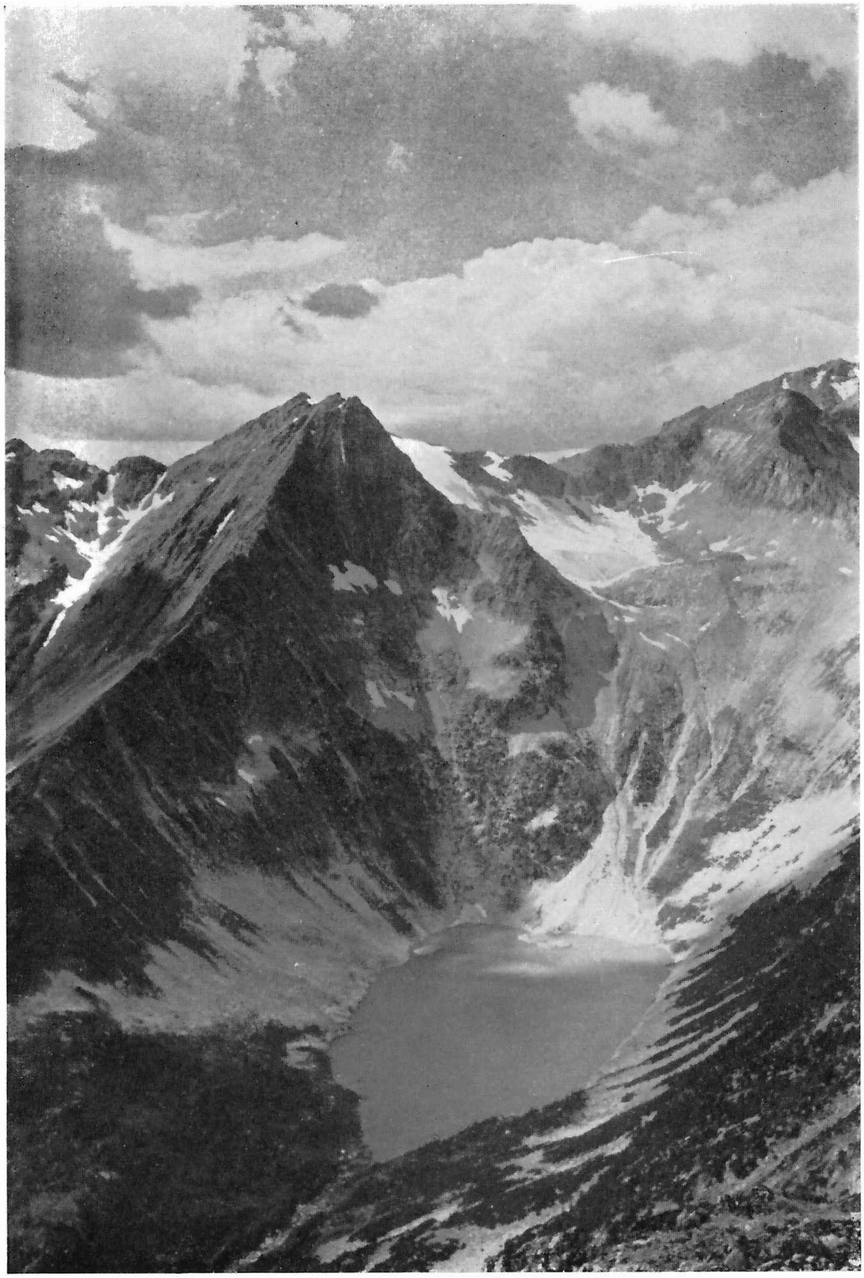
MEMOIR 262

ASHCROFT MAP-AREA, BRITISH COLUMBIA

BY

S. DUFFELL AND K. C. MCTAGGART

GEOLOGICAL SURVEY
DEPARTMENT OF MINES AND TECHNICAL SURVEYS
OTTAWA
1952



98959

Cirque and tarn in Coast Mountains southeast of Skihist Mountain. Topography typical of Coast Mountains. (Page 7.)

CANADA
DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA
MEMOIR 262

ASHCROFT MAP-AREA, BRITISH COLUMBIA

BY

S. Duffell and K. C. McTaggart

OTTAWA
EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
KING'S PRINTER AND CONTROLLER OF STATIONERY
1951

Price, 75 cents

No. 2501

CONTENTS

CONTENTS—*Con.*

CONTENTS—*Conc.*

Illustrations

PREFACE

Ashcroft map-area covers roughly 3,000 square miles of southwestern British Columbia about the historic towns of Ashcroft, Lillooet, and Lytton, the last at the junction of Thompson and Fraser Rivers. It occupies parts of the Coast and Cascade Mountains and the Interior Plateau, and east of Fraser River is mostly readily accessible by rail and highway and by numerous subsidiary roads and trails. For nearly a century it has witnessed sporadic and at times successful efforts at placer gold and lode mining, and in 1871 lay on the route of the first field explorations of the Geological Survey of Canada on the mainland of the province. Since these early years, many geologists have examined and reported on various parts of the Ashcroft area, and recent systematic geological mapping of adjacent areas has raised many problems relative to its geological history, its stratigraphy, and the correlation and nomenclature of its rock formations.

The present report, based on field work by the joint authors, co-ordinates the results of earlier investigations. It deals mainly with the geological succession of formations, which range in age from late Palæozoic to Tertiary; with their relations to the abundant Coast intrusions, some of which are shown to be of early Jurassic age; with the structure of the various rock groups, including an extensive down-faulted belt of Lower Cretaceous sedimentary rocks along Fraser River; and with the considerable variety of metallic and industrial mineral deposits distributed throughout the area. Within Ashcroft map-area are the type localities of the Cache Creek, Jackass Mountain, and Spences Bridge rock groups, the names of the first two of which have survived the preliminary traverse of 1871. Other names long familiar in geological explorations of this general region have been retained, and still others have been introduced in an effort to clarify its complex Mesozoic history. The report includes a selected bibliography of earlier work pertaining to the geology and mineral deposits of the area, and is illustrated by a geological map representative of a plan of systematic geological mapping of the province of British Columbia.

GEORGE HANSON,
Chief Geologist, Geological Survey of Canada

OTTAWA, February 15, 1951

Ashcroft Map-Area, British Columbia

CHAPTER I

INTRODUCTION

GENERAL STATEMENT

Ashcroft map-area lies in southwestern British Columbia between latitudes 50 and 51 degrees north, and longitudes 121 and 122 degrees west, and has an area of about 3,100 square miles (Figure 1).

Although most of the area had years before been geologically mapped on a reconnaissance scale, recent work in adjoining areas had suggested that geological relationships in the Ashcroft map-area should be restudied. This consideration, and others such as the suitability of the area for the study and correlation of formations near the junction of three main physiographic subdivisions, the long range of fossiliferous formations and the possibility of dating with their aid certain major intrusions, and the desirability of an up-to-date account of the economic possibilities of the area, made it advisable to re-map the area.

The writers spent the field seasons of 1945 and 1946 in the area, and the junior author spent about 1 month in 1947 completing the work. Duffell mapped that part of the area lying east of the Fraser River Cretaceous belt. McTaggart mapped the remainder of the area, consisting largely of that part west of Fraser River.

LOCATION AND ACCESSIBILITY

The village of Spences Bridge, at the confluence of Nicola and Thompson Rivers, is 8 miles southeast of the geographical centre of Ashcroft map-area and 178 miles by rail from Vancouver.

Principal towns in the area are Ashcroft, on Thompson River; Lytton, at the junction of the Fraser and Thompson; and Lillooet on Fraser River. Smaller settlements include Cache Creek and Pavilion.

The map-area, lying astride both the Canadian Pacific and Canadian National railways and the Cariboo highway, is easily accessible. In addition, the Pacific Great Eastern railway crosses the northwestern corner of the area, and the Kettle Valley railway, which follows Nicola Valley from Spences Bridge, serves the southeastern part.

East of Fraser River, transportation in Ashcroft area is facilitated by a network of good motor roads. The Cariboo highway along Fraser and Thompson Rivers is paved, and other main roads are well gravelled. Most of the major valleys east of the Fraser are accessible by a road of some sort, and secondary farm and logging roads allow motor transport to slightly travelled parts of the area. Motor and wagon roads provide access to certain parts of the area west of Fraser River, but long stretches close to the river are served only by trail.

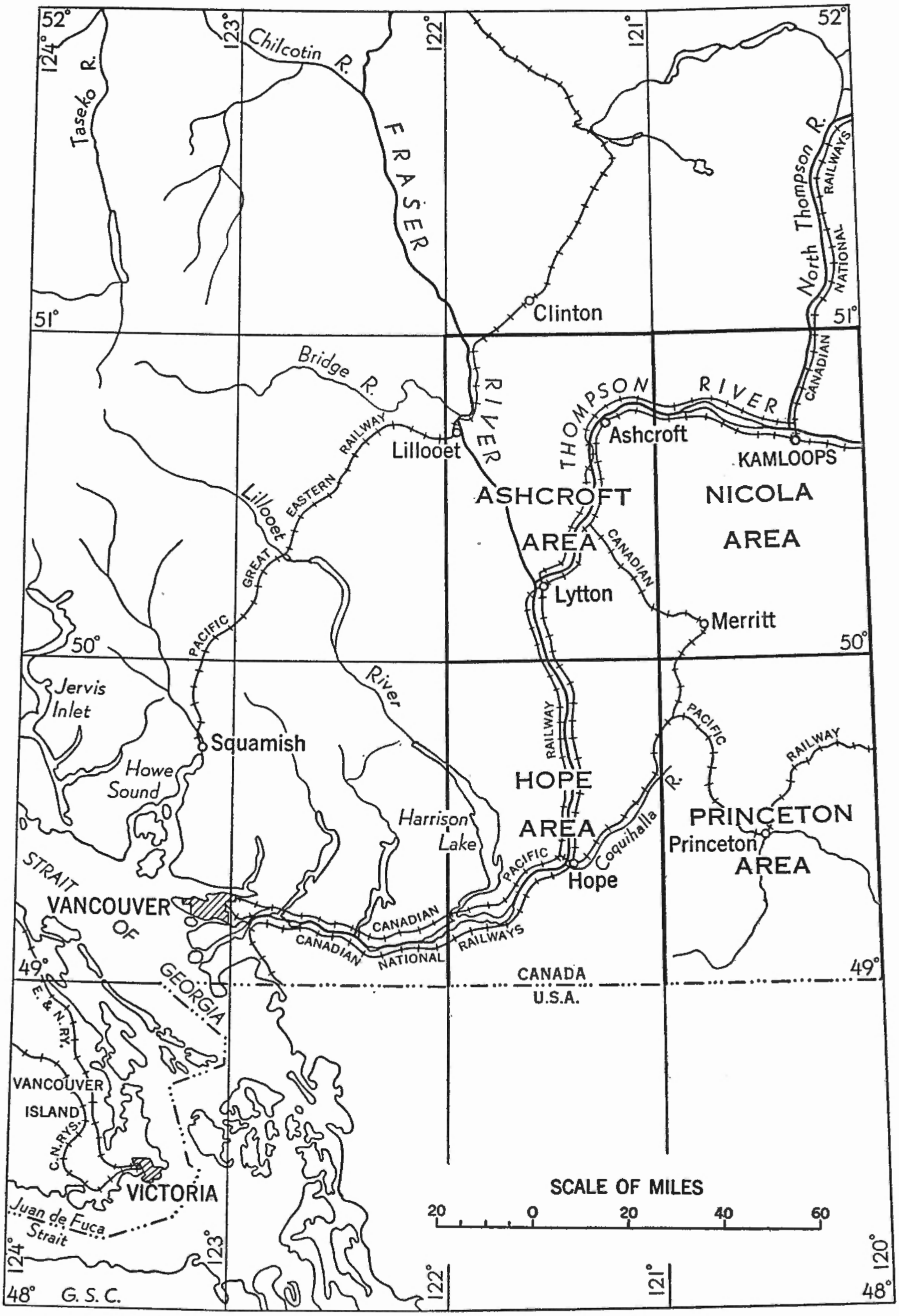


Figure 1. Key map, southwestern British Columbia, showing position of Ashcroft, Nicola, Hope, and Princeton map-areas.

Trails east of Fraser River are plentiful, many of them used by ranchers in moving cattle from one range to another. West of Fraser River, excellent trails follow Kwoiek Creek and the spur lying between the main forks of that stream, both branches of Stryen Creek, and Stein River, Siwhe Creek, and Texas Creek.

POPULATION AND INDUSTRIES

The map-area is populated by not more than 5,000 people, of which Indians form a large proportion. Many Chinese reside in Ashcroft and Lillooet, and a small Japanese settlement has been established near the latter town.

Most of the inhabitants are engaged in agriculture and cattle raising. Fruit and vegetables, of which tomatoes are the most important, are canned at Ashcroft and Lillooet. Ashcroft has long been noted for its potato crop, and in recent years other vegetables have become important.

Maintenance and operation of the railroads occupy many residents. Logging operations have increased during the last few years and are in progress along Nicola River, Botanie Creek, Fountain Creek, and Chrome Creek, a tributary of Scottie Creek.

Mining and prospecting are small but important activities in Ashcroft map-area. Coal, epsomite, gold—both placer and lode—copper, antimony, and molybdenum have been produced, and, in addition, prospectors have discovered deposits of gypsum and others containing chromium, silver, iron, and zinc that have not yet proved to be of economic importance but offer interesting possibilities. In 1947 no significant production was being made from any mine in the area.

CLIMATE

The greater part of Ashcroft map-area lies in the dry belt of British Columbia, and has an average precipitation of from 7 to 10 inches in the valleys and somewhat more at higher elevations. At Ashcroft, well within the dry belt, the average precipitation, over a 30-year period to 1945, was 7·07 inches. At Lytton, on the eastern border of the Coast Mountains, the average over a 24-year period to 1945 was 16·73 inches.

The summers are hot; maximum temperatures at Spences Bridge and Ashcroft reach to above 100 degrees Fahrenheit. At Spences Bridge, temperatures at mid-afternoon during one hot spell in July 1945 ranged from 108 to 112 degrees for several days in succession. Minimum temperatures in winter have reached 20 to 30 degrees below zero, but normal low temperatures in January and February are approximately zero. Because of the dry air, bright sunshine, and generally invigorating atmosphere, the climate, for much of the area, is attractive.

PREVIOUS WORK

The earliest geological work done by the Geological Survey in Ashcroft map-area, and indeed, the first in British Columbia, was that of A. R. C. Selwyn, Director of the Survey, who led an expedition from the west coast to the Rocky Mountains in 1871. He travelled by train from Montreal to

San Francisco and thence by steamer to Victoria, where the party was organized. The party and supplies were carried by stern-wheeler up Fraser River to Yale, where it was discovered that wagons were not available, and it was necessary to proceed on foot with the aid of Indian packers. The first camp was made near the present site of the Alexandra bridge across the Fraser, some 10 miles north of Yale. The route followed the Fraser to Lytton, and Thompson River to Kamloops Lake. From Kamloops, the party proceeded with a pack-train up North Thompson River, and finally after many hardships reached Tête Jaune Cache in the Rocky Mountain Trench. The return trip was made by the same route, except that the pack animals were abandoned at the headwaters of the North Thompson and the journey completed by canoe. It is in Selwyn's report (1872)[1] that the Cache Creek and Jackass Mountain groups were first named and described.

G. M. Dawson, whose name stands first among the early geological explorers of British Columbia, spent the field season of 1877 examining the geology along the main routes of travel in southern British Columbia, and his report and map (1879) cover most of Ashcroft map-area. As this part of Canada became more settled, and the Canadian Pacific railway was completed, it was decided that a more detailed and accurate map was needed, and the field seasons of 1888, 1889, and 1890 were spent in gathering information that was embodied in Dawson's map (1895) and report (1896) on the Kamloops area. The map includes all of the present Ashcroft area except for a strip about 12 miles wide along its southern boundary.

In 1912, C. W. Drysdale (1914) mapped the geology of Thompson River Valley from Kamloops Lake to Lytton, and N. L. Bowen (1914) made a geological reconnaissance from Lytton to Vancouver. In 1915, Drysdale (1916) made a special trip to Highland Valley to study the copper deposits there, and in 1918 and 1919, Leopold Reinecke (1920) examined the mineral deposits adjacent to the Pacific Great Eastern railway from Lillooet to Prince George. In 1925, the Hat Creek coal deposits were examined by B. R. MacKay (1926), who was commissioned to make a special study of them. C. H. Crickmay (1930) studied the Mesozoic strata along Thompson Valley in the vicinity of Ashcroft, where he found Jurassic fossils in rocks that had hitherto been regarded as of Cretaceous age. In 1935, H. C. Horwood (1936) examined the area adjacent to Nahatlatch River. J. S. Stevenson reported on the Transvaal and Highland properties of the Highland Valley camp (1939), and on the Martel mine, about 8 miles north of Spences Bridge, for the British Columbia Department of Mines (1940). In 1942, H. M. A. Rice of the Geological Survey made a special study[2] of the chromite deposits along Bonaparte Valley, and subsequently completed geological mapping of Princeton map-area (1947), which adjoins the southeast corner of the present quadrangle. Mapping of Hope map-area, immediately south of the Ashcroft area, was completed in 1939, and in 1944 W. E. Cockfield (1948) completed field work in Nicola map-area to the east.

[1] References in parentheses are to reports listed in Bibliography, pages 5, 6.
[2] Unpublished report.

ACKNOWLEDGMENTS

The writers wish to express their appreciation of the many courtesies extended them in the field by residents of the area, particularly by Messrs. L. Starnes of Ashcroft, Bert Lehman of Lillooet, Constable T. Blackiston-Gray of the British Columbia Provincial Police, and the Fraser family at Canford.

Efficient assistance in the field was given by R. Thorsteinson, J. W. Lee, and G. E. Whitney in 1945; by R. Thorsteinson, C. E. B. Conybeare, G. E. Whitney, J. A. Roddick, W. Bryden, and R. D White in 1946; and by W. Bryden and H. Gabrielse in 1947.

The part of this report dealing with the Fraser River Cretaceous belt is largely from a dissertation presented by the junior author for the degree of Doctor of Philosophy at Yale University. He is deeply indebted to Professor Adolph Knopf and other members of the faculty for invaluable aid and criticism during the course of the work.

BIBLIOGRAPHY

Armstrong, J. E. (1949): Fort St. James Map-area, British Columbia; Geol. Surv., Canada, Mem. 252.

Bostock, H. S. (1948): Physiography of the Canadian Cordillera; Geol. Surv., Canada, Mem. 247.

Bowen, N. L. (1914): Fraser Valley, Lytton to Vancouver; Geol. Surv., Canada, Sum. Rept. 1912, pp. 108-114.

British Columbia Minister of Mines: Annual Reports.

British Columbia Department of Agriculture: Climate of British Columbia, Report for 1945.

Burwash, E. M. J. (1918): The Geology of Vancouver and Vicinity; Univ. of Chicago Press.

Cairnes, C. E. (1923): Geological Exploration in the Yale and Similkameen Mining Divisions, Southwestern British Columbia; Geol. Surv., Canada, Sum. Rept. 1922, pt. A, pp. 88-127.

——— (1924a): Reconnaissance of Silver Creek, Skagit and Similkameen Rivers, Yale District, British Columbia; Geol, Surv., Canada, Sum. Rept. 1923, pt. A, pp. 46-83.

——— (1924b): Coquihalla Area, British Columbia; Geol. Surv., Canada, Mem. 139.

——— (1930): The Serpentine Belt of Coquihalla Region, Yale District, British Columbia; Geol. Surv., Canada, Sum. Rept. 1929, pt. A, pp. 144-197.

——— (1937): Geology and Mineral Deposits of the Bridge River Mining Camp; Geol. Surv., Canada, Mem. 213.

——— (1944): Geol. Surv., Canada, Map 737A, Hope.

Cockfield, W. E. (1932): Oil Possibilities between Soda Creek and Quesnel, Cariboo District, British Columbia; Geol. Surv., Canada, Sum. Rept. 1931, pt. A, pp. 58-65.

——— (1944): Nicola Map-area; Geol. Surv., Canada, Paper 44-20.

——— (1948): Geology and Mineral Deposits of Nicola Map-area, British Columbia; Geol. Surv., Canada, Mem. 249.

Cole, L. H. (1913): Gypsum in Canada, Its Occurrence, Exploitation and Technology; Mines Branch, Dept. of Mines, Canada, Pub. 245, pp. 95-97.

——— (1928): Sodium Carbonate at Soap Lake, British Columbia; Bureau of Mines, Canada, Investigations of Mineral Resources and the Mining Industry, 1926, pp. 25-28.

Crickmay, C. H. (1930): Jurassic Rocks of Ashcroft, British Columbia; Univ. of California Pub., Bull. of the Dept. of Geol. Sciences, vol. 19, No. 2, pp. 23-74.

Cummings, J. M. (1940): Saline and Hydromagnesite Deposits of British Columbia; B.C. Dept. Mines Bull. No. 4, pp. 32-34 and 42-50.

Davis, E. F. (1918): The Radiolarian Cherts of the Franciscan Group; Pub. of the Univ. of California.

Dawson, G. M. (1879): Report on Exploration in the Southern Portion of British Columbia; Geol. Surv., Canada, Rept. of Prog. 1877-78, pt. B, pp 1-173.

——— (1887): Note on the Occurrence of Jade in British Columbia, and its Employment by the Natives; Canadian Record of Science, vol. II, 1886-1887, p. 364.
——— (1895): Geol. Surv., Canada, Map 556, Kamloops Sheet.
——— (1896): Report on the Area of the Kamloops Map-sheet; Geol. Surv., Canada, Ann. Rept. for 1894, new series, vol. VII, pt. B. pp. 1-427.
Drysdale, C. W. (1914): Geology of the Thompson River Valley below Kamloops Lake, B.C.; Geol. Surv., Canada, Sum. Rept. 1912, pp. 115-150.
——— (1916): Highland Valley Copper Camp, Ashcroft Mining Division; Geol. Surv., Canada, Sum. Rept. 1915, pp. 85-91.
——— (1917): Index Molybdenite Mine, Lillooet Mining Division; Geol. Surv., Canada, Sum. Rept. 1916, p. 54.
Dunbar, C. O. (1932): Neoschwagerina in the Permian Faunas of British Columbia; Trans. Roy. Soc., Canada, sec. IV, pp. 45-50.
Gilluly, James (1933): Replacement Origin of the Albite Granite near Sparta, Oregon; U.S.G.S. Prof. Paper No. 175, pp. 65-81.
——— (1935): Keratophyres of Eastern Oregon and the Spilite Problem; Am. Jour. Sci., 5th ser., vol. 29, No. 171, pp. 225-252; No. 172, pp. 336-352.
Goudge, M. F. (1926): Magnesium Sulphate in British Columbia; Mines Branch, Department of Mines, Canada; Investigations of Mineral Resources and the Mining Industry, 1924, pp. 62-81.
——— (1946): Limestones of Canada, their Occurrence and Characteristics—Part V, Western Canada; Canada, Bureau of Mines, Pub. No. 811, pp. 181-183, 221-225.
Harrington, B. J. (1890): Notes on Specimens of Nephrite from British Columbia; Trans. Roy. Soc., Canada, vol. VIII, sec. III, pp. 61-65.
Horwood, H. C. (1936): Preliminary Report, Nahatlatch Region; Geol. Surv., Canada, Paper 36-7.
Kunz, G. F. (1903): Am. Jour. Sci., 4th ser., vol. XVI, p. 397.
Lay, Douglas (1940): Fraser River Tertiary Drainage History in Relation to Placer-gold Deposits; British Columbia Dept. Mines, Bull. No. 3.
Mathews, W. H. (1944): Glacial Lakes and Ice Retreat in South-central British Columbia; Trans., Roy. Soc., Canada, sec. IV, pp. 39-57.
MacKay, B. R. (1926): Hat Creek Coal Deposit, Kamloops District, British Columbia; Geol. Surv., Canada, Sum. Rept. 1925, pt. A, pp. 164-181.
——— (1947): Report of the Royal Commission on Coal, 1946, Chapter I, Coal Reserves of Canada.
Reinecke, Leopold (1920): Mineral Deposits between Lillooet and Prince George, British Columbia; Geol. Surv., Canada, Mem. 118.
Rice, H. M. A. (1947): Geology and Mineral Deposits of the Princeton Map-area, British Columbia; Geol. Surv., Canada, Mem. 243.
Selwyn, A. R. C. (1872): Journal and Report of Preliminary Explorations in British Columbia; Geol. Surv., Canada, Rept. of Prog. 1871-72, pp. 16-72.
Smith, H. I. (1899): Archæology of Lytton, British Columbia; Amer. Mus. Natural History, Mems., vol. 2, pp. 129-424.
Stevenson, J. S. (1939): Copper-Tourmaline-Hematite Veins at Highland Valley, British Columbia; Toronto University Studies, Geol. Ser. 42, pp. 127-132.
——— (1940): Molybdenum Deposits of British Columbia; B.C. Dept. Mines, Bull. No. 9, pp. 9-11.
——— Uranium Mineralization in British Columbia; Econ. Geol., vol. 46, 1951, pp. 353-366.
Taliaferro, N. L. (1943): Franciscan-Knoxville Problem; Bull. A.A.P.G., vol. 27, pp. 109-219.
Thayer, T. P. (1948): Abstracts, Ann. Meeting of the Geological Society of America, pp. 64-65.
Thompson, M. L., and Wheeler, H. E. (1942): Permian Fusilinids from British Columbia, Washington, and Oregon; Jour. of Palæontology, vol. 16, No. 6, pp. 700-711.
Turner, F. J. (1948): Mineralogical and Structural Evolution of the Metamorphic Rocks; Geol. Soc., America, Mem. 30.
Uglow, W. L. (1922): Geology of the North Thompson Valley; Geol. Surv., Canada, Sum. Rept. 1921, pt. A, pp. 72-106.
Winchell, A. N. (1945): Elements of Optical Mineralogy, Part 2; John Wiley and Sons, Inc.

CHAPTER II

PHYSICAL FEATURES

INTRODUCTION

Three primary physiographic subdivisions of the Canadian Cordillera, namely, the Coast Mountains, the Cascade Mountains, and the Interior Plateau, are represented in Ashcroft map-area. The rugged terrain west of Fraser and Bridge Rivers is an eastern part of the Coast Mountains, which extend from Burrard Inlet at Vancouver northward into Yukon Territory, a distance of 1,000 miles, and locally reach a width of 120 miles. The ranges south of Lytton and east of Fraser River are the northernmost part of the Cascade Mountains, which have their greatest development south of the International Boundary. East of the Coast and Cascade Mountains lies the Interior Plateau, a deeply dissected plateau-like region that occupies much of the interior of southern British Columbia.

COAST MOUNTAINS

Immediately west of Fraser and Bridge Rivers the lofty peaks of the Coast Mountains rise like a wall to heights exceeding 5,000 feet. At intervals along this imposing barrier, mountain streams issue from deep canyons to join the Fraser. Many of the mountain torrents are no more than 3 or 4 miles long; but the larger valleys, occupied by such streams as Nahatlatch and Stein Rivers, and Kwoiek, Siwhe, and Texas Creeks, reach many miles to the west, and, along their relatively gentle gradients, provide natural access to the interior of the Coast Mountains. Many of these larger stream valleys and their tributaries were once occupied by glaciers whose former presence is evidenced by U-shaped valley profiles, and, at the heads of the valleys, by theatre-like cirques now occupied by tarns and small glaciers (*See* Plate I).

Areas underlain by metamorphosed stratified rocks, as in the southwestern part of the map-area and south of Lillooet, although including the highest peaks and most nearly perfect horns, consist in large part of rounded ridges and summits that make for relatively easy travel. Parts of the area underlain by granitic rocks are especially rough; ridges judged passable from a distance are commonly knife-edged, and are interrupted at frequent intervals by cliffs and castle-like prominences. Valley sides are in many places scarred by rock slides and avalanche tracks.

Many peaks of the Coast Mountains in Ashcroft area attain heights of 8,000 to 9,000 feet above sea-level, and Skihist Mountain and a few others exceed 9,500. Timber-line is reached, on the average, between elevations of 6,000 and 6,500 feet. At about 5,000 feet, the trees, mainly spruce, are tall and spindly, but above 5,500 to 6,000 feet, they become stunted and twisted, and tend to be arranged in clumps separated by alpine meadow land. At higher elevations only heather and alpine plants survive, and above 7,500 feet most of these are missing, leaving only the hardiest types, such as lichens and mosses.

CASCADE MOUNTAINS

The Cascade Mountains, whose northern tip extends into Ashcroft map-area and includes Jackass Mountain, Kanaka Mountain, and Mount Lytton, are separated from the Coast Mountains to the west by Fraser River. Their eastern boundary lacks sharp definition, but extends roughly southeast from Lytton into Hope map-area and thence across the International Boundary.

In general, the Cascade Mountains are lower, and less rugged than the Coast Mountains, differences probably due in part to the fact that the latter are formed largely of granitic rocks whereas bedded rocks predominate in the Cascades. In the case of the mountains southeast of Lytton, however, this explanation does not apply, for although their rolling summits resemble the plateau surface to the east more than the sharp-crested Coast Mountains to the west, they are composed almost entirely of granitic rocks. It seems probable, therefore, that differential elevation of the Coast Mountains with respect to the mountains southeast of Lytton was also an important factor in the physiographic history of these two mountain groups.

INTERIOR PLATEAU

Two-thirds of Ashcroft map-area lies within the Interior Plateau of southern British Columbia, an area of rolling uplands dissected by deep valleys.

Except for Blustry Mountain and Cairn Peak of the Clear Range, which rise to more than 7,600 feet above sea-level, the higher elevations in the plateau range between 6,000 and 6,500 feet. These heights are usually reached by gentle slopes from an elevation of 3,500 to 4,000 feet. In most places, particularly on southern and western exposures, such slopes resemble open parkland, and travel across them is easy, but northern slopes are commonly heavily wooded, and travel there more difficult. The steepest slopes are those from the valley bottoms to elevations of 3,500 to 4,000 feet. These may prove difficult of ascent, and along Thompson River, particularly near Lytton, a relief of 3,500 to 4,000 feet may be encountered within a lateral distance of 2 miles.

Valley bottoms and river benches, as around Ashcroft and Spences Bridge, are covered only by a light growth of bunch grass and cactus, thus presenting a bare, desert-like appearance. Many hillsides are free of vegetation, and much rock outcrop is visible. Not until an elevation of 2,500 to 3,000 feet is reached does timber appear, and as timber-line is at an elevation of about 6,500 feet, most of the summits in the plateau area are forested.

DRAINAGE AND DRAINAGE HISTORY

Ashcroft map-area is drained by Fraser River and its main tributary, the Thompson. Drainage directly tributary to Fraser River includes several important streams, such as Stein River and Texas Creek, from the Coast Mountains, as well as many relatively short creeks that head either east or west of Fraser Valley. Elsewhere the area is drained by Thompson River and its tributaries, of which the most important are Nicola and Bonaparte Rivers.

Earlier reports have indicated that the present principal drainage channels were established in late Cretaceous or early Tertiary time. Uglow (1922, p. 89A) describes a peneplaned surface on which the ancestral North Thompson River cut a broad valley. By early Tertiary time this valley had been eroded to about its present depth, and subsequently was partly filled by sediments of Eocene age. Lay (1940, p. 4) presents evidence of somewhat similar conditions along Fraser River. "In Eocene or earlier time, between Soda Creek and Quesnel, eruptions of the Lower Lavas caused extensive damming. Locally, lava filled the valley [Fraser Valley] to a depth of 1,200 feet or more, and the effects of damming were evident far north of Quesnel. Large and noteworthy remaining remnants of these dams through or past which the river now flows, are those in the vicinity of the mouth of Narcosli Creek, and the narrow gorge of the river between Marguerite and Soda Creek". Sedimentary strata of Eocene or later age were deposited in Thompson Valley near Spences Bridge, showing that the valley had been excavated in earlier times.

Fraser and Thompson Rivers and their main tributaries lie in deeply incised valleys several thousand feet below the upland surface of the Interior Plateau. Many of the minor streams, such as Nicoamen River and Barnes Creek, are characterized, in the rolling upland region, by low gradients and gently sloping valley sides, but in their lower courses, as they approach Thompson and Fraser Rivers, are marked by rapids and waterfalls. The sharp contrast between the upland surface and the incised valleys led Dawson and later workers to the conclusion that the region of the plateau had been eroded to a peneplain, and had since been elevated and deeply dissected by the master streams. It has also been suggested (Bostock, 1948, pp. 81-82) that the region of the Coast Mountains was similarly uplifted, and that the summit levels, sloping gently toward the west, represent an ancient erosion surface. There is some evidence of uplift and rejuvenation of the rivers in post-Miocene, probably Pliocene, time, for Miocene or earlier volcanic flows now form the walls of Thompson and Fraser Valleys at several points, and, as Drysdale (1914, p. 123) noted, Miocene or earlier volcanic rocks are bevelled by the upland erosion surface.

Although the drainage of the map-area was greatly disorganized during the period of Pleistocene glaciation, most of the streams have since managed to re-establish themselves along or near their former courses, and in some places have cut into their ancient rocky floors.

CHAPTER III

GENERAL GEOLOGY

GENERAL STATEMENT

Ashcroft map-area provides a bountiful record of sedimentary, volcanic, and intrusive rocks ranging in age from late Palæozoic to Cenozoic times.

The Cache Creek group, of late Palæozoic age, occupies a belt 40 miles long and up to 20 miles wide, extending from Martel station on the Canadian Pacific railway northwesterly, far beyond the northern boundary of the map-area. Rocks of this group are chert, argillite, minor quartzite, crystalline limestone, and altered volcanic rocks, for the most part closely folded and in many places metamorphosed to talc, chlorite, and sericite schist. These are considered to be the oldest rocks in the map-area. Certain areas west of Fraser River are underlain by unfossiliferous rocks, in part highly metamorphosed, that probably include members of the Cache Creek group.

Triassic rocks outcrop along Thompson River north and south of the town of Ashcroft. They include both sedimentary and volcanic types, mainly green, andesitic and basaltic flows with interbeds of hard, greenish grey agglomerate, grey limestone, quartzite, cherty agglomerate, and black shale. Marine fossils collected from the sedimentary strata are of Upper Triassic age, and the strata are, therefore, referable to the Nicola group, which underlies a large part of the adjoining Nicola map-area.

A series of fossiliferous strata composed of conglomerate, sandstone, and shale that underlies Thompson Valley in the vicinity of Ashcroft is of Middle and Upper Jurassic age.

Rocks of Lower Cretaceous age have numerous representatives within the map-area. Early Lower Cretaceous beds of the Brew group, consisting mainly of argillite, conglomerate, and quartzite, outcrop in the Coast Mountains south of Lillooet. A belt of Lower Cretaceous rocks along Fraser River has been subdivided into the Lillooet group and the Jackass Mountain group. The Lillooet group is composed largely of argillite and volcanic conglomerate. The Jackass Mountain group comprises three divisions: Division A consists mainly of greywacke and argillite, Division B of conglomerate and greywacke, and Division C mainly of greywacke.

