CANADA

DEPARTMENT OF MINES AND RESOURCES

MINES AND GEOLOGY BRANCH

GEOLOGICAL SURVEY BULLETIN
No. 5

GEOLOGY AND MINERAL DEPOSITS OF NORTHERN BRITISH COLUMBIA WEST OF THE ROCKY MOUNTAINS

BY
J. E. Armstrong

OTTAWA
EDMOND CLOUTIER
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
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PREFACE

North of the fifty-third parallel and west of the Rocky Mountains, British Columbia embraces a metalliferous region of some 130,000 square miles, much of which is essentially unprospected and its geology unknown in any but the most general terms. Much of it is difficult of access, far from main transportation routes, and virtually uninhabited. And yet in its comparatively brief recorded history a rather astonishing amount of information has accumulated on its better known parts, due in the main to activities connected with mining, prospecting, and geological exploration.

In the present bulletin the author has endeavoured to assemble and correlate the more salient features of the geology, mineral occurrences, and mining history of this broad region, based on several consecutive years of field work and also on the numerous published accounts that have appeared in the past 70 years. An extensive bibliography and accompanying index of geological maps should prove of special interest to those who wish further details on specific parts of the region.

GEORGE HANSON,
Chief Geologist, Geological Survey

OTTAWA, December 4, 1945

GEOLOGY AND MINERAL DEPOSITS OF NORTHERN BRITISH COLUMBIA WEST OF THE ROCKY MOUNTAINS

INTRODUCTION

The part of British Columbia under consideration lies west of the Rocky Mountains, north of latitude 53 degrees, and covers about 130,000 square miles. The Canadian National Railway traverses the southern part of this region and much of the area lying between latitudes 53 and 56 degrees is readily accessible from the railway by roads and trails. Farther north communications are maintained by aeroplane or by long and arduous trips by river-boat and pack-horse.

In this report the writer has attempted to correlate and summarize the geological information on northern British Columbia west of the Rocky Mountains, both published and unpublished, gathered by members of the Geological Survey during the past 70 years. He has also made extensive use of the annual and other reports of the British Columbia Department of Mines.

The first field work in northern British Columbia was carried out by A. R. C. Selwyn of the Geological Survey in 1875 (Selwyn, 1877)[1]. He examined the country along a route between Quesnel and Peace River by way of Prince George, Fort St. James, and Fort McLeod. In 1875 and 1876 G. M. Dawson made a geological reconnaissance in the basins of Blackwater, Salmon, and Nechako Rivers, and on François Lake (Dawson, 1877 and 1878a). The geology and the resources of Queen Charlotte Islands were investigated by Dawson in 1878 (Dawson, 1880), and in 1879 he made a long trip from Port Simpson, near Prince Rupert, to Edmonton, Alberta, by way of Skeena River, Babine trail, Babine and Stuart Lakes, Fort McLeod trail, Parsnip River, Pine Pass, and Peace River (Dawson, 1881). Amos Bowman studied the geology and placer deposits of the Cariboo placer district in 1885 and 1886 (Bowman, 1889). The bedrock geology along Stikine River to Telegraph Creek, along the trail from Telegraph Creek to Dease Lake, and along Dease Lake and River was studied by Dawson in 1887 (Dawson, 1889a). In 1893 R. G. McConnell made a geological reconnaissance of the territory drained by Finlay and Omineca Rivers (McConnell, 1896). J. C. Gwillim investigated the bedrock geology and mineral resources of the Atlin mining district in 1899 and 1900 (Gwillim, 1902b).

Since 1906 one or more Geological Survey field parties have operated in this northern region each year, the scale of the separate investigations depending on the purposes to be served. Altogether between 30,000 and 35,000 square miles, or one-quarter of northern British Columbia west of the Rocky Mountains, has been mapped geologically, and according to modern standards on a scale of 1 inch to 1 or 4 miles. In addition, large areas have been covered by geological reconnaissance (*See* Figure 5).

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[1]Authors' names and dates of publication refer to Bibliography at end of this report.

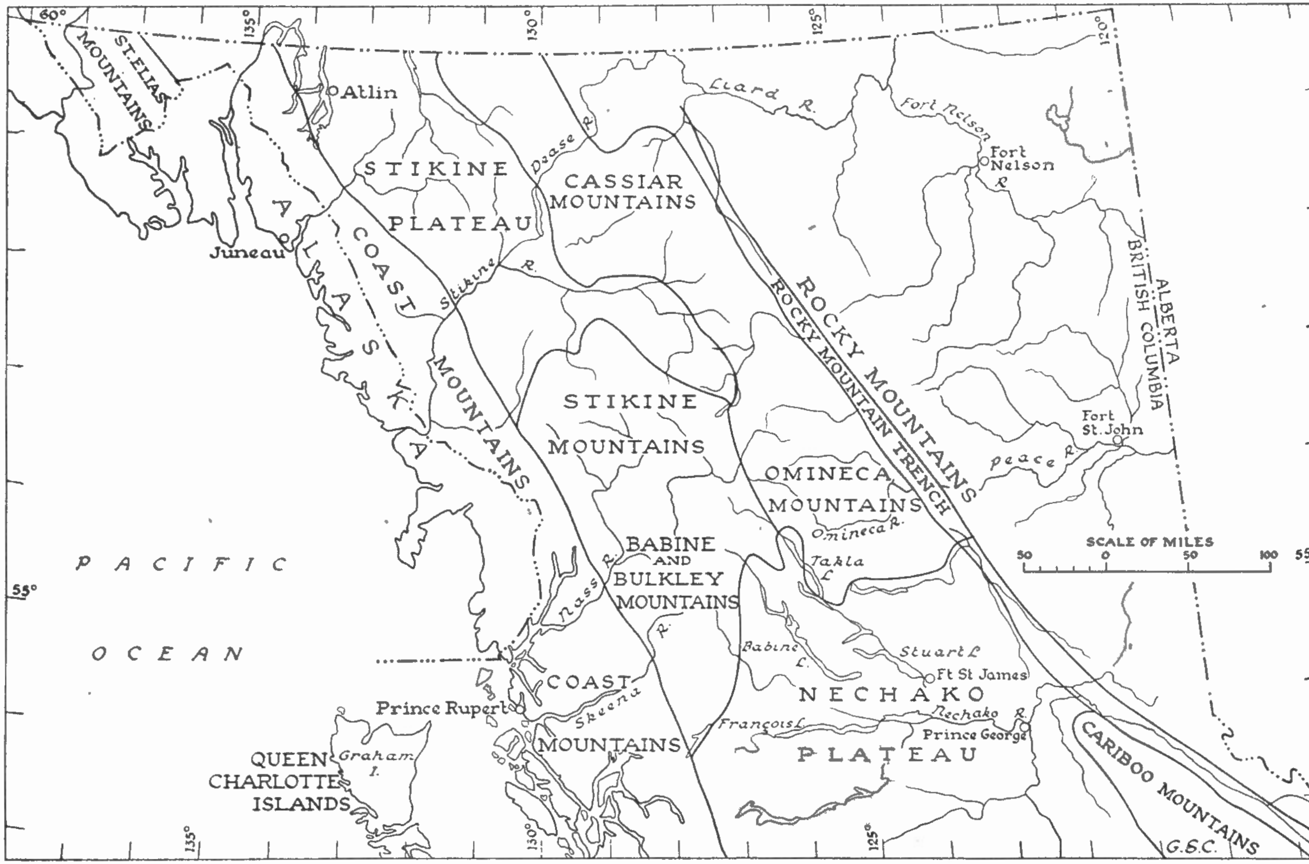

Figure 1. Physiographic divisions of northern British Columbia west of the Rocky Mountains.

PHYSIOGRAPHY

The region under consideration lies wholly within the western Cordillera, and for convenience in description may be divided into the following physiographic parts (Figure 1): Omineca and Cassiar Mountains; Coast Mountains; Nechako Plateau; Cariboo Mountains; Stikine, Babine, and Bulkley Mountains; Stikine Plateau; St. Elias Mountains; and Queen Charlotte Islands.

Omineca and Cassiar Mountains constitute a continuous, northwesterly trending belt, extending from Nation River 400 miles north to Yukon, and lying 50 to 75 miles west of the Rocky Mountain Trench. The Omineca-Cassiar granitic batholith forms the core of these mountains, but the belt comprises a great number of ranges, most of them less than 1,000 square miles in area, separated from one another by wide transverse and lateral valleys several thousand feet deep. Individual peaks and ridges may rise to elevations of from 6,000 to 8,000 feet above sea-level, but in any one range a uniformity of summits is normally found. The ranges show considerable variation in ruggedness; some are composed of ridges with relatively smooth crest lines, whereas others are mainly a series of pinnacle-like peaks. This variation is due largely to the underlying bedrock, the more rugged ranges being composed of granitic and volcanic rocks and the smoother ranges of sedimentary strata.

The Coast Mountains occupy a belt about 100 miles wide bordering the Pacific Ocean, and extend from Fraser River, a few miles north of the forty-ninth parallel, 1,000 miles northwest into the Yukon. These mountains are composed of closely set, high, rugged areas separated by numerous, deep, U-shaped river valleys and fiords that carry the drainage from the eastern slopes westward to the sea. In general the Coast Mountains of northern British Columbia are characterized by great ruggedness; long steep slopes, in many places almost vertical, rise to sharp, needle-like peaks and sawtooth ridges. The average elevation of the summits along the main axis of the system varies from 7,000 to 10,000 feet above sea-level. West of the main axis, along the Pacific Coast, the mountains rise abruptly from an intricate system of fiords and straits to rounded, forested peaks, 4,000 to 5,000 feet high. F. A. Kerr (1936b, pp. 140, 141) states that in northern British Columbia the Coast Mountains east of the main axis are divided by a great synclinal valley trending roughly parallel with the axis. In places the valley is deep and crooked, with peaks on either side rising as much as 9,000 feet above it; in other places it is bordered by rounded mountains 4,000 to 5,000 feet high. The great Coast Range batholith forms the backbone of the Coast Mountains.

Nechako Plateau extends from the Coast Mountains approximately 200 miles east to the Rocky Mountains, and north from latitude 53 degrees for about 150 miles, and occupies some 30,000 square miles. Within it is the Nechako Plain, a lowland area of about 5,000 square miles, lying east of Fort St. James and north of Prince George. This plain consists of wide stretches of comparatively level land at a general elevation of about 2,300 feet above sea-level. An occasional hill or ridge, composed mainly of gravel, rises a few hundred feet above this level. The river valleys are entrenched from 50 to 400 feet, and are bordered by terraces that step up to the plain surface. Most of Nechako Plateau, however, consists of rolling, hilly country; the average relief is from 1,500 to 2,500 feet, with an occasional peak such as Nadina Mountain rising to 4,000 feet above the adjacent valleys. The valleys of the main rivers are wide, with fairly flat bottoms and an average elevation above sea-level of 2,000 to 2,800 feet. The border between Nechako Plateau and the surrounding mountains is drawn arbitrarily and at most places is transitional. A few small mountain ranges have been included in the plateau.

Cariboo Mountains lie within the big bend of Fraser River. They are deeply dissected, the peaks rising 5,000 to 8,000 feet above the valley bottoms, the highest reaching elevations of more than 11,000 feet above sea-level.

Babine, Bulkley, and Stikine Mountains comprise a group of ranges occupying an area of more than 20,000 square miles, bounded on the east by the Omineca-Cassiar Mountains, on the south by Nechako Plateau, on the west by the Coast Mountains, and on the north by Stikine Plateau. Bulkley and Babine Mountains form the southern part of this group, the former lying east of the great Bulkley-Upper Skeena Valley and the latter west of the same valley. These mountains merge with the Nechako Plateau on the south. The Bulkley Mountains merge with the Coast Mountains on the southwest, but toward the northwest the two are separated by Zymoetz River Valley. Both the Bulkley and Babine Mountains are comprised of many individual mountains or mountain groups isolated from one another by wide, low areas or great valleys. Most of the peaks are highly dissected, and some stand more than 7,500 feet above the valleys.

Stikine Mountains lie to the north of Bulkley and Babine Mountains and consist of many closely spaced but distinct ranges separated by a network of valleys. The main valleys and ranges trend northwesterly. The higher peaks of most of the ranges reach elevations of 8,000 feet, and present a skyline of rugged peaks showing a general uniformity of elevations in each range.

Stikine Plateau comprises a great area of plateaus drained largely by Stikine River. It is bounded on three sides by mountains, and extends northwestward to join with Yukon Plateau. The southeastern part lies between the Omineca-Cassiar Mountains on the northeast and Stikine Mountains on the southwest, and consists of an area of high tablelands, mostly above timberline, which is at about 5,000 feet. This tableland area is gently undulating, and is dissected by deep, U-shaped valleys. The main Stikine Plateau is divided into several parts by the larger stream and river valleys, each part forming a smaller plateau. These consist mainly of upland surfaces with an average elevation of 4,000 feet and an average relief of only a few hundred feet. From the plateau surfaces a few mountains rise to elevations of 6,500 feet. Flat-lying Tertiary lavas underlie much of Stikine Plateau.

