not represented.)

The lower zone of alteration appears to lie on the projection of the crest of the lowest anticline and the upper zone on the projected crest of the uppermost anticline. These structural relations are believed to be responsible for the location of the mineral deposits.

The top of the main altered zone, which trends in the main a little east of north, was seen at two points near its northern end, and in the bed of a creek beyond. From these exposures the dip of the upper contact was calculated to be about 7 degrees south. If this dip is maintained—which of course is by no means certain—then in the draw that extends southeast of the camp buildings at least 400 feet must have been eroded from the upper part of the zone.

In the workings, and from drill determinations, the dip of the altered zone is found to be steeply northwest. The body is most irregular, however. At A level its width is about 40 feet; on B level, 200 feet below, about 10 feet; and a drill hole penetrating 100 feet below B level again shows a width of 40 feet. The same pinching and swelling was also noted along strike. Southward from the workings the zone appears to widen to a possible 900 feet.

Offshoots and subsidiary zones are numerous, and either at depth or laterally the main zone may divide or link up with others. In drill holes Nos. 3 and 4 (*See* Figure 3) a subsidiary zone was found to parallel the main zone about 150 feet northwest of it. In drill holes Nos. 1 and 2 two sulphide shoots were found, with a considerable width of dark rock between. Possibly, therefore, the wide part of the altered zone may represent the merging of two separate zones.

The ore minerals are chalcopyrite, pyrite, and sphalerite, with lesser quantities of galena. The orebodies form shoots in the altered zones, and range from bodies of massive sulphides to light disseminations. The best shoot in the mine shows solid masses of the individual sulphides, as well as various interbanded and intermixed ores. The grain of the sulphides is mostly fine.

It is doubtful if any reliable estimate of the average value of the ore can be gained by channel sampling. Fifteen samples, 4 to 8 feet in length, taken from sections other than the leanest, gave the following results:

Copper, 7 samples below 1·0 per cent
5 samples 1·0 to 2·6 per cent
2 samples 2·6 to 6·0 per cent
1 sample 14 per cent
Zinc, 2·0 to 10 per cent
Lead, trace except in four samples showing 0·5 to 0·8 per cent
Gold, 0·1 to 0·3 ounce a ton
Silver, 1·6 to 15·0 ounces a ton

In these samples, the silver values appear to vary with the zinc content, whereas the gold values do not seem to have any particular relation to the sulphides. It has been stated that the gold appears to accompany the copper, but the assays do not confirm this. In fact, the highest gold value was found in a sample carrying very little copper.

Drill holes Nos. 3 and 4 cut a band of mixed sulphides of about the same width and character as in the workings above and about 100 feet below them. In drill holes Nos. 1 and 2 the proportion of pyrite seems to be greater than above: thus in drill hole No. 1 there are only 6 feet of mixed sulphides on the west side of a well pyritized zone more than 50 feet wide. Drill holes Nos. 5 and 6, however, intersect what appears to be the corresponding section of the altered zone 500 feet below B level and 800 feet southwest of its portal (*See* Figure 2), and show well pyritized sections but no ore shoots.

The main ore shoot is cut in two by a light grey, cherty dyke 8 to 18 feet wide. This dyke is composed mainly of quartz and albite, hence may be closely related to the solutions causing alteration of the rocks. It cuts obliquely across the cleavage, at a small angle, and passes into the wall-rocks at both ends of the orebody. No evidence was found of its having any influence on the mineralization; on the contrary, it appears to have been injected near or after the close of ore deposition. If the latter, there has been some rearrangement of the ore minerals by solutions, for the dyke is cut, along its edges, by tiny stringers of chalcopyrite, and the edges are also impregnated with pyrite.

In addition to the principal orebody, a highly pyritized section more than 100 feet wide was cut by drill holes Nos. 1 and 2, more than 100 feet east of the main ore shoot. What may be the same zone appears near the southeast end of the long crosscut on B level. Small amounts of the other sulphides have been found in this section, but not enough to constitute ore.

The second altered zone, near Tulsequah River (*See* Figure 2) has had little work done on it. It is highly pyritized in many sections, and may carry minor quantities of other sulphides. Nothing in the outcrops suggests the presence of an ore shoot, but many of the outcrops of the known orebody looked equally unpromising. In this district of high precipitation solution of metallic minerals is often so complete as to leave only insignificant traces of their presence at the surface.

This altered zone appears to terminate somewhat abruptly at the north, though a dyke continues for some distance farther. The rocks beyond the north end contain much sedimentary material, and hence may belong to the Palæozoic series, which is not readily replaced. The dyke that continues beyond the altered zone may thus indicate the position of the channel through which the altering solutions rose.

MANVILLE

The Manville property lies about 2 miles due north of Tulsequah, at the base of Mount Manville. It may be reached by road, or by a water route $3\frac{1}{2}$ miles long. The property comprises eighteen claims and two fractions. It was discovered by V. Manville in 1929, and optioned to the Treadwell Yukon Mining Company in association with the Alaska Juneau Gold Mining Company. Extensive work was done by these companies during the next year, after which the option was dropped. The development work consisted of an adit 1,950 feet long with crosscuts on either side, and a large amount of diamond drilling.

The deposit is much like that of the Tulsequah Chief. It lies in the Stuhini volcanic rocks about 400 feet southeast of some outcrops of red and grey schists that are considered to represent a minor anticlinal of Palæozoic strata. The Stuhini rocks are the usual massive green types, but they carry much magnetite in masses up to several inches across. Alteration of the magnetite to hematite has produced much jasper-like rock, and veins of jasper are also present.

The volcanic rocks are cut by a sheared zone that strikes northwest and dips from vertical to 45 degrees southwest. The zone is much wider than on the Tulsequah Chief property, and in fact much of the rock that appeared to be massive in the field proved, when examined under the microscope, to be sheared. Specimens of it consist mainly of chlorite, mica, and other secondary minerals.