The Spences Bridge[1] group of volcanic and minor sedimentary rocks occupies nearly 500 square miles of the map-area, mainly east of Fraser River. The rocks of this group consist of tuff, agglomerate, and breccia; green, red, and purple andesite; dark brown basalt; and some interbedded conglomerate and tuffaceous sandstone. Fossil plants collected from the sedimentary members are of mid-Lower Cretaceous age.

A group of sedimentary and volcanic rocks of late Lower Cretaceous age overlies the Spences Bridge group unconformably along Nicola River and underlies much of Nicoamen Plateau. These rocks are correlated with those of the Kingsvale group of the Princeton map-area to the southeast.

[1] Formerly spelled Spence Bridge.

Sedimentary rocks at the base of the group reach a thickness of 800 to 1,000 feet and consist of shale, conglomerate, tuffaceous sandstone, and argillite. These beds are succeeded conformably by a series of volcanic flows and breccias mainly of andesitic and basaltic composition.

Two small areas of conglomerate, sandstone, and shale found at Fraser River and Botanie Creek, near Lytton, are tentatively mapped with the Kingsvale group.

Conglomerate and sandstone underlie a small area at the eastern border of the map-area on Thompson River. Evidence found in the Nicola area to the east suggests that these rocks may be of either Cretaceous or Tertiary age.

On Fraser River, near the mouth of Siwhe Creek, non-marine conglomerate, breccia, arkose, shale, basalt, and volcanic conglomerate have a total thickness of about 4,500 feet. Fossil plants from these rocks indicate an Eocene age.

Sedimentary rocks of Miocene or earlier Tertiary age are exposed at several localities, and are particularly abundant in the northern third of the area. The largest belt of these rocks extends northward from McLean Lake to and beyond the northern boundary of the area, and consist of greenish grey conglomerate, grit, and sandstone. Light-coloured sandstone and shale, in upper Hat Creek Valley, contain lignite in considerable quantity. Small outliers of sedimentary rocks occur on both sides of Pavilion Creek and just south of Spences Bridge.

A great plateau in the northeastern corner of the map-area is underlain by lava flows with minor intercalated sedimentary beds. Fossil plants from the latter have been identified as of Miocene or earlier Tertiary age. The rocks are mainly basaltic lavas, with some associated breccias and tuffs.

Deposits of Pleistocene age are widespread in the map-area. Typical boulder clays are present in the upland areas and in valleys of the plateau country. Outwash deposits of sand and gravel, and silts laid down in glacial lakes are prominent along the main valleys. Recent fluvial deposits of sand and gravel floor the beds of the principal streams.

Batholithic rocks of the Coast intrusions are widespread and fall naturally into three major subdivisions, based on age and distribution. The oldest, the Guichon Creek batholith, exposed east and south of Ashcroft, consists of granite, granodiorite, quartz diorite, and diorite, and is probably of Lower Jurassic age. The Coast intrusions southeast of Lytton, with which are grouped numerous relatively small igneous bodies north of Lytton and east of Fraser River, consist mainly of granodiorite, but include some diorite, quartz diorite, and gabbro. These intrusions are probably of late Jurassic or early Lower Cretaceous age. Coast intrusions underlie large areas west of Fraser River; there they are composed mainly of granodiorite, and are believed to have been emplaced in early Lower Cretaceous time.

Serpentinized ultrabasic rocks were observed in various, widely separate parts of the map-area. Elongate bodies of considerable size outcrop in the Coast Mountains, and several narrow bodies of serpentine seem to be related to the zone of faulting that follows Fraser River. Bodies of serpentine associated with the Cache Creek rocks along Bonaparte Valley are of interest because of their chromite content.

Several small intrusive bodies, ranging in composition from hornblendite to albite syenite, cut the rocks of the Fraser River Cretaceous belt.

TABLE OF FORMATIONS

Era	Period or epoch	Formation		Lithology
Cenozoic	Pleistocene and Recent			Glacial drift, glacio-fluvial deposits; fan and fluvial deposits
	Unconformity			
	Miocene or later			Conglomerate; basalt, tuff, and agglomerate
	Not in contact			
	Miocene or earlier	Kamloops group		Basalt, andesite, rhyolite; associated tuffs and breccias
				Relations uncertain
			Coldwater beds (?)	Conglomerate, sandstone, and shale; coal
	Not in contact			
	Eocene			Sedimentary breccias, conglomerate, arkose, shale, basaltic lava, volcanic breccia
Not in contact				
Mesozoic and/or Cenozoic	Lower Cretaceous or later			Conglomerate, sandstone, and shale
				Not in contact
				Albite syenite, quartz diorite, hornblendite

Era	Period or epoch	Formation	Lithology
		Not in contact	
		Kingsvale group	Andesite, basalt, agglomerate; tuff, breccia
			Conformity
			Arkose, greywacke, shale, and conglomerate
		Unconformity	
		Spences Bridge group	Andesite, dacite, basalt, rhyolite; tuff, breccia, agglomerate; conglomerate, sandstone, greywacke, and arkose
		Fault contact with Spences Bridge group; overlain unconformably by Eocene sedimentary and volcanic rocks	
		Jackass Mountain group	Division A: greywacke, argillite, arkose, and conglomerate Division B: conglomerate, greywacke, and argillite Division C: greywacke, argillite, and conglomerate
		Fault contact	
		Coast intrusions west of Fraser River	Granodiorite and related minor intrusions
		Fault contact, but probably unconformably overlain by Jackass Mountain group	
		Lillooet group	Argillite, volcanic conglomerate, tuffaceous sandstone, conglomerate
		Not in contact with Lillooet group; cut by Coast intrusions west of Fraser River	
Mesozoic	Lower Cretaceous	Brew group	Argillite, quartzite, conglomerate

Era	Period or epoch	Formation	Lithology
	Relation to Brew group unknown; erosional contact with Spences Bridge group		
	Jurassic or Lower Cretaceous	Mount Lytton batholith (Coast intrusions)	Granodiorite, quartz diorite, diorite, and gabbro
	Relation not known		
	Middle and Upper Jurassic		Shale, conglomerate, and sandstone
	Erosional contact		
	Lower Jurassic	Guichon Creek batholith	Granite, granodiorite, quartz diorite, and diorite
	Intrusive contact		
	Upper Triassic	Nicola group	Basalt, andesite, tuff, agglomerate, limestone, quartzite, argillite, greywacke, and arkose
Relation uncertain			
Palæozoic or Mesozoic			Phyllite, quartzite, limestone, argillite, slate, conglomerate, greywacke, chert; greenstone; schist Schist and gneiss
In part correlative with above; probably unconformable with Nicola group			
Palæozoic	Permian and (?) earlier	Cache Creek group	Greenstone, chert, argillite; minor limestone and quartzite, chlorite and quartz-mica schist Marble Canyon limestone
Intrusive into metamorphic rocks of Palæozoic? and probable late Mesozoic age; intruded by Coast intrusions west of Fraser River			
Mesozoic?	Jurassic and/or Cretaceous?		Serpentinized ultrabasic rocks, hornblende diorite, hornblendite, amphibole schist

SEDIMENTARY AND VOLCANIC ROCKS

Palæozoic

PERMIAN AND (?) EARLIER

Cache Creek Group

Introduction. Rocks of the Cache Creek group underlie an area of about 400 square miles east of Fraser River. West of the river, three belts of rocks of doubtful age may comprise or include members of the Cache Creek group. Their description will follow that of this group.

The Cache Creek group consists of a thick assemblage of cherts, argillites, minor limestones and quartzites, andesite flows, agglomerates and tuffs, and their metamorphic derivatives, exposed along Thompson River and the Cariboo Highway from Martel to Cache Creek and north to Clinton. It also includes the massive, recrystallized limestones typically exposed in the Marble Canyon and Pavilion Mountains, and known as the Marble Canyon formation. This limestone, forming a distinct subdivision that may be mapped separately, contains minor intercalations of chert, argillite, and greenstone. Of the remainder of the group, some zones are characterized by a predominance of volcanic materials and others by a predominance of chert and argillite.

Rocks of the group were first studied by Selwyn in 1871, and were included by him in the first classification of rocks of British Columbia (1872, p. 54). His classification included a Lower and Upper Cache Creek group, the type locality for the former being near the settlement of Cache Creek. The Lower Cache Creek group included those rocks mentioned above as occurring along the Cariboo Highway from Martel to Clinton, whereas the 'Upper' group consisted mainly of the massive recrystallized blue-grey limestone known as the Marble Canyon limestone. In 1877, G. M. Dawson, after spending part of a previous season studying limestone beds of Carboniferous age near Stuart Lake, visited the Cache Creek rocks along Thompson River and Pavilion Lake that had been studied earlier by Selwyn. From both Selwyn's Lower and Upper Cache Creek groups Dawson collected fusulinids, which he identified as of Carboniferous age. This evidence of similar age of Selwyn's two groups together with their apparent conformity and interlocking characteristics led Dawson to believe that there was only one group of rocks here rather than two. During the seasons 1888 to 1890 Dawson again studied the Cache Creek rocks along Thompson and Bonaparte Rivers and Pavilion Lake, and his investigations confirmed his earlier belief. He, therefore, placed both of Selwyn's groups in a single unit, which he called 'Cache Creek formation', but still regarded the Marble Canyon limestone as the upper member. This general succession has been accepted in all subsequent geological investigations in this part of the province, but the term 'formation' has been replaced by the more appropriate term 'group'.

Distribution and Thickness. The main exposures of Cache Creek rocks in the map-area are part of a belt that extends from Thompson River northwesterly to and beyond the northern boundary of the map-area. The southern extremity of the belt lies just east of Thompson River at Toketic and has a width of about 2 miles. West and northwest of the river the belt widens, and near the northern boundary of the map-area has a width of more than 20 miles.

The Marble Canyon formation, which is widest in the northern part of the belt, does not outcrop along Thompson River but first appears as a narrow wedge 2 miles northwest of Martel station where it overlies argillites and greenstones. At Blue Earth Lake it has a width of 7 miles, but from Medicine Creek to the bend in Hat Creek it is covered by Tertiary basalts and sedimentary rocks. It outcrops again at the eastern entrance to Marble Canyon and in the Pavilion Mountains, where it has a width of 8 miles and a probable thickness of 6,000 feet. It is flanked on either side by an approximate equal thickness of cherts, argillites, greenstones, minor limestones, and quartzites.

Cherts, which form a large part of the group, are well exposed immediately west of the limestone belt in Pavilion Mountains. They outcrop in cliffs along Pavilion Creek east of the road junction, and form low, rounded outcrops in the vicinity of the road from Pavilion to Kelly Lake. North of the creek draining Kelly Lake they are less prominent.

The greenstones are most abundantly exposed immediately east of the Marble Canyon limestone belt in the Cornwall Hills and Oregon Jack Creek area. To the west of the limestone belt, they are more prominent near Fraser River than near the limestone contact.

Between Pavilion Lake and Fraser River, the Cache Creek rocks are extremely deformed and are now mainly schists. They have been intruded and highly metamorphosed by the granitic rocks exposed on Mount Martley and by the greenish altered diorite occurring east of the highway along Fraser River. Argillaceous rocks predominate in this region and are now rusty brown schists.

Though its aggregate thickness is undoubtedly great, probably 15,000 to 20,000 feet, deformation, metamorphism, general sparcity of outcrops below timber-line, abundance of relatively structureless volcanic rocks, and repetition of beds by folding and faulting, have prevented any accurate determination of the overall succession and thickness of the Cache Creek group. More precise knowledge of the succession, structure, and thickness of the group must, consequently, await the results of more detailed studies than were possible on the present scale of mapping.

Dawson's (1896, p. 47B) minimum estimate of the thickness of the group in this area was 10,000 feet, but he inclined to the belief it exceeded 15,000 feet. Though he was unable to find any sections sufficiently well exposed to be of use in determining the succession, he suggested the following as indicating the general composition of the group in the western part of Kamloops map-area.

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

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

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

The great width of limestone exposed in Pavilion Mountains is due probably to repetition of beds by folding and faulting. Near the western limit of the belt, dips are mainly to the west and southwest at about 60 degrees, but near the eastern boundary the dip though westerly is only about 20 degrees. These attitudes may indicate a synclinal structure with the western limb overturned to the east, but the amount of repetition resulting from minor folding and faulting is not known. It is probable that the limestone has a thickness of about 6,000 feet.

West of the Marble Canyon limestone in Pavilion Mountains, the succession of chert, argillite, minor volcanic material, and limestone dips regularly about 60 degrees southwest. Again the amount of repetition by folding and faulting is not known, but the succession has an estimated thickness of about 7,000 feet.

East of the Marble Canyon limestone in Pavilion Mountains the Cache Creek rocks are not well exposed. For a distance of about 2 miles immediately east of the limestone they are covered by Tertiary sedimentary rocks, beyond which greenstone schists and cherts outcrop intermittently. To the south, in the Cornwall Hills, greenstones and greenstone schists are abundant immediately east of the limestone, and farther east along Bonaparte River cherts and argillites predominate. These rocks have a probable thickness of between 6,000 and 7,000 feet and include Dawson's lower two subdivisions.

An estimation of the total thickness of the group depends upon the major structure, which, because of the difficulties referred to earlier, has not been worked out satisfactorily. If the major structure is synclinal, a possibility indicated by the few attitudes obtained in the limestone, and as suggested by Dawson, then the thickness is about 13,000 feet. If on the other hand the accumulations of cherts, argillites, andesites, minor limestones, and quartzites on either side of the Marble Canyon formation are distinct from one another, and separated by the limestone, then the group has a thickness of about 20,000 feet. Armstrong (1949, p. 33) describes a succession 24,000 feet thick that includes three limestone bands and four separate chert successions. In Ashcroft map-area rocks east and west of the limestone are not entirely similar. Immediately to the west, cherts and argillites predominate, but to the east greenstones are more prominent near the contact. The possibility exists, therefore, that in Ashcroft map-area the Cache Creek group consists of two successions of argillites, cherts, greenstones, minor limestones, and quartzites, separated by the thick series of Marble Canyon limestones.

Lithology. The sharp contrast in topography betweeen areas underlain by the Marble Canyon formation and adjacent areas is due mainly to the massive and prominent character of the limestone outcrops. The limestone forms some of the higher mountains in the map-area, and is recognizable from a great distance. Included within the formation but constituting less than 10 per cent of it are lenses of schist derived from andesites, cherts, and argillites.

Most of the Marble Canyon limestone is blue-white in colour, but white and cream phases were also observed. Locally, contained pyrite weathers so as to colour the surface of the limestone a rusty brown. The rock is of fine to medium grain and generally so massive that attitudes are difficult to obtain. Blue-grey to white, oval-shaped chert nodules 2 to 6 inches broad and about a foot long occur locally in the massive limestone, and through differential weathering are usually raised a little above the surface of the limestone. Most of the limestone has been recrystallized so that many of the original features have been lost. A thin section of the typical limestone showed a groundmass of minute crystals of calcite crossed by stringers of coarser crystalline carbonate. Analyses indicate that at least some of the limestone is very pure, running as high as 99 per cent $CaCO_3$ (Goudge, 1946, p. 225), but, locally, included siliceous material detracts from the purity. Fossil foraminifera have been collected from several localities along the belt.

West of the limestone belt in the northern part of the map-area fine-grained, dark grey to green, locally black, dense, cherty rocks occur in distinct beds 3 to 6 inches thick, and in places comprise several hundred feet of strata. Associated with these beds, referred to by Dawson (1896, p. 40) as "cherty quartzites", are minor amounts of greenstones and dark argillaceous material. The argillites commonly form thin schistose layers between the chert bands. Chert beds of this character form a distinctive part of the Cache Creek group in the Ashcroft area and have been reported from areas of Cache Creek rocks in other parts of the province.

The origin of such chert beds appears to be closely connected with contemporaneous volcanic activity, evidence of which is seen in the presence of abundant volcanic materials such as andesite flows and agglomerates. The theory postulated by Cairnes (1924b, p. 41) for the origin of the chert beds in the Cache Creek rocks of the Coquihalla area and for the Cache Creek cherts in general satisfactorily accounts for their origin in Ashcroft map-area. He puts forward the theory advanced by Davis (1918) for the origin of the Franciscan cherts of California. "The silica is regarded as having been derived from silicate solutions coming in part from the greenstones while the latter were being extruded or were in the process of consolidation beneath the sea, and in part from siliceous springs which derived their content from magmatic reservoirs beneath the sea bottom. The reactions of these silicate solutions, which were probably alkaline, with salts of sea water would precipitate gelatinous silica acid contemporaneously with the normal deposition of argillaceous material obtained by erosion from the adjoining low-lying land areas. The rhythmic segregation of the colloidal silica from these mechanical impurities—a phenomenon that has been produced experimentally—would account for the characteristic banding of cherts and slates which has already been referred to."

The argillites appear to be best developed in the region between Pavilion Lake and Fraser River where they have been greatly disturbed by later granitic intrusions and largely converted to schists. They occur throughout the group, usually in relatively thin beds interbedded with the cherts, greenstones, and minor limestones and quartzites. They vary from black to grey and are commonly coloured brown to reddish brown from the weathering of contained iron sulphides. The dark varieties contain carbonaceous material, which in places gives them a lustrous appearance. The rocks are hard and locally quite siliceous. Of the group they appear to have suffered most from shearing and now have a schistosity that is best developed in the western part of the Cache Creek belt.

The greenstones, which have their greatest exposure in the Cornwall Hills and around Oregon Jack Creek, are green to greyish green, massive, altered andesites, with some agglomerates and tuffs. Minor amounts of chert and dark schistose argillite and pods and minor beds of limestone are interbedded with the greenstones. The volcanic rocks exhibit almost no layering on which attitudes can be taken, are intensely sheared locally, and along Thompson River have suffered metamorphism by the Guichon Creek batholith to the east. Small stocks associated with this batholith have caused intense pyritization and silicification of the greenstones. The altered rocks show as red, yellow, and white outcrops in contrast with the general grey-green colour of the unaltered rocks and scrub vegetation. Many of these outcrops, bare of vegetation, consist of highly silicified greenstones, which, in the dry climate, are intensely coloured by the oxidation products of pyrite. In the vicinity of Oregon Jack Creek the greenstones have been sheared in a north 34 degrees west direction, with the planes of schistosity dipping 75 degrees southwest. They are now mainly silicified schists that, under the microscope, show scattered large quartz grains in a matrix of microcrystalline quartz. Minor amounts of carbonate, a few scattered grains of feldspar, and a little magnetite were also observed. Silicification of the greenstones in this region has been widespread, and 2 miles up Oregon Jack Creek from the highway crossing, abundant quartz stringers cut the greenstones in all directions in a zone that trends north 20 degrees west.

Limestones of the group, other than the Marble Canyon formation, occur in beds up to several hundred feet thick as well as in small lenses or pods interbedded with the other rocks. They range in colour from white to grey to black, and usually weather white or grey. They are fine- to medium-grained rocks and in places very pure. Several small lenses of such limestone may be seen near the road between Cornwall and Cache Creeks.

Quartzites form a very minor constituent of the Cache Creek group and occur rarely, interbedded with the argillites west of the main limestone belt. They are fine- to medium-grained rocks ranging from white to brown and red and commonly have a sugary appearance. They do not normally form any great thickness of strata, the largest bed observed being a white sugary quartzite about 30 feet thick near Martel, where it is interbedded with dark argillites, green cherts, and agglomerates.

Internal Structural Relations. As mentioned previously, the Cache Creek group has been severely deformed, and this, together with the lack of persistent recognizable horizon markers, has made it impossible to determine internal structures and thereby the sequence of the strata and their thickness. It is possible, locally, in areas of good exposures, to obtain sections across small parts of the group, particularly where the distinctive limestones are interbedded with the other rocks; but in large areas underlain by cherts, greenstones, and schistose argillites, determination of the detailed structure and sequence is difficult if not impossible. Strikes indicate a general northwest trend and dips with few exceptions are to the southwest, ranging from 20 degrees to as high as 80 degrees. Exceptional attitudes may be found in the vicinity of granitic intrusions. The persistent southwesterly dip suggests that the strata are overturned to the northeast, probably by pressure applied from the southwest during the period of intrusion of the batholithic rocks of the Coast Mountains.

The few attitudes observed across the limestones in the Pavilion Mountains suggest a synclinal structure overturned to the northeast, and farther south, near Blue Earth Lake, a minor syncline is indicated whose north limb strikes east and dips south. The possible major structure and consequent general sequence have already been outlined, but it is certain that any major structure is complicated by innumerable minor folds and faults both of which have caused repetition of strata.

Shearing and fracturing have affected the whole group in a direction roughly parallel with the strike of the rocks. The limestone beds have suffered less fracturing than the other rock types and have tended to recrystallize rather than fracture under pressure. In the Pavilion Mountains a set of joints in the limestone strikes north 65 degrees east and dips steeply northwest. This set parallels the large cross valley, just north of the map-area, in which lies Kelly Lake. Several narrow dark-coloured dykes that cut the limestone were also observed to trend in this direction.

North from Martel along the Cariboo Highway, rocks of the Cache Creek group are fairly well exposed. They strike generally north 15 to 50 degrees west and dip 25 to 70 degrees southwest. For a distance of about three-quarters mile north from Martel the rocks consist of black slaty argillites, white sugary quartzites, green-grey agglomerates, and rusty brown argillites. For the next mile the principal rock is a grey weathering, black limestone, interbedded with schistose greenstones and argillites. The railway, which here runs below the road, has exposed much of this succession, and the following paced section from south to north along the railway shows the intimate association of the limestones and greenstones as well as the repetition of beds by folding.

Beds and thickness (Feet)	Distance (Feet)	Description	Attitude
A 400	0–675	Black crystalline limestone	Strike, N.15°W., dip, 52°SW.
	675–725	Green schist	
	725–1,340	Black crystalline limestone	Strike, N.20°W., dip, 55°SW.
B 250	1,340–1,890	Schistose greenstones and argillites	Strike, N.50°W., dip, 50°NE.
C 90	1,890–2,040	Black crystalline limestone	
D 60	2,040–2,190	Chloritized schist	
E 25	2,190–2,225	Black crystalline limestone	
D 40	2,225–2,320	Sheared argillites and greenstones	
C 60	2,320–2,385	Black crystalline limestone	
B 130	2,385–2,605	Sheared argillite and greenstone	Strike, N.50°W., dip, 55°SW.
A 150+	2,605–2,755	Black crystalline limestone	
		End of outcrop	

The succession of beds and their attitudes indicate a syncline with the axis through limestone E, and an anticline to the south in group A to account for the great thickness of limestone in that part of the section. The beds have been thickened on the southwest limb of the syncline, but the minimum thickness of strata involved in the section is 400 to 450 feet.

Beyond the end of the limestone outcrop no rock is exposed for about 1,000 feet, to where black argillites and green cherts, striking north 17 degrees west and dipping 60 degrees southwest, outcrop for 2,000 feet. The next outcrops lie just north of Venables Creek where porphyritic flows and green lavas that are mainly andesite strike north 55 degrees west and dip 42 degrees southwest. About a mile north of Venables Creek outcrops are almost continuous along the highway for 3,500 feet and comprise the following from south to north:

	Feet
Greenstone	500
Dull grey, much deformed limestone	1,500
Interbedded limestone and greenstone	1,000
Greenstone	500

For the next mile intermittent outcrops near the road consist entirely of andesite and andesite agglomerate and their metamorphic derivatives.

All the Cache Creek rocks in this part of the area are much broken and silicified, indicating faulting and general brecciation along the west side of the Guichon Creek batholith.

External Structural Relations. Rocks of the Cache Creek group are in contact with nearly all other formations in the map-area, and in each instance have proved to be the older. No well exposed contacts were seen between the Cache Creek and Nicola groups and their structural relations could not be ascertained. The Cache Creek group has been intruded by the Guichon Creek batholith and by the batholithic rocks exposed on Mount Martley. It is unconformably overlain by the Jurassic rocks at Ashcroft, and at Toketic and several other places by late Lower Cretaceous volcanic rocks of the Spences Bridge group. Several small outliers of Tertiary volcanic and sedimentary rocks were noted resting unconformably upon rocks of the Cache Creek group.

Age. The age of the Cache Creek group has generally been considered to range from Pennsylvanian to Permian, and recent evidence tends to indicate that most of it is of Permian age. Few fossil collections were obtained, and most of these were foraminifera from the limestone members.

Selwyn (1872, p. 62) reports that Richardson collected fossils from a limestone bed near Venables Creek, and of these he says: "The limestones in one place were found to contain an abundance of fossils which though in very fragmentary condition, were sufficiently well preserved to throw some light on the age of the formation". The following genera were recognized: *Cyrtina, Spirifera, and Rhynchonella,* and the collections also included a small *Myalina* and a *Euomphalus*. Selwyn and Richardson (op. cit., p. 62) say of these fossils: "Though none of the above have been determined specifically they indicate a horizon between the base of the Devonian and the summit of the Permian". Selwyn and Richardson also collected fusulinids from the Marble Canyon limestone, which W. J. Dawson misidentified as *Loftusia* and considered to be probably of Eocene or Cretaceous age. In 1876, G. M. Dawson collected fusulinids from the thick limestone beds near Stuart Lake in northern British Columbia. The best preserved specimens from this locality agreed closely with those of Shasta county, California, named *Fusulina robusta* by Meek. As the genus *Fusulina* was considered characteristically Carboniferous, Dawson correlated the limestones with the 'Lower Cache Creek' group. In 1877, Dawson (1878, pp. 87-90) revisited Selwyn's original locality in Marble Canyon and collected more specimens of the fusulinids and *'Loftusia'*, and on the basis of the fusulinids assigned to the Marble Canyon limestones a Carboniferous age. He accepted the original identification of *'Loftusia'*, which he named *Loftusia columbiana*, but because of the accompanying fusulinids concluded it was a Carboniferous form rather than Cretaceous or Eocene. In 1932, C. O. Dunbar published an account of his restudy of the slides and sections used by Dawson, and his conclusion (1932, pp. 45-50) was that these slides were not from specimens of *Loftusia columbiana* but cf. *Neoschwagerina columbiana*, which would give the limestones in the Marble Canyon an age somewhere in the Permian. Dunbar says (op. cit., p. 48): "So far as the intrinsic evidence of *N. columbiana* goes it is therefore only possible to say that the limestone of the Marble Canyon is Permian, though the absence from the slides of the more advanced structural types of *Yabeina* and *Sumatrina* suggest a Lower or Middle Permian age rather than Upper Permian".

In 1933, Harry E. Wheeler spent several days in Marble Canyon collecting specimens from the type locality for later study. The results of this study were published (Thompson and Wheeler, 1942), and yield the following information (p. 702): "From a study of well oriented sections of *Loftusia columbiana* Dawson, it becomes obvious that this form should be referred to the genus *Yabeina* Deprat. In addition to *Y. columbiana* we have obtained from the Marble Canyon samples, representatives of one new species and one new variety of the genus *Schwagerina* Nioller, *S. pavilionensis* var. *acris*, poorly preserved specimens which we are referring to the genus *Nankingella* Lee and poorly preserved specimens which we are referring with question to the genus *Stafella* Ozawa". They further state, in the abstract from their paper: "The Marble Canyon limestones of British Columbia, and the limestones of central Oregon and Washington which contain *Yabeina* probably represent the youngest marine Permian known in America".

During field work by the present authors, foraminifera were collected from two localities in the Marble Canyon limestones, one near Blue Earth Lake, the other near the east end of Marble Canyon, just south of the road junction at the bend in Hat Creek. These collections were studied by R. T. D. Wickenden of the Geological Survey, who reports as follows: "The locality from the east end of Marble Canyon contains the usual large specimens of fusulinids previously identified as *Neoschwagerina* by Dunbar and *Yabeina* by Thompson and Wheeler. Both genera are closely related, and the use of the different names may only be a personal technicality. According to Dunbar (1932) the fossils indicate Middle or Lower Permian age, but Wheeler and Thompson conclude that the age is Upper Permian.

"The locality at Blue Earth Lake provided the same large *Yabeina* as the rocks at Marble Canyon, and a very large *Schwagerina*. The rocks at both localities are of the same age.

"This material was subsequently submitted to Dr. Dunbar, and though he admitted some of it showed characteristics of *Yabeina* he considers that this genus occurs in the upper part of the Middle Permian and that these rocks may be of Middle Permian age."

The evidence, then, indicates that much of the Cache Creek group in Ashcroft area is of Middle and possibly Upper Permian age. The lower limit of the group, which is not well defined, may be at some horizon in the Pennsylvanian.

Armstrong (1949, pp. 44-47), working in the Stuart Lake belt of Cache Creek rocks, made several fossil collections, including fusulinids, crinoids, blastoids, corals, and brachiopods. In summing up the evidence from these collections he says (op. cit., p. 46): "the conclusion is reached that the limestone lithological division includes strata in part of probable Upper Pennsylvanian age, in part of Lower Permian age, and in part of Middle Permian age". He redefines the Cache Creek group (op. cit., p. 50) as: "a very thick assemblage 20,000 feet or more, of interbedded sedimentary and volcanic rocks, mainly of Permian age, but probably in part of Pennsylvanian age. The whole of the Permian period may be represented. Foraminiferal limestones and ribbon cherts are characteristic of the group".

Palæozoic or Mesozoic

Metamorphic Rocks in Granitic Batholiths

Certain metamorphosed rocks, found in the Coast intrusions, consist mainly of lenses and patches of chlorite, hornblende, quartz-mica schists, and granitic gneiss. The largest single area of these rocks is on the southern slope of the Scarped Mountains along Thompson River. Some of the rocks in this particular area are identifiable as Cache Creek, but no specific correlation can be made for the others, which may well include strata of Triassic, Jurassic, or Lower Cretaceous age.

Rocks Near Keefers

A tongue of metamorphosed rocks of uncertain age extends northwest into the Coast Mountains from the vicinity of Keefers. Because of the complexity of the folds and the lack of horizon markers, the total thickness of strata is unknown. The rocks were examined along the Canadian Pacific railway by Dawson (1896, p. 101), and were mapped almost in their entirety by Horwood (1936). The assemblage is separated from other metamorphic rocks to the west by a more or less continuous belt of serpentine.

The most abundant rock type occurring in the belt is grey to dark grey, micaceous and graphitic phyllite. The rock is finely laminated, the beds commonly about $\frac{1}{16}$ to $\frac{1}{8}$ inch thick. Bedding and foliation surfaces are in most places parallel with one another, and are commonly minutely plicated. Numerous veins of sugary quartz lie mostly parallel with these surfaces. Under the microscope, the phyllite is seen to consist of a series of thin, subparallel layers composed of sericite and opaque argillaceous matter, probably graphitic, separating and surrounding impure lenticles of quartz, minor albite, and a little tourmaline.

Quartzites form a minor part of the section. Some are pale grey to bluish grey, thinly banded, fine-grained rocks composed almost entirely of quartz. Other, impure, quartzites contain scattered biotite or a little carbonate. Thin sections of the impure quartzites are seen to be composed of quartz with minor carbonate, albite, chlorite, zoisite, biotite, and opaque matter.

Blue-grey and grey limestone and marble occur at intervals throughout the belt of rocks under consideration. Although the beds average about 6 feet in thickness, one at least 80 feet thick was seen.

'Greenstone' is intercalated with the sedimentary rocks in moderate abundance, but is commonly sheared and recrystallized, with consequent destruction of original textures, so that its origin is obscure. The most common variety is a greenish grey to green phyllite, locally faintly banded, and possibly of pyroclastic origin. Hand specimens of a few massive types show scattered patches of chlorite that possibly represent the altered mafic minerals of an igneous rock. These greenish rocks are probably derived in part from volcanic material, and, possibly, in part from basic intrusions. Under the microscope, they are seen to consist largely of chlorite through which is scattered more or less carbonate and quartz. Most of them contain, in addition, a pleochroic amphibole, probably actinolitic, with an extinction angle ranging from 16 to 19 degrees. Other minerals observed are albite, chlorite, biotite, epidote, zoisite, and magnetite.

From Kwoiek Creek north, the belt is composed largely of dark amphibole schists, with which are interbedded some mica schists, quartzites, and marble. A schist from the north fork of Kwoiek Creek consists largely of a pleochroic amphibole with subordinate andesine, quartz, and magnetite.

Strata, for the most part considerably less metamorphosed than those described so far, outcrop along the east side of Fraser River about opposite Keefers. They comprise laminated dark grey to black argillite and slate with minor limestone and quartzite, and total several hundred feet in thickness. They appear to grade into the more highly metamorphosed rocks lying west of Fraser River, and are included with them.

West of Fraser River dips are high, most of them exceeding 60 degrees, and in many places they are nearly vertical. The presence of major throughgoing folds could not be established, and the structure remains obscure.

The strata are invaded by the Coast intrusions. A major fault, separating these rocks from the Lower Cretaceous beds to the east, will be discussed in Chapter IV. The strata are bounded on the southwest by a more or less continuous belt of serpentine along which there has possibly been some faulting.

No fossils have been found in the rocks near Keefers and their age is uncertain. In the presence of limestone and greenstone, the rocks resemble the Palæozoic or perhaps Triassic formations of the district, rather than those of middle or late Mesozoic age. For lack of more definite information, it is concluded that the rocks are probably late Palæozoic in age, but may include younger formations.

Rocks near Lillooet and Texas Creek

Unfossiliferous and metamorphosed rocks extending from the western edge of the map-area near Lillooet south to Siwhe Creek, and also underlying an area at the headwaters of Texas Creek, are probably partly, at least, Cache Creek. Their aggregate thickness is unknown, but is fairly certainly at least 7,500 feet, and probably exceeds 10,000 feet.

The rocks consist of argillite, slate, phyllite, quartzite, greywacke, chert, limestone, and greenstone. Black, dark grey, and pale grey argillaceous rocks, in most places slaty, and locally having a phyllitic sheen, are abundant. Cleavage is in most places parallel with the bedding, and the foliation surfaces are not uncommonly corrugated or minutely wrinkled. Quartzites show considerable variety: some are pale grey to brown and fine grained, but minutely sugary in texture. Others are less pure, and contain paper-thin layers of argillite alternating with thin laminæ of quartzite. Greywackes and pebble-conglomerates containing more or less deformed granules and pebbles up to ¼ inch across are not uncommon. Highly sheared greywackes are characterized by smeared-out films of argillite on foliation surfaces. Greywacke and pebble-conglomerate, not easily distinguished from Lower Cretaceous types, were found northwest of the mouth of Intlpam Creek, west of beds of chert. Pale grey cherts and cherty quartzites, common along the eastern border of this assemblage, are generally massive, forming outcrops in which bedding structures are obscure. Limestones are moderately abundant, occurring in beds up to 4 feet thick. The limestone, some of which is banded, locally contains nodules that are prominent on weathered surfaces.