St. Elias Mountains, in the northwest corner of British Columbia, southwestern Yukon, and southeastern Alaska, contain some of the highest peaks on the continent, Mount Logan, in Canada, reaching an elevation of 19,850 feet, and several others exceeding 15,000 feet. Much of this mountain area is covered by an ice-field.

Graham Island of the Queen Charlotte group consists of the Queen Charlotte Mountains in the western half, a plateau area in the south-central part of the island, and a lowland in the east and north. Queen Charlotte Mountains are formed mainly of serrated and cuesta-shaped peaks, 2,000 to 3,500 feet above sea-level. The plateau area is from 1,000 to 1,500 feet high. The lowland area is a low, gently undulating plain, with no elevations exceeding 400 feet.

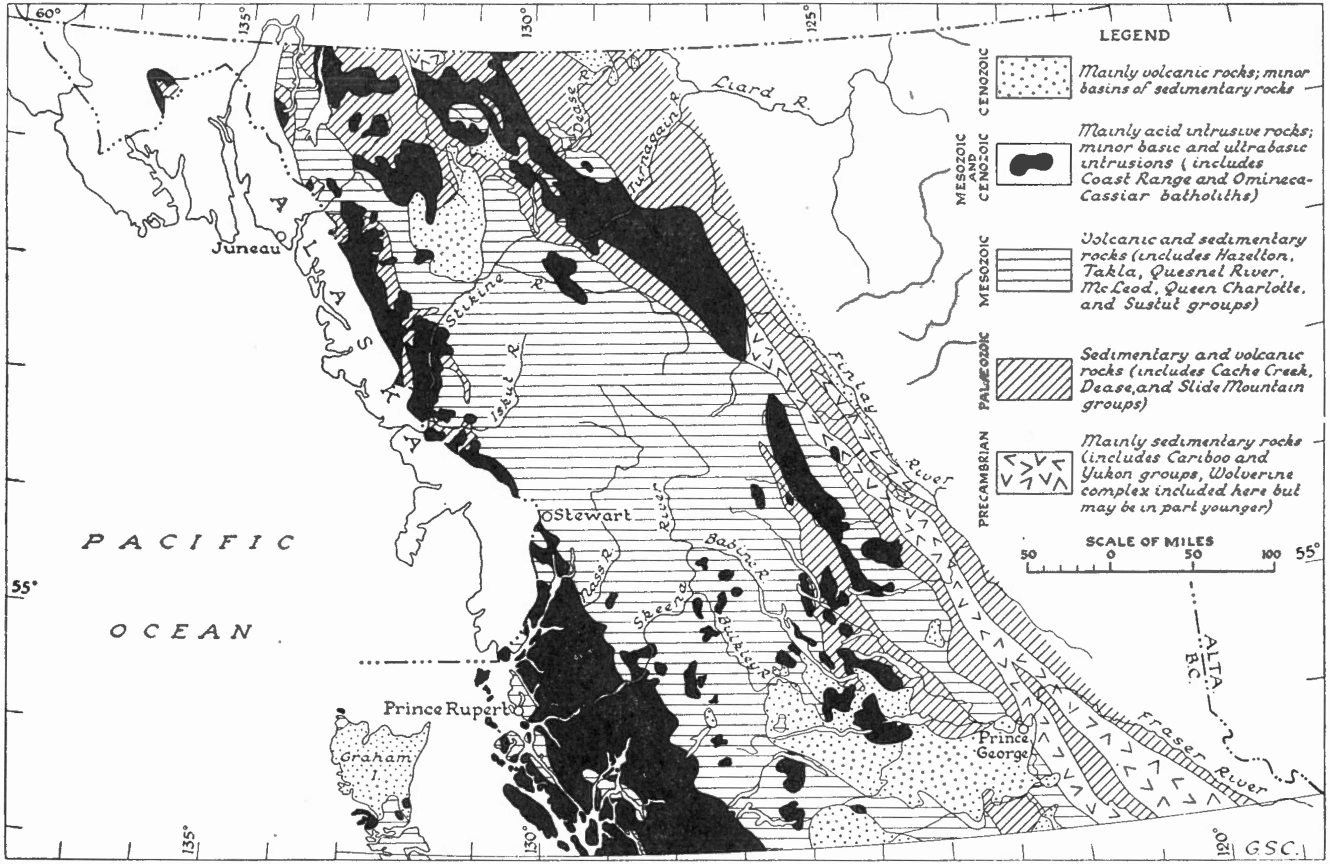

Figure 2. Geology of northern British Columbia west of the Rocky Mountains.

GENERAL GEOLOGY

Precambrian

The oldest known rocks of northern British Columbia are presumably of Late Precambrian (Proterozoic) age. They are predominantly sedimentary rocks and include a maximum thickness of 20,000 to 25,000 feet of quartzite, argillite, and limestone, and derived schists and gneisses. These rocks are exposed in several localities along and west of the Rocky Mountain Trench from Cariboo district to Yukon (Figure 2). North of the Cariboo they are known only through a few reconnaissance surveys, and further work may uncover much larger areas.

In Cariboo district the Precambrian rocks form the Cariboo group and are divided into three conformable sedimentary formations, Richfield at the base, Barkerville, and Pleasant Valley at the top. The series consists mainly of quartzite, limestone, and argillite, with minor amounts of volcanic rocks and schists. The strata are folded into synclines and anticlines that plunge north to disappear beneath younger formations south of Fraser River. The gold-quartz veins of Barkerville area occur in the upper part of the Richfield formation. The Cariboo group is overlain with apparent conformity in one known locality by quartzite and limestone of Lower Cambrian age (Lang, 1938b, p. 14). Unconformably overlying the Cariboo strata is the Slide Mountain series of Upper Palæozoic age (Hanson, 1935b, p. 2).

Northwest of the Cariboo district rocks of the Wolverine complex outcrop along Finlay and Parsnip Rivers. In the area lying between Omineca and Mesilinka Rivers they consist of at least 12,000 feet of quartz-mica schist and micaceous and feldspathic quartzites overlain, possibly unconformably, by 10,000 feet or more of phyllite, slate, quartzite, limestone, and chloritic schist. A ruby-silver gold deposit occurs in quartz-mica schist on Jimmay Creek, 15 miles northeast of Uslika Lake. Quartzite, quartz-mica schist, and limestone predominate near Ingenika and Finlay Rivers. One belt of mainly limestone, several miles wide, extends from south of Osilinka River northwest to Ingenika River and at least 20 miles beyond. Large veins of siderite occur in this limestone, and in a few places, such as at the Ferguson property, silver-lead-zinc deposits have been found in it. South of Omineca River, in Wolverine Range, and immediately north of Mesilinka River the Wolverine complex consists mainly of granitoid gneiss and feldspathic quartzite intruded by abundant pegmatite dykes and sills and small stocks of granodiorite. The rocks of the Wolverine complex have been regarded as Precambrian because of their appearance of great age, and have been compared with the Shuswap complex of southern British Columbia (McConnell, 1896, p. 33; Dolmage, 1927, p. 25). Recent field work (Armstrong and Thurber, 1945a, p. 5) indicates that this appearance has resulted mainly from metamorphism and granitization, and is independent of the age of the formations involved. However, the Wolverine complex may contain Precambrian formations as it lies unconformably below rocks of Permian age (Cache Creek group) outcropping north of Osilinka River. Also, the main area of the Wolverine complex lies along a northwestern projection of the belt of late Precambrian rocks of the Cariboo district.

The only other area of presumably Precambrian rocks in northern British Columbia is near Atlin Lake. There the formations consist of micaceous and chloritic schists, crystalline limestone, and granitic and hornblendic gneisses, and have been correlated with the Yukon group of late Precambrian age (Geological Survey, Canada, 1930). Similar rocks near Teslin Lake and east of Teslin Lake along the Alaska Highway are considered to contain at least some formations of Cambrian or later Palæozoic age.

The Precambrian beds were laid down in a sea that at its maximum probably extended from beneath the Rocky Mountains for an unknown distance west beyond the present limit of exposures, and north from the Cariboo district into Yukon. This conclusion is based on the assumption that some of the formations contained in the Wolverine complex and Yukon group are definitely of Precambrian age.

Palæozoic

The oldest Palæozoic rocks in northern British Columbia are found in the Cariboo district, and are of Lower Cambrian age. They consist of quartzite and limestone, contain fossil trilobites, and overlie with apparent conformity the Cariboo group of presumably Precambrian age (Lang, 1938, p. 14).

Ordovician and Silurian fossils have been found in sedimentary formations outcropping in the Dease Lake - Stikine River region and near Liard River (Figure 2). Elsewhere in northern British Columbia there are no recorded discoveries of pre-Carboniferous fossils. Sedimentary and volcanic strata of Permian age and others of possibly Carboniferous age occur, apparently, in an almost unbroken, northwesterly trending belt extending from the Cariboo district to Yukon (Figure 2). East of the Coast Range and between the Yukon boundary and Omineca River is a large, relatively unexplored region that may be underlain in part by pre-Carboniferous, Palæozoic strata. Apparently, however, the area extending south of Omineca River to the Cariboo district and from the Rocky Mountain Trench to the Coast Range was a landmass during most of Middle Cambrian to Carboniferous time.

In the Dease Lake-Stikine River region both upper and lower Palæozoic formations are included in the Dease group, which consists of 15,000 feet of limestone, argillite, quartzite, and chert, with minor greenstone and schists. The age of the entire group has not been established. It contains fossils of Permian age and also of probable Silurian age (Kerr, 1926, p. 81; Hanson and McNaughton, 1936, p. 5). Several thousand feet of sedimentary rocks lie beneath the fossiliferous Silurian beds, so it would seem that much of Palæozoic time is represented by the Dease group. Graptolitic black shales of Ordovician age were found by Dawson on lower Dease River in rocks lithologically similar to those of the Dease group (Dawson, 1889a, p. 93).

Elsewhere in northern British Columbia Permian and, presumably, Carboniferous rocks are abundant in the Atlin-Teslin Lakes region, in the Takla-Stuart Lakes area, and in the Cariboo district. They comprise 10,000 feet or more of limestone, chert, argillite, greenstone, and derived schists, and have been correlated with the Cache Creek group of southern British Columbia. The Cache Creek group has recently been redefined as a very thick assemblage of interbedded sedimentary and volcanic rocks, mainly of Permian age, but also probably in part of Pennsylvanian age (Armstrong and Thurber, 1945a, p. 7). Foraminiferal limestones and ribbon cherts are characteristic of the group. The Slide Mountain group of Cariboo district although lithologically similar to the typical Cache Creek group may be in part older. This group has been divided into three members: the Guyet conglomerate at the base; the Greenberry limestone; and, at the top, the Antler argillite and chert. Fossils of probable Mississippian age were collected from the Greenberry formation (Johnston and Uglow, 1926, p. 21). The collections, however, were unsatisfactory, and it is quite possible that the fauna is post-Mississippian in age.

In Atlin district the Permo-Carboniferous formations include the Braeburn limestone, Taku chert and argillite, and Mount Stevens greenstone and amphibolite.

No fossils later than Middle Permian age have been identified in any Upper Palæozoic formation. However, at most places the Middle Permian strata are overlain conformably by thick accumulations of volcanic flows, breccias, agglomerates, and tuffs, indicating that the close of the Palæozoic era was characterized by volcanic activity. This volcanic activity was accompanied or followed by a period of uplift and erosion extending, apparently, to Upper Triassic time. In many places Upper Triassic and younger strata are composed in large part of material derived from Permian rocks.

Mesozoic

Fossiliferous strata of Lower and Middle Triassic age are not known in northern British Columbia west of the Rocky Mountains, although these periods may be represented in places by volcanic rocks. Upper Triassic to Lower Cretaceous rocks, however, occur throughout the region, and underlie the larger part of the area between the Coast Range and Omineca-Cassiar batholiths (*See* Figure 2). Marine sedimentary rocks, including limestone, predominate in Upper Triassic sections; continental and marine strata alternate throughout the Jurassic; and continental sedimentary rocks comprise most of the presumably Lower Cretaceous beds, indicating an overall change from marine conditions in Upper Triassic to continental conditions in Lower Cretaceous time. Coal seams occur in sections of Jurassic and Lower Cretaceous rocks, but predominate in those of Lower Cretaceous age. Local accumulations of volcanic rocks occur throughout Upper Triassic to Lower Cretaceous time, and in many places comprise most of the formations. Upper Cretaceous rocks occur in a few, widely scattered localities. They are mainly continental sedimentary rocks and appear to have formed in local basins of sedimentation.

Upper Triassic rocks are most extensive in Dease Lake and Stikine River areas. In Dease Lake area they consist of limestone and, probably, volcanic rocks. Hanson and McNaughton (1936, pp. 6, 7) mapped the Upper Triassic beds with the Dease group of Permian and earlier age, stating that the Triassic rocks could not be distinguished lithologically from older strata. The Upper Triassic section in Stikine River area consists of interbedded limestone, argilite, greywacke, conglomerate, tuff, breccia, and andesite.

