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MEMOIR 329

GEOLOGY OF TERRACE MAP-AREA, BRITISH COLUMBIA

(103 I E½)

S. Duffell and J. G. Souther

1964

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PLATE I. View southwesterly into Coast Mountains from O. K. Range.

GEOLOGICAL SURVEY
OF CANADA

MEMOIR 329

GEOLOGY OF TERRACE MAP-AREA, BRITISH COLUMBIA (103 I E½)

By
S. Duffell and J. G. Souther

DEPARTMENT OF
MINES AND TECHNICAL SURVEYS
CANADA

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GEOLOGY OF TERRACE MAP-AREA, BRITISH COLUMBIA
(103 I E ½)

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GEOLOGY OF TERRACE MAP-AREA, BRITISH COLUMBIA

Abstract

Terrace map-area covers 2,800 square miles of the Coast and Hazelton Mountains of west-central British Columbia. The Coast Mountains are composed largely of rocks of the Coast Intrusions, which cut sedimentary and volcanic rocks from Permian to Cretaceous age. The main contact runs, generally, northwesterly but large apophyses extend eastward. Granodiorite and adamellite predominate in the main mass and quartz-diorite, diorite, gabbro, and minor syenite in the apophyses and stocks; true granite forms a minor component of both. These rocks may be divided into four main facies on the basis of type and proportion of mafic content: gabbro, pyroxene-quartz diorite, inner, and border facies. Each facies may be subdivided again on a basis of textural and colour variation.

Dykes fall into four main groups and are instrumental in the location of mineralized quartz veins.

The Hazelton Mountains to the north are composed largely of sedimentary strata of Upper Jurassic-Lower Cretaceous age, here named the Bowser Group. These rocks, previously included with the Hazelton Group or referred to as the Skeena Formation, are now known to underlie thousands of square miles of north-central British Columbia, and are sufficiently distinctive to be classed as a group.

The Pleistocene period produced the wide, flat, gravel- and clay-filled Kitimat-Kitsumkalum Valley, so important now to the economy of the area, providing ample room for industrial and urban development.

Occurrences of gold, silver, lead, zinc, and copper minerals are common.

Résumé

La région de Terrace couvre une superficie de 2,800 milles carrés et englobe une partie de la chaîne Côtière et des monts Hazelton, dans le Centre occidental de la Colombie-Britannique. La chaîne Côtière se compose principalement de roches des Intrusions côtières, qui coupent des roches sédimentaires et volcaniques dont l'âge varie du Permien au Crétacé. Le contact principal s'étend généralement vers le nord-ouest, mais d'importantes apophyses se prolongent vers l'est. La granodiorite et l'adamellite prédominent au sein de la masse principale, tandis que la diorite quartzeuse, la diorite, le gabbro et un peu de syénite se rencontrent surtout au sein des apophyses et des stocks. Dans les deux cas, on trouve du granite typique en tant que constituant secondaire. Ces roches peuvent être divisées en quatre faciès principaux selon le type et la quantité des minéraux mafiques: gabbro, diorite à pyroxène et à quartz, faciès intérieur et faciès limitrophe. Chacun des faciès peut à son tour être subdivisé selon les variations de texture et de couleur de la roche.

Les dykes forment quatre groupes principaux et ont influé dans une certaine mesure sur le lieu de formation des filons de quartz minéralisés.

Les monts Hazelton, au nord, se composent surtout de strates sédimentaires dont l'âge varie du Jurassique supérieur au Crétacé inférieur et auxquelles on donne le nom de groupe Bowser. Ces roches, qu'on rattachait autrefois au groupe Hazelton ou qu'on surnommait formation Skeena, forment, comme on

le sait maintenant, les assises d'une aire de plusieurs milliers de milles carrés dans le Centre-Nord de la Colombie-Britannique. Elles sont suffisamment typiques pour qu'on puisse les classer comme groupe.

La vallée de Kitimat-Kitsumkalem, qui est large, planche et remplie de gravier et d'argile, s'est formée au Pléistocène. Elle est aujourd'hui très importante pour l'économie de la région, car on y trouve amplement d'espace pour l'établissement d'industries et d'agglomérations urbaines. La région renferme de nombreux gîtes d'or, d'argent, de plomb, de zinc et de cuivre.

PREFACE

Early geological work in Terrace map-area was mainly concerned with mineral deposits. The present study of the geological setting for these deposits is also part of a program of systematic geological investigation designed to furnish a better understanding of this complex and important part of British Columbia, and is a continuation of the work started in Whitesail Lake map-area. It is particularly timely because of the recent construction and development of the aluminum smelter and town at Kitimat nearby.

The authors present revisions to the stratigraphy of the area, the results of a detail study of granitic rocks of the Coast Intrusions, and a discussion of the mineral possibilities.

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

OTTAWA, June 16, 1963

Memoir 329—Geologie des Kartenblattes von Terrace, Britisch-Kolumbien.

Von S. Duffell und J. G. Souther

Beschreibt die Geologie eines gebirgigen Gebiets im Westen des mittleren Britisch-Kolumbien, Ein groβer Teil des Berichts befaβt sich mit einer Erörterung der groβen Granitmassen, die in sedimentäre und vulkanische Gesteine des Spätpaläozoikums und des Mesozoikums eingedrungen sind.

Мемуар 329 — Геология листа геологической карты Террас в Британской Колумбии.
Авторы: С. Дуффелль и Дж. Г. Соутер.

Описание геологии горного района в западно-центральной Британской Колумбии. Большая часть работы посвящена описанию и истолкованию крупных гранитных тел внедренных в осадочных и вулканических породах поздне-палеозойского и мезозойского возраста.

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Chapter I

INTRODUCTION

Terrace map-area covers about 2,800 square miles of the Coast and Hazelton Mountains of west-central British Columbia, between latitudes 54° and 55°N and longitudes 128° and 129°W.

The writers commenced the study of the area in 1953 and completed the field work in 1955. Souther spent two seasons in that part of the area east of Skeena River and Kitimat River valleys, from the southern boundary north to Legate Creek. His work included a special study of the batholithic rocks and particularly the eastward-trending apophyses. Duffell studied the remainder of the area.

Location and Accessibility

The town of Terrace, situated near the confluence of Skeena and Kitsumkalum Rivers, is the main business and administrative centre of the area. Kitimat, 40 miles south of Terrace at the head of Kitimat Arm, was in the early stages of construction and development during the period of the survey. Shames, Remo, Dobies, Usk, Pacific, and Dorreen are all small centres along the Canadian National railway. The small settlement of Copper River at the junction of Zymoetz and Skeena Rivers includes a store and several family dwellings. Summer cottages and a few permanent dwellings compose the growing community at Lakelse Lake.

The Prince Rupert line of the Canadian National Railways runs diagonally across the area along the north and west sides of Skeena River and a branch line connects Terrace with Kitimat.

The main gravel highway follows the east and south sides of Skeena River crossing by bridge at Terrace to the north side where it continues to Prince Rupert. Ferry crossings of Skeena River may be made at Usk and Copper River. Poorly maintained roads extend short distances from Usk and Dorreen; a good gravel road connects Terrace with Kitsumkalum Lake along the east side of Kitsumkalum River. On the west side of Kitsumkalum River and Lake the Columbia Cellulose Company has built a system of roads to facilitate their logging operations. Roads extend up all the major valleys to the west of Kitsumkalum Valley and the main road extends up Cedar River to Sand Lake and beyond the northern boundary of the map-area. A good gravel road connects Terrace with Lakelse Lake, and extends south to connect with Kitimat. An old wagon road passable by jeep extends up Zymoetz River as far as Dardanelle Creek. A number of mining and logging roads are passable by jeep but are not generally usable.

A good trail has, at some time, been cut along practically every major tributary stream draining into Skeena and Kitsumkalum Rivers, but over the years few of these trails have been maintained. Relatively good trails were found from

Lakelse Lake to Kitimat River, but not so up the river and along Zymoetz River above Dardanelle Creek, up Chimdemash, Legate, Shannon, Goat, and Douglas Creeks. A good trail leads from Rosswood to mining claims on Maroon Mountain and from the Lakelse road up Mount Thornhill.

The lack of good trails together with the rugged topography and dense forest cover makes the use of pack-horses impossible, hence resort must be made to back-packing in all parts of the area that are more than 3 to 4 miles from a main road.

Charter and scheduled airlines operate from an all-weather field at Terrace airport, and charter float-plane service is available at Lakelse Lake.

The charter air service was used to air-drop supplies on mountain ridges distant from the main routes of access; back-packing was done up to and between drops. This method of operation greatly facilitated work in the more remote parts.

Climate, Forest Cover, and Fauna

The greater part of the map-area lies in the Coast District of British Columbia and has a typical coast climate. Only in the northeast corner does the climate approach that of the interior of the province.

High local relief in the Coast and Hazelton Mountains causes wide variations in climate within the map-area. According to Köppens classification, the Skeena and lower Kitimat valleys are "Marine West Coast" with warm, temperate rainy climates. At elevations between 2,500 and 3,000 feet the climate is "Humid Continental—Cool Summer", and between 3,000 and 5,000 feet it is "Humid Continental—Cool Short Summer". Above 5,000 feet the average temperature of the warmest month is less than 50°F, which places those regions in Köppens "Polar" classification.

Records of rainfall are available only for Terrace and Kitimat. At Terrace over a 38-year period to 1954 the average annual rainfall was 49.5 inches but at Kitimat it was 89 inches over a 13-year period. The summers of 1953 and 1954 were unusually wet. In 1953 between June 1st and September 15th rain was recorded on eighty-seven days, and during a similar period in 1954 rain was recorded on seventy-three days. A more serious deterrent to field work was the fog and low clouds that shrouded the peaks and ridges making travel along them hazardous. Warm moist air from the Pacific Ocean, driven inland by prevailing west winds, condenses over the mountains to form a persistent layer of cloud. North of Oliver Creek on Skeena River the vegetation changes and the dense undergrowth disappears, indicating a much lower precipitation in the valley there than farther west and south. Snowfall in the mountains was particularly heavy during the period of the survey. Snow covered the hills down to 4,000 feet elevation as late as mid-July, and in some protected localities it lasted into August.

The type and density of forest cover varies with elevation from dense rain forest in the lower valleys to an alpine, sub-arctic flora above 4,000 feet. In the valleys the abundant trees are western red cedar, western hemlock, amabilis fir,

and black spruce. Less common, are sitka spruce, yellow cedar, and lodgepole pine. Some cottonwoods grow on the river flats near Terrace; near Dorreen along the river, groves of poplar may be seen. Most of the forest is fully mature with trees from 100 to 200 feet high predominating. These screen a great deal of sunlight from the forest floor, which is permanently damp and covered by a luxurious growth of mosses, ferns, devil's club, soapberry, and many other broad-leafed plants.

On mountain slopes below 3,500 feet western hemlock, lodgepole pine, and white spruce are dominant species. At these elevations the forest floor is relatively free of undergrowth. Above 3,500 feet and up to timber-line, alpine fir and mountain hemlock are common. Areas below timber-line that are free of large trees are invariably choked with a dense, tangled growth of alder and willow. Red alder, trembling aspen, black cottonwood, and a few Douglas maple from Skeena Valley. Smaller animals present in important numbers include fisher, marten, weasel, mink, muskrat, skunk, beaver, fox, coyote, lynx, marmot, and rabbit.

Moose, and black and grizzly bear are general throughout the area. Mountain goat are found on all the higher ranges and Coast deer are occasionally reported from Skeena Valley. Smaller animals present in important numbers include fisher, marten, weasel, mink, muskrat, skunk, beaver, fox, coyote, lynx, marmot, and rabbit.

Franklin's grouse is the most common gamebird. Blue and ruffed grouse are also represented, and ptarmigan are plentiful above timber-line.

Sockeye, spring, and cohoe salmon ascend Skeena and Kitimat Rivers and tributaries. Sockeye were observed spawning in Kitimat River up to but not beyond Davies Creek. The salmon are followed upstream by hair seals which are common in Skeena River and the lower part of Kitimat River.

Population and Industry

Settlement in the map-area is confined to the Skeena, Kitimat, and Kitsumkalum Valleys. During the time the work for this report was being carried out, Kitimat was under construction and Terrace was the major centre for the area. In 1939 the population of Terrace was 900; construction activity in the area subsequent to World War II caused a great influx of people, and by 1956 the population had increased to about 8,000. The town of Kitimat was well under construction in 1955, and the *Financial Post* for March 23, 1957, estimated the population[1] at 13,000 in homes and 5,000 in camps. The population of the rest of the map-area is approximately 500 persons.

Prior to the construction of the aluminum smelter at Kitimat, logging was the prime industry. The Columbia Cellulose Company maintains its woods division at Terrace, thus making the town the centre for the company's huge forest management operations west of Kitsumkalum River. Several smaller logging and sawmill

[1] *Canadian Official Railway Guide* for 1963 gives the population as 8,000.

operations at Terrace and Usk and along Skeena River provide employment for local residents. Operations of the Canadian National Railways with such centres as Terrace, Kitimat, and Pacific also provide continuing employment.

Mining and prospecting have been a small but important industry in the area since early time. Gold, silver, copper, lead, and zinc have all been produced in small quantities, and in 1953 high grade limestone was being quarried for use by the Columbia Cellulose Company.

With the increase in population over the past decade agriculture has taken on a more important role. Main development has been near Terrace where fruits and vegetables are readily cultivated along the terraces and river flats. A few families derive their entire income from agricultural pursuits but with an expanding market at Kitimat for farm produce more of the population will be engaged in farming generally.

Increased services required by future increases in population at Kitimat and Terrace will bring secondary and subsidiary industries to the area. Terrace itself, at the junction of the Skeena-Kitsumkalum and Kitimat Valleys, is well situated to become a major junction and distributing centre. It has one of the few all-weather airfields in western British Columbia, is a rail and road junction point, and is only 40 miles by rail or road from an ocean port at Kitimat. In addition the broad expanse of valley at Terrace and between Terrace and Kitimat allows ample space for residential and industrial sites. It seems, therefore, that the economic future of the area should be bright.

Previous Work

Previous geological surveys in the area have all been of an exploratory or reconnaissance nature. The first geological report was by James Richardson (1876)[1] of the Geological Survey of Canada, who in 1874 visited the present site of Kitimat with C. Horetsky, a Canadian Pacific Railway survey engineer. Richardson described briefly the wide Kitimat Valley and some of the surficial deposits in it. In 1877, another railroad engineer, H. J. Cambie, traversed Skeena River from Port Essington to Bulkley River and described the conditions along the route (Cambie, 1878).

In 1879, G. M. Dawson (1880) made a geological reconnaissance along Skeena River from Port Essington to Bulkley River. He correlated the volcanic rocks north of Kitselas with the Porphyrite group of François and Tatlayoko Lakes.

During the seasons 1906 to 1910 W. W. Leach (1907, 1911) conducted geological investigations in Bulkley Valley and upper Skeena Valley north of Kitselas. His work on the stratigraphy of the Porphyrite group in the vicinity of Hazelton revealed the transition of the so-called Porphyrite group from volcanic to sedimentary rocks. This led Leach to rename the group the Hazelton Group. During the season of 1910 Leach (1911) reported briefly on the mining properties and the geology at the head of Kleanza Creek.

[1] Names and/or dates in parentheses are those of publications listed in the Bibliography.

Following the completion of the Grand Trunk Pacific Railway in 1912, R. G. McConnell made a study of the section exposed along the route from Prince Rupert to Aldermere, British Columbia. In addition to the Hazelton Group, he recognized sedimentary and volcanic rocks of Triassic age and sedimentary rocks of Cretaceous age which he referred to as the Kitselas Formation and the Skeena Formation respectively. He also described, briefly, crystalline rocks of the Coast Range and outlying stocks.

After World War I, further mapping and geological investigations were carried out on a more comprehensive scale. From 1922 to 1925 George Hanson of the Geological Survey made reconnaissance trips from Skeena River to Kitsault River and to Stewart; from Prince Rupert to Burns Lake; and in the upper part of Zymoetz River. The Zymoetz River study, done in 1925, included a part of the Terrace area east of Skeena River between Zymoetz River and Oliver Creek. It was the first study to demonstrate the very irregular nature of the eastern contact of the Coast Range batholith and to call attention to the varying composition of the intrusive rocks. The only additional mapping within the area was done by J. R. Marshall, who in 1926 studied a small area near Lakelse Lake.

Mineral deposits in the area have been examined by various members of the British Columbia Department of Mines, and during the seasons of 1935 and 1936, E. D. Kindle (1937a, b) of the Geological Survey of Canada studied the mineral properties near Terrace and along Skeena River to Cedarvale just beyond the northern boundary of the map-area.

The Prince Rupert sheet (Map 278A, 1933) presents a compilation of all the above work to that date and is the most complete published map of the area. No systematic mapping has been done in this area between Kindle (1937) and the commencement of the work described in this report.

Acknowledgments

Many persons gave assistance and extended courtesies. Mr. and Mrs. J. Bell of Usk were particularly helpful and took personal interest in the work; the late W. Cooper of Pacific Western Airlines cooperated in planning and executing air-drops, and supplied general information on the country. For courtesies extended in the field the writers are also indebted to the staff of the Columbia Cellulose Company, and to George Smith of McElhaney, McRae, Smith, and Nash, consulting engineers of Vancouver, British Columbia.

That part of the report dealing with the granitic rocks and pre-Bowser Group stratified rocks formed part of a Ph.D. thesis by J. G. Souther at Princeton University where all the petrographic work of these rocks was done. Grateful acknowledgment is made to the faculty of Princeton for their help and criticism. In particular the writer is indebted to Drs. A. F. Buddington and H. H. Hess for critical reading of the thesis manuscript, and to Drs. F. B. Van Heuten and B. F. Howell for helpful suggestions.

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Thin sections were prepared in part by the lapidary section of the Geological Survey and in part by the lapidary section at Princeton University. All fossil identifications were made by officers of the Geological Survey of Canada.

R. Kretz, G. Poulter, and H. Greenwood were capable senior assistants. R. Nixon, A. Kieth, P. W. Brock, T. Antoniuk, D. Fletcher, H. Carswell, R. Nelles, C. R. Saunders, H. Dougan, and A. Kryzka rendered service as field assistants.

Chapter II

PHYSICAL FEATURES

The region is best described as one of complex mountainous topography at a stage of early maturity; rugged mountainous terrain is dissected by deeply incised river valleys. Pacific Ranges of the Coast Mountains occupy by far the greater part of the area, with ranges of the Hazelton Mountains only in the northern third. The Coast and Hazelton Mountains are similar in general aspects; both include peaks more than 9,000 feet in elevation with local relief of 5,000 to 7,000 feet. Both have been modified by alpine glaciation and their higher ranges are characterized by serrated ridges, horn peaks, cirques, and cols. Alpine glaciers are common to both.

The boundary between these two physiographic units is not clearly defined but is generally considered to lie through the deep valleys of the Cedar, Kitsumkalum, Skeena, and Zymoetz Rivers.

Coast Mountains

The Coast Mountains in Terrace map-area are typical of the Pacific Ranges. The lower peaks—4,000 to 5,000 feet in elevation—have well-rounded tops but very steep sides. The higher peaks and ridges are sharp crested, commonly serrated, and have cirque glaciers and permanent snowfields (*see* Pl. I). Streams cutting these ranges are deeply incised and occupy canyon-like gorges. These ranges are composed almost entirely of granitic rocks with minor amounts of metamorphic rocks.

Hazelton Mountains

The Hazelton Mountains (Pl. II), in contrast to the Coast Mountains, are composed mainly of Upper Jurassic and Lower Cretaceous sedimentary strata and minor volcanic rocks. Granitic stocks and cupolas form the core of many of the ranges but such rocks are relatively rare. The Seven Sisters Peaks (Pl. II A) with peaks up to 9,140 feet—the highest in the area—are the most spectacular of the Hazelton Mountains. The lower parts of these ranges are fairly easy to ascend, but the peaks are rugged and commonly sharp crested. Many of the areas just at timber-line are parklands with open spaces, small lakes, and stunted evergreens. Except for the higher peaks, the Hazelton Mountains are not so rugged as their granitic counterparts in the Coast Range.

Drainage and Drainage History

Except for those streams tributary to Kitimat River and minor streams flowing directly into Kitimat Arm, all drainage in the area is tributary to Skeena River with Zymoetz and Kitsumkalum Rivers being major tributaries.

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The two major streams are at grade or nearly so. A few small rapids remain but for the most part their valleys are characterized by broad flood plains one half mile to two miles wide and two to three times the width of the meander belt. Major tributaries are still actively down-cutting. Rapids and falls are common and flood plains have been built only where a transient base-level has been established by resistant rock. Secondary tributaries are all in the early youth stage—many form a continuous series of falls and cascades throughout their entire length.

The drainage is not normally integrated. Major rivers are superposed and show little or no relation to structure, though the Kitsumkalum-Kitimat drainage valley may be a result of faulting. Locally, jointing has exerted drainage control as is indicated along Skeena River between Kitselas and Pitman. There tributaries on opposite sides of Skeena River occur in pairs, their mouths directly opposite. Each pair forms a smooth east-west arc, convex to the north and parallel with a major joint set in the granodiorite. A very pronounced instance of joint controlled drainage is exhibited by Williams Creek where it flows through an area of granodiorite possessing perfect rectangular jointing.

Perhaps the most spectacular physical feature of the whole area is the broad drainage valley, referred to in this report as the Kalum-Kitimat Valley, that extends north from Kitimat Arm across Skeena River up Kitsumkalum and Cedar Rivers thence across a low divide to Sand Lake and beyond the northern boundary of the map-area, finally to meet with Nass River. The floor of this valley, now neavily forested, is from 2 to 7 miles wide and relatively flat. Kitimat River which occupies its southern part, and Kitsumkalum River, to the north, are obvious misfit streams, too small to have built such an extensive flood plain. The large amount of fluvioglacial deposits of sand, gravel, silt, and clay that covers the valley bottom from Kitimat to Kitsumkalum Lake indicates that the Pleistocene period played an important role in the physical history of this dominant feature.

The common occurrence of the U-shaped cross-section of stream valleys and the rounded nature of the lower hills attest to former continental glaciation. Grooves and striations along Skeena River indicate ice movement down this valley; all major valleys were probably avenues of escape for the accumulations of ice in the adjacent mountainous areas. During the last stages of the glaciers these valleys were flooded with meltwater and filled with fluvioglacial material.

In pre-Glacial times it is most probable that the ancestral Nass and Skeena Rivers flowed through the Kalum-Kitimat Valley to Kitimat Arm. Headward erosion by the lower Nass and lower Skeena Rivers subsequently captured the older drainage and diverted it to the present westward course. The time of this event is difficult to determine. It may have occurred prior to the formation of the Cordilleran ice-sheet, but it was certainly accomplished by the close of the Pleistocene period.

Estuarine deposits of silt and sandy blue-grey clay containing marine shells are exposed along the banks of Kitimat River from its mouth up to the point where it turns eastward out of the main valley. Between this point and Lakelse the

gradual seaward slope of the Kalum-Kitimat Valley is interrupted by a relatively high, pitted outwash plain that forms the divide between Kitimat drainage on the south and Skeena drainage on the north. Road-cuts on the north and south edges of the plain expose crudely stratified glacio-fluvial sand, gravel, and boulders. Except for numerous kettles—of which Onion and Clearwater Lakes are the largest—the surface of the plain is flat and stands between 600 and 700 feet above present sea-level. An abandoned meltwater channel about 20 feet deep and several hundred feet wide cuts across the plain near Onion Lake. Like the surface of the plain, the bottom of the channel is perfectly flat, suggesting that it was cut down to grade level.

North of the pitted outwash plain, extensive deposits of marine clay are exposed in road-cuts along the east side of Lakelse and along the railway west of Lakelse where they rest directly on glacially polished bedrock. The most northerly exposure of marine clay was noted near the bridge across Williams Creek where about 65 feet of clay is exposed at an elevation of 400 feet above sea-level. The bluish grey to brown clay beds are one half inch to 4 inches thick and separated by thin porous sandy layers. South of this exposure, near Furlong Creek, the clay contains many ice-rafted boulders and pebbles as well as marine shells. The latter have been identified by Miss F. J. E. Wagner of the Geological Survey who says:

> The shell fragments are those of the marine pelecypod *Mytilus edulis.* This species normally lives on rocky shores, but is also known to attach to stones and other shells along muddy shores. The shells are fragile and weather readily. Preservation of the specimens submitted would suggest little or no transport after death, quick burial, and no reworking of the deposit. A marine origin is indicated for the clay.

East of Lakelse the top of the clay is between 400 and 500 feet above sea-level. It is overlain by about 200 feet of stratified sand and gravel with foreset beds dipping 15 to 20 degrees south. These beds are overlain at the surface by a layer of boulder till from 5 to 10 feet thick.

North of Lakelse, between Sockeye Creek and Skeena River, is a second large outwash plain on which the Terrace airport is built. Like the kettled plain south of Lakelse, this surface is between 600 and 700 feet above sea-level and steeply dipping foreset beds around its western perimeter indicate a deltaic origin. A prominent ice-contact face crosses Skeena Valley about 2 miles northeast of Terrace airport and forms the northeastern boundary of the outwash plain.

The foregoing data indicate a complex glacial history including at least two major glacial advances and two prolonged halts in the final recession of the ice. During the advance of Pleistocene ice the Kalum-Kitimat Valley was scoured and most of the original deposits were removed. Ice filled the valley and moved southward down Kitimat Arm. Towards the end of glaciation the ice receded northward and was followed inland by an arm of the sea that drowned the valley up to at least the 600-foot contour. It is not known how far the glacier retreated up Skeena Valley as no marine deposits have been recognized beyond Williams Creek. During this retreat the thick deposits of marine clay were deposited. Melting icebergs

dropped their load of sand and boulders onto the muddy bottom where it was buried along with the shells of marine molluscs. Along the margins of the estuary, deltas of sand and gravel were built on top of the finer sediments and some of these have been preserved as terraces along the valley walls between 600 and 700 feet above sea-level.

The glacial retreat was followed by a rapid advance which brought the ice-front to a point 3 miles south of Lakelse where it stagnated in a curving arc between Forceman Ridge and End Lake. A prolonged halt in ice movement followed, during which time the great kettled plain south of Lakelse was built. The surface of this plain must once have been a broad tidal flat at the head of a fiord.

This period of stagnation was followed by a steady recession of the glacier. As the glacier retreated northward a lake must have formed between its nose and the ice-contact face that forms the northern edge of the pitted outwash plain. For a short time this lake continued to drain southward through the shallow meltwater channel near Onion Lake but the present westward drainage must have been established shortly after the ice receded to a point north of Lakelse River. As the ice receded it deposited a thin boulder till which is preserved on top of the deltaic deposits formed during the earlier marine submergence.

A second prolonged halt in the recession of the ice is indicated by the ice-contact face that crosses Skeena Valley east of the Terrace airport. During this time the extensive sand and gravel deposits north of Lakelse were laid down. Unlike the flat surface of the kettled plain south of Lakelse, this surface slopes gently towards the southwest. Steeply dipping foreset beds along the western and southern perimeter of the plain indicate that the flood plain was deposited in water that flooded the Skeena Valley up to at least the 600-foot contour. Although no fossils have been found in these deposits, it is probable that the water was an arm of the sea extending up Skeena Valley. This is suggested by the nearly identical elevation of the deltas in this flood plain and the surface of the pitted outwash plain south of Lakelse.

Widespread submergence is also indicated by the presence of persistent terraces along Skeena and tributary valleys at an elevation between 600 and 700 feet. In the Kitsumkalum Valley the 700-foot terrace stops about a mile north of Deep Creek where it is separated by a gentle slope from a 400-foot terrace above the town. This lower terrace has been recognized at the mouth of Williams Creek and at many other points in the Skeena Valley and probably indicates a slight pause in the gradual withdrawal of the sea.

Terraces above the level of maximum submergence are also present. These are the work of marginal lakes and marginal meltwater channels during periods of glaciation. A persistent terrace 20 to 100 feet wide at an elevation of about 1,000 feet follows the south slope of Zymoetz River for 14 miles without any measurable change in elevation. Isolated remnants occur at about the same elevation on Skeena and Kleanza Valleys.

As the load of Pleistocene ice was removed the land began to rise and the Skeena and Kitsumkalum Rivers eroded through the old flood plain. The immense

deposits of sand and gravel resulting from the Pleistocene period are of importance economically as well as geologically, and have provided extensive level areas suitable for the location of industrial and residential areas.

The Kalum-Kitimat Valley probably represents the surface expression of a major fault. The valley is a wide, fairly straight lineament with different rocks on each side. The main contacts are offset across the valley indicating some disruption.

The east side of the valley is underlain by granitic rocks as far north as Kitsumkalum Lake, but on the west side sediments of the Bowser Group come as far south as Zymagotitz River. There are more roof pendants and inclusions on the west side of the valley than on the east side. The hot springs at Lakelse Lake and the recent lava flow in the valley just north of the map-area indicate the presence of a disturbed and active zone. The geology suggests the relative movements to be that the east side moved upward and northward relative to the west side. This would account for the variation in rocks on opposite sides of the valley.

Chapter III

GENERAL GEOLOGY

The geology of Terrace map-area may briefly be stated as that of a part of the eastern contact of the Coast Range batholith, and the flanking metamorphosed sedimentary and volcanic rocks that range in age from late Palaeozoic to early Cretaceous. The stratigraphy of the thick sequence (15,000 to 20,000 feet) of metamorphosed volcanic and sedimentary rocks is imperfectly known. Correlations of sections from one area to another, or even from one place to another in a small area, cannot be made with certainty. Fossil evidence obtained proves the existence of rocks of Permian, Triassic, Jurassic, and Cretaceous? age, but their boundaries are difficult to establish. Some earlier workers have considered the whole Mesozoic section to be conformable but the study described in this report suggests an angular unconformity between volcanic rocks referable to the Hazelton Group and the overlying sedimentary sequence referred to as the Bowser Group.

Fossiliferous Palaeozoic limestone and associated greenstones occur as small pendants in the batholithic rocks or as narrow lenses along the flanks of eastward-extending tongues of the batholith. Limestone boulder conglomerate, greywacke, and chert believed to be of Triassic age rest unconformably above the Palaeozoic rocks without marked angular discordance. Lying above the Triassic rocks in conformable succession is a series of volcanic and minor sedimentary rocks referable to Middle Jurassic strata of the Hazelton Group. These rocks may be divided into a lower division of coarse andesitic breccia, green andesite, and intercalated greywacke and argillite; and an upper division of red, green, and purple, porphyritic and amygdaloidal andesitic flows with minor basalt, rhyolite, and dacite. This upper division is lithologically similar to volcanic rocks lying conformably above Middle Jurassic sedimentary strata in Whitesail Lake map-area to the southwest (Duffell, 1959). Lying above the Middle Jurassic volcanic rocks with marked angular discordance is a series of marine and continental sedimentary rocks of Upper Jurassic age that may include some Lower Cretaceous strata and is referable to the Bowser Group. Marine beds near the bottom of this group yielded ammonites, pelecypods and brachiopods of Upper Jurassic age. Greywacke and argillaceous beds higher in the group yielded perfectly preserved plant remains mainly of Jurassic age but possibly including some of Cretaceous age.

The structure is dominated by the Coast Intrusions, which occupy most of the western and southwestern parts of the area and intrude all the sedimentary and volcanic formations described above. The main contact of the intrusions trends northwesterly across the area in an extremely irregular manner. Great apophyses extend northeastward nearly to the eastern boundary of the area. The intruded strata generally dip to the northeast, away from the main contact; local structures although often complex, tend to conform to the local configuration of the intrusive bodies.

Table of Formations

Era	Period or Epoch	Formation	Lithology
Cenozoic	Pleistocene and Recent		Sand, gravel, clay, silt
	Unconformity		
Mesozoic or Cenozoic	Cretaceous or later	Coast Intrusions	Mainly biotite granodiorite and adamellite, with border zone of hornblende granodiorite, quartz diorite, diorite, and migmatite. Outlying stocks of pyroxene-quartz diorite and gabbro
	Intrusive Contact		
Mesozoic	Upper Jurassic and Cretaceous	Bowser Group	Fossiliferous marine and terrestrial conglomerate, greywacke, and shale
	Unconformity		
	Jurassic	Hazelton Group	Porphyritic and amygdaloidal andesite flows; minor basalt, dacite, and rhyolite. Porphyritic andesite breccia, tuff, greywacke, argillite
	Conformable Contact		
	Triassic?		Limestone-boulder conglomerate, greywacke, shale
	Unconformity		
Palaeozoic	Carboniferous and Permian		Fossiliferous white limestone, argillaceous grey limestone, shale; greenstone

Granodiorite and adamellite (quartz-hornblende-mica diorite) are dominant rocks of the main batholith. Apophyses and stocks are generally more basic and consist mainly of quartz diorite, diorite, gabbro, and minor syenite. True granite is a minor component of both.

Dykes are abundant in the area and cut both bedded and batholithic rocks. They vary widely in composition and include such rock types as granite, diorite, aplite, lamprophyre, basalt, and porphyritic variations; pegmatites are conspicuous by their absence. Commonly dykes have exercised structural control on the localization of mineral deposits.

Regional metamorphism is of the lowest grade. Chlorite, muscovite, and minor epidote are present as secondary minerals in volcanic and sedimentary rocks but, with the exception of rocks near igneous contacts and faults, the texture and mineral composition of the original rocks have not been greatly altered. Contact metamorphism on the other hand has been extremely varied. Commonly rocks adjacent to the batholith are of the albite-epidote-amphibolite facies. Some rocks may show no megascopic alteration, whereas others fall within the highest grades of contact and dynamic metamorphism. Crystalline schists and gneisses of the latter type are more commonly developed along contacts with the main batholith than along contacts with apophyses and stocks.

Deuteric alteration of the granitic rocks, with the development of sericite, actinolite, and epidote, is almost universal throughout the area.

SEDIMENTARY AND VOLCANIC ROCKS

Palaeozoic

Permian and (?) Earlier

Rocks of Permian age, indicated by contained fossils, are exposed in several relatively small areas adjacent to intrusive contacts. Prior to the fossil evidence uncovered during the course of field work for this report, these rocks had been included with Mesozoic strata. Only Marshall (1927) had indicated the possibility that some of these may be older than Triassic. Main exposures are along Skeena River southwest of Terrace and on Mount Thornhill and Zymoetz River east of Terrace. These exposures form a rather discontinuous belt trending southwest near the town of Terrace.

The group consists of two thick limestone members underlain by structureless greenstones that are probably the metamorphic equivalent of a clastic sedimentary series. The lower limestone is a grey to black argillaceous calcareous rock interbedded with limy shales. The upper limestone member is bluish white massive pure limestone.