Greenstones show considerable variety. Some are greenish, fine-grained rocks containing much chlorite, and are only slightly foliate; others are strongly foliate. Certain pale greyish green foliated greenstones show crosscutting relations, suggesting that many other lithologically similar but concordant greenstones are altered sills. Hornblende schists are common near the headwaters of the north fork of Texas Creek.

In the narrow gorge east of the outlet of Seton Lake, the rocks are highly metamorphosed and contain numerous sills and small irregular masses of granodiorite probably related to the elongate intrusion south of Lillooet. Metamorphic rocks of many types include biotitic quartzite, marble, hornblende schist, quartz-mica schist, and granitic gneiss.

The following is a roughly approximate section measured along the north-trending ridge east of the head of the north fork of Texas Creek:

	Thickness Feet
Top of section	
Hornblende schist, rusty quartzite, attitudes irregular..........	?
Mainly hornblende schist; some quartzite; a few 6-inch beds of limestone..................................	840
White mica-quartz schist; some blue-grey quartzite; locally biotitic quartzite.	600
Grey slate, partly well laminated; a few 2-foot beds of limestone	150
Grey slate with abundant rusty quartz veins	920
Mainly pale grey slate and phyllite; some grey, limy schist..	1,150
Quartz-white mica schist, grey and limy; some slate.........	100
Steel-grey slate and white mica phyllite	300
Gap, possibly a concealed fault, attitudes irregular..........	300
Mainly pale to dark grey slate; minor quartzite; occasional beds of sheared arkose and fine-grained conglomerate....	1,200
Slaty argillite, some with white mica on bedding planes; a little fine-grained quartzite, and a few beds of nodular limestone.	1,800
Total thickness.	7,460

The structure between Seton Lake and Texas Creek is apparently anticlinal. Southeast of Texas Creek, dips are steep, both to the northeast and southwest, and the structure is not understood. In the upper part of Texas Creek, the beds dip fairly uniformly to the southwest at high angles. Their relation to the strata extending from Lillooet to Siwhe Creek is not certain. It may be pointed out, however, that part of the eastern assemblage lying west of the elongate intrusion south of Lillooet is lithologically similar to those beds at the head of Texas Creek.

The eastern assemblage is in contact on the northeast with rocks of the Lillooet group along a steeply dipping fault. On the southwest it is separated from the rocks of the Brew group by a fault whose course is marked by disturbance in adjoining strata and by a wide rusty zone. Both assemblages are cut by rocks of the Coast intrusions.

No fossils have been found in any of these rocks. Dawson, whose study of the belt was mostly limited to the eastern exposures, assigned the rocks to the Cache Creek group, because chert, argillite, greenstone, and serpentine are common to both. Farther west, away from Fraser River, cherts are less conspicuous or are lacking, and the resemblance of the rocks to those of the Cache Creek group is less striking. More detailed work may reveal Mesozoic rocks among these strata.

Rocks Northwest of Nahatlatch Lake

A belt of metamorphosed strata extending from Nahatlatch River northwest to the western edge of the map-area is bounded on the east by the main serpentine belt, and on the west by the granitic rocks of the Coast intrusions. The thickness of the strata involved is many thousands of feet, but, because the structure and stratigraphic succession are unknown, close estimates are impossible.

The rocks consist mainly of grey phyllite, argillite, conglomerate, and greywacke. Near intrusive contacts, they have undergone considerable metamorphism.

Grey to black phyllites are the most common rocks of the belt. Many specimens show rusty cubic pits that were originally occupied by pyrite, and others show minute knots that are probably incipient porphyroblasts. Foliation surfaces are commonly minutely plicated. Stringers of clear, sugary quartz, averaging about ⅛ inch in thickness, lie roughly with the foliation. In places the phyllite contains abundant crystals of andalusite up to 2 inches long; these are so crowded in certain layers as to form most of the rock, and locally are completely altered to muscovite. Under the microscope, the average phyllite is seen to consist of carbonaceous matter, quartz, albite, and white mica.

Grey, laminated argillites are less common than the phyllites, but are well developed on the ridge east of Kwoiek Needle in the forks of Log Creek. Laminæ average about 1 inch in thickness, and show grain gradation. The rocks resemble those exposed in railway cuts along the Canadian Pacific railway north of North Bend in Hope map-area.

Conglomerate, associated and interbedded with dark phyllite and impure quartzite, is found at many localities in that part of the belt north of Kwoiek Needle and west of the serpentine belt. Beds are commonly

only a few feet thick, but two, 30 and 40 feet thick, were seen. At least some of the beds are lenticular. At one locality, where the conglomerate is only moderately sheared, roundstones up to 9 inches by 4 inches were noted, but mostly they range from ½ inch to 2 inches in diameter. At most exposures, the conglomerate is highly sheared and the enclosed pebbles greatly elongated, so that it is difficult to determine their original nature. Many pebbles are of a pale brownish grey aphanitic rock possibly of volcanic origin. Others, showing porphyritic and granitic textures, are undoubtedly of intrusive rocks. Pebbles of coarse greenstone and of cherty material were also noted. The matrix of the conglomerate ranges from a pale, unfoliated rock through a micaceous, graphitic phyllite to a glistening, fine-grained mica schist.

Light grey to grey, massive, fine-grained rocks, apparently originally impure sandstones or greywackes, are fairly abundant. A thin section of such a rock was seen to be composed of recrystallized grains of quartz, surrounded by a rather abundant matrix consisting of white mica and chlorite. Another contained much carbonate and zoisite, and a third, some biotite in addition to quartz, chlorite, and white mica.

Greenstones are not abundant in this succession and are not markedly different from those lying to the east of the serpentine belt.

Close to the batholithic rocks, the strata have been subject to strong metamorphism, and distinctive minerals have formed, of which brown garnets are the most conspicuous. A glistening phyllite from a point just east of the stock near Kwoiek Needle consists largely of biotite and quartz, with minor garnet, chloritoid, sericite, and magnetite. A thin section of a rudely foliated rock consists of a mosaic of quartz and parallel alined biotite, the C-axes of the quartz grains tending to lie parallel with the plane of foliation. Staurolite, characteristically twinned, a little muscovite, tourmaline, and considerable opaque material comprise the rest of the rock. Cordierite, garnet, blue-green amphibole, and quartz are the principal components of a laminated rock of sedimentary origin occurring close to the small stock about 3 miles south of Akasik Mountain.

The bedding planes, in general, dip steeply, mostly between 70 degrees and vertical. Only rarely, however, can the direction of tops be determined, so that little can be said of the nature of the folds beyond that they are tight and possibly isoclinal.

The strata extend southeasterly into the adjoining Hope map-area, where they appear to include representatives of the Upper Jurassic or (?) Lower Cretaceous Ladner group (Cairnes, 1944). They also afford several points of similarity with the rocks of the early Lower Cretaceous Brew group, which is found southeast of Lillooet. Both successions include great thicknesses of argillaceous rocks in which distinctive laminated types are included. Conglomerate members are common in both. The presence of granitic roundstones in the conglomerates suggests a Mesozoic age, for no Palæozoic granites are known in the district. Although the evidence is not conclusive, it seems probable that the rocks of this belt are, in part at least, of Mesozoic, perhaps late Mesozoic, age.

Mesozoic

TRIASSIC

Nicola Group

Introduction. Rocks of the Nicola group are well exposed at the type locality in the adjoining Nicola map-area east of Ashcroft area where they were recently restudied by W. E. Cockfield (1948). In the type area they consist principally of volcanic rocks, with which are associated minor amounts of limestone, argillite, and conglomerate. The volcanic rocks may very largely be grouped under the general term greenstones, but include green, red, or grey lavas with breccias, tuffs, and agglomerates. The lavas are mostly andesites and basalts, and vary from fine-grained types to coarsely porphyritic rocks. In places thin bands of argillite, lenses of limestone, and, more rarely, thin beds of conglomerate are present.

Distribution. Rocks assigned to the Nicola group outcrop mainly along or near Thompson River, from Spatsum to the eastern boundary of the map-area. The outcrops are not continuous, for the group is intruded by narrow bodies of granite, overlain by rocks of Jurassic age at Ashcroft, and covered by Tertiary lavas at McAbee. East of Barnes Lake, small areas of Nicola rocks occur as roof pendants in the Guichon Creek batholith.

Just above the confluence of Nicoamen and Thompson Rivers, on both sides of the Thompson, is a limited area of green andesite, green and red porphyritic flows, and agglomerates cut by granite. The assemblage closely resembles rocks of the Nicola group and has been assigned to it on lithological grounds. Complex faulting in this particular region has brought these rocks to the surface.

Greenstones and siliceous schists intruded by granitic and other dykes outcrop within a small area opposite the mouth of Spius Creek on Nicola River. This area is part of a much larger area of Nicola rocks mapped by Cockfield (1948) in Nicola map-area.

Between Spatsum and Basque on the Canadian Pacific railway, and lying as a narrow selvage ½ mile to 2 miles wide between the edge of the Guichon Creek batholith and Thompson River is a series of interbedded greenstones, agglomerates, quartzites, greywackes, and limestones. The limestones have yielded fossils of Upper Triassic age, and on the basis of these fossils the rocks have been assigned to the Nicola group.

Lithology. In Ashcroft area volcanic rocks of the group consist in part of dark green, medium-grained lavas ranging in composition from andesite to basalt that may be included under the general term 'greenstone'. Fine-grained, red, andesitic lava, grey, porphyritic lava, and grey, green, black, and purple agglomerates are common. Some of the agglomerates are hard and siliceous. The size of the fragments is usually not greater than 1 inch.

Beds of white to grey, fine-grained, fossiliferous limestone, 50 to 250 feet thick, thin-bedded, grey to green quartzites and greywackes, and dark impure argillites, may be interbedded with the volcanic rocks.

One bed of massive, blue-grey limestone, containing chert stringers and nodules, and resembling closely the Marble Canyon limestone, outcrops northwest of the intersection of the highway and Venables Creek. Poorly preserved fragmentary fossils collected from this bed included a belemnite cast, indicating a Mesozoic age. On the basis of these fossils this limestone was assigned to the Nicola group.

Silicification and carbonatization of the greenstones and porphyries have been caused by the intrusion of granitic and other dykes at Canford and on the Fairview group of claims. Some of the limestones in the bedded strata at Basque are slightly garnetiferous near their contact with the Guichon Creek batholith.

Structural Relations. In Ashcroft area almost every exposure of Nicola group strata shows some evidence of intrusion in the form of dykes, tongues, and cupolas of granite. On the Fairview group of claims near the eastern boundary of the area and near the granitic intrusion there, north trending fractures in the Nicola rocks contain zinc and copper minerals. The bedded rocks near Basque have been intruded by tongues and cupolas of the Guichon Creek batholith, but strike generally east to northeast and dip north to northwest at 15 to 50 degrees. Near the faulted contact with the intrusive body they have a local strike of north 20 degrees west and dip 75 degrees southwest. A traverse across these bedded Nicola rocks, from the eastern end of the railway bridge at Basque southeasterly to the contact with the Guichon Creek batholith, crossed approximately 6,400 feet of strata, which comprised:

	Thickness Feet
Interbedded, hard, dense, grey-green agglomerates, and white to grey, fine-grained limestone; minor quartzite	800
Grey to green, dense, siliceous agglomerates; dark, fine-grained quartzite, and dark argillite	2,600
Thinly bedded, fossiliferous, dark, limy argillites; grey limestone, minor quartzite, and greywacke	3,000

No well-exposed contacts of Nicola rocks with those of the Cache Creek group were observed, so that their structural relations are uncertain. Near Ashcroft, rocks of the Jurassic belt overlie the Nicola rocks unconformably. Tuffs and conglomerates of the Lower Cretaceous Kingsvale group overlie Nicola rocks unconformably near Canford, and near Semlin and McAbee, Tertiary basaltic flows were observed resting on rocks of the Nicola group.

Age. The only diagnostic fossils found in rocks of the Nicola group within the map-area were obtained from the strata at Basque, at an elevation of 3,800 feet, 2 miles east of the railway bridge that crosses Thompson River south of Basque station. The fossils occur in a limy argillite, interbedded with arenaceous strata. From the fossils collected, F. H. McLearn of the Geological Survey identified three genera of ammonites, *Paratropites* cf. *spepsumensis, Discotropites,* and *Protrachyceras,* and two species of the pelecypod *Halobia*: *Halobia* cf. *cordillerana* Smith, and *Halobia* cf. *pacilis.* These fossils, according to McLearn, indicate an age comparable with the Karnic of Upper Triassic time.

No fossils of Jurassic affinities, such as were mentioned by Dawson (1896, p. 112B), were found, and in view of the evidence accumulated since Dawson's time it seems hardly possible that any part of the group could be of Jurassic age.

JURASSIC

Jurassic Rocks at Ashcroft

Distribution. The town of Ashcroft lies about midway of a belt of marine Jurassic sedimentary rocks, 4 miles in width, that extends northerly for 15 miles from the vicinity of Basque station to the escarpment of Tertiary lavas north of Cache Creek. In the southern part of the belt the rocks are evenly distributed on either side of Thompson River, but farther north the river turns east and the entire belt lies between it and the Tertiary escarpment to the west. Rocks of this belt underlie most of the low country around Ashcroft, and, though largely covered by river deposits, are well exposed in railway cuttings, rock canyons, such as the 'Black Canyon', and in the lower hills on either side of Thompson River. The prominent bare rounded hills across the river from Ashcroft are composed almost entirely of these rocks, which have a total thickness of about 5,000 feet.

Lithology. Rocks comprising the Jurassic belt consist of conglomerate and sandstones interbedded with fossiliferous black shale. The sandstones, which are largely arkosic, are mainly finer grained phases of the conglomerates, and the black shale at some horizons includes thin beds of green to fawn feldspathic sandstone. The conglomerates occur in the lower parts of the succession and are composed of roundstones of granite, and rocks derived from the underlying Cache Creek and Nicola groups. The dark fossiliferous shales are more abundant in the upper parts of the succession and are well exposed near the mouth of Minaberriet Creek. This assemblage is quite distinct from the surrounding rock groups, from which it can readily be separated.

The conglomerate at the base of the Jurassic series is a coarse, greenish grey rock composed of well-rounded fragments up to boulder size of the underlying rock formations, held together in a limy matrix. It grades upward into a coarse greenish grey arkose, also with a limy cement. The conglomerate may be seen east of Thompson River near the Highland Valley road, where it overlies the granitic rocks of the Guichon Creek batholith. This accumulation of conglomerate and arkose at the base of the series has a thickness of about 500 feet. Separated from this basal accumulation of conglomerate and arkose by about 1,400 feet of black shale, is a second accumulation of conglomerate and sandstone about 1,000 feet thick. This second conglomerate differs little from the basal bed in the nature of its component roundstones, but its matrix is arenaceous rather than limy. Above this lies about 2,000 feet of black shale that is characterized at some horizons by the presence of thin beds of fawn to grey, feldspathic sandstone. These black shales are well exposed where Minaberriet Creek descends into Thompson River. In 1926 Crickmay (1930, p. 37) studied this belt in some detail and measured the following section:

Top of section	Thickness Feet
Black shale	600
Sandstone and thin shale beds	360
Black shale	1,000
Conglomerate with sandstone	1,130
Black shale with sandstone beds in some parts	1,370
Calcareous arkose above basal conglomerate	467
Total thickness	4,927

Structure. Nearly everywhere the Jurassic shales have been much disturbed and crushed, but the more massive conglomerate beds are less deformed. The belt appears to have been preserved in a synclinal trough between hard resistant rocks of the Nicola and Cache Creek groups. Near Basque, in the south the belt strikes nearly north and dips are westerly, but from the vicinity of Cornwall Creek north the rocks trend northwest and are folded about axes striking north 35 degrees west. Opposite Ashcroft dips of 62 degrees northeast were observed, and near Cache Creek, dips are as high as 75 degrees southwest.

Contacts with rocks of adjacent groups were noted in several places. On the west slope of the bare hill that extends south from Cornwall Creek, between the highway and Thompson River, basal conglomerate of the group overlies lavas of the Nicola group. The contact strikes north 60 degrees west and dips 20 degrees northeast. Near the mouth of Barnes Creek, black shales strike north 35 degrees west and dip 64 degrees southwest. Along the eastern border of the belt, near the Highland Valley road, conglomerate with a highly calcareous matrix may be seen overlying granitic rocks of the Guichon Creek batholith.

About ¾ mile east of Basque is a small isolated patch of Jurassic rocks, the position of which may be due to faulting. The adjoining rocks are greenstones, porphyritic flows, and agglomerates of the Nicola group, and some granite. The inclination of the Jurassic rocks in this area rarely exceeds 20 degrees, but the strike is irregular. At the base of this sedimentary patch, and resting directly on hard, dense, green, porphyritic lava of the Nicola group, is conglomerate composed at the base of large, subangular, granitic boulders and grading upward into conglomerate consisting of well-rounded pebbles, the matrix throughout being limy.

On the west side of Cache Creek, where that stream emerges from the Tertiary escarpment, Jurassic shales and sandstones were found dipping westward at from 44 to 70 degrees. They appear to lie unconformably on rocks of the Cache Creek group, which here have reached the surface on a small subsidiary fold and now form a very small wedge-shaped area in the centre of the younger rocks.

Rocks of the Jurassic belt were observed to be overlain unconformably by Tertiary lavas. Flat-lying rhyolite porphyry and columnar basalt overlie Jurassic rocks east of the Highland Valley road near the southern extremity of the belt; on the west side of Barnes Lake, similar rhyolite porphyry overlies sandstones and shales of the Jurassic series; and to the east of Bonaparte River and south of the highway to Kamloops, roughly columnar basalt, 75 to 100 feet thick, forms a flat-topped hill and overlies rocks of the Jurassic belt.

Age. These Jurassic rocks were first studied and reported on by Dawson (1879, p. 111B), who classified them as Mesozoic and referable in part to the Lower Cretaceous Jackass Mountain group. Later, Dawson (1896, p. 154B) states: "No fossils have been found in any part of this area, but its lithological identity with the Cretaceous of adjacent parts of the Fraser Valley is sufficient to fix its Cretaceous age".

In 1912, C. W. Drysdale (1914, p. 139) found specimens of a very large, coarsely ribbed pecten, on the hill opposite the mouth of Barnes Creek, which was examined and reported on by T. W. Stanton as follows: "So far as the characters are preserved, this specimen might be Jurassic, Cretaceous, or Tertiary, but is probably from the Jurassic". However, Drysdale correlated these rocks provisionally with the Queen Charlotte Islands formation of Lower Cretaceous age, with which Dawson had included the Jackass Mountain conglomerate.

During his detailed study of these rocks in 1926, Crickmay (1930) collected abundant ammonites and pelecypods, which he identified as of Middle and Upper Jurassic age. According to him the beds at the base of the succession are characterized by the pelecypod *Pleuromya rhyncophoria* and the ammonite *Fontannesia* cf. *carinata,* indicating an early Middle Jurassic age. From the shales outcropping along the banks of Thompson River, and in the Black Canyon, 2 miles below the mouth of Cornwall Creek, Crickmay collected numerous specimens of ammonites, which he identified as '*Gowericeras*' sp. and which, according to him, represent a Callovian stage in early Upper Jurassic time.

During field work for this report, fossils were collected from the black shales on Minaberriet Creek and in the Black Canyon. The collections were reported on by Hans Frebold of the Geological Survey of Canada as follows:

"The collection from the Black Canyon contains various indeterminate pelecypod species and some ammonites. The latter are poorly preserved, but judging from the general shape of the specimens and the type of ribs, probably belong to the genus *Seymourites.* There are forms with fine ribs and others with strong ribs, so it seems possible that different species are represented. Their age, if *Seymourites,* is Callovian (lower Upper Jurassic).

"In addition to indeterminate pelecypods, the collection from near the mouth of Minaberriet Creek contains some very poorly preserved ammonites, which may belong to the genus *Seymourites,* and, if so, are of Callovian age".

LOWER CRETACEOUS

Introduction

Rocks of Lower Cretaceous age are abundant in Ashcroft map-area. One belt of mainly sedimentary rocks lies along or adjacent to Fraser River Valley. Another extends northwest into the Coast Mountains from a point near the mouth of Siwhe Creek. A third belt, consisting mainly of volcanic rocks, extends across the map-area from the southeast to the northwest corner. Rocks of the sedimentary belts are assigned to the Brew, Lillooet, and Jackass Mountain groups. The volcanic rocks are included in the Spences Bridge and Kingsvale groups.

The Brew group lies to the west of Fraser River in the Coast Mountains. The rocks of this group had been examined at only a few points by Dawson, and were referred by him to the Cache Creek formation. The Lower Cretaceous rocks along Fraser River were first reported on by Selwyn (1872), who described the strata exposed along the road at Jackass Mountain south of Lytton and assigned them to the Jackass Mountain Conglomerate group. The name was later changed to Jackass Mountain group by Dawson, who included the group in the Queen Charlotte Islands formation. The latter name is no longer in good standing, for the type section to which the name was applied was long ago shown to include both Jurassic and Cretaceous strata separated by an unconformity. The rocks of Ashcroft map-area included by Dawson in the Queen Chalotte Islands formation have been subdivided, and most of them are now included in the Lillooet and Jackass Mountain groups.

Two volcanic assemblages, found along Nicola River, were referred to by Dawson as the 'Lower Volcanic' and the 'Upper Volcanic' groups. They are separated by a sedimentary series, and were considered to be of Tertiary age. This succession has since been shown to comprise both early upper Lower Cretaceous and late Lower Cretaceous rocks. The older volcanic assemblage, now known as the Spences Bridge group, is overlain unconformably by the sedimentary and volcanic formations that comprise the Kingsvale group.

Brew Group

Distribution. The Brew group, named after Mount Brew, a prominent peak composed largely of rocks of this group, underlies a belt south of Lillooet extending from the vicinity of Mount Brew southeast to a point near Fraser River. Fossils collected from these rocks indicate a Lower Cretaceous age. The group is probably at least 8,500 feet thick and may be considerably thicker.

Lithology. At, and south of, Mount Brew the Brew group consists of argillite, quartzite, conglomerate, and metamorphic derivatives of these rocks. The lower part of the group is at least 2,600 feet thick and probably more than 4,500 feet thick. It consists mainly of blue-grey argillite and fine-grained quartzite, but includes some grey, brownish, and black types. A few beds of pebble conglomerate and a highly fossiliferous bed of light grey quartzite occur within the upper few hundred feet of this part of the group. The argillites and fine-grained quartzites are locally well bedded, laminæ being commonly about ½ inch thick. They have been metamorphosed, and show considerable development of biotite, which occurs as distinct flakes up to 2 mm. across; equidimensional reddish garnets are scattered through the rock.

Boulder conglomerate, locally at least 600 feet thick, overlies the succession described above. The boulders are well rounded, up to 8 inches in diameter, and generally closely packed. At several places it was observed that extremely elongate boulders lay in parallel orientation, probaby as a result of deformation. The boulders show considerable variety in appearance, but because they have been metamorphosed their identification is difficult. Many of them are of buff to white, fine-grained rocks possibly of volcanic origin. Others are coarse grained and of granitic texture, resembling diorite. Still other types noted include dark argillite, quartzite, coarse-grained gneiss, and vein quartz. The matrix is a quartzite showing much secondary biotite.

Banded argillite and impure quartzites, totalling at least 3,200 feet in thickness, overlie the conglomerate. Locally these rocks show varve-like bedding. They lie, in part, near a tongue of granodiorite and are considerably metamorphosed, mainly to somewhat foliated biotitic quartzites.

Microscopic examination of a thin section cut from an imperfectly foliate specimen of grey argillite from the lowest division of the group revealed a fine-grained, irregular mosaic of quartz and white mica through which are scattered metacrysts of biotite and magnetite. A little epidote, chlorite, clinozoisite (?), and carbonate comprise the balance of the rock. Another section, from a specimen of dark grey, almost black, argillite, from the same lower division, was seen to consist largely of quartz and opaque matter, probably largely carbonaceous, with minor metacrysts of biotite containing sigmoidal trains of inclusions of opaque material. Some carbonate, magnetite, and a little white mica, are scattered through the rock. Two other specimens from the same division of the group were obtained from the gorge of Texas Creek and closely resemble the argillite first described except that they contain euhedral garnets. A laminated specimen from the uppermost division consists of alternate thin beds of arenaceous and argillaceous material. Under the microscope, the arenaceous beds are seen to consist largely of an interlocking aggregate of quartz with minor plagioclase (about An_{25}) twinned invariably, so far as could be determined, according to the pericline law. Scattered through the aggregate are metacrysts of biotite and a little magnetite. The argillaceous bands are composed largely of quartz and plagioclase, with considerable opaque material, probably largely carbonaceous, biotite, abundant garnets, and a few prisms of tourmaline.

Structure. The strata of the Brew group dip in general to the southwest, forming a homoclinal succession that appears to be only slightly faulted.

On the southwest, the group is invaded by the Coast intrusions, and to the east is in faulted contact with rocks, in part at least, of the Cache Creek group. The fault, which dips steeply, is marked along much of its course by abrupt changes in attitude in the adjacent strata and by wide rusty zones.

Age and Correlation. A collection of fossils from the main ridge 1¼ miles south of Mount Brew was reported by J. A. Jeletzky of the Geological Survey to include *Aucella* ex. gr. *crassicollis* Keyserling, of early Lower Cretaceous (Lower Neocomian) age.

The strata of the Brew group resemble certain parts of those metamorphosed strata of uncertain age in the southwestern part of the area, particularly those west of the serpentine belt. It has been pointed out that those rocks probably include representatives of the Ladner group of Coquihalla area. A correlation of the Brew group with the Ladner group is suggested by the similarity of the stratigraphy of the two groups. Each consists mainly of argillaceous rocks, which, some thousands of feet above the base of the section, are succeeded by thick conglomerate and arenaceous beds above which fine-grained sedimentary rocks predominate. That the Brew group is probably of early Lower Cretaceous age, whereas the Ladner group is believed by Cairnes (1924, pp. 52, 55) to be probably Jurassic, perhaps Upper Jurassic, argues against the suggested correlation. The Jurassic age of the Ladner group, however, was based mainly on the fact that it was overlain by the Dewdney Creek group believed to be probably of Upper Jurassic age, and as the Dewdney Creek group is now known to be at least partly of Lower Cretaceous age, it is possible that the Ladner group of Coquihalla area is younger than was originally supposed.

Lillooet Group

Introduction. The Lillooet group, named after the town of Lillooet, occupies the western part of the Fraser River Cretaceous belt from Siwhe Creek northward. The thickness of the group is not known, as its base was not found at a locality where measurements could be made. Structural complexity added to the difficulty of forming an estimate, and the best that can be said is that the group has a minimum thickness of 2,500 feet and may exceed 5,000 feet.

Lithology. Argillite, with minor greywacke, makes up most of the lower part of the group, and volcanic conglomerate and tuffaceous sandstone bulk large in the upper part. At two localities along the western border of the Fraser River Cretaceous belt, one at the nose projecting from the Coast Mountains 6 miles southeast of Lillooet and the other at a point 5 miles south of Texas Creek, a conglomerate containing cobbles of granitic rocks, limestone, and chert possibly represents the base of the Lillooet group. At the first locality it is overlain by a few feet of tuffaceous sandstone and volcanic conglomerate and occurs to the west of and at a higher elevation than an assemblage of highly altered rocks cut by small serpentine bodies. Perhaps these exposures represent a fault slice in which the older rocks on which the Cretaceous rocks were deposited are exposed, although possibly the conglomerate is intra-formational and the supposed older rocks are merely highly altered Cretaceous strata. At the second locality, the conglomerate is separted from cherts to the west by a band of highly sheared serpentine.

Argillite of the lower part of the Lillooet group is conspicuously bedded and so is easily distinguished from that of the younger Cretaceous units. It shows, in many places, varve-like laminæ that average about ¾ inch in thickness, and rhythmic successions of such laminæ were observed through thicknesses of several feet. In other places, argillite shows distinct lamination without grain gradation, the laminæ ranging from a fraction of an inch up to 2 to 3 inches in thickness. The beds exhibit complex and irregular crenulation, which is believed to have been produced before the consolidation of the sediments. Lenticular masses of limy argillite, up to 6 feet long and 8 inches thick, in some places surrounded by 2-inch layers of aragonite, are not uncommon. A few 2-inch beds of laminated limestone were seen. Included with the argillites are beds of greywacke and massive black argillite averaging about 3 feet in thickness.

The upper part of the Lillooet formation includes a large proportion of volcanic conglomerate and tuffaceous sandstone, with some interbeds of argillite closely resembling those already described. The beds of volcanic conglomerate and tuffaceous sandstone range in thickness from about 2 to 30 feet, and a single bed has been followed for about 1,000 feet. No bedding was seen within the individual strata. The rocks consist largely of greenish and bluish grey aphanitic fragments of volcanic material ranging in size from sand grade to 1 inch or more in diameter, averaging about ¼ inch, set in a structureless matrix. Most specimens contain, in addition, angular fragments of feldspar and some of quartz. Size sorting is poor. Angular blocks of bedded argillite, oriented at random and averaging about a foot in longest dimension, are common in many exposures.

Under the microscope, the conglomerate and sandstone are seen to consist of a mixture of lithic grains, mainly of various kinds of volcanic rocks but including some of sedimentary types, and grains of feldspar, quartz, and minor pyroxene and amphibole. Lithic grains predominate over mineral grains in most of the thin sections examined, and form on the average about 75 per cent of the rock, reaching a maximum of 95 per cent. Feldspar is next in abundance, followed by quartz, which rarely exceeds 4 per cent of the total.

Of the lithic grains whose shape has not been altered since deposition, most are rounded but have low sphericity. Most of the feldspar grains are extremely angular, being bounded by cleavages, crystal faces, or abrupt fractures. In many thin sections, lithic grains are seen to be in mutual contact along their boundaries, a projection of one grain being accommodated by a re-entrant in its neighbour, suggesting that, under stress, they have been dissolved at points of contact and the material removed in solution, allowing the grains to become closely fitted together.

Most of the lithic grains are of igneous origin, and show many of the textures typical of volcanic rocks. The common varieties consist of laths of albite set in a matrix of chlorite. Textures include trachytic and porphyritic. In some, the albite laths are arranged in radiating groups. In most specimens, chlorite has replaced the centres of some of the feldspar crystals, leaving rectangular frames. Some grains contain pseudomorphs of chlorite after amphibole, and in others, crystals of clinopyroxene are found. Grains of a quartz-rich porphyry, comprising a maximum of about 5 per cent of the lithic grains of some of the rocks, are composed largely of albite and quartz. The quartz phenocrysts are rounded, and show narrow embayments and rounded inclusions of quartz-feldspar aggregates. Some of the volcanic grains are amygdaloidal.

Of mineral grains, most are plagioclase, and of these, all that were determined are albite. Clastic grains of orthoclase are rare. Many of the quartz grains are similar to the quartz phenocrysts of the volcanic grains described above, and are probably of similar origin. Pyroxene and amphibole are rare.

The matrix is scanty and largely secondary, consisting of fine-grained aggregates of albite, quartz, and chlorite. Some sections show considerable secondary carbonate and epidote.

Structural Relations. North of the mouth of Cinquefoil Creek, dips in the Lillooet group are in most places steeply northeast. The structures are not simple, however, for at many localities the beds are overturned, and wherever more or less continuous exposures are found, the structure is seen to be extremely complex. Opposite the mouth of Texas Creek, east of Fraser River, the beds are steeply and irregularly folded. At the mouth of Texas Creek, the group consists of completely shattered argillite, and exposures resemble talus material cemented by red iron oxide. Dawson (1896, p. 149B) considered these rocks to be a "friction breccia", but the exposures are so extensive that it is difficult to believe that the rock is a fault breccia, and conceivably the material is that of a rock slide that descended from the west side of Fountain Ridge. North and northeast of Lillooet the beds are in many places overturned. In the bed of Bridge River the dips of the strata range from 60 degrees northeast to vertical. Faults intersect the strata, but in the absence of key beds, their significance is unknown.

The Lillooet group is believed to be in fault contact with the rocks to the west. This relationship will be discussed in detail on a later page, in dealing with the nature of the boundaries of the Fraser River Cretaceous belt.

In many places where the Lillooet group is in contact with the succeeding Division A of the Jackass Mountain group, the contact zones, marked by structural discordance, rusty breccia, and shearing, are believed to be faults. Several facts, however, suggest that an unconformity separates the two groups. The structures of the Lillooet strata, characterized by high dips, overturned beds, and complex folds, stand in marked contrast with those of the Jackass Mountain beds, in which dips are relatively low. An additional fact suggesting unconformity is seen in the large number of dykes and sills that cut the Lillooet strata but are relatively rare in the younger rocks. On the other hand, ½ mile north of the mouth of Bridge River, on the upper road, volcanic conglomerate and argillite of the Lillooet group are overlain by greywacke of Division A of the Jackass Mountain group, in what appears to be structural conformity. At this same locality, however, the Lillooet group is cut by a sill that has been largely replaced by prehnite. This alteration is probably closely related to the prehnitization that affected many of the rocks of the area, and which is described in a later section of this report. As detrital prehnite is found in specimens from Division C of the Jackass Mountain group, it seems logical to assume an interval of erosion during which a considerable thickness of rock was removed. An intervening period of folding would facilitate such erosion, and would probably occur between the Lillooet and Jackass Mountain groups, between Divisions A and B of the Jackass Mountain group, or possibly at both horizons. The structural evidence cited on a later page indicates that the Jackass Mountain group includes no angular unconformity, and suggests, therefore, that the unconformity occurs between the Lillooet and Jackass Mountain groups rather than at the higher horizon. As will be seen later, this unconformity may mark the time of emplacement of the Coast intrusions of this district.

Origin. The Lillooet group is largely of marine origin, as indicated by the contained marine fossils. The coarse-grained rocks referred to as volcanic conglomerate and tuffaceous sandstone are believed to be of pyroclastic origin, although the possibility exists that they were derived by erosion from older volcanic rocks. The predominantly, locally exclusively, volcanic character of the clastic grains, the angularity of the feldspar fragments, the evidence of rapid accumulation seen in the lack of stratification in the beds, and the alternation with fine-grained well-laminated argillites, suggesting abrupt changes in volume and kind of material supplied, favour a pyroclastic rather than normal sedimentary origin. Much of the material may have been deposited on land as breccias and tuffs, to be carried thereafter into the neighbouring sea.

Age and Correlation. Fossils, although far from abundant, were found at several localities. At two of these, the fossils collected were small, poorly preserved belemnites, and at a third, brachiopods and crinoid plates. A friable boulder of argillite, almost certainly from the lower part of the group, found near Dawson's fossil locality close to Intlpam Creek (Dawson, 1896, p. 149B), contained numerous specimens of *Aucella,* which were reported on by J. A. Jeletzky of the Geological Survey as: "*Aucella* sp. ind. (ex. aff. *crassicollis*) Keyserling; most probably early Lower Cretaceous (Lower Neocomian)".