Upper Triassic rocks have been mapped with others of Jurassic age in Manson and Takla areas, and form part of the Takla group (Armstrong and Thurber, 1945a, p. 8). This group consists of interbedded volcanic and lesser sedimentary rocks, ranging in age from Upper Triassic to Upper Jurassic. In Manson Creek and Takla map-areas there is little evidence of orogenic disturbance or of an erosional interval between Triassic and Jurassic time. However, to the north, in Aiken Lake area, a conglomerate zone, several thousand feet thick near the middle of the Takla group, indicates a period of uplift, intrusion and erosion. The Triassic rocks are characterized by the occurrence of limestone in quantity, a feature not noticeable in succeeding Mesozoic or Tertiary formations.

Jurassic and, presumably, Lower Cretaceous strata form the Hazelton group of central British Columbia, the Quesnel River group of Cariboo district, the McLeod group of Dease Lake - Stikine River region, the Laberge group and "Older Volcanics" of the Atlin area, and the Vancouver group of Queen Charlotte Islands. The Hazelton group is widespread from Portland Canal to Prince George, and comprises a conformable succession, possibly 10,000 feet thick, of interbedded greywacke, argillite, conglomerate, tuff, breccia, andesite, and basalt. In most places the volcanic rocks occur as lens-shaped masses up to many miles long and thousands of feet thick that are roughly conformable with overlying and underlying sedimentary rocks.

On the basis of contained fossil shells and plants the rocks of the Hazelton group range in age from pre-Middle Jurassic to Lower Cretaceous, and include what have been called Hazelton group and Skeena formation or series (Armstrong, 1944b). The shell collections that have been identified are from beds of two ages: (1) Middle Jurassic, and (2) Upper Jurassic or possibly very early Lower Cretaceous. No fossil plants have been found in the Middle Jurassic beds, which are mainly marine; however, plants have been collected from many localities in the younger beds, which consist of interbedded continental and marine strata. The plants represent two distinct flora, correlated provisionally with the Kootenay and Lower Blairmore of Alberta, and are, presumably, of Lower Cretaceous age. However, marine shells of Upper Jurassic or, possibly, very early Lower Cretaceous age were collected on Hudson Bay Mountain from a bed 300 feet stratigraphically above coal measures containing fossil plants identified as of Lower Blairmore age, so that, until further palæontological investigations have been made, it is not possible to indicate how much of the Hazelton group is Lower Cretaceous.

The Hazelton group has been subdivided in places, but over much of its outcrop area it contains few fossils of diagnostic value, and the limits of the group are not known. Coal is associated with continental strata of the Hazelton group in many localities. These continental coal-bearing members of the group were originally thought to comprise the Skeena formation or series and to overlie the Hazelton group conformably, according to some geologists (Leach, 1911, p. 94), or unconformably, according to others (Hanson, 1926, p. 108). However, later studies in the type area have indicated that no satisfactory stratigraphic division can be made, and that continental strata comparable with the Skeena appear at various horizons in the Hazelton group (Armstrong, 1944c). Fossil plants collected from the coal beds in Hazelton-Smithers area are all of Lower Blairmore age. The Groundhog coal measures contain flora of Kootenay and Lower Blairmore ages (Malloch, 1914a, p. 86).

Bitter Creek, Nass, Kitsault River, and Goose Bay formations are parts of the Hazelton group in the Portland Canal area. Near the Coast Range and Omineca batholiths the Hazelton group rocks are much metamorphosed and sheared. The Premier and Hidden Creek (Anyox) orebodies and hundreds of smaller mineral deposits occur in Hazelton group rocks near these batholiths.

The Quesnel River and McLeod groups bear a general resemblance to the Hazelton group and the Polaris-Taku orebody occurs in rocks of the McLeod group.

In the Atlin area interbedded greywacke, arkose, shale, argillite, and tuff of Jurassic age form the Laberge group, and andesite, basalt, and related tuff and breccia of Jurassic age are called "Older Volcanics".

The Tantalus conglomerate, sandstone, shale, and coal seams of presumably Lower Cretaceous age overlie the Laberge group conformably.

The Vancouver group of Queen Charlotte Islands includes the Maude and Yakoun formations of Jurassic age, and is composed of argillite, sandstone, and tuff overlain by basalt and agglomerate. These rocks are overlain unconformably by the Haida formation of the Queen Charlotte group (Mackenzie, 1916b, p. 49). This formation is of late Lower Cretaceous age, and grades upward into the Honna and Skidegate formations of Upper Cretaceous age. These Cretaceous formations consist of both marine and continental strata, the latter containing coal seams. The transition from Lower to Upper Cretaceous has been observed at no other place within the region under present consideration.

Greywacke, shale, and conglomerate of continental origin and containing plants of Upper Cretaceous and Paleocene ages outcrop near Takla, Bear, and Thutade Lakes, and comprise the Sustut group (Armstrong, 1945). Smaller areas of similar strata, and presumably of Upper Cretaceous age, occur in the Houston and Dease-Stikine areas. The Upper Cretaceous may be represented elsewhere by volcanic rocks.

Cenozoic

TERTIARY

The Cretaceous period closed with mountain building, and it is quite probable that during succeeding Tertiary time most of northern British Columbia west of the Rocky Mountains lay above sea-level. Locally, and at various times during the Tertiary, deposits of sandstone, shale, conglomerate, and lignite accumulated in freshwater basins (*See* Figure 2). Vulcanism was widespread in northern British Columbia from Eocene to Pliocene time, and basaltic and andesitic flows several thousand feet thick cover most of the older formations in the central part of the province south of the Canadian National Railway. Volcanic activity has continued until recent time.

Small areas of Paleocene or Upper Cretaceous sedimentary rocks occur at intervals from Vanderhoof to Hazelton, and also in the Rocky Mountain Trench, where they constitute the Sifton formation. At one locality south of Burns Lake they form an interbed in rhyolitic lavas and breccias.

Fossil flora have been collected from Tertiary beds at many localities on the mainland of northern British Columbia, and according to W. A. Bell of the Geological Survey (personal communication) they represent two distinct ages, the earlier probably Paleocene or Lower Eocene, and the later, previously classed as Upper Eocene or Oligocene, now considered to be possibly as late as Upper Oligocene or Miocene.

Most of the Tertiary volcanic rocks in northern British Columbia are younger than the Upper Oligocene-Miocene sedimentary beds and lie unconformably above them, although in a few places Tertiary volcanic and sedimentary strata are interbedded. The great mass of flat-lying basaltic and andesitic lavas in central British Columbia comprises the youngest consolidated rocks of the region, and was probably erupted during Miocene and Pliocene times. Also considered to be of Miocene and Pliocene age are the Masset volcanic formation of Queen Charlotte Islands (Mackenzie, 1916b, pp. 76-79) and the "Newer Volcanics" of the Atlin region (Geol. Surv., Canada, 1930).

The only marine strata of Tertiary age are found on Queen Charlotte

Islands, and comprise the Skonun formation consisting of conglomerate, sandstone, and shale, and containing fossil shells of probable Miocene age (Mackenzie, 1916b, pp. 73-76).

QUATERNARY

During Pleistocene time all of northern British Columbia, except possibly some of the higher peaks, was covered by the Cordilleran ice-sheet, which was at least 5,000 feet thick in places. The ice accumulated in the mountains, particularly the Coast Mountains, and moved out from them in all directions. The Coast Mountains still contain numerous glaciers that may be remnants of the ice-sheet. As a result of ice movement, most of the unconsolidated material that had accumulated during the Tertiary period was redistributed and bedrock was deeply eroded. However, in the Dease, Manson, and Cariboo placer districts stream gravels are found resting on bedrock and are overlain by glacial drift. They are probably in part of late Tertiary age (Johnston, 1926, p. 48) and in part early Pleistocene deposits (Johnston and Uglow, 1926, p. 30). In the Cariboo and Dease districts there was more than one advance and retreat of the ice-sheet, and interglacial deposits were formed during periods of temporary recession (Johnston and Uglow, 1926, p. 29; Johnston, 1926, p. 48). As a result of glaciation, deposits of glacial drift as much as several hundred feet thick are found in most of the existing valleys. The glacial deposits consist of boulder clay, sands, gravels, and silts. In the valley of Slough Creek in the Cariboo borings have shown that the surface deposits are 287 feet thick. White silts of glacial origin mantle an area of more than 1,000 square miles around Prince George. Since the recession of the ice the entire region has risen several hundred feet, so that thick deposits of marine and lake sediments are found above present ocean and lake levels. Existing streams have in most places cut through the glacial deposits into bedrock. Gravels and sands of post-Glacial age occur in many of the existing valleys, in places capping boulder clay.

Some vulcanism has persisted from Tertiary time. Pleistocene and Recent volcanic cones and related flows occur in Stikine River and Portland Canal areas.

Intrusive Rocks

Except for the area immediately west of the Rocky Mountains there is scarcely an explored area in northern British Columbia 25 miles in radius in which intrusive rocks do not occur (*See* Figure 2). They range in age from pre-Carboniferous to Tertiary, and in composition from ultrabasic to acidic, but most of them are Mesozoic granitic rocks. The intrusive bodies vary in size from that of the great Coast Range and Omineca-Cassiar batholiths to small stocks, sills, and dykes. All the metallic mineral deposits of northern British Columbia are believed to have originated from solutions genetically related to the various intrusions.

The oldest intrusions recorded in northern British Columbia are the Proserpine dykes and sills of the Barkerville area. They are quartz-porphyries, felsites, and aplites, and they cut Precambrian rocks but not the overlying, probable Mississippian rocks, indicating that their intrusion was in pre-Mississippian time (Johnston and Uglow, 1926, p. 17). Similar intrusions in the vicinity of Osilinka and Mesilinka Rivers cut rocks of the Wolverine complex of probable Precambrian age, but do not intrude the overlying Permian rocks.

The oldest intrusive bodies of batholithic proportions are exposed near Topley and Burns Lake. They are coarse-grained, pink, foliated granites that have been deeply eroded. They cut Permian strata and are overlain by fossiliferous sedimentary rocks containing flora characteristic of Jurassic time, but which may be Cretaceous (Lang, 1942a). Masses of diorite near Babine Lake have been correlated with the granites. These intrusions may be of Jurassic age or even older, in which case they antedate the bulk of the Coast Range batholithic rocks, which intrude Lower Cretaceous strata of the Hazelton group.

The dominant geological feature of the Coast Range is its great composite batholith and numerous related intrusions. The main mass has a length of more than 1,100 miles, from the northern part of the State of Washington northwestward to Yukon, and a width, in places, of 100 miles; in northern British Columbia it averages 50 miles wide. Related intrusions occur as far east as Smithers and Owen Lake, and as far west as the Queen Charlotte Islands. The rocks of the main batholiths are dominantly granodiorites and quartz diorites. Variations from these types include quartz monzonite, and minor granite, diorite, and gabbro. The central part of the batholith is composed mainly of granodiorite, quartz diorite, and quartz monzonite. Different phases undoubtedly represent intrusions of different ages as they cut one another. Most of the satellitic intrusions are of granodiorite and quartz monzonite, but a few more basic bodies have been recorded. The Premier, Big Missouri, Hidden Creek (Anyox), Dolly Varden, Red Rose, Silver Standard, Duthie, Rocher Déboulé, and Polaris-Taku orebodies, and innumerable smaller mineral deposits, occur in or near the Coast Range batholith and related intrusions.

On Queen Charlotte Islands, intrusive rocks correlated with the Coast Range batholith cut early Upper Jurassic formations and are overlain by others of late Lower Cretaceous age (Mackenzie, 1916b, p. 53). Along the Canadian National Railway from Terrace to Smithers, Jurassic and probable Lower Cretaceous strata of the Hazelton group have been invaded by the batholith and by related intrusions (Kindle, 1937a, p. 6, 1937b, p. 7; Armstrong, 1944b and 1944c). In the Portland Canal area the Coast Range batholith cuts rocks of Jurassic age that have been correlated with the Hazelton group (Hanson, 1935, p. 175). In Stikine River area the Coast Range intrusions cut Upper Jurassic and probable Lower Cretaceous formations and are apparently overlain by Upper Cretaceous strata (Kerr, 1935b). About 200 miles south of Smithers the batholith cuts rocks of late Lower or early Upper Cretaceous age (Dolmage, 1929, p. 85). Near Owen Lake a small granite stock, probably related to the Coast Range intrusions, cuts a sedimentary formation whose age as determined from fossil plants is probably Upper Cretaceous (Lang, 1930, p. 75). It is evident from the above that various phases of the Coast Range batholith and related intrusions range in age from Upper Jurassic to Upper Cretaceous and possibly later, and that a large part was intruded in Lower Cretaceous or later times. Some of the intrusions are regarded as of late Upper Cretaceous or early Tertiary age (Dolmage, 1928, p. 85).