Within this sheared zone, but much narrower than it, is an altered zone resembling that on the Tulsequah Chief property. In the central part it is very narrow for a length of about 300 feet, but then widens abruptly at both ends to 200 to 300 feet. The western boundary is fairly sharply defined, a peculiarity due, in part at least, to the presence of small faults. The eastern boundary is fairly definite in the narrow part of the zone, but elsewhere is poorly defined. The character of the altered materials is like that on the Tulsequah Chief property, and need not be further described. As in the Tulsequah Chief, also, the zone branches and splits. Traversing the length of it is a narrow, highly sheared section containing in most places a few inches of black gouge.

The principal orebody is indicated by eight trenches to be about 900 feet long on the surface, with a maximum width of 27 feet, though in general considerably less. In the long drift it appears to be not more than 500 feet long, and considerably narrower than at the surface. Three channel samples taken at the surface and reported by Mandy (24, 1929) gave values as follows:

Length	Gold	Silver	Copper	Zinc	Lead
Feet	Oz. per ton		%	%	%
12..........	0·1	6·0	1·6	12·8	....
27..........	0·06	6·8	2·8	20·2	0·8
5............	0·2	7·5	2·0	14·4	2·8

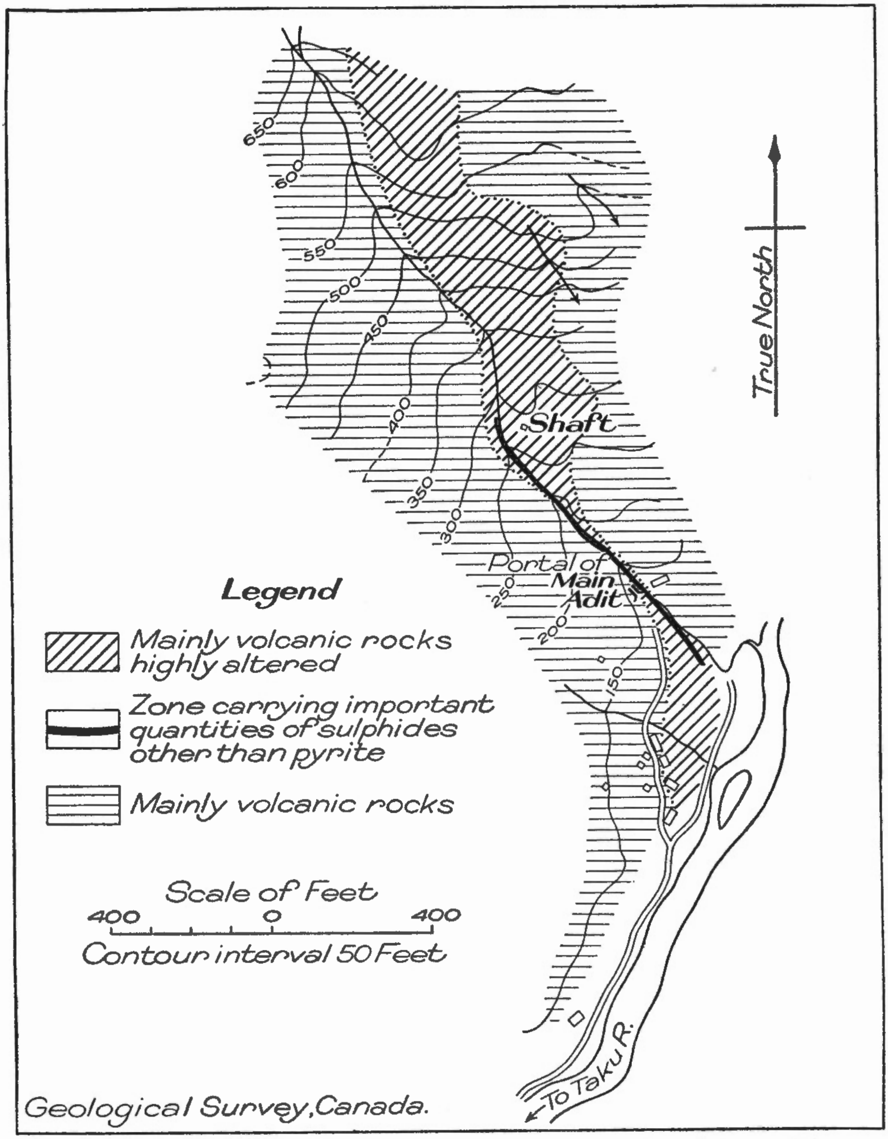


Figure 4. Area adjacent to Manville workings, Atlin mining division, B.C.

In addition to this main lens, many smaller ones are present, ranging in size from tiny lenses to masses up to 100 feet long and 30 feet maximum width. All these bodies are undoubtedly lenticular, and hence may be expected to pinch out at no great depth. Others may, of course, reappear at greater depths, but more extensive development will be required if this is to be determined. However, in view of the fact that the Palæozoic rocks probably lie at no great depth beneath, the hope of commercial orebodies there seems small.

POTLATCH

The Potlatch and Banker groups of claims are on the east side of Tulsequah River between 2½ and 4 miles from the mouth. The properties were staked in 1929 and optioned to the Alaska Juneau Gold Mining Company. The option was dropped after a year's prospecting had been done.

The main showings on these claims are in the Permian limestone, and are later described with that group of deposits. Those considered here lie about a mile to the north, along the Tulsequah trail, and are in the Stuhini volcanic rocks. They lie on the projection of the axis of an anticline of Palæozoic rocks that outcrops farther to the north.

The volcanic rocks and the mineralization are similar to those on the Tulsequah Chief and Manville properties, but the ore lenses are quite small. They have been prospected by a few trenches. The best section displayed in these has two zones of massive sulphides, 2 and 3 feet wide respectively, separated by 5 feet of soft, rotten rock. No sampling was done.