The Lillooet group is probably to be correlated with the Dewdney Creek group of Coquihalla area, and with Division A of the modified Dewdney Creek group of Princeton area (*See* table, p. 51). Fossil evidence for the correlation is weak, and about all that can be said is that belemnoids are found in both units. The lithological similarity of the proposed correlatives and their stratigraphic positions, each overlain by a similar thick succession of coarse, clastic, sedimentary rocks, argue for the suggested correlation.

Jackass Mountain Group

Introduction. Strata of the Jackass Mountain group underlie the greater part of the Fraser River Cretaceous belt. The group has been subdivided into three distinct units. Division A consists largely of fine-grained greywacke, Division B largely of boulder conglomerate, and Division C mainly of greywacke and argillite.

Division A. Rocks of Division A are well exposed along the southern and southwestern flanks of the Camelsfoot Range and strata assigned to it are found also near Cisco and Kanaka. In most places the strata are in fault contact with the Lillooet group, and a complete section was not found, but the division is at least 2,000 feet thick.

The lowest known part of Division A consists largely of non-marine arkose, conglomerate, and shale locally rich in carbonaceous matter, and is at least 400 feet thick. The upper part is composed mainly of massive, fine-grained greywacke, with some coarse greywacke, argillite, and conglomerate, and has an aggregate thickness of about 1,800 feet at some localities, and may be considerably thicker.

Non-marine beds of the lower part of the division are exposed northeast of the mouth of Bridge River in the gorge of Fraser River. Other non-marine beds, probably a part of this division, are found in a few places along the west side of Fountain Ridge.

Northeast of the mouth of Bridge River, the non-marine beds consist of arkose, conglomerate, and shale. The arkose is a buff, coarse-grained, highly feldspathic rock, in places seamed by $\frac{1}{2}$-inch layers of bright coal.

Conglomerate beds, totalling perhaps 80 feet in thickness, are notable for their high content of chert pebbles. Shale beds, although highly carbonaceous, yielded no recognizable plant fossils.

The bulk of the upper part of the division consists of a blue-grey, fine-grained greywacke, which locally grades into siltstone and argillite. In many places it carries dark grey to black, irregular fragments of siltstone up to ½ inch across, which do not show any special orientation. In most exposures, bedding can be detected only after close and careful search; it is represented by thin, indistinct layers that cannot be traced for more than a few inches. Greywackes and argillites are locally concretionary, and thin beds of conglomerate are found at some localities. Lenses, a few inches thick, of reddish weathering limy rock are not uncommon. The greywacke is in many places fossiliferous, but fossils occur singly and at great intervals, and large collections are difficult to make. Coarse-grained greywacke comprises a minor part of the group.

Microscopic examination of the typical, fine-grained greywacke yielded little diagnostic information. Two sections were found to consist mainly of angular quartz and feldspar, with minor lithic fragments, but a third, of about the same grain size, is composed largely of chlorite-rich lithic fragments, with some quartz, feldspar, muscovite, and bleached chlorite. A relatively coarse-grained specimen was seen to consist of about 70 per cent lithic grains and 30 per cent mineral grains. Apparently most of the lithic grains are of volcanic material, largely replaced by chlorite, but some of them are formed of interlocking aggregates of quartz and albite, and are possibly fragments of siliceous volcanic rocks. About 25 per cent of the rock consists of fragments of albite feldspar; quartz fragments comprise about 5 per cent of the rock, and muscovite, biotite, epidote, magnetite, and chloritic material occur in small amounts.

Division B. Strata of Division B, consisting largely of coarse conglomerate, outcrop in both northern and southern parts of the Fraser River Cretaceous belt, but were not observed in the interval between Lytton and the southern part of Fountain Ridge. They are excellently exposed on the west flank of Jackass Mountain, 10 miles south of Lytton, where highway and railway cuts improve the splendid exposures described by Selwyn (1872, p. 60). In the north, the division is exposed on Fountain Ridge and along the south and southwestern flanks of the Camelsfoot Range. Massive boulder conglomerate was observed at three localities along the east side of these mountains north of the mouth of Fountain Creek, but its stratigraphic position is not clear. The division is about 1,200 feet thick about 4 miles north of the southern edge of the map-area, and about 1,750 feet thick on the west slope of the Camelsfoot Range, near the western border of the map-area. In most places, however, faulting has prevented reliable measurements.

Although consisting mainly of conglomerate, the division includes beds of greywacke and argillite. At Jackass Mountain, a section about 600 feet thick in the middle and upper part of the division includes about 450 feet of conglomerate, 140 feet of greywacke, and 10 feet of argillite. Here, the conglomerate beds range in thickness from 5 to 100 feet, most of them being 8 to 20 feet thick. Greywacke beds range from 1 foot to 50 feet in thickness, and average about 10 feet. Farther north, the same succession holds, and in general the proportion of greywacke to conglomerate increases upwards.

Conglomerate beds are not conspicuously lenticular, and evidences of cut-and-fill are extremely rare. Bedding structures within conglomerate layers are obscure, the roundstones being generally arranged in disorderly fashion. In a few places, a rude imbricate structure can be recognized, and in others, the long axes of the ellipsoidal roundstones lie parallel with the conglomerate bed, but these fabrics are rarely well enough developed to afford a clue to the attitude of the beds. The size of the roundstones ranges from sand grade to boulders 1·5 feet in diameter, with little material between sand grade and ½ inch. Boulders 1 foot in diameter are not rare, but the average size is about 4 inches. The roundstones of any particular bed are well sorted as to size; most of them are well rounded, but a few angular blocks of argillite, up to 16 inches in greatest dimension, were seen in the conglomerate. Commonly the matrix is so abundant that the roundstones are not in contact with one another, but in many places they are closely packed. The relation appears to hold that the larger the roundstone, the greater the proportion of matrix.

The roundstones are of many rock types but 30 to 90 per cent by volume of them are from leucocratic, quartz rich, granitic rocks. Greenish, fine-grained, igneous rocks, probably volcanic, are locally prominent, totalling in some places 50 per cent. Green, grey, and blue-grey chert seldom accounts for more than 5 per cent of the total. Other rock types noted include grey and black argillite, quartzite, feldspar porphyry, white vein quartz, and conglomerate.

The matrix of the conglomerate shows some variation. In many places, particularly where the roundstones are small, the matrix is black argillite. Typically the matrix is a medium- to coarse-grained greywacke, indistinguishable from that of the greywacke beds of this division.

Greywacke beds appear, on casual inspection, to be distinctly separated from the conglomerate beds, but on close examination the material of the greywacke beds is found to be continuous with the matrix of the conglomerate. Beds of greywacke persist laterally for scores of feet, maintaining a constant thickness. Cut-and-fill structures are rare. Greywacke is nearly everywhere massive, and bedding structures were observed in it at only a few localities. In the hand specimen it is a greenish grey rock composed of ill-defined lithic grains of which individuals can be distinguished with difficulty, together with angular grains of feldspar and minor quartz. It resembles closely the greywacke of Division C.

In most places, the argillite, which forms only a small part of the division, is massive, although some graded bedding was seen.

Division C. Strata of Division C are well exposed in the higher parts of the Camelsfoot Range, on Fountain Ridge, and northwest, and southwest of Lytton. The top of the division is not exposed, but a minimum of 5,000 feet of strata is represented.

The division consists largely of greywacke, thinly interbedded greywacke and argillite, conglomerate, and argillite. Non-marine beds, consisting largely of argose and greywacke, with minor pyroclastic (?) beds, outcrop near the mouth of Fountain Creek, and near Lytton.

Massive greywacke, forming 60 to 70 per cent of the division, occurs in beds averaging 60 feet in thickness that are continuous along strike for great distances. The typical greywacke is massive, showing no trace of bedding. Locally it contains angular slabs of bedded argillite up to 3 feet long, most of which lie parallel with the beds. Some of the slabs have been worn and rounded, the fragments then resembling lenses of argillite in the greywacke. Not uncommonly, isolated pebbles, mostly of granitic material, are found in the greywacke. The greywacke is typically grey to brownish grey, weathering to buff. The grain size averages a little less than 1 mm. In the hand specimen, angular grains of feldspar and quartz, and flakes of black slate can be distinguished, and in some, a few leaves of muscovite or biotite. In thin section, the rock is seen to be composed of rock fragments and mineral grains, the latter chiefly albite and quartz that generally predominate over rock fragments. The minerals noted include albite, quartz, clinopyroxene, hornblende, orthoclase, sphene, apatite, and magnetite. Plagioclase other than albite was noted in only a few thin sections. Detrital prehnite was identified in two thin sections, one from a specimen from Fountain Ridge and one from beds near Lytton. Of the lithic fragments, aggregates of large grains of quartz and albite are the most abundant. Fragments of volcanic rock are composed of albite laths set in a matrix of chlorite. Grains of carbonaceous slate and phyllite, conspicuous in the hand specimen, are fairly common. Much of the matrix of the greywackes is chloritic material. The grains are very angular and size sorting is poor. Interbedded with the greywackes of Division C are massive, bluish or greenish rocks that differ principally from the typical greywackes in being composed largely, and locally almost entirely, of fragments of volcanic rock. Although no proof of pyroclastic origin was found, the rocks are possibly tuffaceous.

Sections composed of alternating laminæ of fine-grained greywacke and argillite, averaging about 1·5 inches in thickness, form a large part of the division. The greywacke beds are commonly irregularly crossbedded, the bedding being marked by thin, discontinuous streaks of argillite. In many places, the greywacke and argillite form varve-like laminæ, the greywacke grading upward into argillite.

Conglomerate beds comprise perhaps 4 per cent of the division. They range up to 30 feet in thickness, contain cobbles of granitic material, and do not differ greatly from the conglomerate of Division B.

A group of strata along the summit of Fountain Ridge just north of the southernmost exposure of Division B, consists mainly of indistinctly bedded grey and black argillite, with some conglomerate. Its stratigraphic position is uncertain, but because it appears to overlie the beds of Division B, it is assigned provisionally to Division C.

Division C includes non-marine beds near the mouth of Fountain Creek and others that underlie a large area near Lytton. At Fountain Creek, the rocks consist largely of arkose, with subordinate carbonaceous shale and conglomerate. These rocks resemble, in part, the non-marine beds of Division A near the mouth of Bridge River. Near Lytton, arkose, tuffaceous (?) sandstone, greywacke, conglomerate, and shale containing abundant plant remains, underlie the lower slopes of Fraser Valley, and are in contact to the west with, and apparently overlain by, greywacke beds similar to those of the upper part of Division A. These greywacke beds are, in turn, overlain by strata typical of Division C. It is conceivable that these non-marine beds, which locally include conglomerates, represent Division B, but they are, for the present, included in Division C.

Arkoses from the vicinity of Lytton are pale grey to white rocks, most of them speckled with flakes of biotite, and resemble fine-grained granites. Under the microscope they are seen to consist dominantly of albite, quartz, and quartz-feldspar aggregates, with minor orthoclase, microcline, biotite, sphene, chlorite, epidote, and magnetite. Grains of phyllite, fine-grained mosaics of quartz and albite, volcanic rock, and chert are not abundant. Most of the clastic grains, which average about 0·5 mm., are extremely angular.

Rocks possibly of pyroclastic origin are interbedded with arkose 1 mile south of Lytton. In the hand specimen, the rock is not easily distinguished from the dark greywackes of the vicinity. A thin section, however, shows that about 90 per cent of it consists of volcanic fragments composed of labradorite and chlorite. Other fragments of coarsely crystalline quartz and zoned plagioclase, the latter ranging in composition from sodic andesine to sodic oligoclase, comprise about 3 per cent of the section. The balance of the rock is largely plagioclase, quartz, and a little biotite. Most of the labradorite crystals are replaced along their edges and traversed by fine networks of untwinned sodic plagioclase with indices close to that of Canada balsam.

Directly west of Lytton, two light grey beds, each about 2 feet thick, stand in sharp contrast with the dark shale and greywacke with which they are interbedded. In the hand specimen these beds consist of chalky white material in which are set irregular brown fragments and a few angular grains of quartz and feldspar. This chalky material is soft, and can be crumbled between the fingers. Under the microscope it is seen to consist of grains of dark brown volcanic material surrounded and partly replaced by a zeolite, which forms the bulk of the rock. A few angular grains of quartz and albite, and a little secondary carbonate were observed. The optical properties of the zeolite are in close agreement with those given by Winchell (1945, p. 392) for leonhardite, which occurs most commonly in veins or as amygdules in flows; its origin west of Lytton is obscure, but is possibly hydrothermal.

Internal Structural Relations. The abrupt appearance of the coarse conglomerate of Division B is suggestive of an unconformity. Evidence of angular discordance is found at the small knob ½ mile north of Kanaka, where there occurs an isolated patch of cobble-conglomerate that is believed to be a remnant of the northwestern extension of Division B. Argillite and greywacke of Division A outcrop within a few feet of the conglomerate of Division B and strike directly into it. The actual contact is not exposed at this point, and conceivably a fault may pass between the argillite and the conglomerate. At another place nearby, a thin layer of breccia at the base of the conglomerate contains fragments resembling the greywacke of Division A. Other evidence is found about 4 miles north of the south edge of the map-area, where the strata of Division A dip steeply to the east beneath the conglomerate of Division B, whereas the conglomerate, where attitudes can be obtained, dips at fairly low angles to the east.

In the northern part of the map-area, the measured thickness of Division A is different at different localities, but this difference does not necessarily indicate an unconformity, because the lower contact of Division A is in most places a fault. At four localities along the southern and southwestern flanks of the Camelsfoot Mountains, where the contact between the two divisions is well exposed, there is some evidence of erosion at the contact, but no angular discordance was observed. At several other places attitudes taken on traverses across the contact suggest structural conformity and the evidence to the contrary, found in the southern part of the area, is perhaps due to faulting and to distortion of beds near faults. It is concluded, therefore, that there is an erosional unconformity at the top of Division A, but that the presence of angular discordance at the contact cannot be considered proved.

From opposite the mouth of Kwoiek Creek to the southern edge of the map-area, a distance of some 8 miles, the Fraser River Cretaceous belt has an average and fairly regular width of about 1 mile. It is crossed at intervals by transverse faults that in most places are concealed by overburden.

West of Lytton, the strata of Division C of the Jackass Mountain group dip in general southwest. Numerous faults, some seen and others inferred from abrupt changes in attitude, traverse the rocks. Fountain Ridge, farther north, is believed to be cut by several northwest-trending faults. Only one of those shown on the map was seen; the others are inferred, because it seems impossible to explain the observed stratigraphic relations by folding. The fault shown along the summit of Fountain Ridge and crossing Fraser River was seen at the river and at the north end of Fountain Ridge and was projected south through points at which the attitudes of the beds change abruptly.

At several localities, the rocks of Division B appear to have acted independently of adjoining strata, possibly because they tend to fracture rather than to deform. At the nose that projects westward from Fountain Ridge, 2 miles northeast of Lillooet, Division B dips steeply north in contrast with the adjoining rocks, which dip southerly.

Faults are everywhere an abundant and characteristic feature of the Jackass Mountain group, whereas dips are relatively moderate, and folds inconspicuous. Although many fault blocks have been identified as such, the boundary faults are commonly concealed and their positions inferred from indirect evidence. Because of the lack of continuity due to faulting, the positions of the strata of some of the fault blocks in the stratigraphic section are in doubt.

The prevalence of faulting over folding is believed to be due to a combination of several factors: (1) Most of the rocks of the Jackass Mountain group, and particularly those of Divisions B and C, are thick bedded and ill adapted to folding, and tend rather to fracture. (2) The Fraser River Cretaceous belt lies between major faults in a zone where compressive, tensional, and shearing stresses can reasonably be supposed to have been applied suddenly and irregularly. (3) The belt of rocks is narrow relative to the great aggregate thickness of the strata that compose it, so that under compression or shearing stress, fracturing rather than buckling would be expected.

A section of Division A of the Jackass Mountain group was measured on the southern flank of the Camelsfoot Range, about 1 mile northeast of the mouth of Bridge River.

Top of section	Thickness Feet
Conglomerate of Division B	
Division A	
Greywacke, coarse-grained	325
Argillite, black, concretionary	30
Greywacke, well-sorted	15
Argillite, black, massive, concretionary; with minor dark, medium-grained greywacke	100
Argillite, laminated, dark	15
Covered	105
Greywacke, fine-grained; and argillite, partly well bedded; few thin beds of red weathering, limy argillite	100
Greywacke, coarse-grained	10
Pebble-conglomerate, granitic pebbles	3
Greywacke, medium-grained	60
Greywacke and argillite, massive and concretionary, locally fossiliferous	255
Greywacke, dark, fine-grained, locally blue-grey, fossiliferous	105
Siltstone, dark grey; massive greywacke	120
Greywacke, fine- to medium-grained; outcrops sporadic	100+
Total thickness	1,343

A section well exposed along Fraser River, northward from the railway bridges at Cisco, includes about 1,100 feet mainly of fine-grained, bluish grey greywacke, which is locally fossiliferous. These beds are overlain by about 400 feet of blue-grey, coarse-grained greywacke, and a little pebble-conglomerate. The typical fine-grained greywacke resumes for 100 feet, beyond which outcrops become scarce. The section south from the Cisco bridges, along Fraser River, is locally faulted and folded, and elsewhere covered, so its true thickness and relation to the section north of the bridges are uncertain. Beds of this section, totalling about 2,490 feet in thickness, and showing fairly constant attitudes, consist mainly of massive, blue-black or blue-grey greywacke, locally concretionary and fossiliferous, with minor coarse-grained greywacke. The fine-grained greywacke locally grades into siltstone.

The following section, measured on the southwest flank of the Camelsfoot Range near the western edge of the map-area, includes Division B, and parts of Divisions A and C.

	Thickness Feet
Division C	
Greywacke, blue-grey, massive; minor intra-formational breccia; probably includes some argillite; outcrops not continuous	830
Alternations of massive greywacke and sections of thin-bedded argillite and greywacke	230
Greywacke, greenish, coarse-grained, possibly tuffaceous	220
Argillite, black, partly varve-like	200
Greywacke, massive, uncommonly feldspathic	190
Argillite, black, concretionary	20
Cobble- and pebble-conglomerate, with blocks of argillite up to 1 foot across	40
Greywacke, massive	50
Boulder-conglomerate	10
Greywacke, massive	150

	Thickness Feet
Division B	
Mainly boulder-conglomerate	200
Argillite, laminated; greywacke	60
Boulder-conglomerate; greywacke interbeds; section not completely exposed	1,295
Covered	300
Division A	
Mainly black argillite and siltstone; a few limy layers	320
Greywacke, fine-grained, blue-grey, massive; siltstone fossiliferous	300
Total thickness	4,415

A section of Division C was measured on the east side of Fountain Ridge, 2 miles south of the mouth of Fountain Creek.

	Thickness Feet
Top of section	
Greywacke, massive; minor interbeds of thinly bedded argillite and greywacke	750
Argillite, massive, black, concretionary	100
Greywacke, massive, coarse-grained	180
Greywacke and argillite, interbedded, beds mainly 2 to 6 inches thick	460
Greywacke, mainly massive	270
Argillite and greywacke, thin-bedded	70
Covered	100
Mainly greywacke, coarse-grained, partly soft and crumbly	200
Argillite and greywacke, thinly interbedded	420
Intraformational breccia of angular to subrounded fragments of argillite, up to 3 feet across, in a matrix of greywacke	10
Argillite and greywacke, thinly interbedded	50
Greywacke, massive	140
Greywacke, partly well bedded, and an 80-foot section of thinly laminated argillite and greywacke	170
Mainly greywacke, with 2-foot beds of alternating thin layers of argillite and greywacke; some intraformational breccia	280
Greywacke, medium- and coarse-grained, locally well bedded; beds of laminated argillite 1 foot to 4 feet thick	740
Greywacke, medium- to coarse-grained; minor argillite; section includes a 10-foot bed of boulder-conglomerate	330
Conglomerate with granitic boulders	10
Mainly greywacke, coarse-grained; a little intraformational breccia, and a 2-foot bed of pebble-conglomerate containing argillite and granitic pebbles	450
Total thickness	4,730

External Structural Relations. In the northern part of the map-area, the Jackass Mountain group is in contact with the Spences Bridge group along what is believed to be a steeply dipping normal fault. This contact will be considered more fully in the discussion of faulting along Fraser River (Chapter IV).

The structural nature of the contacts near Siwhe Creek, of the Jackass Mountain group with the Lillooet group and with rocks of Eocene age is unknown, and the map shows only one interpretation. It is certain that the Eocene beds rest unconformably on the Cretaceous rocks, for they contain easily recognizable pebbles derived from them. In this instance, however, the contact seems to have a dip steeper than that of the Eocene beds, and is, therefore, possibly a steeply dipping fault.

The Jackass Mountain group is in contact with the granitic rocks southeast of Lytton along a fault the evidence for, and the nature of which, will be discussed in Chapter IV.

Origin. The oldest rocks of Division A of the Jackass Mountain group are of non-marine origin, but the bulk of the division was deposited in marine waters. The massive character of the marine beds probably indicates steady deposition with little opportunity for reworking.

The problem of the origin of Division B is more difficult. Two possibilities will be examined: deposition in a large body of standing water, such as a marine seaway or a lake; and deposition by running water, as along the flood plain of a river, or as a series of subaerial fans.

Interstratified argillite beds of Division B containing marine fossils were evidently laid down in marine waters. These beds, however, may have been deposited during temporary incursions of the sea, and most of the division may have accumulated in some other environment. Against deposition of the bulk of the division in standing water is the difficulty of transporting by currents or wave action the necessary coarse detritus. Although it might be suggested that, if conditions were such that a rapidly sinking basin or trough adjoined an abrupt highland, coarse material might be swept some distance along the sloping floor of a body of standing water, it seems improbable that it could be projected a mile or more from shore. It is concluded, therefore, that the main part of the division was probably not deposited in a seaway or lake.

The main argument in favour of deposition by running water is that coarse material is thus easily transported. The objection that sediments deposited by running water would be characterized by much crossbedding and cut-and-fill structure, whereas the rocks of Division B rarely show such structures, is believed not serious, for in the absence of any kind of bedding within the massive conglomerates, it is impossible to say whether such structures are present or not.

In summary, it is believed that the conglomerate of Division B accumulated largely under subaerial conditions and that it consists of fluvial deposits that were at times inundated by the sea. It is possible that the strata were laid down on a narrow foreland lying between a highland and a seaway, rather than along the flood plain of a large river. The change in conditions signalized by the abrupt appearance of coarse conglomerate in the stratigraphic section is probably due to uplift in the source area, increased stream gradients, and increased supply of detritus. It is possible that the uplift suggested was due to isostatic adjustment following and consequent on the emplacement of the Coast intrusions west of Fraser River, and that the adjustments took place in part along the major fault zone that roughly parallels the Fraser. If this hypothesis is accepted, the provenance of the granitic detritus in the conglomerate of Division B would necessarily lie to the west of Fraser River, rather than in the granitic intrusions to the east. It seems improbable, however, that they were derived from the Lower Cretaceous intrusions immediately west of the

Fraser, for the time interval available for their unroofing would seem to be inadequate. An alternative is that the detritus had its origin in an earlier phase of the Coast intrusions, perhaps lying to the west of those emplaced in early Lower Cretaceous time.

Strata near the base of Division C yielded a few marine fossils, and a fragment of an ammonite was found in argillite, several thousand feet above the base, so the strata are in part of marine origin. The local presence of coarse conglomerate and of intraformational breccia suggests desposition in fairly shallow water, perhaps near shore. Beds rich in carbonaceous matter are, apparently, either freshwater or near-shore marine deposits.

Age. Fossils collected from Division A of the Jackass Mountain group were reported on by F. H. McLearn of the Geological Survey.

Locality: ½ mile west of west edge of map-area, northeast side of Bridge River; elevation, 5,000 feet.
Trigonia (at least two species)
Belemnoid
Age: Lower Cretaceous.

Locality: ½ mile west of west edge of map-area; northeast side of Bridge River; elevation, 3,600 feet.
Pecten sp.
Pleuromya sp.
Nemodon? sp.
Small fragments of an ammonite
Age: Lower Cretaceous.

Locality: 1 mile east of west edge of map-area; north side of Bridge River; elevation, about 2,500 feet.
Pecten sp.
Pleuromya sp.
Nemodon? sp.
Shasticrioceras sp.
Belemnoids
Age: the age is Lower Cretaceous and possibly the Barremian stage or middle of the Lower Cretaceous.

Locality: 150 yards northwest of the south end of the Canadian Pacific Railway tunnel at Cisco.
Trigonia (*Scabrae section*).
Age: Cretaceous.

J. A. Jeletzky of the Geological Survey examined one collection from Division A, and his report follows.

Locality: on the main line of the Canadian Pacific railway, 1 mile due north of Kanaka.
Hibolites? sp. indet.
Remarks: "Upper Jurassic or Lower Cretaceous. In the boreal province of Eurasia (and of North America) this genus would suggest Lower Cretaceous rather than Upper Jurassic".

Only two collections were made from Division B of the Jackass Mountain group; they were examined by F. H. McLearn, who reports:

Locality: east slope of extreme north end of Fountain Ridge, at an elevation of about 2,000 feet.
'Shasticrioceras'? n.sp.
Age: Lower Cretaceous, possibly the Barremian (mid-Lower Cretaceous) stage.

Locality: 1½ miles north of Falls Creek station, on main highway.
Pecten (Entolium) sp.
Pleuromya sp.
'Shasticrioceras' sp.
'Terebratella' cf. *whiteavia* Anderson
Remarks: "The specimen of *'Shasticrioceras'* is too small for positive identification; the age is probably Lower Cretaceous".

J. A. Jeletzky examined collections from strata assigned to Division C.

Locality: 1½ miles west and 1 mile north of Lytton.
Pleuromya vancouverensis Whiteaves
Aucella sp. indet., apparently of Upper Jurassic affinities.
Age: more probably Upper Jurassic than Lower Cretaceous.

Locality: 1⅓ miles west and 1 mile north of Lytton.
A small lamellibranch strongly resembling an Upper Jurassic *Aucella,* and suggestive of Upper Jurassic rather than Lower Cretaceous age.

Locality: 1 mile south and 1 mile west of Lytton.
Acroteuthis? sp. (cf. *Acroteuthis shastensis* Anderson)
Remarks: "the age is most probably Neocomian (early Lower Cretaceous). The tentative specific determination may or may not suggest contemporaneity with the Paskenta group in California, from which *Acroteuthis shastensis* Anderson was originally described. According to European standards, the genus *Acroteuthis* is diagnostic of early Lower Cretaceous time and does not appear in uppermost Jurassic formations. The same relations are suggested by F. M. Anderson (1938, 1945) for the younger Mesozoic area of California and Oregon. Therefore, it seems reasonably safe to regard the strata at this locality as of Neocomian rather than uppermost Jurassic age".

A collection from near the base of Division C was examined by F. H. McLearn.

Locality: 2 miles south and 1½ miles east of Kanaka.
Trigonia (*Quadratae* section?)
Age: probably Cretaceous.

Collections of plant fossils from Division C were reported on by W. A. Bell of the Geological Survey.

Locality: 1¼ miles west and about ½ mile north of Lytton.
Ferns
- *Cladophlebis virginiensis* Fontaine
- *Coniopteris* sp.
- *Coniopteris heterophylla?* (Fontaine)
- *Sphenopteris latiloba?* Fontaine

Cycadeoids
- *Pyterophyllum? concinnum?* Heer

Incertae sedis
- *Podozamites*

Age: a Lower Cretaceous age is indicated.

Locality: At Fraser River level, west side of Fraser, opposite Canadian National Railway station at Lytton.
Ferns
- *Cladophlebis virginiensis* Fontaine forma *acuta*

Remarks: the presence of this species by itself is not indicative of precise age, although probably Lower Cretaceous.

Locality: on road, west side of Fraser River, about ¼ mile southwest of Lytton.
Ferns
Cladophlebis virginiensis Fontaine forma *acuta*
Ruffordia? goepperti? Seward
Cladophlebis sp.
Age: the age, with some doubt, is considered to be Aptian. *Cladophlebis* sp. is a new species that was noted previously in a collection from a part of the Skeena group. It was there accompanied by some Jurassic holdovers, but the florule as a whole was considered provisionally to be Aptian (early upper Lower Cretaceous).

Locality: east side Fraser River, ½ mile south of Canadian National Railway bridge at Lytton.
Ferns
Gleichenites nordenskioldi (Heer) emend Seward
Conifers
Elatides curvifolia (Dunker)
Age: an Aptian age is indicated, equivalent to that of the Luscar formation in Alberta and to part of the Shasta series of California and Oregon.

Locality: 150 yards west of the mouth of Fountain Creek.
Ferns
Cladophlebis sp.
Cycadophytes
Nilssonia sp.
Ptilophyllum speciosum (Heer)
Pterophyllum concinnum Heer
Conifers
Elatides curvifolia (Dunker)
Elatides dicksoniana (Heer)
Caytoniales
Sagenopteris sp.
Age: an early upper Lower Cretaceous (Aptian) age is indicated.

The collections from Divisions A and B of the Jackass Mountain group are reported to be of Lower Cretaceous age, possibly of the Barremian (mid-Lower Cretaceous) stage. The collections from Division C include some fossils reported to be possibly of Upper Jurassic age, others of early Lower Cretaceous (Neocomian) age, and still others of early upper Lower Cretaceous (Aptian) age. As Division C is younger than Divisions A and B, it seems reasonable that it is of Lower Cretaceous rather than Jurassic age and to accept, provisionally, a mid-Lower Cretaceous age for the Jackass Mountain group.

Correlation. To make clear the following discussion of the correlation of the Jackass Mountain group, it is useful to review certain of the steps by which progress has been made in working out the stratigraphy of the Cretaceous rocks of the region.

Selwyn (1872) assigned the name 'Jackass Mountain Conglomerate group' to the conglomerate, shale, and greywacke of Jackass Mountain. Cairnes (1924b), in Coquihalla area, some 40 miles south of the southern edge of the Ashcroft map-area, named and described the Dewdney Creek group, which there consists largely of pyroclastic rocks, and from its contained marine fossils was identified as of either Upper Jurassic or Lower Cretaceous age, and more probably the former. His descriptions of the pyroclastic rocks can be applied, in part, to many of the rocks of the Lillooet group of the Ashcroft area. Another sedimentary group consisting largely of coarse clastic materials was regarded as probably of

Lower Cretaceous age, and Cairnes believed that this overlay the Dewdney Creek group unconformably. No fossils were found in these rocks. As he continued his work to the south and southeast, into the Similkameen River district, Cairnes (1923, 1924a) found that the Dewdney Creek strata included more normal clastic material but that the tuffaceous character of the group was still pronounced. Additional fossils were found but they threw no further light on the age of the group. Cairnes showed also that the strata that he had been referring to as 'Lower Cretaceous' were probably, in part at least, equivalent to the Pasayten series of Daly.

Snow (Cairnes, 1944), in 1938 and 1939, traced the Jackass Mountain group from the southern boundary of Ashcroft map-area to Coquihalla River where it appeared to lie on the extension of the clastic 'Lower Cretaceous' rocks mapped by Cairnes (1924b).

Rice (1947, pp. 15-19), working in Princeton map-area, revised some of Cairnes' work southeast of Coquihalla area, and included with the Dewdney Creek certain rocks that were considered by Cairnes to belong to the Pasayten group. Rice included four units in the Dewdney Creek group, Divisions A, B, C, and D.

The Lower Cretaceous (and late Jurassic?) stratigraphy as worked out in Coquihalla area and along Similkameen River by Cairnes, and in Princeton area by Rice, are summarized in the following table, and in the right-hand column a comparison is made with what may be the corresponding succession in the Ashcroft area.

Coquihalla map-area	Similkameen River district	Princeton map-area		Ashcroft map-area	
		Pasayten and Kingsvale group		Kingsvale group	
		[1]Spences Bridge group		Spences Bridge group	
'Lower Cretaceous'	Pasayten group		Division D 7,200		Division C 5,000
		Dewdney Creek group	Division C 1,300–2,100	Jackass Mountain group	Division B 1,500
			Division B 1,800		Division A 2,200
Dewdney Creek group 6,500–10,000	Dewdney Creek group		Division A 5,800	Lillooet group 2,500–5,000	
Ladner group 7,950				Brew group 8,500	

[1] Does not appear in Similkameen River district.

The presence of *Shasticrioceras* in Division B of the Dewdney Creek group, and in Divisions A and B of the Jackass Mountain group, supports the correlation. Furthermore, the correspondence in lithology, sequence, and thickness suggests that the correlation of the Jackass Mountain group proposed in the foregoing table is valid. In view of the fact, however, that the Lower Cretaceous succession, in the Ashcroft area at any rate, most probably includes an unconformity of some importance, the similarity in thickness of some of the units is probably fortuitous. It seems not improbable, however, that the same sequence of rocks occurs southeast of Ashcroft map-area.

Spences Bridge Group

Distribution. The Spences Bridge group occupies about 500 square miles of Ashcroft map-area, more than any other surficial rock group. It forms a belt 2 to 15 miles wide extending northwesterly from below Spius Creek on Nicola River to beyond the northwest corner of the area. It occupies the northeast slope of Nicola Valley and underlies the Pimainus Hills. Southeast of Thompson River the belt widens and includes part of the Nicoamen Plateau south of Spences Bridge. Along Thompson River rocks of the group are exposed from Nicoamen River to Martel on the Canadian National railway. Northwest of the Thompson they occupy a wide area between Botanie Creek and the eastern slope of Twaal Valley, and extend northwesterly to include Murray Peak, Blustry Mountain, and Cairn Peak. They cross Fraser River south of Pavilion Creek, and pass into the northwest corner of the map-area.

Any statement of the thickness of the Spences Bridge group must at best be in the nature of an estimate, because the base of the group is not exposed where the section is otherwise most complete and because of the difficulty experienced in recognizing and following horizon markers. Dawson (1896, p. 179B) estimated the thickness to be 5,300 feet, and Drysdale (1914, p. 137) more than 5,000 feet. Because dips are generally low and in many places nearly horizontal, some idea of the thickness of the group may be obtained from the differences in elevation of different parts of the group. From the base of the exposed section on Laluwissin Creek, where the Spences Bridge rocks are in faulted contact with the batholithic rocks of Botanie Mountain, to the summit of Murray Peak, the difference in elevation is 3,000 feet. Farther south, on Botanie Creek, the base of the group, also in faulted contact with intrusive diorite, lies 3,000 feet below the summit of the Plateau to the east, which is occupied by Spences Bridge rocks. The mountain west of the settlement of Spences Bridge and south of Murray Creek has, from Thompson River to its summit, a vertical relief of about 5,000 feet, throughout which the typical agglomerates and porphyritic flows of the Spences Bridge group are exposed. East of Nicola River, near Skuhun Creek, waterlain tuffs, agglomerates, and andesite and rhyolite flows form a succession more than 3,000 feet thick, between the river and the contact with the Guichon Creek batholith to the northeast.

Lithology. The Spences Bridge group is composed mainly of an accumulation of lavas and pyroclastic rocks that show great differences in lithology over short distances. Interbedded with these and occurring locally at the base, are minor amounts of waterlain material, consisting of tuffaceous conglomerates, sandstone, and waterlain tuff. However, all such occurrences are unimpressive when compared with the great volume of volcanic rocks. These are mainly andesites and dacites, but rhyolites and basalts are common. Breccias and agglomerates of both explosive and flow types form a large part of the group.