Although only partly explored, the Omineca-Cassiar batholith is believed to be 400 miles long, extending from Manson Creek to north of the Yukon-British Columbia boundary. Wherever studied the main batholith varies in width from 8 to 30 miles. Smaller bodies, which are probably genetically related to the main mass, are numerous along its western margin. Near Manson Creek the batholith is mainly of granodiorite, which grades into diorite and, in places along its borders, into gabbro and pyroxenite. In the Cassiar district the commonest rock type in the batholith is probably granite, but there are other types ranging from granite to gabbro, and the various phases grade into one another. In proportion to its size the Omineca-Cassiar batholith includes more basic rock than the Coast Range batholith. In the Omineca district it is of post-early Upper Jurassic and pre-early Upper Cretaceous age (Armstrong, 1945). A number of mineral deposits associated with the batholith have been discovered, but because of their remoteness none has yet proved commercial.

A number of small basic intrusions occur along the eastern border of the Omineca-Cassiar batholith. They range in composition from peridotite through pyroxenite to gabbro, and in size from small sills to stocks 100 square miles in area. Most of these basic rocks are partly to completely altered to serpentine. Nearly all contain small concentrations of chromite. They are post-Permian in age, and probably represent an early phase of the Cassiar-Omineca batholith.

Small stocks, sills, and dykes of rhyolite and quartz porphyry are found invading probable Upper Oligocene or Lower Miocene rocks along the Prince Rupert line of the Canadian National Railway. A few small mineral deposits have been attributed to them.

STRUCTURAL GEOLOGY

The Precambrian, Palæozoic, and Mesozoic formations of northern British Columbia have a general northwesterly trend, but locally structures are quite irregular. The Coast Range and Omineca-Cassiar batholiths have a northwest elongation roughly parallel with the invaded strata.

As a rule the older rocks in any one district are more deformed and altered than the younger rocks. For example, in the Stuart Lake-Takla Lake region, the Cache Creek rocks of Permian age and the Takla group of Triassic and Jurassic age have been intensely folded and faulted, the average dip exceeding 60 degrees; the Upper Cretaceous rocks have been folded and faulted to a much lesser extent, the average dip being less than 45 degrees; and the late Tertiary (Miocene and Pliocene) volcanic flows are essentially flat-lying. Cache Creek rocks are usually schistose; the Takla group rocks are partly altered, but generally retain their original textures; Upper Cretaceous rocks are unaltered; and the late Tertiary flows appear very fresh. Similar relations between younger and older rocks have been observed in most of the explored part of northern British Columbia. Also, as a general rule, formations near batholiths are more intensely deformed and altered than those farther away. In the Manson Creek area all the pre-batholithic rocks lie near intrusions and have an average dip in excess of 60 degrees, whereas in the Cariboo district no large intrusive bodies are exposed, and the strata generally dip at angles of less than 40 degrees.

The structures in northern British Columbia probably owe their development to several periods of deformation, the more important taking place in pre-Carboniferous, late Jurassic or early Cretaceous, late Cretaceous or early Tertiary, and post-Oligocene time. However, most of the intense deformation probably took place during and after batholithic intrusion in late Jurassic to early Tertiary time.

Major, northwesterly and northerly trending fault zones, 40 miles and more in length, have been mapped in the Stuart Lake-Manson Creek district. The most important of these is the Pinchi fault zone, with an overall length of at least 150 miles. This fault zone follows the eastern border of the Omineca-Cassiar batholith for at least 100 miles, and it is quite probable that the batholith, because of its relative rigidity, acted as a buffer against later regional stresses, thereby localizing the fault zone along the batholith border.

In the Hazelton-Smithers region the main valleys appear to lie along major fault zones (Armstrong, 1944c), and each individual mountain range or massif, as for example Rocher Déboulé Range, which is 250 square miles in area, may represent a fault block. Much of the folding in this region is asymmetrical, and in places overturned folds have developed into overthrust faults. Malloch (1913, p. 87) has described somewhat similar fault and fold structures in the Groundhog coal area.

The above are only a few examples of major faults in northern British Columbia. As geological field work progresses more will be recognized, and more light will be thrown on the undoubtedly complex structures of this great region.

HISTORY OF MINING

The history of the settlement of northern British Columbia is inseparably associated with the development of the mineral wealth of the province.

The first recorded discovery of gold in British Columbia was made in 1851 by Haida Indians from Mitchell Inlet, on the west coast of Moresby Island, Queen Charlotte Islands, and was reported to the Hudson's Bay Company in Victoria. In the following year the Company sent an expedition to Mitchell Inlet, and gold-bearing quartz veins were discovered at Thetis Cove. The first lode-gold mining in the province was carried out on this deposit, and some rich ore was produced from open-cuts on a small shoot. More recently this deposit, known as the Early Bird, has been mined at intervals in a small way.

The first important impetus to mining and to the development of northern British Columbia came with the discovery of extraordinarily rich placer gravels on Lightning and Williams Creeks in the Cariboo district in 1861. By the end of 1862 more than 30,000 miners had poured into these placer fields. With their discovery transportation difficulties were introduced that called for a speedy remedy if supplies adequate for the new camp were to be obtained. As a result the famous Cariboo Road, completed in 1865, was built by the Royal Engineers under Colonel Moody, from Yale to Barkerville.

For the next 10 years a comprehensive search for placer deposits continued throughout northern British Columbia. The Omineca placer field was discovered between 1868 and 1871, and the Cassiar placers between 1872 and 1874. From 1875 to 1898 no important placer or lode discoveries were made and the known placer camps continued to produce at an ever diminishing rate. Lode mining was attempted on the Burns Mountain and Quesnel Quartz properties in the Cariboo, but without success.

Miners on their way to the Klondike placer fields in Yukon found placer gold in the Atlin area in 1898. Except for the Cariboo this field has proved the most productive in British Columbia, and in recent years has been the most promising, fresh discoveries having been made in 1927 and 1937. Lode-gold mining was first attempted in Atlin area in 1900, on the Imperial deposit, but the operation proved unprofitable. The

Engineer mine came into production in 1910 and was operated intermittently to 1934, producing altogether about 17,500 ounces of gold.

The first lode deposits were staked along Portland Canal and in the Bear River district in 1898 by a party of prospectors looking for placer. Staking did not attain great proportions until 1908, when, owing to successful development work by the Portland Canal Mining Company, an influx of prospectors took place. Nearly all available ground in Bear River Valley was staked by 1910, and has since been held or restaked. Production of silver, lead, and zinc, in this area, began in 1908 and continued intermittently to 1932.

In the Anyox district mineral claims were staked in 1898, but it was not until 1914 that mining and smelting began at the principal discovery, the Hidden Creek mine. From 1914 to 1936, when operations ceased, the Hidden Creek and Bonanza mines produced more than 650,000,000 pounds of copper.

Salmon River district was prospected early, but the principal claims of the Premier mine were not staked until 1910, and it was 1917 before the property became a mine of value. From 1918 to 1944 the Premier and adjoining B. C. Silver and Sebakwe mines have produced approximately 1,697,000 ounces of gold, 38,255,000 ounces of silver, and 25,730,000 pounds of lead.

The first discovered deposit of value in the Marmot River district, the Porter Idaho lead-silver mine, was staked in 1919. Between 1924 and 1927 this property yielded 190,200 ounces of silver and 278,400 pounds of lead.

Properties along Alice Arm marketed ore intermittently from 1911 to 1921. The Dolly Varden was the most important of these, producing 1,304,409 ounces of silver from 1918 to 1921.

Although the initial discoveries along the Canadian National Railway between Usk and Vanderhoof were made in the late nineties, it was not until the completion of the railway in 1914 that any production resulted. During the war of 1914-1918 the Rocher Déboulé copper mine and the Silver Standard lead-zinc-silver mine, both near Hazelton, were operated profitably. Since 1918 only two properties have been mined successfully. They are the Duthie, a silver-lead-zinc mine near Smithers, and the Red Rose tungsten mine near Hazelton. The latter came into production in 1942, and was closed in 1943 after a recovery of 1,194,000 pounds of tungsten concentrates.

The Surf and Pugsley mines on Princess Royal Island were operated successfully from 1916 to 1926, and again from 1936 to 1942. The overall production was 385,000 ounces of gold and 6,300,000 pounds of copper. The Surf Point and Edye Pass mines on Porcher Island were intermittent gold-copper producers from 1931 to 1938.

Although several attempts were made prior to 1930, it was not until 1933, when the Cariboo Gold Quartz mine commenced milling, that the Cariboo gained prominence as a lode-gold camp. Island Mountain mine started production the following year. To the close of 1944 these two mines have yielded about 508,000 ounces of gold.

In 1937 the Polaris-Taku mine on Taku Inlet became British Columbia's most northerly producing gold mine. Between 1937 and 1942, when the mine closed due to war conditions, 89,330 ounces of gold were recovered.

The Pinchi Lake mercury mine, and the Bralorne Takla mercury mine, represent the most recent mining developments in northern British Columbia. The deposit at Pinchi Lake was discovered in 1937 by J. G.

Gray, while in the employ of the Geological Survey. From 1940 to 1944, inclusive, Pinchi Lake mercury mine produced more than 4,000,000 pounds of mercury.

Approximate Metal Production in Northern British Columbia to the end of 1944

Lode gold	2,860,000	ounces
Placer gold	2,610,000	"
Silver	51,650,000	"
Copper	663,000,000	pounds
Lead	36,305,000	"
Zinc	4,610,000	"
Mercury	4,150,000	"
Tungsten concentrates	1,194,000	"

ECONOMIC GEOLOGY

Summary of Economic Geology

RELATION OF METALLIFEROUS DEPOSITS TO INTRUSIONS

Most metalliferous deposits are generally considered to have resulted from igneous activity. Many of the deposits of northern British Columbia are in or near intrusive bodies and are believed to have formed from emanations given off by the magmas from which the intrusive rocks crystallized (*See* Figure 4).

A large proportion of the known deposits are related in place, and, presumably, in origin, to the Coast Range composite batholith. The Porcher and Princess Royal Islands' gold-copper veins occupy shear zones in the batholith. The following mines, as well as hundreds of prospects, are situated along the eastern margin of the Coast Range composite batholith: Polaris-Taku, Engineer, and Big Missouri, gold; Premier, gold-silver-lead; Dunwell, silver-lead-zinc; Esperanza, Prosperity, and Porter-Idaho, silver-lead; and Dolly Varden, silver. All of these deposits have probably originated from the same magma as the batholith, but it is by no means certain that all of them formed at the same time, or that they are all related directly to similar lithological phases of the batholith. The phases composing the composite Coast Range batholith probably range in age from late Jurassic or earlier to early Tertiary, and it is quite possible that each period of intrusion had a corresponding period of mineralization. Undoubtedly some of these were more important than others, but as yet sufficient field work has not been done to establish empirical rules.

The Anyox copper deposits are chalcopyrite replacements in amphibolite and argillite. The amphibolite is intrusive into the argillite, and both are believed to be part of the Hazelton group. Intrusive rocks forming part of the Coast Range batholith occur nearby and no doubt underlie the deposits. Hanson (1935a, pp. 44, 45) states that although these may be the source of the deposits, the available evidence suggests that the ore deposits and amphibolite are connected in origin. However, the time of ore deposition may have been as late as the intrusion of the Coast Range batholith, and indeed the amphibolite may be an early phase of the batholith.

Mineralization has occurred in or near most of the small granodiorite bodies outcropping between Hazelton and Owen Lake. The Rocher

Déboulé copper and the Red Rose tungsten orebodies are in a granodiorite stock underlying Rocher Déboulé Mountain. The Silver Standard and Silver Cup silver-lead-zinc mineralization are near small stocks of granodiorite. The Duthie and related silver-lead-zinc deposits on Hudson Bay Mountain are believed to have been derived from a stock underlying the mountain. The Owen Lake gold-silver veins occur in a small stock of diorite. Although mineral deposits in the Driftwood Mountains, on Dome Mountain, and near Topley do not lie near intrusions, they may be and probably are derived from intrusive bodies not yet exposed.

The Omineca-Cassiar batholith and its contact zones are relatively unprospected, and as yet few mineral deposits are known. The Aiken Lake and Uslika Lake gold-copper deposits lie in or near the batholith along its eastern border. They are believed to have been formed from later emanations given off by the magma from which the intrusive rocks crystallized.

Although the sources of the ore-forming solutions of the Pinchi Lake mercury belt and the Manson and Cariboo gold belts are not known, they are probably connected with unexposed, deep-seated intrusions.

RELATION OF METALLIFEROUS DEPOSITS TO STRUCTURE

The major folds and faults of northern British Columbia strike northwesterly and are roughly parallel with the elongation of the Coast Range and Omineca-Cassiar batholiths. This general trend is the broad controlling factor in the distribution of the mineral deposits, many of which lie in northwesterly trending belts along the borders of the major batholiths, or are related to major structures such as the Pinchi and Manson Creek fault zones. Exceptions to this northwest alinement of mineral deposits are particularly noticeable near the smaller intrusive bodies about which the ore deposits are commonly clustered, as, for example, on Rocher Déboulé Mountain.

Most of the metalliferous deposits occurring in or near intrusive bodies owe their position to structural features that permitted circulation of mineralizing solutions. They occur as veins or vein-like replacement bodies occupying shear, fault, or fracture zones. For example, the Princess Royal Island gold-copper deposits occupy shear or fracture zones in granodiorite; the Premier and B. C. Silver gold-silver-lead orebodies lie along fracture and shear zones in porphyry; and the Dolly Varden silver deposits occur along a fault zone in felsite.