MOUNT STAPLER

Along Shazah Creek on Mount Stapler claims have been staked and some work has been done. The rocks on the mountain are mainly Palæozoic schists and quartzites with some synclines of Stuhini rocks, all cut by dykes of granodiorite. All the rocks, but particularly the volcanic members, are heavily impregnated with pyrite, and values in precious metals have been reported.

Development here might yield favourable results, but the unlikelihood of any orebody extending downward into the Palæozoic rocks should be taken into consideration before any extensive work is undertaken.

OTHER MINERALIZED AREAS

On Ericksen Mountain a plainly visible rusty band parallels the structure. Other rusty zones occur near Ericksen Creek, and in the valley east of the main Ericksen-Ashby deposits, which are considered replacements in limestone. In Stuhini Valley staking was done along the creek in 1930, between the mouth and the quartz monzonite mass 10 miles up the valley. None of the mineralized areas was examined, but their descriptions indicate that they are altered zones mineralized with pyrite, like those already described. A few of them also carry galena and sphalerite. Similar altered zones were seen on Yellow Bluff, and in Zohini and Morepat Valleys. Some of the latter have been staked, and are reported to carry sulphides of the base metals.

GOLD-ANTIMONY DEPOSITS

The Whitewater, Silver Queen, and Silver Bird claims lie on the west side of Tulsequah River some 5 or 6 miles from its mouth, on the southern flanks of Whitewater Mountain. The rocks of the area are the Palæozoic quartzites, argillites, and crystalline limestones, overlain unconformably by the Stuhini volcanic rocks. They lie on the west flank of the Tulsequah syncline, which, as already noted, plunges to the southeast. The angle of plunge must, however, be small, because the local pitch of fold is, in many places, in the opposite direction. The general strike, as the mapping indicates, is north 20 to 40 degrees east.

The Stuhini rocks thus form only a shell on the valley wall, and the shell will vary in thickness with the minor folding, being thinner on anticlines and thicker in the synclines. The valley of Wilms Creek has been cut completely through this shell, showing that its maximum thickness there is about 2,700 feet.

The volcanic rocks are sheared in many places. In general the sheared zones parallel the strike of the folds, north 20 to 40 degrees east, but the trends are not constant, and in places may swing at right angles to this. The sheared zones are also most irregular in shape and behaviour; thus a wide zone may narrow to a few inches of gouge or may split into several thin zones.

The sheared zones are more or less altered, as in the properties previously described. Alteration, as before, consists in the transformation of the volcanic rocks to mixtures of quartz, white mica, carbonate, and bleached chlorite.

Pyrite is present throughout the altered zones, which weather to rusty tints and in places are friable and rotten to a considerable depth. The pyrite is present in distinct crystals, as irregular grains of peculiar rounded or rosetted shapes, as skeleton crystals, and as massive irregular patches, which in places, with quartz, have vein-like forms. Stibnite is abundant on the Whitewater claims, and less so on the other groups. It is usually fairly massive and irregularly distributed, and forms veins with quartz and other minerals. It replaces some of the massive pyrite, and cuts some of the quartz in distinct veinlets. Arsenopyrite has been observed only on the Whitewater and Silver Bird claims, in certain sections of the altered zones. It occurs entirely as disseminated crystals of unusual, needle-like shape, up to ½ inch long. In places these crystals are grouped so closely as to give the impression of massive veinlets or lenses. In other places the arsenopyrite appears to form a cement for highly shattered masses of quartz and other minerals. Neither gold nor gold telluride was observed under the microscope or in hand specimen, but assay returns reveal its presence. Investigations by the Ore Dressing Division of the Mines Branch, Ottawa, have shown that it is not recoverable by ordinary amalgamation or cyanidation, but that practically all is recoverable by flotation with the arsenopyrite. Spectroscopic examinations further confirm the existence of the gold in the arsenopyrite. It is, therefore, probably present in solid solution. However, the amount of gold present is not proportional to the amount of arsenopyrite, hence possibly the arsenopyrite may be of more than one age, and some of it barren of values.

The width of the parts of the altered zones mineralized by mixed sulphides varies greatly. On the Whitewater claims some zones show mixed sulphides across their entire width, whereas on the Silver Bird mixed sulphides are confined to narrow bands that represent very limited parts of the altered zones.

Quartz is usually abundant in the sections of mixed sulphides, and appears to be of widely different ages. Some is older than the arsenopyrite, some was deposited along with it, and some traverses broken crystals of arsenopyrite and hence is later. It occurs in a variety of forms, as fragments in breccia, as irregular bodies replacing the volcanic rocks, and as veinlets both regular and irregular. It ranges in colour from white or pink to dark grey.

It is clear that the solutions responsible for the alteration of the country rock and the deposition of ore minerals were active over a considerable period of time, throughout which they varied notably in composition. Repeated shearing or shattering movements permitted access to different parts of the zones, so that the individual minerals are abundant in some places, scarce in others. In the later stages the brittleness of the more quartzose sections, which could shatter readily, may have influenced considerably the movement of solutions.

Besides the deposits in the Stuhini rocks, there were also some in the Palæozoic beds. These will be described in a later section.

POLARIS-TAKU MINE[1] (WHITEWATER CLAIMS)

(By D. C. Sharpstone)

"Three men, Ray Race, Walter Hedman, and Ray Walker . . . discovered the Whitewater property (now known as the Polaris-Taku) during the summer of 1929. . . . During the summer of 1930 . . . the showings were examined by the N. A. Timmins Corporation, which secured an option on the claims, and started extensive trenching and diamond drilling in 1931. . . . The Timmins trenching exposed a large number of veins, from at least ten of which good gold values were obtained over widths of 1 to 15 feet. While much of their drilling succeeded in finding good ore, it was difficult to make correlations with the surface showings, and in three holes which were drilled under some of the most important surface showings, no ore was found. The conclusion was reached that the veins were extremely erratic, lenticular, and restricted replacements. Consequently, the option was dropped in the fall of 1932.