Most of the lavas are porphyritic and were termed porphyrites in the early literature. They are fine- to coarse-grained rocks, of various colours, commonly showing thin, lath-shaped phenocrysts of feldspar $\frac{1}{16}$ to $\frac{1}{8}$ inch in length. The colours are red, green, mauve, purple, brown, grey, white, and black and are commonly in light shades. A thin-section study of seven samples of lava from the vicinity of Skuhun Creek showed six to be andesites and one a dacite. A similar study of specimens from Blustry Mountain, 30 miles to the northwest, showed mainly dacites and one rhyolite. The predominant feldspar is andesine, and the ferromagnesian minerals are mainly augite and diopside. The feldspars of the groundmass commonly show flow structure around feldspar phenocrysts. Some of the more acidic flows are characterized by a fine banding and others exhibit spherulitic structure. Both vesicular and amygdaloidal types are represented, with quartz, calcite, and, less commonly, zeolites forming the amygdules.

The agglomerates and breccias that form a large part of the group are mainly grey to green. Fragments are generally from $\frac{1}{4}$ inch to 2 inches in greatest dimension, but massive blocks 2 feet in length and more than 1 foot wide were observed. Many of the agglomerate beds contain carbonized fragments of stems and twigs.

The sandstones, arkoses, and tuffs are fine- to medium-grained rocks in various shades of grey, commonly with a green or yellow tinge. Along Botanie Creek, the sedimentary beds are composed of materials derived largely from batholithic rocks. Most of the sedimentary and tuff beds contain carbonized fragments of wood and some contain identifiable fossilized ferns.

In places the volcanic rocks are much decomposed, and commonly show such secondary products as saussurite, carbonate, iron oxides, and chlorite. In some instances decomposition has progressed so far as to completely mask the original mineral composition of the rock.

Structure. The overall structure of the Spences Bridge group is one of the gentle folds, with dips of from 10 to 40 degrees, but in many places the flows are horizontal or nearly so. The general trend of the rocks is northwesterly. Along the northeast slope of Nicola Valley the rocks dip gently to the southwest and probably form the northeast limb of a broad syncline. Near the boundaries of the group, steep dips, slickensided surfaces, and sheared beds indicate faulted contacts. Faults also occur within the group, but because of the difficulty of following marker beds, the amount of dislocation or offset is uncertain.

Thin seams of white and pink calcite were commonly observed traversing lavas of the group.

Individual flows and beds are not widespread, so that sections at one locality do not bear close resemblance to those at another except perhaps in their overall character.

A traverse up the mountain south of Skuhun Creek from the road, east to the granite contact gave the following section:

Top of section	Thickness Feet
Mainly green to grey tuff, tuffaceous sandstone, and agglomerate; minor andesite	500
Hard, dense, greyish red andesite; light-coloured dacite	550
Tuffaceous sedimentary beds; minor agglomerate	400
Hard, dense, light-coloured rhyolite; minor andesite and dacite	1,100
Blue-grey, fine-grained agglomerate; dark basaltic and andesitic lavas	600

The interval from the road west to Nicola River, though underlain by Spences Bridge rocks, is drift covered.

About 25 miles northwest, on Laluwissin Creek, above the faulted contact of the group with the batholithic rocks, a partial section was observed as follows:

Top of section	Thickness Feet
Dark columnar basalt	800
Flat-lying conglomerate, composed of cobbles of granodiorite, hard tuffaceous sandstone, volcanic rocks, and chert held in a sandy matrix	25±
Green, crumbly agglomerate, containing ¼- to ½-inch fragments	100±
Faulted contact with granodiorite	

In several places rocks of the Spences Bridge group were seen resting unconformably on Cache Creek rocks. They overlie the granitic rocks of the Guichon Creek batholith, and are in faulted contact with the batholithic rocks of Botanie Mountain. At no place were they observed in contact with rocks of the Nicola group or with rocks of the Jurassic belt at Ashcroft.

Dykes, probably of Tertiary age, were observed in many places cutting the Spences Bridge rocks. On the northeast side of Nicola River, about 4 miles above its mouth, several narrow, parallel, brown weathering dykes may be seen cutting the group. They strike north 5 to 10 degrees east and dip vertically. In the vicinity of Spences Bridge, dykes are common, and up Murray Creek the Spences Bridge group is cut by a 30-foot gabbro dyke that will be described later. At Martel, near their contact with the Cache Creek group, the Spences Bridge rocks have been intruded by several light-coloured porphyritic dykes.

Age. The rocks now included in the Spences Bridge group were believed by Dawson (1896, map) to be of Tertiary age, and were referred to by him as the 'Lower Volcanic' group. It was not until 1912, when Drysdale (1914) restudied the rocks in the vicinity of Spences Bridge, that definite fossil evidence of their age was found. On the western slope of Pimainus Hills, about halfway between Nicola River and Pimainus Creek, at an elevation of 2,500 feet above sea-level, Drysdale found plant remains in a tuff bed in Dawson's 'Lower Volcanic' group. These fossils were studied by Dr. F. K. Knowlton of Washington, who regarded them as probably of

Kootenay (Lower Cretaceous) age, but with decided Jurassic affinities. More recently W. A. Bell of the Geological Survey re-examined this collection and reports as follows:

Ferns
Gleichenites giesekania Heer
Sagenopteris sp.
Cladophlebis sp.
Cycadophyta
Nilssonia schaumbergensis (Dunker)
Nilssonia cf. *orientalis* Heer
Conifers
Podozamites lanceolatus? Lindley and Hutton
Elatides? curvifolia? (Dunker)
Pityophyllum (*Cephalotaxopsis?*) sp.
Age: "a Lower Cretaceous age is definitely indicated, and an Aptian (early upper Lower Cretaceous) age is considered most probable".

During field work by the present writers, fossil plant remains were found at two localities within the group. One of these is beside the highway about ¼ mile below the confluence of Nicoamen and Thompson Rivers. The fossils are found in dark argillites and arkoses that outcrop between the highway and Thompson River. The second locality is at an elevation of 2,500 feet on the creek that flows into Nicola River about ½ mile below Dot on the Kettle Valley railway. Here the plant remains are found in sedimentary beds consisting of a brown conglomerate, containing pebbles of granite and buff-coloured lava, and sandstone and shale. Both collections were reported on by Bell as follows:

First locality
Ferns:
Sphenopteris latiloba Fontaine
Gleichenites giesekiana (Heer) emend Seward
Gleichenites porsildi Seward
Gladophlebis parva Fontaine
Cycadeoids
Pseudocycas unjiga (Dawson) Berry
Conifers
Anthrotaxites? ungeri? Halle
Second locality
Ferns:
Gleichenites giesekiana? (Heer) emend Seward
Sagenopteris sp.
Conifers
Elatides curvifolia (Dunker)
"These indicate most probably an Aptian age in the Lower Cretaceous".

The age of the Spences Bridge group is, therefore, fairly well established as that of the Aptian or early upper stage of the Lower Cretaceous series.

Kingsvale Group

Distribution. Rice (1948, p. 25), in the Princeton map-area, found a series of younger volcanic rocks resting unconformably above the Spences Bridge group, with in places a sedimentary zone at its base. Fossil plant remains collected from these sedimentary rocks proved to be of late Lower

Cretaceous (Albian) age. To this group of rocks Rice assigned the name Kingsvale "after the railway station of Kingsvale near which the only good fossil locality found in the group in the Princeton map-area occurs".

The Kingsvale group rocks extend northwestward into Ashcroft map-area, where they underlie an area of about 275 square miles, mainly in the high region between Nicoamen and Nicola Rivers known as the Nicoamen Plateau. Within the Ashcroft area, the Kingsvale group constitutes a belt about 10 miles wide extending from the southeast corner of the map-area northwest as far as Thompson River. No counterpart of these rocks was recognized to the west and northwest in the Scarped Mountains and on such hills as Murray Peak, Blustry Mountain, and Cairn Peak. The eastern boundary of the belt is roughly defined by Nicola River and the western boundary by a line through Prospect Creek and Nicoamen River. Small outliers of the group overlie the batholithic rocks on the eastern slope of the mountains southeast of Lytton.

The thickness of the Kingsvale group could not be measured as no complete sections were found. Dawson (1896, p. 178B) estimated the thickness of the rocks in the Nicoamen Plateau, now included in the Kingsvale group, to be 3,600 feet. In the vicinity of Skeikat Creek, from the base of the group at Nicola River to the top of Nicoamen Plateau, the difference in elevation is between 3,000 and 3,500 feet, and as the rocks of the group are relatively flat lying, this difference is an approximate measure of their thickness. On the other hand, the summit of Zakwaski Mountain, the highest point in Nicoamen Plateau, is only a little more than 1,000 feet above the batholithic rocks on which the Kingsvale group rests, so that the surface on which the group was deposited must have been very uneven.

Lithology. In Ashcroft map-area the Kingsvale group is composed largely of a succession of basaltic and andesitic lavas and fine to coarse agglomerates, tuffs, and breccias that have at their base a zone of sedimentary rocks of varying thickness, which in places may be missing.

The lava flows, mostly andesites and basalts, are partly porphyritic. They are of fine to medium grain and may be red, grey, green, mauve, purple, brown, or black. Amygdaloidal and vesicular varieties are common, with amygdules composed of quartz, calcite, some mineral of the zeolite group, or a green chloritic material. In many places the basalts weather into a coarse, earthy debris containing abundant amygdules that have been freed from the parent rock.

About 7 miles southeast of Mimenuh Mountain, at an elevation of 5,700 feet, there outcrops a light grey, fine-grained, dense lava flow, probably an andesite, which exhibits flow lines. Under the microscope a thin section of this rock shows feldspar laths too minute for identification, some augite, much fine magnetite, and no quartz.

Zackwaski Mountain is composed of a light-coloured, brownish grey lava in which pyroxene is more abundant than feldspar. Very little quartz is present, but magnetite is abundant in small grains. A brown alteration product of the magnetite tinges even freshly broken surfaces of the rock. The rock breaks with a crude conchoidal fracture into thin plates and quadrangular blocks from 1½ to 2 inches thick.

The top of Mimenuh Mountain, the other prominent peak on the plateau, is composed entirely of a hard, greenish grey, much decomposed porphyritic lava. In the hand specimen a few small phenocrysts of feldspar and ill-defined phenocrysts of ferromagnesian minerals are seen to lie in a dense fine-grained groundmass. Under the microscope the feldspars are seen to be zoned and slightly altered to calcite. Certain elongate crystals now altered to chlorite and magnetite were probably originally hornblende.

The agglomerates are generally grey to green, but some are brown, red, or purple. Some are very coarse, but generally the fragments are not more than 1 inch across. A hand specimen of a fine-grained agglomerate was seen to be composed of fragments of light-coloured volcanic rocks in a tuffaceous matrix in which, under the microscope, only small quartz grains could be distinguished.

The basal sedimentary beds may be as much as 800 to 1,000 feet thick or may be missing. Although these beds are exposed along Nicola River for about 16 miles, the best exposures were found 1½ to 2 miles up Shakan Creek. There they consist of buff to green arkose and grit, soft dark mudstone, grey to greenish grey conglomerate containing pebbles of granite and Nicola group rocks, and hard, dark, thin-bedded argillite. Many of the beds contain fragments of stems and leaves, and the mudstone yielded abundant well-preserved plant fossils.

Structure. In Ashcroft map-area, rocks of the Kingsvale group lie in a broad syncline to the southwest of Nicola River. Dips are low and in various directions and subsidiary flexures are gentle. Volcanic rocks of the group do not permit good measurement of attitudes. When viewed from a distance, these massive rocks show some semblance of stratification, but this cannot be distinguished at the outcrop. Along Nicola River dips are to the southwest, but at many places on the Nicoamen Plateau the flows are horizontal or nearly so. Gentle folds are common, and may be seen in the lavas along the highway between Nicoamen River and Spences Bridge. West of Skuhun Creek, an anticlinal fold reveals about 1,000 feet of sedimentary strata, as follows:

Top of section	Approximate thickness Feet
Basaltic flows	
Green conglomerate	60
Green-grey sandstone	70
Not observed	70
Feldspar porphyry flow	10
Hard, thin-bedded, black argillite	200
Buff-coloured, coarse arkose; red sandstone; green to grey conglomerate, containing pebbles of Nicola and granitic rocks	380
Fossiliferous, soft, dark mudstone; light buff and green arkose and grit	200

To the south, on Nicola River, Dawson (1896, p. 181B) estimated that a thickness of 800 feet of these sediments was exposed in a synclinal structure. The contact, between the sedimentary strata and the flows above them, though observed in only a few places, appeared to be conformable.

The Kingsvale group as a whole is little disturbed, and faulting is inconspicuous; faults may occur, but are not easily discerned because of the general similarity of the rocks. Near Spius Creek a light brown dyke striking north 65 degrees east and dipping 85 degrees to the northwest was observed cutting red lavas of the group. Several other small dykes were also observed in this vicinity. These dykes and possibly others that were not observed appear to be the only younger rocks with which the Kingsvale group is in contact. The group overlies the Spences Bridge and Nicola rocks unconformably, and rests directly on the batholithic rocks of the mountains southeast of Lytton.

Age and Correlation. There is now fairly conclusive proof of the age of the Kingsvale group. The plant remains collected by Rice at Kingsvale were well preserved and were determined by W. A. Bell of the Geological Survey as of late Lower Cretaceous (Albian) age. Material collected by the writers from the sedimentary beds along Nicola River were also studied by Bell and were considered to be of the same age as those collected by Rice. The following lists indicate a comparison of the flora at the two localities:

Kingsvale		Nicola River
	Ferns	
Cladophlebis ambiguum (Heer)	—	*Cladophlebis ambiguum* (Heer)
	—	*Cladophlebis frigidia* (Heer)
Sphenopteris (*Anemia?*) sp.	—	
Gleichenites giesekiana (Heer)	—	*Gleichenites* sp.
Sagenopteris sp.		
	Conifers	
Pagiophyllum ambiguum (Heer)	—	
Elatocladus sp. Seward	—	
Sequoia condita (Lesquereux)	—	*Sequoia condita* (Lesquereux)
Desmiophyllum sp.	—	
Naguopsis longifolia? Fontaine	—	
Syparissidium? gracile? Heer	—	
	Angiosperms	
Phyllites asplenoides Berry	—	
Sapindopsis sp.	—	*Sapindopsis magnifolia* Fontaine
Menispermites potomacensis Berry	—	*Menispermites potomacensis* Berry
	—	*Nemulites* sp.
Trochodendroidis potomacensis (Ward)		

The similarity in the collections from both places leaves little doubt that they are from the same zone. In view of the fossil evidence from both the Kingsvale and Nicola River localities a late Lower Cretaceous age, the Albian stage of European chronology, is indicated for the Kingsvale group.

In Princeton map-area to the southeast of the Ashcroft area, plants of the same age have been collected from the Pasayten group of mainly sedimentary rocks. In Hope map-area, the Skagit formation of mainly volcanic rocks may be of the same age, though no fossils have been found in it.

Late Lower Cretaceous Rocks near Lytton

Rocks of late Lower Cretaceous age, possibly part of the Kingsvale group, underlie a narrow belt along Fraser River extending from just north of Lytton to at least 1 mile north of the mouth of Stein River, and are also found in the valley of Botanie Creek, northeast of Lytton.

The rocks are poorly exposed, and continuous outcrops were found only near the mouth of Stein River and along the highway on the east side of the Fraser, about 1 mile north of the mouth of Stein River.

At and near the mouth of Stein River, the lowest exposed rocks consist of at least 40 feet of massive conglomerate containing close-packed, well-rounded pebbles of white quartz, blue and green chert, and black argillite. They are overlain by about 200 feet of buff and purplish weathering greywacke, a little fine-grained conglomerate, and grey shale. Medium-grained greywacke predominates in the lower part of this section, and shale, with thin greywacke interbeds, forms the upper part. The shale is in part limy, and contains the chitinous remains of small gastropods. Some of the shale is carbonaceous, and in a few places approaches a lignite in composition.

About 1 mile north of the mouth of Stein River, cobble-conglomerate, at least 100 feet thick, occurs in fault contact with granodiorite to the northeast. Well-rounded, ellipsoidal boulders up to 1 foot in diameter are about 45 per cent quartzite, 30 per cent reddish lava, with prominent quartz phenocrysts, 10 per cent chert, 5 per cent coarse granitic rocks, and the balance argillite, feldspar porphyry, grey shale, white quartz, and hard conglomerate. Shale, greywacke, and some arkose underlie the conglomerate. Shales, concretionary and locally carbonaceous, are highly coloured in shades of green, red, and purple.

Conglomerate, composed mainly of pebbles of chert and quartz, and indistinguishable from that found at Stein River, outcrops just west of Botanie Creek. Outcrops are few in this vicinity, but some arkose, greywacke, and carbonaceous shale were seen. The shale locally passes into low-grade lignite.

A thin section of a greyish brown greywacke consists of about 40 per cent quartz, 20 per cent feldspar, mainly albite but including some orthoclase, 3 per cent biotite and muscovite, about 25 per cent of various kinds of lithic grains, and 12 per cent chloritic material, largely matrix. Only a few grains are rounded, and size-sorting is poor. Most of the other thin sections examined indicated that the greywacke is partly replaced by carbonate.

At Stein River, the strata are folded into almost symmetrical anticlines and synclines, one of which plunges about 10 degrees to the south. To the north, close to the granodiorite, the structure is obscure. Dips range from horizontal to vertical and strikes are in all directions, probably the result of distortion along the fault that separates these rocks from the granodiorite to the east. The fault zone lying between these rocks, which probably occupy a down-faulted block, and the older Lower Cretaceous strata to the west is exposed at Stein River, but its direction of dip could not be determined. Similar structural conditions are found at Botanie Creek, where the Cretaceous strata are in contact on the west and south with granodiorite, and on the east with metamorphic rocks intruded by the granodiorite.

Faults that intersect the granodiorite along Thompson River would, if projected to the north, form the boundaries of this area of Cretaceous rocks, which, as Dawson has suggested (1896, p. 154B), probably forms a down-faulted block. The strata were probably deposited on the granodiorite, which is believed to be of Jurassic or possibly early Lower Cretaceous age.

The Lower Cretaceous sedimentary rocks of Fraser River and Botanie Creek are of non-marine origin, as indicated by their content of plant remains and non-marine shells. Coarse conglomerates suggest high gradients in the area adjoining the site of deposition, and perhaps fluvial conditions. The carbonaceous shales may represent swampy areas in a flood plain or near the mouths of rivers. The limy shale that contains gastropods is probably a freshwater-lake deposit, perhaps formed near the edge of an alluvial plain.

Fossil collections from these rocks were examined by F. H. McLearn and W. A. Bell of the Geological Survey and reported on as follows:

Locality: at Stein River, down stream from road bridge.
Non-marine Unionidae or Sphaeriidae

Locality: below highway, on north side of prominent gully, ¾ mile north of Stein River on east side of Fraser River.

Angiosperms
Rhamnites sp.
Sapindopsis variabilis Fontaine
Trochodendroides potomacensis (Ward)
Araliaephyllum
Cinnamomoides ovalis (Dawson)
Ficus ovatifolia? Berry
Juglandites sp.
Age: florule considered to indicate an Albian (late Lower Cretaceous) age.

Locality: Ferry Landing, east side Fraser River, ¾ mile north of Lytton.

Angiosperm
Laurophyllum sp.
Age: Provisionally considered to be Albian (late Lower Cretaceous).

For the purpose of this report, these late Lower Cretaceous rocks have been tentatively mapped with the sedimentary strata of the Kingsvale group. They could also be correlated with the Pasayten group of Princeton map-area (Rice, 1947), which is of non-marine origin and consists of about 20,000 feet of mainly sedimentary rocks.

CRETACEOUS OR TERTIARY

Conglomerate and Sandstone

A formation consisting mainly of conglomerate, but containing some interbedded sandstone, extends into Ashcroft map-area from the east and occupies about 1½ square miles east of Twin Lakes and south of Thompson River. North, across Thompson River, a small area of the same formation was encountered at about the same elevation. The formation is more widely exposed north and south of Kamloops Lake in the adjoining Nicola map-area to the east, and has recently been studied there by Cockfield (1948).

The conglomerate is green to brown, and consists of roundstones from the underlying Cache Creek and Nicola groups and the granite that intrudes them. The cement is mostly arenaceous. Boulders exposed in the conglomerate north of Thompson River are from 10 to 12 inches in diameter. According to Cockfield (1948, p. 21), much of the conglomerate occurs in thick beds with comparatively thin interbeds of sandstone and, locally, beds of shale. No diagnostic fossils were found, but a few carbonaceous plant fragments were seen.

Within Ashcroft map-area, the relationship of these rocks with adjacent formations is clear. The conglomerate rests unconformably on the Nicola group and the granite that intrudes it, and is overlain by Tertiary lava flows. A conglomerate bed south of Thompson River is nearly flat-lying, but farther east Cockfield reports dips to the southwest of from 10 to 30 degrees.

Dawson (1896) and Drysdale (1914) mapped these beds with the Coldwater group of early Tertiary age, although no fossils were found on which to base a correlation. Cockfield (1948, p. 22) found that these rocks showed more regional metamorphism than those of the Coldwater group and that they were intruded by small granitic bodies that did not cut rocks whose correlation with the Coldwater was established by fossils. Under the circumstances he believed that these rocks should not be grouped with the Coldwater until more evidence of their age had been obtained. He, therefore, mapped them as Cretaceous or Tertiary, a classification followed in this report.

Cenozoic

EOCENE

Introduction. Eocene rocks are found west of Fraser River in the vicinity of Siwhe Creek (*See* Plate III A). The rocks are, in part, steeply folded, and where they are best exposed, on the ridge 1 mile south of Siwhe Creek, they are traversed by a north trending fault that separates two different assemblages. The western assemblage, at least 3,000 feet thick, consists of boulder- and cobble-conglomerate, sedimentary breccia, arkose, and carbonaceous shale. The eastern fault block is composed of basalt, volcanic breccia, volcanic conglomerate, arkose, and shale, totalling some 1,450 feet in thickness.

The relation between the two assemblages is not certain. On the ridge 2½ miles south of Siwhe Creek, rocks typical of the eastern assemblage, but lying west of the fault, dip to the east, and if projected north would stratigraphically overlie the rocks of the western assemblage. It is tentatively concluded, therefore, that the eastern assemblage is the younger.

Lithology. The lowest beds of the western fault block consist almost entirely of coarse breccia and boulder-conglomerate, mainly of granitic material. The beds contain blocks and boulders up to 1½ feet in diameter set in a coarse, angular, and unsorted matrix largely of granitic debris. Boulders noted in the conglomerate and breccia include, besides massive and foliated granitic types, mica schist, brown lava, spotted slate, grey feldspar porphyry, conglomerate, contorted gneiss, chert, and white quartz. Little or no well-sorted arkose and no shale were seen in the lower part of the section. The average grain size diminishes upwards, and the upper beds consist of pebble- and cobble-conglomerate and arkose, with minor shale, some of which is rich in plant remains. Cut-and-fill structures are common throughout the section, and much of the stratification, particularly in the higher beds, is obviously fluvial.

The lowest rocks exposed in the eastern section are basalt flows overlain by volcanic breccia. Individual flows could not be distinguished, but, assuming concordance with overlying breccia, the lavas are at least 250 feet thick. Breccias overlying the lava are composed of angular fragments of lava and greywacke up to a foot across, embedded in a crumbly, reddish brown matrix. The slopes underlain by lava and breccia are stained a deep red, due to the abundance of ferric iron in the volcanic rocks. The lower breccia beds show little evidence of size-sorting, and interbeds of sedimentary material are rare or wanting. Higher in the section, however, the proportion of interbedded arkose and shale increases, and the coarse material, although still largely volcanic in origin, is rounded. The upper two-thirds of the section consists largely of conglomerate with some arkose and a little shale. The conglomerate includes cobbles of coarse- and fine-grained greywacke that were undoubtedly eroded from rocks of the Jackass Mountain group. Also noted were cobbles of purple and brown volcanic rocks, chert, white quartz, granite, porphyry with feldspar phenocrysts, biotite, granite-gneiss, blue-black argillite resembling that of the Brew group, quartzite, and soft black shale. Cobbles up to 8 inches in diameter are common. Most of the granitic and metamorphic cobbles are well rounded. Lava fragments are poorly rounded, and many are angular blocks. Inter-beds of arkose, which are not well exposed, are locally lenticular.

The arkose of the western assemblage is a light grey rock in which flakes of biotite are conspicuous, giving the rock the appearance of fine-grained granite. Under the microscope, a specimen of medium grain was seen to contain about 60 per cent albite and oligoclase and 30 per cent quartz. Several detrital aggregates of prehnite were noted. Other mineral grains identified include biotite, chlorite, microcline, epidote, sphene, and magnetite. Lithic grains, mainly quartz-feldspar aggregates, schist, and chert, are not abundant. The rock is poorly size-sorted and the fragments are extremely angular.

A thin section of a specimen of the reddish basalt at the base of the eastern section consists of about 75 per cent labradorite (An_{65}), 15 per cent magnetite, and 10 per cent fine-grained matrix. Labradorite occurs mainly as narrow laths, averaging about 0·1 mm. in length. Magnetite is mainly interstitial to labradorite, and is partly oxidized, giving the rock its red colour. Some of the magnetite occurs as relatively large subhedral spongy masses. Patches of an unidentified mineral, with indices near those of quartz, form a fine mosaic scattered through the rock, and perhaps represent the last part of the lava to consolidate. Amygdules of anhedral heulandite, which encloses a little apatite(?), occur throughout the rock. The texture is pilotaxitic.

The matrix of a conglomerate bed high in the eastern assemblage consists of about 80 per cent lithic grains, 12 per cent quartz, 5 per cent plagioclase, and the balance of detrital biotite, muscovite, orthoclase, and green amphibole. Of the lithic grains, volcanic types are most abundant; others include chert, phyllite, quartzite, and coarse aggregates of quartz and feldspar.

Structure. It has been noted that a steeply dipping, north-trending fault divides the Eocene rocks into two assemblages. Movement was apparently such that the eastern block was relatively depressed. In the gorge of Siwhe Creek, the strata are compressed into tight folds (*See* Plate III B) that, apparently, do not persist to the south. It seems fairly certain that the entire assemblage was deposited unconformably on the Cretaceous rocks, for its conglomerate contains easily recognized pebbles of many of them. The Eocene strata, apparently bounded by faults, form one of the many fault blocks along Fraser River Valley, and it is believed that the steep dips and tight folds of the Eocene beds are the products of local stresses developed during faulting, and are not related to regional folding.

Origin. The sedimentary members of the Eocene rocks, as shown by plant remains and the obviously fluvial nature of most of the sedimentary material, are probably entirely of terrestrial origin. The fossil flora is reported by W. A. Bell of the Geological Survey to indicate a warm temperate to subtropical climate.

In the coarseness, angularity, and chaotic arrangement of the blocks and boulders, in the lack of sorting of the matrix materials, and in the prevalence of cut-and-fill structures, the lower beds of this series resemble those of alluvial fans deposited at the foot of a steep escarpment. The gradual decrease upwards in the size and angularity of the detritus is probably partly due to the filling of the basin of deposition so that lower gradients prevailed, and partly due to decreasing gradients in, or supply from, the source area. Apparently deposition was interrupted by volcanism, during which flows were extruded and volcanic breccia deposited. Overlying volcanic conglomerate probably represents the re-establishment of fluvial conditions, during which much debris from flows and breccias was redistributed. The higher beds, consisting largely of cobble-conglomerate, are probably of fluvial deposition.

The abundance of coarse material that can be fairly certainly recognized as originating from nearby exposed intrusive rocks and surficial formations of the Coast Mountains perhaps indicates relative uplift of that region, and it is possible, in view of the position of the Eocene deposits, that movement along the major fault that bounds them on the west produced a scarp along which piedmont fans were formed.

Age and Correlation. A collection of plant fossils from the upper beds of the western assemblage was reported on by W. A. Bell of the Gelogical Survey as follows:

Ferns
- *Asplenium?* sp.

Conifers
- *Sequoia langsdorfii* (Brongniart) Heer

Angiosperms
- Dicotyledons
  - *Viburnum antiquum* (Newberry)
  - *Crotonophyllum stanleyanum* (Dawson)
- Monocotyledons
  - *Sabalites florissanti?* (Lesquereux) Berry

"The presence of *Crotonophyllum stanleyanum* and of *Sabalites florissanti?* indicates a correlation with the Burrard formation. The Burrard flora is considered, tentatively, to be Middle Eocene".

The relationship of these rocks to those of the Kamloops group is not known. They could possibly be included with this group, but because of their isolated occurrence, faulted condition, and distinctive flora they have been described separately.

MIOCENE OR EARLIER

Kamloops Group

Introduction. The Kamloops group was proposed by Cockfield (1948, p. 30) to include most of the Tertiary rocks in Nicola map-area, comprising both the Coldwater and Tranquille sedimentary beds as well as large accumulations of volcanic rocks. Roughly 450 to 500 square miles of the Ashcroft area are underlain by rocks of Tertiary age that may be included in this group; in fact, exposures of Tertiary lavas in the northeast corner of the area are co-extensive with volcanic rocks on Deadman River that Cockfield mapped as part of the group.

In Ashcroft area all the Tertiary volcanic rocks, with the exception of one small exposure near Glen Fraser, may be included in the Kamloops group. All the Tertiary sedimentary rocks, except, perhaps, the Eocene rocks already described and one small occurrence on Ferguson Creek (the small creek flowing into Bonaparte River about 2 miles south of Scottie Creek), are most probably referable to the Coldwater beds. Most of the Tertiary sedimentary exposures in Ashcroft map-area are small and have yielded no direct fossil evidence of their age, so that their correlation can be based only on lithological similarities and structural relationships. Some of the areas of these rocks are too small to show on the map.

Coldwater Beds (?). The Tertiary sedimentary strata on both sides of lower Hat Creek were referred by Dawson (1895, Kamloops Sheet) to the Coldwater beds. These outcrops are part of a belt 2 to 4 miles wide extending from near McLean Lake to beyond the northern boundary of the map-area. The strata consist mainly of fawn to grey-green to green sandstones, conglomerates, and grits. The roundstones of the conglomerates are mainly of chert, greenstone, limestone, and shale derived from the underlying Cache Creek beds and are embedded in a limy cement. One outcrop of conglomerate on Maiden Creek appeared to be scarcely consolidated, as the pebbles could be broken out by hand. Farther west along lower Hat Creek, where the conglomerates are in contact with the underlying Marble Canyon limestones, they take on a reddish hue, and their weathered products impart a dull red colour to the soil. The strata dip to the east at from 15 to 40 degrees. Dawson (1896, p. 212B) describes the belt as follows: "The west edge of the Tertiary area is found about three miles and a half below the bend made by Hat Creek at the east end of Marble Canyon, where the rocks overlying the limestone consist of a conglomerate, chiefly composed of limestone fragments but also containing pebbles of chert and other rocks. The beds are firmly coherent and weather reddish. To these succeed, in ascending order, a great series of sandstones and conglomerates, the materials which have been for the most part derived from the cherty quartzites of the Cache Creek formation. The cement is calcareous, the usual colours of the rocks greenish-grey, grey or brown. The conglomerates are sometimes lenticular, but on the whole the beds are extremely regular. They are nowhere very coarse. Shales seldom occur, nor were any tuffaceous or other beds of volcanic origin observed. The beds dip in most places at angles of 30 to 50 degrees. The thickness of the entire series as here found is about 5,000 feet".

The basin of Tertiary sedimentary rocks on upper Hat Creek, believed by Dawson to constitute the upper horizons of the Coldwater beds, is probably best known for its contained coal. The boundaries of this area are difficult to determine because of the immense amount of glacial debris overlying the bedrock. Few outcrops were seen except along the bed of the creek itself and on the steeper slopes of the valley; the broad flat of upper Hat Creek Valley gives little or no indication of the character of the underlying bedrock. Dawson (1896, p. 207B) says: "The upper valley of Hat Creek which runs from south to north along the east base of the Clear Mountains is largely floored by sedimentary beds, generally soft shales and sandstones. The whole surface of this wide valley is, however, so thickly covered with drift deposits that it is impossible to define the area of these Tertiary beds with any precision. The outline given on the map is probably as nearly exact as is possible from natural exposures, but it is only really in that part of the valley near Limestone and Medicine Creeks and thence northward that the Tertiary sedimentary deposits are actually exposed. Thus the southern extent of these beds, and their width in the southern part of the valley is particularly open to doubt".

During field work, an attempt was made to delimit the area occupied by these Tertiary sedimentary rocks. A close search was made of the valley flat for outcrops, and several were found along the creek or close to it. The southernmost outcrops of sedimentary rocks encountered were in the valley of Medicine Creek; south of this only volcanic rocks were observed. The present mapping, therefore, shows that a much smaller area is underlain by these rocks than is indicated on Dawson's Kamloops Sheet. Even in the vicinity of the coal measures the outcrops are far from plentiful. Coal outcrops along the creek bed and, west of the creek, little disturbed, light-coloured, soft shales and mudstones are overlain unconformably by vesicular lavas. Near the creek some of the coal measures have been exposed by surface stripping, and these strike north 20 to 40 degrees west and dip 75 degrees southwest. This dip may indicate faulting close to the creek.

On the ridge south of Pavilion Creek, between it and Fraser River, there occurs, between elevations of 3,000 and 3,500 feet, a narrow band of Tertiary sedimentary rocks consisting of light-coloured, fawn, red, and grey sandstones, and conglomerate. These beds are fairly well consolidated, little disturbed, and overlie the batholithic and Cache Creek rocks that form the mountain mass. The conglomerate consists principally of well-rounded pebbles from cherts and greenstones of the Cache Creek group, with a small percentage of pebbles of lava and batholithic rocks. The conglomerates have supplied the material that forms the landslide opposite the Indian village on Pavilion Creek. Outcropping at the edge of the cultivated flat on the north side of Pavilion Creek is a red pebble-conglomerate that is obviously continuous with similar beds to the south of the creek.

Near Spences Bridge an occurrence of Tertiary sedimentary strata is poorly exposed and is of limited areal extent. Some coal is exposed, and work on the seam, which in places reaches a thickness of 6 feet, reveals the character of the asociated sedimentary beds. These consist of buff, impure sandstones and argillites that contain numerous seed or bud capsules, none of which is sufficiently well preserved to indicate other than a Tertiary age. The exposure, though too small to show on the map, is indicated by a number representing an occurrence of coal.