The lode-gold deposits of the Barkerville gold belt are an interesting example of structural control. They occur along a northwesterly trending belt, and are concentrated in a much fractured zone in the upper part of the Richfield formation beneath relatively impervious rocks. Mineralizing solutions rising from an underlying source encountered the impervious cap rock, which acted as a dam and forced the solutions to remain in the zone of fractured rocks where the gold-bearing quartz veins were formed along the fractures (Hanson, 1935b, p. 15).

The Pinchi Lake and Bralorne Takla mercury deposits lie along a major fault zone extending from near Fort St. James 150 miles northwest to Omineca River. The orebodies occur in sheared and brecciated limestone or in carbonatized serpentine. In most of the deposits it is apparent that the fault zone provided abundant channelways for the mineralizing solutions. In many places relatively impervious cap rock and fault gouge have acted as traps to rising solutions and have induced local concentrations of cinnabar. Although "trapping" is undoubtedly an important factor in localizing these ores, the relative permeability of the solution channels is of equal or greater importance. The source of the mercury-bearing solutions is probably some deep-seated intrusion.

The gold-quartz veins and the placer deposits of the Manson Creek area lie along a major fault zone, more than 40 miles long (Armstrong and Thurber, 1945a, p. 13). The rocks along this fault zone have been altered hydrothermally to an aggregate of quartz, ankeritic carbonate, chlorite, and mariposite. Most of the placer gold apparently resulted from erosion of these altered rocks and quartz veins along the fault zone. No genetic relationship is apparent between the lode deposits along the fault zone and any nearby volcanic or intrusive rocks. The source of the ore-bearing solutions is probably some deep-seated intrusion. The fault zone provided abundant channelways for mineralizing solutions, and deposition occurred wherever conditions were favourable.

Mineral Deposits

PLACER GOLD

In 1857 placer gold was discovered on lower Fraser and Thompson Rivers. The news of the discovery spread rapidly and by the end of October 1858 some 10,000 miners were working on Fraser River from Fort Langley to Lytton. By 1859 the more adventuresome miners had reached Quesnel, and by 1861 the rich deposits on Williams and Lightning Creeks in the Cariboo district were discovered. In the following year most of the other rich creeks in the Cariboo became known. The first recoveries from Cariboo placers were remarkable; apparently more than $2,000,000 in gold was recovered before the end of 1861. In consequence a second great migration of miners to British Columbia commenced in 1861 and continued undiminished to 1864. The easily worked bonanza deposits of the Cariboo quickly yielded their wealth, and from 1863 a progressive decline in the yearly output ensued. As interest diminished in the Cariboo, prospecting for placer gold spread farther north, and in 1868 the Omineca placer field came into prominence with the discovery of gold on Silver Creek. By 1871 all important creeks in the Omineca field were known. This field has never been particularly rich, and it was practically abandoned in 1872 when placer gold was discovered at the headwaters of Dease River in the Cassiar. There the more important creeks—McDame, Dease, and Thibert—were found by 1874. When the spectacular gold discoveries of 1896 in the Klondike, Yukon, became known, a great horde of miners swarmed into that district. On their way they discovered the rich placer gold of the Atlin area, in 1898. Important discoveries of placer gold since 1900 have been on Squaw Creek, Atlin district, in 1927, and on Wheaton Creek, Cassiar district, in 1937.

Between 1858 and 1944 the placer gold output for British Columbia was in excess of 3,400,000 ounces. The Cariboo, Atlin, Cassiar, and Omineca goldfields are responsible for at least 75 per cent of this yield. The approximate overall production figures are: Cariboo, 1,910,600 ounces; Atlin, 620,000 ounces; Cassiar, 30,000 ounces[1]; and Omineca, 46,000 ounces.[1]

The important placer fields of northern British Columbia lie in the Interior Belt between the Coast and Rocky Mountains, an area of relatively

[1]The production figures for the Cassiar and Omineca goldfields are for the period 1900 to 1944. No earlier records are available.

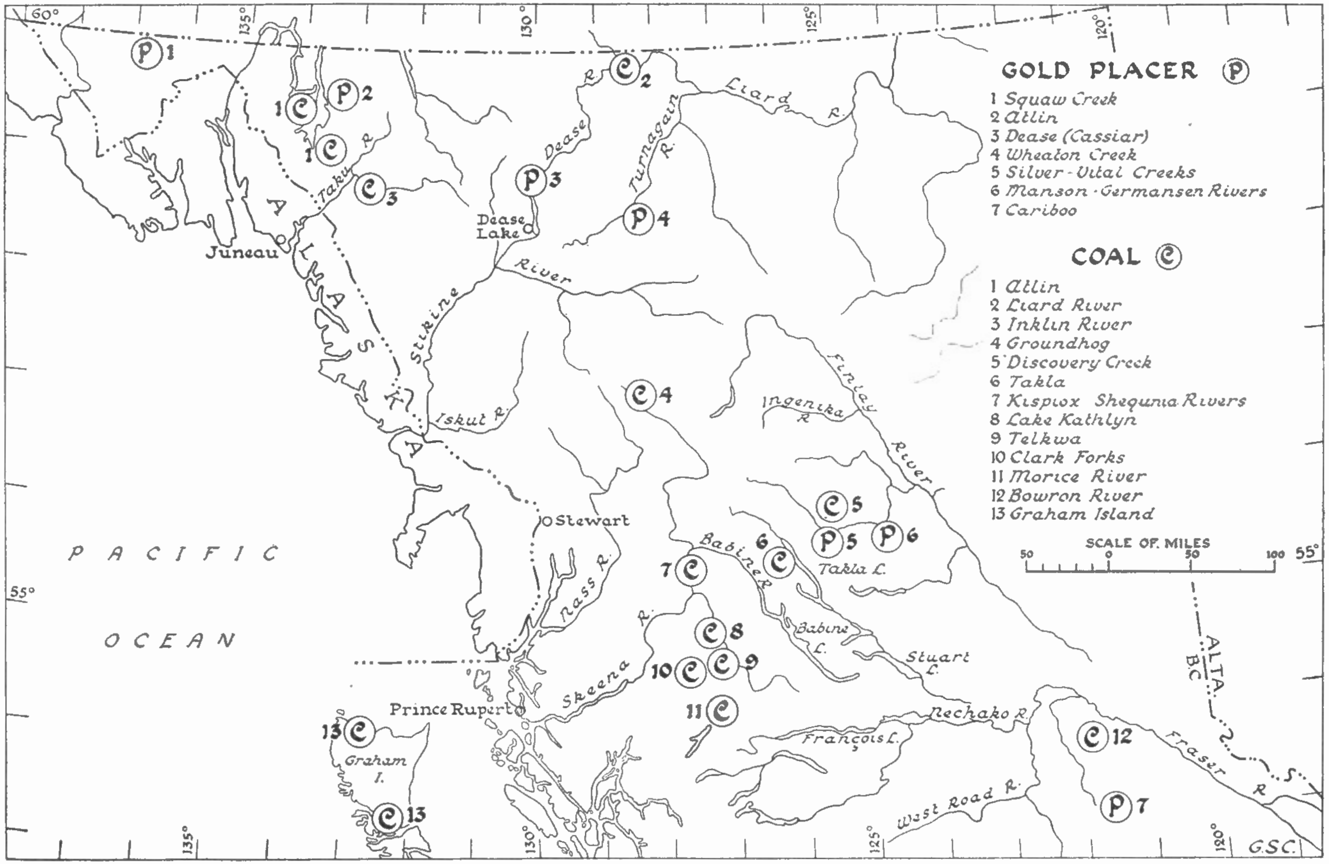

Figure 3. Gold placers and coal fields of northern British Columbia west of the Rocky Mountains.

low relief (*See* Figure 3). Bedrock in the placer fields varies greatly in composition and age, but in most of the placer areas contains numerous quartz veins mineralized with sulphides and free gold. The quartz veins formed during periods of batholithic intrusion in Mesozoic and early Tertiary time. This mineralization was followed by long periods of erosion in later Tertiary time, at the close of which many rich and continuous placer deposits probably existed in northern British Columbia. With the advent of glaciation most of such deposits were either obliterated or became so mixed with barren glacial debris as to have little or no economic value. Here and there, however, placer gravels escaped the action of the ice and remnants of original Tertiary placer deposits remain. Elsewhere, placer deposits have been formed mainly as a result of inter-glacial and post-glacial streams cutting through the glacial debris and eroding the bedrock.

Johnston and Uglow (1926, pp. 50-52) state that the gold placers or pay-streaks in the Cariboo district occur in four different ways. (1) In ancient stream gravels resting on bedrock and in many cases buried beneath glacial drift. These placers are by far the most important in the area. The pay-streaks on bedrock are best in the narrow, deep parts of the creeks, and do not occur to any great extent in the wider, upper parts near the sources, where valley glaciation has been pronounced, nor are they rich in the wide, deeply buried lower parts of the creeks. The pay gravels, in part at least, were deposited in Tertiary time, but were reworked, to some extent, by stream action in Pleistocene time. (2) In pay-streaks that occur in places in gravels on bedrock benches at various heights above the present creeks, and in a few places in abandoned or partly abandoned stream channels high above these creeks. The rock benches were formed in pre-glacial or, possibly, in inter-glacial time, and some of the gold on the benches may be pre-glacial. (3) At several places in inter-glacial pay-streaks, that is, in pay gravels overlain and underlain by glacial drift. It is evident that the gold in them was mostly derived from glacial drift, and only in small part from bedrock. (4) In places in irregular masses of gravel included in glacial drift, and to some extent in glacial gravels filling stream valleys. No important deposits are represented by this class.

In the Dease (Cassiar) area the placer gold occurs in three ways (Johnston, 1926, pp. 48, 49). (1) In gravels resting on bedrock in old high-level channels of Dease and Thibert Creeks. Most of these deposits lie beneath glacial drift, and are probably pre-glacial (late Tertiary) in age. (2) In glacial and inter-glacial gravels that partly filled the old stream channels and present valleys. As a rule the gold is scattered through these gravels and is only slightly concentrated into pay-streaks. (3) In post-glacial or surface gravels in the beds and on low benches of the present streams. These gravels were rich in places below where old, gold-bearing channels had been cut away by the present streams. A similar threefold classification of the placer deposits could be made for Omineca and Atlin districts.

It is evident that many of the rich placer pay-streaks in northern British Columbia rest on bedrock beneath glacial debris. The preservation of these old stream gravels is remarkable when the effects of glaciation are considered. They commonly lie in narrow valleys, normally V-shaped, that presumably lay across the course of ice erosion. In these valleys the glaciers must have been stagnant, and upon melting deposited their load of debris upon the placer gravels, thus ensuring their preservation.

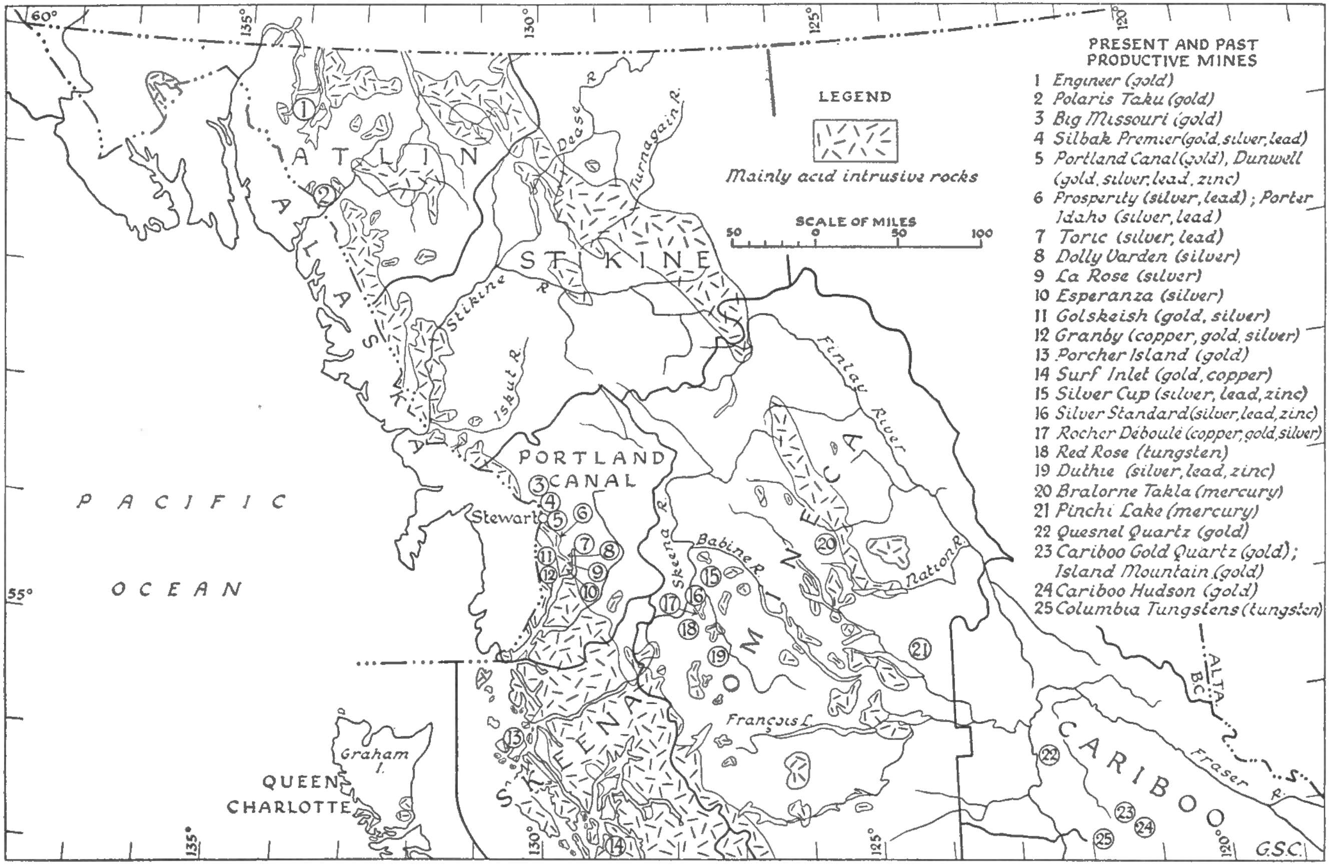

Figure 4. Productive mines of northern British Columbia west of the Rocky Mountains. Boundaries of mining divisions as of 1939.