Distribution and Thickness

The best sections of these rocks are on the north side of Mount Thornhill and on the north side of Zymoetz River. Rocks included with this group are also

exposed along the highway west of Terrace between Remo and Shames and on the north face of Nash Ridge. Small outcrops of fossiliferous limestone of this group show through the heavy mantle of fluvioglacial material along the Remo road west of Terrace airport. On Zymoetz River, 2 miles above Dardanelle Creek, a small area of highly fossiliferous Permian limestone outcrops on both sides of the river. Similar limestone though unfossiliferous occurs adjacent to the intrusive contact north of Kleanza Lake and in several roof pendants.

No complete section was observed and the greenstone sections exhibit so little structure that any figure given for thickness of these rocks must of necessity be a vague estimate. The greenstone section on Nash Ridge, though interrupted by several small cupolas of granite, must have a thickness of at least 5,000 feet. The section on Mount Thornhill is also estimated to be at least 5,000 feet thick.

Lithology

The greenstone complex of this group is commonly so highly altered that little of the original character of the rocks remains. Epidote, chlorite, biotite, and hornblende are common minerals and many of the rocks may be classed as quartz-mica schists and pseudo-diorites. Silicification has been common and many rocks show the development of porphyroblastic feldspar; *lit-par-lit* injection and migmatization were also observed.

Despite the widespread alteration, outcrops were observed that suggested that many of the rocks in this complex belonged to a sedimentary sequence. Meta-calcareous greywackes and recrystallized blue-white limestone were observed on the small knoll at the mouth of Lakelse River. Though the actual outcrop was not observed the presence of limestone is indicated on Nash Ridge by boulders in White Creek. Meta-greywackes and meta-argillites were observed on Nash Ridge. Similar rocks occur north of Skeena River near Shames associated with limestone. Many of the rocks there show signs of granitization, with *lit-par-lit* injection and migmatite prevalent. Quartz-mica schist is common and small outcrops of scarn were observed.

The argillaceous limestone member, estimated to be about 1,000 feet thick, consists of interbedded shaly limestones, calcareous mudstones, and minor shales, all of which are highly fossiliferous. Slump structures and intraformational conglomerate are found throughout. Fragments of black calcareous mud and abundant mud-filled worm burrows are randomly distributed in a matrix of grey argillaceous limestone. This gives the rock a mottled appearance which is accentuated by the slightly dolomitic matrix.

Insoluble residues from three typical specimens each comprised about 30 per cent of the weight of the rock. They consisted of clay, silt, and silicified fossil remains of bryozoan and small brachiopods.

The upper white limestone member rests conformably on the argillaceous limestone. The contact is well exposed on the cliffs north of Zymoetz River immediately east of Dardanelle Creek and again on the south side of Zymoetz River

2 miles above the mouth of Dardanelle Creek. At both localities the transition from one to the other is complete within a few feet. In the section north of Zymoetz River 50 to 100 feet of fossiliferous pure white limestone comprises the lower part. Insoluble residues of eight specimens averaged 2.3 per cent and consisted of mica clay, silts, and a few grains of quartz. The white limestone is overlain by a 20- to 50-foot bed of impure limestone containing about 40 per cent large white fusulinids in a rose-coloured matrix of carbonate and iron oxide. This bed is a distinctive horizon marker and can be traced along the north side of Zymoetz River west of O.K. Creek, and picked up again on the roof pendant on Copper Mountain.

The above beds cannot be recognized in the section west of Mount Attree, which is presumably near the same stratigraphic horizon. There the limestone is pure white or white with fine discontinuous blue bands. It forms massive beds 10 to 30 feet thick, some of which are separated by coarse sandstone partings 5 to 6 feet thick. Of particular interest are several partings 1 inch to 2 inches thick, of angular pebbles of andesitic composition. These partings were observed to be only one pebble thick at some places. They possibly represent fragments blown out in a volcanic eruption.

Limestone lenses 400 to 500 feet thick outcrop near Shames. Most of this thickness is composed of argillaceous limestone with interbedded greenstone and quartz-mica schist, but a central bed 75 to 100 feet thick of bluish white limestone is sufficiently pure to be quarried for commercial use. No fossils were found in these beds but they have a similar occurrence and appearance to the rocks on Mount Thornhill and Zymoetz River.

Structural Relations

The Permian rocks are exposed only adjacent to igneous contacts, where they appear to have been dragged upward during intrusion. They conform to the igneous contacts and most commonly dip away from them. These rocks are separated from the overlying Triassic? rocks by an erosional unconformity without apparent angular discordance.

Age and Correlation

Fossils were collected from outcrops of limestone in several different localities. The similarity in faunas proves that the rocks at these localities belong to the same group or formation and are of the same age. Much of the material is fragmentary and poorly preserved but sufficient diagnostic material remained to identify the assemblage as of Lower Permian age. Details of the collections by P. Harker are as follows:

Locality: One mile northeast of the junction of Zymoetz River and Dardanelle Creek. (GSC loc. 25445)

Spirifer sp.
Neospirifer sp. cf. *N. cameratus* Morton

Marginifera sp.
Productus cf. *P. uralicus* Tschernyschew
Productus sp.
lophophyllid corals
Schwagerina sp. or possibly *Parafusulina* sp.

Locality: One mile northeast of junction of Zymoetz River and Dardanelle Creek, 300 feet stratigraphically below loc. 25445. (GSC loc. 25446)

Dictyoclostus sp.
Productus sp. *semirecticulatus* group
rugose coral

Locality: North bank of Zymoetz River, 1½ miles from mouth. (GSC loc. 25448)

Productus sp. brachial valve of large species, probably of *P. uralicus* type
Orthotetes sp.

Locality: North bank of Zymoetz River, 2½ miles from mouth. (GSC loc. 25449)

Pustula sp.
lophophyllid coral
fenestellid bryozoa

Locality: South bank of Zymoetz River, a mile above Dardanelle Creek. (GSC loc. 25450)

Lissochonetes sp.
Dictyoclostus sp.
Productus sp. cf. *P. uralicus* Tschernyschew
Lophophyllidium? sp.
fenestellid bryozoa
Tabulipora? sp.

Locality: On Remo road 3 miles west of Terrace airport. (GSC loc. 23484)

Spirifer sp. cf. *S. alatus* Schlotheim?
Neospirifer sp. ex gp. *N. cameratus* Morton
Dictyoclostus sp.
internal casts of brachiopods
numerous fenestellid bryozoa
moulds of crinoid stems

These collections contain a number of late Palaeozoic brachiopods that are found in both the Pennsylvanian and Permian. There is a broad general faunal similarity in all the lots and all are believed to be of approximately the same age. The two spirifers from locality 23484 are fairly typical late Carboniferous or early Permian forms. The *Dictyoclostus* fragment, from the same lot seems to be one of the late Palaeozoic coarse ribbed productids of *D. uralicus* type. The fusulinids from locality 25445 are of Lower or Middle Permian age.

The fusulinids in collection 25445 and the lithological nature of the rocks there indicate a correlation with the Cache Creek Group of southern and central British Columbia and the Braeburn and Taku Groups of northern British Columbia and Yukon. The Asitka Group (Lord, 1948, p. 11) of McConnell Creek area also contains fossils of Lower Permian age. (Harker, pers. com.)

Mesozoic

Triassic?

Rocks grouped as Triassic? in Terrace map-area are not well defined. Correlation is made on stratigraphic position, lithological similarities, and structural relations. No clear-cut distinction can be made between these rocks and those of the overlying Hazelton Group. They are separated from the underlying Palaeozoic rocks by an erosional unconformity and a basal limestone-boulder conglomerate, of which some boulders contain fossils of the underlying Palaeozoic rocks.

R. G. McConnell (1914) included the metamorphosed volcanic and sedimentary rocks bordering the Coast Range batholith along Skeena River in his Kitselas Formation to which he assigned a tentative Triassic age. Later workers (Hanson, 1923; Kindle, 1937) included all these rocks with the Hazelton Group, and they have subsequently been regarded as Hazelton. The writers believe that at least some of these rocks should be grouped as Triassic, particularly those on upper Kleanza Creek that unconformably overlie Permian rocks with the basal limestone-boulder conglomerate mentioned above. The conglomerate is believed by the authors to represent the basal member of the Triassic sequence. It is followed by a series of greywackes, banded volcanic sandstones, tuffs, minor limestones, and fine volcanic breccias, all part of the Triassic section.

Distribution

Triassic? rocks in Terrace map-area are similar to the Palaeozoic rocks in that they occur mainly adjacent to contacts with, or as roof pendants in, the batholithic rocks. Best exposures are at the east end of the O. K. Range, between Kleanza Creek and Zymoetz River, on Kitselas Mountain, on the eastern slope of Mount Attree, and at the heads of Williams and Schulbuckhand Creeks. Similar rocks are present on Bornite Mountain and Mount Vanarsdoll and Lean-to Mountain, as well as between Remo and Zymagotitz River. Several smaller areas were noted as roof pendants on Chist Creek and at the head of McKay Creek. Rocks at the base of Fire Mountain have been included with this group.

Lithology

The basal limestone-boulder conglomerate is the most easily recognized member of the succession. It varies greatly in thickness and in the section south of upper Kleanza Creek it is several hundred feet thick. The member is completely heterogeneous and rarely shows signs of bedding or banding. On weathered surfaces the limestone boulders have been partly or wholly dissolved giving the rock a distinctive

pitted appearance. The pebbles and cobbles consist of unsorted fragments of limestone, andesite, chert, and argillite. Average size is 3 to 4 inches but blocks up to 2 feet in diameter are common and a few reach a diameter of 3 feet. Chert fragments are most abundant near the base of the member and locally comprise the bulk of the rock. Chert pebble conglomerate is exposed immediately above the Permian limestone near the mouth of Zymoetz River and again on the ridge east of Mount Attree. About 75 per cent of the fragments are angular white, green and black chert ranging in size from $\frac{1}{16}$ inch to 2 inches. The remaining pebbles, mostly porphyritic andesite, silicified limestone, and argillite, are much more rounded than the chert.

The matrix of the conglomerate forms 15 to 20 per cent of the rock and near the base of the member consists largely of sand-sized detrital calcite and chert fragments, surrounded by finer iron oxide, calcite cement, and recrystallized rock flour. The percentage of calcite decreases upward in favour of increasing tuffaceous material and comminuted volcanic rock.

Lying conformably above the basal conglomerate is a series of greywackes, banded volcanic sandstone, siltstone, chert, and fine volcanic breccia. On Kleanza Creek and Mount Attree, sections of these rocks are approximately 1,000 feet thick. The lower 300 to 400 feet consists of massive beds of coarse-grained, unsorted, grey to pale green greywacke in beds 5 to 15 feet thick.

Fragments composing these rocks commonly vary from fine to coarse sand, and rarely do they reach a diameter as large as 2 or 3 inches. They are completely unsorted and commonly highly angular. Quartz and feldspar are major constituents but grains of calcite, iron oxide, and recrystallized chert occur in minor amounts. The quartz is present in clear distinct grains but the feldspar grains are so highly sericitized that it is difficult to distinguish them from the matrix. Because of this difficulty the ratio of quartz to feldspar is also difficult to determine. However, despite the tendency to underestimate the percentage of feldspar, it normally exceeds that of quartz. All the feldspar and most of the quartz grains are angular, but about one third of the larger quartz grains are well rounded and have high sphericity.

Pebbles contained in some of the greywacke beds are probably the best evidence of the rock types that provided the material for the rocks. These pebbles all come from porphyritic volcanic rocks containing phenocrysts of feldspar, quartz, and hornblende. The feldspars of the pebbles are the same composition as the feldspar grains in the greywacke and the quartz grains of the pebbles are similar in size and roundness to those in the greywacke. The quartz and feldspar grains of the greywacke were therefore most probably derived from phenocrysts in the volcanic rocks.

The matrix of these rocks, which in some specimens comprises over 50 per cent of the volume, is characterized by a high percentage of green chloritic material. The original material has been largely obscured by recrystallization and development of secondary, interstitial epidote, but it most probably consisted of finely comminuted feldspar, chloritized ferromagnesian minerals, and rock fragments. The

matrix of the greywacke beds was derived in large part from the matrix of the volcanic source rocks and chloritized ferromagnesian minerals.

Above the coarse greywackes and interbedded with them in their upper part is a sequence of red, purple, and green banded volcanic sandstones, water-lain tuffs, and chert. The whole series is characterized by graded bedding which is largely responsible for their banded appearance. Individual graded beds vary from less than an inch to a foot in thickness and commonly grade from fine silt to coarse sand within 1 inch or 2 inches. Mud-cracks are commonly developed in the shaly upper surface of graded beds and intraformational fragments of similar material are distributed through the coarse part.

A rhythmic repetition of 1- to 6-inch graded beds is characteristic of the lower half of the sequence. The coarse fraction of each bed is a heterogeneous medium- to coarse-grained volcanic sandstone, the texture of which is best described as micro-breccia. The amount of matrix varies from 20 to 50 per cent and consists of micas, recrystallized silica, iron oxide, and secondary epidote.

The fragments of these micro-breccias consist of highly angular pieces of quartz, feldspar, iron oxide, and volcanic rock. They differ from the underlying greywacke in having a much higher proportion of feldspar and quartz and much more iron oxide. In many beds feldspar constitutes 75 per cent of the fragments and the matrix contains so much iron oxide that it appears almost opaque in thin section.

Mud-cracks and intraformational conglomerate prove a shallow-water origin for these rocks, yet the highly heterogeneous unsorted nature of the sands indicates that they were not moved far by current action. It seems probable that they are true water-lain tuffs derived from ash of repeated volcanic eruptions. Where the ash fell into bodies of still, shallow water, graded beds of heterogeneous fragments were formed. Elsewhere ash was sorted to form sandstone and shale or incorporated as matrix in the volcanic breccias.

One hundred and fifty feet of fine-grained to aphanitic, hard siliceous rock, in beds a foot to 5 feet thick, occur near the centre of the volcanic sandstone sequence. Well-defined, green, white, and rose banding, varying in width from that of a pencil line to 3 inches, is characteristic of these beds. A few of the bands are coarse enough to show graded bedding but as a rule the original composition of the fragments, now largely quartz and epidote, cannot be determined.

Near the top of the group massive beds of coarse greywacke again appear and these are overlain by fine andesite breccia that grades upwards into coarse volcanic breccias of the Hazelton Group.

Metamorphism

Rocks of this series are somewhat less altered than the older Palaeozoic rocks. Epidote, chlorite, and hornblende are the common metamorphic minerals, giving the rocks a general greenish colour. The matrix has been particularly affected by metamorphism and it is there that chlorite and mica are prevalent.

In some instances chlorite constitutes as much as 50 per cent of the volume of the rock. This alteration of the matrix makes identification of the original material very difficult. Many of the subrounded larger fragments and pebbles have been epidotized causing the weathered surface of the rock to have a spotted appearance. On fresh surface the pebbles are not easily observed and the rock appears as a fine-grained meta-andesite; their fragmental nature however is readily observed on a weathered surface. Close to contacts with the Coast Intrusions these rocks are typical greenstones and have lost most of their original characteristics.

Structural Relations

The Triassic? rocks of Terrace map-area unconformably overlie the Palaeozoic rocks and are separated from them by a limestone-boulder conglomerate that contains boulders of the older rocks. They are within themselves a conformable series and appear to grade upward into the overlying Hazelton Group. The contacts drawn on the accompanying map are placed where the unsorted coarse clastic rocks become more abundant than sandstones. All members of this series are cut by the Coast Intrusions. Dips vary from 20 to 80 degrees, commonly away from contacts with the batholithic rocks. Strikes conform with the contacts, rarely differing greatly in direction from them.

Age and Correlation

No fossils were found in these rocks (though Hanson (1926) reports *Daonella,* a Triassic type, from the argillites), and no definite or precise age may be assigned on a palaeontological basis. Structurally they overlie the Permian strata unconformably and underlie the lower beds of the Hazelton Group. Their most probable age is Triassic. It must be pointed out, however, that no clear distinction can be made between these rocks and those of the Hazelton Group. They may possibly be equivalent to part of the Takla Group of Fort St. James area.

Jurassic

Hazelton Group

For many years this group has been a catchall for Jurassic rocks, including many unidentified rocks of Mesozoic age occurring along the eastern border of the Coast Intrusions and in central British Columbia. As a result the upper and lower limits of the group as well as its rock constituents have been somewhat confused. Relationships with other rocks differ in different areas so that the group was ill-defined. Depending on the area mapped, and to some extent on the individual worker, the group has been reported as including all rocks from Triassic to Cretaceous or has been restricted solely to the Jurassic period. In some areas it consists mainly of volcanic rocks, in others of sedimentary rocks possibly of continental origin, and in still others of equal amounts of marine sedimentary rocks and volcanic rocks.

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The commonly deformed and poorly preserved invertebrates contained in the marine sedimentary strata have given some definite information. Unfortunately these horizons though widespread are by no means continuous, making correlation in areas where they are not present particularly difficult. Some beds contain fossil leaves and plants but these sometimes disagree with the age indicated by invertebrates from adjacent beds thus adding to the general difficulties of the group. Establishment of the more or less similar and parallel Takla Group (Armstrong, 1946) increased rather than decreased the general difficulties. Rocks of similar lithological character and fauna were included in different groups in adjacent map-areas. Perhaps the greatest controversy revolved about whether the Jurassic-Cretaceous boundary was conformable or unconformable, and as a result rocks of the so-called "Skeena" Group were sometimes included with and sometimes separated from the Hazelton Group.

In recent years as more of the country became mapped (Whitesail Lake, Nechako River, Operation Stikine) a broader perspective of the rocks of north-central British Columbia was obtained. From this and from the new information available some order began to appear and the reasons for the state of confusion became clearer.

Volcanic and sedimentary rocks from Triassic to Cretaceous age are widely distributed in central British Columbia and especially along the eastern contact of the main Coast Intrusions. Their stratigraphic division and correlation is made especially difficult by scarcity of fossils and the presence of great thicknesses of lithologically similar volcanic rocks of small areal extent.

The failure to synthesize the available material into a general stratigraphic succession is largely a consequence of conditions of sedimentation and lack of sufficient areal studies. The entire Mesozoic period was one of intrusive, tectonic, and volcanic activity accompanied by the rapid accumulation of clastic sediments and volcanic flows, in a large number of interconnected basins. Deposition of marine and continental clastic material took place contemporaneously within separate parts of the same mobile belt as did the accumulation of purely volcanic or sedimentary deposits.

Few breaks of major proportions have been apparent during Mesozoic time but continuous fluctuations of the mobile belt produced many local unconformities. These conditions produced a thick series of interfingering volcanic and sedimentary units, each of limited extent. In general, eugeosynclinal conditions prevailed. Into this interfingering sequence was emplaced the Coast Intrusions which deformed and metamorphosed the strata and their contained fossils. Many fossil collections have been made from these rocks but commonly the individual specimens are so poorly preserved that they fail to be diagnostic.

Previous work on these rocks has been concentrated along the eastern contact of the Coast Intrusions where the evidence is (both physically and scientifically) difficult to obtain. However, recently an erosional unconformity has been shown to exist between Lower and Middle Jurassic strata along the east side of the Whitesail Lake map-area (Duffell, 1959), and the west side of Nechako

River map-area (Tipper, 1959). It was suggested that this unconformity marked the boundary between the Takla Group rocks below and the Hazelton Group rocks above, and that no Middle Jurassic strata should be included with the Takla Group. This established, at least in the two map-areas concerned, a lower limit for the Hazelton Group.

No definite Upper Jurassic-Lower Cretaceous strata associated with the Hazelton Group were observed in Whitesail Lake map-area. The Hazelton Group there consists of highly fossiliferous marine sedimentary beds, underlain and overlain by volcanic rocks. A few small outliers of Upper Jurassic-Lower Cretaceous rocks occur in the southeastern part of Smithers map-area (Armstrong, 1944a), and a much larger area occurs in the northwest corner, where it is an eastward continuation of the widespread occurrence of these rocks in the northern part of Terrace map-area. Operation Stikine indicated that these rocks continue northward to the Groundhog and headwaters of Iskut River and that they cover an area up to 100 miles wide extending approximately 200 miles north from their occurrence in Smithers and Terrace map-areas.

One of the big controversies in the past has been whether these rocks should be included with or separated from the Hazelton Group. When separated they were referred to as the Skeena Group, first introduced by Leach (1911). Hanson (1926) in the Zymoetz River area concluded that the Skeena Formation in the area rests unconformably on the Hazelton Group; Jones (1926) reached a similar conclusion from his detail study on Hudson Bay Mountain. Kerr (1937) disagreed with this interpretation and Armstrong (1944b) was unable to satisfactorily separate Skeena from Hazelton strata and so put them all into the Hazelton Group. Buckham and Latour (1950) included the Groundhog strata in the Hazelton Group, as did Muller in 1950 (unpub. rept. GSC).

In Terrace map-area, which covers the southwestern end of this large Jurassic-Cretaceous basin of sedimentation, the base of these rocks is a dark argillite that contains marine fossils of Upper Jurassic (Oxfordian) age. This argillite is followed by a series of conglomerates, greywackes, and argillites. The whole sequence lies unconformably on the underlying Hazelton Group, and the change in lithology and trend is such as to indicate a major break. This interpretation agrees with that of Hanson (1926) who mapped part of these rocks in the Zymoetz River area. Farther north, from work on Operation Stikine, rocks that form part of this sedimentary basin have been shown in places to be in structural conformity with the pre-Upper Jurassic rocks and in others to be in fault contact with adjacent rocks. However, throughout the whole area of the basin the change in sedimentation from marine and volcanic to continental facies takes place immediately above the horizon at which the ammonite *Cardioceras* occurs. This is the Oxfordian stage of the Upper Jurassic. In Terrace area this horizon appears to mark the boundary between the Hazelton Group rocks below and the sedimentary rocks of the basin above. These rocks have been referred to in the past as "Skeena Formation" but this name has not met with agreement and does not indicate the extent of the Jurassic-Cretaceous sediments. As these rocks

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are best exposed in the vicinity of Bowser Lake it is suggested by J. A. Roddick (pers. com.) that they be named the Bowser Group and separated from the Hazelton Group. The authors concur with this suggestion.

The upper limit of the Hazelton Group in the Terrace area would then be the base of the *Cardioceras*-bearing beds which unconformably overlie Hazelton Group rocks. (Farther north in the Telegraph Creek area there is a great thickness of Bowser Group strata below the *Cardioceras* beds.) The lower limit of the Hazelton Group would be the top of the Lower Jurassic, as suggested in Whitesail Lake and Nechako River map-areas.

Distribution

In Terrace map-area rocks assigned to the Hazelton Group are well exposed along the eastern border of the area and in outcrops with the older rocks along contacts with the Coast Intrusions. They comprise a lower division, about 3,000 feet thick, of sedimentary and fragmental volcanic rocks and an upper division of mainly volcanic flow rocks that is at least 4,000 feet thick. Rocks of the lower division are present along Skeena River between Dorreen and Usk, on Kitsumkalum Mountain, along the eastern end of Bornite Range, and as a narrow band extending from the headwaters of Kleanza Creek south to Chist Creek. They also occur as roof pendants in the Coast Intrusions, comprising most of the peak of Wedeene Mountain and several unnamed peaks to the south and also occupy the ridges along the west side of Kitimat Valley in the vicinity of Iron Mountain.

Volcanic rocks of the upper division are best exposed on Mount Sir Robert, upper Legate Creek and along the western border of the area as far south as Beta Peak. Certain small areas of these rocks show through the sedimentary cover as windows in the younger Jurassic-Cretaceous rocks.

Lithology

The *lower division* is made up almost entirely of massive bedded, coarse breccias, some minor andesitic flows, intercalated finer clastic material representing argillaceous sedimentation, and perhaps some water-lain tuff.

The coarse breccias rarely show any trace of bedding or banding, the size and orientation of the fragments being completely haphazard. Commonly no break in deposition can be recognized over thicknesses of several hundred feet. Individual fragments vary in size from that of sand grains to blocks 2 feet or more in diameter; the average size is about 2 inches. All are angular to subangular and have low sphericity.

In contrast to their heterogeneous size distribution the composition of the fragments is most uniform throughout. They consist essentially of green, red, and purple, porphyritic andesite, similar to that of the upper volcanic division. Both fragments and matrix contain up to 30 per cent white andesine phenocrysts, ranging in size from 1 to 2 mm. Those in the matrix are apparently derived from comminution of porphyritic andesite, and, being more resistant than the groundmass, have been little altered in the process. Some of the andesite fragments however do show

signs of predepositional surface weathering. Commonly the matrix, which forms up to 50 per cent of the breccias, is the same colour as the fragments and contains about the same percentage of phenocrysts. This rock appears entirely homogeneous, and the distinction between fragments and matrix is apparent only on polished and some weathered surfaces.

In addition to plagioclase, the matrix of the breccias contains grains of iron oxide, minor quartz, and locally amphibole. Surrounding these is a dark chloritic mesostasis of recrystallized rock flour, fine disseminated iron oxide, and secondary epidote.

The sedimentary beds consist of grey to black, fine-grained argillite and greywacke. Some of the greywacke shows graded bedding and banding with width up to a quarter of an inch between light and dark grey bands. Much of this material has been converted to quartz biotite and chlorite schists so that little is left of the original rock. However, there are sufficient local areas where the original sedimentary nature of rocks can be recognized. This division also contains minor flows, varying in thickness from 10 to 30 feet, whose composition is identical with those comprising the bulk of the upper division.

The *upper division* is composed of a series of massive volcanic rocks, mainly andesite but to a lesser extent, basaltic, dacitic, and rhyolitic flows and some andesitic breccia. These rocks are commonly bright in colour, being green, grey-green, red, purple, white, and rarely black.

Andesite flows of remarkably uniform composition comprise over 80 per cent of the section. Almost without exception, the andesites are porphyritic, the phenocrysts being white feldspar or dark green pyroxene. Some flows are vesicular, others amygdaloidal, but flow structure is poorly developed and no pillows were observed. At least half the flows contain amygdules of calcite, epidote, or quartz, and rarely of a pink zeolite. Locally amygdules make up 25 to 30 per cent of the rock, and are as much as 3 inches in diameter. Amygdules that contain more than one mineral commonly occur in well-defined concentric zones. Calcite amygdules with epidote rims and quartz cores are most abundant. Unfilled vesicles are rare, but one 40-foot flow on Williams Creek has a 6-foot scoriaceous top and vesicle pipes near the base.

In thin sections the texture of the andesites is seen to be hyalo-ophitic to trachytic; andesine phenocrysts are embedded in a felted matrix of elongate, tabular feldspar crystals of slightly less calcic composition. Interstitial to the feldspar is a groundmass of augite, devitrified glass, ore minerals, and alteration products, chlorite, epidote, and secondary magnetite, both as inclusions in the phenocrysts and in the groundmass. The feldspar, particularly in the phenocrysts, is clouded with secondary clinozoisite or epidote which makes its optical determination difficult if not impossible. With one exception—a labradorite from the dark vesicular basalt on Williams Creek—all the feldspars that could be determined were within the range oligoclase-andesine. The phenocrysts are unzoned and have simple albite or Carlsbad twinning.

Phenocrysts of ferromagnesian minerals rarely form more than 10 per cent of the rock. A few of the sections examined contain what appear to be primary hornblende phenocrysts. In the remainder augite is the primary dark mineral. In addition most of the rocks contain grains of pale green amphibole, probably uralite, formed during alteration of the flow. In well-developed crystals, the primary hornblende is commonly bounded by regular prism faces. They contain inclusions of sphene and most are at least partly replaced by light green amphibole and chlorite. Augite was the only pyroxene identified in the sections studied. It is present both as euhedral and subhedral phenocrysts and as interstitial sub-ophitic grains. In some sections the pyroxene is altered to aggregates of secondary hornblende, calcite, chlorite, and epidote, but it is commonly clear and fresh even when the surrounding feldspar is thoroughly saussuritized.

Light purple, red, and salmon-pink dacites and rhyolites are found throughout the succession but are much less abundant than the andesites. Unlike the andesites they are characterized by pronounced flow banding, caused by alternating layers of quartz and devitrified glass charged with minute feldspar crystals, ore minerals, and alteration products.

Andesite breccia, similar to that in the upper series, is interbedded with the flows in both the Williams Creek and Chist Creek sections. Individual beds are rarely more than 20 or 30 feet thick and together they comprise only a few per cent of the total thickness. Thin lenticular beds of water-lain volcanic sandstone with the breccia show both graded beds and crossbedding, mud-cracks, and intraformational fragments of red mudstone. The matrix of the sandstone is commonly calcareous.

Structural Relations

No clear distinction can be made between the underlying Triassic? rocks and the lower pyroclastic division of the Hazelton Group. On the accompanying map the contact is arbitrarily drawn where the unsorted coarse clastic rocks and breccias become more abundant than the sandstones and finer clastic rocks. For this reason the Hazelton rocks as mapped may contain some older rocks and vice versa. The thickness of the group is difficult to establish as all the rocks have suffered at least minor faulting and shearing and none of the members is sufficiently distinctive or continuous to permit correlation from one locality to another. The andesite flows of the upper division follow the pyroclastic rocks of the lower division in conformable succession. Flow contacts are inconspicuous except where amygdaloidal tops or intercalated breccia occurs. Except for coarsely porphyritic or amygdaloidal varieties, flow structure is absent or poorly developed. No pillow structures were observed. Dips are commonly 35 to 65 degrees and, as in the older rocks, away from contacts with the Coast Intrusions. In Bulkley Ranges, on Mount Sir Robert, a broad expanse of the flows of the upper division are warped into gentle folds having northwest-trending axes. Both divisions of the group are overlain unconformably by Upper Jurassic-Lower Cretaceous sedimentary rocks and have been invaded by elements of the Coast Intrusions.

Age and Correlation

No fossil remains were found in rocks assigned to the Hazelton Group in Terrace map-area. The andesites of the upper division on Mount Sir Robert are a westward extension of similar andesites and volcanic rocks assigned to the Hazelton Group in Smithers map-area (Armstrong, 1944a). They are also similar to volcanic rocks in Whitesail Lake map-area that conformably overlie fossiliferous sedimentary rocks of the Bajocian stage of the Middle Jurassic (Duffell, 1959). As they are overlain in Terrace map-area by fossiliferous sedimentary rocks of the Oxfordian stage of the Upper Jurassic, there is a strong possibility that these volcanic rocks are of Middle Jurassic age.

Jurassic and Cretaceous

Bowser Group

Rocks included in this group, for which the term Bowser Group is proposed, consist of a series of marine and freshwater shales, argillites, greywackes, sandstones, and conglomerates with minor tuffs towards the base. They occupy the northern third of Terrace map-area and differ markedly from all the older sedimentary and volcanic rocks. They are an accumulation of fine to coarse clastic material in beds from a few inches to hundreds of feet thick. Some of the argillaceous beds contain marine fossils, others contain plant remains; deposits of coal and carbonaceous material are prevalent. In Terrace map-area the Bowser Group lies unconformably on rocks of the Hazelton Group. This relationship was also noted by Hanson (1925) in Zymoetz River area, by Jones (1926) on Hudson Bay Mountain, and by Leach (1911). Some writers have included some of these rocks as an upper division of the Hazelton Group, whereas others have referred to them as the Skeena Formation. Unfortunately these workers were dealing only with a very small part of the wide area of central British Columbia that now appears to be underlain by these rocks. It has long been known that the coal measures in the Groundhog region were contained in these rocks, but it was not until Operation Stikine was accomplished in 1956 that the full areal extent of this sedimentary basin was appreciated. The report on Operation Stikine (Map 9-1957) says of these rocks as follows:

> The southeast third of the map-area covers a part of a large basin of sedimentary rocks that extends about 200 miles northwest from near Hazelton, British Columbia, and is up to 100 miles wide. The rocks in this basin, which in this area comprise nearly all of the Skeena Mountains and outcrop at many places in the Coast Mountains, contain numerous fossils of Upper Jurassic to Lower Cretaceous age. The principal rocks are black, fine-grained, commonly slaty argillite and shale, dark greywacke and chert fragment subgreywacke. In the Bowser Lake district the greywacke is very dark and fine grained, but towards the northeast, and northwest it becomes coarser, more feldspathic and siliceous, and is frequently associated with intraformational, conglomeratic lenses composed of fragments of black argillite. The intercalation of argillite and greywacke produces a bedding conspicuous from a distance throughout the entire basin. Minor rock types, most abundant in the northern and eastern parts of the Skeena Mountains include calcareous argillite,

> chert-pebble conglomerate and coal. Limestone or rocks directly of volcanic origin are virtually absent. Continental and marine beds interfinger in the northeast part of the Skeena Mountains and in some places plant remains are found associated with marine fossils . . . Sections about 10,000 feet thick have been measured in the Skeena Mountains and the minimum total thickness of the unit is estimated to be in the order of 20,000 feet. Structures in this map-unit are extremely complex, with major folds averaging about four per mile and many overturned and recumbent structures.

The composition, fossil content, and general character of the rocks in Terrace map-area assigned to this group are identical with the description above. It is most probable that they are also continuous with the rocks described in the Stikine report, but this still has to be proved. These rocks represent sedimentation during Upper Jurassic and Lower Cretaceous time in a large basin in north-central British Columbia. The rock types are identical and widespread over the whole basin and thus form a stratigraphic and lithological unit that is readily identified. It is the opinion of the writers that these rocks should be separated from the Hazelton Group and given a separate distinctive name. The name Bowser Group is proposed because of the excellent exposures of these rocks in the vicinity of Bowser Lake (*see* Operation Stikine, Map 7-1957).

Distribution in Terrace Map-area

Rocks included in the Bowser Group in this map-area are well exposed north of Oliver Creek and in Seven Sisters Peaks. They extend westward and underlie the Nass Range of the Hazelton Mountains. West of Kitsumkalum Valley, they are present along the lower parts of Nelson River, Star Creek, and Erlandsen Creek. They are present on Alice Peak, Mount Allard, and the peaks to the north. In a few creek bottoms and near contacts with masses of Coast Intrusions older rocks may be included. No rocks equivalent to these were found south of Terrace or east of Skeena River south of Mount Sir Robert. In Terrace map-area the rocks placed in this group represent the southwestern edge of the basin, but due to invasion by granitic bodies, the rocks are altered and involved structurally with the older rocks making their clear distinction sometimes difficult. Though they have been mapped separately, it is possible that in mapping metamorphosed members of one group may be included with rocks of the other group.

No definite thickness was obtained for the Bowser Group rocks in this map-area. Part of a section near Oliver Creek measured over 3,500 feet, but it is probable that the maximum thickness in the area is as much as 8,000 feet.