"Immediately upon Timmins dropping their option, the property was taken over by the Alaska Juneau Gold Mining Company. This company . . . started a tunnel from the lower hillside at an elevation of 245 feet, to cut several veins exposed by Timmins' drill holes. . . . Four veins, from 2 to 14 feet in width, were cut, which contained commercial gold values, and upon two of these some drifting was done. No. 4 vein was developed for a length of 115 feet to the northeast of the tunnel, where it was cut off by a large fault. . . . A 45-foot segment of "A" vein, lying between two small faults, was also drifted upon in the west end of the tunnel. . . . No work was done to find the faulted segments. In the fall of 1934 the company relinquished their option for the twofold reason that (1) veins seemed too complicated, and (2) tests indicated a complex metallurgical problem and poor gold recovery.

"Upon termination of the Alaska Juneau option, the writer started negotiations with the owners on behalf of Edward C. Congdon, of Duluth, Minnesota, and his associates, and late in 1934 secured an option on the property. In May, 1935, work was again started in the lower Alaska Juneau tunnel to explore for the faulted continuation of the ore bodies exposed there. . . . Remarkable success attended this work . . . and by February, 1937, sufficient ore had been developed to warrant mill construction.

"Within the mine workings (*See* Figure 5), the formation consists of hard green massive andesite and silicified tuffs, alternating with comparatively soft phyllite and schist. The exposed bands of massive tuffs range between 300 and 500 feet in width, while the schist bands are usually narrower, ranging between 100 and 200 feet in width. . . . It is believed that they (the schists) represent more argillaceous zones along which most of the movement and adjustment occurred during deformation and folding. . . .

---

1 EDITOR'S NOTE. When Dr. Kerr examined this property in 1932 development was confined to trenches and some diamond drilling. Later, much exploration was carried on, and mining operations began in November 1937. A description of the developments was written in 1938 by D. C. Sharpstone, and published in the Transactions of the Canadian Institute of Mining and Metallurgy, vol. XLI, 1938, pp. 481-500. As this publication may not be readily available to many readers, it has seemed desirable to quote largely from Sharpstone's paper, to bring the information regarding this property up to date so far as possible.

"A complex system of veins occurs in the greenstones, which have two habits of occurrence:

(1) along contacts between schist and massive greenstones;

(2) traversing massive greenstones.

Both systems of veins are of similar age and mineralization.

"The largest and most persistent vein so far developed is of the contact type. Known as "A" vein (*See* Figure 5), the fissure generally follows the contact between massive greenstone on the footwall and schist on the hangingwall. However, in places it diverges from the contact either into the schist or greenstone. The best ore occurs where the fissure is on the contact or in massive greenstone.

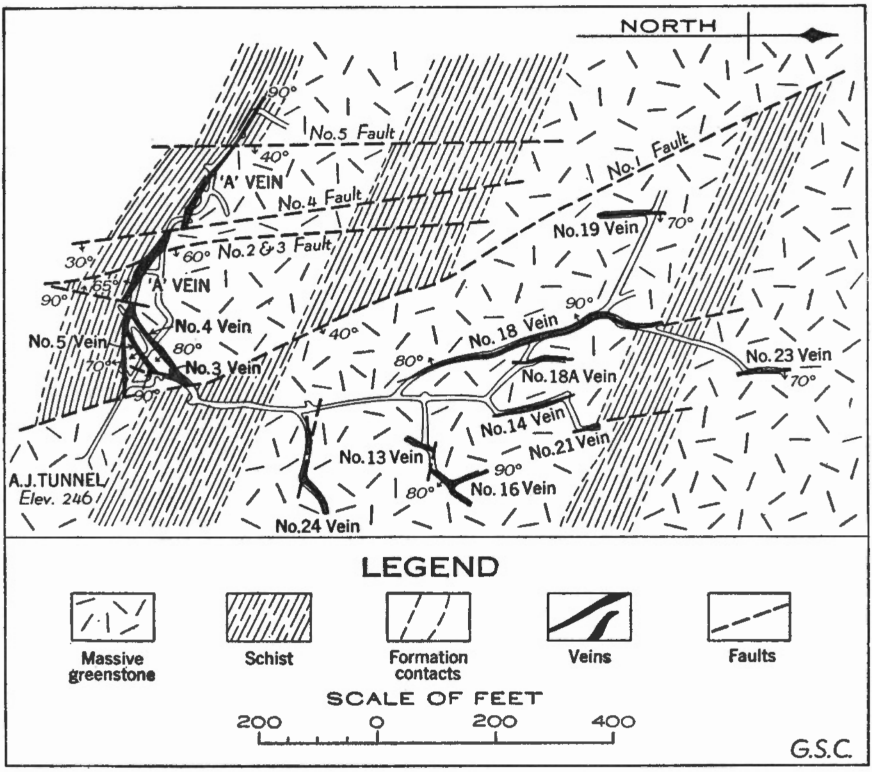


Figure 5. Polaris-Taku mine, Atlin mining division, B.C., showing vein and fault system on the A. J. level, by D. C. Sharpstone, 1938.

The strike is generally east-west to north 70 degrees west[1], and the dip 65 degrees south to vertical. The vein varies from 2 to 25 feet in width, and averages about 8 feet. It has been developed for a length of approximately 1,000 feet, and indications on the surface suggest that it may extend for an additional 1,000 feet.

"The transverse veins strike from north 10 degrees west to north 60 degrees east. Veins of this type are prolific, but smaller than the contact type. All so far developed lie in the footwall and to the north of "A" vein. The veins occur solely in the hard, massive, and brittle bands of greenstone, and die out when

[1] It will be noted that the average strike of the bedding, according to Kerr, is north 20 to 40 degrees east. It would appear, therefore, that the mine, in which the average strike is north 70 degrees west, must be developed on a drag fold.—Ed.

they intersect a schist zone. However, not infrequently, what appears to be their counterpart is found in the next succeeding band of greenstone beyond the schist. Several of the veins have been found to branch from "A" vein, but none cross it and continue beyond on the hangingwall side. Many junctions and intersections occur between the transverse veins, because of their diversity of strike and dip.