LODE GOLD

More than three hundred lode-gold deposits are known in northern British Columbia west of the Rocky Mountains. Commercial production has been obtained from seventeen of these, and small shipments of high-grade ore have been made from at least fifteen others (Figure 4). Much exploratory work has been done on many of the remainder, some of which should eventually reach production. The approximate output of the productive mines is recorded in the following table:

Name of mine	Period	Production		
		Gold	Silver	Miscellaneous
Atlin Mining Division		Ounces	Ounces	
Engineer	1910-1933	17,450		
Polaris-Taku	1937-1942	89,330	4,990	
Cariboo Mining Division				
Cariboo Gold Quartz	1933-1944	331,600	27,600	
Island Mountain	1934-1944	176,250	26,520	
Quesnelle Quartz	1938-1939	185?		
Cariboo Hudson	1938-1939	5,185	2,625	
Burns Mountain Gold Quartz	1878-1881?	1,000?	....	
Portland Canal Mining Division				
Silbak-Premier Gold Mines, Ltd. (Premier, B. C. Silver, Sebakwe)	1918-1944	1,696,830	38,255,220	25,731,160 lbs. lead
Golskeish	1919-1930	4,700	25,000	
Big Missouri (Buena Vista)	1938-1942	58,350	43,010	
Portland Canal	1907-1911	2,000	tons concentrates	
Queen Charlotte Mining Division				
Early Bird	1851-1852?	1,000?		
Skeena Mining Division				
Porcher Island Mines, Ltd. (Surf Point, Edye Pass)	1931-1938	19,870	6,940	19,000 lbs. copper
Surf Inlet Con. Mines, Ltd. (Princess Royal Island, Surf, Pugsley)	1916-1926	385,200	199,950	6,294,750 lbs. copper

Atlin and Stikine Mining Divisions

Approximately forty lode-gold prospects have been staked in this region. Two of them, the Engineer, near Atlin, and the Polaris-Taku, on Taku River, were developed into producing mines. The Engineer has produced intermittently, commencing in 1910 and continuing to 1933. The Polaris-Taku started milling in 1937, and ceased production in 1942 owing to war conditions.

The ores at the Engineer mine occur in fissure veins in sheared Jurassic shale and greywacke. The principal gold-bearing veins lie on either side of a shear zone, and trend toward it at various angles, but none has been traced into or across it. The shear zone has an indicated length of 4,000 feet, and is as much as 65 feet wide. It is well mineralized with quartz and pyrite, and contains some gold. The veins range from a few inches to 4 feet in width, and several are more than 1,000 feet long. In addition, two quartz-vein stockworks, each more than 200 feet wide, have been tested, but are not known to carry gold in commercial quantities. The chief metallic mineral in the veins is native gold; in addition, small particles of tellurides, as well as some pyrite and native antimony, also occur. The veins lie near the eastern edge of the Coast Range batholith, and granite-porphyry dykes occur in their vicinity. It is quite probable that the veins are genetically associated with these granitic rocks, and that materials composing them were deposited from solutions derived from the granitic magma (Cairnes, 1913, pp. 75, 89).

The orebodies at the Polaris-Taku mine are veins along shear zones in Mesozoic rocks at the contact between schist and greenstone or in greenstone. The largest and most persistent vein is of the contact type. It varies from 2 to 25 feet in width and averages about 8 feet, and has been developed for 1,000 feet. The ore minerals are, in order of abundance: arsenopyrite, pyrite, stibnite, and native gold; the gangue minerals are quartz, carbonate, and "fuchsite" (green chrome mica). Several periods of mineralization have been recognized (Sharpstone, 1938, p. 50). The first consisted of intensive replacement of the greenstones and schists along the shear zones by carbonate, quartz, and minor pyrite and "fuchsite." Following carbonatization, abundant pyrite and arsenopyrite were deposited, and most of the gold was introduced at that time. Then came the introduction of a succession of vein minerals, including quartz, carbonate, and varying amounts of sulphides. Aplite dykes outcrop on the property, and phases of the Coast Range batholith outcrop 3 to 5 miles west of it.

In addition to these two productive mines, the Tulsequah Chief property has attracted considerable attention. The mineral deposits on this prospect are similar to those at the Polaris-Taku except that they contain chalcopyrite, sphalerite, and galena in addition to the other ore minerals.

All known lode-gold deposits in Atlin and Stikine mining divisions lie near or in the Coast Range and Omineca-Cassiar batholiths, and the mineralizing solutions from which the deposits were formed probably are genetically related to these batholiths.

Cariboo Mining Division

The Cariboo Gold Quartz, Island Mountain, and Cariboo Hudson mines, and at least twenty-five other lode-gold deposits, occur along the Barkerville gold belt of Cariboo mining division.

Underground exploration began at Cariboo Gold Quartz and Island Mountain mines in the seventies, and several unprofitable attempts at mining had been made by 1890. After 40 years of relative inactivity, exploration began again, and the Cariboo Gold Quartz mine was brought into production in 1933, and the Island Mountain mine in 1934.

The lode-gold deposits of the Barkerville gold belt are concentrated in limestone, argillite, and quartzite in the upper part of the Richfield formation, the oldest member of the Precambrian, Cariboo group. The lode deposits comprise both quartz veins and sulphide replacement bodies. The latter consist of limestone beds and lenses replaced by massive and disseminated gold-bearing pyrite, which is accompanied, in a few places, by some chalcopyrite, galena, and scheelite. The largest deposit of this type forms the main orebody at the Island Mountain mine. Several replacement bodies also occur at the Cariboo Gold Quartz mine. Quartz veins greatly outnumber replacement deposits, and are of five different kinds (Hanson, 1935b, p. 17): (1) transverse veins crossing the strata roughly at right angles; (2) diagonal veins striking north 70 degrees east to east; (3) lenticular (bedded) veins parallel to the strata; (4) large strike-fault veins occupying earlier faults, and almost parallel to the strike and dip of the strata; and (5) northerly striking fault veins. In the Barkerville area the transverse veins constitute the most numerous and most important type, and the diagonal veins are next in importance. The transverse veins are in general 150 feet or less in length and 4 feet or less in width, and the diagonal veins are generally a little wider and longer. The main orebodies at the Cariboo Gold Quartz mine occur in the transverse veins. Those at the Cariboo Hudson mine are in northerly striking fault veins. Some of the veins are barren, but most of them contain pyrite; other minerals that may be present are arsenopyrite, sphalerite, and galena. Cosalite and telluride are associated with coarse gold at the Cariboo Gold Quartz mine, and scheelite is abundant in some veins at the Cariboo Hudson mine.

At least twenty known lode-gold deposits occur in this mining division outside the Barkerville gold belt, but only two, the Burns Mountain Gold Quartz and Quesnelle Quartz mines, have proved productive, and that on a small scale. The Burns Mountain Gold Quartz mine produced about 1,000 ounces of gold in the seventies. The Quesnelle Quartz mine was first operated in 1881, and again in 1932 and 1939. Quartz veins mineralized with pyrite occur in quartzite and schist on the Burns Mountain property, and along a greenstone schist contact at the Quesnelle Quartz mine.

Omineca Mining Division

No gold mines have been developed in Omineca mining division, although about eighty lode-gold deposits are known. Six properties, including the Fiddler at Doreen, the Glacier Gulch on Hudson Bay Mountain, and the Hyland Basin in the Driftwood area, have made small test shipments of high-grade ore, mainly to the British Columbia Assay Office at Prince Rupert. Most of the deposits are quartz veins occupying fissure, shear, and fault zones in sedimentary and volcanic rocks of the Hazelton group. They occur near or in small intrusions, or along the main east border of the Coast Range batholith. Pyrite, galena, sphalerite, chalcopyrite, and minor quantities of other sulphides are the ore minerals.

Portland Canal Mining Division

Approximately eighty-five lode-gold deposits have been staked in Portland Canal mining division. Six properties have developed producing mines, and at least five others have shipped small tonnages of high-grade ore. Three of the producers, the Premier, B. C. Silver, and Sebakwe mines, are operated by Silbak-Premier Gold Mines, Limited. The main producer has been the Premier mine, but in recent years most of the production has come from the other two. The Big Missouri mine operated at a loss between 1938 and 1942. The Golskeish mine was operated by Granby Consolidated for several years, primarily as a supply of quartz flux for the smelter at Anyox. The Portland Canal Mining Company produced 2,000 tons of concentrates from the Gypsy and Little Joe claims in 1910 and 1911. The Gold Leaf, Honeymoon, Oral M, Victoria, and Georgia River Gold properties have marketed small tonnages of ore at various times.

The principal lode-gold deposits in Portland Canal mining division contain gold, silver, lead, zinc, and copper in varying amounts. The deposits at the Premier, B. C. Silver, and Sebakwe mines are well-defined, vein-like replacements up to 60 feet wide and as much as 2,000 feet long (Hanson, 1935a, p. 45). The orebodies consist in general of galena and sphalerite, with minor amounts of chalcopyrite, native gold, and electrum. Near the surface tetrahedrite, argentite, native silver, and ruby silver are abundant. Much of the ore is fairly solid sulphide with interstitial quartz gangue, but locally the quartz gangue is so plentiful that the bodies might be called quartz veins. The deposits occur in orthoclase-quartz porphyry or in sheared tuffs cut by the porphyry.

The Portland Canal, Golskeish, Gold Leaf, Honeymoon, Oral M, and Victoria deposits consist of quartz veins in sheared argillite. Galena, sphalerite, and chalcopyrite are the ore minerals. The Victoria deposit is in the Portland Canal fissure zone.

Mineral deposits on the Big Missouri property are of two types: (1) replacement and impregnation of favourable beds in tuff and fine conglomerate, the mineralized zones consisting of a fine-grained mixture of galena, sphalerite, chalcopyrite, and pyrite in a siliceous gangue; and (2) closely spaced gold-quartz veinlets, which contain some native gold and cut the sulphide mineral zones.

Queen Charlotte Mining Division

Approximately fifteen lode-gold deposits are known in the Queen Charlotte Islands. Included in them is the Early Bird property, the first producing lode mine in British Columbia. This property was operated by the Hudson's Bay Company in 1851 and 1852, at which time about 1,000 ounces of gold was recovered. In recent years small trial shipments of ore have been made from the Early Bird and Southeastern properties.

The ore deposits on both properties consist of narrow quartz veins occupying fracture zones in altered volcanic rocks. The veins are mineralized with pyrite, chalcopyrite, and native gold.

Skeena Mining Division

The Surf and Pugsley mines on Princess Royal Island and the Surf Point and Edye Pass mines on Porcher Island have been the only producing lode-gold mines in Skeena mining division. The Surf and Pugsley mines were operated from 1916 to 1926 by Belmont Surf Inlet Mines, Limited, and again from 1936 to 1942 by Surf Inlet Consolidated Mines, Limited. Surf Point and Edye Pass mines were operated from 1931 to 1938 by Porcher Island Mines, Limited. At least forty other deposits have been staked in Skeena mining division. Several of them, including the Star and Bear near Terrace, have made small test shipments of high-grade ore.

The orebodies on the Surf Point, Edye Pass, Surf, and Pugsley properties consist of quartz veins occupying shear or fracture zones in Coast Range granodiorite. Chalcopyrite and pyrite are the main ore minerals.