Lithology

This group in Terrace map-area is a bedded series of marine and freshwater clastic rocks composed of the detrital material from the erosion of a mainly volcanic terrain. The rock types are coarse to fine greywackes, rarely approaching a subgreywacke or quartzose sandstone. These grade on the one hand into grits, fine-pebble conglomerates, and coarse boulder conglomerates (*see* Pl. III A), and on the other hand to light and dark grey argillites and slates. No distinctly lime rocks or pure quartz sandstones are present. Feldspar is commonly more

abundant than quartz in the fine-grained rocks, and pebbles and boulders of porphyritic volcanic rocks are most common in the conglomerates. The darker bands of greywacke are comprised of finer material than the lighter coloured bands and contain more carbonaceous material. Beds of carbonaceous material are common and some coaly material was observed. The argillite beds may contain marine invertebrates or plant remains or both. Wood fragments are common in most beds. Commonly the larger pebbles and cobbles are rounded to subrounded, but the finer grains are subangular to subrounded. There is no definite succession in the group progressing from coarse to finer material. Conglomerate may be followed by greywacke or argillite and vice versa. In a 3,000-foot section measured near Oliver Creek greywacke was twice as abundant as conglomerate. Greatest thickness of any one greywacke stratum was 700 feet and of conglomerate stratum 200 feet. Thinner sections measured on Maroon Mountain gave a higher proportion of argillite than the section on Oliver Creek. Thickest conglomerate stratum measured there was 300 feet, but the average thickness was 50 to 100 feet.

Conglomerates of the group vary greatly in grain size. Roundstones of the finer grained varieties average half an inch in diameter and in the coarse varieties may be 10 to 12 inches in diameter. Conglomerates are commonly grey to brownish grey. Beds may be of one- or two-pebble thickness or as much as 300 feet. Roundstones, particularly in the Oliver Creek and Seven Sisters Peaks regions, consist largely of porphyritic volcanic rocks derived from the Hazelton Group, some granitic rocks, minor sedimentary rocks, and quartz. Matrix is commonly finer grained material of the same character and is a greywacke. In upper Kitsumkalum Valley and Wesach Mountain a fairly fine grained quartz-pebble conglomerate is present. The rock is blue-grey, and is composed of rounded to subrounded pebbles of white quartz, blue-grey chert, and dark argillite in a matrix consisting of quartz grains, rare plagioclase, and rock flour.

Greywackes are probably the most abundant rock type in the group. They are commonly light grey to dark grey, but may be brownish grey or black. They are composed mainly of grains of feldspar, subordinate quartz, and fragments from the older volcanic rocks. They are essentially finer grained representatives of the conglomerates. Depending on their grain size, colour, and composition, various kinds of greywacke beds occur in the group.

One conspicuous variety exhibits a marked banding between light and dark layers that vary from one sixteenth of an inch to an inch thick. Crossbedding was observed in this type. In thin section the light bands were seen to consist of an aggregate of subangular to subrounded grains of clouded plagioclase with minor quartz. The darker bands consisted of much finer material of a similar nature, but contained more alteration products and carbonaceous material.

Another prevalent type is a light grey, fine- to medium-grained, dense rock that contains fragments of dark argillite. These argillite fragments commonly are of similar size to the other grains and are well rounded, but because of their dark colour they are conspicuous against the lighter background. Not uncom-

monly much larger angular fragments of dark argillite are embedded in the lighter grey greywacke. Where such fragments are abundant the rock resembles a breccia of angular black argillite held together by a matrix of light grey greywacke. The greywacke matrix consists largely of clouded plagioclase, very minor quartz, alteration products, and silt. It is not uncommon for a bed of uniform greywacke of this type to contain layers of conglomerate one pebble thick.

Other greywackes in the sequence are quartzose in character, commonly dark grey or banded light and dark grey, and light brown. These varieties contain a much larger percentage of well-rounded quartz grains that may comprise as much as 50 per cent of the whole.

Another variety of greywacke, which appears to be most common near the base of the group, is composed largely of grains of volcanic rocks, plagioclase, minor quartz, and alteration products. It is not distinctive in hand specimen, but may be seen in thin section.

The argillites are commonly dark grey to black, but may be light grey. They may contain plant remains or marine invertebrate fossils and are probably of lagoonal origin. They may be classed as siltstones and are composed essentially of the more finely comminuted material that constitutes the greywackes and conglomerates. Banding between dark and light coloured layers, similar to that described in the greywackes, is also present in some argillites. In the argillites this banding is more conspicuous on a weathered surface than it is on a fresh surface. The rocks are relatively fresh looking and, except where they are in close contact with the Coast Intrusions, show little alteration.

Age

The age of the group is determined by the invertebrate marine fossils obtained from argillaceous beds near the base. These fossils were studied and identified by H. Frebold of the Geological Survey of Canada. One is the ammonite *Cardioceras,* which is an index fossil establishing the age as that of the lower Oxfordian stage of the Upper Jurassic epoch. Other fossils listed below were collected but they are not diagnostic species. Belemnites are common in the argillites and were observed over a wide area.

The collection of marine invertebrate fossils was made along the Skeena River highway about 4 miles north of Oliver Creek and a mile above a bend in the river locally known as Devils Elbow. It is almost directly across the river from Dorreen. Collections were made from this locality in each of the three seasons of work in the area but it was not until late in the season of 1954 and again in 1955 that specimens of *Cardioceras* were found.

The following species were collected from this locality:

GSC loc. 23485—

Belemnites sp. indet.
Trigonia aff. *scaphogonia argo* Crickmay
Pleuromya sp. indet.

Gervillia aff. *ashcroftensis* Crickmay
Modiolius aff. *sphenoproratus* Crickmay
other indeterminable pelecypods

GSC loc. 26640—
Cardioceras sp.
Belemnites sp. indet.

GSC loc. 26639—
Belemnite
Pinna sp.
Pleuromya?
other pelecypod fragments

GSC loc. 26642—
Belemnites sp. indet.
Trigonia sp. indet. Fragments that show similarities to *Trigonia* aff. *scaphogonia argo* Crickmay
Pleuromya sp.

GSC loc. 32532—
Trigonia? fragments
Gervillia sp. indet.

GSC loc. 32533—
Trigonia sp.
Pleuromya sp.

GSC loc. 32535—
Cardioceras cf. *canadense* Whiteaves
Cardioceras cf. *americanum* Reeside
Cardioceras sp.

A second locality about a mile north of where the cardioceratids were found, and also on the road gave the following species:

GSC loc. 26641—
Belemnites sp. indet.
Trigonia sp. indet. Fragments similar to *Trigonia* cf. *scaphogonia argo* Crickmay
Gervillia sp. indet. Fragments similar to *Gervillia* aff. *ashcroftensis* Crickmay
Pleuromya? sp. indet.

Wood fragments are common in all the rock types of the group but the siltstones and a few of the fine greywackes contain fossiliferous plant remains, some beds being unusually prolific. Specimens were collected from several localities but none of the forms was diagnostic.

The following species were identified by W. L. Fry, formerly of the Geological Survey:

Cedar River where telegraph trail crosses (GSC loc. 4230)
Equisetites sp.—nodal rings and stems

Cladophlebis sp.—fragment of Primae
cf. *Nilssonia*?—doubtful fragment
Ginkgoites sibirica (Heer) Seward
Baiera sp.
Pityophyllum nordenskiöldi (Heer) Krysht

Small lake across Skeena River opposite mouth of Lorne Creek (GSC loc. 4339)
Czekanowskia sp.
cf. *Cladophlebis* sp.
Ptilophyllum sp.

On Skeena River highway near mouth of Flint Creek (GSC loc. 4340)
Baiera concinna Heer
Baiera sp. (2)
Phoenicopsis sp. indet.
Araucarites sp. (cone scale)

Road-cut 6,000 feet south of the mouth of Flint Creek (GSC loc. 4341)
Cladophlebis cf. *C. spectabilis* (Heer) Fontaine
Baiera sp.
Czekanowskia sp.

On CNR near Ritchie station 7 miles north of Dorreen (GSC loc. 4397)
Pterophyllum inaequale Fontaine

Fry discusses the stratigraphic value of the collection as follows:

> The difficulties inherent in arriving at an accurate identification of specimens of this degree of preservation should be indicated prior to any discussion of their stratigraphic value. Detailed investigations and critical identification of material from this group of plants are based upon cuticular studies. These are not possible with the specimens of this collection. Furthermore the lack of good venation patterns in some of the specimens introduces another element of possible error. These points are mentioned because they must be borne in mind when evaluating any stratigraphic conclusions reached herein.
>
> The most outstanding feature of the assemblage is the dominance of the ginkgoalean elements in the forms of *Czekanowskia, Baiera* and *Phoenicopsis. Baiera* reached its dominance early in the Jurassic but continued into Lower Cretaceous Wealden floras. *Czekanowskia* and *Phoenicopsis* reached their greatest development in the Jurassic. *Cladophlebis,* with rare exception, is not particularly useful. However, the species to which one of the specimens is referred is a Jurassic one. The complete absence in this small assemblage of anything suggestive of higher than lowermost Cretaceous forms and the seeming dominance of the ginkgoalean elements suggests a flora with late Jurassic affinities. It is not possible, however, to eliminate from consideration the possibility of lowermost Cretaceous as the evidence in this case and elsewhere used to separate Upper Jurassic and Lower Cretaceous floras is very meagre. It is conceivable that we are dealing with a transition zone between systems in so far as floras are concerned.

The weight of evidence from the invertebrate fossils and plant remains indicates that the lower beds of the group are of Upper Jurassic age but that the group itself extends upward into the Lower Cretaceous and therefore transcends the boundary between the Jurassic and Cretaceous periods.

Structural Relations

The Bowser Group of rocks overlies the mainly volcanic Hazelton Group unconformably. There is an angular unconformity on the northern slope of the mountain east of Oliver Creek between rocks of this group and the underlying folded volcanic rocks of the Hazelton Group. On Carpenter Creek west of Skeena River, relatively unaltered argillites of the Bowser Group overlie contorted and sheared volcanic rocks of the Hazelton Group. Commonly structures in the Bowser are gently undulating anticlines and synclines. Dips are gentle averaging 30 to 35 degrees, except close to contacts with Coast Intrusions. The stock on the core of the Seven Sisters Peaks has folded the beds into rather small tight folds that are distinct from the broader structures away from intrusive bodies. Intrusion by innumerable small dykes and sills has caused minor dislocation of the strata, in some places affording structures for the deposition of mineral deposits.

Disruption of the beds by faults was observed; an excellent example of such may be seen in the road-cut about a mile south of Flint Creek, where the beds have been dragged abruptly upward evidently by fault action (Pl. III B). Along Little Oliver Creek, beds of the Bowser Group were found in fault contact with lava flows of the upper division of the Hazelton Group. No younger sedimentary or volcanic rocks were observed in the map-area but rocks of the group have been invaded by phases of the Coast Intrusions. The relationships commonly observed are those associated with intrusive granitic bodies. The adjacent sedimentary rocks of the Bowser Group are dislocated, thrown into tight local folds, cut by granitic dykes, and in places slightly altered by contact metamorphism. Little evidence of granitization was seen.

INTRUSIVE ROCKS

Coast Intrusions

The term Coast Intrusions was used by Rice (1947, p. 33) for those plutonic rocks that occur largely in the Coast Range but may be present outside that physiographic province. They comprise a distinctive suite of rocks including granodiorite, granite, quartz diorite, diorite, quartz monzonite, monzonite, and related rocks. In southern British Columbia they may be separated from an intrusive suite that contains less quartz and is characterized by reddish coloured syenites that locally contain sufficient quartz to be classed as granites. This latter suite overlaps the Coast Intrusions in time sequence but is perhaps a little younger. No general term has been given to these quartz-deficient rocks, but they include such bodies as the Otter granite in Princeton area (Rice, 1947) and the Coryell batholith in Nelson area (Little, pers. com.). No intrusive rocks of quartz-deficient suite were found in Terrace map-area, therefore, the term Coast Intrusions may readily be applied to all the batholithic rocks of the map-area.

The Coast Intrusions of the Terrace map-area form part of the continuous granitic terrain, 1,100 miles long and 80 to 100 miles wide, that extends along the coast of British Columbia and Alaska. As indicated above, it comprises a complex of different rock types ranging in composition from gabbro to granite.

Reconnaissance work has suggested that some sort of relation exists between the composition of the various phases and their positions in time and space. Buddington's work in Alaska (Buddington and Chapin, 1929) indicates a change from predominantly quartz diorite on the southwest to predominantly quartz monzonite on the northeast. South of Portland Canal, Dolmage (1923) reported that, with some exceptions, the more silicic varieties lie in the centre of the batholith. In the Stikine district, Kerr (1936) considered the batholithic rocks to include six to ten different types ranging in age from Triassic to Cretaceous. He indicated the three major phases as occupying roughly parallel north-south belts that become progressively younger and more acidic from west to east. In 1937 Kerr compared the rocks along Skeena River with those of the Stikine district. On the basis of feldspar composition and proportions of major constituents he distinguished six phases, again ranging in age from Triassic to Cretaceous and becoming progressively more acidic from oldest to youngest.

More recently Armstrong (1954) classified rocks of the Coast Intrusions near Vancouver according to the relative proportion of mafic constituents, chiefly hornblende and biotite. They found that plagioclase composition is so variable that rock classifications employing it are not applicable to field mapping. Their map of the granitic rocks of the Vancouver area shows a tendency for hornblendic rocks to form a marginal facies around biotite-bearing rocks. Duffell (1959) in Whitesail Lake map-area indicated this characteristic. From the contact into the batholith the ferromagnesian mineral present in the granitic rocks changes from dominantly hornblende to dominantly biotite.

Some workers describe the transition from one phase to another as being abrupt but indistinct; others describe it as being completely gradational and lacking any sign of brecciation. Depending on the prejudice of the particular writer, these circumstances have been interpreted to mean that:

(1) The 'Coast Batholith' is composed of closely related batholiths intruded at successive intervals of time.
(2) The variation is due to contamination and assimilation of foreign material by an essentially homogeneous magma.
(3) It is due to varying degrees of replacement of originally heterogeneous sedimentary and volcanic rocks.

Terrace map-area provides an excellent opportunity for the study of different facies of these batholithic rocks. The area is largely underlain by elements of the Coast Intrusions and part of the main eastern contact extends northwesterly across the area in an exceedingly erratic and sinuous manner.

Four great apophyses of granitic rock project northeasterly from the main mass. They are nearly perpendicular to the regional structure and extend 15 to 18

miles into the older country rocks. These are referred to in this report, from south to north, as the Williams Creek, Kleanza Creek, Chimdemash Creek, and Legate Creek apophyses. The Williams Creek apophysis is the smallest of the four, extending east only 4 or 5 miles, whereas the others exceed 15 miles in length. Souther studied these apophyses in detail, as well as some of the larger areas underlain by the batholithic rocks. In his study an area of some 300 square miles was investigated along the eastern contact of the batholith. Four main facies were distinguished, their areal extent delimited and their textural, mineralogical, and structural characteristics studied.

Sufficient data were not collected from all parts of the map-area underlain by granitic rocks to delimit definitely the areas of the different facies, and there they were mapped as Coast Intrusions undivided.

Classification and Distribution of Facies

In attempting to subdivide the crystalline rocks a modification of Armstrong's scheme of classification, based on relative proportions of mafic constituents, was found to be most useful. Hornblende-bearing, biotite-bearing, and pyroxene-bearing rocks occur in separate, fairly well-defined areas and are distinctive both in the field and in thin section. In general, hornblendic rocks form a marginal facies around an inner facies of biotite-bearing rocks. Pyroxene-bearing rocks form a distinct early suite that is more or less restricted to the Chimdemash apophysis. Gabbro, although widely and erratically distributed, is locally continuous enough to be mapped separately. The batholithic rocks have accordingly been divided into four major facies, namely:

(1) Gabbro facies (olivine-bearing and associated rocks)
(2) Pyroxene quartz diorite facies (pyroxene-bearing rocks)
(3) Inner facies (biotite—hornblende facies; biotite hornblende)
(4) Border facies (hornblende—biotite facies; hornblende biotite).

These divisions, based on the type and proportion of mafic constituents, are readily recognized in the field. The same general divisions are apparent when modal analyses of the major constituents are compared. Figure 1 shows the results of plotting modal quartz, plagioclase, and potash feldspar (recalculated to 100 per cent) on a triangular diagram. This shows that rocks of the inner facies and those of the pyroxene quartz diorite facies form two distinct statistical groups, the former having a higher ratio of quartz to potash feldspar. A third statistical group is formed by hornblendic rocks of the border facies.

The gabbro facies and the pyroxene quartz diorite facies form separate, relatively small intrusive bodies emplaced before the main body of the batholith. They are sufficiently distinct lithologically to prevent their confusion with later intrusions. The phases of the main body of the batholith possess a greater similarity and are, therefore, more difficult to classify. An initial distinction is made between the relatively uniform, clearly magmatic rocks of the central part of the batholith (inner facies) and the heterogeneous hybrid rocks surrounding

them (border facies). The inner facies includes biotite granodiorite and adamellite of three different ages—termed here green, pink, and white granodiorite. They are mineralogically similar but can be differentiated on the basis of texture, and type and extent of deuteric alteration. The border facies consists mainly of hornblendic rocks of hybrid origin. They cannot be differentiated as to age, but at least three more or less distinct zones are recognized, an inner zone of hornblende granodiorite, an intermediate zone of migmatite, and an outer zone of hornblende diorite and quartz diorite (Table I).

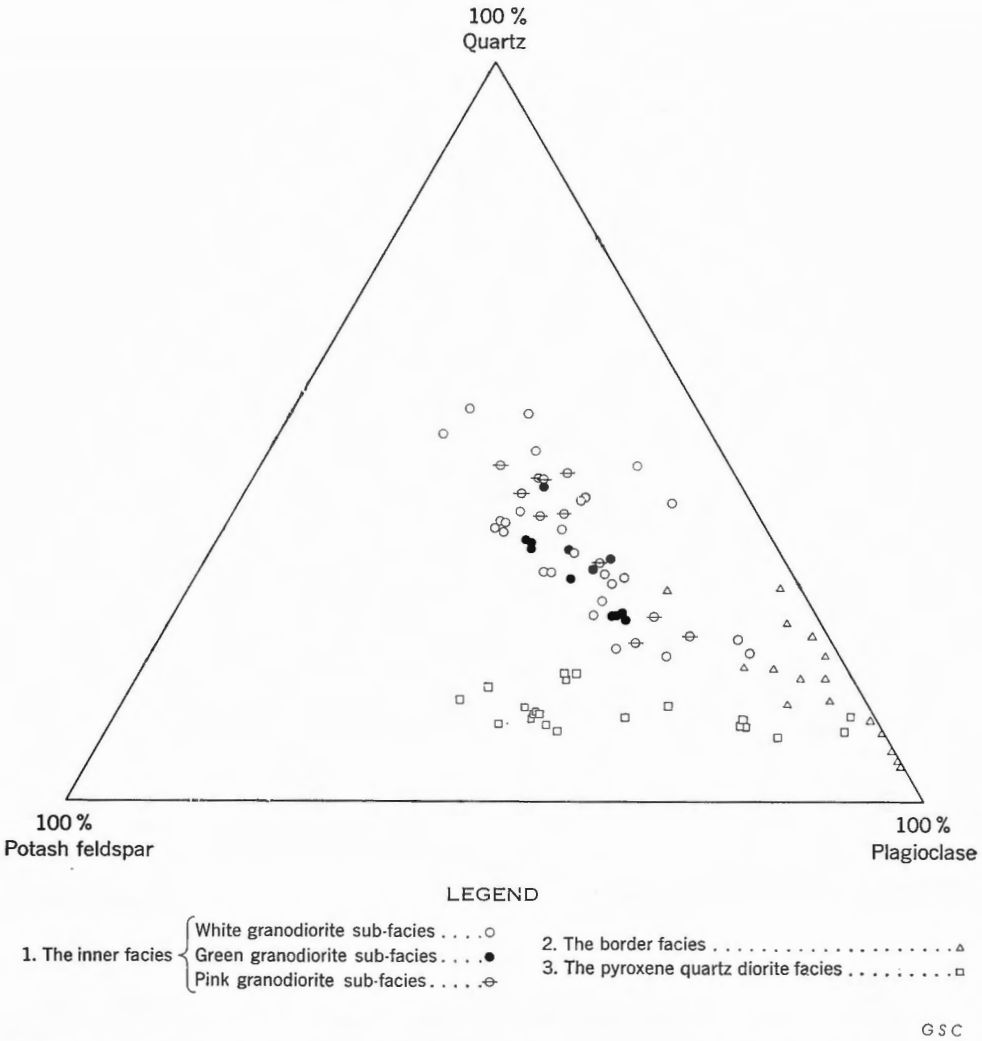

FIGURE 1. Diagram showing the modal quartz, plagioclase, and potash feldspar of 86 specimens from the Coast Intrusions. Three statistical groups are present.

Table I

Classification of the Batholithic Rocks

—Increasing Age—

Border Facies Granodiorite, quartz diorite and minor amphibolite; hornblende biotite; total mafic minerals 10%			*Inner Facies* Granodiorite, adamellite and minor quartz diorite; biotite hornblende; total mafic minerals 10%
Hornblende diorite and Quartz diorite Sub-facies Uniform, hornblende pseudo-diorite and quartz diorite showing little or no evidence of mobilization	*Migmatite Sub-facies* Mixed rocks in which the discontinuous phase forms 50% of the volume	*Hornblende Granodiorite Sub-facies* Contaminated granodiorite in which the discontinuous phase (inclusions) form 50% of the volume	*White Granodiorite Sub-facies* Feldspar clear or moderately sericitized; poikilitic texture *Green Granodiorite Sub-facies* Feldspar strongly saussuritized; hypidiomorphic-granular texture *Pink Granodiorite Sub-facies* Feldspar clouded with iron oxide dust; granophyric textures
Pyroxene Quartz Diorite Facies			
Border Phase Fine-grained non-porphyritic quartz diorite	*Coarse-Grained Non-Porphyritic Phase* Coarse-grained non-porphyritic granodiorite	*Porphyritic Phase* Porphyritic granodiorite and adamellite	*Central Phase* Adamellite and granophyre
Gabbro Facies Quartz diorite . . Hornblende diorite . . Pyroxene gabbro-diorite . . Olivine gabbro			

—Increasing distance from contact—

Each of the facies and sub-facies is a heterogeneous assemblage of rocks embracing several genetically related phases that may or may not be petrographically similar. Thus a facies cannot be rigidly defined in terms of mineralogical composition. It is, rather, an assemblage of rocks that, on field and petrographic evidence, can be logically grouped together as a unit.

The phases within a given rock facies may be continuous or discontinuous. The transition from one phase to another may be completely gradational or sharp and clearly intrusive. On the basis of clearly crosscutting relations the

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emplacement of eleven (phases) was determined and found to apply throughout the area. These are from oldest to youngest:

(1) Pyroxene-bearing rocks
(2) Amphibolite and gabbro (relation to (1) unknown)
(3) Hornblende diorite
(4) Hornblende quartz diorite
(5) Hornblende-biotite quartz diorite
(6) Hornblende-biotite granodiorite
(7) Non-porphyritic biotite granodiorite
(8) Porphyritic biotite granodiorite
(9) Biotite granite
(10) Hornblende granophyre dykes
(11) Basalt dykes.

The recurrence of this series over a large area suggests that it is a fundamental relationship, although most of the phases do not form continuous units. They are minor variants of distinct igneous rock facies and each major facies or sub-facies may contain several of the above types. Mineralogically similar but genetically unrelated types may occur in two or more rock facies.

Gabbro Facies

Two areas showing the gabbro facies were encountered during the study. The main area lies at the head of Davies Creek where about 5 square miles is underlain by an assemblage of basic rocks ranging in composition from olivine gabbro to hornblende quartz diorite. A much smaller area occurs on Mount Thornhill, where it is present as a roof pendant 300 feet wide and 1,300 feet long, in hornblende granodiorite. The olivine gabbro in this roof pendant was pre-batholithic and was subsequently invaded by the granodiorite. The Davies Creek body is difficult to reach and only two traverses were completed across it. In general the centre is a uniform, coarse-grained, olivine gabbro that is black on fresh surfaces and exhibits a high resinous luster. The coarse-grained gabbro grades through a transitional zone of hornblende diorite and quartz diorite into granodiorite to the south. This transition zone varies from less than a quarter of a mile to more than half a mile in width, and contains a few dykes of granodiorite presumably associated with the main batholith. The diorites are variable in composition and texture, but are commonly coarse grained with distinctive glomeroporphyritic clusters of hornblende.

The central core of the Davies Creek olivine gabbro mass is essentially structureless, exhibiting no banding or variation throughout 3,000 feet of vertical exposure. The mineralogy and texture is also extremely uniform. Unzoned labradorite, pyroxene, olivine, and iron ores are all enclosed in large plates of poikilitic brown hornblende (Pl. IV A). The plagioclase is euhedral to subhedral. The olivine and pyroxene have circular or elliptical outlines resulting from partial resorption. The augite is commonly mantled by hypersthene, which appears to

have crystallized simultaneously with magnesian augite. Thus crystallization followed the normal cotectic trend for undersaturated basaltic magma as outlined by Poldervaart and Hess (1951). Hornblende appears to have crystallized late, partly replacing the earlier formed pyroxene crystals. Plagioclase formed throughout the entire period of crystallization and during the latter stages formed simultaneously with hornblende giving rise to ophitic-like intergrowths of the two minerals. Myrmekitic zones of pyroxene and magnetite or ilmenite are common in all rocks of this facies and are believed to be the result of simultaneous crystallization.

The coarse-grained gabbro of the central core grades rather abruptly into the more feldspathic rocks of the transition zone and the change is complete within a distance of 50 to 60 feet. Increase in modal feldspar is accompanied by disappearance of olivine and pyroxene and appearance of minor amounts of biotite and quartz. The texture changes from uniformly coarse-grained poikilitic gabbro to glomeroporphyritic diorite and quartz diorite with highly variable grain size. The hornblende of these rocks is more nearly euhedral than that of the gabbro and is free of inclusions. Plagioclase is zoned, ranging from labradorite to andesine.

The origin of the transition zone is difficult to ascertain but the absence of any direct contact between gabbro and granodiorite suggests that the diorites were formed through reaction of the granodiorite magma and the gabbro. The central mass of gabbro is certainly intrusive in character and like the olivine gabbro inclusion on Mount Thornhill was probably emplaced earlier than the granodiorite. The transitional zone must therefore be related to the granodiorite for if the diorite represented an original border phase of the gabbro it would certainly be cut through at some point by the granodiorite.

The highly variable textures of the transition rocks as well as the presence of swirls and streaks of hornblende schlieren indicate that the process was not one of static replacement involving the transfer of silica and alkalies to the basic rocks. It appears instead that the gabbro along the contact became disaggregated and the minerals distributed throughout the contact zone of the invading granodiorite magma. The entire zone must have become mobile enough to flow and produce the schlieren structures.

Reciprocal reaction between the gabbroic minerals and the granodiorite magma, as outlined by Bowen (1928), would account for the observed mineralogical changes; that is minerals higher in the reaction series would react with the liquid to produce minerals in equilibrium with it. In the Davies Creek gabbro body the first of these changes was the complete replacement of pyroxene by hornblende. The latter mineral, being in equilibrium with the granodiorite magma, continued to crystallize within the hybrid magma. The glomeroporphyritic clusters of hornblende in the hybrid rocks may be recrystallized remnants of large poikilitic hornblendes derived from the gabbro. If the derived hornblende acted as nuclei for the further precipitation of hornblende from the granodiorite magma the glomeroporphyritic texture would be accentuated.

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Feldspar of the transition rocks also shows evidence of reciprocal reaction between derived crystals and liquid. Plagioclase of the gabbro is entirely unzoned labradorite and that of the granodiorite is strongly zoned andesine-oligoclase. Plagioclase of the transitional rocks is moderately zoned and ranges from labradorite to andesine. The labradorite cores are presumably derived from the gabbro and the andesine rims crystallized on them from the liquid.

Pyroxene Quartz Diorite Facies

The pyroxene quartz diorite facies occurs only in the eastern part of the Chimdemash apophysis, which is composed of pyroxene diorite, quartz diorite, granodiorite, quartz monzonite, and associated swarms of alaskite dykes. The suite differs in several respects from all other rocks of the Coast Intrusions and seems to be related to an independent centre of intrusive activity near Chimdemash Lakes. It is probably the earliest intrusive suite in the area as it is cut by dykes and cupolas of pink granodiorite similar in composition, character, and colour to the earliest phase of the main batholith, in the western part of the apophysis.

Subdivisions

Four main subdivisions or phases of the pyroxene quartz diorite facies have been made, based largely on textural variations and colour. They are the quartz diorite, or border phase; granodiorite, or coarse-grained non-porphyritic phase; granodiorite and adamellite, or porphyritic phase; and the adamellite granophyre, or central phase. The various phases of the Chimdemash apophysis are symmetrically arranged with respect to the outer contact. Mineralogical variation representing modes of specimens taken at regular intervals between the outer contact and the centre of the apophysis is shown in Figure 2 and Table II. Transition from one phase to another is gradational across the entire apophysis indicating that the various subdivisions or phases of the pyroxene quartz diorite facies are the result of crystallization processes rather than of separate intrusions.

Contacts between phases are commonly gradational but any of the inner phases may locally intrude or replace any of the outer phases. This gives rise to confusing field relations. A dyke of one phase may have sharp contacts at one point and may be completely gradational with its host at another. At still another point, it may itself be cut by a third phase that is completely gradational at the centre of the apophysis.

Contact Relations

Volcanic rocks along the north and south sides of the apophysis dip steeply away from the contact but at the eastern end or nose, the massive flows dip steeply towards the contact. The massive flows have been moderately folded but not overturned, and have not suffered appreciable faulting or shearing.

Along most of the contact fine-grained, black quartz diorite is in sharp intrusive contact with andesite flows and fragmental rocks. Very few dykes of this phase

extend into the country rock and no recognizable inclusions of andesite occur within the intrusion. There is no discernible contact metamorphism of the flows and only slight alteration of the fragmental rocks, the latter having developed epidote porphyroblasts within a 5- or 10-foot zone along the contact.

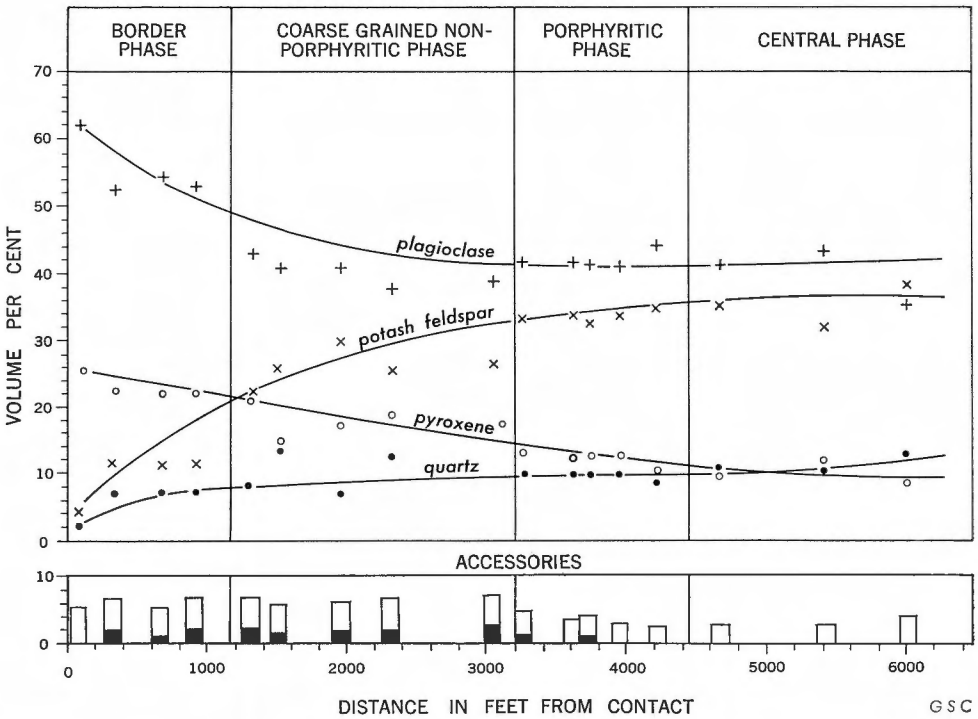


FIGURE 2. Diagram illustrating the variation in modal composition of the Chimdemash rocks according to their distance from the contact.

At several points dykes of an inner phase have broken through the quartz diorite shell to intrude the volcanic rocks. Dykes in greatest number and continuity stem from the central phase. Commonly they show all the characteristics of replacement dykes but a few are intrusive, at least in part, and show evidence of dilation in the walls. Some crosscut pre-existing structures without causing dilation, others merge into zones of replacement breccias that show all gradations in degree of replacement. In some of these replacement breccias the fractures have been healed without appreciable modification of the shape of the blocks. In others replacement has proceeded inward from the fractures until the blocks have been reduced to isolated elliptical residules comprising half the total volume of the zone. Alaskite dykes up to 50 feet thick cut all phases of the apophysis and commonly occur in parallel swarms radiating from the central phase. Many individual dykes extend 4 to 5 miles into the country rock but do not cut the pink granodiorite in the western part of the apophysis. This fact, together with

Table II

Rocks of the Chimdemash Apophysis

PHASE	FIELD CHARACTERISTICS	PLAGIOCLASE	PYROXENE	POTASH FELDSPAR	QUARTZ	ACCESSORIES
BORDER PHASE Fine-grained Non-porphyritic Quartz diorite	Both feldspar and mafic minerals; black to dark grey with high resinous luster, average grain size 1 to 2 mm; sharp intrusive contacts against Hazelton volcanic rocks	$An_{48 \pm 5}$ Unzoned lath-like euhedral crystals with simple albite twinning, almost totally free of alteration products	Augite (approximately Wo_{40} En_{45} Fs_{15}). Interstitial or subophitic grains; most grains are uniform but a few show very fine exsolution lamellae on (001,) about 30% converted to pale green chlorite	Small anhedral, untwinned grains interstitial to all other crystals	Small interstitial grains some of which embay plagioclase, uniform extinction	Magnetite and apatite, the latter in crystals up to 2 mm long
COARSE-GRAINED NON-PORPHYRITIC PHASE Granodiorite	Feldspar dull green, pyroxene black with high luster, average grain size 3 to 4 mm; uniform granitic texture; gradational with border phase	$An_{40 \pm 6}$ Unzoned subhedral crystals partly replaced by quartz and potash feldspar, clouded by alteration products, mainly sericite and actinolite	Augite ($2v \pm 50°$) All grains show rounded outlines due to partial replacement by plagioclase but subophitic texture not completely destroyed; coarse exsolution lamellae of pigeonite on (001,) about 70% converted to pale green chlorite	Anhedral untwinned grains interstitial to, and partly replacing, plagioclase; intergrown with quartz as granophyre; not clouded	Interstitial to and embaying plagioclase; intergrown with potash feldspar as granophyre; uniform extinction; contains a few small apatite inclusions	Magnetite, hematite, and apatite, the latter in crystals up to 4 mm long
PORPHYRITIC PHASE Granodiorite and adamellite	Green feldspar phenocrysts and dull black mafic minerals surrounded by a very fine grained light or dark rose matrix, phenocrysts vary from 2 to 10 mm and constitute up to 50% of rock, matrix aphanitic to fine grained; gradational with, and intrusive into, above phases	$An_{36 \pm 4}$ Unzoned anhedral grains strongly embayed by quartz and potash feldspar, moderate to intense clouding by iron oxide dust; forms phenocrysts up to 10 mm in diameter	Augite ($2v \pm 50°$) Replacement by plagioclase has reduced all grains to circular or elliptical islands several of which may be in optical continuity and be remnants of a large crystal; about 80% converted to chlorite but pseudomorphs of exsolution lamellae remain	Anhedral, interstitial grains replacing and mantling plagioclase; intergrown with quartz as granophyre and locally pseudomorphic after plagioclase; moderately clouded with iron oxide dust	Interstitial to and embaying plagioclase, in some grains replacement by quartz is almost complete; intergrown with potash feldspar as granophyre, uniform extinction	Magnetite, hematite, and apatite, the latter commonly in clusters of crystals up to 2 mm long
CENTRAL PHASE Adamellite and granophyre	Deep rose coloured feldspar, green glomeroporphyritic feldspars and clusters of pyroxene may or may not be present; forms replacement bodies in all above phases	An (not determined) Unzoned anhedral grains partly replaced by quartz and potash feldspar; forms glomeroporphyritic clusters with altered pyroxene	Augite ($2v \pm 50°$) Occurrence similar to above but in a more advanced stage of replacement by plagioclase; about 90% converted to chlorite	Forms a mosaic texture with quartz, the two minerals mutually replacing plagioclase; moderately clouded with iron oxide dust	Forms a coarse mosaic with potash feldspar, the two minerals mutually replacing plagioclase; uniform extinction	Hematite, magnetite, and small apatite crystals

the close spacial relation of the dykes and the pyroxene rocks, suggests a genetic relationship and supports the hypothesis that the pyroxene rocks were emplaced prior to the pink granodiorite.