About 100 yards northeast of the point where the Pacific Great Eastern railway crosses the motor highway south of Glen Fraser, there is an exposure of well-indurated conglomerate too small to show on the map. It consists mainly of large roundstones from rocks of the Cache Creek group, lavas of the Spences Bridge group, and granitic rocks from the Coast intrusions. The outcrop is traversed by two dykes, indicating at least some intrusive activity subsequent to deposition. This conglomerate was considered by Dawson (1896, p. 211B) to be a product of the early stages of the Pliocene erosion, probably because it contains roundstones of lava from the Clear Range, which he considered to be Tertiary in age. As the rocks in this range are now considered to be late Lower Cretaceous in age, it is possible that the conglomerate was formed at an earlier date than believed by Dawson.

Volcanic Rocks. The greatest expression of Tertiary volcanism in Ashcroft map-area is in the northeast corner, where lava flows of the Kamloops group occupy a platean that extends from the valley of Bonaparte River easterly to the valley of Deadman River, just beyond the eastern boundary of the map-area (*See* Plate 11 B). The flows in the plateau have a thickness of 3,500 feet. This plateau forms part of a great region to the north, and stretches south to Thompson River, where erosion has exposed the underlying older rocks along the valley slopes. South of the river, basalts of the Kamloops group overlie the granitic rocks of Barnes Creek, and Glossy and Forge Mountains. Volcanic rocks of Tertiary age also occur as outliers west of the main area. There are occurrences near Ashcroft, in the Trachyte Hills, and in the Pavilion Mountains; one area along upper Hat Creek and west of Blue Earth Lake occupies about 45 square miles, and a small outlier outcrops in the northwest corner of the area. Most of these rocks may belong to the Kamloops group but they may include some younger basalts such as the plateau basalts of Rice (1947, p. 31).

Volcanic rocks of the Kamloops group consist mainly of dark, commonly scoriaceous, basalt flows and breccias, andesite, and associated tuff and agglomerate. Colours are mainly black, but include some red, brown, grey, green, mauve, buff, and white. The rocks are generally massive and of fine to medium grain, but rarely so coarse grained as to resemble a plutonic rock. Porphyritic varieties occur locally, and many of the lavas exhibit flow lines. Vesicular and amygdaloidal types are common; the amygdules are mainly of chalcedony and calcite. Many features characteristic of volcanic rocks were observed, such as pumice, scoriaceous lava, columnar jointing, agglomerate, flow breccia, lapilli, volcanic bombs, and fragments of partly devitrified obsidian. Many of the outliers are basalt flows, some of which have a high content of magnetite. The large basaltic outlier in the centre of Pavilion Mountains contains sufficient magnetite to affect the compass, and Drysdale (1914, p. 142) reports that the basalt capping north of the mouth of Bonaparte River contains more than 50 per cent magnetite. Under the microscope, a thin section from a fine-grained dark basalt from Lookout Point showed several phenocrysts of feldspar in a groundmass of minute feldspar laths and magnetite grains. Some hexagonal crystals, which have decomposed to a mass of minute magnetite grains, may have been olivine. The feldspar is labradorite (An_{65}), and the feldspar laths of the groundmass show flow structure around the phenocrysts.

The small outlier in the Trachyte Hills northwest of McLean Lake is a light cream-coloured porphyritic lava exhibiting flow lines. Under the microscope it shows phenocrysts of plagioclase and biotite in a fine-grained groundmass of albite.

Light-coloured rhyolitic and andesitic lavas were encountered on the northwest slope of Glossy Mountain, but on Forge Mountain to the south the lava is mainly fine-grained dark basalt.

Porphyritic rhyolite rests on deformed dark shales of Jurassic age and caps the hill between the town of Ashcroft and Barnes Lake. This porphyritic flow was probably one of the earliest phases of Tertiary volcanism in the district. It was termed by Drysdale (1914, p. 141) the Ashcroft rhyolite porphyry and is described by him as follows: "The rock is a rhyolite porphyry varying from coarse to fine in texture. It is a light greenish grey holocrystalline rock with mica as the chief ferromagnesian constituent and small limpid quartzes and feldspars as phenocrysts. Under the microscope it was found to consist of apatite, zircon, iron ore (pyrite, magnetite), titanite, biotite, plagioclase, orthoclase, partly kaolinized orthoclase and biotite. Apatite is present in small needles and prismoids". The flow is jointed in planes parallel with the slope of the hill, the joints resembling planes of bedding. The fact that this flow once occupied a larger area is indicated by the occurrence of a small outcrop of the same rock about 2 miles south, where it is overlain by a horizontal layer of dark, columnar basalt.

Perhaps the most spectacular outlier is the one that rests on the east slope of Bonaparte River 2 to 2½ miles below Cache Creek settlement. From the highway, this slab of rock appears to rest on the clays and gravels that form the bank of the river. It is about 200 feet wide, several hundred feet long, and as much as 70 feet thick, being much thinner near the lower end of the outcrop. The uppermost part of the slab consists of 30 to 40 feet of columnar basalt, the columns standing almost perpendicular to the slope of the hill. Conformably underlying the basalt is a thin series of sedimentary strata consisting of sandstones, shales, and thin coaly layers. The largest of the coaly layers forms the base of the section throughout the exposure. Fossil leaves and twigs found in the shale and sandstone were studied by W. A. Bell and identified as of Tertiary age. Rice (unpublished report) collected some fossil leaves from these beds in 1942 and Bell reports:

"The following are present:

Sequoia langsdorfii (Brongniart) Heer
Equisetum sp. cf. *E. similkameenense* Dawson
Tilia aspera (Newberry) La Motte
Viburnum sp.

"The flora is too small for age diagnosis, but suggests very strongly a Tertiary age not younger than the Miocene. There is nothing to invalidate possibility of correlation with the Tertiary flora present at Chu Chua and elsewhere in central British Columbia, regarded by Berry as Upper Eocene but possibly as young as early Miocene."

The regular bedding of the stratified material indicates that it was originally horizontal. It is probable that this outlier slid to its present position after breaking away from the edge of a formerly more widespread deposit, since eroded away.

Agglomerates were observed only in the plateau region in the northeast corner of the area. These were thick beds composed of slightly rounded fragments up to 3 feet in diameter, all of which were common types of Tertiary lava. On Barricade Creek, near its junction with Deadman River, 1,000 feet of agglomerate of this type is overlain by about 2,000 feet of vesicular basalt. Cockfield (1948, p. 38) reports the occurrence of similar agglomerate along Deadman River in Nicola map-area.

Locally, beds of thinly laminated, pale, argillaceous material, 50 to 100 feet thick, containing fossil leaves are intercalated with the flows. One such occurrence was observed at the fossil locality in the Tertiary lava marked on the map 4 miles east of Cache Creek post office.

Structure. In Ashcroft map-area, the rocks included in the Kamloops group are for the most part little disturbed. The steepest dips were those found in the Coldwater (?) beds exposed along lower Hat Creek, where dips up to 45 degrees were noted. Generally, dips of more than 25 degrees are rare, and commonly the strata are horizontal, several of the outliers forming flat-lying caps on the hilltops. Dips of 10 to 20 degrees were observed in the plateau in the northeast corner of the area, and the lava forming the outlier in the Trachyte Hills shows flow lines that strike north and dip 25 degrees northeast. Rocks of the group overlie all other consolidated rocks of the area with the possible exception of a small outcrop of conglomerate on Ferguson Creek, to be described later, and a small exposure of lava at the mouth of the creek that flows into Fraser River 2 miles south of Glen Fraser.

Age. In Ashcroft map-area, many of the occurrences of rocks included in the Kamloops group yielded no evidence of their age except in their structural relations and lithological similarity to known Tertiary rocks. Consequently, it is possible that some younger basalts have been mapped with the group. Fossil leaves were collected from the thin argillaceous interbed occurring near the base of the group, at the fossil locality marked on the map 4 miles east of the post office at Cache Creek. From the collection W. A. Bell identified:

Sequoia langsdorfii (Brongniart) Heer
Sapindus obtusifolius Lesquereux
Dictophyllum sp.

He states that: "An early Tertiary age is indicated, but too few species are represented to indicate any particular stage".

MIOCENE OR LATER

Sedimentary Rocks. At an elevation of 3,600 feet on Ferguson Creek, the small creek entering Bonaparte River 2 miles south of Scottie Creek, a flat-lying bed of conglomerate of small areal extent overlies Cache Creek rocks. The cobbles and boulders are not well rounded, and consist almost entirely of Tertiary vesicular lava, derived probably from the plateau in the northeast corner of the map-area. The age of the conglomerate is certainly post-Oligocene and may be post-Miocene.

Volcanic Rocks. A small body of fresh-appearing volcanic rocks, too small to show on the map, is exposed on the creek that flows into Fraser River 2 miles south of Glen Fraser. At, and for some distance above, Fraser River, shattered and sheared conglomerates, probably part of the Jackass Mountain group, are overlain by unconsolidated sands and gravels indistinguishable from the river and glacial outwash deposits common throughout the area. About 200 feet above Fraser River the unconsolidated material appears to be overlain by a succession of flat-lying red agglomerate, tuff, and grey basalt flow breccia. The exposed volcanic rocks occupy about 900 square feet and form a low scarp along the north bank of the creek for a distance of 75 to 100 feet. Although the volcanic assemblage appears to overlie the unconsolidated gravels, the possibility exists that the gravels are merely lying against the side of the volcanic rocks. This small occurrence may be of late Tertiary age and correlative with the Valley basalt of Cockfield (1948, p. 40) and Rice (1947, p. 32).

PLEISTOCENE AND RECENT

During Pleistocene time, all of Ashcroft map-area, except possibly the highest peaks of the Coast Mountains, was covered by ice. Erratics were found in these mountains to an elevation of 8,300 feet near the head of Texas Creek, and at 8,150 feet on Askom Mountain, and glacial striæ were seen south of Skihist Mountain, on a ridge rising above 8,000 feet. The occurrence of erratics on certain unrounded, almost horn-like peaks, would suggest great erosion at the higher elevations since the maximum expansion of the ice, and that some of the most angular of the high peaks had been covered by ice.

Glacial striæ, some recorded by Dawson and others measured by the writers, indicate that the general direction of ice movement was about southeast, veering towards south in the southern part of the map-area (Figure 2). Although the Coast Mountains were probably an important gathering ground for the ice, the general trend of the striæ, southeast and roughly parallel with the edge of the Coast Mountains, shows that most of the ice came from the northwest. Ice was probably discharged eastward from the interior of the Coast Mountains, but was forced to the southeast across the Interior Plateau. Apparently Fraser Valley exerted some influence on the direction of ice movement, but Thompson Valley, trending nearly directly across that direction, caused little or no deflexion.

Most of the valleys of the Coast Mountains owe their present forms to glacial action, and were shaped mainly during the valley glacier stages that preceded and followed the period of maximum glaciation. South and southeast trending valleys are mostly wide, symmetrical, and U-shaped, showing truncated spurs and hanging valleys. East-trending valleys are commonly asymmetric in cross-section, the south walls precipitous and the north walls gently sloping. This effect is, apparently, due to the plucking and steepening action of small glaciers and patches of ice and snow that persist the year round on the north-facing walls.

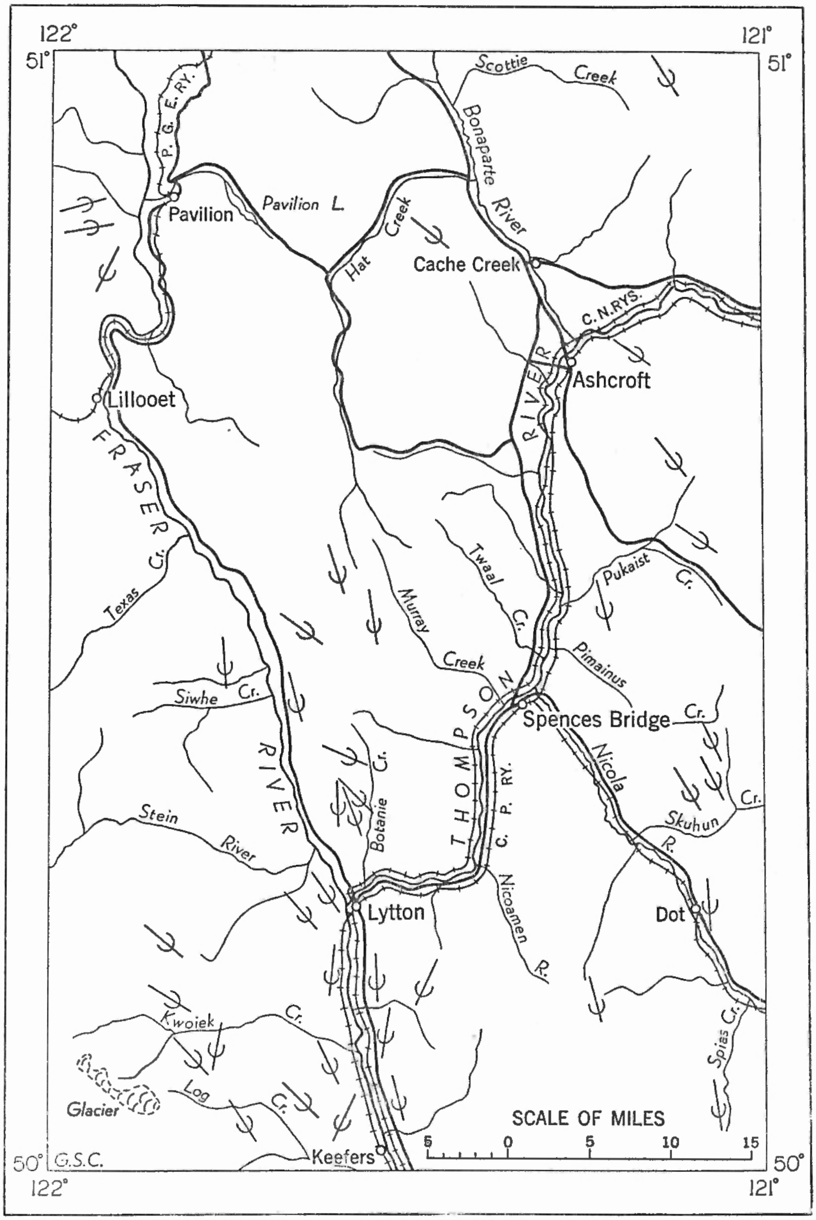


Figure 2. Ashcroft map-area, showing glacial striæ.

Deposits of glacial drift mantle most of the plateau region, and form thick deposits in the broad valley of upper Hat Creek and in the vicinity of the headwaters of Inkiku and Pukaist Creeks and the creek south of Scottie Creek. Areas relatively free from drift deposits include the southeast parts of Pavilion Mountains, the Mountains southeast of Lytton, and the ridges and peaks of the Coast Mountains.

Deposits of 'White Silts' (Dawson, 1896, p. 283B) are best developed along Thompson River between Ashcroft and the eastern border of the map-area, and especially near the mouth of Bonaparte River. They are also prominent between Ashcroft and a point not far below Spences Bridge, and occur along Nicola River Valley as far up as Dot (*See* Plate IV A). In that part of Thompson Valley between Murray Creek and Lytton, very few, if any, deposits were seen. Silts are found also at Lillooet and for a few miles to the south along Fraser River.

The white silts, occurring in banks up to 400 feet high, are of a dull white colour. They have a fine, uniform texture, and are generally well bedded in horizontal layers up to 3 or 4 inches thick. In many places they form steep to vertical walls from which, here and there, huge masses of material have slumped to the valley bottoms.

The distribution of white silts supports the mode of origin postulated by Mathews (1944, p. 39). According to him, as the Pleistocene ice-sheet retreated Thompson Valley was opened around Kamloops but was dammed off towards the west by a lobe of ice, so that a long, narrow, glacial lake was formed. At a later stage, the ice retreated down Thompson Valley below Spences Bridge. The lake at this stage covered a large part of Nicola Valley and all of Thompson Valley above Murray Creek. This expanse of water, glacial Lake Thompson, was the site of deposition of the white silts.

The tendency of these silts to become unstable when saturated with water, and the ease with which they have been eroded by subsurface water, have caused serious difficulties in the maintenance of railways and foundations of buildings.

A prominent hillock of unconsolidated material, apparently mainly gravel and sand, lies east of Lillooet at the foot of Fountain Ridge (*See* Plate IV B). It stands above the general level of the outwash deposits to be described later, is irregular in shape, and has a summit showing irregular depressions, some of which trend southerly. This material is probably that of an ice-contact deposit, possibly a kame or kame-terrace. High-level terraces along Bridge River, near its mouth, and on Cinquefoil Creek, are probably of similar origin. Many of the low-level ice-contact deposits were partly or completely destroyed or buried during the deposition of the suc-
miles to the south along fraser River.

Glacial outwash deposits are abundant along Fraser River, particularly along that part extending from the mouth of Siwhe Creek to the northern edge of the map-area. They form more or less continuous benches, in many places on both sides of the river, and originally were continuous across the valley. They attain a thickness of about 900 feet near Pavilion Creek. The deposits consist largely of coarse boulder and cobble gravels, but include layers and lenses of sand and fine gravel, and locally considerable thicknesses of silt. They are believed to have been built up by an aggrading river that was overloaded by glacial outwash and reworked drift supplied by tributary streams, the material accumulating to a depth sufficient to increase the gradient of the main stream to a point where it could carry the detritus supplied. In some places, these gravels are folded and faulted, perhaps as a result of slumping near melting ice blocks. Some such deposits are perhaps better included with the ice-contact deposits referred to above.

Similar deposits may be seen along Thompson River Valley. That section of the valley from Thompson to the eastern boundary of the map-area contains a great thickness of fluvioglacial material that has been terraced by the meandering river.

In addition to the dissected outwash deposits, large alluvial fans have formed at the mouths of many of the smaller tributaries of Fraser River and are not uncommon along the Thompson. Excellent examples were observed at the mouths of Laluwissen and McGillivray Creeks. The fans are composed mainly of parallel layers, up to 6 feet thick, of unsorted, angular, and rounded fragments, some of which reach a diameter of 4 feet. There are minor beds of gravel, sand, and clay. The inclination of the beds is about 6 degrees. The streams at whose mouths they are found have long since cut down through the fans, the surfaces of which are in many places 200 feet or more above the present level of Fraser and Thompson Rivers. It is considered probable that these fans consist largely of mud flows that swept down the side valleys onto the outwash plain during that period when streams occupying them were clearing their channels of the glacial debris left in them as the ice receded. A somewhat similar fan, composed mainly of gravel, blocks the east end of Seton Lake, west of Lillooet. Small fans, some composed of mud-flow material, are forming at present at the mouths of many small gullies and streams along Fraser Valley.

Fraser and Thompson Rivers have dissected the ice-contact deposits, outwash deposits, white silts, and fans, and have left a succession of terraces that are exceptionally well developed along Fraser River near Lillooet. They are also prominent in that part of Thompson Valley between Murray Creek and the eastern boundary of the map-area. The river gravels deposited during the formation of the terraces and the cutting of the river channels to their present levels, truncate and overlie the older deposits. The surfaces of some of the terraces and benches are covered by a layer of fine silt of aeolian origin.

INTRUSIVE ROCKS

Ultrabasic and Associated Rocks

Introduction

Serpentinized ultrabasic rocks are widely distributed throughout Ashcroft map-area. They are most abundant in the Coast Mountains in the southwestern part of the area, where they form sill-like bodies of large dimensions. Smaller bodies occur sporadically along the western boundary of the Fraser River Cretaceous belt. Numerous serpentine masses, found along Bonaparte Valley, are of particular interest because of their contained chromite. Associated with the serpentinized ultrabasic bodies are several kinds of rock, including pyroxenite, talc, and 'white rock'.

Ultrabasic Rocks of the Coast Mountains

Ultrabasic rocks of the Coast Mountains, probably originally peridotites, pyroxenites, and dunites, are all partly to completely altered to serpentine, and locally to talc and carbonate. Many of the ultrabasic bodies are too small to be shown on the accompanying geological map.

The weathered surfaces of serpentine outcrops commonly show a rough crust up to ½ inch thick that is yellowish buff, orange, reddish brown, or grey. In a few places a thin, scaly, bluish coating was observed. Certain weathered surfaces show a structure in which circular nuclei about a foot in diameter are surrounded by deeply fretted material in which folds, swirls, and shears appear to be developed.

The commonest type of serpentine is a medium to dark green rock spotted with dark green clots and pseudomorphs after pyroxene. On weathered surfaces of such rock, a little magnetite is visible, commonly euhedral, and locally oriented along parallel lines. Under the microscope the rock is seen to consist largely of minute blades of serpentine forming a rude criss-cross pattern surrounding serpentine pseudomorphs after pyroxene. Magnetite and carbonate are minor constituents. Coarse-grained serpentine, composed of glistening, platy crystals of serpentine up to 2 mm. in length and oriented at random, is not uncommon, and all gradations between these and fine-grained types occur. Locally, the serpentine is strongly slickensided and composed of dark green shiny lenticles separated by irregular layers of yellowish green serpentine.

Many of the serpentine rocks contain considerable amounts of talc and carbonate. A common type consists of serpentine, probably pseudomorphous after pyroxene, brown to orange crystalline carbonate, and irregular patches of white talc. In some places, equant crystals of calcite up to ½ inch across occur in the serpentine. Tremolitic amphibole is locally conspicuous.

Certain parts of some of the serpentine bodies consist of corroded crystals of enstatite up to ½ inch in length set in a matrix of fine-grained talc. Under the microscope, enstatite is seen to form subhedral crystals in which partings are much better developed than the prismatic cleavage. Veinlets of serpentine and magnetite follow partings and fractures in the enstatite. Talc and serpentine form the matrix. Crystals of euhedral but partly skeletal magnetite occur throughout the rock.

A few thin sections were observed to contain residual crystals of optically positive olivine, but otherwise do not differ from those of the common serpentine rocks.

The serpentine rocks are believed to be altered ultrabasic intrusive bodies. Such a relief is supported by the common derivation of serpentine from peridotites, pyroxenites, and dunites, and by the presence in the rocks under consideration of olivine and orthorhombic pyroxene, which are common in ultrabasic rocks.

In the vicinity of the Clarke antimony prospect, south of Skihist Mountain, pyroxenite dykes cut a serpentine body. These range up to 6 feet in width, and where seen strike about north and dip vertically. They are composed of crystals of enstatite reaching a length of 1 inch, but averaging about ¼ inch. In places, the crystals show a preferred orientation. Under the microscope, the dyke rock is seen to consist of subhedral prisms of enstatite, which has a strong basal and less pronounced (100) parting. Serpentine and magnetite replace enstatite, in part completely, and the former presence of enstatite can be inferred from the lines of magnetite that mark the parting planes of the original pyroxene. Serpentine is mostly anhedral, showing wavy extinction, and contains much ragged magnetite. Patches of talc and carbonate occur throughout the rock.

Several bodies of talc were noted, and are abundant on the ridge 2 miles south of Kwoiek Creek and a little less than 3 miles west of Fraser River. Some of these are associated with serpentine, but a few lie several hundred feet from the nearest known body of serpentine. Some appear to be composed of almost pure talc; others contain a considerable admixture of brownish carbonate. Probably such bodies are ultrabasic rocks completely altered to talc or talc and carbonate. Similar occurrences of talc occur just south of the mouth of Nahatlatch River (Cairnes, 1926, p. 41).

No systematic distribution of the several kinds of serpentine-bearing rocks was noted, though more detailed mapping might reveal some definite arrangement of rock types. It is, perhaps, noteworthy that although serpentine is invariably produced, talc, carbonate, and tremolite are of sporadic occurrence. This distribution is in accord with the hypothesis that serpentinization is produced by solutions associated with the ultrabasic intrusions, whereas talc, carbonate, and tremolite are the result of alteration of the serpentine by hydrothermal solutions emanating from other, commonly younger, less basic intrusions, not necessarily genetically related to the ultrabasic rocks.

The ultrabasic bodies of the Coast Mountains are mostly elongate and concordant, resembling sills. Small bodies of schist and limestone were noted in traverses across some of the serpentine masses. The longest serpentine zone traced has a length of about 20 miles, and ranges in width up to about ¾ mile. Its continuity north of Kwoiek Creek is not certainly established.

The age of these ultrabasic rocks is unknown. A possible continuation of the main serpentine zone is found to the southeast, extending to and beyond Coquihalla River in Hope map-area, and to the northwest, in Bridge River district. The serpentine belt of Coquihalla map-area is believed by Cairnes (1930, p. 147A) to be probably of Cretaceous age. Ultrabasic bodies of Bridge River district are placed provisionally in the Jurassic by Cairnes (1937).

The ultrabasic rocks under consideration intrude rocks possibly of Palæozoic, but more probably of late Mesozoic, age.

Ultrabasic Rocks along Fraser River

Several bodies of serpentinized ultrabasic rocks occur at and near the western boundary of the Fraser River Cretaceous belt. Most of these occur near Lillooet, but serpentine is found at two localities west of Fraser River between Siwhe and Cinquefoil Creeks, and at one locality a little more than 2 miles north of Kanaka. None of these bodies is large enough to show on the accompanying geological map.

North of Lillooet, the serpentine body or bodies are apparently elongate, trending slightly west of north, and are at least 50 feet in exposed width. A mass south of Lillooet, exposed for about ½ mile along the road, has a width of at least 300 feet at one place. The bodies to the south are, apparently, small.

Most of the serpentine is dark green to black. Some weathers to a reddish buff and resembles in this respect the large serpentine bodies found to the west in the Coast Mountains. Flashing pseudomorphs of serpentine after pyroxene are scattered through much of the rock. The serpentine is in most places greatly fractured, and is traversed in every direction by fractures with slickensided surfaces that are commonly coated with transluscent light green serpentine. In one thin section, the rock is seen to consist of serpentine showing poorly developed mesh structure with networks of chrysotile veinlets—fibres normal to the walls—cutting the rocks in all directions. Pseudomorphs of serpentine after pyroxene are abundant, and in a few of these, relict clinopyroxene is preserved. Chromite (?), dull red in transmitted light, has been fractured and veined by chrysotile. No olivine was seen. A second section revealed veinlets of talc cutting a well-developed mesh structure. Minute grains of talc and magnetite, concentrated in the centres of some of the meshes, are possibly the product of alteration of residual olivine.

Bodies of 'white rock' were noted in the serpentine rocks a few miles south of Lillooet along the road, and in the small serpentine body near Cisco. Somewhat similar bodies were seen in a serpentine mass in the Coast Mountains on the east slope of Askom Mountain, and also at Ferguson Creek in Bonaparte Valley. Similar rocks have been described by Cairnes from Coquihalla area (Cairnes, 1930, p. 194A). South of Lillooet, the 'white rock' consists of inclusions in the serpentine of grey and greenish grey to white material up to 20 by 5 feet in exposed dimensions. They are found only at some outcrops, and their distribution and shapes suggest that they may be fragments of disrupted tabular bodies. They are in most places bounded by shear zones that cut the serpentine, but elsewhere a transition from green slickensided serpentine to pale greenish grey material is seen. Much of the grey material is soft and apparently decomposed. The freshest specimen that was obtained is seen under the microscope to consist mainly of actinolitic amphibole, prehnite, and clinopyroxene, with minor amounts of chlorite and carbonate. The pyroxene is, apparently, a variety of diopside. The fibrous habit suggests that it is jadeitic, but the optic angle suggests that the jadeite molecule is present, if at all, in small amount. Irregular patches of carbonate and a little chlorite replace pyroxene. Veinlets of prehnite, showing comb structure, and narrow cataclastic zones cross the rock. Another, somewhat softer and apparently more decomposed specimen is composed mainly of a cloudy aggregate of clinopyroxene. The pyroxene, occurring as broad indistinct anhedra, has optical properties that suggest diopside. Almost colourless garnet occurs sporadically as equant grains throughout the rock and also forms the material of narrow, sheared, and twisted veinlets. Microscopic cataclastic zones, along which the minerals have been reduced to material so fine that it appears to be isotropic, contain residual fragments of pyroxene. The origin of these bodies is unknown. They are possibly intrusions that cut the serpentine, or xenoliths included by the ultrabasic rocks. In any case, they have been broken up by stresses affecting the serpentine and have been altered, probably by hydrothermal solutions.

The serpentine rocks occur along and near the fault that bounds the Fraser River Cretaceous belt on the west. The fault, cutting the granodiorites of the Coast Mountains, cannot have originated in earlier than Lower Cretaceous time, and it is certain that some post-Eocene movement has occurred along it. If the intrusion of the ultrabasic rocks was governed by this fault, it would at first seem that they must be of post-Lower Cretaceous age. The possibility exists, however, that the serpentines, older than the faulting, were squeezed from their natural positions into the fault zone. In support of such a hypothesis are the much slickensided and sheared condition of the serpentine, the disrupted fragments of 'white rock', and the microscopic evidence of cataclasis. Taliaferro (1943, p. 205) describes 'cold' intrusions of serpentine from California, where serpentine, apparently of pre-Lower Cretaceous age, has locally been squeezed into Miocene rocks. His evidence for 'cold' intrusions is the highly sheared nature of the serpentine, the association of serpentine bodies with faults, and incongruous age relationships. T. P. Thayer (1948) has described similar 'cold' intrusions from Oregon. In view of such occurrences, it must be stated that although the serpentine rocks of Fraser Valley probably reached their present positions in post-Lower Cretaceous times, it is possible that the ultrabasic rocks from which they are derived were emplaced much earlier and at some distance from the present positions of the serpentine bodies.

Ultrabasic Rocks of Bonaparte Valley

Bodies of ultrabasic rock outcrop on both sides of Bonaparte Valley from south of Cache Creek to Clinton. They appear to be small, the largest outcropping over an area of less than 20 acres, but most are not well exposed and it is difficult to determine their dimensions and shapes. They are associated with rocks of the Cache Creek group and are not found cutting the Jurassic strata near Ashcroft.

The rocks consist almost entirely of serpentine, but the presence of chromite and pseudomorphs of serpentine after pyroxene are regarded as strong evidence of their derivation from ultrabasic rocks, such as dunite and peridotite. Assuming that the proportion of relict pyroxene is an indication of the original composition of the rock, it is estimated that peridotite was about seven times as abundant as dunite.

The fresh serpentine is mostly a dark green rock consisting of indistinct grains of serpentine, with occasional light green translucent grains of serpentine, and pseudomorphs after pyroxene. Some of the serpentine, particularly that which contains appreciable amounts of chromite, weathers to a buff or orange, and mesh structure, not visible in the weathered rock, becomes conspicuous. Pyroxenite, which is not common, occurs as dykes cutting the serpentine. It appears to be only slightly serpentinized, and consists almost entirely of a pyroxene with properties closely resembling those of pigeonite. Thin sections of serpentine reveal a well-developed mesh structure, the lines of the meshes accentuated by particles of magnetite. Chromite occurs as disseminations, layers, lenses, pods, and irregular bodies. Pink, chromiferous chlorite and the chrome garnet, uvarovite, are associated with the chromite.

Chalcedony and quartz are abundant in the buff weathering serpentine, and fill closely spaced joints that stand out as a fretwork on the deeply weathered outcrops. Opal is found in the upper parts of the outcrops, close to the contact with the Tertiary conglomerates elsewhere described. Carbonates and talc are not common.

The age of the ultrabasic bodies is not known, but they are certainly younger than the Cache Creek group and, as they do not cut the Jurassic rocks near Ashcroft, it is possible that they were emplaced in pre-Jurassic time.

Hornblende Diorite and Related Rocks

Hornblende diorite and related rocks are found in association with many of the serpentine bodies of the Coast Mountains, and do not occur in any abundance apart from them. They show considerable variety, and are in places metamorphosed, so that they are separated with difficulty from other metamorphic rocks of quite different origin.

The least altered rocks of this group are hornblende diorites. A specimen from a small body in the south fork of Texas Creek, near the serpentine bodies, is of medium grain, locally porphyritic, and in a few places approaches a hornblendite in composition. In thin section, a medium-grained specimen is seen to consist of plagioclase (An_{30}) and hornblende. Biotite occurs in small amounts, some of it enclosed by the hornblende. Quartz forms about 5 per cent of the rock. Apatite, sphene, and magnetite are scattered through the rock.

Rocks of similar appearance are well exposed on Pyramid Mountain, where they are associated with the main serpentine belt. The rocks, locally gneissic, consist of a mixture of dull, pale buff, almost earthy looking feldspar, and dark, somewhat stubby, amphibole crystals. Under the microscope, the rock is seen to be highly altered. Plagioclase (An_8) is largely replaced by zoisite and epidote. A few, fresh looking, fine-grained aggregates and veinlets of quartz and albite are scattered through the rock. Amphibole, probably hornblende, is pleochroic in shades of brown, and has an extinction angle of about 19 degrees and a large optic angle. Patches of the amphibole crystals are colourless, and the ends of the prisms are mostly altered to masses of acicular crystals of tremolite.

Hornblendites are found at a few localities and are locally associated with the diorites. They are largely composed of dark brown anhedra of hornblende up to ½ inch in diameter. Under the microscope, the hornblende is seen to be pleochroic in shades of brown. Anhedral olivine makes up about 4 per cent of the rock, and biotite and large apatite crystals each account for about 2 per cent. A little magnetite makes up the balance of the primary minerals. Secondary minerals include tremolite, chlorite, talc, and carbonate.

Near the Clarke antimony prospect, south of Skihist Mountain, the hornblende diorites, intruded by granodiorite, are relatively unaltered and easily distinguished from neighbouring rocks, but, traced to the south, they become gneissic and, finally, amphibole schists, and are difficult to distinguish from the schists developed in bedded rocks. The same conditions obtain in the area between Skihist and Akasik Mountains, where there are some undoubted bodies of diorite, some of metamorphosed sedimentary rocks, and much amphibole schist that may be derived from either. It is possible that some of the hornblende-rich rocks occurring with serpentine bodies are the product of hydrothermal alteration of serpentine.

Most of the hornblende rocks form elongate bodies, trending parallel with the serpentine masses, and are locally a succession of sill-like bodies with partings of schist.

At three localities, the diorites were observed to be cut by members of the Coast intrusions, and at one, at the head of the north fork of Texas Creek, to intrude serpentine. At most places, however, the nature of the contact between diorite and serpentine is obscured by shearing and alteration of both rocks.

Coast Intrusions

Introduction

Parts of three major batholiths or batholithic complexes underlie about one-third of Ashcroft map-area. Although two, and possibly all three, are of different ages, they are grouped together as Coast intrusions. The Guichon Creek batholith, named by Cockfield (1948, p. 16), is exposed in the eastern part of the map-area, east and south of Ashcroft, and extends into Nicola map-area. The Mount Lytton batholith extends from the central part of the area toward the south and southeast into Hope and Princeton map-areas. A third area underlain largely by Coast intrusions lies west of Fraser River.