SILVER-LEAD-ZINC

Approximately three hundred and forty silver-lead-zinc deposits are known in northern British Columbia west of the Rocky Mountains. Most of them are in the Portland Canal area or along the Canadian National Railway between Usk and Burns Lake. Ten of these deposits were producing mines at various times; at least ten others have made test shipments of ore, and of the remainder more than twenty have been explored by shafts and adits (*See* Figure 4). Little production is recorded from any of these properties since the drop in price of silver, lead, and zinc in 1930. The mines that have been productive are listed in the following table:

Name	Year	Gold	Silver	Lead	Zinc
		Ounces	Ounces	Pounds	Pounds
		Portland Canal Area			
Dolly Varden	1918-1921		1,304,409		
Esperanza	1911-1927	107	68,905	1,062	
Dunwell	1927	4,805	102,000	1,264,700	1,608,600
Toric	1928-1929		30,533	41,879	
La Rose	1926-1927	15	15,579	2,688	
Prosperity	1928-1930	480	1,700,000	1,150,000	
Porter Idaho	1924-1927		190,200	278,400	
		Hazelton-Smithers Area			
Duthie	1924-1930	776	739,055	1,920,487	1,606,014
Silver Standard	1913-1922	1,100	626,000	1,225,000	1,400,000
Silver Cup	1929	Mined 5,800 tons			

The following properties made test shipments varying from 5 to 75 tons: Ida, Marmot, Silverado Limited, and Spider, in Portland Canal area; Silver Creek, Sunrise, and Victory, in the Hazelton-Smithers area; Golden Eagle and Topley-Richfield, in the Topley area; and the Owen Lake mine near François Lake.

Portland Canal Area

The silver-lead-zinc deposits of Portland Canal area form three distinct groups:

(1) Quartz veins containing one or more of the metals, silver, lead, and zinc.
(2) Silver-barite-jasper deposits.
(3) Silver-lead deposits.

Quartz Veins Containing One or More of the Metals Silver, Lead, and Zinc. Included in this group are the following properties: Dunwell, Esperanza, La Rose, Marmot, Silverado, Ida, and Spider. Veins on the Dunwell, Esperanza, and Marmot properties cut argillite or argillaceous quartzite of the Hazelton group, whereas those on the Silverado, Spider, and Ida properties intersect volcanic members of the same group. Dykes and sills outcrop on all these properties. Except on the Silverado, where the vein is 20 feet wide, the veins are generally less than 6 feet in width, and most of those that are well mineralized are less than 3 feet wide. They occur along fault, fracture, fissure, or shear zones. The veins contain galena, sphalerite, tetrahedrite, chalcopyrite, pyrite, arsenopyrite, pyrrhotite, native silver, ruby silver, and silver sulphides in varying amounts. The source of the minerals is not known, but it is presumed to be underlying parts of the Coast Range composite batholith (Hanson, 1935a, p. 39).

Silver-Barite-Jasper Deposits. The Dolly Varden and Toric properties have been the only producers in this group. At least twelve other deposits are known, and all occur in volcanic rocks of the Hazelton group. The deposits are characteristically vein-like replacements and are commonly

10 to 15 feet wide, but range in width from 5 to 40 feet or, in a few instances, to as much as 75 feet (Hanson, 1935a, p. 42). A few may be simple fissure fillings, but most of them are mineralized breccia and shear zones in which ore minerals have partly replaced the wall-rock and partly filled open spaces. The vein at the Dolly Varden mine is 5 to 25 feet wide and consists of dark, vitreous quartz presumably replacing volcanic rock and containing pyrite, galena, sphalerite, tetrahedrite, native silver, argentite, ruby silver, and pearceite. Production was from a bonanza ore shoot within 200 feet of the surface. The ore assayed as much as 1,000 ounces of silver a ton, and values were chiefly in the silver minerals. The rich silver ore is thought to be of secondary origin by some geologists, and of primary origin by others. The source of the ores may be intrusive rocks not exposed at the surface, and if so, is probably the magmatic source of the volcanic rocks in which the deposits occur (Hanson, 1935a, pp. 43, 44).

Silver-Lead Deposits. Included in this group are the Prosperity and Porter Idaho deposits. Both consist of quartz veins along shear and fault zones in volcanic members of the Hazelton group. The veins are, in general, less than 6 feet wide. The principal ore mineral is galena, but much of the silver is contained in silver minerals and tetrahedrite. The veins and ore shoots have the appearance of having been formed chiefly by replacement.

Hazelton-Smithers Area

The ore deposits of the Duthie and Victory properties on Hudson Bay Mountain are sulphide replacements and fissure fillings along shear and fault zones in volcanic members of the Hazelton group. Numerous dykes outcrop on both properties. The Duthie lodes range from a few inches to 8 feet wide, and from 700 to more than 3,500 feet long. The ore minerals are galena, sphalerite, arsenopyrite, chalcopyrite, tetrahedrite, and ruby silver, and the gangue is quartz and carbonate. The source of the ore is believed to be a deep-seated intrusion forming the core of Hudson Bay Mountain.

The Silver Creek deposits on Hudson Bay Mountain are lens-shaped orebodies consisting of sulphide replacements of limestone of the Hazelton group. A granodiorite stock outcrops nearby.

The ore deposits of the Silver Standard mine on Glen Mountain and the Silver Cup mine on Nine Mile Mountain consist of fissure veins cutting sedimentary rocks of the Hazelton group. Small granodiorite stocks outcrop on both properties. There are ten veins on the Silver Standard property ranging from 6 inches to 8 feet in width and 100 to 1,000 feet in length. The ore minerals are galena, sphalerite, and tetrahedrite, and minor amounts of other sulphides in a quartz gangue. Some veins carry appreciable gold values.

The veins on the Sunrise property on Nine Mile Mountain are in intersecting fault fissures in granodiorite. They consist of jamesonite, sphalerite, galena, cosalite, pyrite, arsenopyrite, and tetrahedrite in a quartz gangue, and argentite in a quartz gangue.

Canadian National Railway Belt from Houston to Burns Lake

Interesting lead-zinc deposits occur at Owen Lake, near Topley, and near Babine Lake. The veins at Owen Lake mine occur along shear zones in fine-grained diorite. They are narrow, and contain chalcopyrite, sphalerite, minor galena, and alaskaite in a quartz-barite-rhodochrosite gangue. The ore deposits on the Topley-Richfield and Golden Eagle properties near Topley consist of narrow replacement veins along shear zones in andesite breccia. The vein minerals are chalcopyrite, pyrite, galena, tetrahedrite, quartz, and carbonate. The ore deposits of Taltapin mine near Babine Lake are narrow fissure veins in greenstone, and consist of sphalerite, galena, chalcopyrite, and tetrahedrite in a quartz-carbonate gangue.

Ingenika River

The Ferguson property is on the summit of a small limestone hill about a mile south of Ingenika River, 16 miles west of its confluence with the Finlay. The limestone, which is probably of Precambrian age, is folded into a small syncline plunging northwest. The deposit is decribed (Dolmage, 1928, p. 39) as consisting of replacement veins in, or close to, this syncline. The ore minerals are galena, sphalerite, and minor other sulphides in a siderite and quartz gangue. Associated with the sulphide veins is a large irregular mass of vein quartz. The richest ore lies close to the contact of this quartz body, but does not appear to penetrate it. The largest showing is more than 50 feet long, and contains two 5-foot bands of ore, one carrying 7·4 per cent zinc, 29·6 per cent lead, and 11 ounces of silver a ton and the other 5·1 per cent zinc, 16 per cent lead, and 4·1 ounces of silver a ton.

COPPER

Approximately two hundred copper deposits are known in northern British Columbia west of the Rocky Mountains. Most of them are in the Portland Canal area and along the Canadian National Railway between Usk and Smithers, and occur on the eastern margin of the Coast Range composite batholith or associated with related intrusions (*See* Figure 4). A few deposits have been found associated with the Omineca-Cassiar batholith. Productive mines were developed on only five of the deposits; a few others have made small test shipments; and most of the remainder are of mineralogical interest only. The five producers were the Hidden Creek, Bonanza, Outsider, and Maple Bay mines near Anyox, operated by the Granby Consolidated Mining and Smelting Company, and the Rocher Déboulé mine near Hazelton.

Between 1914, when operations commenced, and 1936, when they ceased, the Hidden Creek and Bonanza mines produced more than 650,000,000 pounds of copper, 105,000 ounces of gold, and 6,500,000 ounces of silver. The Outsider and Maple Bay mines produced about 4,000,000 pounds of copper from 1906 to 1926, inclusive. The Rocher Déboulé mine was operated during the war of 1914-1918, when approximately 5,750,000 pounds of copper, 4,200 ounces of gold, and 63,000 ounces of silver were produced.

The orebodies of the Hidden Creek and Bonanza mines were chalcopyrite replacement deposits in amphibolite, and at the contact between amphibolite and adjacent argillite. The deposits varied in size from vein-like bodies a few feet wide and a few hundred feet long, to large, irregular masses as much as 1,000 feet long and deep and 200 feet wide. The ore-bodies in the amphibolite lay parallel to the direction of shearing. Ore consisted of solid sulphide, of amphibolite ribboned with sulphide, of highly silicified rock with sulphides, and of all gradational types. The sulphides were chalcopyrite, pyrrhotite, pyrite, magnetite, arsenopyrite, and sphalerite. The average ore at the Hidden Creek mine contained 1·5 per cent copper, about ⅓ ounce of silver, and 10 cents in gold a ton. The average ore at the Bonanza mine contained about 3 per cent copper, and silver and gold amounting to a dollar or less a ton.

The orebodies of the Outsider and Maple Bay mines were quartz veins mineralized with chalcopyrite, and occurred in amphibolite.

A few of the copper deposits in the northern part of the Portland Canal area, including the Red Cliff and George Copper mines, have made various small test shipments. They occur as chalcopyrite replacements or quartz veins mineralized with chalcopyrite, and are for the most part in Hazelton group volcanic rocks.

The ore deposits of the Rocher Déboulé mine, which were mined for copper, consisted of vein-like replacements that occupied fissure zones in granodiorite. These replacements contained chalcopyrite and minor quantities of other sulphides in a gangue of hornblende and quartz.

Most of the remaining copper prospects in northern British Columbia are either quartz veins mineralized with chalcopyrite or chalcopyrite-bornite disseminations in fractured host rocks. Some of the latter are very large and of low grade. The Richmond orebody on Copper Island in Babine Lake is estimated to contain 8,000,000 tons of 0·8 per cent copper ore.

MERCURY

Pinchi Lake and Bralorne Takla mercury mines, both productive, occur in the Pinchi Lake - Takla Lake area (*See* Figure 4). During the field season of 1937 cinnabar was discovered by J. G. Gray of the Geological Survey in Permian limestone on the north shore of Pinchi Lake where the main showings of the Pinchi Lake mercury mine were later developed. The property was optioned to the Consolidated Mining and Smelting Company, and in June 1940, a reduction plant with a rated capacity of 50 tons a day was brought into operation. In 1943 the plant had a capacity of more than 1,000 tons a day. The grade of the ore treated is reported to average 5 to 10 pounds of mercury a ton, and production during the years 1940 to 1944 exceeded 4,000,000 pounds. The Bralorne Takla mercury mine was brought into production in November 1943 with the completion of a 50-ton mill. Production of mercury from these two properties was far in excess of Canadian requirements, and Canada was able to supply the United Kingdom and the United States with part of their needs. Both properties ceased operations during the summer of 1944 due to an excessive supply of mercury.

The Pinchi Lake and Bralorne Takla mercury mines, although 90 miles apart, occur within the Pinchi Lake mercury belt. This belt lies along a major fault zone extending from southeast of Fort St. James 150 miles northwest to Omineca River. The fault zone varies in width from 200 to 5,000 feet, but in most places does not exceed 1,000 feet. Its eastern margin represents the contact between stratified Permian rocks on the west and Mesozoic formations and the Omineca-Cassiar batholith on the east. It seems probable that the fault zone marks the site of major thrust faulting from the west, and that the Permian rocks moved up with respect to the Mesozoic formations. Intense faulting occurs in the Permian rocks within the fault zone. There the more important faults trend northwesterly, dip steeply southwest, and may join a major low-angle thrust fault at depth. The Pinchi and Bralorne Takla orebodies and numerous smaller mercury deposits occur along or near the fault zone in sheared and brecciated Permian limestone or in carbonatized serpentine. In most of the deposits it is apparent that the fault zone provided abundant channelways for mineralizing solutions, and that deposition occurred wherever other conditions were favourable. In many places relatively impervious cap rock and fault gouge have acted as traps to rising solutions and have induced local concentrations of cinnabar. At the Pinchi Lake mercury mine the larger cinnabar orebodies are in limestone overlain by schist.

Although "trapping" is undoubtedly an important factor in localizing ore, the relative permeability of the solution channels is of equal or greater importance. Cinnabar is the only mineral of importance. No genetic relationship is apparent between the mercury deposits and any nearby volcanic or intrusive rocks. The source of the ore-forming solutions is not known, but is probably connected with some deep-seated intrusion. Probably the deposits were formed during Tertiary time.

TUNGSTEN

British Columbia's largest tungsten producer, the Red Rose mine, is situated near Hazelton (*See* Figure 4). It was brought into production in January 1942 upon completion of a 30-ton mill. Production continued until November 1943, when operations ceased due to a decreased demand for tungsten. In 1942 and 1943, 1,194,000 pounds of tungsten concentrates were recovered from the property.