Mode of Emplacement and Crystallization History

Steeply dipping concordant contacts along the north and south sides of the apophysis are indicative of forceful upward intrusion. The steeply inward dipping volcanic rocks at the northeast suggest that the magma escaped from its main chamber and expanded in this direction to override partly the rocks there. The almost continuous outer shell of fine-grained quartz diorite gradational with the inner phases suggests that the entire assemblage was emplaced as a single intrusion. Therefore, the mode of emplacement is indicated as that of forceful emplacement of a relatively viscous magma that expanded towards the northeast overriding some of the rocks in that direction. An outer shell of fine-grained quartz diorite was formed, which is gradational with the inner phases.

This gradational transition from one phase to another is a result of progressive crystallization of the magma from the outside towards the centre. As very few dykes of the quartz diorite phase extend into the country rock, the magma must have been quite viscous at the time of its initial emplacement. As crystallization proceeded volatiles became enriched in the central, fluid part. This increased the fluidity of the residual magma to the point where it could be injected for appreciable distances along fractures in the solidified outer shell. As soon as crystallization of a particular zone reached the point where the rock would fracture it was intruded by more volatile-rich material from the interior. The high volatile content of these dykes would explain their high reactivity with the volcanic rocks. During the final stages of crystallization a large volume of volatile-rich residual fluid containing silica, iron, and potash escaped from the centre of the intrusion. The red replacement dykes and breccias were formed during this stage as were most of the replacement textures of the inner phases.

Plagioclase and augite were the first minerals to crystallize and their ophitic texture suggests that they formed simultaneously (Turner and Verhoogen, 1951). There is no resorption of earlier formed crystals, in the outer quartz diorite phase, and their idiomorphic outlines are preserved. Therefore, the outer quartz diorite must have solidified completely before changes in the residual liquid were sufficient to upset the crystal-liquid equilibrium. In the central phases, however, early formed crystals of augite are partly resorbed by plagioclase. As a result most of the pyroxene in the central phase has been reduced to circular or elliptical remnants, completely enclosed in plagioclase (Pl. IV B).

All the augite of the central phases contains exsolution lamellae on (001) that are presumed to be pigeonite. This characteristic is either missing or very rare in the border phase where its development was hindered by the more rapid cooling.

By the time potash feldspar and quartz began crystallizing, early formed plagioclase was no longer in equilibrium with the residual liquid. The plagioclase has

therefore been partly replaced by both these late minerals and its original idiomorphic outlines destroyed. Granophyric intergrowths of quartz and potash feldspar similar to those of the pink granodiorite are present in all the central phases of the intrusion. As in the pink granodiorite, quartz continued to crystallize longer than potash feldspar and most of the present graphic outlines are the result of quartz replacement of early formed orthoclase or anorthoclase.

The higher degree of deuteric alteration in the inner phases compared with that of the border phase is a consequence of their higher volatile content. The feldspars are clear in the outer phase, contain minute sericite and actinolite crystals in the intermediate phases, and are intensely clouded with iron oxide dust in the central phase. This iron oxide dust gives the central phase its red colour.

Inner Facies

Biotite granodiorite with or without minor hornblende is by far the most abundant and continuous facies of the Coast Intrusions in Terrace map-area. It forms a more or less homogeneous central mass west of the complex rocks comprising the border facies. Commonly it is gradational with rocks of the border facies. Where the border facies is missing the granodiorite of the inner facies is in sharp intrusive contact with the country rock.

Three distinct sub-facies are recognized and designated, by virtue of their colour, as the green, pink, and white biotite granodiorite. This differentiation is based largely on differences of texture and degree of hydrothermal alteration, and is justified on the grounds that the sub-facies occupy separate, well-defined areas and show consistent relations to one another. The relative ages of the pink and green granodiorite could not be established, but both are definitely older than the white granodiorite and are cut by numerous dykes and apophyses of it. As seen from the table of modal analyses (Fig. 3) there is little or no quantitative mineralogical difference between the sub-facies, but they are easily distinguished both in the field and in thin section on the basis of properties listed in Table III.

Pink Granodiorite Sub-facies

The pink granodiorite sub-facies comprises most of the Kleanza Creek apophysis and the central part of the Chimdemash apophysis. It is intruded by dykes and cupolas of the white granodiorite and is gradational with the green granodiorite. Its relation to the pyroxene quartz diorite facies is not certain, but it is believed to be younger.

Both adamellite and granodiorite phases are present. At the eastern end of the Kleanza Creek apophysis granodiorite forms swarms of subangular inclusions in the adamellite and both phases are intrusive into slightly metamorphosed volcanic rocks of the Hazelton Group. This suggests that the granodiorite blocks are cognate inclusions derived from an early intrusive phase. Elsewhere the two phases are completely gradational with one another and show no apparent relation to contacts.

The pink granodiorite is the only facies with a pegmatitic phase other than small replacement veins. The pegmatite has a grain size from three to five times

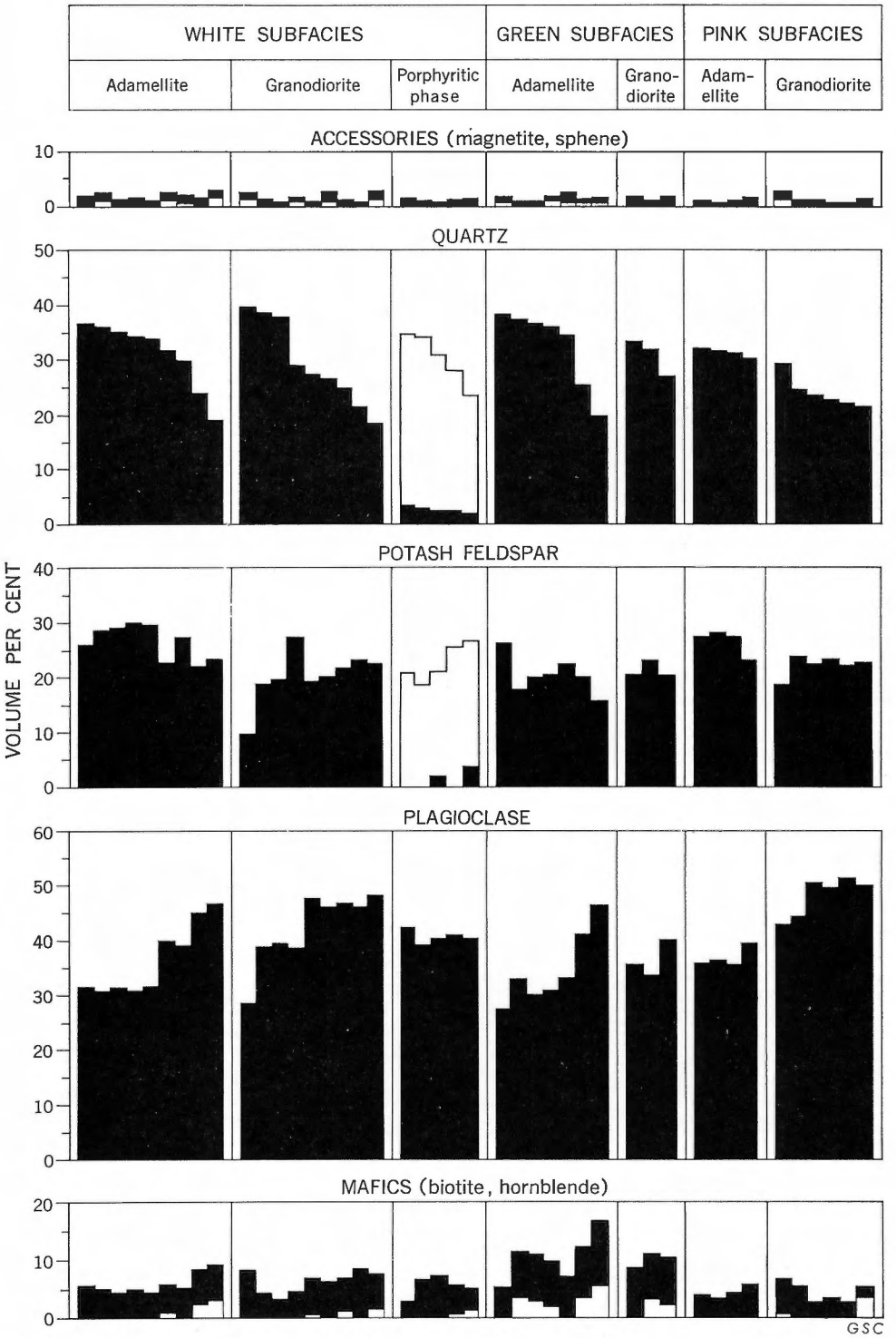


FIGURE 3. Modal analyses of typical specimens from the inner facies. Groundmass (white) and phenocrysts (black) are shown separately for the porphyritic phase.

Table III

Textural Differences in Rocks of the Inner Facies

GROUP		FIELD CHARACTERISTICS	DEGREE OF VARIATION	DEUTERIC ALTERATION	QUARTZ	POTASH FELDSPAR	PLAGIOCLASE		MAFIC CONSTITUENTS	ACCESSORIES
							Textural Relations	Range of Zoning		
WHITE GRANODIORITE	Major Phase	White, clear feldspars and unaltered biotite; uniform non-porphyritic medium- to coarse-grained granitic texture	Most uniform phase of batholith, the only variation is presence or absence of small amounts of hornblende; inclusions small and few except near contacts	Very slight; a small amount of sericite and actinolite in the plagioclase, other constituents free of alteration products	Moderately strained, interstitial to and apparently replacing both feldspars	Interstitial, generally poikilitic, may or may not be perthitic	Euhedral to subhedral, partly replaced by quartz and potash feldspar, enclosed by poikilitic potash feldspar	An_{36} to An_{12}	Generally brown biotite only, small euhedral hornblendes may comprise up to 20% of the total mafic content; biotite occurs as discrete subhedral grains	Abundant sphene occurring as euhedral crystals, minor magnetite and apatite, the latter as very fine needles in both quartz and feldspar
	Porphyritic Phase	¼ to ½″ white, euhedral feldspar phenocrysts in a fine-grained to cryptocrystalline matrix	Extremely uniform in both texture and composition	Slight or absent except immediately adjacent to contacts with non-crystalline rocks	With potash feldspar in groundmass, may form 2% or 3% of phenocrysts	Almost entirely restricted to groundmass, where it forms a very fine grained mosaic with quartz	Euhedral, phenocrysts	An_{27} to An_{10}	Biotite and minor hornblende, both as euhedral phenocrysts	Minor sphene; magnetite and apatite, apatite needles 2 to 3 times as large as in major phase
	Inclusions: In Interior	Small, elliptical or circular, fine- to medium-grained granitic texture	Uniform in any one area, but hornblende to biotite ratio varies from one locality to another	Same as enclosing rock	Moderately strained	Non-perthitic, interstitial but not poikilitic	Subhedral	An_{40} to An_{25}	Similar to, but more abundant than in, major phase; higher ratio of hornblende to biotite	High sphene content, always much coarser grained than in major phase
	Inclusions: Near Contacts	Angular, variable in size; very mafic, mostly very fine grained to aphanitic, commonly rich in epidote and green poikilitic hornblende	Highly variable in composition and texture; vestiges of primary sedimentary features common	Usually highly sericitized and epidotized	Not strained	Mostly absent or as small interstitial grains, not perthitic	Unzoned	About An_{40}	Biotite and hornblende, or both, hornblende is mostly poikilitic, biotite occurs in clusters	High magnetite content and some apatite in places
PINK GRANODIORITE	Major Phase	Pink or pink and white feldspar	Same minerals throughout but texture varies from fine- to coarse-grained non-porphyritic	Plagioclase clouded by very fine, opaque dust responsible for pink colour, probably hematite	Not strained	Highly perthitic, interstitial to, and partly replacing, plagioclase	Euhedral to subhedral crystals, partly replaced by quartz and potash feldspar	An_{40} to An_{18}	Brown biotite, in discrete subhedral to euhedral crystals; minor hornblende in small euhedral prisms visible in some sections	
	Inclusions	Angular dark green blocks of variable size and shape	Highly variable; almost all retain some vestige of volcanic or sedimentary structure	Mostly highly chloritized and epidotized	Not strained		Unzoned, anhedral crystals	About An_{40}	Green hornblende and biotite, both largely chloritized	Magnetite, minor apatite and sphene
GREEN GRANODIORITE	Major Phase	Feldspar dull green due to alteration products, biotite in clusters of minute flakes, commonly chloritic	Highly variable in amount of mafic constituents; inclusions numerous; quartz diorite and diorite are minor gradational variants	Plagioclase almost totally clouded by coarse-grained sericite and actinolite, biotite largely converted to pennenite	Granular, recrystallized mosaic, not strained	Mostly microcline, non-perthitic, interstitial to, and replacing, plagioclase	Euhedral to subhedral	An_{42} to An_{9}	Brown biotite in clusters of small flakes associated with magnetite, green hornblende, and sphene	Magnetite, minor apatite and sphene
	Inclusions	Small (2–3″), subangular, mafic clots randomly distributed throughout the mass	Uniform in size, shape and composition	Same as enclosing rock	Granular, recrystallized mosaic, not strained	Interstitial, non-perthitic grains	Subhedral grains partly replaced by quartz	Not determined	Green, poikilitic hornblende and clusters of small biotite flakes	Magnetite, apatite, and secondary sphene

that of the host rock and forms poorly defined dykes up to 4 feet thick and irregular masses up to 15 feet across. The mineral assemblage is the same as in the granodiorite though the pegmatite contains a higher percentage of quartz and potash feldspar. The presence of pegmatite suggests that the pink granodiorite was relatively rich in volatiles.

Locally the granodiorite has been modified by hydrothermally introduced quartz that has replaced various amounts of feldspar. The affected areas appear as linear zones many hundred feet wide, within which small 'pools' or segregations of quartz up to 5 feet across have formed at the expense of the granitic minerals. There is no sign of brecciation but rather a progressive increase in the amount of intergranular quartz from 20 to 25 per cent in the normal granodiorite and as much as 80 to 90 per cent in the quartz pools. Wall-rock adjacent to such zones is commonly cut by a boxwork of barren quartz veins.

All rocks of the sub-facies are characterized by pink or rose plagioclase. The colour is imparted by a dust of extremely fine opaque particles more or less evenly distributed throughout the plagioclase crystal. Though the particles can barely be resolved, even with high power under the microscope, chemical tests indicate a higher content of iron in the pink plagioclase than the uncoloured. The two types may also be separated magnetically. These facts together with the red colour suggest that the dust is finely disseminated hematite.

Textural Variations

Of thirty-six thin sections of pink granodiorite examined, nineteen exhibit granophyric intergrowths of quartz and potash feldspar (Pl. V A). Similar textures are found in the central phases of the pyroxene quartz diorite facies but are rare in the white and green granodiorite sub-facies. Simultaneous crystallization and replacement have both been proposed as possible mechanisms of formation. The various arguments are outlined by Spencer (1945) and need not be repeated here.

In the pink granodiorite the granophyre appears to be interstitial though it forms over 50 per cent of some of the rock. The size and shape of the individual graphic frets vary greatly even within a single thin section; smaller ones tend to be myrmekitic whereas the larger intergrowths are more irregular. Relations between graphic frets and idiomorphic crystals of quartz and feldspar suggest that replacement played a dominant role. Large grains of quartz are in optical continuity with graphic frets along their borders and islands of microcline have sometimes been isolated within the quartz. These are inevitably in optical continuity with adjacent crystals of microcline, which are themselves intricately embayed by quartz. Quartz sometimes replaced the outer part of plagioclase crystals in such a way that twin lamellae are truncated by vermicular embayments of quartz. These features suggest but do not prove a replacement origin. It seems fairly certain that the granophyre is related to some unique feature of the pink granodiorite, most probably its relatively high water content. It is reasonable to suspect that, prior to localization along fractures, silica-rich solutions permeated the intergranular space of the entire

rock mass. This is where the graphic texture probably developed through selective partial replacement of interstitial potash feldspar.

Coarse vein-perthite is a common textural feature of the pink granodiorite that is rare in the other sub-facies. The albite lamellae are commonly irregular, tending towards patch perthite, and are large enough in some cases to show fine albite twinning. These coarse perthites are the result of unmixing and coalescence at a late stage of crystallization. According to Williams (1954) unmixing of the potash feldspar is promoted by autometamorphism and slow cooling as well as by post-consolidation regional or contact metamorphism.

Contact Relations

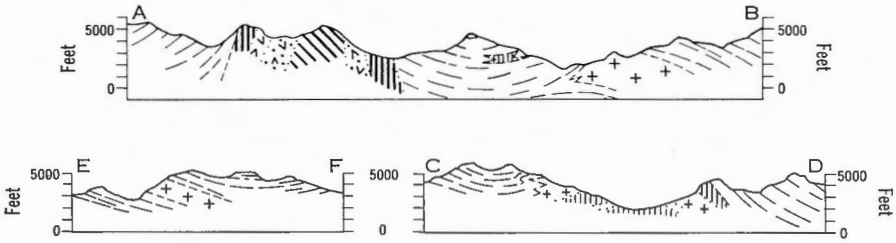
Contacts between Hazelton Group rocks and the pink granodiorite are characterized by an extensive zone of injection breccia. There has been no plastic deformation of the wall-rock or development of schistose structures or hybrid zones. The pink granodiorite was emplaced by shattering and intrusion along a maze of interconnecting fissures. Early quartz diorite phases were themselves shattered and intricately dyked by the later pink granodiorite.

The individual dykes vary in width from less than a quarter of an inch to 60 feet; both large and small dykes have fine-grained selvedges against the country rock. Commonly the chilled edge of a dyke is continuous with the chilled edges of all intersecting dykes indicating that a large part of the dyke complex was liquid at the same time and emplaced at the same time. The dykes, in general, show remarkable continuity even the smallest ones extending several tens of feet without changing direction or thickness.

The physical characteristics outlined above indicate that the pink granodiorite magma was intruded in a very fluid condition under high differential pressure and that the country rock was not plastically deformed. Such characteristics would result if a volatile-rich magma were intruded early in the magmatic history, in this case prior to emplacement of the large central masses of the white and green granodiorite sub-facies that caused a regional rise in temperature.

The relation of outcrop pattern to topography in the Kleanza Creek apophysis presents an interesting structural problem. The eastern bulge of the apophysis is connected to the main mass by a relatively narrow belt of granodiorite that is both roofed and floored by greenstone. Within the eastern bulge itself is a central area of injection breccia similar to that adjacent to the outer border. This central area is also the lowest point topographically and it too may represent a contact. All the larger feeder dykes in the breccia zones are subhorizontal, suggesting that the main movement of magma was lateral rather than upward.

It is not suggested that the entire Kleanza Creek apophysis was emplaced by lateral migration of magma, for there is no reason to suspect that its western part is not continuous at depth. However, the eastern bulge and its connecting tongue of granodiorite appear to have been emplaced by lateral injection of magma from the main reservoir (Fig. 4) in much the same manner as that proposed by Hunt (1937) for the batholiths of the Henry Mountains. This ex-



Sections along lines A-B, C-D and E-F

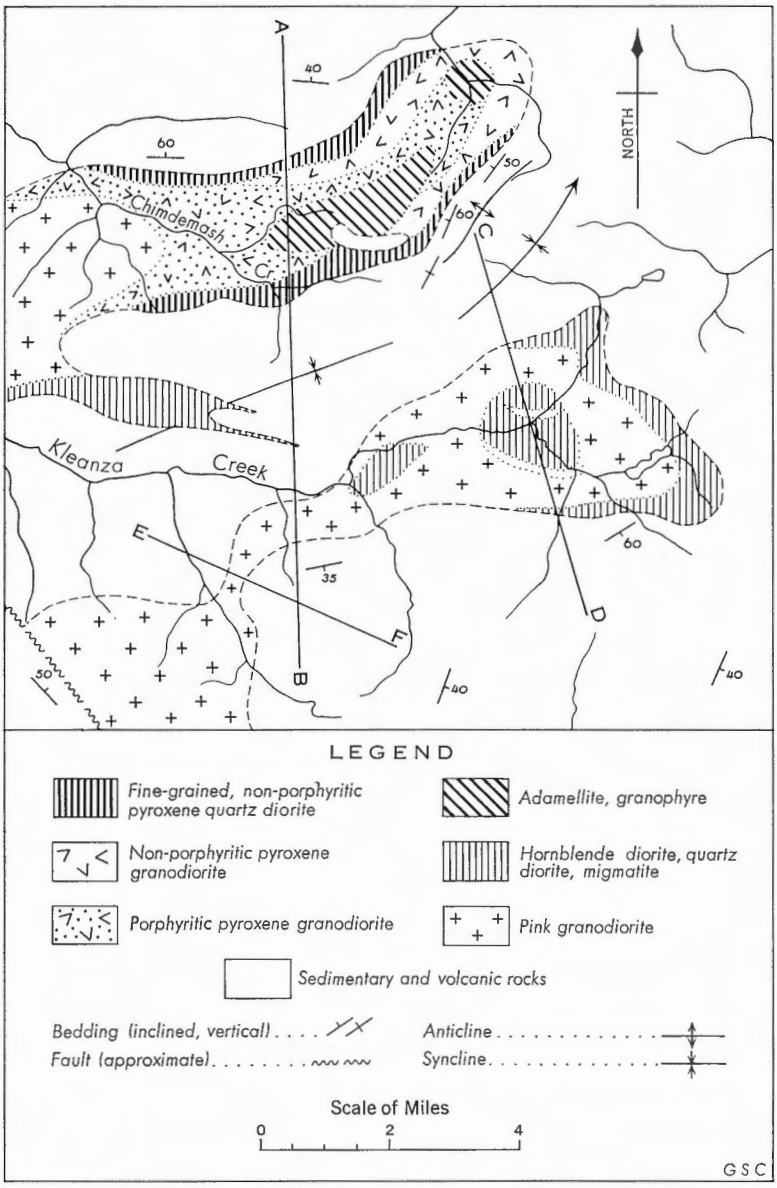


FIGURE 4. Map and schematic sections of the Kleanza Creek apophysis.

plains the structural and topographic relations as well as the relatively low grade of contact metamorphism along much of the eastern end of the apophysis.

Green Granodiorite Sub-facies

Green granodiorite underlies a large area north of Terrace and a smaller area near the head of Kitimat River. At both places it is cut by dykes of white granodiorite and thus represents an earlier phase of the batholith. It is everywhere separated from the volcanic and sedimentary strata by a wide zone of mafic-rich hybrid rocks with which it is completely gradational.

Most of the primary textural and mineralogical features have been obscured by intense deuteric alteration and metamorphic effects resulting from emplacement of the younger white granodiorite. The feldspars are crowded with alteration products, chiefly sericite, actinolite, and minor epidote. Alteration of the plagioclase has progressed too far for index determination to be made but extinction methods indicate an approximate range of zoning from An_{20} to An_{35}. Biotite has been partly replaced by pale green poikiloblastic hornblende and in some sections by penninite. It occurs as clusters of minute flakes, rather than as discrete grains, associated with its alteration products, magnetite, sphene, chlorite, and green hornblende. This occurrence of biotite is characteristic of the rock and is probably the result of post-consolidation deuteric and hydrothermal activity.

Small mafic-rich inclusions are common in the green granodiorite. They are rarely more than 5 to 6 inches long and average about an inch. At least half of them are subangular, but their boundaries are everywhere gradational with the host rock, and except for higher mafic content they have the same mineral assemblage. The biotite of the inclusions occurs in clusters similar to those in the granodiorite.

Emplacement of the green granodiorite was similar to that of the younger white granodiorite, described in the section following, and it is probable both magmas originated from the same source. Though its composition differs little from that of the younger white granodiorite, the green sub-facies was intruded much earlier in the magmatic cycle and there was an appreciable lapse of time prior to the emplacement of the white sub-facies. This is significant when considering the origin of the diverse rock types within the batholith. The lack of any great difference between the green and the white granodiorite points to the conclusion that magmatic differentiation was not a major factor in producing the present diversity of phases. The minor variants of both sub-facies, viz., associated diorite and quartz diorite, are the products of the contamination of granodiorite magma by more basic material derived from the wall-rocks.

White Granodiorite Sub-facies

The white granodiorite is the most uniform in texture and composition of the three subdivisions of the inner facies. Modes of typical specimens arranged accord-

ing to Johannson's (1932) classification are shown in (Fig. 3). There is no consistent relation between the adamellite and the granodiorite, but quartz diorite is a common gradational phase between granodiorite and more basic rocks of the border facies. It is also common in the vicinity of inclusion swarms which are sparsely distributed throughout the mass.

A porphyritic phase of the white granodiorite forms irregular masses adjacent to contacts and occurs as dykes up to several hundred feet wide and over a mile long. It exhibits both intrusive and gradational contacts with the white granodiorite, but is clearly intrusive into all other rocks of the area. The central and western parts of a small apophysis near the head of Schulbuckhand Creek is composed of normal, coarse-grained, white granodiorite but the contact zone and eastern part are porphyritic. Dykes of similar porphyry within the granodiorite commonly have narrow chilled edges containing feldspar phenocrysts of the same size and character as those in the centre of the dyke. As seen from Figure 3, the modal composition of the porphyritic and non-porphyritic phases is almost identical. Both contain euhedral plagioclase with strong progressive zoning and rare oscillatory zoning. In the porphyry the plagioclase is surrounded by a fine-grained mosaic of quartz and potash feldspar (Pl. VI A); but in the non-porphyritic phase it is surrounded and partly replaced by large poikilitic potash feldspars and interstitial quartz (Pl. VI B).

Field relationships suggest that both phases were derived from the same initial magma. The porphyritic phase was formed when cooling was rapid enough to retard normal crystallization of quartz and feldspar. It is, therefore, more common in later phases of the intrusions, which are of relatively small size and thermal capacity.

From these relations we can infer something of the nature of the magma during its emplacement. Crystallization and progressive zoning of the plagioclase and crystallization of most of the biotite must have proceeded during or prior to the emplacement of the magma. The presence of abundant phenocrysts in the porphyritic phase indicates that crystallization of plagioclase was largely complete by the time the magma reached its final position. At the same time the components of quartz and potash feldspar must have been in mutual solution at high temperature. The porphyritic phase contains on the average 45 per cent phenocrysts and 55 per cent matrix representing respectively the solid and liquid fractures of the magma at the time of emplacement.

The interstitial fluid of the porphyry cooled too quickly to permit the growth of coarse crystals; instead a uniformly fine-grained mosaic of quartz and potash resulted. There was little opportunity for reaction between plagioclase phenocrysts and residual fluids, thus the sharp euhedral outlines of plagioclase phenocrysts in the porphyry contrasted with the partly replaced plagioclase of the major phase. Post-consolidation cooling was too fast for unmixing of soda orthoclase; thus the potash feldspar is non-perthitic.

The main mass of white granodiorite cooled sufficiently slowly to permit large distinct crystals of quartz and potash feldspar to form, and at the same time partly replace early crystals of plagioclase. Commonly potash feldspar crystals grew to

sufficient size to enclose several plagioclase crystals giving the rock a poikilitic texture. Cooling after consolidation was also slow, permitting the unmixing of soda orthoclase and the formation of perthite.

Contact Relations

Commonly the granodiorite grades through a zone of quartz diorite into the complex mafic rocks of the border facies. Where the border facies is absent, as along much of the contact south of Chist Creek, coarse-grained granodiorite is in direct contact with sedimentary and volcanic rocks. The contact is sharp and the stratified rocks, although truncated on a regional scale, are conformable in detail. Complex folding near contacts is clearly related to forceful emplacement as is the low-grade dynamothermal metamorphism of the contact rocks.

Inclusions

Inclusions are rare in all phases of the white granodiorite, but two distinct types are recognized, one, the angular inclusions near the border, the other, the swarms of elliptical mafic clots sparsely and haphazardly distributed throughout the granodiorite. Both types are rich in apatite and sphene and have a relatively high ratio of hornblende to biotite. The angular inclusions of the border zone are obviously derived from the wall-rock and commonly retain vestiges of primary banding. The inclusions represented by the elliptical mafic concentrations are similar to their host rock, differing only in their higher mafic content and finer grain. The tendency for the granodiorite to grade into quartz diorite in the vicinity of inclusion swarms supports the hypothesis that these mafic-rich elliptical forms are the ghosts of foreign inclusions incorporated at an early stage of intrusion and subsequently modified by reciprocal reaction with the magma.

Internal Structures

The white granodiorite sub-facies is exceedingly uniform in texture. It is normally a uniform non-porphyritic medium- to coarse-grained plutonic rock exhibiting typical granitic texture. It is locally porphyritic where ¼- to ½-inch white euhedral phenocrysts of feldspar occur in a fine-grained to cryptocrystalline matrix. Concordant foliation, resulting from crystal alignment during viscous flow is not common. In the rare instances where foliation is present it bears no relation to contacts but is the result of post-consolidation shearing followed by recrystallization. The same characteristic was observed in this sub-facies of the Coast Intrusions on Kitlope Lake in Whitesail Lake map-area (Duffell, 1959). Visible flow structure is absent from the porphyritic phase as well as the main sub-facies.

Border Facies

The border facies is defined by its position relative to the homogeneous rocks of the inner facies. It forms a wide outer zone around the main body of the batholith and a narrower zone around parts of the Kleanza Creek apophysis, as well as several roof pendants. It contains a complex assemblage of rocks

of several origins, but which possess sufficient common features for them to be grouped together. Their very heterogeneity sets them apart from the large homogeneous masses of granodiorite of the inner facies. The border facies is characterized by the abundance of hornblende which commonly exceeds biotite. The rocks of this facies are believed to be the product of interaction between the magma, its associated volatile constituents, and the older sedimentary and volcanic rocks. Some of the varieties are dominantly magmatic, others just as dominantly metasomatic or metamorphic. Most are hybrids resulting from a combination of all three processes. Three sub-facies are discussed, viz., a hornblende granodiorite, a hornblende diorite-quartz diorite, and a migmatite.

Hornblende Granodiorite Sub-facies

Medium- to fine-grained hornblende granodiorite forms a transitional zone between the biotite granodiorite of the inner facies and the country rock. It may or may not be separated from the country rock by a hybrid zone or replacement migmatite. It is completely gradational with the central mass of biotite granodiorite and with the hybrid rocks.

The boundary between the granodiorite of the inner facies and the hornblende granodiorite has been taken arbitrarily at the point where total mafic minerals exceed 10 per cent of the rock and include megascopic hornblende. The most useful field criterion for distinguishing between the two is the much greater abundance of inclusions in the hornblende granodiorite. Where the inclusions exceed 50 per cent of the total volume the rock has been classed as migmatite, and where hornblende exceeds biotite, the rock is classified with the hybrid pseudodiorite.

Inclusions in the hornblende granodiorite are of two types, one showing no evidence of alteration the other being completely reconstituted. Both types may occur together. The latter is by far the most abundant. They are commonly elliptical or lenticular and drawn out into tenuous streaks or schlieren. Immediately surrounding these reconstituted types the granodiorite contains a higher percentage of ferromagnesian minerals and commonly hornblende exceeds biotite. The unaltered inclusions occur only when the granodiorite is in direct contact with unmetamorphosed country rock, and are rarely more than a few feet from the contact. They are angular and commonly retain some elements of their texture and structure.

Where the hornblende granodiorite is in direct contact with sedimentary and volcanic rocks neither has been appreciably modified. Contacts are sharp and the granodiorite within 5 or 6 feet of the contact has developed an indistinct concordant foliation. Dykes of granodiorite extending into the walls show evidence of dilation but do not as a rule show chilled edges.

Petrography

Modes of five typical specimens of hornblende granodiorite are shown in Table IV. These differ from modes of the granodiorite of the inner facies by

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having a higher mafic content and less potash feldspar. Hornblende is always present and unlike the poikilitic plates of the hybrid diorites, it occurs as small euhedral prisms. Plagioclase is euhedral to subhedral and zoned similarly to the plagioclase of the inner facies (An_{20}-An_{40}). Quartz and potash feldspar are entirely interstitial and the quartz is invariably highly strained. Potash feldspar may or may not be perthitic.

Table IV

Modal Analyses of Five Typical Specimens of Hornblende Granodiorite

Specimen No.	1	2	3	4	5
Quartz	15.9	11.6	12.0	20.4	25.7
Potash Feldspar	17.5	5.1	10.3	16.5	18.4
Plagioclase	46.6	57.4	61.2	45.2	36.2
Biotite	8.4	9.8	4.4	5.9	7.6
Hornblende	9.2	12.0	11.4	7.3	9.1
Accessories	2.4	4.1	0.7	4.7	3.0
Magnetite	1.4	2.0	0.4	0.9	0.8
Pyrite		x			
Sphene	1.0	1.5	0.3	0.4	0.6
Apatite	x	x	x	x	x
Epidote	x	0.6			
Myrmekite		x		3.4	1.6

Accessory minerals, magnetite, sphene, and apatite occur in about the same amount as in the granodiorite of the inner facies although sphene is particularly abundant in and near inclusions.