"The largest transverse vein so far developed is 18 vein, which has been opened on one level for a length of approximately 450 feet. Ten others of commercial value have been developed over lengths of 50 to 200 feet. These veins average 3 to 5 feet in width. Numerous others, on which no commercial bodies of ore have yet been found, also occur.

"A series of reverse faults occur which strike generally about north 10 degrees west and dip 35 to 60 degrees east. Faulting is both pre- and post-mineral, and rather clearly represents adjustments which began before the introduction of mineralization and continued after mineralization had ceased.

"The most common relation is a horizontal offset of veins of from ten to forty feet, but in one case, an offset of at least 100 feet is suspected. In other places, veins die out against the faults, and again, some of the smaller faults are displaced by later movement along the veins. Generally, the faults carry very little gouge and often are very inconspicuous. A little ankerite has commonly been introduced along the faults, and sometimes other mineralization is present. One fault, called No. 4, has displaced "A" vein on the A. J. level for approximately 20 feet, and is marked by only three inches of ankerite and no gouge. A hinge movement is characteristic of several of the faults, which on one level may have a throw of 40 feet, while 250 feet above, the movement may be less than 5 feet.

Oreshoots and Mineralization

"Vein mineralization consists of arsenopyrite, pyrite, stibnite, possibly pyrrhotite, and gold in a gangue of quartz and carbonates. The gold is associated with the arsenopyrite and possibly to some extent with pyrite. It very seldom occurs free.

"Under the highest magnification, no free gold can be seen even in rich specimens, and there is a strong suggestion that most of it occurs in a state of solid solution, or extremely fine intergrowth with arsenopyrite.

"The sulphide content of the veins averages between four and five per cent. Arsenopyrite is most abundant with pyrite next in importance. Although fairly abundant in some specimens, stibnite comprises less than one-tenth of one per cent of the vein matter. Very small amounts of an unidentified mineral, probably pyrrhotite, have been observed under the microscope dusted through the vein.

"The first period of mineralization consists of intensive replacement of the greenstones and schists, along the shear zones, with carbonates and some pyrite.

"In addition to the carbonates and pyrite, the chrome mica fuchsite is abundantly developed, while in places there is marked silicification. Replacement occurred not only within the shears, but extended into the walls for a distance of from several inches on the smaller veins, to as much as 25 to 30 feet on the larger. This process of alteration and replacement no doubt continued through the later periods. On the surface, oxidation of pyrite has conspicuously emphasized the hydrothermally altered and replaced wall rock along the veins.

"Following carbonation, abundant arsenopyrite and pyrite were introduced which replaced the carbonate rock. The arsenopyrite of this period occurs characteristically as very fine disseminated needles, and the pyrite as fine disseminated grains. Most of the gold was introduced in this period.

"Then came a succession of vein introductions including quartz, carbonate, and varying amounts of sulphides. Some veins were of quartz and carbonate, while others were of carbonate crossed by later quartz, and still others of quartz crossed by later carbonate. Numerous angular to rounded inclusions of greenstone containing disseminated arsenopyrite and pyrite are conspicuously present in the later veins. The last period of mineralization consisted of carbonate and stibnite, which occurs as stringers crossing the earlier vein materials. No gold values of consequence were introduced during this period.

"The dynamic effects were evidently prolonged and recurrent. Shattering must have recurred four or five times during mineralization, or alternated with it to develop such a series of veinlets, one crossing the other. F. A. Grout reports that, under the microscope, even the late carbonate veins appear to have been deformed under sufficient pressure to notably bend and break the carbonates.

"Generally, the mineralization lacks the characteristic signs of very high or very low temperatures, and for this reason is classed as mesothermal. If pyrrhotite were definitely recognized, it might become necessary to change the classifications to hypothermal.

"Throughout the mining area, the processes of mineralization have been profound and intensive. Orebodies of commercial size have only been deposited on the larger and stronger shears, but, along numerous weaker shears and fissures small lenses and irregular replacements occur. The full succession of mineralization is best developed on the strong "A" vein of contact type. The transverse veins, which are weaker and along which less movement has occurred, tend to contain more of the first generation arsenopyrite and pyrite and less of the later quartz and carbonates. However, the latter are often of higher grade, since most of the gold was deposited with the first generation arsenopyrite. Replacement of this material by late solutions has had the apparent effect of diminishing gold values, rather than increasing them, through the process of re-solution and transportation of the metal content.

"Oreshoots so far developed range from 50 to 800 feet in length, with widths ranging to 35 feet. The walls frequently pinch and swell and show considerable irregularity, both in the vertical and horizontal plane. Frequent replacements, and development of ore in the walls of the veins add to the irregularity of the deposits. The vertical range of commercial mineralization has not yet been determined, but has been proven from an elevation of 700 feet to sea level, the lowest point yet prospected. The greatest vertical range of ore yet developed on any one vein is about 400 feet.

"Commercial replacements and mineralization along fissures have been demonstrated to die out rapidly in some of the veins and from present information, it is suggested that the vertical range of oreshoots will, in general, be about equivalent to their horizontal length. However, no limits have yet been indicated of the depth to which oreshoots will recur, and it is anticipated that the range will be much greater than that now developed. All commercial mineralization so far found is limited in areal extent to an area approximately 2,000 feet square, which lies in the heart of the company's holdings. Away from this area, numerous carbonated and pyritized shear zones have been found, but they are barren of the later gold and arsenopyrite mineralization.

"Gold values in the veins show remarkable continuity and uniformity, and usually show a direct relationship to the amount of arsenopyrite present. While arsenopyrite in some areas carries more gold than in others, it has never been found to be barren, and good arsenopyrite mineralization almost always indicates good gold values. As the gold content of the arsenopyrite increases, it commonly takes on an increasingly brassy lustre, as compared with its usual steel grey colour. Very few high grade assays are obtained from the veins, values seldom exceeding 1·5 ounces. The average gold content of oreshoots varies between ·25 and ·60 ounces."