The property of Columbia Tungstens Company, Limited, was the only other tungsten producer in northern British Columbia. A 50-ton pilot mill was installed in 1937, destroyed by fire in 1938, and rebuilt in 1939. Operations ceased in 1941. Approximately 10,000 pounds of tungsten concentrates were recovered.

Interesting occurrences of tungsten minerals have been recorded from many other mineral deposits in northern British Columbia. The more important of these are as follows: Molly B., in Portland Canal district; Black Prince and Whitewater, in Omineca district; and Wolframite and Tungsten, in Atlin district.

The Red Rose, Black Prince, and Whitewater deposits are in, or close to, small stocks of diorite and granodiorite. The tungsten occurs as wolframite, ferberite, and scheelite in quartz veins occupying shear or fault zones. The main vein on the Red Rose property traverses a diorite stock and bordering sedimentary rocks. It is as much as 12 feet wide and about 400 feet long, and contains in addition to the tungsten minerals, molybdenite, chalcopyrite, pyrite, and tourmaline. The Black Prince vein is in granodiorite and contains a similar variety of minerals to the Red Rose. This mineral association suggests high temperatures at the time of deposition, and it is probable that the ore solutions are genetically related to the intrusive stocks.

The ore deposits mined on the Columbia Tungstens property consisted of short, discontinuous, and narrow veins and lenses of quartz carrying scheelite, and minor amounts of pyrite, galena, and sphalerite. The veins lie between two intersecting faults in Precambrian sedimentary rocks. No intrusive rocks outcrop near the property.

The Molly B. deposit consists of scheelite and molybdenite in a band of lime silicate rock formed by high-temperature replacement of a bed of limestone. Granite outcrops 1,000 feet from the showing.

The Tungsten and Wolframite occurrences contain wolframite in irregular quartz veins in feldspar porphyry and granodiorite.

MOLYBDENUM

During the war of 1914-1918 a minor production of molybdenum was obtained from two properties in northern British Columbia: Tidewater Molybdenum Mines, Limited, in the Portland Canal area, shipped 383 tons of ore, and the New Hazelton Gold Cobalt Mines, Limited, at Hazelton, shipped 27 tons of ore. At least fourteen other mineral deposits in northern British Columbia contain molybdenite, but only two, the Stella group near Endako and the Molly B. in the Portland Canal area, are molybdenum properties.

On the property developed by Tidewater Molybdenum Mines, Limited, the molybdenite occurs in pegmatitic quartz veins, as much as 10 feet wide, that appear to be offshoots of a small stock of granite. Locally the granite contains patches of disseminated molybdenite. The rocks intruded by the granite, and in which the veins occur, are hard, argillaceous quartzites. The molybdenite occurs in thin, flaky seams distributed throughout the quartz veins. Apparently the veins and the molybdenite were derived from the body of granite during its consolidation. The average grade of the ore is probably less than 2 per cent molybdenite.

On the Molly B. property, molybdenite and scheelite occur in a band of lime silicate rock formed by replacement of a bed of limestone. Granite outcrops 1,000 feet from the deposit.

The deposit developed by Hazelton Gold Cobalt Mines, Limited, is essentially a gold-cobalt-arsenic property, molybdenum being of minor value only. The ore occurs as small shoots along a strong fissure in a granodiorite boss and bordering sedimentary rocks. The metallic minerals in order of abundance are: arsenopyrite, safflorite, molybdenite, and chalcopyrite.

The Stella property contains quartz veins as much as 2 feet wide, in pink granite. Molybdenite is disseminated through the quartz veins and granite wall-rock. The veins and molybdenite were probably derived from the granite in which they occur, and were formed at a late stage in the cooling in a manner similar to pegmatites.

ANTIMONY

In 1939 and 1940 a total of about 100 tons of antimony ore was shipped from the property of the Stuart Lake Antimony Mines, Limited, near Stuart Lake. The deposit consists of several narrow quartz veins along fissures in Permian greenstone and argillite. The veins carry stibnite, pyrite, and a little tetrahedrite.

MANGANESE

Several small deposits containing manganese minerals have been staked near Fort Fraser. The manganese oxides, pyrolusite and psilomelane, occur in quartzite beds. The largest showing is approximately 4 by 10 feet.

CHROMIUM

Small concentrations of chromite occur in the ultrabasic rocks in the Fort Fraser-Takla area. The largest known deposit would not contain more than 25,000 tons of chromite. The deposits were probably derived from the ultrabasic rocks by magmatic differentiation.

MICA

Deposits of good quality muscovite mica occur in northern British Columbia at Mica Mountain near Fort Graham, and near Tête Jaune Cache on the Canadian National Railway. Small shipments have been made from both localities. The mica is in pegmatite dykes that cut Precambrian (?) mica schists. Sheets up to 10 by 16 inches have been reported from Tête Jaune Cache and up to 5 inches square from Mica Mountain.

IRON

A deposit of limonite occurs on Summit Creek, a tributary of Zymoetz River. The ore lies on altered porphyry impregnated with pyrite, and contains at least 500,000 tons of easily mined, nearly pure limonite.

Magnetite deposits of commercial grade occur on Moresby and Louise Islands in the Queen Charlotte Islands. They are mainly replacement bodies in porphyry and limestone near their contact with granodiorite. The six most promising deposits contain a possible mineable tonnage of from 10,000 tons in the smallest to 300,000 tons in the largest.

PYRITE

A large pyrite deposit occurs on Ecstall River in Skeena mining division. It is reported to contain 5,000,000 tons of ore.

COAL

Coal has been found in widely scattered parts of northern British Columbia west of the Rocky Mountains, in Jurassic or Lower Cretaceous, and Tertiary rocks. The only production has been from the coal measures of Bulkley Valley.

Jurassic or Lower Cretaceous Coal

Coal measures of Jurassic or Lower Cretaceous age occur in the Groundhog area near the headwaters of Skeena River, in the Bulkley-Lower Skeena River drainage basin, in the Babine River-Takla Lake-Omineca River area, and on Bowron River east of Prince George.

The Groundhog coal measures underlie an area of about 900 square miles, and consist of sandstone, shale, conglomerate, and coal of the Hazelton group, and contain plants of both Kootenay and Blairmore ages. Thirteen seams have been found in the upper 1,240 feet of beds. Four of them are 3 to 12 feet thick. The coal ranges in rank from bituminous to anthracite.

Coal seams are known at the following localities in the Bulkley-Lower Skeena River drainage basin: on Glacier and Coal Creeks, tributaries of Zymoetz River; on Shegunia and Kispiox Rivers, tributaries of Skeena River about 10 miles north of Hazelton; on Bulkley River at Seaton; west of Lake Kathlyn; on Goat Creek near Telkwa; on Coal, Goldstream, and Chisholm Creeks, tributaries of Morice River near its headwaters; and at the headwaters of the south fork of Telkwa River. All the coal of commercial quality occurs in sedimentary members of the Hazelton group, consisting of sandstone, shale, and conglomerate. The best coal appears to be of Lower Blairmore age. The strata are cut by minor intrusions and in places lie near younger volcanic rocks, and, as a result, the coal ranges from low-grade bituminous to low-grade anthracite depending on its nearness to the igneous rocks. Intense folding and faulting of the beds, with resultant squeezing and crushing of the coal seams, has been observed in most of the areas. Owing to the small amount of exploratory and development work done, data pertaining to the number, extent, and quality of the seams are meagre. In Lake Kathlyn basin, twenty seams of low-grade anthracite, from 6 inches to 4 feet thick, are known. At least ten seams of bituminous coal varying in thickness from 2 feet 6 inches to 14 feet outcrop on Goat Creek near Telkwa. The only recorded production is from these two areas. During 1943 and 1944 about 100 tons of coal a day were being mined in the Goat Creek basin. Elsewhere in the Bulkley-Lower Skeena River drainage basin, the coal is too low grade, the seams too narrow, or the area too difficult of access to make mining profitable.

Seams of low-grade bituminous coal outcrop on Tuchi River, which flows into Babine Lake; on Firepan and Bates Creeks, which flow into Takla Lake; and on Discovery Creek, a tributary of Omineca River. The coal measures on Discovery Creek consist of sandstone, shale, and conglomerate, and, on the basis of contained fossil shells in apparently overlying marine beds, are of Jurassic age.

The Bowron River coal basin is about 50 miles above the mouth of the river, or about 40 miles east of Prince George. The coal measures contain at least three workable seams, measuring 5, 10, and 12 feet in thickness, and numerous thinner seams ranging up to 3 feet thick.

Coal measures of Upper Blairmore age outcrop on Graham Island of the Queen Charlotte Islands. The coal seams occur in the Haida formation, which consists of 2,000 to 5,500 feet of mainly sandstone and shale with a few beds of conglomerate. Bituminous coal is found at a single zone in this formation about 2,500 feet above the base. It forms one to three seams varying from 3 to 18 feet in thickness, and outcrops at various localities.

Tertiary Coal

Coal deposits of Tertiary age occur on Dease, Rapid, and Tuya Rivers in the northwestern corner of British Columbia; on Graham Island; and along Chesllata Lake. The seams are all of lignite and most of them are either too thin or too inferior in quality to warrant development under existing conditions. The Tertiary coal on Graham Island is the most promising.

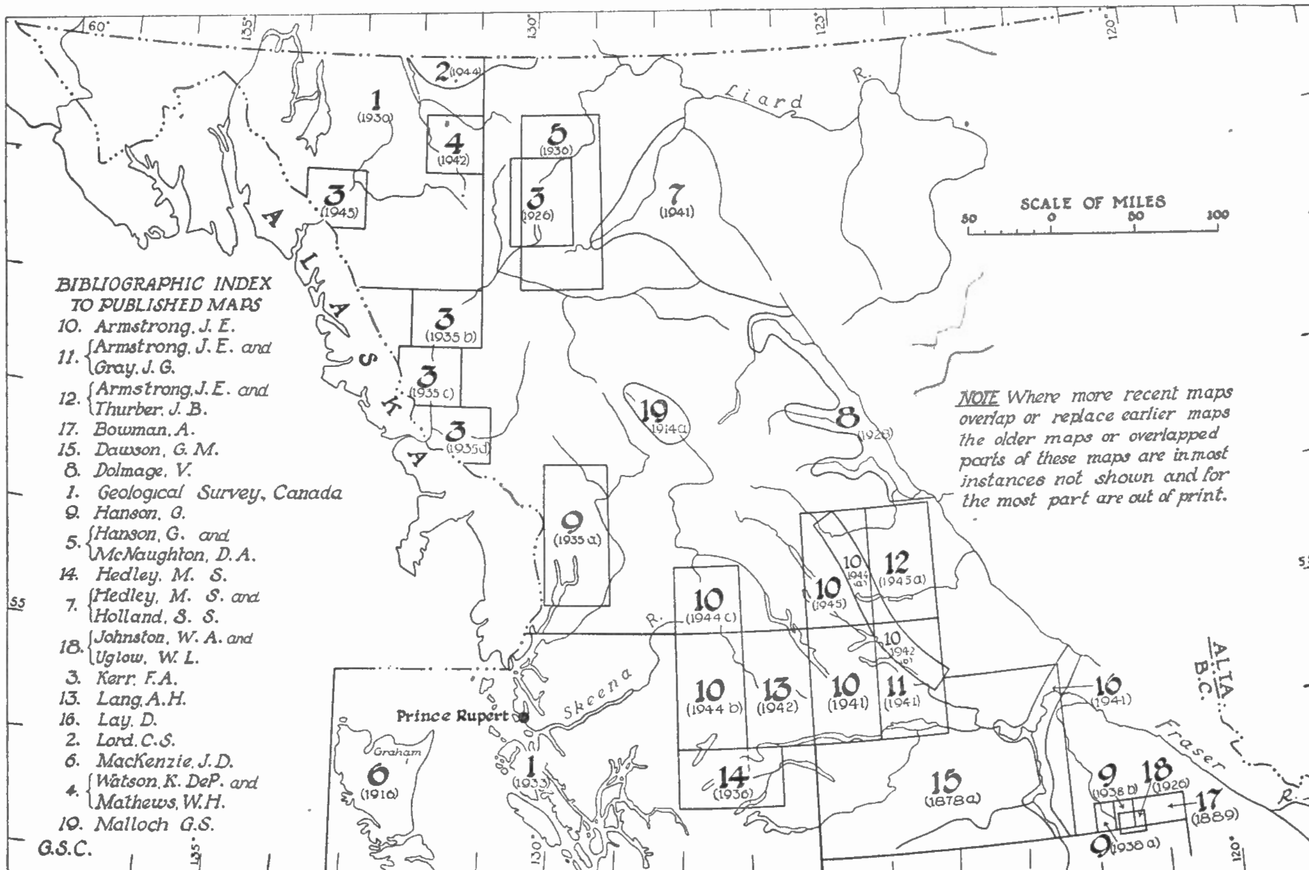

Figure 5. Bibliographic index to published maps.

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