Origin

The hornblende granodiorite is clearly intrusive but is not the product of a separate magma. Gradation from hornblende granodiorite of the inner facies indicates both are products of the same magma, the differences between them being produced by contamination of the outer zone of the intrusion. Abundant inclusions in the hornblende granodiorite provide evidence of contamination by gross fragments, and petrographic and field data indicate that these have been assimilated both mechanically and chemically by the magma.

Composition of the original magma was probably near that of the biotite granodiorite that forms the major part of the inner facies. Incorporation and assimilation of andesitic and more basic material derived from the country rock produced a hybrid magma richer in hornblende than in biotite. The more andesitic material assimilated, the greater the amount of hornblende. During this process the andesitic fragments or inclusions were themselves converted to material similar in composition to the hybrid magma. The fact that most inclusions contain min-

eral suites similar to the granodiorite itself suggests that equilibrium was closely approached immediately prior to complete crystallization. The presence of the two types of inclusions indicates their incorporation at different times and under different conditions. At the present level of exposure the hornblende granodiorite appears to have been emplaced as a semicrystalline mass, probably too viscous and cool effectively to incorporate or assimilate fragments of country rock. The walls are therefore unaltered as are the inclusions derived from them. Completely reconstituted inclusions were derived from some lower level at a time when the magma was more fluid.

Aside from the chemical reaction between magma and inclusions, mechanical disintegration appears to have been an important factor in the modification of both inclusions and magma. Deformation of the inclusions is demonstrated by the dominance of elliptical and lenticular shapes and even more graphically by the streaks of schlieren. The inclusions must have been plastic and the sialic component partly or completely liquid, leaving sponge-like masses of hornblende crystals. These masses yielded to the smallest movements of the magma and were eventually drawn out into the streaks of schlieren or the component hornblende crystals separated and surrounded by the liquid magma. The partly disaggregated inclusions and the mafic-rich granodiorite surrounding them are undoubtedly the products of such a process.

Hornblende Diorite and Quartz Diorite Sub-facies

Fine- to medium-grained hornblende diorite and quartz diorite form a wide marginal zone along the eastern contact of the green granodiorite. Their contact with the granodiorite is gradational. In a few places intrusive dykes of granodiorite cut them but commonly there is an imperceptible transition from hornblende diorite, through hornblende-biotite quartz diorite, to the biotite granodiorite of the main batholith. No consistent relation exists between the diorite and the country rock. Some contacts are sharp and obviously intrusive, others show a gradual transition from bedded rock to crystalline diorite.

An excellent example of the gradational type of contact is found on the western end of O.K. Range where hornblende diorite is in contact with breccias and greywacke of Triassic age. The bedded rocks strike almost perpendicular to the contact with the diorite and, at half a mile from it, are only slightly metamorphosed. The greywacke is a massive bedded, dark green rock composed mainly of plagioclase and rock fragments in a chloritic matrix and contains only minor amounts of quartz and feldspar. The matrix of the breccia is similar to that of the greywacke. The bulk composition of the sediments is probably very close to that of andesite.

As the contact is approached, recrystallization of the chloritic matrix is the first visible change in the sediment. Closer to the contact feldspar has recrystallized simultaneously with the development of hornblende porphyroblasts, and the resulting granoblastic texture gives the rock the appearance of a fine-grained diorite. In the breccia the fine-grained matrix is more susceptible to recrystallization than

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the fragments. Consequently the fragments may persist after the matrix has been completely dioritized. As recrystallization proceeds further, even the fragments lose their identity and the rock assumes a fairly uniform dioritic texture.

Nearer to the main granodiorite contact the textures and structures of the diorite become more complex. Small lenses and pods of mafic-poor diorite and quartz diorite become abundant. Narrow linear zones and small irregular masses of diorite occur that are extremely coarse grained and contain hornblende crystals up to three quarters of an inch long. Non-dilational, replacement dykes of quartz diorite and granodiorite are common and locally the mafic-rich diorite has been fractured and brecciated and the openings filled with quartz diorite.

The transition between the diorite and the central mass commonly shows signs of mobilization. In some places complex mixed rocks, or migmatites have resulted. In others the only evidence of movement is given by indistinct swirls and streaks or schlieren. The contact on O.K. Range is of this type, transition is gradational throughout and there is no zone where phases of markedly different composition occur together. The ratio of mafic to non-mafic minerals gradually decreases towards the granodiorite. Hornblende gives way to biotite, and quartz and potash feldspar occur as interstitial minerals.

With the exception of the Chimdemash rocks, true diorite was not observed in sharp contact with the country rock. Locally quartz diorite of the hybrid zone is in sharp, apparently intrusive contact with slightly metamorphosed volcanic rocks but the relation nowhere persists for more than several hundred feet.

Petrography

The feldspar of the diorite is unzoned, simply twinned andesine, rather than oligoclase as in the granodiorite. Only in the quartz diorite near the transition to granodiorite is the plagioclase as sodic as oligoclase and there it commonly occurs as mantles on andesine cores. In the fine-grained, mafic-rich diorites the plagioclase is commonly clouded with epidote, actinolite, and hydrous micas. In the coarser grained, less mafic diorites and quartz diorites the plagioclase is relatively clear.

Potash feldspar is absent from most of the hornblende diorite and is only a minor constituent of all other rocks in the hybrid zone. In the quartz diorite it is interstitial to all other minerals and commonly forms mantles on plagioclase.

Hornblende of the diorite is green and highly poikilitic commonly enclosing up to 50 grains of plagioclase in one porphyroblast. In the quartz diorites, hornblende commonly forms clusters. Individual crystals tend to be more anhedral than in the diorites and freer of inclusions.

Biotite first appears in the quartz diorite associated with hornblende and sphene.

Mode of Emplacement

The diorites and quartz diorites of the marginal facies are almost certainly the products of reciprocal reaction between the granodiorite magma, its associated

volatile constituents, and the wall-rocks. At least part and probably most of the diorite formed by static replacement of sedimentary and volcanic rocks. The dioritized breccias that retain 'ghosts' or original fragments were certainly formed in this manner. Simple recrystallization of the wall-rocks that are similar in bulk composition to the diorites is all that is required for a transition from one to another.

Narrow, 1-inch lenses and stringers of more feldspathic material near the centre of the hybrid zone are considered to be of replacement rather than intrusive origin. They possess all the characteristics of replacement dykes listed by Goodspeed (1940), including gradational contacts without chilled edges and non-dilation of intersected structures. Not uncommonly the dykes and lenses are coarser grained than the diorite they transect, but their modal composition is similar.

Larger dykes are composite, formed by recurrent fracturing and replacement along a single zone as suggested by Goodspeed (1940). They have a pronounced lamellar structure, caused by parallel mafic layers, which are rarely more than an inch apart. These mafic-rich layers probably represent the limits of replacement from a single fracture.

The schlieren streaks and swirls in the inner part of the hybrid zone were undoubtedly produced by flowage of semi-liquid material. It seems likely that the hybrid quartz diorite of the inner zone became sufficiently mobile to intrude the outer zone and, locally, the country rock. The few sharp contacts between hornblende quartz diorite and country rock probably originated in this manner.

Migmatite Zone

The term migmatite is used here to describe a zone of complex mixed rocks that surrounds much of the batholith. The rocks range in composition from amphibolite to pegmatite, and have evolved through the combined action of numerous processes.

As the amounts of feldspathic segregation increase in the hornblende diorite and quartz diorite, the rock grades into migmatite. There is no definite boundary between the two types and no attempt has been made to separate them on the map. For descriptive purposes the boundary is taken at the point where light coloured, feldspathic material forms a continuous network through the diorite. Towards the batholith proper, migmatite grades into contaminated hornblende granodiorite and the boundary is taken where granodiorite forms more than 50 per cent of the rock volume.

Not all the igneous contacts exhibit the ideal sequence described above. Pseudo-diorite or both pseudo-diorite and migmatite may be missing or all three zones (pseudo-diorite, migmatite, and hornblende granodiorite) may be absent, in which case biotite granodiorite is in direct contact with the wall-rock.

The migmatite zone is characterized by the association of rocks that differ greatly in composition. It is also a zone of complex igneous structures and textures. In the following description the various structural features are treated separately. They do not have any consistent spatial relationship to the border zone, and any number of them may be superimposed in a single outcrop.

Feldspathic Stringers and Segregations

Near the transition zone between pseudo-diorite and migmatite the rock is traversed by an intricate network of feldspathic stringers that varies in width from one sixteenth of an inch to two inches. Individual stringers may pinch and swell considerably, and some are mere lenses or irregular clots with no apparent interconnection. The stringers consist of quartz, oligoclase, minor orthoclase, and coarse-grained hornblende. The hornblende occurs most abundantly along the border of the stringers or in clusters of large crystals concentrated where stringers intersect or change direction.

The feldspathic stringers and segregations with their hornblende border are believed to be the products of metamorphic differentiation. It has been shown (Stillwell, 1918; and Eskola, 1933) that contrasting mineral assemblage can develop from an initially homogeneous rock through chemical or mechanical movements of material. In most rocks the two processes occur together, and this has been true of the feldspathic segregations described above.

Igneous Breccias

Igneous breccias form over 50 per cent of the migmatite zone. There are four or five distinct varieties, which differ from one another in composition, shape, and density of fragments. In Figure 5 the modes of ten inclusions from six different breccias are compared with the rock enclosing them. The fragments are finer grained and more mafic than the matrix and have a higher ratio of hornblende to biotite.

The commonest type of breccia is that formed by replacement of pseudo-diorite. It consists of irregular blocks of pseudo-diorite in a continuous phase of less mafic rock. Contacts between the blocks and matrix are gradational and the blocks themselves have random orientation and are about equidistant from one another. There is every gradation from massive pseudo-diorite to those containing about 50 per cent granodiorite matrix.

Breccias with more than 50 per cent matrix invariably show evidence of mobilization, with consequent deformation and alignment of the mafic blocks and the development of foliation in the matrix. These rheomorphic breccias are indistinguishable from breccias of purely magmatic origin. Ideally they occur near the central and inner part of the migmatite zone where the percentage of fluid was sufficient to allow relative movement between blocks. There are, however, several well-defined linear zones of similar breccia that cut all phases of the migmatite and locally extend into massive pseudo-diorite. These vary in width from 2 to 50 feet, and consist of subrounded diorite, quartz diorite, and rare greenstone inclusions in a matrix of granodiorite or adamellite (Pl. V B). Contacts between the granodiorite matrix and inclusions, and between matrix and wall-rock are sharp and well defined. The inclusions are oriented with their long axes parallel with the borders of the breccia zone and the matrix has developed a concordant foliation that is accentuated near the borders. The entire mass appears to have been emplaced as a solid-liquid aggregate forcefully intruded into the wall-rock, yet there is little or no

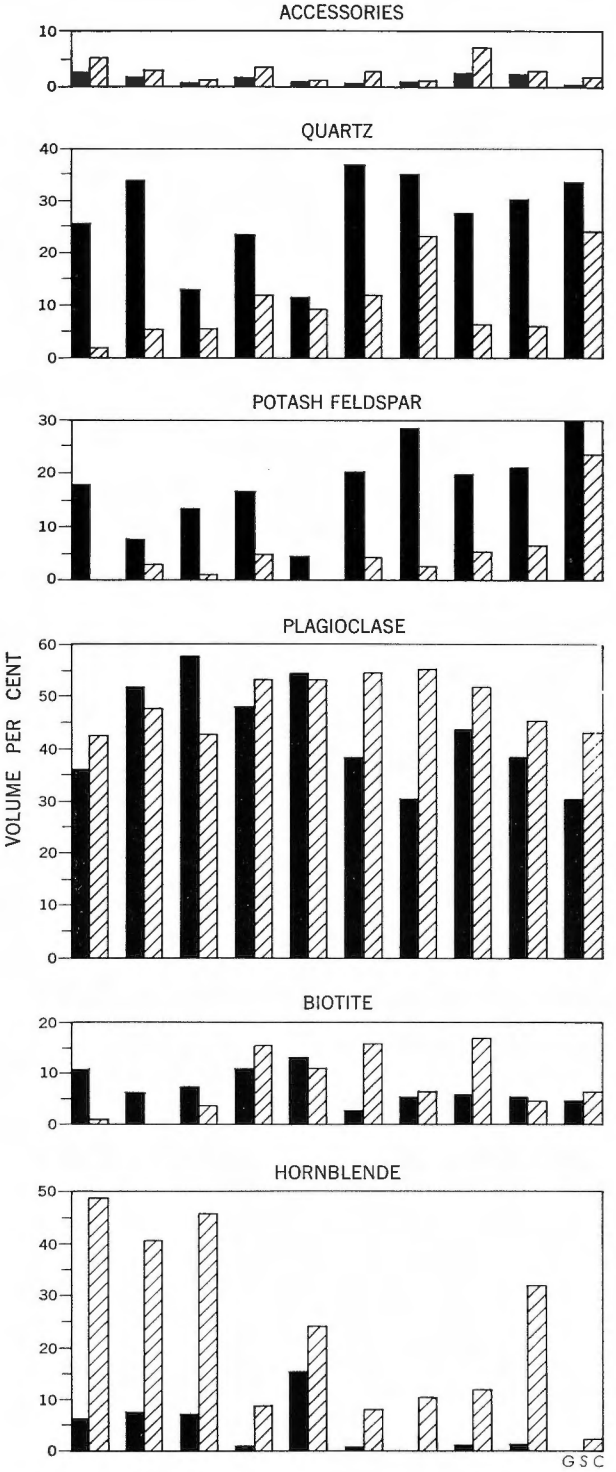

FIGURE 5. Modes of ten inclusions (ruling) from six different igneous breccias, compared with modes of the rocks enclosing them (black). Figures are volume per cent.

evidence of dilation or fracturing in the walls. The breccias are therefore considered to be rheomorphic and to have been formed by mobilization of composite fracture zones.

Injection breccias formed by the incorporation of foreign fragments in an actively flowing magma are found along parts of the contact where the migmatite zone is relatively narrow. Two distinct types occur, with no gradation between them. One contains unmetamorphosed fragments derived from the adjacent walls and incorporated in biotite or hornblende granodiorite. The second has a more varied structure and composition and a single outcrop may include several distinct phases, each successive phase having brecciated and incorporated the earlier phases.

Breccias of the first type are the least common. They are present around the Chimdemash apophysis where Hazelton Group rocks have been brecciated and intricately intruded by a network of pink granodiorite dykes. Breccias of this type also occur along the main batholithic contact south of upper Kitimat River and around the roof pendant on Mount Bolton. In the latter, dykes and sills of biotite granodiorite have been injected along joints and bedding planes of the rocks in the roof pendant. There has been little or no reaction between the inclusions and magma, thus many of the primary features of the inclusions have been preserved. The inclusions themselves have, however, been rotated relative to one another. Inclusions of this type are rarely found more than 30 feet from the contact.

The second type of injection breccia is well exposed near the mouth of Chist Creek. It consists of angular fragments of mafic rock enclosed in and cut by dykes of lucocratic rock. It includes as many as five distinct phases each of which has brecciated and intruded all earlier phases (Pl. VII A). The fragments are all more mafic than the enclosing matrix, and many are composite fragments containing two or more earlier phases enclosed in a later phase. There is evidence of dilation and rotation of fragments, but not of reaction between phases. Contacts are sharp and well defined but without chilled margins.

Breccias of this type were undoubtedly formed in the outer shell of the main intrusion which went through repeated cycles of solidification, fracturing, and emplacement of new material in the fractures. At least part of the inclusions are cognate, as they represent earlier phases. The differences in composition are due to contamination of an essentially uniform granodioritic magma rather than to differentiation.

Amphibolite

An amphibolite body outcrops on Shames River where it is exposed over a width of 250 feet. Several smaller bodies occur near the head of Chist Creek and on the mountains north of Kitimat River. These bodies are irregular and roughly tabular, and occur as large inclusions in the granodiorite. Contacts with the hornblende granodiorite are sharp and intrusive. The irregular shape of these bodies suggests that the amphibolite was in a plastic state at the time of its incorporation.

Within the massive bodies of coarse-grained amphibolite are stringers and irregular patches of lucocratic granodiorite. These are discontinuous, secretionary bodies, formed in part by abstraction and local concentration of the salic interstitial material of the amphibolite. This has resulted in depletion of the salic minerals in the amphibolite immediately surrounding the feldspathic segregations.

The hornblende, unlike that of the small clots and lenses described previously, is completely euhedral and non-poikilitic, with most of the crystals having narrow overgrowths of slightly different compositions. Quartz, andesine, and minor potash feldspar are interstitial, and small amounts of magnetite and sphene are present as accessories.

The origin of these amphibolite bodies is uncertain, but a rock similar to the olivine gabbro on Davies Creek and Mount Thornhill could provide a source of basic rock that might be converted to amphibolite through interaction with the magma.

Foliation

Most of the rocks in the migmatite zone show a strong mineral parallelism. Inclusions have been rotated and drawn out in planes of foliation to such an extent that they in places form tenuous bands of schlieren. In the inner part of the migmatite zone the foliation is unidirectional and roughly concordant with the main igneous contact; on the outer edges, it has no consistent attitude but forms swirls and undulating patterns whose orientation is controlled largely by enclosed fragments and local variations in viscosity.

Some of the granodiorites and quartz diorites appear to have developed a pronounced foliation early in their evolution; they have been brecciated and the fragments rotated relative to one another. As a result the rock possesses completely haphazard orientation of foliation planes. Formation of such breccias was accompanied or closely followed by rheomorphism or plastic flowage. Finer grained material between the rotated fragments contains the same minerals as the fragments and has a pronounced flow structure parallel with the borders of the enclosed blocks. The foliation planes of some of the blocks are bent and dragged into local conformity with flow lines in the rheomorphic matrix (Pl. VII B).

Summary and Conclusions

From the foregoing it is concluded that the main body of Coast Intrusions in Terrace map-area is a composite batholith of granitoid rock that resulted from separate emplacements of granitic material over a long period of time. The exact limits of this period are unknown, but it is indicated that intermittent emplacement occurred throughout a large part of the Mesozoic era. Granitic pebbles and boulders in conglomerate of late Jurassic time indicate that at least some granitic rocks were emplaced and unroofed by that time. It seems probable that the granite from which these pebbles were derived was emplaced at least as early as Middle Jurassic and possibly during Lower Jurassic time. In Whitesail Lake area a breccia of Middle Jurassic age contains granitic fragments of considerable size,

indicating the emplacement of granitic material prior to the Middle Jurassic epoch. Plutonic activity continued at least into the Cretaceous period and perhaps later, as is shown by the granitic rocks that cut Lower Cretaceous strata in the northern part of the area. As these strata are the youngest exposed rocks in the area it is impossible to estimate whether active emplacement occurred in more recent times or not. The fact that green granodiorite intrudes Cretaceous rocks and is itself intruded by at least one other major phase of the Coast Intrusions suggests that emplacement of granitic material continued into Middle or perhaps even Upper Cretaceous time. In the Houston area, Lang (1942) indicates the presence of granitic rocks of Tertiary age.

Pyroxene diorite and quartz diorite of the Chimdemash apophysis and olivine gabbro at the head of Davies Creek are the oldest plutonic rocks exposed in the area. Both are intrusive into rocks of the Hazelton Group and both are cut by granodiorite of the main mass of Coast Intrusions. There is therefore no criteria to determine their relative age. The mineral content and zonal arrangements of both these bodies suggest that they were emplaced as single intrusions that differentiated in place.

With the exception of the Chimdemash apophysis—which contains a genetically related series of rocks ranging from basic diorite to granophyre—there is no evidence of progressive differentiation within the main mass or batholith. The central part of the batholith consists almost entirely of biotite granodiorite and adamellite. Nowhere is there evidence of large-scale intrusion of more basic magma. Some evidence exists, however, of at least three separate ages of granodiorite-adamellite intrusion, each of essentially the same composition. This rules out the possibility that the granite is the result of progressive differentiation of a parent basic magma. If this were so, one would expect to find wider differences in composition in the various granodiorites than actually exists. The granodiorite was more probably derived from the partial melting of deeply buried geosynclinal sediments and andesitic volcanic rocks. The successive pulsations of granodioritic material arose from partial melting of the geosynclinal rocks at successively higher levels. As partial melting of any zone progressed the composition of the liquid continually changed until the point of mobilization and intrusion was reached. The point of mobilization would be determined by the amount of liquid present and would therefore correspond to a given composition range, in the present case, granodiorite-adamellite.

That the granodiorite was emplaced by forceful upward intrusion is shown by the following criteria:

(1) Deformation of wall-rocks to conform with granitic contacts
(2) Rotation of fragments in contact breccias
(3) Elevation of roof pendants relative to their stratigraphic equivalents in the wall-rock.

The granodiorite has therefore moved out of its original environment of formation, and consequently at the present level of exposure there is little evidence of partial melting or intense thermal metamorphism of the wall-rock. The older, more deeply

buried Palaeozoic rocks show more evidence of metamorphism and metasomatism towards granitic material than do the younger, less deeply buried strata. Contact relations of the granodiorite with the younger rocks are distinctly intrusive rather than those pertaining to granitization.

The emplaced granitic material did, however, react with the wall-rock to produce hybrid and pseudo-plutonic rocks, which are confined to a discontinuous zone around the outer margin of the batholith. This reaction results in two main and distinct facies in the batholithic rocks: an inner facies consisting of clean massive biotite granodiorite-adamellite, and a border facies consisting of complex products of interaction between the granodiorite magma and country rock. The products of this interaction are notably rich in amphibole. Ideally the border facies consists of three zones: an outer zone of hornfels and pseudo-diorite, an intermediate zone of migmatite, and an inner zone of contaminated hornblende granodiorite. These represent respectively the zones of static recrystallization, of rheomorphism and metamorphic differentiation, and of contamination and reciprocal reaction. It seems probable that the physical conditions that led to the formation of these rocks were imposed by the emplacement of a relatively fluid magma and associated volatile constituents. The border facies is, therefore, a by-product of emplacement and not the source from which the magma was derived or a phase in any way related to the origin of the magma. It is reasonable to assume that at places within the border facies conditions occurred that differed only slightly from those under which the main granodiorite magma was formed. It is possible, therefore, that secretionary bodies of granodiorite were formed within the border facies. These secretionary bodies then would be formed by the application, on a smaller scale, of the same processes that formed the granodiorite of the main magma, namely the partial melting of sedimentary and volcanic rocks of andesitic affinities under suitable physical conditions.

The local mobilization of the innermost zones of the border facies and their intrusion along with the central core of the magma have in places cut out the pseudo-diorite and migmatite zones and upset the ideal zonal arrangement outlined above. Thus, some contacts show a complete gradation from recrystallized andesite through pseudo-diorite, migmatite, hornblende granodiorite to biotite granodiorite and others demonstrate direct contacts between any of the inner zones and relatively unaltered wall-rock. The innermost parts of the intrusion would be most likely to reach the higher levels, and complete gradation from one zone to the next would be found only where erosion had exposed the actual places where intense interaction between magma and walls occurred. This would explain the sharp intrusive contacts in the younger rocks as compared with the gradational aspects of the contacts with older rocks. The intrusion is visualized as a telescoping process with the inner parts moving highest and out of the mobilized shells as intrusion progresses. It is believed to have proceeded laterally as well as upward, and in the Kleanza apophysis to have formed a long tongue projecting eastward from the main body of the batholith.

Dykes

Intrusive rocks in the form of small stocks, cupolas, sills, and dykes form a distinctive and important group within the map-area. They are particularly abundant in the Terrace-Kitselas-Mount Thornhill section, where they occur in swarms, and are well exposed in railway- and road-cuts along Skeena River and adjacent streams. They are also abundant near Seven Sisters Peaks and at the north end of Kitsumkalum Lake, where they have invaded rocks of the Bowser Group. In general, they are most numerous in those areas near the contact of older rocks with the main batholithic rocks. An excellent example of the manner in which such intrusive material invades bedded rocks may be seen on Wesach Mountain (Pl. VIII) where sedimentary rocks of the Bowser Group are intricately interlaced with dykes and sills that are in sharp contrast to the sedimentary strata. Intrusive material may form as much as 50 per cent of the volume of rock.

The hypabyssal rocks included in this group vary widely in type. By far the greater number are porphyritic, but few have identical mineral composition, textures, or alteration products; even those dykes that fit into the same general classification exhibit different minerals as phenocrysts. Aphanitic types also occur and these may be acid or basic in bulk composition. These hypabyssal intrusive rocks probably represent the last expressions of the emplacement of the Coast Intrusions with which they are undoubtedly associated. Their great variety may be due to their origin in separate minor differentiates of the Coast Intrusions, which in the late stages of emplacement would have widely different compositions from place to place. With very few exceptions, the dykes are of the dilation type with sharp boundaries and chilled edges. Some show evidence of having crystallized from a liquid whereas others have undoubtedly been emplaced in a plastic state.[1]

Broadly the dykes fall into four major groups:

(1) Porphyritic
(2) Lamprophyre
(3) Aplite
(4) Basalt.

These groups appear to possess a crude zonal arrangement with respect to the larger masses of Coast Intrusions. The porphyritic type is most abundant some distance from the contact with the batholithic rocks. Nearer the contact aplite dykes become more plentiful, and finally within the batholithic rocks themselves lamprophyre dykes predominate. Basalt dykes do not show any particular zonal peculiarities.

Field and mineralogical evidence indicates that the porphyritic type was emplaced early in the dyke sequence, perhaps contemporaneously with, or slightly later than, the latest phases of batholithic rocks. These were followed in sequence by aplite and lamprophyre dykes, quartz veins, and finally the basalt dykes.

[1] R. Kretz, a graduate student with the party in 1954, studied many of the dykes as a basis for a M.Sc. thesis. Some results of this study are incorporated in the following paragraphs.

Exceptions to this order do occur, indicating that dykes of one particular kind were perhaps not all emplaced at one time.

Economically the dykes have played an important role in the location of mineral deposits. Open spaces have developed along the borders of dykes and these dilatant zones have formed the loci of mineral deposition.

Description of Dyke Groups

Porphyritic Dykes

Porphyritic dykes are by far the most common type and are observed mostly cutting rocks of the Bowser and Hazelton Groups. On Seven Sisters Peaks they are associated with the small stock that forms the core of the range. The stock itself is a porphyritic granite or porphyritic quartz monzonite with about 23 per cent plagioclase (An_{32}), 29 per cent quartz, 45 per cent orthoclase, and the remainder biotite and accessory minerals. The slightly discordant and extremely sharp upper contact of the stock has been exposed by recession of a cirque glacier on the main peak. Extending upward from the stock into the overlying sedimentary rocks are numerous dykes and apophyses that constitute up to 50 per cent of the rock immediately above the contact. Many dykes extend outward into the country rock in random fashion and vary in width from 4 to 20 feet. Most are simple intrusions but a few are composite in character. Of the seven dykes examined in this area, six were porphyritic quartz diorite, diorite, granodiorite, or quartz monzonite, and one was a poikilitic syenite. All but the syenite are genetically related to the stock.

The diorite dykes are dark green and the quartz monzonite nearly white. Characteristically they contain phenocrysts of quartz and feldspar ranging in size from 1 mm to 1 cm in longest dimension, in a fine-grained to aphanitic groundmass. The plagioclase phenocrysts are oligoclase or andesine (An_{27}-An_{37}). Two quartz diorite dykes examined have composition similar to that of the stock itself. Granodiorite and diorite dykes have much less silica but increased aluminum, calcium, and magnesium; accessories are similar to other dykes.

The augite syenite dyke examined occurs 2 miles north of the small lake at the headwaters of Oliver Creek. It is a dark green, medium-grained poikilitic rock essentially composed of augite, andesine (An_{32}), and orthoclase. A small amount of biotite is present that in places has altered to a green chlorite.

Porphyritic dykes related to the Coast Intrusions north of Terrace may be observed cutting the volcanic and sedimentary rocks of the Hazelton and Bowser Groups. These dykes range in width from a few inches to 100 feet, and commonly show sharp straight contacts. Though they may all be included under the general grouping of porphyritic they vary widely in composition and texture. Rarely are two dykes of identical composition or of the same minerals as phenocrysts. Most are porphyritic, but some are medium- to fine-grained hypidiomorphic. Colours are commonly grey, white, green, pink, or brown, and weathered surfaces are dark brown, rusty brown, or green.

Quartz, which is present in most dykes, may occur in the groundmass alone or as phenocrysts as well. In the groundmass it is present as minute anhedral grains intergrown with feldspar.

Plagioclase, as andesine or oligoclase and commonly zoned, is present in all dykes, the only exception being in an albite syenite dyke that contains phenocrysts of albite 2 cm long.

Orthoclase is present as anhedral grains in the groundmass or as euhedral phenocrysts. Microcline and perthite are primarily confined to aplite dykes.

Hornblende is the most abundant mafic mineral, and is present both as phenocrysts and in the groundmass. Augite was noted only in one dyke. Biotite is fairly common but less abundant than hornblende, and occurs sometimes as an alteration product of amphibole. Chlorite and epidote also are present as alteration products.

The dominant feature of the rocks is their porphyritic texture. The phenocrysts, in order of abundance, are feldspar, quartz, and mafic minerals which vary in size from 1 to 20 mm. The groundmass is essentially a fine-grained intergrowth of quartz and feldspar with minor amounts of mafic and accessory minerals.

Little or no metamorphism was observed along any of the contacts between the dykes and older rocks, the only effect being a slight baking.

A number of granitoid dykes and minor cupolas of differing composition were observed cutting the batholithic rocks in the Terrace-Kitselas-Mount Thornhill area. The following rock types were observed: granophyric granite, albite granite, aplite, granodiorite, porphyritic granite, and epidosite.

The granophyric granite is in the form of a small stock-like body that outcrops near Dobies. Its contact with the batholithic rocks is irregular and may be gradational or sharp. It is blue-grey, and is composed essentially of a granophyric intergrowth of quartz and orthoclase.

Irregular masses within the granophyric granite stock are composed of albite granite aplite. This is a blue-grey aphanitic rock containing scattered crystals of red-brown garnet. It is composed essentially of an allotriomorphic intergrowth of quartz and albite grains $\frac{1}{10}$ mm in diameter. The remaining minerals are andesine phenocrysts (An_{31}), magnetite, biotite, and chlorite. Several dykes of this material were noted in the Copper River area. Though mineralogically identical, they are finer grained, are approximately 7 feet wide, and lie parallel with the lamprophyre dykes.

The granite aplite dykes are nearly white and are composed essentially of quartz and microcline, with an average grain diameter of $\frac{1}{2}$ mm. Contacts are straight and either gradational or sharp. The albite granite aplite dykes are more finely grained and have sharper contacts than the typical granite aplite dykes. These dykes were most probably formed in fractures in the batholithic rock while it was still somewhat plastic.

Narrow dykes of granodiorite, porphyritic granite, and epidosite were also noted.

Lamprophyre Dykes

Swarms of lamprophyre dykes cut the Coast Intrusions in the Terrace-Kitselas-Mount Thornhill area and are more abundant than the albite and granitoid types in the same area. Elsewhere, however, few such dykes were noted. They are essentially spessartite or biotite spessartite but some may contain sufficient biotite to be classed as kersantite.

These dykes vary in thickness from an inch to 20 feet and have extremely sharp contacts. Lenses or slabs of granodiorite, partly or completely isolated from the wall, may be seen in some dykes. Many have been sheared along their contacts, and some of these shear zones contain minor mineral deposits. The major plane of shearing is one that strikes east and dips 70 degrees south; another prominent plane strikes N70°W and dips 56 degrees south. The dykes are undoubtedly of the dilation type, injected into tension fractures in the granodiorite. Cause of the fractures is most probably movement in a north-south direction.

The lamprophyre dykes are blue-grey, green, or black, mesocratic or melanocratic rocks with an aphanitic texture. A few show flow structure but in most the phenocrysts and the minerals of the groundmass are randomly arranged. The composition of the plagioclase phenocrysts is about An_{37}. In longest dimension these phenocrysts may reach 1 cm. Some dykes contain dark green phenocrysts of hornblende and clusters of randomly oriented biotite crystals. A few dykes show flow structure. Commonly secondary foliation is visible along the dyke borders caused by shearing movements parallel with the contacts. In such cases the dyke near its borders is altered to a biotite schist.

Quartz and plagioclase phenocrysts were apparently the first to crystallize. These were followed by hornblende, biotite, plagioclase, orthoclase, quartz, apatite, sphene, and magnetite-ilmenite of the groundmass. This second group of minerals crystallized together with a typical igneous texture. Thirdly, late deuteric alteration produced such minerals as biotite, chlorite, epidote, albite, white mica, leucoxene, etc. Finally, shearing caused the formation of biotite, muscovite, and plagioclase in the sheared parts of the dyke.

Basalt Dykes

A number of basalt dykes were observed though they are not nearly so plentiful as lamprophyre dykes. On a fresh surface, the black basalt dykes show subhedral phenocrysts of augite or euhedral black hornblende about a millimetre long in an aphanitic black groundmass. Most are vesicular or amygdaloidal and show spheroidal structure or columnar jointing, and some show a chilled edge. Amygdules may be quartz, calcite, natrolite, or chlorite.

All the dykes contain from 40 to 60 per cent plagioclase with a composition of An_{50} to An_{70}. Amphibole and pyroxene are present in various amounts. Other minerals present are chlorite, biotite, magnetite, and apatite. Quartz is absent.

Plagioclase occurs as phenocrysts or as anhedral grains intergrown with amphibole and colourless or pale brown augite. Phenocrysts are commonly zoned and

most are more sodic than the plagioclase of the groundmass. Chlorite forms a large proportion of the rock volume, filling spaces between crystals as well as vesicles in the rock.

Relation of Dykes to Mineral Deposits

The emplacement of the many dykes has had an important bearing on the location of mineral deposits in the area. The dykes themselves are not important as mineral deposits, but open spaces along their borders—due to fracturing either contemporaneous with or subsequent to emplacement—have formed the loci of mineral deposition.

On the Grotto group on Hardscrabble Creek a 12-inch quartz vein carrying gold, silver, and copper occurs along the contact of a porphyritic granodiorite dyke.

At the Dorreen Gold Mine a 2-foot vein is located along a bedding fault that stops abruptly at the contact with a 100-foot wide porphyritic quartz monzonite dyke. The emplacement of the dyke developed a dilatant zone in which the vein quartz and ore minerals were deposited.