SILVER QUEEN

The main showing on the Silver Queen is approximately at the position indicated on the map. There a width of 200 feet of volcanic rocks highly impregnated with pyrite is exposed. In places the pyrite is massive. It is replaced by some stibnite and chalcopyrite. No arsenopyrite has been observed, nor important gold values found, though sampling has not been thorough.

At present the property is mainly of interest because the strike of the altered zone above, projected northward, carries into some of the main showings on the Whitewater claims.

SILVER BIRD

An extensive altered zone on the Silver Bird claims strikes somewhat east of north. Between elevations of 1,200 and 1,500 feet a width of some 200 feet was seen, and the total width is reported to be about 1,000 feet, though this undoubtedly includes some unaltered or slightly altered parts. Traced uphill, the altered zone passes into unaltered green volcanic rocks some 300 to 500 feet above. Downhill the first exposures are those of the underlying Palæozoic rocks. Some smaller zones are exposed to the west; to the east exposures are few. Thus, concealed beneath the drift, there must be a complete cross-section of this altered zone on the hillside, and further exploration may reveal the presence of orebodies.

The most important mineral showings to date are found along a very small stream known as Sulphide Creek, which follows a fracture trending roughly north, with a dip in places as low as 30 degrees east. There has been considerable shattering along the fracture and in places it carries some gouge-like material. In others it is filled by a quartz-cemented breccia highly mineralized with arsenopyrite, together with some pyrite and stibnite. Values of $8 to $24 in gold to the ton are reported. However, the "vein" is relatively short, and a foot or less in width. Its wall-rocks are impregnated with arsenopyrite and carry up to $2 a ton in gold.

ANTIMONY DEPOSITS

The antimony deposits seem very similar to the Whitewater group of gold-antimony deposits, except that gold and arsenopyrite are lacking. Only two deposits are known, on the Surveyor and Council groups of claims. They were not visited by the writer, but have been described by Dr. J. T. Mandy (24, 1930, p. A121) as follows:

"The (Surveyor) group of 10 claims is situated on the west slope of Sittakanay mountain, on the left bank of the south fork of the Taku River (the south bank of Stuhini Creek) about half a mile from its mouth. The occurrence consists of a well defined shear zone about 11 feet wide, striking north 50 degrees west (mag.) and dipping 50 degrees southwest. This has been traced up the mountain from elevation 50 feet to 190 feet above the river. The zone is banded and reticulated in structure and well mineralized with streaks, bunches, and veinlets of massive and disseminated stibnite, accompanied by a fine dissemination of pyrite, in a gangue of quartz with some calcite. . . . a sample . . . taken from the big cut at the upper end assayed: gold, nil;

silver, nil; arsenic, nil; antimony, 37 per cent . . . The antimony ore is remarkably free from refractory adulterants and may possibly be of commercial importance on this account."

The Council group of claims is about a mile southwest of the Surveyor group. Trenches, according to Mandy, display a shear zone very like that seen on the Surveyor group, and with similar mineralization.

LEAD-ZINC DEPOSITS

An altered and heavily pyritized zone, from 1,000 to 3,000 feet wide, apparently surrounds the mass of granodiorite on Mount Lester Jones. The precise width is difficult to determine, because the granodiorite itself is heavily pyritized in the marginal parts, so that its contacts, on the surface at least, cannot be placed.

The rocks around the granodiorite are the andesitic lavas and tuffs of the Stuhini and King Salmon groups. Besides their impregnation with pyrite, they have been highly silicified, probably also with addition of carbonates and white mica. Veins cut these altered zones and in places extend beyond them, but for the most part do not extend more than a few hundred feet from the intrusive mass. They are composed of calcite, quartz, and pyrite, with lesser amounts of chalcopyrite, galena, arsenopyrite, and sphalerite. All these sulphides are coarsely crystalline, and tend to occur in bunches rather than intimately intermixed. Most of the veins seen are narrow.

Little of economic value has yet been found in this area, and unless it shall be proved that considerable bodies of the rock mass can be mined as a whole, it seems unlikely that it will be found of worth.

The Red Cap and Red Cap Extension groups of claims have been staked on these bodies, in Red Cap Valley along the lake, and have been described by J. T. Mandy (24, 1931, p. A63).

LEAD-ZINC-SILVER DEPOSITS

Lead-zinc-silver deposits are formed as replacements in the Permian limestone. They differ from the replacements in volcanic rocks in that they are controlled mainly by the distribution of the limestone rather than by its structure, so that the rocks enclosing the limestone are generally the walls of the deposit. Where replacement has not been complete, fractures or bedding planes may constitute the walls.

The deposits include the Potlatch-Banker group of claims, the Ericksen-Ashby group, and a small deposit of sulphides near the end of Shazah Valley, just above the valley flat on the southeast side.

POTLATCH-BANKER

The main showings on these claims straddle the boundary between them, just above the valley flat on the east side of Tulsequah Valley about 2½ miles above its mouth. Development work consists of several deep trenches and diamond drill holes. The deposits are in bedded and massive Permian limestones, which in places are well silicified. The bedding strikes north 30 to 60 degrees west. The structure appears to be anticlinal in general, with many minor folds, and a plunge at a low angle to the southeast. The limestone is exposed, though not continuously, across a width of more than 200 feet. In the trenches may be seen several long masses of green rock, which are probably volcanic rocks included in minor synclines. A hole drilled directly beneath some of these cut no green rock.

Trenching has revealed the presence of rather short, irregular lenses of mixed sulphides, scattered about without system except that their longer axes seem to parallel the strike. Most of the lenses are less than 8 feet wide, and have been found throughout an area 300 to 400 feet long and more than 200 feet wide. They appear to be quite shallow; drill holes show little mineralization below, and even in trenches 10 feet deep the mineralization shows a noticeable decrease from top to bottom.