Guichon Creek Batholith

Distribution and Lithology. The Guichon Creek batholith occupies a large area east of Nicola River and extends eastward into Nicola map-area, where it was studied by Cockfield (1948). All thin sections studied by him were from specimens of quartz diorite, or granodiorite, with the exception of some from local gabbroic phases along Guichon Creek. The rocks are typically grey, with some pink and some greenish grey phases. A thin section of a medium-grained, light grey quartz diorite from Forge Mountain shows about equal amounts of quartz and feldspar; some of the plagioclase is zoned. Orthoclase does not exceed 5 per cent of the rock. Biotite and hornblende are abundant, and magnetite, zircon, sphene, and apatite are accessory minerals. Near some of the copper-bearing quartz veins that occur in this batholith, the rock has taken on a pinkish coloration. Under the microscope, this pink rock is seen to contain clear quartz, but the feldspar, which is mainly plagioclase (An_{14}), is altered. Hornblende is the common ferromagnesian mineral. Near other copper veins the granitic wall-rocks have been largely altered to sericite. In the area between Calling and Pimainus Lakes, the quartz diorite is light in colour, coarse in grain, and is composed of large crystals of quartz, plagioclase, orthoclase, and biotite, with subordinate hornblende. A thin section from a specimen taken near the northern contact of the batholith on Inkikuh Creek shows alteration to epidote, chlorite, and sericite, which are probably responsible for the green colour of the rock in this vicinity.

In most places the batholith is massive, but it has been subjected to stresses that have caused shears to form in an east-west direction. Faults are common at or near the contacts, though none appears to be long.

Relations with Other Rocks. The Guichon Creek batholith has intruded both Cache Creek and Nicola group rocks along Thompson River and has caused much hydrothermal alteration, particularly in members of the Cache Creek group. Not far from the motor road to Highland Valley and at a point on it between 6 and 7 miles from Ashcroft, sedimentary rocks of the Ashcroft Jurassic group may be seen overlying the batholith. Along Pimainus Creek basalts of the Spences Bridge group were observed overlying the batholithic rocks.

On Forge and Glossy Mountains basalts and andesites of the Kamloops group overlie the granitic rocks, and in many places where erosion has removed the younger rocks it has exposed copper-bearing veins in the batholith.

Age. Because of the batholith's relations with rocks of the Nicola group and the Ashcroft Jurassic sedimentary rocks it is possible to date its period of intrusion closely. The Nicola rocks intruded by the batholith belong to the Karnic stage of Upper Triassic time, whereas the Jurassic rocks overlying it are of early Middle and Upper Jurassic age. Therefore, the batholith was emplaced between early Upper Triassic and early Middle Jurassic time, most probably during the Lower Jurassic.

Mount Lytton Batholith

The Mount Lytton batholith includes those batholithic rocks exposed on Laluwissin and Izman Creeks, on Botanie Mountain, Munt Lytton, and in the mountains southeast of Lytton, and on Kanaka and Jackass Mountains. At the southern boundary of the map-area, these rocks attain a width of 17 miles and have been traced to the south and southeast through Hope and Princeton map-areas to the International Boundary. The small stocks exposed on Mount Martley, Pavilion Lake, south of Pavilion, and in the northwest corner of the map-area are also included with this batholithic group.

The rocks are mainly granodiorite and quartz diorite, but include some older gabbro and related basic rocks. Certain zones along which these rocks have been albitized will be discussed in another chapter.

Gabbro and related basic rocks are found in that part of the mass that extends north of Thompson River in the vicinity of Laluwissin and Izman Creeks, and also form the peak south of Botanie Mountain. The rocks are extremely heterogeneous, and locally contain abundant inclusions of pre-batholithic formations. Gabbro from the upper part of Izman Creek is a moderately coarse-grained, medium grey rock in which mafic minerals are inconspicuous. In thin section, the rock is seen to consist of about 45 per cent of calcic plagioclase, slightly zoned but of composition about An_{70}; about 5 per cent amphibole patches; about 20 per cent of aggregates of fine-grained secondary white mica and minor chlorite, the latter apparently replacing amphibole; and the remainder mainly of aggregates of zoisite and clinozoisite. Locally coarse- and fine-grained hornblendites are abundant, and irregular apophyses of one type cutting another, or breccias of one type cementing the other were seen. The basic rocks are considered to be relatively older than the more abundant granodiorites and diorites because inclusions of them were noted in the granodiorite in several places, and at a contact between the two types a leucocratic rock was seen to cut gabbro.

Granodiorite and quartz diorite comprise by far the greater part of the intrusive rocks south of Thompson River. They are pale grey, fresh-looking, medium- to coarse-grained rocks of granitic texture, in which the principal mafic minerals, hornblende and biotite, vary in proportions at different localities. Thin sections of typical rocks consist of about 70 per cent zoned plagioclase. Orthoclase is generally interstitial, and subordinate in amount to subhedral plagioclase. Quartz, generally clear and colourless, may exhibit a bluish tinge. Biotite, almost black in the hand specimen, is strongly pleochroic. Hornblende is of the common variety. Accessory minerals include abundant sphene, locally as relatively large crystals, and minor zircon, apatite, and iron ore. Chlorite and epidote replace the mafic minerals in part, and secondary white mica is abundantly scattered throughout the plagioclase.

In the vicinity of Mount Martley, and along Fraser River north and south of Pavilion Creek, are stock-like intrusive bodies believed to be of the same age as the main Mount Lytton batholith, but separated from it by a fairly wide expanse of Spences Bridge rocks.

The Mount Martley stock and that at the northwestern end of Pavilion Lake are composed mainly of medium- to coarse-grained, holocrystalline quartz diorite showing some hornblende and large phenocrysts of biotite. Under the microscope well-zoned plagioclase crystals range in composition from An_{35} to An_{23} and are mainly andesine. Quartz, clear and unaltered, is in lesser amount than the feldspar. Hornblende predominates over biotite, and is highly pleochroic, and chlorite is an alteration product of both. The feldspars are partly saussuritized. Sphene and magnetite are accessory minerals. A dark grey, very much sheared diorite outcrops east of the highway from south of Glen Fraser to Pavilion Creek. A thin section of this highly sheared diorite reveals albite with minor orthoclase, much epidote and zoisite, and some chlorite. Veinlets of prehnite and carbonate cut the rock. The diorite was in all probability originally similar to the Mount Martley stock, but has been involved in the faulting and alteration that affects the formations along Fraser Valley.

The small body of diorite in the northwest corner of the map-area is similar to that described above, but is not so highly altered.

The granodiorites and quartz diorites show preferred orientation of biotite and hornblende that is particularly well marked near Fraser River, south of Lytton. Mafic minerals are arranged in layers that strike north 20 degrees west and dip 20 to 60 degrees to the northeast. The strike corresponds roughly with that of the axes of inclusions of pre-batholithic rocks, and is probably a primary feature.

Pegmatite bodies, characterized by conspicuous pink feldspars, are abundant east of Lytton and near the mouth of Botanie Creek. Aplites are locally associated with them.

Jointing is well developed in the batholithic rocks exposed in the upland surfaces of the mountains southeast of Lytton. Two directions were noted, one striking north 15 to 20 degrees east, and the other, less well developed, north 30 to 70 degrees west. Jointing has apparently influenced the topography, for narrow valleys alternating with abrupt ridges lie parallel with the stronger joints.

Several shear zones were observed in these intrusive rocks, and are especially strong near the small lake southeast of Lytton, near which the rocks have been altered, apparently by hydrothermal solutions. The nature of the alterations will be discussed in Chapter V.

The main batholithic mass throughout its length within Ashcroft map-area is bounded on the west by a steeply dipping fault that is described later. Near the mouth of Nicoamen River it intrudes rocks believed to be part of the Nicola group. It is overlain by, and older than, the volcanic rocks of the Spences Bridge group, though in most places in fault contact with them. Lavas of the Kingsvale group overlie the batholith south of Thompson River. Much of the mass in the southern part of the map-area resembles, and is in part continuous with, the Eagle granodiorite of Hope and Princeton map-areas where it is intruded by batholithic rocks of post-Lower Cretaceous age (Cairnes, 1944).

East of Lytton the batholithic rocks cut strata assigned to the Nicola group, and are overlain by rocks of the Spences Bridge and Kingsvale groups. They must, therefore, have been emplaced between late Upper Triassic and mid-Lower Cretaceous times. The relationship of the Mount Lytton batholith to the batholithic intrusions west of Fraser River is not clear. The two great areas of batholithic rocks are separated for a distance of 40 miles within the map-area by a belt 2 miles or less in width, and if of the same age, the intrusions on either side might be expected to resemble each other lithologically and structurally. The fact that the basic rocks of Botanie Mountain have no counterpart west of Fraser River is not necessarily a point of dissimilarity, as these basic rocks are older than the main granodiorite mass of the Mount Lytton batholith, and may represent an entirely independent rather than an early phase.

A difference between the two complexes is seen in the type of pegmatite associated with each. Those associated with the Coast intrusions west of Fraser River are typically white as compared with the pink pegmatites of the mountains southeast of Lytton. Another point of dissimilarity is the lack of concordance of foliation in the two masses as brought out by the rather scanty observations shown on the map. Furthermore, the Coast intrusions west of Fraser River are post-earliest Lower Cretaceous in age, whereas the rocks of the Mount Lytton batholith were unroofed by mid-Lower Cretaceous time. If the two complexes are contemporaneous, the Mount Lytton batholith must have been intruded, unroofed, and considerably eroded in this relatively short interval. It seems, consequently, more probable that the two intrusive masses are of different ages, that the Mount Lytton mass is the older, that it was emplaced in Jurassic time, and that it is more nearly contemporaneous with the Guichon Creek batholith.

Coast Intrusions West of Fraser River

Introduction. Coast intrusions west of Fraser River are part of the main intrusive core of the Coast Mountains, which extends some 1,000 miles along the western border of British Columbia, through southeastern Alaska, and into Yukon Territory.

Lithology and Structure. The Coast intrusions of Ashcroft map-area, west of Fraser River, consist almost exclusively of coarse-grained granodiorite. Although biotite granodiorite is the most abundant type, hornblende granodiorite is not uncommon. Outcrops representing several types of hornblende-rich rocks and showing complex crosscutting relations, were seen along the south fork of Stryen Creek. Locally, the granodiorite contains innumerable inclusions, some angular and blocky, of dark massive material, and others of schist. In places numerous large angular inclusions of granitic rock occur in the granodiorite, and are easily distinguished from it by sharp differences in granularity or fabric. Locally, the granodiorite shows a rusty weathered surface, which is pronounced at the western edge of the map-area, south of Stein River.

In thin section, the granodiorite is seen to be composed largely of plagioclase, which in most specimens is strongly zoned, ranging in some crystals from An_{47} to An_{23} and locally oscillatory, with an average composition about that of oligoclase (An_{25}). Potash feldspar, mostly orthoclase, but in some specimens microcline, was not seen to exceed about 5 per cent of the rock, and in some thin sections was not identified. Quartz forms up to 35 per cent of the rock. Biotite, the common mafic mineral, forms large, squat, hexagonal prisms. Black hornblende is generally a minor constituent, and in many thin sections is represented only by small, corroded-looking remnants. Some specimens contain a little muscovite. Of accessory minerals, apatite and magnetite are everywhere present, sphene is common, and zircon not rare. The granodiorite shows various types and degrees of alteration. Epidote is common, and in some specimens appears to be of deuteric origin. Plagioclase is not uncommonly dusted with saussuritic products. Biotite and hornblende are, in many specimens, partly altered to chlorite. At one locality, and possibly at many, the granodiorites have been albitized, and are cut by veinlets of prehnite; these alterations will be discussed in Chapter V.

Pegmatites, seen at only a few places, consist of white feldspar, bluish quartz, and large plates of muscovite. Aplites are not common. Lamprophyre dykes are moderately abundant. A thin section of a specimen from one in the upper part of Texas Creek consists of biotite, pleochroic brown hornblende, and minor amounts of a colourless pyroxene, set in a matrix of mainly sodic plagioclase, with minor interstitial quartz and large apatite grains.

In general, pegmatites, aplites, zenoliths, and other variations from the average granodiorite become fewer away from the borders and towards the central parts of the intrusive masses.

In many places, the dark minerals of the granodiorites show a preferred orientation, the degree of its development differing with the locality. A preferred orientation may, in some instances, be recognized from a distance, but at close range be so vague as to be undetectable. At some localities the biotite flakes are not only oriented but are collected into bands, the outcrop consisting of granodiorite through which at narrow intervals parallel layers up to 4 inches thick, rich in biotite, cross the rock. The attitudes of the preferred orientation of dark minerals, which are shown on the map accompanying this report, are insufficient to allow any comparison with the detailed studies of fabrics of other batholiths.

The contacts of the batholithic rocks in most places roughly parallel the strike of the schistosity and bedding of the rocks that they intrude. Less is known of the dip of the contacts. At Askom Mountain, the contact dips gently northeast, cutting across the strata of the Brew group, which dip to the southwest. The western contact of the tongue of granodiorite extending northwest from the north fork of Texas Creek appears to be nearly vertical, apparently dipping more steeply than the intruded strata.

The Coast intrusions west of Fraser River cut the Brew group of earliest Lower Cretaceous age, and are in fault contact with the rocks of the Fraser River Cretaceous belt. Eocene rocks contain detritus derived from these intrusions. The relation to the Mount Lytton batholith has already been discussed.

Age. The problem of the age of the Coast intrusions west of Fraser River is made particularly difficult because the contact of the batholithic rocks with the strata of the Fraser River Cretaceous belt is a fault, so that indirect evidence must be relied upon in any attempt to date them closely. From their relations to the Brew group and the Eocene rocks, it can be stated that they are, in part at least, post-early Lower Cretaceous and pre-Eocene in age.

In Ashcroft map-area, the Coast intrusions show many of the features commonly ascribed to syntectonic intrusions, for they are composed essentially of granodiorite, parts of them are elongate parallel with tectonic axes, they are locally gneissic, and they are in a general way concordant, although locally crosscutting. The emplacement of these intrusions, if syntectonic, would be accompanied by deformation and possibly regional metamorphism in immediately adjacent areas, and such deformation would be marked by unconformities, probably angular discordances, in the stratigraphic column. In Ashcroft map-area, the stratigraphic column is incomplete, and many of the rocks have been so highly disturbed, largely during post-intrusive diastrophism, that the presence of unconformities is difficult to establish. The fact, however, that the volcanic rocks of the Spences Bridge group lie more or less undisturbed, and are nowhere intruded by granodiorite or similar rocks, suggests that the Coast intrusions west of Fraser River may be pre-Spences Bridge, and, therefore, pre-Aptian (pre-early upper Lower Cretaceous) in age.

That the Coast intrusions west of Fraser River locally contain albite and veinlets of prehnite, apparently formed during an episode of albitization and prehnitization that affected many of the rocks along and adjacent to the Fraser River Cretaceous belt, and that some of the rocks of the Jackass Mountain group contain detrital prehnite, suggest that these intrusions are pre-Jackass Mountain group in age. These considerations would seem to limit the time of intrusion to the early mid-Lower Cretaceous, and it is possible that an unconformity at the base of the Jackass Mountain group marks the time of emplacement of the Coast intrusions of the western part of Ashcroft map-area.

Minor Intrusions

Hornblendite

A 6-foot sill of hornblendite cuts steeply dipping rocks of Division A of the Jackass Mountain group just east of Kanaka. The rock consists almost entirely of nearly equi-dimensional crystals of common hornblende up to ½ inch across. A little quartz, apatite, and magnetite, and secondary chlorite and carbonate comprise the balance.

Gabbro

Outcrops of gabbro are found along the east side of Fraser River a mile southeast of Lillooet. The rock, fairly light in colour, consists mostly of labradorite (An_{60}), with subordinate clinopyroxene, hypersthene, hornblende, apatite, and magnetite. Secondary minerals include amphibole, replacing both pyroxenes, prehnite, forming irregular stringers and replacing labradorite, and pyrite. The texture is hypidiomorphic granular.

About 2½ miles up Murray Creek from its mouth, a gabbro dyke, about 30 feet thick, striking north 20 degrees east and dipping 75 degrees southeast, cuts volcanic rocks of the Spences Bridge group. The rock consists largely of laths of labradorite (An_{60}), and clinopyroxene. Minor components include hornblende, biotite, quartz, apatite, and magnetite. The texture is subophitic. Secondary minerals include chlorite, actinolite, epidote, and white mica.

Albitized Gabbro

Altered fine-grained gabbro outcrops about a mile south of Lillooet, near the mouth of the river that drains Seton Lake. Although possibly altered lavas of the Cache Creek group, these rocks are believed to be more probably intrusive, perhaps related to the gabbro of this vicinity, and to have been intruded along or near the major fault that here bounds the Fraser River Cretaceous belt.

The dark green, massive, fine-grained rock is locally highly fractured and slickensided. In thin section it is seen to consist largely of albite (An_6), clinopyroxene, sphene, and magnetite. The texture is sub-ophitic, many of the albite laths being partly enclosed in pyroxene. Veinlets of cloudy albite traverse the rock, and some of the material of the veinlets is in optical continuity with the albite laths that they encounter. Chlorite replaces albite and pyroxene. Veinlets of strongly pleochroic epidote cut through the rock. These rocks have evidently been albitized, and reference to them will again be made in Chapter V.

Similar rocks, some of them dykes, are found north and south of Lillooet, at several localities near the main fault. They consist largely of albite and clinopyroxene, and are locally traversed by stringers of prehnite.

Alnöite

A dark grey alnöite dyke cuts the rocks of the Nicola group about 2 miles east of Semlin and has been described by Drysdale (1914, pp. 133-134). The rock contains plates of biotite up to 1 inch in diameter, set in a fine-grained groundmass. Under the microscope, it is seen to consist of large phenocrysts of biotite, olivine, and augite in a fine-grained groundmass of the same minerals. The augite is zoned, and the olivine is largely altered to serpentine. Perovskite occurs in small, dusty square outlines, and melilite in lath-shaped crystals. The melilite is partly altered to calcite. Magnetite is disseminated in small grains through the groundmass. Feldspar is entirely wanting in the rock.

Porphyritic Diorite

Sills and irregular crosscutting bodies of porphyritic diorite intrude the Lillooet group southwest of the mouth of Bridge River, and Palæozoic or Mesozoic rocks just east of Fraser River at the southern border of the map-area. The rock consists of a grey, finely crystalline groundmass, through which are scattered euhedral to anhedral phenocrysts of feldspar up to 10 mm. in diameter, and occasional phenocrysts of biotite. Under the microscope, the feldspar phenocrysts are found to be strongly zoned plagioclase, ranging in composition from An_{45} to An_{20}, that is partly to completely replaced by a fine-grained mixture of carbonate and secondary white mica. The few biotite phenocrysts are almost completely replaced by quartz, chlorite, and carbonate. The groundmass consists mainly of strongly zoned plagioclase, biotite, a little quartz, and magnetite.

Albite Syenite

Numerous, small, hornblende-rich intrusive bodies occur in the Fraser River Cretaceous belt west and south of Lytton. All but one of these are of less than mappable size. The largest appears to be roughly equidimensional in plan, but most of them occur as dykes and sill-like bodies up to 30 feet thick.

Most of these rocks consist essentially of hornblende and albite. The large body west of Lytton is coarse grained, hornblende crystals ranging up to ½ inch in length. In many places hornblende predominates over albite, and in a few the rock approaches a hornblendite in composition. Locally, the rock is a breccia consisting of angular fragments of hornblendite set in a matrix in which albite and hornblende are present in about equal amounts. In thin section the rock is seen to consist of pleochroic hornblende, with an extinction angle of 24 degrees, albite (An_4), orthoclase, apatite, sphene, and magnetite. Albite shows no zoning. Secondary minerals include abundant zoisite, epidote, chlorite, pyrite, and considerable white mica. In some thin sections the feldspar is highly saussuritized. A specimen from the western side of this body consists almost entirely of feldspar and quartz, with minor chlorite after biotite, and apatite, zircon, and magnetite. Plagioclase is euhedral to subhedral; quartz is interstitial to plagioclase. The plagioclase appears, at first glance, to be strongly zoned, but the effect is heightened by the zonal arrangement of saussuritic products, and close study shows that although there is some zoning, the main change in composition occurs near the outer rim. The inner parts of the plagioclase crystals average about An_{10}, locally reaching An_{15}, but the clear rims of the crystals are of composition An_3.

The dykes and sills resemble the hornblende-rich rocks described above, except that they are of fine grain and the hornblende crystals are needle-like. The plagioclase is albite, about An_6, in all specimens examined. Radiating acicular aggregates of pleochroic tourmaline(?) are conspicuous in the interstitial quartz of some of these rocks.

The presence of albite rather than a more calcic plagioclase, coupled with the high percentage of common hornblende in many of these rocks, suggests that they were originally perhaps dioritic in composition, and have been albitized. This possibility will be discussed further in Chapter V.

These rocks intrude strata of the Jackass Mountain group and are, therefore, of post-Lower Cretaceous age.

Quartz Diorite

Bodies of quartz diorite are exposed along and near the western flank of Fountain Ridge. The exact shapes of these are unknown, but most appear to be elongate parallel with the strike of the enclosing rocks. The largest is slightly less than a mile in length. The rock is light grey and massive, and composed mainly of white feldspar and quartz through which are scattered crystals of biotite and amphibole. Under the microscope, the rock is seen to consist of about 70 per cent zoned plagioclase, ranging in composition from An_{37} to An_{22}, 15 per cent quartz, 10 per cent biotite and common hornblende, 3 per cent orthoclase, and the balance of sphene, zircon, apatite, chlorite, and muscovite. The rock is relatively fresh looking, the only alteration noticed being the formation of a little chlorite at the expense of biotite and hornblende, and the development of secondary white mica in plagioclase.

Although no intrusive contact was seen, these rocks would appear to intrude strata of the Lillooet group, and would, therefore, be post-Lower Cretaceous in age.

Obsidian(?) Dyke

A dyke composed largely of glass intrudes quartz diorite on the ridge nearest the western edge of the map-area west of Akasik Mountain. The dyke, about 6 feet wide, is composed largely of a reddish brown crypto-crystalline material containing more or less contorted, $\frac{1}{8}$-inch, light-coloured bands. The edges of the dyke are of black shiny glass showing an obscure banding and containing occasional grains of feldspar and quartz. Under the microscope, a thin section of the central part of the dyke is seen to consist largely of glass, but to be so crowded with xenocrysts, minute spherulites, and cavity linings and fillings as to account for its lack of glassy appearance in the hand specimen. The faint banding of the glass selvage is seen to be due partly to concentrations of minute spherulites, and partly to clusters of grains of plagioclase, biotite, quartz, hornblende, apatite, and magnetite. Some of the plagioclase is zoned, of composition An_{45} to An_{30}. The broken nature of the minerals enclosed in the glass and their concentrations in different proportions at different places suggest that they are xenocrysts. The index of refraction of the glass, near 1·497, indicates that it is siliceous rather than basic.

CHAPTER IV

FAULTING ALONG FRASER RIVER

An outstanding structural feature of the area is the series of faults lying along the eastern edge of the Coast Mountains and bounding the Fraser River Cretaceous belt. There is some evidence to indicate that the overall nature of the movement along this zone was to elevate, relatively, the Coast Mountains to the west with respect to the Interior Plateau to the east. The rocks of the Cretaceous belt in part occupy a graben along this zone, as was pointed out by Bowen (1914, pp. 108, 110), but elsewhere appear to have been displaced in the same sense as the suggested general movement, being depressed with respect to the Coast Mountains to the west, but elevated relative to the terrain to the east.

The general nature of the Cretaceous belt is not incompatible with the belief that it lies along a fault zone. The belt, about 70 miles long in the area mapped, and ranging in width from a few hundred yards to 6 miles, extends in a relatively straight line, flanked by batholiths and formations of several ages and types. The rocks of the Cretaceous belt are in most places more highly deformed and disrupted than those of the bordering units.

Data collected at various points along the Cretaceous belt indicate that it is bounded by steep-dipping faults. South of Lytton, the faults are exposed at several localities. The eastern fault is well exposed in the north fork of Mowhokam Creek. The western fault can be seen in the valley of a large creek at a point about 3 miles southwest of Lytton. At numerous other places, the shattered nature of the rocks, and the attitudes of the beds close to the contact, indicate fault boundaries. About 7 miles north of Lytton, the fault contact between late Lower Cretaceous sedimentary rocks and granodiorite lying to the east is clearly seen in road cuts. Farther north, Eocene rocks, structurally a part of the Cretaceous belt, dip nearly vertically at their contact with the older intrusions to the west, and the contact is certainly a fault.

From Cinquefoil Creek northwards, the contact between the rocks of the Cretaceous belt and gently dipping lavas of the Spences Bridge group lies along a deep valley. The volcanic rocks, if projected a short distance westward, would come against the Lower Cretaceous strata that here rise 2,500 feet above the valley floor. This consideration, and the fact that where the contact crosses Fraser River, east of Fountain station, there are several shattered zones, indicate a fault contact. The western contact, from Siwhe Creek northwards, was not seen. At many places, the contact is occupied by serpentine and igneous dykes of several kinds. From Lillooet northwards, the general line of the contact is marked by outcrops of rusty silicified material, in part brecciated.

That the western fault is steeply dipping is indicated by its trace, the course of which is not materially influenced by topography. At Stein River, for example, the trace of the fault is thrown only slightly out of alinement, probably to the east, in traversing a valley 2,000 feet deep. Attitudes in the Cretaceous rocks near the western contact in the southern part of the map-area are mostly steeply east, and suggest that some movement on the fault was such as to lower the Cretaceous strata relative to the rocks on the west. In the northern part of the area, strata believed to be older than those of the Fraser River Cretaceous belt rise, on the west, thousands of feet above them, suggesting that movement was such as to lower the Cretaceous rocks relative to the older rocks.

The trace of the eastern boundary fault suggests that it is steeply rather than gently dipping. Along the greater part of its length, the Cretaceous strata are in contact with batholithic rocks that in places rise abruptly 6,000 feet above the Cretaceous beds. If it be assumed that the boundary fault is moderately inclined, in view of the fact that the batholithic rocks are probably older than most of the sedimentary strata, it seems logical to conclude that the Cretaceous rocks have been depressed relative to the batholithic rocks.

The nature of the movement on the northern section of the eastern boundary fault is not certain, for its solution depends largely on the relative ages of the two groups of rocks involved. The best evidence seems to indicate that the volcanic rocks are the younger, and, therefore, that the movement has been such as to depress the volcanic rocks with respect to those of the Cretaceous belt to the west.

In summary, from the south edge of Ashcroft map-area to the mouth of Cinquefoil Creek, the Fraser River belt appears to occupy a graben. North of Cinquefoil Creek, rocks to the west of the belt appear to have been relatively elevated, but rocks to the east appear to have been relatively depressed. The fault zone that extends southeast from the southern end of Fountain Ridge to Botanie Creek and Thompson River is perhaps subsidiary to the principal fault zone. Movement on it has apparently been such as to elevate the intrusive rocks with respect to the lavas. The course of the fault south of Thompson River is unknown; it possibly joins the main zone south of Lytton.

In the large view, the Cretaceous belt is perhaps to be regarded as composed of a series of fault blocks or slivers that have been involved in a major zone of faulting along which the rocks to the west have been relatively elevated. That the Cretaceous rocks in the southern part of the area appear to have subsided as a graben, perhaps indicates only that compressive forces relaxed sufficiently to allow subsidence, but gives no information as to the relative movements of the batholithic rocks to east and west. In the northern part of the map-area, there is some indication that, relative to the Fraser River Cretaceous belt, the rocks to the west have been elevated and those to the east depressed. The Cretaceous belt in this region may be considered as a horse involved in a fault zone, displaced in conformity with the major movement on the fault but to a lesser extent, resulting in a step-like gradation, showing increasing displacement to the east. The complex structures of the Cretaceous belt are believed to be largely due to stresses produced during movement on the major fault zone along which the Cretaceous belt lies.

The extent of this major fault zone beyond the limits of Ashcroft map-area is unknown. A fault zone[1] in the Bridge River district that extends up Yalakom River Valley, and across the head of Churn Creek, is possibly on the northwest extension of the western boundary fault in Ashcroft map-area. This fault is shown extending to the southeast in Hope map-area (Cairnes, 1944) for a short distance. Faults in the southeastern part of Hope map-area and in the southwestern part of Princeton map-area (Rice, 1947) are perhaps related in some way to the zone under discussion.

There is evidence suggestive of intermittent movement along the Fraser River fault zone. In connection with the origin of the conglomerate of the Jackass Mountain group, it was pointed out that there may have been movement along the zone during Lower Cretaceous time. It was suggested in another place that Eocene beds were possibly deposited as fans at the base of a fault scarp. Post-Eocene faulting is proved, for Eocene beds are involved in faulting along the Fraser River fault zone. Many workers have remarked that profiles across the axis of the Coast Mountains show that the eastern side is higher than the western, and it has been suggested that these mountains represent an elevated, tilted, and dissected erosion surface. If such tilting took place, it seems probable that differential movement would occur along the east side of the Coast Mountains at the fault zone under discussion. The suggested intermittent movement, far from proved, is somewhat analogous to that which is inferred to have taken place during the post-igneous history of the Sierra Nevada batholiths of the western United States.

[1] Leech, G. B.: Geol. Surv., Canada; oral communication.

CHAPTER V

ALBITIZATION AND PREHNITIZATION

INTRODUCTION

A feature of many of the rocks in, and adjacent to, the Fraser River Cretaceous belt is their content of albite. Although it seems certain that the albite of some intrusive rocks is secondary, and probably the result of metasomatism, it is believed that only the older bedded rocks of the Cretaceous belt have been albitized, and that the albite of the younger formations is of detrital origin. In some places, deposition of prehnite accompanied albitization.

ALBITIZATION OF INTRUSIVE ROCKS

Coarse-grained rocks, characterized by conspicuous blue or blue-grey quartz grains, occur at, and northwest of, Botanie Mountain. Such rocks underlie an area about 7 miles long and, at most, 1 mile wide, along the west side of the Botanie Mountain igneous mass. The hand specimen consists essentially of blue, somewhat smoky quartz, and grey feldspar. Under the microscope, a thin section is seen to be composed of about 50 per cent quartz and 40 per cent albite. The blue quartz contains abundant needle-like crystals that are probably rutile. No original mafic minerals remain, but may be represented by patches of chlorite, epidote, and magnetite that occur throughout the slide. The boundaries between quartz and albite grains are locally sutured, but in most places they are marked by stringers of fine-grained chlorite. Veinlets of albite and of epidote, chlorite, and quartz, traverse the rock. Albite is sprinkled with fine-grained white mica and aggregates of epidote.

These rocks resemble in many respects albite granites of Oregon that are believed by Gillully (1933) to be of replacement origin. He finds every graduation between diorite and albite granite, the feldspars of intermediate varieties showing incomplete replacement of andesine by albite. The presence of veinlets of albite, the composition of the albite, some of which is as sodic as An_4, the widespread occurrence of epidote, and the blue colour of the quartz, attributed to the presence of needles of rutile, are cited as evidences of hydrothermal alteration of dioritic rocks to albite granites. Hydrothermal solutions are believed to have been localized along zones of brecciation that are abundant in the altered rocks. The close similarity between the albite granites of Oregon and those occurring near Botanie Mountain is striking, and there seems little doubt that they are of similar origin.

Mention has been made of a diorite body south of Pavilion Creek near Fraser River. This rock has been highly sheared and broken, and is locally rich in albite. Thin sections of the altered rock consist largely of Albite (An_4) that is considerably deformed and fractured. Quartz is present in minor amounts. Patches of chlorite and epidote probably mark the sites of the original mafic minerals, and veinlets of prehnite, quartz, carbonate, and epidote traverse the rock. An intensely altered specimen, showing strong cataclasis, consists of about 40 per cent epidote, and the balance mainly of albite (An_6) and quartz.

Southeast of Lytton, the quartz diorite is locally highly sheared and faulted. Thin sections of these intrusive rocks show that they are rich in albite. They consist of albite (An_3), quartz, much bleached biotite, large crystals of sphene, and some magnetite. The central parts of the albite grains are charged with prisms of secondary white mica and equidimensional grains of zoisite or clinozoisite. Epidote is found throughout.

A specimen from the eastern edge of the Coast intrusions southeast of Kanaka shows similar alteration. Biotite has been largely altered to chlorite, but the hand specimen otherwise resembles the average granodiorite. In thin section, however, the rock is seen to consist of albite (An_8), quartz, biotite, chlorite, apatite, titanite, and magnetite. Albite is sprinkled with secondary white mica and zoisite. Large grains of epidote are scattered through the slide, and veinlets of prehnite and epidote lie along fractures and micro-breccias.

Intensely brecciated intrusive rocks, probably dykes or sills, occur on the east slope of Askom Mountain near the fault that bounds the Brew group. The rock has been completely shattered, the fragments ranging in size from ½ inch to microscopic. In thin section, angular fragments of quartz show undulose extinction, and plagioclase—albite (An_3)—is deformed and broken. Carbonate forms large aggregates and stringers, and chlorite is abundant.

The albite-rich rocks from Pavilion Creek, the mountains southeast of Lytton, Kanaka, and Askom Mountain are believed to have been albitized. Albite as sodic as An_4 is, apparently, rarely if ever pyrogenic (Gillully, 1933, p. 74). The presence of epidote and prehnite may be cited in support of albitization. Turner (1948, p. 124) states "...if the lime set free during albitization of spilites becomes sufficiently concentrated in the active solutions to outweigh the accompanying soda in its metasomatic influence, deposition of prehnite or epidote in vesicles of adjacent basalts, or even pseudomorphous replacement of plagioclase by epidote or prehnite may occur". At each locality faults are known or can be inferred from the sheared and broken condition of the rocks. Such faults would act as channelways for albitizing solutions.

Albitized gabbros from the vicinity of Lillooet have been described. The occurrence in them of veinlets of albite and epidote leaves little doubt of albitization. Prehnite veinlets in adjacent gabbro are perhaps related to the process in the manner suggested by Turner.

Albitization of the albite syenites west of Lytton is more difficult of proof. The composition of the albite, locally An_4, and the high proportion of hornblende, which suggests a basic rock rather than an acidic one, have been cited in favour of albitization. The presence of epidote, tourmaline(?), and pyrite probably indicates hydrothermal action.

ALBITIZATION OF SEDIMENTARY AND PYROCLASTIC ROCKS

There is considerable evidence that some of the bedded rocks of the Fraser River Cretaceous belt have been albitized. The various rocks in most places contain albite as the only plagioclase. Most of the albite is less calcic than An_6, and, as stated before, albite of very low lime content is, apparently, rarely, if ever, pyrogenic. The association of pyroxene, chlorite, and albite, found in lithic grains of certain beds of the Lillooet group, is incongruous, and probably indicates that the albite is secondary.

Although the albite of the detrital rocks is most probably secondary, it may have been derived by erosion from a terrain underlain by albite-rich rocks, such as spilites, or albitized intrusions, or it may have been introduced hydrothermally into the strata of the Cretaceous belt. Several factors support the second hypothesis. The rocks of the Cretaceous belt are involved in a zone of faulting along and near which there has been considerable albitization of intrusive rocks. Furthermore, volume relations appear to favour the hypothesis. The sampling of the rocks adjoining the Fraser River belt, admittedly imperfect, nevertheless indicates that there is much more non-albitized than albitized rock. In the sedimentary rocks of the Cretaceous belt, however, albitic material predominates, and it would seem improbable, therefore, that it is derived by erosion from albite-rich rocks.