The gold quartz vein on the Dardanelle group is an excellent example of the role played by dykes in the emplacement of ore deposits. There a quartz-albite dyke 18 to 24 feet thick cuts through granodiorite and greenstones for a distance of at least 6,000 feet. Quartz veins containing gold occur at intervals along both contacts of the dyke.

A quartz-galena-chalcopyrite vein occurs along the foot-wall of a quartz albite dyke on the Galena group on the upper reaches of Chimdemash Creek. Many other examples of the connection between quartz veins and dykes could be mentioned but the foregoing descriptions illustrate the relationship.

Chapter IV

ECONOMIC GEOLOGY

Mining and prospecting have played an important part in the settlement and development of Terrace map-area. Both placer and lode deposits have been worked, as well as some deposits containing non-metallic material. Gold, silver, lead, zinc, copper, tungsten, and limestone have all been mined, but only the limestone quarry was active during the period of this survey. The number of adits, test pits, trails, and ore dumps encountered is evidence of active mining operations in the past and of the intensive search for economic minerals.

Since the end of World War II other industries, such as logging and construction, have eclipsed mining as a livelihood but the search for new deposits still continues. New roads built by logging companies and the new highway to Kitimat make access to formerly remote areas much easier.

Most sulphide occurrences in the area are in narrow veins that give little promise of a continuous mining operation. However, it is possible that some of these deposits could be worked profitably in a small way. The development of the high-grade limestone quarry at Shames, the possible development of the concentrating grade magnetite deposit on Iron Mountain, and the utilization of the immense sand and gravel deposits for local construction point to possible future mining developments. The widespread occurrence of molybdenite and scheelite in veins and granitic rocks near contacts suggests the possibility that economic deposits of these minerals may some day be found in the area.

HISTORY

Placer gold deposits on Lorne, Chimdemash, Fiddler, and Kleanza Creeks were all worked as early as 1884, Lorne Creek being the biggest producer. Large-scale hydraulic operations were attempted by the Dry Hill Hydraulic Mining Company on Lorne Creek in 1917 and by the Cassiar Hydraulic Mining Company on Kleanza Creek in the period 1912 to 1922 without success. Douglas Creek at the head of Kitsumkalum Lake produced small amounts of placer gold for over 20 years. It seems significant that all the creeks on which placer mining was most successful head in the same range of mountains.

Mineral claims on lode deposits were first staked in 1893 near Usk—the Emma, Four Aces, and Madden being the first on which there is a record of development. By 1910 there were about 200 claims staked on deposits containing gold, silver, and copper. By 1914 prospecting had reached farther afield and copper deposits were discovered near the heads of Kleanza, Ste. Croix, and Chimdemash Creeks and near Pitman on the Canadian National Railways. Silver, copper, and

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lead ores were found on Legate Creek, and gold, lead, zinc, and copper on Fiddler Creek. About the same time mineral discoveries were made on Mount Thornhill near Terrace and at Kitsumkalum Lake.

For the next 15 years small-scale mining operations were carried out and some new discoveries were made. The economic depression which began in 1929 caused almost complete cessation of mining in the area for several years. In 1933 Columario Consolidated Gold Mines Limited developed their property on Bornite Mountain. Quartz veins containing gold-bearing pyrite were explored and some material containing up to half an ounce of gold per ton was mined, but not enough of this material was available to make a lasting operation and the property closed in 1935. Omineca Gold Quartz Mines Limited developed their property on Zymoetz River between 1937 and 1941. About the same time the Nicholson Creek Mining Corporation started development of their holdings north of Usk and continued doing some exploration each year till 1955. The establishment of a sampling mill at Prince Rupert during this period helped considerably, and today a small mill in the area that could handle the general type of ore present in the veins would help to increase interest in some of the properties.

In 1957 Frobisher Limited became interested in the magnetite deposit on Iron Mountain near Kitimat, and carried out some preliminary surveys.

E. D. Kindle of the Geological Survey of Canada, in 1935 and 1936, examined the accessible deposits in the area (1937 a, b). Little or no work has been done on most of the properties in the intervening period. Trails to many of the properties have deteriorated through neglect so that they are now non-existent or impassable. Of the workings examined during the survey many of the open pits are now filled with debris and adit entrances are blocked by caved timbers and rock fall, making examination practically impossible even when the showings were found. Many of the properties were visited by the authors, but for those not seen or where examination was not possible, description is taken from the reports of Kindle.

CLASSIFICATION OF DEPOSITS

The mineral deposits of the area may be classified broadly under the following headings:

1. Metalliferous deposits
   - A. Placer deposits
   - B. Lode deposits
     - Vein deposits containing some or all of the metals gold, silver, lead, zinc, copper, tungsten
     - Iron deposits.
2. Non-metallic deposits
   - A. Limestone deposits
   - B. Marl deposits
   - C. Sand and gravel deposits.

METALLIFEROUS DEPOSITS

Placer Deposits

Placer mining for gold on the tributaries of Skeena River was active in 1884 and gold was found in such creeks as Lorne, Kleanza, Chimdemash, and Douglas at the head of Kitsumkalum Lake. Lorne Creek proved to be the richest and has been worked spasmodically by individual placer miners up to the present. The recorded production, which probably does not reflect the actual production, is given as 4,574 ounces. Recorded production from other nearby creeks is practically nil, one ounce being recorded from Fiddler Creek.

The other stream recording a significant gold recovery is Douglas Creek at the head of Kitsumkalum Lake, with a recorded production of 319 ounces. Douglas Creek was worked as early as 1886 and intermittently till 1923 when Mr. D. Shaw acquired several leases and actively worked them till 1931. Since then there has been little or no work done.

The most interesting fact to emerge from the history of placer mining in the area is that both Lorne and Douglas Creeks, the two creeks giving the best placer production, head in the same mountain, which suggests that mountain as the source of the gold.

Dry Hill Placer Group

References. Ann. Rept., Minister of Mines, British Columbia: 1898, p. 1152; 1899, p. 657; 1900, p. 790; 1901, p. 991; 1902, p. H47; 1903, p. H52; 1904, p. 101; 1905, p. 82; 1906, p. 109; 1914, pp. 137, 175; 1930, p. 154; 1931, p. 77; 1932, p. 86. Geol. Surv., Canada, Mem. 212, p. 53, 1937.

The Dry Hill placer group is on the north side of Lorne Creek, a short distance west of Skeena River. The claims cover an ancient channel of Lorne Creek about 2,000 feet long. This channel is a gravel-filled depression that connects with Lorne Creek a mile above its mouth and enters the Skeena Valley at a point three eighths of a mile north of the creek. The outlet end of the depression, known as the Dry Hill pit, has been worked sporadically by various operators for almost 50 years. Hydraulic operations were carried out between 1901 and 1917 by the Dry Hill Hydraulic Mining Company but without great success.

An excellent detailed description of the operations on this property is given by Douglas Lay in the annual report of the Minister of Mines of British Columbia for 1930, pages 154-159.

In 1936 the property was owned by S. A. Corley of Prince Rupert, who drove a tunnel underneath the Dry Hill, expecting to intersect a narrow deeper channel of the old stream. The adit was driven 240 feet in a westerly direction with a 15-foot crosscut to the north at the face, but no deeper channel was found.

70594-7—6½

Kleanza Creek

References. Ann. Rept., Minister of Mines, British Columbia: 1912, p. 115; 1913, p. 109; 1914, p. 175; 1922, p. 97; 1932, p. 86. Geol. Surv., Canada, Mem. 212, p. 54, 1937.

There are no records of the gold recovery from this creek, but the Cassiar Hydraulic Mining Company installed a complete hydraulic plant on the creek in 1912 and carried on intermittent operations until 1922. Since then small-scale sluicing by individuals has been carried out intermittently in a section about 2 miles above the mouth of the creek.

Porcupine Creek (Quill Creek)

References. Ann. Rept., Minister of Mines, British Columbia: 1931, p. 79. Geol. Surv., Canada, Mem. 212, p. 54, 1937.

M. F. Burke of Cedarvale, and F. McLean and J. Bulzac of Prince Rupert, did considerable work in 1936 on their placer lease 3 miles above the mouth of Quill Creek. About 1,000 feet downstream from the shear zone on the Windfall group an adit was driven south into the south bank of Porcupine Creek a few feet above water level. The adit is about 75 feet long and follows closely the contact between bedrock and overlying gravels. As the banks of Quill Creek are formed of steep bluffs of argillite and tuff, about 40 feet high elsewhere in this vicinity, there is some evidence that the adit follows an old abandoned stream channel. Some fairly coarse gold was recovered during the summer by sluicing the gravels taken from the adit. The owners estimate the gravel to carry about 10 cents a yard in gold.

During sluicing operations considerable coarse pyrite was found to collect in the riffle-boxes. A sample of this pyrite gave on assay: gold, 1.14 ounces a ton; silver, 0.80 ounce a ton.

Lode Deposits

With the exception of the magnetite deposits at Iron Mountain, the lode deposits of the area consist of narrow quartz veins that have formed in faults, shear zones, and other openings, and along the margins of dykes. Though different minerals may dominate in different parts of the area the metals present in the veins are commonly lead, zinc, copper, gold, and silver. Tungsten is reported from many of the veins, particularly from those in and near granitic rocks. Veins in or adjacent to the granodiorite mass between Mount Knauss and Shannon Creek all report the presence of scheelite. Generally veins occurring in volcanic rocks of the Hazelton Group have a predominance of copper mineralization. On the other hand, veins occurring in sediments of the Bowser Group appear to have a predominance of lead, zinc, and silver minerals though gold and copper do occur.

As most of the veins are similar in mineral character, it is best for descriptive purposes to group the deposits geographically rather than mineralogically.

Deposits in the Vicinity of Kitsumkalum Lake

Silver Plate and Silver Cup (1)[1]

These claims lie approximately 2¼ miles up the trail from Cedar River crossing. The main showing, which is 200 to 250 yards east of the trail, at an elevation of 1,050 feet, consists of open pits and trenches that expose a 25- to 30-foot brecciated zone bounded on both walls by quartz veins 1 foot to 2 feet wide. The vein on the foot-wall strikes east and dips 70 degrees south. This is followed on the hanging-wall by a brecciated and silicified zone. In the hanging-wall of the brecciated zone quartz stringers up to 10 inches wide occur. The main veins are mineralized with chalcopyrite, sphalerite, galena, and tetrahedrite.

Nothing had been done on this property for years and when visited in 1953 the workings were in poor condition. One adit reported by Kindle (1937a) had caved and was overgrown by good sized trees.

Following is a detailed description of the workings given by Kindle (1937a, p. 11):

> The deposit is under a heavy cover of drift and has been exposed by trenches at intervals for 150 feet along its strike . . . .
>
> A quartz vein ranging from 1 to 2 feet in width occurs along a fault striking north 70 degrees east and dipping 70 degrees south. A quartz vein of the same width lies along a parallel fault 30 feet to the south. Between the two the sandstone and argillite have been severely brecciated and cut by minor faults. The brecciated zone has been impregnated and cemented by vein quartz, and small quartz veins have formed along the minor faults. The quartz in both the veins and brecciated zones is mineralized with galena, chalcopyrite, tetrahedrite, and light brown sphalerite.
>
> A 20-foot shaft was sunk about ten years ago on some of the best-looking ore along the fault vein and some of the ore from this operation is still stock piled. A representative specimen taken from an open-cut by W. M. Brewer in 1914 assayed: gold, a trace; silver, 56.4 ounces a ton; copper, 4.8 per cent; lead, 6.1 per cent; zinc, 19.4 per cent. A sample taken by the writer across 48 inches of the mineralized brecciated zone near the shaft assayed: silver, 4.27 ounces a ton; gold, a trace; copper, 0.44 per cent; lead, 1.04 per cent; zinc, 2.18 per cent.
>
> One hundred feet southeast of the shaft an adit has been driven north for 50 feet. It intersects the two main veins and the mineralized brecciated zone between them. Five feet from the adit entrance there is a 4-inch quartz vein; at 9 feet an 8-inch quartz vein; at 16 feet an 18-inch quartz vein; at 20 feet a 6-inch quartz vein; at 25 feet a 3-inch quartz vein; and at 45 feet a 21-inch quartz vein. The intervening rock from 10 feet to 45 feet from the adit entrance comprises the brecciated zone, but it does not carry as much quartz as in the vicinity of the shaft, nor is it as well mineralized with sulphides. A channel sample taken across the 21-inch quartz vein near the face of the adit and on the west side, assayed: silver, a trace; gold, 0.02 ounce a ton; copper, 0.02 per cent; lead, 1.10 per cent; zinc, 0.15 per cent. An 18-inch channel sample taken across the quartz vein 16 feet from the adit entrance on the east side, assayed: silver, 0.14 ounce a ton; gold, none; copper, 0.04 per cent; lead, 0.19 per cent; zinc, none.

A grab sample from the dump at the sheared zone taken by the authors in 1953 assayed: Au, 0.01 oz; Ag, 28.14; Cu, 4.14 per cent; Pb, 3.80 per cent; and Zn, 19.69 per cent.

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[1] Numbers in parentheses are those used on the map to show the location of the properties.

Belway and Rex (16)

References. Ann. Rept., Minister of Mines, British Columbia: 1914, p. 105; 1918, p. 49; 1927, p. 63; 1931, p. 36. Geol. Surv., Canada, Mem. 212, p. 13, 1937.

This property, situated on the east side of Kitsumkalum Lake about a mile south of Rosswood, was visited in the summer of 1953. Rocks are metamorphosed sediments of the Bowser Group, which there strike east-west and dip 30 to 60 degrees north. Some of the rocks have suffered ptygmatic folding, epidotization, and silicification, accompanied by a slight copper mineralization. At a rocky point on the lake the sediments are cut by a gabbro sill about 70 feet thick.

A large pit about 10 feet deep was sunk on the south side of the gabbro sill, and just east of the pit a 33-foot adit was driven into the gabbro in a direction of N20°W along two small fractures that carried epidote and minor chalcocite, and bornite. Three hundred and fifty feet south from the sill or dyke an adit has been driven along a shear zone 30 inches wide. This sheared zone parallels the strike of the beds, which is N70°W, dips 30°N, and contains epidote and minor bornite.

Kindle (1937a) reported that a grab sample of material on the dump gave an assay of 0.34 ounce silver and 0.24 ounce gold a ton.

Martin Group (12)

References. Ann. Rept., Minister of Mines, British Columbia: 1918, p. 50; 1925, p. 69; 1926, p. 73; 1928, p. 71.

This group of claims lies 6 miles west of the north end of Kitsumkalum Lake and is reached by a logging road and trail that leaves the lake opposite Rosswood, heads west to Mayo Creek, and thence follows up the creek to the canyon, which is crossed by a wooden bridge. On the north side of the creek the trail climbs steeply by a series of switchbacks to the property at an elevation of 2,500 feet above sea-level.

When the property was visited in 1953 the adit, which started in granodiorite, had caved and the entrance was blocked. Obviously no work had been done for many years.

The description of this property is that given by Kindle (1937a):

> A narrow quartz vein heavily mineralized with sulphides occurs along a fault in grey, coarse-grained granodiorite at an elevation of 2,550 feet. The granodiorite extends down the mountain side to the river, but 50 feet above the vein is in contact with overlying intruded sediments, chiefly greywacke and argillaceous quartzite. A second parallel vein occurs in the sediments 125 feet above the main vein.
>
> The main vein strikes north 40 degrees east magnetic and dips 55 degrees northwest. Its average width is 12 inches and the maximum width about 18 inches. Four large rock trenches expose the vein at regular intervals for a little over 300 feet. A channel sample taken across 12 inches of quartz in the southwesternmost pit assayed a trace of silver and 0.02 ounce of gold a ton. Sixty-five feet farther northeast in the second pit the vein is heavily mineralized with massive pyrrhotite cut by small galena stringers. A channel sample 7 inches long across the vein in this pit assayed: silver, 5.04 ounces a ton; gold, 0.16 ounce a ton. In the remaining two pits the vein contains a high proportion of galena, some arsenopyrite and sphalerite, but almost no

pyrrhotite. Seventy-five feet below the vein a crosscut adit was driven northwest. The vein was intersected 230 feet from the entrance and consisted of only a few inches of barren quartz. The adit was continued an additional 45 feet, but no other veins were encountered.

The second vein is exposed for only a few feet by natural agencies between two large trees. The vein is 75 feet above the contact of the sediments and granodiorite and is enclosed in greywacke which strikes from 80 to 90 degrees northeast and dips 50 degrees north. The vein strikes north 40 degrees east and dips 42 degrees northwest. It is 7 inches wide, and is about 75 per cent solid arsenopyrite and 25 per cent quartz. A channel sample across it assayed: gold, 0.20 ounce a ton; silver, 0.36 ounce a ton; arsenic, 14.44 per cent. This occurrence suggests the desirability of searching for other veins in the sediments.

Portland Claims (20)

References. Ann. Rept., Minister of Mines, British Columbia: 1922, p. 47; 1923, p. 47; 1924, p. 48; 1925, p. 69; 1927, p. 63; 1930, p. 74. Geol. Surv., Canada, Sum. Rept. 1923, pt. A, p. 42; Mem. 205, p. 15, 1937.

These claims are situated on the west side of Kitsumkalum Lake at the shoreline about a mile north of the mouth of Nelson River, and near a small granodiorite stock. They were first staked in 1921 and considerable work was done on them in 1924 and 1925 by Kalum Lake Mines Limited.

When the property was visited in 1953 all shafts were filled with water and the adit was in poor condition. Previous reports indicate that the Kalum Lake Mines Limited sank an inclined shaft 60 feet, from which a drift was run westerly for 210 feet. The vein on which the work was done is reported to be about a foot wide, and mineralized with pyrite and minor chalcopyrite. On the main dump granodiorite cut by quartz stringers is abundant. An assay of a selected sample of this material on the dump taken in 1930 by J. T. Mandy gave 0.62 ounce in gold and 2.2 ounces in silver per ton.

Three hundred feet southeast of the shaft an adit has been driven for 85 feet on a quartz vein in the granodiorite. The vein above the adit portal is about 28 inches wide and has a strike of N75°E and a dip of 65°S. Forty feet within this adit the vein narrows to 6 inches and a second vein 4 inches wide comes in along the north wall. At the face of the adit the veins have narrowed to 2 inches separated by 2 feet of altered granodiorite. Assays at the face taken by Kindle (1937a) ran only minor amounts of gold and silver.

Deposits on Maroon Mountain

Bear (14), *Gold Cap, Guld* (13), *and Black Wolf* (15) *Claims*

References. Ann. Rept., Minister of Mines, British Columbia: 1920, p. 41; 1921, p. 43; 1923; p. 47; 1924, p. 47; 1925, p. 68; 1926, p. 72; 1927, pp. 63-64; 1928, pp. 72-73; 1930, pp. 74, 76.

The Bear, Gold Cap, and Guld claims, and the Black Wolf group are all situated on the northwest slope of Maroon Mountain. They received considerable attention prior to the depression that began in 1929 but nothing has been done since. These claims are staked on narrow quartz veins, which in places reach a maximum width of 3 feet but average only a foot or less (Fig. 6). They occur in

the greywackes, conglomerates, and argillites of the Bowser Group that compose Maroon Mountain, and follow the bedding planes of the sediments where shear zones or open spaces have developed due to slippage along bed boundaries. Commonly they lie below a conglomerate bed that varies in thickness from 120 to 250 feet but they may also occur in cross-fractures that cut the bedding. Metallic minerals consist of galena, sphalerite, pyrite and pyrrhotite, and minor chalcopyrite which contain gold, silver, lead, copper, and zinc. Access is by a good trail that starts behind 'Olanders' ranch about a mile south of Rosswood. A branch trail that heads south from the main trail at an elevation of approximately 4,000 feet leads to the Motherlode claim at the headwaters of the south fork of Hall Creek.

The Bear claim has had the most development work done on it, there being two adits and numerous open cuts. The best outcrops on the Bear vein are a few feet above the upper adit where it has a width of 3 feet over a length of about 50 feet. However, it soon narrows to 6 inches and pinches out within 200 feet. The upper tunnel driven east for 26 feet intersected the vein 15 feet below the outcrop. A drift was extended about 5 feet each way on the vein. Samples taken from the north face in 1928 by H. T. James assayed gold, 1.26 ounces; silver, 3.5 ounces a ton; lead, 6 per cent and zinc, 4 per cent.

A lower adit, about 85 feet below the upper tunnel, was driven 150 feet east to the vein. Drifts were driven for 25 feet south and 39 feet north. The vein was only a few inches wide on the south face at this level, but 16 inches on the north face. A sample across the north face taken by Kindle (1937a) gave gold 1.36 ounces and silver 1.2 ounces a ton. A grab sample taken from the dump by the author in 1953 gave gold 0.42 ounce a ton, silver 24 ounces a ton, copper 0.02 per cent, lead 4.25 per cent, and zinc 4.40 per cent.

The Gold Cap and Guld claims are to the northeast of the Bear claim.

The Black Wolf group is situated south of the Bear claim and is geologically the same except that the vein dips at 15 degrees, having flattened considerably. An adit was driven along the vein for a distance of 70 feet. The vein has a maximum width of about 10 inches, and carries very minor amounts of gold and silver.

Motherlode Claim (17)

References. Ann. Rept., Minister of Mines, British Columbia: 1920, p. 41; 1921, p. 43; 1923, p. 48; 1930, p. 74. Geol. Surv., Canada, Mem. 205, p. 21, 1937.

The Motherlode claim is situated on the northwest slope of Maroon Mountain at the headwaters of the south fork of Hall Creek. Rocks on the claim belong to the Bowser Group and are cut by a small quartz diorite stock.

Two adits were driven into the knife-edge ridge—one at an elevation of 5,400 feet, the other 200 feet lower—in an attempt to intersect the source of rich quartz float found in the talus of the hillside. It is reported that a sample of the float collected by J. T. Mandy in 1930, assayed: gold 0.04 ounce, and silver 19 ounces to the ton; copper 0.03 per cent, lead a trace and zinc 4.4 per cent. There is no record that the vein was found. The portal to the lower tunnel was

blocked by snow when the property was visited by Kindle in 1935 (1937a), and the same condition prevailed when the property was visited by the authors in 1953.

Keystone and Lucy O'Neil Claims (19)

References. Ann. Rept., Minister of Mines, British Columbia: 1921, p. 44. Geol. Surv., Canada, Mem. 205, p. 22, 1937.

These claims were not visited by the authors during the course of the work, the trail up Maroon Creek being fallen in, washed out, blocked by down trees, and generally impassable. The following is a description by Kindle (1937a):

> The Keystone and Lucy O'Neil claims are on the north fork of Maroon creek, about 8 miles east of Kitsumkalum lake. The Keystone is on the west side, and the Lucy O'Neil on the east side, of the creek, a short distance north of the forks. A pack-horse trail now much overgrown follows Maroon creek from the lake to the claims.
>
> A 3-foot quartz vein heavily mineralized with pyrite and chalcopyrite outcrops in a cliff of massive, grey diorite on the east side of the stream just above the water. The vein is on the lower side of a dark, fine-grained diabase dyke about 3 feet wide that strikes north 30 degrees west and dips 60 degrees northeast. Some vein quartz also occurs on the hanging-wall side of the dyke, but only in small, discontinuous lenses. The diorite adjoining the veins is altered and pyritized for several inches.
>
> A shaft, 20 feet deep, was sunk on the vein in 1921 by George Little and associates. At the bottom of the shaft the vein is 4½ feet wide and the quartz is evenly mineralized with pyrite and chalcopyrite. Two channel samples were taken across the vein, close to the bottom on the east side of the shaft. The first sample, 32 inches in length, taken adjacent to the dyke, assayed: gold, a trace; silver, 0.89 ounce a ton, and copper, 3.48 per cent. The second sample, from the remaining 22 inches of the vein adjoining the diorite, assayed: gold, 0.02 ounce a ton; silver, 0.68 ounce a ton; and copper, 1.51 per cent; across the 4½ feet the copper averages 2.68 per cent.
>
> On the projected extension of the vein on the west side of the stream, 60 feet distant, a shear zone has a similar strike and dip, but has no vein filling. The diabase dyke lies 15 feet north of the shear zone, but has a more northerly strike and its dip is reversed to southwest. Vein formation on the east side of the stream was evidently dependant upon both dyke and fracture zone following the same path. Since they are known to diverge on the west side of the creek, it follows that any future prospecting should be done on the east side of the creek along the strike of the dyke. A thick drift cover hinders trenching.

Deposits near Amsbury

References. Ann. Rept., Minister of Mines, British Columbia: 1916, p. 97; 1922, p. 47; 1927, p. 62; 1929, p. 76. Geol. Surv., Canada, Sum. Rept. 1925, Pt. A, p. 118, Mem. 205, 1937, p. 24.

Near Amsbury, greenstones and recrystallized limestones of probable Permian age outcrop along Skeena River and in the creeks tributary thereto. These rocks are sheared and metamorphosed by the emplacement of the Coast Intrusions, which form the main rock masses in the adjacent mountains. The shear zones are commonly mineralized with quartz, magnetite, pyrite, and minor chalcopyrite. A number of prospects of this type have been explored near Amsbury, of which the Autumn group (58) of claims is the best known.

This group is situated about 1,000 feet northwest of the CNR tracks, about 3 miles west of the Amsbury flag stop. At elevation 375 feet three pits have been sunk over a distance of 250 feet on a silicified and epidotized shear zone containing sparse pyrite and chalcopyrite mineralization. Two adits were driven into the hillside to intersect the sheared zone at depth. The first, which is 130 feet long, cut 6 feet of shear zone at 70 feet from the portal. The second adit, 150 feet southwest of the first, cut a 3-foot silicified zone at 35 feet. Assays indicate either low amounts of gold and silver, or none.

Deposits on Mount Thornhill

Mount Thornhill, southeast from Terrace and on the south side of Skeena River, is composed mainly of grey granodiorite that includes some small roof pendants of Palaeozoic and Triassic rocks. Narrow quartz veins occur in fractures in the granodiorite and in the roof pendants. The presence of gold, silver, copper, lead, and zinc has been recorded from most of the occurrences. The Globe (49), La Libertad (50), Ptarmigan (51), St. Paul and X (53), A-claim (54), B-claim (55), Coin claim (56), and Eureka (57) are all properties on Mount Thornhill. Little or no work has been done on any of these claims since they were visited by Kindle in 1935. A detailed description of the properties is given in Memoir 205 of the Geological Survey of Canada.

Deposits on Zymoetz River

Dardanelle Group (Omineca Gold Quartz) (52)

References. Ann. Rept., Minister of Mines, British Columbia: 1914, p. 116; 1918, p. 52; 1921, p. 94; 1927, p. 123. Geol. Surv., Canada, Sum. Rept. 1925, pt. A, p. 115; Mem. 205, pp. 33-35, 1937.

This property is situated on the north bank of Zymoetz River about 10 miles upstream from the Terrace-Usk highway, and is connected with the highway by a road that was passable by jeep when the authors visited the property in 1953. Work was done on this property from 1935 to 1940.

The deposit is an excellent example of the occurrence of quartz veins along the contacts of a dyke; a very common type of occurrence in Terrace map-area. Hornblende and hornblende biotite granodiorite containing some dioritic inclusions underlie the property. These rocks are cut by a 15- to 25-foot quartz albite dyke which strikes N70°E to 80°E and dips at 70° to 75°N. Quartz veins 1 foot to 6 feet wide occur at intervals along both contacts of this dyke for a distance of more than 600 feet. A number of assays for gold and silver, recorded in previous reports on this property, were taken from various vein outcrops, and can be used only as a general indication.

In the Minister of Mines Report for 1927, Douglas Lay reports an assay of: 0.12 ounce of gold and 2 ounces of silver a ton, lead nil, and zinc 1 per cent.

In the 1914 Minister of Mines Report for British Columbia, W. M. Brewer reported an assay of: gold 0.22 ounce and silver 0.8 ounce a ton.

E. D. Kindle (1937a) reported assays as follows:

	Gold oz per ton	Silver oz per ton
Sample 1	0.38	10.54
2	0.015	0.21
3	0.06	0.26
4	0.07	0.05
5	0.345	0.16

A grab sample taken by the writer in 1953 from mineralized material on the dump gave gold 0.195 ounce and silver 0.48 ounce a ton.

In 1935 a 56-pound sample of ore was sent to the Mines Branch at Ottawa for testing (Bureau Mines Pub. 771, pp. 170-174). Ore minerals present in the sample were pyrite, sphalerite, galena, chalcopyrite, and covellite. Copper minerals are present sparingly. The sample assayed as follows:

gold	0.815 oz a ton
silver	18.22 oz a ton
copper	0.64 per cent
lead	8.16 per cent
zinc	3.15 per cent

Tests indicated that little of the gold content was free milling.

The adit driven along the dyke to intersect the veins at depth, when visited in 1953 was 1,646 feet long. Vein quartz was present in the adit walls from 388 feet to 443 feet, from 1,113 feet intermittently to 1,254 feet, and from 1,317 to 1,350 feet.

Zymoetz Group (47)

References. Ann. Rept., Minister of Mines, British Columbia, 1934, p. C4.

This property, situated on both sides of the road to the Omineca Gold Quartz property about a mile east of the highway bridge, was not visited by the authors. The following is a report by Kindle (1937 a, pp. 35, 36):

> A quartz vein is exposed in the bed of a small stream about 60 feet above Zymoetz river. The vein strikes across the creek and may be followed for about 50 feet on each side of the stream. The vein strikes east and dips 75 degrees north. The country rock is a medium-grained quartz diorite. Where the vein crosses the creek it is split into two parts for a short distance, each part being about 8 inches wide and separated by 3 feet of quartz diorite. The vein is well mineralized with sphalerite, pyrite, and some galena. The vein is exposed by open-cuts 200 feet west of the stream and there is 2 feet wide and heavily mineralized with coarse pyrite. Down stream from the outcrop an adit 65 feet long was driven north to intersect the vein. Where the vein is cut, 55 feet from the entrance, it has a width of over 2 feet and is mineralized with sphalerite, pyrite, and a little galena. A 28-inch channel sample taken by the writer across the vein on the west wall assayed: gold, 0.08 ounce to the ton; silver, 0.15 ounce to the ton; zinc, 0.32 per cent; lead, a trace.
>
> About 300 feet farther up the stream and 150 feet vertically above the vein just described is another quartz vein on which a 6-foot adit has been driven east from the stream bed. Here the vein is 24 inches wide and the quartz is well mineralized with pyrite and small amounts of finely crystalline magnetite. It strikes roughly east and

west and dips 35 to 40 degrees north. A 23-inch channel sample taken across the vein in the face of the adit where free gold had been reported showed only a trace of gold and a trace of silver. Fifty feet to the west where the vein is exposed on the other side of the stream its width is only 8 inches and about 25 feet higher up the vein pinches out as it also does on the opposite side of the stream.

Fifty feet south of the 6 foot adit, a quartz albite dyke cuts the quartz diorite country rock in the steep bluff on the east side of the stream. The dyke is 10 feet wide at the stream, but farther northeast gradually widens to 18 feet or more. Forty feet north of the adit a similar quartz albite dyke 10 feet wide is exposed. It narrows gradually to a few feet in width in a southwest direction, but maintains its width to the northeast.

Providence Group (48)

References. Geol. Surv., Canada, Mem. 212, p. 11, 1937.

The Providence group lies about half a mile north of the wagon road along Zymoetz River and 4 miles east of the main highway. The property was not visited during the course of the survey and the following description is from Kindle (1937b, pp. 11, 12).

Several pits expose narrow shear zones traversing silicified limestone at elevation 1,100 feet. Samples taken here by the writer showed only traces of gold and silver.

About a quarter mile farther northeast, at elevation 1,250 feet, four pits have been cut at 50-foot intervals on a band of highly altered and silicified limestone. The altered and silicified rock ranges from 10 to 30 feet in width and has been traced for over 1,500 feet in a northeast direction. The writer collected half a dozen samples along the zone between elevations of 1,250 and 1,450 feet, which assayed only traces of gold and silver.

At elevation 1,200 feet, a short distance east of the four pits, a small quartz lens containing galena and tetrahedrite is exposed in the bed of a creek.

Properties on O.K. Range

A large number of quartz veins have been discovered on the Skeena River slope of O.K. Range, between Zymoetz River and Kleanza Creek, and also at the eastern end of the range near Kleanza Lake. The underlying rocks consist of metamorphosed sedimentary rocks of probable Triassic age and volcanic rocks of the Hazelton Group that are intruded by various facies of the Coast Intrusions and dykes emanating therefrom. The main exposures of granitic rocks are in the valley of Skeena River. Many of the veins occur along dyke contacts and in shear zones parallel with them; some are in the granitic others in the metamorphic rocks.

The veins are commonly less than 3 feet wide but many are less than a foot wide. They consist of quartz, pyrite, some chalcopyrite, minor amounts of galena, sphalerite, and tetrahedrite, with rare molybdenite which is present in many of the veins and granitic rocks of the area. The presence of gold, silver, lead, zinc, and copper is indicated from assays of the vein material. Though most of the veins discovered have had some prospecting and minor development done on them, only the Columario Consolidated Gold Mines Limited property underwent major development, which culminated in the operation of a 100-ton mill from September 1934 to June 1935.

The following properties have been recorded on O.K. Range: Adeline claim, White Bluffs group, Black Bull and Gem, Terrace, Silver Bow and Silver Cliff claims (43), Beanstock, Rakeoff, Rosie, Columario Consolidated Gold Mines Limited (42), Victor group, Golden Crown group; and the Montana group (46), Wells group (45), and Avon group (44) near Kleanza Lake.

No work of consequence has been done on any of these properties since prior to World War II, and many of them are now difficult to find. All are described in detail in Memoirs 205 and 212 of the Geological Survey of Canada (Kindle, 1937a, b).

Silver Bow and Silver Cliff Groups (43)

References. Ann. Rept., Minister of Mines, British Columbia: 1925, p. 124; 1926, p. 124. Geol. Surv., Canada, Mem. 205, p. 38, 1937.

A number of quartz veins containing silver, lead, and zinc occur on these claims. They lie adjacent to feldspar porphyry dykes that intrude the volcanic and granitic rocks. Granitic rocks, offshoots from the main mass of Coast Intrusions, occupy the west side of the mountain below 1,500 feet elevation. The veins formed along fissures striking south to southeast, and dipping 50° to 60°E. Best assays reported were from a vein at 2,000-foot elevation, which varied in width from a fraction of an inch to 3 feet and was traced for more than 200 feet along strike. In its widest part this vein is mineralized with galena, sphalerite, tetrahedrite, and pyrite. A representative sample gave the following assay: gold, 0.08 ounce a ton; silver, 6.34 ounces a ton; lead, 7.62 per cent; zinc, 2.37 per cent. A similar type of vein, which strikes south and dips 60°E, over a traced length of 250 feet has an average width of 6 inches. Assay results were: gold, 0.035 ounce a ton; silver, 0.62 ounce a ton; lead, 0.05 per cent; zinc, 0.20 per cent.