Pyrite, sphalerite, and galena are the principal sulphides, and chalcopyrite, tetrahedrite, jamesonite, and magnetite are present in smaller amount. Carbonates and quartz form the chief gangue minerals; the richer parts of the deposits are high in quartz. The sulphides vary widely in proportions from place to place; they are commonly coarsely crystalline, and excellent specimens may be obtained from the numerous vugs. Assays that appear to be representative of the well-mineralized sections show more than 100 ounces of silver to the ton, and a little gold.

In the writer's opinion, the mineralization is confined to the crest of an anticline plunging southeast. If this is correct, the deposit will have been removed by erosion to the northwest, but to the southeast the anticline should plunge beneath the younger volcanic rocks, and its full thickness be thus preserved. Though the deposit is only a few feet thick where exposed, it is impossible to know how much of it has been eroded away; and the full thickness, beneath the volcanic cover, may be considerably more.

ERICKSEN-ASHBY

The Ericksen-Ashby group of claims is situated on the north end of Ericksen Mountain. The showings range from near river level to heights of some 3,000 feet. They were staked by Ericksen and Ashby in September 1929, and some work was done on them in the 3 succeeding years.

Mount Ericksen is a narrow ridge with very steep sides, and above 2,000 feet exposure is almost continuous, except for patches of talus. The rocks are the pre-Permian sandy argillites and quartzites, overlain by the Stuhini volcanic group; between the two is a sheet, only a few feet thick, of Permian limestone. The sheet may have been discontinuous before deformation, but if not the very complex folding it has since undergone has made it so. It now forms numerous discontinuous patches of very irregular shape. To represent it at all on the map it has been necessary to exaggerate considerably the extent and continuity of these patches.

Mineralizing solutions appear to have travelled along between the pre-Permian and Mesozoic rocks replacing any limestone with which they came in contact. In places, where they encountered shear zones in the volcanic rocks, they replaced them also, as described on page 63. Thus the mineralized replacements of limestone are thin, discontinuous, blanket-like bodies. Three such patches on a very steep wall on the east side of the mountain were estimated to cover areas, respectively, 200 feet by 50 feet, 300 to 400 feet by 100 feet or less, and 50 feet by 10 feet. The rusty surfaces thus estimated are probably larger than the underlying deposits, as water running over the surface would carry the rust downward. Such patches were observed in the anticline for some 3 miles of its length.

The minerals present are pyrite, with lesser amounts of sphalerite and galena, in a gangue of quartz and remnants of limestone. Malachite stain in places suggests that chalcopyrite is present locally. Excellent specimens of the sulphides can be found in places. J. T. Mandy reports (24, 1929, p. C119) that a sample of galena assayed about 23 ounces of silver to the ton, with a trace of gold.

SILVER-LEAD-ZINC VEINS

HIGHLAND BOY

The Highland Boy group of six claims lies adjacent to the International Boundary on the north side of Sittakanay River. It is owned by William Donaldson and Dr. C. P. Jennie, and is one of the oldest, if not the oldest, groups in the map-area.

The showings occur in pre-Permian rocks just west of a draw that crosses the ridge and is largely filled with drift. The workings consist of an adit 72 feet long, a shallow pit above the end of this, several open-cuts, and a shaft in the draw, which in 1932 had not reached bedrock.

The quartzites and quartz-mica schists here are intensely folded and give the impression of a succession of small, nearly isoclinal folds. They strike slightly east of north, and dip mainly to the east. Like all the pre-Permian rocks they carry large masses of barren quartz; besides this there are quartz veins carrying massive pyrite, and a vein of galena and arsenopyrite on which most of the work has been done.

The vein lies in a shatter zone that strikes north 35 degrees east and dips vertically. At the south end of the above-mentioned pit, which is about 20 feet long, a stringer less than an inch wide carries arsenopyrite and galena. At its north end a foot of quartz carries arsenopyrite, which is said to run $11 a ton in gold; and beside it an irregular stringer an inch wide of arsenopyrite, pyrite, and galena said to carry silver values. West of this is 3 feet of quartz with pyrite, said to run $1.50 to $2 a ton in gold. About 60 feet north of the pit a shatter zone of quartz and schist is visible, carrying much pyrite in places, and reported to have yielded three samples carrying high gold assays, which, however, could not be repeated. At 90 feet beyond the pit a trench shows pyrite stringers cutting quartz and schist, and said to assay $1.50 a ton in gold.

The adit, which runs west from the draw, cut what was supposed to be the downward extension of the vein in the pit at about 69 feet from the portal. The vein in it is a stringer 3 inches wide of quartz and pyrite.

GOLD-ARSENOPYRITE VEINS

SILVER BIRD

In the Palæozoic rocks on the Silver Bird claims gold values have been found in certain quartz veins across an area perhaps 75 feet wide across the strike. Though many of the veins are barren, like most of the quartz in the Palæozoic rocks, others are said to assay from $1 to $2, with erratic assays up to $30 a ton. These veins were found in the valley of a small stream called Middle Creek, which lies just beyond the area of Stuhini volcanic rocks.

Careful examination has shown that the quartz veins are of two types. A creamy, massive, fine-grained variety is the barren quartz common throughout the Palæozoic rocks. The other has a darker grey colour, is more vitreous, and carries vugs filled with quartz crystals. It occurs in irregular masses, in tiny stringers, and as breccia cement. Hand specimens show smears of a light bronzy white mineral, which tarnishes to resemble an unusual variety of pyrite. Polished specimens show that it is arsenopyrite, in thin streaks up to ½ inch long. The association is very similar to that present in the gold deposits in the volcanic rocks, and the two are, therefore, considered to be closely related.