At other localities quartz veins occur alongside an 18- to 20-foot feldspar porphyry dyke that cuts andesitic volcanic rocks. These veins are about 15 to 20 inches wide, and give low values in gold, silver, and copper.

Columario Consolidated Gold Mines Limited (42)

References. Ann. Rept., Minister of Mines, British Columbia: 1919, p. 97; 1920, p. 81; 1921, p. 95; 1922, p. 97; 1923, p. 102; 1925, p. 125; 1928, p. 142; 1929, p. 148; 1930, p. 136; 1931, p. 70; 1933, p. 96; 1934, p. C2. B.C. Dept. of Mines, Bull. No. 1, 1932, p. 55. Geol. Surv., Canada, Sum. Rept. 1925, pt. A, p. 117; Mem. 205, pp. 41-43, 1937.

This property is one of the few in the area that actually reached production. It is located on the Skeena River slope of O.K. Range between elevations 1,700 and 2,300 feet. A total of about 8,000 feet of underground workings was done in eleven adits during the development of seven vein structures (Fig. 7). The veins occur on a system of fractures that strikes N30° to 45°W and dips 50° NE. Most of the veins are in volcanic rocks near masses of granodiorite or along contacts between these two types of rocks. Where the veins enter granodiorite they tend to pinch out within a short distance. Veins also occur along contacts of dykes that parallel the fracture system.

In 1933 three sacks of ore weighing 200 pounds were shipped to the Mines Branch at Ottawa for testing. The lot was crushed, ground, and sampled and was found to contain: gold, 1.44 ounces a ton; silver, 3.51 ounces a ton; copper, 0.42 per cent; lead, 0.02 per cent; arsenic, 0.01 per cent. Polished section examination showed that the gold was not present in the free state but was associated with pyrite.

First work was done on this property in 1919 by the Kleanza Company. In 1927 Columario Gold Mines Limited was formed and pursued active development until 1933 when it was succeeded by the Columario Consolidated Gold Mines Limited. Under the latter company the mill and tramway were built and development continued. The mill operated from September 1934 to June 1935, when operations ceased. In 1939 the property was leased by W. W. Duncan of Usk with the purpose of shipping selectively mined ore from the old workings. It is recorded that 15.86 tons of selected ore and ten samples were shipped to the sampling plant at Prince Rupert.

Montana (46), *Wells* (45), *and Avon* (44) *Groups*

References. Ann. Rept., Minister of Mines, British Columbia: 1908, p. 65; 1909, p. 84; 1914, pp. 121, 122; 1917, pp. 95-96; 1924, p. 120; 1927, p. 96. Geol. Surv., Canada, Sum. Rept., pt. A, p. 114, 1925; Mem. 212, pp. 14-15, 1937.

These three groups are located just south of Kleanza Lake at the eastern end of O.K. Range, and are underlain by volcanic rocks of the Hazelton Group. They are noted mainly for the copper-bearing veins and sheared zones occurring on them—the copper minerals being chalcocite, bornite, and chalcopyrite. The veins and sheared zones may be as much as 4 feet wide but are commonly under 3 feet. Assays of samples indicate that gold and silver values are negligible, and that copper is the only mineral of economic interest. Assays of 1.18 per cent and 3.48 per cent copper have been returned from samples taken across the better veins on these claims.

Properties on Bornite Range

Properties situated on Bornite Range are: Lucky Jim, Continental, Banner Homestake, Four Aces, Independence (37), Silver Basin (41), and Silver Crown (40), Toulon, Madden, St. Elmo (25), Singlehurst (39), and Bornite King groups.

Rocks underlying the range are composed of metamorphosed sedimentary rocks of probable Triassic age and altered volcanic rocks referable to the Hazelton Group. These rocks are cut by apophyses and dykes of the Coast Intrusions. Most of the occurrences are in the volcanic rocks of the Hazelton Group and are in the form of mineralized quartz veins or shear zones. Here also some of the veins occur along contacts of dykes.

The veins and shear zones strike generally N60°W and dip 45° to 60°SW, but a few diverge from this pattern.

Metallic mineral content of the veins and shear zones is bornite, chalcocite, chalcopyrite, pyrite, and tetrahedrite. Significant assays in silver and copper have been returned from some of the veins.

All the properties listed above are described by Kindle (1937b). Most of them have had some minor underground development or prospecting without too much success. The most developed group, the Singlehurst, is described below.

Singlehurst Group (39)

References. Ann. Rept., Minister of Mines, British Columbia: 1899, p. 655; 1900, p. 786; 1901, pp. 990 and 997; 1902, p. 46; 1914, p. 131. Geol. Surv., Canada, Mem. 212, pp. 30-32, 1937.

This property is situated near the summit of Bornite Mountain at an elevation of 4,700 feet, and was one of the first properties in the area to be seriously worked. Active development began in 1899 and by 1901 a vertical shaft some 130 feet deep had been sunk with crosscuts to the vein at the 60- and 100-foot levels.

At the 30-foot level, 45 feet of drifting has been done on the vein; at the 60-foot level, 16 feet; and at the 100-foot level, some 60 feet. About 5 tons of ore were shipped to a smelter in 1902.

At the shaft the vein is composed of 8 inches of quartz and several inches of altered wall-rock. The vein has been followed for a distance of about 275 feet and has in this distance a thickness between 6 and 10 inches. It occurs in a fault that strikes N20°E and dips 75°SE. A representative sample taken by Kindle from the remains of about fifty bags of crushed ore assayed: gold, 0.02 ounce a ton; silver, 35.64 ounces a ton; copper, 0.20 per cent. Other assays high in silver have been recorded from this property.

Properties on Kitselas Mountain

Properties recorded on Kitselas Mountain near Usk are as follows: Cordillera (35), Lucky Luke (36), Oxford group and Nugget group (38) and Copper King group.

Rocks on Kitselas Mountain consist mainly of metamorphosed sedimentary and volcanic rocks of probable Triassic age and altered volcanic rocks referable to the lower part of the Hazelton Group. The mineral occurrences are similar in character to those on Bornite Range in that they are narrow lenticular deposits occurring in fractures and shear zones carrying a low content of gold and silver but somewhat higher content of copper. Metallic minerals present in the deposits vary a little in the different occurrences. The Cordillera, Lucky Luke, and Nugget properties are characterized by bornite, chalcocite, chalcopyrite, pyrite, and free gold, the Oxford by coarse pyrite, and the Copper King group by pyrite and chalcopyrite.

All the properties except the Oxford and Nugget groups have had some underground development, the Lucky Luke mine having the greatest amount, but no work has been done since the early 1930's.

Lucky Luke Group (36)

References. Ann. Rept., Minister of Mines, British Columbia: 1918, p. 110; 1919, p. 98; 1923, p. 104; 1924, p. 88; 1925, p. 125; 1928, p. 146; 1934, p. C4. Geol. Surv., Canada, Sum. Rept. 1925, pt. A, p. 116; Mem. 205, p. 49, 1937.

The Lucky Luke mine is on the east slope of Kitselas Mountain, at an elevation of 1,000 feet, and about 1½ miles southwest of Usk. A rough road leads from the mine to the railway and thence to Usk, but as no maintenance has been done on this road since 1934 it is not now useable. The property was operated from 1917 to 1923 by L. E. Moodie and R. Lowrie. In 1923 and 1924 S. A. Davis carried on development work and shipped 25 tons of hand-sorted ore, which yielded 18 ounces of gold, 316 ounces of silver, and 11,162 pounds of copper. In 1934 R. W. Seely carried out further development work but nothing has been done since.

The deposit consists of a series of narrow, lenticular quartz lenses in a shear zone that strikes N70°W and dips 65°N. The quartz is mineralized with bornite, chalcopyrite, pyrite, chalcocite, and some visible free gold. The gold is associated with steel-grey chalcocite.

The workings consist of a main crosscut adit at elevation 990 feet that runs S25°W for 120 feet to the mineralized fault zone (Fig. 8). The zone is then followed by a drift in a direction west-northwest for 130 feet, where it is cut by a cross-fault. The cross-fault has been followed southwest for 35 feet without finding any continuation of the shear zone. In the drift, the shear zone varies in width from 3 to 6 feet and the quartz lenses average about 9 inches, though they may pinch out entirely for a few feet.

No drifting has been done on the shear zone east of the crosscut adit. According to Douglas Lay in the annual report of the Minister of Mines, British Columbia, for 1934, the winze that was sunk 80 feet from the adit level showed the vein material to pinch and swell, and in the bottom to be 2½ feet wide. Since 1935 the winze has been full of water and so could not be examined by either Kindle in 1935 or the authors in 1953. At an elevation of about 1,045 feet and some 130 feet south of the main adit portal, a 20-foot adit cuts the shear zone, which is then followed by a drift in a west-northwest direction for 96 feet. In the drift, the shear zone averages 3 feet wide and contains narrow lens-shaped bodies of quartz up to 18 inches wide. The two levels, at 990 feet and 1,045 feet, are connected by a raise on the vein.

During the operation of the mine an aerial tramway one third of a mile long connected the ore bin at the mine with a small mill near the railway at the foot of the mountain.

When the property was visited in 1953 there was no sign of mill or tramway, all buildings were collapsed and the cribbing at the adit portal needed considerable repair. There had been several rock falls in the drift and timbering showed signs of decay. The mine appeared to be very wet and the winze was full of water.

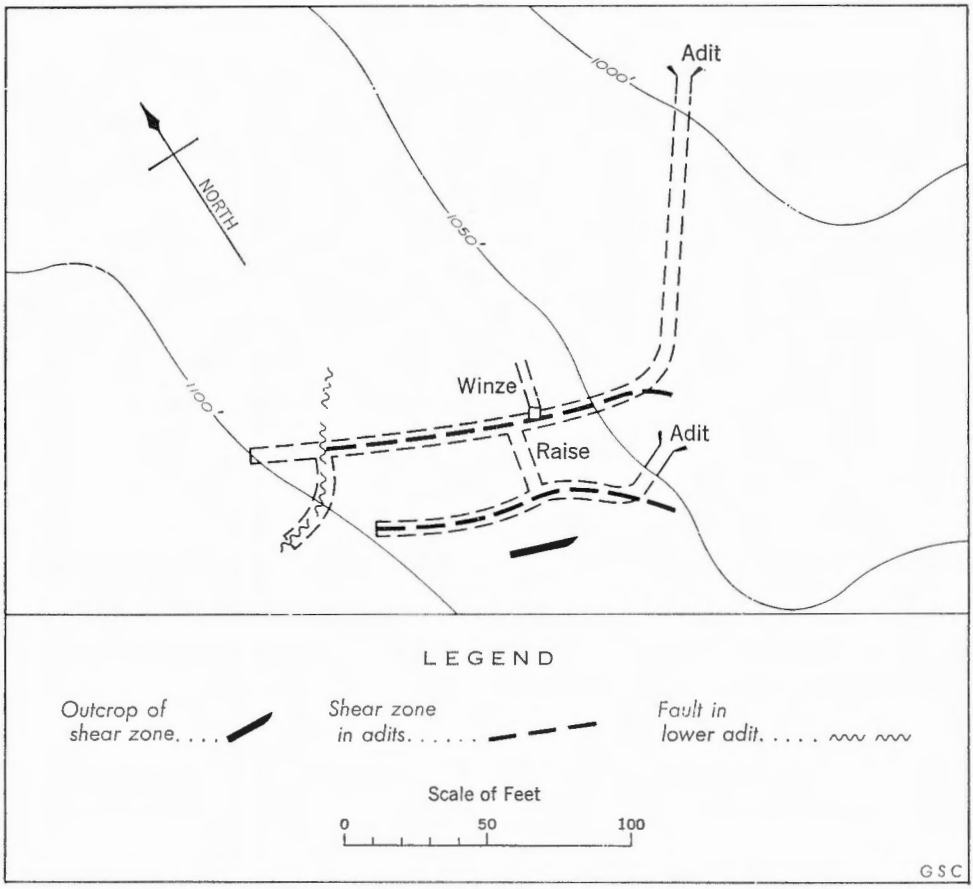

FIGURE 8. Plan of underground workings, Lucky Luke mine (after Kindle, 1937a).

Cordillera Group (35)

References. Ann. Rept., Minister of Mines, British Columbia: 1914, p. 141; 1917, p. 97; 1918, p. 110; 1919, p. 98; 1920, p. 80; 1921, p. 95; 1922, p. 97; 1923, p. 101; 1925, p. 125; 1926, p. 124. Geol. Surv., Canada, Sum. Rept. 1925, pt. A, p. 115; Mem. 205, pp. 46-48, 1937.

This property, a mile southwest of Usk at the base of Kitselas Mountain, was first staked in 1914. Development work was carried out by the Kitselas Mountain Copper Company which built a small amalgamation mill in 1920 and produced some gold, silver, and copper. Further work was done in 1929 and 1930 but nothing since. Exploratory work, consisting of a total of more than 1,650 feet of underground workings on two levels, was done on a system of quartz veins that strike northwest and dip 15 to 35 degrees northwest. The veins are relatively short quartz lenses repeated along strike; some have been exposed for lengths of from 60 to 90 feet. Widths varied from a few inches to 11 feet, the average

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probably being less than 3 feet. These quartz lenses are mineralized with bornite, chalcocite, chalcopyrite, and gold. The workings of this property are heavily overgrown with new growth bush and difficult to find; they were not visited by the authors.

Nugget (38) *and Copper King Groups*

References. Ann. Rept., Minister of Mines, British Columbia: 1914, p. 142; 1923, p. 105; 1928, p. 145. Geol. Surv., Canada, Mem. 205, p. 52, 1937.

These groups are on the Hankin Creek slope of Kitselas Mountain and are reached by a good trail up Hankin Creek from the railway. When visited in 1954 the trails were in fair condition but the workings had deteriorated so that less could be seen than when they were visited by Kindle in 1935. The veins are similar in nature to those on the Lucky Luke and Cordillera, i.e., narrow lens-like quartz bodies mineralized with chalcocite, chalcopyrite, pyrite, and some gold.

Nicholson Creek Mining Corporation (26)

References. Ann. Rept., Minister of Mines, British Columbia: 1934, p. C5; 1935, pp. 7-10; 1936, p. C37; 1938, p. B39; 1939, p. A68; 1940, p. A54; 1941, pp. A41, 55; 1948, p. A76; 1952, p. 85; 1953, p. 92; 1954, p. 85; 1955, p. A21. Geol. Surv., Canada, Mem. 205, pp. 53-57; Paper 36-20, pp. 35, 36.

The Nicholson Creek Mining Corporation owns a large number of claims, covering about 6 square miles between Lowrie and Shannon Creeks, on the west side of Skeena River north of Usk. The company, incorporated in the State of Washington, commenced operations on the property in 1934 and until 1955 carried out a great deal of exploration by surface trenching, diamond drilling, and underground development on the many mineral showings occurring on the claims. Unfortunately no orebody of economic proportions has been discovered to date. Mr. W. D. Galbraith was in charge of the work at the property during the period 1951 to 1955 and showed the authors every courtesy. Some of the claims, such as the Diadem taken over by the Corporation in 1934, already had considerable underground and surface exploration done on them.

The area covered by the Corporation's claims is underlain by metamorphosed sedimentary and volcanic rocks that have been grouped with the Triassic rocks of the map-area. These metamorphosed rocks have been invaded by a tongue of granodiorite extending onto the property from a larger body to the north and west. In effect the bedded rocks are part of the metamorphic zone along the eastern margin of the Coast Range batholith. As a result the sedimentary and volcanic rocks have been sheared, broken, and silicified, and narrow quartz veins and sparsely mineralized lenses have formed along fractured zones. Near the contact of the granodiorite and the bedded rocks the former is in places itself fractured and faulted and veins have formed in these fractures.

In the bedded rocks the veins and mineralized zones carry pyrite, sparse bornite and chalcopyrite, minor scarn minerals, and in places some scheelite. Assays showed that in the precious metal content is low.

Several thousand feet of underground development on mineral occurrences in the bedded rocks has shown little but narrow quartz veins following the sheared zones. On the Diadem claim an adit 1,050 feet long, driven across the strike of the shearing, cut only a few minor stringers. On the Orion claim there are about 1,200 feet of drifts and crosscuts and numerous surface trenches and open-cuts. This work was done on narrow quartz veins that follow shear zones and schistosity in very fine grained silicified bedded rocks. The strike of veins is N70°W with a dip of 50°SE.

In the granodiorite tongue near its contact with the bedded rocks several sheared, fractured, and silicified zones are visible on the surface, one as much as 20 feet wide. These zones contain quartz veins that are commonly less than 2 feet wide but may widen to as much as 4 feet. These veins and shear zones carry pyrite and molybdenite with negligible values in gold and silver.

In an attempt to intersect these structures underground, the Corporation in 1934 drove an adit in a direction S38°W from a point on the south bank of Shannon Creek at an elevation of 1,533 feet, and approximately 3½ miles from the mouth. The portal of the adit is on the southeast bank of a northerly flowing tributary of Shannon Creek known as Molybdenum Creek. The surface showings are about 1,200 feet southwest of the portal and about 400 to 500 feet higher.

The adit ultimately was extended to over 1,700 feet, all in granodiorite. It intersected dozens of minor faults and shear zones and some narrow quartz veins bearing pyrite and molybdenite but nothing comparable with the surface showings. Many of the sheared zones are filled with dark green dykes that strike N25°W and dip 65°NE. Near the end of the adit one of these has been followed south for 225 feet. Other workings off this adit amount to about 300 feet of drifting and crosscutting along sheared zones all of which failed to uncover veins of economic size. Work on this adit was intermittent during the period 1937 to 1948. In 1948 the plant was moved to the Orion claim where underground work proceeded on the showings there. This work was being extended in 1955 but operations ceased in that year.

Properties on Hardscrabble Creek

The properties accessible from Hardscrabble Creek are the Diorite group (22), the Grotto group (21), and the A-B group (23).

The geology and mineralization is similar to that of other properties in Skeena Valley. The contact of the granodiorite of the Coast Intrusions with Triassic rocks and rocks of the Hazelton Group is about 4 miles west of Skeena River on Hardscrabble Creek. The intruded rocks are fractured, sheared, and cut by dykes. Veins and mineralized lenses are present in some of the fractures and along the contacts and walls of dykes.

A-B Group (23)

References. Geol. Surv., Canada, Mem. 205, p. 57, 1937.

The A-B group of claims is on the ridge between Shannon and Hardscrabble Creeks, about 3 miles west of the railway line along Skeena River. From the

railway line a bulldozer road leads up the north bank of Hardscrabble Creek for 1¾ miles to the camp on the Grotto group. From there the trail crosses the creek and heads up the ridge. The showings are at elevation 2,650 feet, near two small lakes. When these showings were visited on June 27, 1954 the lakes were still frozen and snow-covered. The showings consist of three cuts covering a total length of 226 feet on a sheared zone, which in pit #1 is 20 feet wide. The rock in the zone is broken and rusty, and carries disseminated pyrite. Two quartz veins 18 inches and 15 inches wide within the zone are separated by about 10 feet of broken and sheared country rock. The strike of the vein is N75°E and the dip 45°NW. Both veins are mineralized with pyrite and chalcopyrite. A sample from the narrow vein assayed: gold, 0.005 ounce a ton; silver, 0.70 ounce a ton; copper 0.39 per cent.

Pit #2 is 53 feet distant in a direction N80°E. It is 15 feet wide but contains no definite quartz veins, though quartz is present in the shear zone. The material of the sheared zone carries disseminated pyrite and chalcopyrite. A sample taken across a width of 11 feet assayed: gold, 0.005 ounce a ton; silver, 0.36 ounce a ton; copper, 0.23 per cent.

Pit #3 is 173 feet to the northeast of pit #2. Only 7 feet across the showing was visible, the remainder of the pit being filled with snow; the material was similar to that in the other pits. An 8- to 10-foot dyke occurs along the foot-wall of the shear zone.

Diorite Group (22)

References. Ann. Rept., Minister of Mines, British Columbia: 1916, p. 98; 1929, p. 152; 1931, p. 71; 1937, p. 4; 1952, p. 85. Geol. Surv., Canada, Mem. 212, pp. 37-38, 1937.

The Diorite group is less than half a mile west of the railway on Hardscrabble Creek. There the Hazelton Group of volcanic rocks is cut by cupolas of granodiorite and quartz-albite dykes, some of which help to form the walls of the narrow canyon through which the creek flows at this point. Near the top of the rock bluffs on the north side of the creek, an open-cut and short adit expose chalcopyrite and sparse bornite along minor faults and fractures in a quartz-albite dyke. The sulphides are also present along the contacts of 6-inch wide granodiorite dykes that cut the quartz-albite dyke. Other cuts and short adits have been made in the same dyke. One 25 feet below the upper cut exposes a half-inch seam of chalcopyrite along a small fault. On the opposite side of the creek a short adit and some open-cuts explored the occurrence of chalcopyrite and bornite along joint planes in the volcanic rocks.

When visited in 1954 these workings were heavily overgrown with second growth bush and very difficult to find.

Grotto Group (21)

References. Ann. Rept., Minister of Mines, British Columbia: 1929, p. 152; 1931, p. 71; 1937, pp. 4-7; 1938, p. 27; 1939, p. 69; 1940, p. 55; 1952, p. 85; 1953, p. 92. Geol. Surv., Canada, Paper 36-20, pp. 34, 35; Mem. 212, pp. 38-40, 1937.

The Grotto group lies about 1¾ to 2 miles up Hardscrabble Creek from the railway. A good tractor road leads up the north bank of the creek from the railway to the camp, which consists of cookhouse, bunkhouses, and camp buildings, all in good condition.

Narrow quartz veins and stringers occur on this property along the rocky walls of the creek, between elevations 500 and 600 feet and again between 1,000 and 1,500 feet. They occur adjacent to contacts of dykes, cupolas of the Coast Intrusions, and along shears and faults in the Hazelton Group rocks. They strike generally northeast and dip 35° to 70°NW. Metallic minerals present in these narrow veins have been determined as pyrite, chalcopyrite, and specularite, with minor amounts of sphalerite, petzite, hessite, empressite, richardite, chalcocite, and possibly native tellurium.

No. 1 vein, on the north side of Hardscrabble Creek just at creek level, lies adjacent to a 12- to 15-foot porphyritic granodiorite dyke, and has been explored by an adit drift for over 100 feet with an average width of quartz of 12 to 15 inches.

Alteration of the wall-rock increases the width of the vein zone to about 20 inches but the altered rock carries little gold and silver.

The vein outcrops on the stream bank on the hanging-wall side of the dyke, and at that point is 29 inches wide. In the adit at 17 feet from the portal a narrow 10-inch vein is followed on the hanging-wall of the dyke for about 15 feet. The adit continues on the foot-wall and exposes a quartz vein averaging 12 inches wide for about 33 feet. At footage 50 feet from the portal the vein turns slightly towards the west wall of the drift and shows only stringers in the drift but at 63 feet a slash in the west side of the drift shows a vein zone 39 inches wide still on the foot-wall of the dyke.

From 63 to 72 feet the adit roof is timbered and at 85 feet the vein pinches out on the level but is exposed in a raise to surface, still on the foot-wall of the dyke. At 100 feet the adit crosses the dyke to the hanging-wall side and intersects a vein 21 inches wide. A sample of this vein taken at the intersection assayed: gold, 0.01 ounce a ton; silver, 0.42 ounce a ton; and copper, 0.02 per cent. At 116 feet the vein pinches out with no further vein intersections to the end of the drift at 150 feet.

The main vein followed by the adit is on the foot-wall of the dyke but some lenses on the hanging-wall may not have been fully explored, though their general character would be the same as those on the foot-wall.

No. 2 adit, which is about 300 feet upstream and on the opposite side of the stream, explores a quartz vein of similar appearance. The adit exposes this vein for about 25 feet where it pinches out against a fault. In the adit the vein is 6 to 9 inches wide. In 1952 and 1953 some work was done in both No. 1 and No. 2 adits and a 20-foot winze was sunk on the vein in No. 2 adit. Although the winze was full of water when the property was visited, J. Bell of Usk who did the work volunteered the information that the vein reached a width of 3 feet in the winze. In 1953 a 32-ton shipment of selected ore from sub-drifts off this

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winze assayed: gold, 0.57 ounce a ton; silver, 17.07 ounces a ton; and copper, 2.60 per cent.

Properties on Carpenter Creek

Gold Dome Group (18)

References. Ann. Rept., Minister of Mines, British Columbia: 1945, pp. 63-64.

Carpenter Creek is the second major creek above Pitman siding (coming into Skeena River from the west), and heads in a cirque on the south side of Mount Knauss. Some argillite of the Bowser Group outcrops on the south fork of the creek. A group of claims has been staked in this cirque by John Creagh of Vancouver. These can be reached by an excellent 6-mile trail that connects with the railway track. Mr. Creagh has built cabins at the railway and at the lip of the cirque, just at timber-line.

The main group of four claims is known as the Gold Dome group, and is underlain by granodiorite that is cut by narrow quartz veins from 2 inches to at least 18 inches wide. Two of these veins carry scheelite, which is present in the quartz as patches and streaks. One such streak measured 1 inch to 2 inches wide and was visible along the veins for a distance of 20 inches.

One vein on the south side of the cirque has a strike of N40°E and dips 55°SE. The workings on this vein were filled in and little could be seen. According to Mr. Creagh this vein is not as high grade as a similar vein on the north side of the cirque.

Vein No. 2, on the north side of the cirque, strikes N40° to 60°E and dips 65°SE. It has a maximum width of 18 inches and can be followed several hundred feet up the hillside.

An open-cut about 20 feet along the vein exposes some high grade scheelite.

West of the scheelite occurrences, flat-dipping, narrow quartz veins may be seen extending along the cliff face for several hundred feet. These veins carry some chalcopyrite, galena, and sphalerite. A grab sample of this material assayed: gold, 0.595 ounce a ton; silver, 51.48 ounces a ton; copper, 1.76 per cent; lead, 1.32 per cent; zinc, 5.2 per cent.

Mr. Creagh states that a second group of claims to the west (known as the Warrior group) at the head of the south fork of Carpenter Creek includes a quartz vein carrying galena and sphalerite. This group was not visited.

Properties on Mount Knauss

Dorreen Gold Mine (11)

References. Ann. Rept., Minister of Mines, British Columbia: 1916, pp. 101-104; 1925, p. 131; 1937, pp. 41-44; 1949, p. 94; 1950, p. 81; 1952, p. 82. Geol. Surv., Canada, Mem. 212.

This property is situated on Knauss Creek about 4 miles west of Dorreen Station on the Canadian National Railways. The workings are on the steep wall of a glacial valley at an elevation of 2,200 feet above sea-level. No work has been

done at the property since 1953 and roads, trails, and buildings have all suffered heavily from the ravages of snowfall and run-off. The road between the property and Dorreen Station is impassable.

The property was first staked in 1914 by Louis Knauss; the same year it was bonded to Martin Welch who drove the main adit (Fig. 9). In 1916 the property was bought by the Fiddler Creek Gold Mining Company which drove a lower adit through 183 feet of drift to bedrock to intersect the vein; this working caved in. In

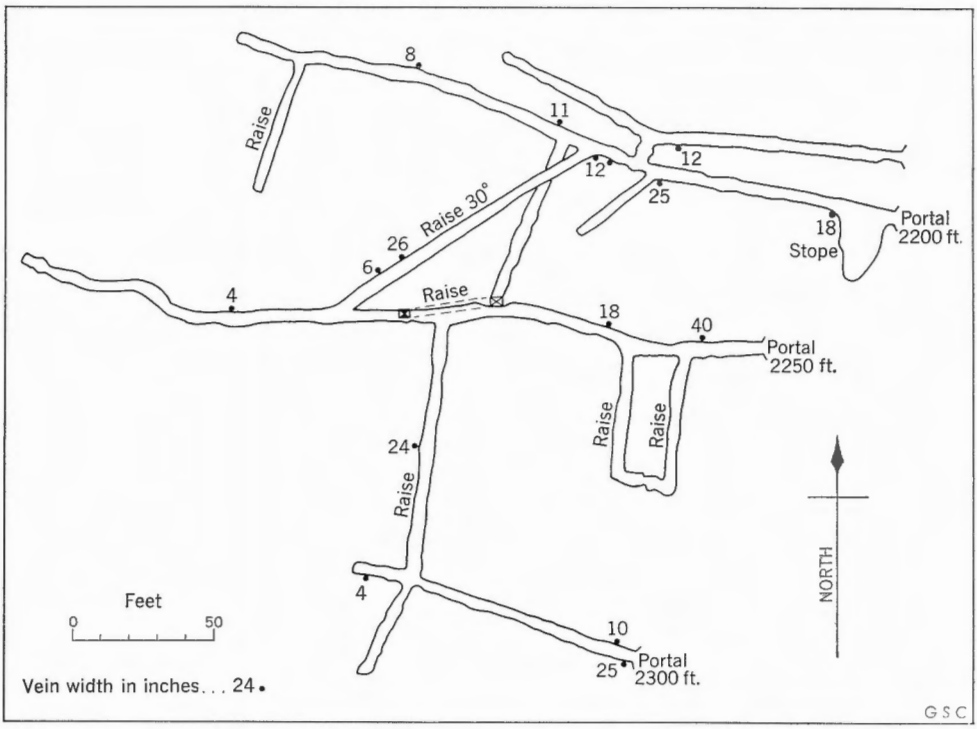

FIGURE 9. Plan of workings Dorreen gold mine, 1954.

1923 J. F. Duthie acquired the property and in 1924 shipped 80 tons of ore which assayed: 1.67 ounces gold a ton; 6.0 ounces silver a ton; 6.2 per cent lead; 1.3 per cent copper; and 5.8 per cent zinc. In 1926 the property was taken over by J. W. Treadway who shipped about 100 tons of ore. No further work was done until 1949, when L. W. Patmore and J. W. Treadway sold the property to Dorreen Gold Mining Company. A truck road was completed to the property from Dorreen and a 30-ton-per-day cyanide mill erected. In 1952 further development was carried out and 525 tons of ore were milled which produced 20 tons of concentrate averaging: 5.25 ounces gold a ton; 13.05 ounces silver a ton; 17.3 per cent lead; 7.4 per cent zinc; and 2.6 per cent copper. Except for some diamond drilling in 1953, work ceased in 1952.

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The vein, which occurs along the bedding planes of strata of the Bowser Group, outcrops near the contact of a wide quartz diorite dyke that strikes N30°W and dips 55°SW. Strata of the Bowser Group strike N50°W and dip 25°NE. The fissure in which the vein has formed occurs along a bedding plane fault in the Bowser Group rocks. The vein varies in width from 5½ feet near the portal of the main adit and close to the dyke to a few inches at the end of the adit and on the uppermost level. The workings show the vein to be lens shaped, thickest at the dyke and near the portal, and diminishing in size and value with increase in distance from the dyke.

Seventy feet stratigraphically above this vein is a similar vein with a width of 8 to 12 inches.

Metallic minerals contained in the vein include chalcopyrite, covellite, galena, pyrite, sphalerite, tetrahedrite, and arsenopyrite. Gold is not visible to the naked eye.

Undergound workings consist of 466 feet of drifts and 115 feet of crosscuts on the 2,200-foot level; 212 feet of drifts on the 2,250-foot level; and 123 feet of drifts and 48 feet of crosscuts on the 2,300-foot level. The levels are connected by raises along the vein, and an ore chute has been driven to connect the lower two levels. All levels have portals on the hillside.

Patmore Group (10)

References. Geol. Surv., Canada, Mem. 212, p. 44, 1937.

This property was not visited during the course of the survey and the following description is by Kindle (1937a, pp. 44, 45). No work has been done on the claims since Kindle wrote his report.

> This property is in the south side of Fiddler creek about 6 miles west by wagon road and foot trail from Dorreen station. The wagon road to the Fiddler property is followed as far as Knauss creek, from where a foot trail 2 miles in length leads westerly to the showings. The property was first prospected over twenty years ago, at which time a short adit was driven and surface stripping and trenching done. The claims were relocated in 1934 by Mr. Patmore of Prince Rupert. Premier Gold Mining Company, Limited, did a little surface work that year.
>
> No. 1 showing is at elevation 2,550 feet. A number of small quartz veins in altered, fine-grained quartz diorite have been exposed by trenching and stripping in an area roughly 100 feet long and 40 feet wide. The quartz stringers average about 6 inches in width and 50 feet in length and are well mineralized with galena and sphalerite, with lesser amounts of pyrite and chalcopyrite. The longer veins, which trend south up the mountain slope, are intersected by cross veins, but the total amount of vein quartz does not exceed 10 per cent of the rock mass. The estimate includes numerous fine quartz veinlets less than ½ an inch in width which traverse the altered quartz diorite. The intrusive is brown stained on weathered surfaces through oxidation of a small pyrite content.
>
> A representative sample of the mineralized vein quartz taken from a small pile of hand-sorted ore assayed: gold, 0.12 ounce a ton; silver, 2.28 ounces a ton; lead, 1.00 per cent; zinc, 1.05 per cent.
>
> Other exposures of the altered quartz diorite with quartz stringers were seen 150 feet west of the No. 1 showing and again 125 feet south up the mountain side.
>
> No. 2 showing is at the same elevation, 1,200 feet farther west along the mountain side. The intervening area is drift covered. Mineralized quartz stringers striking south

to southwest occur in altered quartz diorite in a manner analogous to the occurrence at the No. 1 showing. The veins and intrusive are exposed by cuts in a stripped area about 50 feet wide and 60 feet long. There are a number of smaller exposures 200 feet north down the mountain side. At elevation 2,500 feet a 37-foot adit was run south at a point just below the stripped zone. The adit is in altered quartz diorite for 35 feet, with 2 feet of argillite at the face. The argillites strike easterly and dip 40 degrees north. Argillites are exposed again about 25 feet above the stripped zone, and strike easterly with a dip of 40 degrees north. The evidence indicates that the altered quartz diorite occurs as a sill and that its strike and dip correspond approximately with the strike and dip of the mountain slope. This being so, other occurrences of the altered diorite cut by mineralized quartz stringers might be found by digging test pits through the overburden in the area between the two main showings.

In the adit a 6-inch channel sample taken across a quartz vein 20 feet from the portal assayed: gold, 0.14 ounce a ton; silver, 2.68 ounces a ton; lead, 2.92 per cent A representative sample taken from an ore pile at the foot of the stripped zone assayed: gold, 0.20 ounce a ton; silver, 0.78 ounce a ton; lead, 1.15 per cent. An assay made on a typical specimen of altered quartz diorite gave a negative test for both gold and silver.

Properties near Ritchie

Canadian Swede Group (6)

References. Ann. Rept., Minister of Mines, British Columbia: 1928, p. 149; 1930, p. 138. Geol. Surv., Canada, Mem. 212, p. 47, 1937.

This group is situated about 2 miles west of Ritchie flag station, and is reached by way of truck road from the station. At elevation 650 feet, a 90-foot adit has been driven along a narrow vein in gently dipping argillites of the Bowser Group. The vein, which varies in width from 6 inches of quartz to 4 feet of sheared rock and quartz stringers, occurs along a fault zone; it strikes north and dips vertically. The quartz carries about 1 per cent sulphide, largely pyrite which gives assays of only a trace in precious metals. Elsewhere on the property narrow quartz veins and stringers of similar character were noted.

September (7) *and July* (8) *Groups*

References. Geol. Surv., Canada, Mem. 212, p. 46, 1937.

These two groups of claims occupy the wide valley at the headwaters of Douglas Creek and the north fork of Lorne Creek, and are reached by trail from Ritchie.

Narrow quartz veins from 3 inches to 3 feet thick are exposed for about 100 feet along strike. Veins on the September group strike north and dip 50° to 70°E; those on the July group strike N60°W and dip 10°N. Veins on both groups are mineralized with pyrite and some chalcopyrite and pyrrhotite. They carry little gold and silver.

Windfall Group (2)

References. Ann. Rept., Minister of Mines, British Columbia: 1931, p. 71. Geol. Surv., Canada, Mem. 212, p. 47, 1937.

This group is about 2 miles west of the railroad, and can be reached by a trail up the north side of Quill Creek. At elevation of 1,000 feet and about 100 feet

above the creek, a quartz lens containing sphalerite, galena, chalcopyrite, and pyrite occurs at the crest of a small anticline in sediments of the Bowser Group.

About 100 feet north and above the showings, a thick feldspar porphyry sill outcrops in the form of a high bluff. The emplacement of this sill apparently fractured and deformed the sedimentary rocks near it, allowing the formation of small veins. There are a number of open-cuts and short adits on other veins in the vicinity, but all the pits and openings are now filled with rock-slide material so that it is not possible to see any veins exposed in them. No work has been done on these showings since Kindle's visit in 1936.

Properties on Ridge between Chimdemash and Ste. Croix Creeks

The following properties are situated on the ridge between Chimdemash and Ste. Croix Creeks: United Ste. Croix (30), Galena (33), Silver Mitts (34), Shenandoah (29), St. Elmo (25), and Bradle Bane (24). The first four groups of claims are situated near the crest of the ridge along both sides of the north fork of Chimdemash Creek; the latter two are very much lower down and near Skeena River.

The ridge is underlain by rocks of the Hazelton Group that have been intruded by stocks, cupolas, and dykes of the Coast Intrusions. Narrow, discontinuous quartz veins fill fractures in the Hazelton Group rocks and along the contacts of dykes. The veins carry the sulphides pyrite, chalcopyrite, galena, and bornite and give low assays in gold and silver. Little or no work has been done on any of these groups since before World War II.

Properties at the Head of Legate Creek

References. Ann. Rept., Minister of Mines, British Columbia: 1916, 1917, 1919, 1921, 1923, 1925, 1928, 1929. Geol. Surv., Canada, Sum. Rept. 1925, pt. A, pp. 111-112; Mem. 212, pp. 19-24, 1937.

Four properties, the M and M (32), M and K (28), Frisco (27), and Zona May (31) groups are all situated at the head of Legate Creek near a small stock of Coast Intrusions that cuts rocks of the Hazelton Group. The properties are all above timber-line, and are reached by a trail (now washed out and overgrown) up Legate Creek.

The veins occur in fractures in the Hazelton Group rocks, in the diorite intrusive rocks, or along dyke contacts. They are commonly less than 2 feet wide but may be as much as 5 feet. The quartz carries the metallic minerals pyrite, galena, tetrahedrite, and chalcopyrite, some bornite and sphalerite, and minor amounts of specularite. Commonly the metallic minerals are sparsely disseminated in the quartz but may be massive, as in places on the M and K group. Assay of material from these veins showed that they contain little gold but fair amounts of silver, copper, and lead. A sample from the massive material on the M and K group, taken by Kindle in 1936, assayed: gold, a trace; silver, 3.10 ounces a ton; copper, 10.98 per cent; lead, 26.51 per cent.

Consolidated Mining and Smelting Company carried out some exploration on the M and K group in 1928 and 1929 without success. No work has been done on these properties since.

Properties on Seven Sisters Peaks

Several mineral occurrences have been explored but without success. The Seven Sisters group (3) has had the most exploration but the Caledonia claims, 2 miles to the southeast, have had some open-cuts and short adits excavated on a mineralized zone in sedimentary rocks of the Bowser Group. These rocks underlie the whole range and are intruded by a small stock that forms the core of the range. The sedimentary rocks are sharply crenulated and deformed in the vicinity of the stock. Concentrations of pyrite and pyrrhotite with minor amounts of galena and sphalerite occur along faults and fractures in the Bowser Group. The pyrite and pyrrhotite carry minor amounts of gold and silver.

The deposits on the Seven Sisters group were prospected by D. W. Mines from 1926 to 1928, and by Consolidated Mining and Smelting Company of Canada Limited in 1929. The well-built camp at elevation 4,100 feet had by 1954 become too dilapidated for use. The trail to the property is used by people climbing Seven Sisters Peaks. The workings had deteriorated greatly, and were very wet and difficult to observe.

The following is a description of the property after Kindle (1937b, pp. 49-51).

Seven Sisters Group (3)

References. Ann. Rept., Minister of Mines, British Columbia: 1925, p. 130; 1926, p. 125; 1927, p. 126; 1928, p. 150; 1929, p. 153; 1930, p. 138.

The veins occur in folded sedimentary rocks for 4,000 feet along the west slope of the mountain between elevations of 4,200 and 4,600 feet. The sediments include conglomerate, sandstone, greywacke, argillite, and arkose, with interbedded volcanic tuffs. In the vicinity of the main workings these rocks strike north and dip 28 degrees east into the mountain, and the veins are found along faults that have the same strike and dip. Several hundred feet farther west down the mountain slope the rocks strike north, but dip 30 degrees west. This indicates that the veins occur at the main workings on the east limb of an anticlinal fold, the axis of which strikes north. About 900 feet north of the inclined shaft at Chisholm creek a number of rock trenches were cut on pyrrhotite veins that occur along faults of small displacement striking north and dipping 40 to 45 degrees east. In several of the pits and along the creek the argillites were seen to strike easterly and to dip 35 degrees north. Here again the veins occur along the north-plunging nose of the anticline, along faults that strike parallel to the axis of the anticline. About 1,800 feet north of the creek, in the vicinity of the Chisholm tunnel, pyrrhotite veins and lenses are found on the crest of a second anticline, the axis of which also strikes north. Again the faults and fissures along which the veins were formed lie roughly parallel to the axis of the fold.

Small dykes of quartz diorite porphyry intrude the sediments and are older than the veins. A body of diorite is reported some distance north of the claims.

Where the vein appears strongest, at elevation 4,325 feet, a shaft inclined at 28 degrees was sunk for about 175 feet and levels were run at points 50 and 112 feet, respectively, down the shaft. On No. 1 level a drift run south 110 feet follows much of the way a fault gouge zone 6 inches wide. In several places the gouge gives place to brecciated argillite up to 2 feet in width containing a little quartz, calcite, and pyrite.

The north drift on this level is 78 feet long with a crosscut east for 23 feet at a point 28 feet north of the shaft, and a 15-foot crosscut east at the north face. An adit 120 feet in length connects with the north drift 21 feet north of the shaft. Immediately north of the shaft the vein consists of 6 inches of quartz containing up to 50 per cent of pyrite. A channel sample taken across this part of the vein assayed: gold, 0.08 ounce a ton; silver, 0.36 ounce a ton. On the north wall of the east crosscut the vein is 24 inches wide, consisting of 12 inches of calcite well mineralized with galena and sphalerite and 12 inches of brecciated argillite containing up to 10 per cent of pyrite. Fifteen feet farther north the vein pinches and gouge about 4 inches thick continues to the end of the drift except for one small 3-inch calcite lens. A 24-inch channel sample taken across the vein at the east crosscut assayed: gold, a trace; silver, 0.24 ounce a ton; zinc, 1.95 per cent; lead, undetermined.

On No. 2 level a drift was run north for 105 feet, with crosscuts running east and west for 25 feet at a point 68 feet north of the shaft. In the north half of the drift the vein averages about 4 inches in width, but elsewhere there is 4 to 6 inches of fault gouge with no vein filling. A channel sample taken across the vein at the crosscuts assayed: gold, none; silver, a trace.

In the shaft the vein persists from the surface down as far as the first level, but there is very little vein filling between the first and second levels. Commencing several feet below the No. 2 level, a 50-foot continuation of the inclined shaft is water filled.

The Chisholm adit, 75 feet in length, is at elevation 4,560 feet, about 2,500 feet north of the inclined shaft. The adit is driven in almost flat-lying, tuffaceous beds impregnated with a little pyrite and chalcopyrite. Forty feet from the portal a branch drift runs 31 feet northwest along a 6-inch quartz calcite vein dipping 50 degrees northeast. The vein contains up to 20 per cent of pyrite. A channel sample taken across the vein on the east wall of the adit assayed: gold, a trace; silver, 0.36 ounce a ton. Near the face of the main adit a number of small vertical fissures contain seams of solid pyrrhotite with little chalcopyrite up to 1 inch in thickness. An assay of a representative sample of this sulphide gave: gold, a trace; silver, 0.41 ounce a ton; copper, 0.32 per cent.

About 200 feet north of the Chisholm adit a lens of massive pyrrhotite containing a little chalcopyrite is exposed in a deep trench. The sulphide body strikes north and dips 65 degrees east. At the trench its width is 15 feet, but along the surface the lens pinches out at points 60 feet north and 50 feet south. A typical sample of the solid sulphide assayed: gold, a trace; silver, 0.16 ounce a ton; platinum, none; nickel, none; copper, 0.08 per cent.

Caledonia Group (4)

The Caledonia group is on the south slope of the Seven Sisters Peaks about 2 miles southeast of the Seven Sisters group. The showings are just above timber-line at elevations between 5,000 and 5,500 feet. The claims are reached by a well-cut trail that leaves the highway at a point about 4½ miles north of Oliver Creek. Part of the lower end of the trail, which has been burned and is covered with second growth bush, is difficult to follow; the remainder of the 11 miles to the cabin at timber-line is well graded and easy to follow. A trail leads from the cabin to the showings.

The claims are underlain by sedimentary rocks of the Bowser Group: conglomerates, greywackes, and argillites. These have been fractured and sheared by the emplacement of the Seven Sisters stock with the resultant formation of narrow quartz veins and some mineralized zones. The main showings consist of a mineralized zone that is exposed along the face of a low ridge. Strike of zone is

N10°W with a dip of 65°W. The zone has been traced for a distance of 375 feet along strike by several pits and short crosscut adits. The width of the zone averages 8 feet with a fairly strong mineralized zone 8 to 12 inches wide on the hanging-wall. When the property was visited in 1954, the uppermost or most northerly workings were filled with snow, and the lowermost cut was filled with rock and mud.

Very little quartz is present in the zone, and the metallic minerals, pyrite, pyrrhotite, chalcopyrite, galena, sphalerite, and arsenopyrite, replace the country rock. Two grab samples were taken, one from the northernmost pit and one from the southernmost pit 375 feet distant. These samples assayed as follows:

	Gold oz per ton	Silver oz per ton	Copper %	Lead %	Zinc %
Sample No. 1	Trace	1.22	0.10	0.23	4.48
Sample No. 2	Trace	6.59	0.26	4.50	8.42

In 1954 this group was held by W. McRea of Usk but was dropped in that year.

Magnetite Deposit on Iron Mountain (60)

Iron Mountain lies about 10 miles north of Kitimat, at the railroad bridge across Wedeene River.

The core of the mountain is a hornblende granodiorite stock that is ringed by metamorphosed volcanic rocks. Much of the stock itself is a mixture of metamorphosed rock and granodiorite but the centre of the stock is free of hybrid rock types.

On the Kitimat River side of the hill, in a contact zone with the metamorphosed Hazelton Group rocks, magnetite is present with minor pyrite and chalcopyrite. This zone strikes about N10°E and dips 75°W, and may be traced for over a mile.

The rock in which the magnetite occurs is dark green and consists of hornblende, epidote, diopside, magnetite, zoisite, biotite, and altered feldspar. No sediments were recognized and the rocks probably are the metamorphosed equivalents of Hazelton Group volcanic rocks, which occur adjacent to the diorite rocks elsewhere in the vicinity.

The magnetite occurs in lenses within this zone that have been traced for a distance of between 1 mile and 2 miles. Some of the lenses are reported to be up to 200 feet long and 50 feet wide, others much smaller.

The presence of magnetite on this mountain was known shortly after the turn of the century. In 1908 a location line for a railroad passed within a mile of the deposit which had even then been explored by adits and open-cuts. Some

further work was done in 1919 and 1929 but nothing has been done since 1929. In 1957 Frobisher Limited became interested in the deposit. They opened the workings and carried out a geophysical survey, which indicated a magnetic anomaly some 5,000 feet long and up to 400 feet wide.

Possibilities of developing the deposit are now much brighter, because of the nearness of the railway and the available shipping facilities at Kitimat.

NON–METALLIC DEPOSITS

Marl Deposits

Buccaneer of the North Claim (5)

References. Ann. Rept., Minister of Mines, British Columbia: 1931, p. 72; 1932, p. 90. Geol. Surv., Canada, Mem. 212, p. 54, 1937.

This claim is on the flat ground of a gravel bench about a mile west of Ritchie flag station. It includes a deposit of marl that occurs along the gently dipping slope of the eastern shore of a small lake. The lake occupies a small depression in the wide gravel bench that extends from the river west for over a mile. In a trench 300 feet long and 15 feet wide the marl is exposed to a depth of 10 feet. It is very white and contains minute shells. Test pits indicate that the deposit extends under the lake bottom. A sample taken by Kindle in 1936 gave: 53.4 per cent CaO; 0.4 per cent aluminium and iron oxides; phosphates, none; and insoluble matter after ignition, 3 per cent.

In 1935, several carloads of the material were shipped to be used as soil dressing on farms near Terrace. No work of consequence has been done on the deposit since.

Limestone Deposits

References. Ann. Rept., Minister of Mines, British Columbia: 1953, p. 191; 1954, pp. 180-181; 1955, p. 154. Mines Branch (Ottawa) Pub. 452, pp. 175-177.

Included in the Palaeozoic rocks of the area are lenses and beds of recrystallized limestone that may have possibilities for commercial utilization under favourable economic conditions. Such deposits are known on Shames River and Zymoetz River. These limestones are commonly white but may be grey greenish white, brownish white, or blue-white. They are medium to coarse grained and may be very pure. They occur interbedded with greenstones and quartz-mica schists which may affect their purity.

During the period 1953 to 1955, A. E. Barr of Prince Rupert developed the deposit at Shames (59) for quarrying, and shipped some 15,000 tons of material to the Cellulose Company plant at Port Edwards.

This deposit is reported on by W. A. Parks in the *Ornamental and Building Stones of Canada,* volume 5, 1917. There he reports that the average rock is 97 per cent $CaCO_3$ but that the deposit is cut by so many faults and shears that its utilization for building stone was doubtful.

The quarry opened by Barr in 1953 is at elevation 800 feet, on the south half of lot 4510, range 5. It is connected to the loading ramp at the railway by a 1½ mile truck road. By 1954 the quarry was well developed on a bed that had a strike of N60°E and dipped 80°NW. The limestone can be traced up the hillside to elevation 2,700 feet. It varies in width from 100 feet to 400 feet but is interbedded with greenstones and quartz mica schists, which make quarrying difficult and reduce the effective width of the limestone. In 1954, though the limestone being quarried was 145 feet wide, it contained lenses of greenstone that posed problems in quarrying and purity of product. Where the limestone is present as pure white recrystallized limestone in sufficient widths for quarrying it can be mined for shipment. In order to keep the shipments of sufficiently high grade it was necessary to hand pick and wash each truckload.

Following are two analyses of relatively pure material being quarried:

	Sample No. 1	Sample No. 2
SiO_2	0.2	0.7
Al_2O_3	0.0	0.2
Fe_2O_3	0.1	0.1
CaO	55.7	55.0
Mg O	0.0	0.0
Na_2O	0.1	0.1
K_2O	0.1	0.1
H_2O+ / H_2O-	0.1	0.3
TiO_2	0.0	0.0
P_2O_5	0.0	0.1
MnO	0.1	0.1
CO_2	43.7	43.5
Total	100.1	100.2

Sand and Gravel Deposits

Pleistocene and Recent outwash and stream deposits, up to 500 feet thick, cover the Kitimat-Kitsumkalum Valley. At Terrace, a series of terraces has been cut in these deposits by Skeena River. South of Terrace the broad, flat surface of the deposits is used for the airport, and at Kitimat the deposits underlie the area of the townsite. A thin layer of soil at the top of these deposits is used to some extent for cultivation. Below this soil layer excellent deposits of sand and gravel are available for railroad ballast, road metal, and construction purposes. At Kitimat a hill of well-sorted and stratified stream sands and gravels has proved an excellent source for road and construction fill and material for concrete (Pl. IX B). Some of the clay beds may be suitable for brick manufacture.

Hot Springs

The successful redevelopment in 1958, by R. Skoglund, of the hot springs at Lakelse (Pl. IX B), between Terrace and Kitimat, should benefit the economy of the whole area. Terrace is now readily accessible by road, and the springs are alongside the Terrace-Kitimat highway. Canadian Pacific Airlines maintains scheduled flights between Terrace and Vancouver.

The springs have been known for many years, and were to some extent developed as early as the first World War. They had been operated intermittently until 1936, but have been idle since. There are nine springs in all, the largest being some 100 feet across (Pl. IX A). The water, which has a temperature of 186°F, is reported to contain lithium.

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1954: Petrology. An Introduction to the Study of Rocks in Thin Sections; W. H. Freman and Co.

110804

A. View north to the Seven Sisters Peaks.

PLATE II

111062

B. View north across Legate Creek valley. Quartz diorite forms foreground ridge; distant peaks are Mesozoic volcanic rocks.

70594-7—9

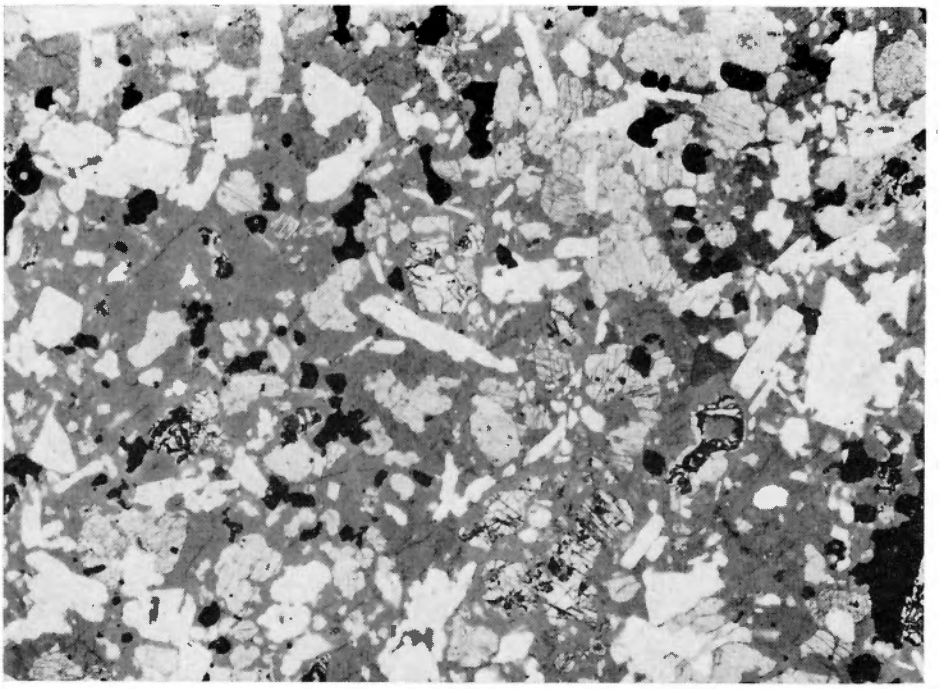
110803

A. Conglomerate, Bowser Group, headwaters of Oliver Creek. White boulder in centre is granite.

PLATE III

110793

B. Vertical dragfolds in beds of argillite and greywacke, Bowser Group, along highway south of Flint Creek.



111108

PLATE IV A. Olivine gabbro facies. Poikilitic hornblende enclosing crystals of magnesian augite, labradorite, olivine, and magnetite. (plain light x10)

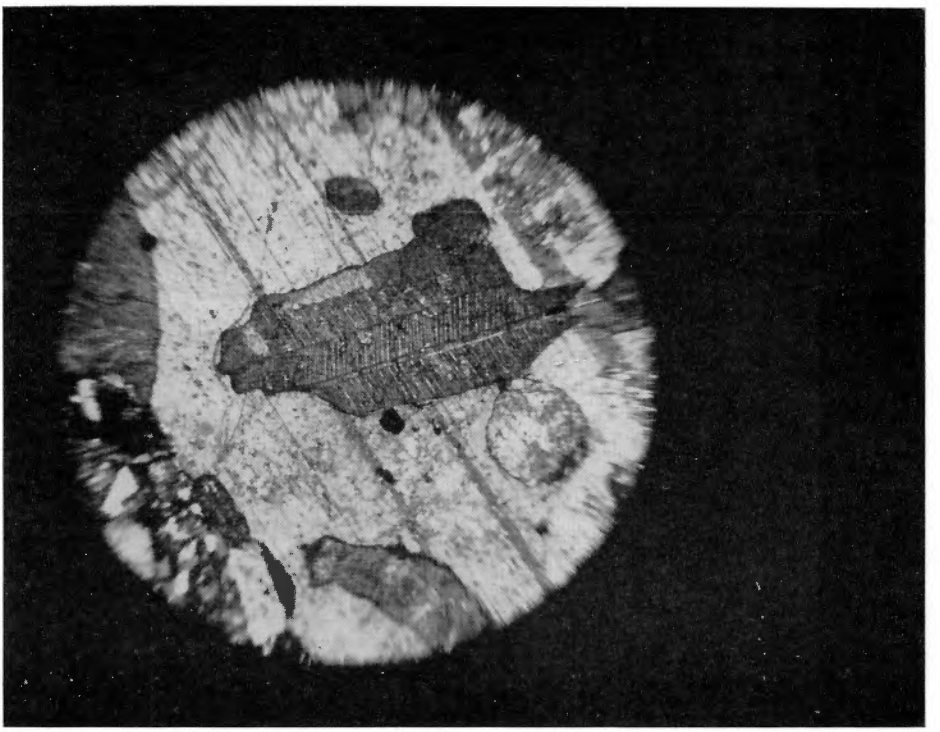


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PLATE IV B. Photomicrograph of a partly resorbed grain of augite enclosed in plagioclase. The exsolution lamellae are probably pigeonite. (x40 — crossed nicols)

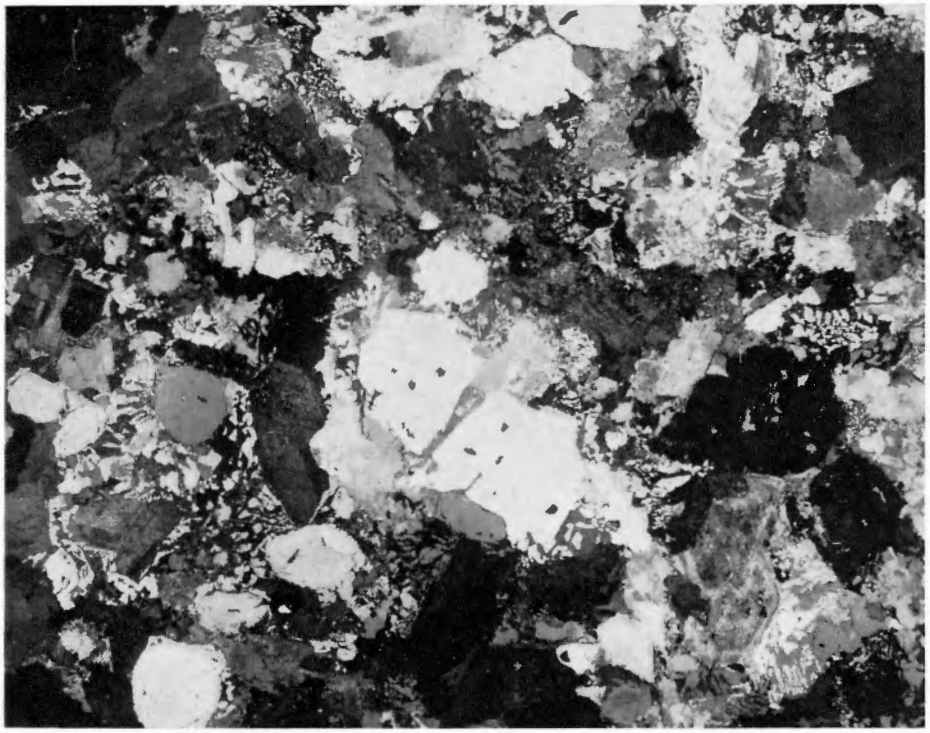

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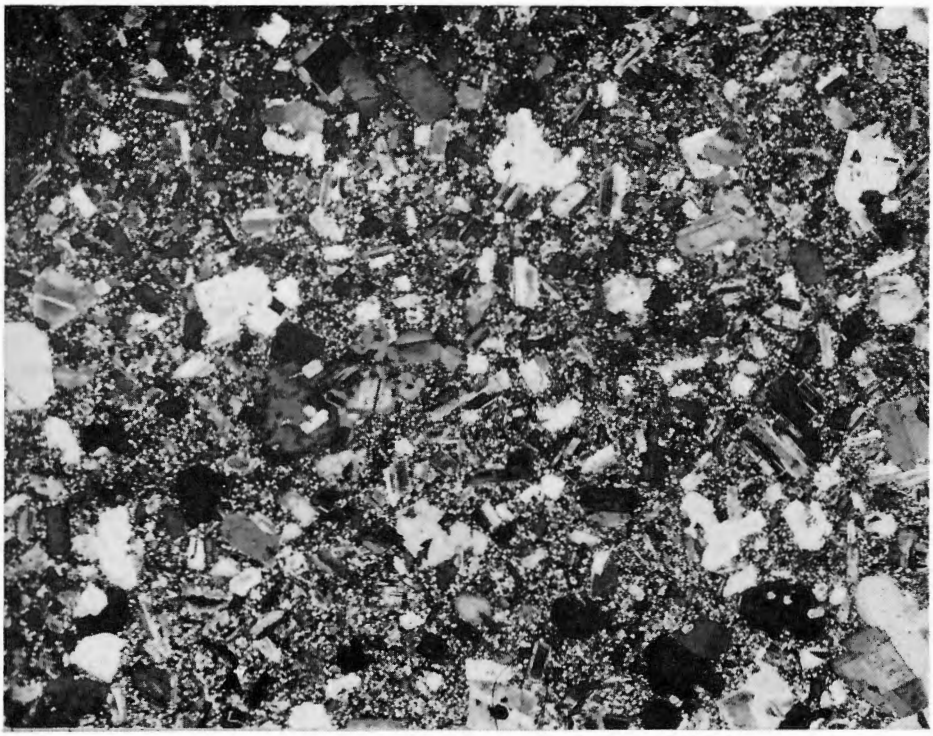
PLATE V A. Photomicrograph of pink granodiorite showing granophyric intergrowths of quartz and potash feldspar. (x10—crossed nicols)

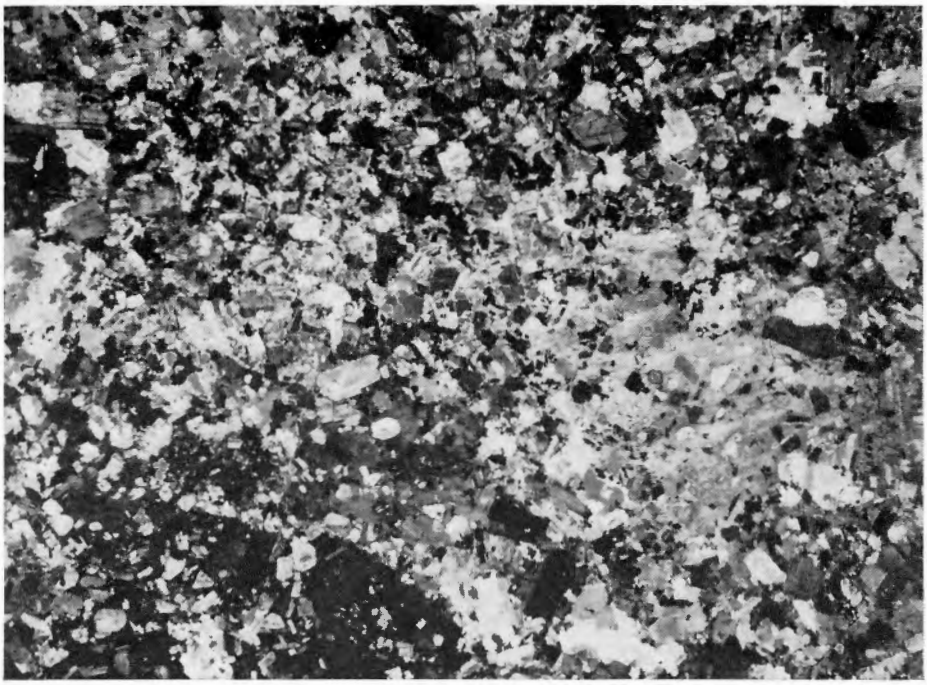
111077

PLATE V B. Rheomorphic breccia resulting from the mobilization of a composite fracture zone in pseudodiorite.



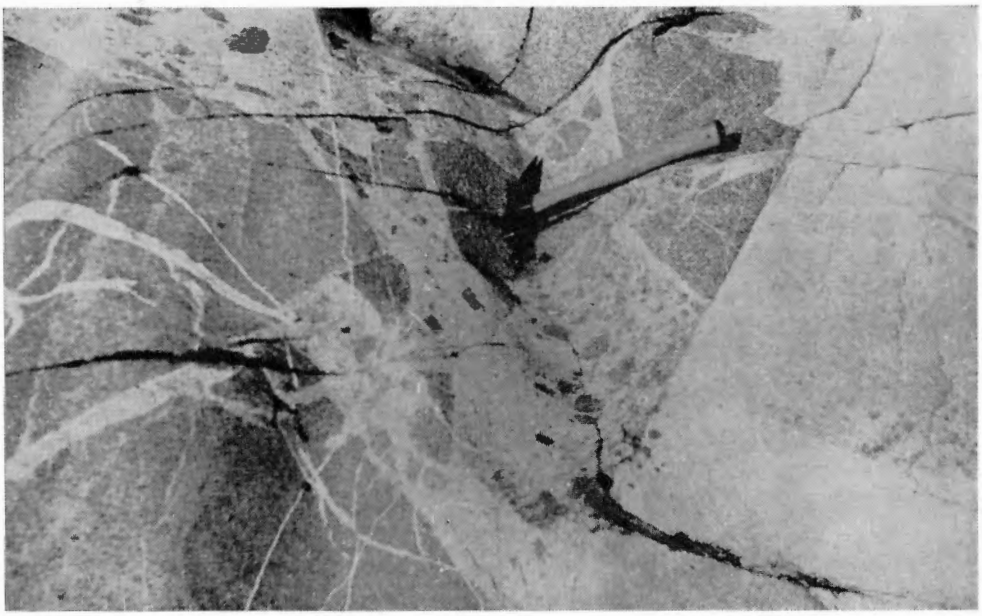
111110

PLATE VI A. Photomicrograph of the porphyritic phase of the white granodiorite. Strongly zoned phenocrysts of plagioclase are surrounded by a fine-grained mosaic of quartz and potash feldspar. (x10—crossed nicols)



111111

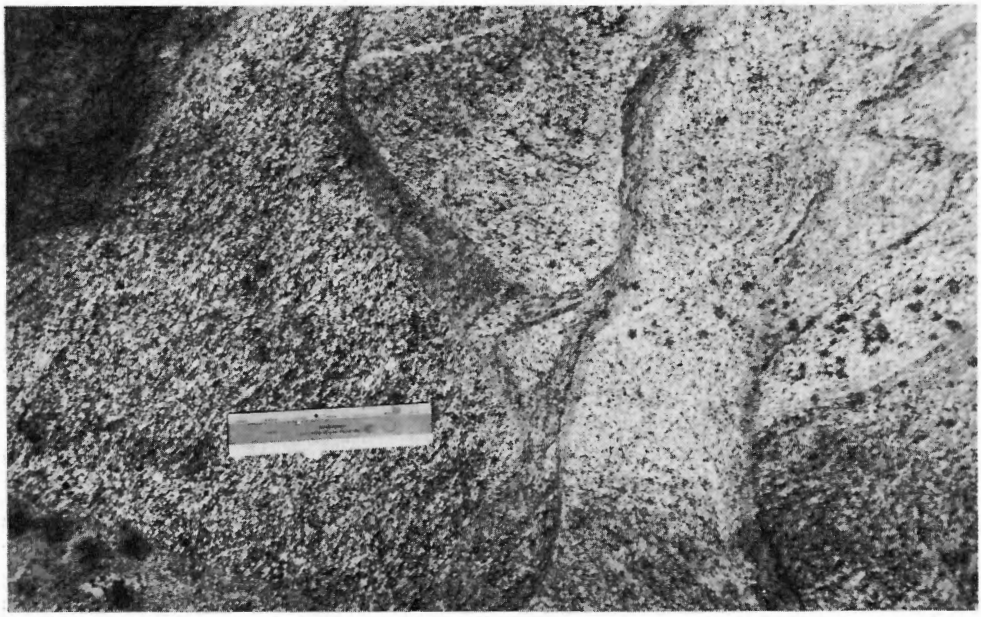
PLATE VI B. Photomicrograph of non-porphyritic phase of the white granodiorite. Large poikilitic grains of potash feldspar enclose, and partly replace, strongly zoned crystals of plagioclase. (x7—crossed nicols)



111068

A. Outcrop showing crosscutting relations between five distinct phases of the batholithic rocks.

PLATE VII



111073

B. Rheomorphic breccia in which the previously foliated blocks have been rotated relative to one another and a secondary foliation has developed in the mobilized matrix.

PLATE VIII. Wesach Mountain from Maroon Mountain. Most of the light coloured lenses are porphyritic dykes and sills cutting strata of the Bowser Group, which underlie the mountain.

110796

A. Main pool, hot springs at Lakelse.

PLATE IX

B. River gravels at Kitimat. This material was washed, screened, sized, and crushed for use in cement and fill during construction at Kitimat.

110794

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