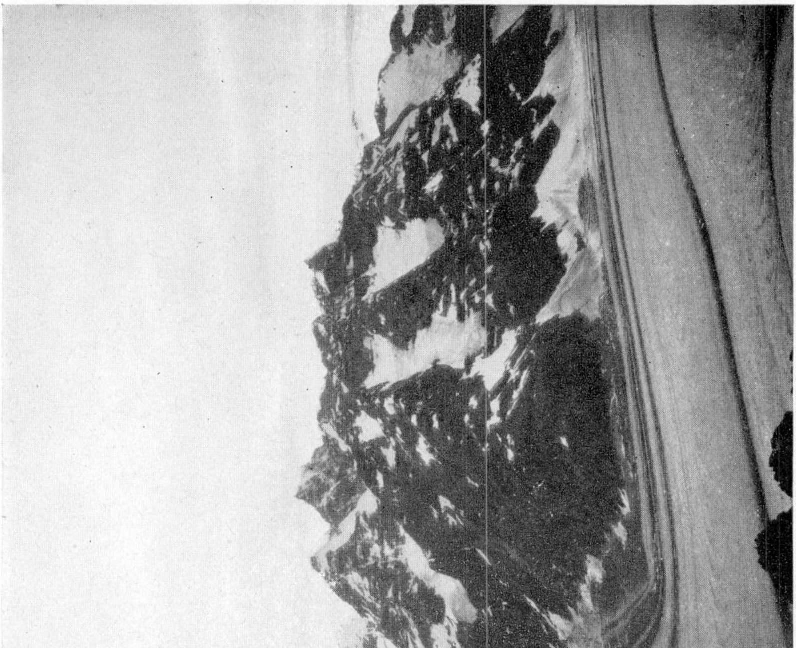
GRAPHITE

The owners of the Red Cap group of claims have reported the presence of graphite on the top of the ridge a mile northwest of Mount Lester Jones. Some samples weighing more than a pound were brought down, and appear to be high-grade graphite with a somewhat sheared texture. As no coal or carbon, from which the graphite might have formed by alteration, has been found in the King Salmon or Stuhini rocks, the graphite is probably vein material.

COAL

No coal of economic importance has been found within the map-area, although some very thin seams occur at the base of the Sinwa limestone, and there is much carbon in all the post-Triassic rocks. If coal seams exist, they are most likely to be found in the Takwahoni or the lower part of the Sinwa groups. A 4-foot seam has been reported on Taku River 12 miles above the head of canoe navigation, the limit of which is usually considered to be the junction of Sloko and Nakina Rivers, at the extreme northern limit of the area mapped.

Plate II



View southwesterly across Tulsequah Glacier and up ice-strewn tributary to Tulsequah Lake. Photo by International Boundary Commission, 1910. (Page 4.)

PLATE III

View easterly across Taku River Valley to Mount Lester Jones, in right background. Note the steep slopes above the main valley bottom, and approximate elevation of timber-line. (Negative R.B. 135-1930.) (Pages 9, 14.)

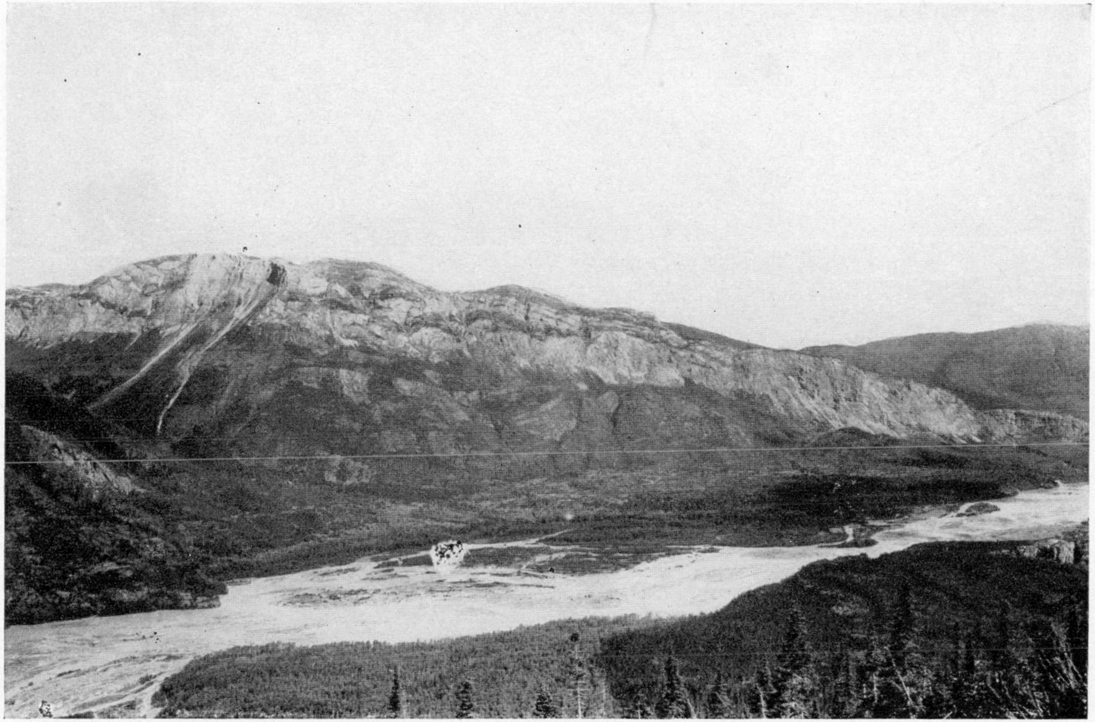
PLATE IV

View southwesterly down Taku River Valley from near Mount Headman, over wide flat on either side of the lower courses of King Salmon and Takwahoni Creeks. (Negative R.B. 50-1930.) (Page 14.)

PLATE V

View northerly up Nakina River Valley to beyond the northern boundaries of the map-area. The relative low relief and rolling topography of this western margin of the Stikine Plateau is in marked contrast with that of the Coast Mountains on either side of Taku River. (Negative R.B. 9-1930.) (Page 13.)

PLATE VI



View northerly across upper Taku River Valley towards Sinwa Mountain, showing section of the Sinwa limestone formation (light grey). (Negative R.B. 106-1930.) (Page 35.)

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