In spite of this mass of indirect evidence, other considerations suggest that only the older rocks of the Cretaceous belt have been albitized, and that the albite of the younger formations is detrital. In the Lillooet group, no plagioclase other than albite was found. If a pyroclastic origin is admitted for any of the rocks of this group, it is difficult to see how they could have been albitized before deposition, for, presumably, much of the material forming them is juvenile matter blasted out of volcanoes and quickly carried to the sea. A highly altered sill, not elsewhere described, cuts volcanic conglomerate of the Lillooet group on the upper road, north-east of the mouth of Bridge River. The sill contains abundant prehnite, and if the view that prehnitization and albitization go hand in hand is accepted, the presence of prehnite would support the hypothesis of albitization. In summary, the evidence is believed to favour the albitization of the rocks of the Lillooet group.

Microscopic study of Division A of the Jackass Mountain group yielded no proof of albitization. In the limited number of slides examined, albite was the only plagioclase identified, but whether it was introduced hydrothermally or whether it is detrital is unknown.

Albite is the only plagioclase identified in the typical conglomerates and greywackes of Divisions B and C of the Jackass Mountain group. Non-marine beds west and south of Lytton, however, show considerable variety in the kind of plagioclase they contain. In certain rocks, only albite is found, but in others, labradorite and oligoclase are found together. At least one specimen from this succession contains albite-quartz aggregates and volcanic grains rich in labradorite. Such a combination is believed to argue strongly for detrital origin for this particular albite, and, if detrital, suggests that other albite of this group may well be detrital. Detrital prehnite was noted in two thin sections from Division C, and if a close relation between prehnitization and albitization is accepted, this occurrence would suggest that the associated albite also is detrital. The evidence cited above, although somewhat offset by the fact that albite syenites, possibly the product of albitization, cut these rocks, is believed to indicate that the albite of the Jackass Mountain group is of detrital origin.

The late Lower Cretaceous rocks are at least locally rich in albite, but no compelling evidence of albitization was discovered.

In summary, it seems probable that the rocks of the Lillooet group have been albitized, but that the albite of the Jackass Mountain group and of younger formations would appear to be of detrital origin.

PREHNITIZATION

Along the motor road, at the nose that projects eastward into Fraser Valley about 6 miles south of Lillooet, an area too small to map separately is underlain by rocks that are highly altered, sheared, and traversed by narrow stringers of mashed serpentine (*See* p. 74). The rock is dark grey, fine grained, and of almost cherty appearance. Under the microscope, the original texture of the rock is seen to have been completely destroyed. The rock consists mainly of a fine-grained aggregate of prehnite and a cloudy, almost isotropic material of uncertain composition in which a few formless aggregates of minute grains of albite can be distinguished. Veinlets traversing the rock consist of coarse quartz mosaics through which are scattered radiating groups of acicular prehnite and chlorite.

The occurrence of prehnite in and near certain albitized rocks at various points along the 50-mile section between Kanaka and Pavilion Creek have been commented on in preceding pages of the report, and their possible relation to albitization has been noted.

CONCLUSIONS

Many of the igneous and some of the sedimentary and pyroclastic rocks lying along and near the Fraser River Cretaceous belt have locally been albitized, possibly by solutions of hydrothermal origin. Prehnite was probably deposited at the same time. That the Lillooet group was subjected to albitization seems probable, but most of the younger rocks appear to have been enriched in albite by the incorporation of detrital albite and albite-rich material whose provenance is unknown.

The zone of albitized rocks of Ashcroft map-area is similar in some respects to a belt of rocks described by Gillully (1935). The Permian rocks of eastern Oregon consist partly of keratophyres, spilites, and allied pyroclastic rocks that have been intruded by plutonic rocks, some of which are the albite granites referred to in an earlier part of this chapter. He cites considerable evidence to show that albite of the lavas and pyroclastic rocks is of metasomatic origin.

The origin of the albitizing solutions of Ashcroft map-area is unknown. It is difficult to relate the solutions to any particular intrusion, although possibly they are associated with the Coast intrusions that lie west of Fraser River. Possibly one or more of the main faults tapped a source of albite-rich solutions.

CHAPTER VI

ECONOMIC GEOLOGY

GENERAL STATEMENT

Gold, copper, antimony, molybdenum, epsomite, and coal have been produced in Ashcroft map-area, and, in addition, occurrences of iron, zinc, silver, chromium, and gypsum are known. Development of mineral resources in the eastern part of the area is favoured by easy accessibility, both by road and rail, relative proximity to populated centres, and availability of water power and timber. The part of Ashcroft area lying west of Fraser River, because it is relatively inaccessible, has not been thoroughly prospected, but the known occurrences of ore minerals here should encourage further search.

One of the first discoveries of placer gold in the interior of British Columbia was on the Thompson, near Nicoamen River, in 1857. News of this discovery, reaching California, was probably responsible for the rush of some 20,000 placer miners into Fraser Valley the following year. In that year, placer gold was discovered on Bridge River. In many places along Fraser and Bridge Rivers, great orderly piles of boulders still mark the benches where the gold seekers of the fifties and sixties worked the gravels. The Big Slide mine, one of the earliest lode mines in British Columbia, and the first in Ashcroft map-area, was discovered in 1872. Between 1899 and 1905 the important deposits of the Highland Valley copper camp were found. Of the various mines of this camp, the principal producer in Ashcroft map-area was the O.K. mine, which in 1916 and 1917 produced 10,000 tons of ore averaging 3·6 per cent copper. Since 1919, several thousand tons of epsomite have been mined and shipped from the Basque deposits. The Hat Creek coal deposits, which have produced intermittently since 1925, have probable reserves of 28,000,000 tons and possible reserves of a further 28,000,000.

CLASSIFICATION OF MINERAL DEPOSITS

For descriptive purposes, the mineral deposits are classed as follows:

- Metalliferous deposits
  - Placer deposits
  - Lode deposits
    - Antimony deposits: Clarke and Watkinson prospects
    - Chronium deposits: Cache Creek, Cornwall Creek, Scotty Creek, and Ferguson Creek deposits
    - Copper deposits: O.K. mine (Chataway group), Kathleen claim, Glossy group, Transvaal group, Highland group, Maggie mine, and Victory claim
    - Copper-gold deposits: Big Slide (Grange) mine
    - Gold deposits: Glacier, Serpentine and Summit groups, and Lytton Gold prospect
    - Iron deposits: Toketic deposit
    - Molybdenum deposits: Index prospect
    - Molybdenum-gold deposits: Martel prospect
    - Silver deposits: Paystreak group
    - Zinc deposits: Fairview and Coronation groups

Non-metallic deposits
- Coal
- Gypsum
- Jade
- Limestone
- Salines
- Vesuvianite

METALLIFEROUS DEPOSITS

Placer Deposits

Early in the history of the Ashcroft area, placer miners swarmed over the rivers and tributary streams on their way to the Cariboo district, and from that time to the present some gold has been won each year from the gravels and sands along the main streams within the boundaries of the map-area. In the late years of the 19th and beginning of the present centuries, annual production of placer gold from the area ran as high as $40,000 to $50,000, mainly from the efforts of Chinese and Indians. In later years, annual production was véry low, but increased during the depression years after 1930, and in 1939 reached 570 ounces. Little placer mining was done during World War II, and in 1945 and 1946 production was 37 and 18 ounces of gold respectively.

During the years 1945 to 1947 few placer operations were in progress. Mr. Leonard of Lillooet worked ground on the east bank of Fraser River near the mouth of the creek flowing into the river 2 miles south of Glen Fraser. His working consisted of an adit driven into the gravel on the river bank. The floor of the adit was the bedrock on which the gravels lay. He had attained some success the previous year, but when the property was visited, in July 1946, he was repairing the damage caused by high water of the previous spring and it was impossible to enter the adit.

In 1947, a drag-line was being installed about 2 miles south of Lillooet on Fraser River, with the object of testing the river gravels at that point. In addition, preparations were being made to work the gravels on the northeast side of Fraser River opposite Fountain.

Lode Deposits

ANTIMONY DEPOSITS

Clarke Prospect (22)[1]

References: B.C. Minister of Mines, Ann. Repts.: 1915, p. 253; 1916, pp. 264, 518; 1931, p. 114.

The Clarke antimony prospect lies near the western edge of the map-area on Antimony Mountain. In 1914, five claims were staked by Indians from Keefers. Mr. W. S. Clarke, also of Keefers, obtained a half interest in the property, and in 1915 shipped 3 tons of selected ore to Seattle for treatment. This returned $92.50 a ton in antimony. In 1916, it is reported that the Consolidated Mining and Smelting Company of Canada, Limited,

[1] Numbers in parentheses refer to properties named or located on the accompanying map.

became interested in the property, but heavy snow prevented prosecution of the work and the option was allowed to lapse. Little or nothing has been done since. The present ownership is unknown.

A fault zone, which can be traced for several hundred feet, cuts the granodiorite. Stibnite occurs in irregular quartz veinlets that form a stock-work along the zone. Mineralization is sporadic.

Watkinson Prospect

Reference: Dawson, G. M., 1896, pp. 343-344.

Dawson reports that "stibnite occurs near Watkinson's, about 23 miles above Lytton, on the Fraser. The vein is reported to be about 14 inches wide, with quartz and calcite. The stibnite holds traces of gold and 2·187 ounces of silver to the ton of 2,000 lbs.". The locality, about ½ mile south of the intersection of the highway and Cinquefoil Creek, was visited, but the vein was not found. Rocks in the vicinity are closely folded beds of the Lillooet group, here cut by rusty granitic dykes. Abundant veinlets of quartz and calcite were seen, and pyrite occurs irregularly in the dykes. The mineralization is of interest for it represents the only known occurrence in the rocks of the Fraser River Cretaceous belt. Tetrahedrite is reported from near this same locality.

CHROMIUM DEPOSITS

Near Bonaparte River, from below Cache Creek to Clinton, numerous bodies of chromite-bearing serpentine occur within the Cache Creek rocks. Of these the most important have proved to be those on Scottie and Ferguson Creeks.

The chromite in most of the deposits occurs as disseminated grains, but locally is more concentrated and occurs as streaks or bands containing as much or more chromite than serpentine, and as bunches or nodules of massive chromite. At Scottie and Ferguson Creeks, all phases between disseminated and massive types may be found, and no distinct boundaries separate mineable from non-mineable material. The chromite probably crystallized during the consolidation of the ultrabasic rock from which the serpentine has been derived. The serpentine bodies are too small to be shown on the accompanying map, but occurrences along Bonaparte River Valley are depicted in Figure 3.

The principal occurrences are found at the Cache Creek, Cornwall, Scottie Creek, and Ferguson Creek properties.

Cache Creek Occurrence (6)

Reference: Munitions Resources Commission, Canada, Final Report 1920, pp. 42-44.

The Cache Creek property is situated on the west bank of Bonaparte River near the highway junction at Cache Creek. It includes the old Oppenheim occurrence described by Dr. W. A. Ferrier in the Munitions Resources Commission report of 1920. The workings described in that report are now all caved and the exposures could not be seen.

About 600 feet west of the T.U. Auto Camp at Cache Creek and 650 feet above the road, a lens of serpentine approximately 1,000 feet

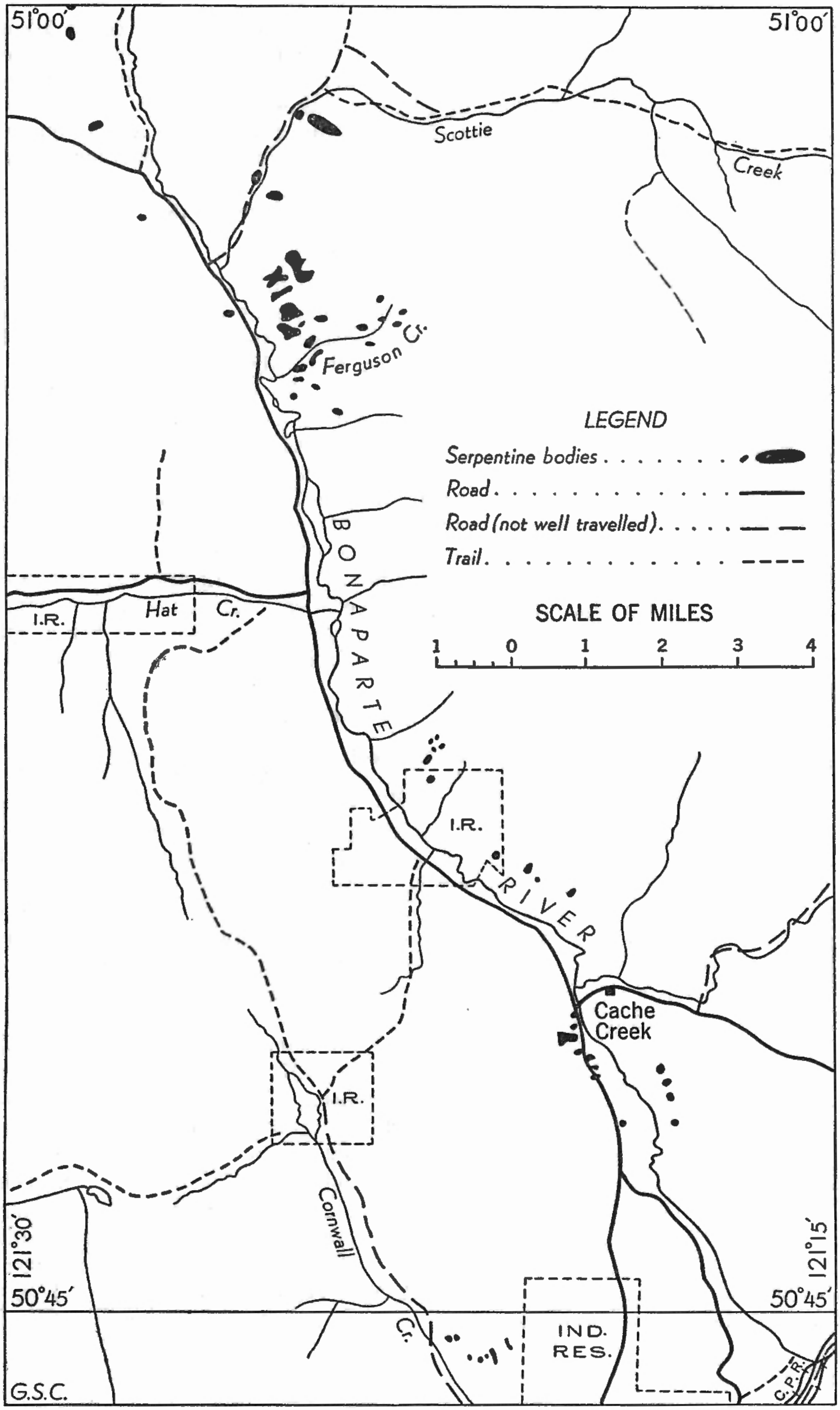


Figure 3. Sketch map, showing location of serpentine bodies along and near Bonaparte River (after Rice, 1942).

wide trends parallel with the valley. In this lens, so far, only one mass of solid chromite, weighing 3 tons, has been found; it has been mined for sampling and testing purposes. In 1939, 1940, and 1941, Ardens Limited of Calgary, under the direction of Messrs. Oakes of Calgary and Starnes of Ashcroft, prospected the claims, their program including a magnetometer survey and some diamond drilling, but no other chromite occurrences were discovered.

Cornwall Creek (Chrome Pit) Occurrence (8)

Reference: B.C. Minister of Mines, Ann. Rept. 1938, p. F69.

The property on which this discovery was made was staked in 1938 by Lester Starnes of Ashcroft. It is situated about 2 miles up Cornwall Creek from the highway crossing, and consists of twenty claims. In 1939, some exploratory work was carried out by the Calgary Mineral Syndicate with J. O. Williams of Ashcroft in charge of the work. The property is sometimes referred to as the Williams chromite deposit. The claims were allowed to lapse, and were restaked by T. Blakiston-Gray of Lytton and his associates, but no further work has been done.

The claims are reached by about 3 miles of rough motor road over open country. A cabin in good repair is situated close to Cornwall Creek, and a good trail leads to the open-pits and 50-foot adit that have been cut into the serpentine outcrops. None of the workings exposed any chromite in place, and the only chromite seen was that from a large boulder. This may have come from another occurrence farther north along Bonaparte River as no other float of similar nature was found on the property.

Scottie Creek (2) *and Ferguson Creek* (3) *Deposits*

References: Reinecke, L., 1920, pp. 86-91. Geol. Surv., Canada, unpublished report by H. M. A. Rice, 1942. B.C. Minister of Mines, Ann. Repts.: 1915, pp. K285-286; 1927, pp. C211-212; 1928, p. C220; 1929, p. C229; 1930, pp. A198-199.

Scottie and Ferguson Creeks are tributaries joining Bonaparte River from the east. Ferguson Creek enters the Bonaparte about 2 miles south of Scottie Creek and 3 miles north of Hat Creek. The showings on Scottie Creek are reached by a narrow wagon road, suitable for cars and trucks, that branches from the Ashcroft-Clinton highway at the mouth of Scottie Creek. There is no road to the Ferguson Creek showings.

The chromite on Scottie Creek was first discovered in 1901, but no work was done until 1918 when wartime demands stimulated exploration. Stewart and Calvert of Oroville, Washington, mined about 500 tons of the material that year but none was shipped. In 1927 the Consolidated Mining and Smelting Company of Canada, Limited, optioned two claims on Ferguson Creek and one on Scottie Creek, and staked extra ground. Several short adits were driven and tests were made of the ore, but results were not promising and operations ceased in 1931. The claims on Ferguson Creek were allowed to lapse, and eight claims on Scottie and Chrome Creeks were Crown granted in 1939. No work was done by the company after 1931. During World War II, the Ferguson Creek deposits were covered by four claims held by D. B. Sterrett of Kamloops, and Henry Cargyle and J. L. Burr of Ashcroft. It was intended to option the Scottie

Creek deposits from the Consolidated Mining and Smelting Company and to operate both deposits. However, nothing materialized and no work was done.

H. M. A. Rice of the Geological Survey examined the deposits on Ferguson Creek in 1942. He concluded that although they contained no ore of direct shipping grade, there were 20,000 tons of 15 per cent Cr_2O_3 reasonably assured, with an excellent chance of finding additional lenses to the extent of another 20,000 tons. The material would require concentration. Concentration tests by the Bureau of Mines at Ottawa revealed that ore from the Ferguson west showings offered the best chance of exploitation, concentrating readily on a Wilfley table to 50 per cent Cr_2O_3 and 15 per cent Fe at grinds of from minus 28 to minus 35 mesh, and yielding a chrome-iron ratio of 2·25 to 1. On the Ferguson east and Scottie Creek deposits it was not found possible to obtain Wilfley table concentrates of much better grade than 44 per cent Cr_2O_3 and 14 per cent Fe at a grind of minus 48 mesh. A chrome-iron ratio of only 2 to 1 was obtained.

COPPER DEPOSITS

O.K. Mine (*Chataway Group*) (17)

References: Drysdale, C.W., 1916, pp. 88-89. B.C. Minister of Mines, Ann. Repts.: 1915, pp. K278-279; 1916, pp. K265, 430; 1918, p. K474; 1919, p. N183; 1922, p. N140; 1930, p. A203.

The O.K. property, originally consisting of the O.K., I.O.U., Apex, F.O.B., and E.P.U. claims, is situated on the southwest side of Highland Valley about a mile north of Calling Lake. It is reached by an old road that branches from the Highland Valley road at a point about 26 miles from Ashcroft. The road to the mine was passable by light truck in 1945, but the bridges and corduroy were in poor condition. The road climbs to an elevation of 5,400 feet and leads to the old concentrator and workings that have been idle since 1917. The buildings are now useless, and the workings are inaccessible. The main showings are on the O.K. claim, and it was here that the underground development work was done.

The ore lies along a fracture in the Guichon Creek batholith, and consists of copper sulphide minerals in a gangue of sericitized wall-rock, quartz, and fault gouge. Ore minerals are chalcopyrite, chalcocite, bornite, and secondary copper minerals.

The property was developed by an adit driven along the strike of the shear zone for 218 feet. In testing the width of the ore along the adit 55 feet of crosscuts were driven. A winze is reported to have been sunk from the adit level and to be in ore to its depth of 50 feet. Ore for the concentrator came from between the adit level and the surface. During the active period of the property, in 1916 and 1917, 10,000 tons of ore are reported to have been mined and run through the concentrator. The average assay of the ore was 3·6 per cent copper. From this operation 1,487·8 (wet) tons of concentrates were shipped, assaying 20·33 per cent copper and 1·9 ounces silver a ton.

The stope was carried through to the surface where it is now represented by an opening roughly 250 feet long and 10 to 12 feet wide. Locally, where short cross fractures contained ore, the width may be as much as 30 feet.

The main fracture carries a width of from 2 to 4 feet of gouge, which in places contains ore minerals. The shear zone strikes north 80 degrees east and dips steeply south. The open stope is now partly filled with material sloughed from the walls, and examination of the old workings is impossible. Today, further prospecting of the shear could be done quite easily by modern diamond drilling methods.

Kathleen Claim (20)

References: B.C. Minister of Mines, Ann. Repts.: 1922, p. N141; 1923, p. A159; 1924, p. B139.

The Kathleen claim lies about 3 miles south of the O.K. mine, and has a similar mineral deposit in a vein of like character, which strikes north 25 degrees east. Nothing more than a little surface trenching has been done on this showing.

Glossy Group (12)

References: Drysdale, C. W., 1916, p. 88. B.C. Minister of Mines, Ann. Repts.: 1915, pp. K269, 276-277, 446; 1916, p. K265; 1917, p. F225; 1924, p. B140.

This property consists of the Glossy, Forge, Cinder, Sapphire, and Turquoise claims, and in 1946 was held by J. L. Burr of Ashcroft, a son of J. W. Burr one of the original owners. It is situated on the western slope of Forge Mountain at an elevation of 5,200 feet.

The claims were first staked in 1904, and a little trenching was done before 1915 when the property was optioned by Messrs. Carlson, Dunlevy, and Berle of Vancouver, who sank a shaft on the Forge claim. The property reverted to the owners in January 1916, and nothing has been done since. During exploratory work 21·8 tons of carefully selected ore were shipped to the Tacoma smelter; this assayed 0·03 ounce of gold and 2·96 ounces of silver a ton and 12·62 per cent copper.

The main workings consist of the Forge shaft, approximately 8 by 6 feet and reported to be 100 feet deep. This shaft was full of water when the property was visited and the shaft-house decayed beyond repair. A pit 30 feet deep, about 250 feet east of the Forge shaft, has been sunk on a 5-foot vein that strikes north 80 degrees west, dips northerly at 70 degrees, and is evidently a continuation of the vein encountered in the shaft. Several other showings have been exposed by open-cut work, and in one of these a crushed zone about 12 feet wide contains five small quartz stringers in which ore minerals are scarce. The zone strikes north 40 degrees west and dips steeply to the northeast. East of the 30-foot pit, an open-cut exposes a fracture containing quartz and sparse ore minerals. It strikes north 20 degrees east and dips 67 degrees easterly. This work was done at least 30 years ago, and the workings are now grown over with small bushes and trees or filled with soil and water.

The host rock is that of the Guichon Creek batholith, and the vein deposits resemble those of other properties in Highland Valley. On the property, the batholithic rocks are exposed in a belt ¼ to ½ mile wide between the main mass of Cenozoic volcanic rocks on the east and a small outlier to the west. The veins occur in fracture zones in the batholithic rocks, and consist of chalcocite, bornite, chalcopyrite, azurite, malachite, some pyrite, and specular hematite, in a gangue of quartz, tourmaline, calcite, and crushed wall-rock. The wall-rock, normally a typical grey quartz diorite, is pink near the vein, due to the presence of a pink feldspar.

Except for the 21·8 tons of hand-picked ore shipped in 1915, no other shipments have been made from the property. The present dilapidated condition of the old workings makes examination and appraisal difficult. Probably the easiest and cheapest method of testing the continuation of the structure and value of the property would be by diamond drilling.

Transvaal Group (13)

References: Drysdale, C. W., 1916, pp. 88-90. B.C. Minister of Mines, Ann. Repts.: 1901, p. 1090; 1902, p. H193; 1905, p. J205; 1906, p. H255; 1907, p. L135; 1915, pp. K269 and 276; 1917, pp. F224-225; 1929, p. C228; 1930, pp. A195-196; 1931, p. A108.

This property, situated at an elevation of 6,000 feet in a valley between the two summits of Forge Mountain, is near the east boundary of the map-area. It is reached by a mountain road about 7 miles long that branches east from the main Highland Valley road about 20 miles from Ashcroft. The road to the property, though not now suitable for motor transport, could be made usable with little trouble.

The property, originally staked in 1899, consists of six Crown-granted claims, the Transvaal, Pretoria, Mafeking, Imperial, Chamberlain, and Ladysmith, and the Pretoria Fraction. Of the original owners, William Knight, J. Hoskings, and George Novak, Mr. Novak, who was living in Ashcroft in 1946, still retains an interest in the property.

The claims were explored in 1901 and 1902, and extensive work was done in 1906 and 1907 when the property was under bond to the Consolidated Mining and Smelting Company of Canada, Limited. Further work was done by Mr. Novak in 1929, 1930, and 1931.

The workings consist of two shafts, now caved, and an adit, which at the time the property was visited was closed by a locked and barred door. Numerous cuts and surface trenches occur to the south and east of the adit. Annual reports of the B.C. Minister of Mines indicate that the main shaft was sunk for 200 feet, with 340 feet of drifting and 40 feet of crosscutting on the 100-foot level and 75 feet of drifting on the 200-foot level. Lateral work in and from the adit is indicated as approximately 725 feet.

Veins occur in fractures and joint planes in the batholithic host rocks, and a zone of fracturing has been traced in a north-south direction for several hundred feet. The veins consist of black, sooty tourmaline, quartz, and fractured wall-rock, mineralized with minor amounts of azurite, malachite, chalcopyrite, and chalcocite. They range in width from a fraction of an inch to 3 feet, but are generally less than a foot wide. The length of any one continuous section of a vein is not more than 20 feet.

Highland Group (14)

References: Drysdale, C. W., 1916, p. 90. B.C. Minister of Mines, Ann. Repts.: 1902, p. H194; 1907, p. L136; 1915, pp. K275-276; 1917, p. F225; 1922, p. N141; 1924, p. B139.

The Highland group of claims is situated on Forge Mountain about 2 miles south of the Transvaal group. The veins are similar to those of the Transvaal in occurrence and character and the two properties are connected by an old road. Exploration was carried out during the early years of the century when a shallow shaft was sunk, several surface pits cut, and a 115-foot adit driven into the hillside about 2,000 feet northeast of the shaft. These workings are now caved and inaccessible.

Maggie Mine (4)

References: B.C. Minister of Mines, Ann. Repts.: 1907, pp. L134 and 215; 1913, p. K183; 1915, pp. K284-285 and 366; 1929, p. C215; 1930, p. A199.

The Maggie mine is situated near the Cariboo Highway about 2 miles north of the confluence of Hat Creek and Bonaparte River. Some exploration and underground development were done in 1907, but no new work has been done since and the workings are now caved and inaccessible.

Reports of the B.C. Minister of Mines indicate that in 1907 development work had progressed as far as the opening of three levels, the lowest 185 feet below an adit level. In addition to a shaft, 1,100 to 1,200 feet of underground lateral work was reported as well as some stoping on No. 2 level. An attempt was made to re-open the property in 1915, but this hardly progressed past the dewatering stage. The next recorded work was in 1930, when the mine was again dewatered but little else accomplished.

The Cache Creek rocks are here highly sheared, and are vividly coloured by oxidation of pyrite. Workings on the property followed a shear zone striking northeast and dipping 70 degrees southeast. The zone contained chalcopyrite, and during early developments about 50 tons of selected ore sent to the Ladysmith smelter yielded 2 ounces of silver a ton, no gold, and 8 per cent copper. Low assay returns in lead and zinc have also been reported. Examination of the workings was impossible because of their poor condition. The siliceous material on the dumps and the amount of silica and pyrite in evidence in the rocks close to the workings indicate strong hydrothermal activity in this vicinity.

Victory Claim (15)

The Victory claim, staked by Eric McColl of Lillooet in 1941, lies at the western end of the ridge between Laluwissen and McGillivray Creeks, at an elevation of 5,000 feet. Mineralization of interest is in evidence along the fault that cuts the Coast intrusions in this vicinity, the fault zone extending northwest and southeast of the claim for some miles. The rocks at the showings consist largely of what appear to be inclusions in the main intrusive mass. The fault zone here strikes about north 60 degrees west and dips nearly vertically. Along and near the fault the rocks are pyritized and extremely rusty, and at a few points lenses composed almost entirely of fine-grained pyrite occur in the reddish decomposed matter of the fault. A little copper stain was noticed.

COPPER-GOLD DEPOSITS

Big Slide (Grange) Mine (1)

References: Dawson, G. M., 1896, p. B339. B.C. Minister of Mines, Ann. Repts., 1881, p. 395; 1882, p. 361; 1883, p. 411; 1884, p. 422; 1885, p. 491; 1886, pp. 207-209; 1887, pp. 273-274; 1889, p. 289; 1896, p. 550; 1897, p. 558; 1899, p. 727; 1928, p. C214; 1930, p. A198; 1931, p. A110; 1932, pp. A149-154; 1933, pp. A184-185, 311; 1934, pp. A28, A29, F23, G48; 1935, pp. A28, A30, F57.

The Big Slide mine was not visited, and the following account of the property is abstracted from the references cited.

The property is situated on the east bank of Fraser River near the mouth of the creek draining Kelly Lake. It was discovered in 1872, and some development and milling by a crude arrastra was done in 1881. In 1886, a 10-stamp mill was erected and the property operated for a few months in 1887, during which time it was visited by G. M. Dawson of the Geological Survey. Material taken by Dawson from the concentrates assayed 0·408 ounce gold and 0·933 ounce silver a ton (Dawson, 1896, p. 340B). The property lay idle until 1928, when the Big Slide Mining and Development Company was formed to operate it. Some development was carried out by this company, but the operation was generally unsuccessful. While still held by the above company the property was examined in detail by A. M. Richmond, assistant resident mining engineer for the B.C. Department of Mines (1932, pp. A149-154). In 1933, Grange Mines, Limited, acquired the property, began an active program of development, and erected a 25-ton mill. The mill operated during 1934 and up to August 1935, when active operation ceased. In 1937, Grange Consolidated Mines was formed to take over the property, but little other than maintenance work was done, and all work ceased in 1940. The property lay idle until 1946, when Rusdon Mines, Limited, combined the Big Slide property with some claims to the southeast and did about 1,900 feet of diamond drilling. Nothing has been done since.

The property is difficult of access, but during its active period could be reached by road and steep trail from Kelly Lake station on the Pacific Great Eastern railway. Kelly Lake may also be reached by road from Lillooet and Clinton.

In 1934, during the operation of the mill, 646·1 ounces of gold, 765 ounces of silver, and 4,669 pounds of copper were obtained from 3,330 tons of ore milled.

The rocks in the vicinity of the property are shales, cherts, and greenstones of the Cache Creek group, which are here intruded by a small stock of diorite. In the mine workings the diorite is the dominant rock, and forms the host for two narrow lenticular quartz veins, referred to as the foot-wall and hanging-wall veins. These veins pinch and swell and may reach widths of 3 to 4 feet, but 8 inches is average. The foot-wall vein has a much flatter dip than the hanging-wall vein and probably joins it at depth. Northwest of the mine workings, the hanging-wall vein, which is the stronger of the two, outcrops in the bluffs for 1,000 feet where it strikes north 30 degrees west and dips 70 degrees northeast.

The ore consists of pyrite, pyrrhotite, arsenopyrite, chalcopyrite, marcasite, limonite, and native gold in a gangue of quartz and minor carbonate. The native gold is visible only in dense pyrite. The ore commonly occurs as banded sulphides with quartz, but in the wider sections of the veins may occur as isolated patches of sulphides. In most parts of the underground workings a thin parting of gouge appears between the vein filling and the walls.

The property has been developed on seven levels, three of which are adit levels. No. 3 level is the main haulage level, and from it access to the lower workings is by winze. In 1935, when the seventh level was opened, 260 feet of drifts, 52 feet of crosscuts, and 50 feet of raises were run before the mine closed.

Grange Mines, Limited, also controlled the property of Pavilion Mines, Limited, lying to the south. This property has a deposit similar to that at the Big Slide mine. It has been explored by a 170-foot shaft and about 325 feet of lateral work on two underground levels. There has been no production.

GOLD DEPOSITS

Glacier Group (24)

Reference: B.C. Minister of Mines, Ann. Rept. 1929, p. 236.

The Glacier group lies at an elevation of about 7,000 feet on the northeast side of the nose that lies between the north and south forks of Kwoiek Creek, and is reached by good pack-trail from the mouth of Kwoiek Creek. The rocks consist mainly of steeply dipping argillites and slates, with some greenstone and serpentine. The slates and greenstones are cut by dykes that appear to be offshoots of the large mass of granodiorite lying to the northwest. One, and probably two, quartz veins, ranging in thickness from a few inches to 6 feet, lie in the bedding planes of the slates. Pyrite and arsenopyrite are abundant in the quartz, and it is reported that assays show both gold and silver.

Workings consist of numerous open-cuts and one adit about 40 feet long. There is no record of production.

Serpentine and Summit Groups (26)

Reference: Horwood, 1936, p. 5.

Horwood reports that "the Serpentine and Summit groups, of eight and six claims respectively, held by W. D. Munro (since deceased), lie north and south across the serpentine band about 11 miles along the trail that runs along the ridge northwest of Keefers. A lens of schist in the serpentine on the hill overlooking the first large tributary of Kwoiek Creek contains a 60-foot shear zone, with white quartz veins up to 5 feet wide. In places the veins contain a few specks of pyrite, which is said to carry small amounts of gold. The intervening bands of schist carry a much larger amount of pyrite, and all exposures are rusty and weathered. Other veins and shear zones similar to those mentioned, occur on the property".

Lytton Gold Prospect (21)

Reference: B.C. Minister of Mines, Ann. Rept. 1935, p. A31.

The Lytton Gold prospect is on Mount Roach about 7 miles west and 2 miles south of Lytton, and is reached by trail via Stryen Creek. The property is owned by the estate of the late W. D. Munroe, formerly of Lytton.

The rock in the vicinity of the prospect is coarse-grained granodiorite of the Coast intrusions, which locally contains inclusions of gneiss and schist. A quartz vein extends up the northwest slope at Mount Roach, over the ridge, and some distance down the southeast flank of the mountain. It is at least 1,200 feet long and ranges in width from 6 inches to 6 feet, averaging more than 4 feet for considerable distances. It has an average strike of north 60 degrees west and dips 20 to 55 degrees northeast. A few narrow subsidiary veins were noted. East trending faults, dipping from 30 to 60 degrees south, offset the vein some tens of feet at irregular intervals. When the property was visited in 1946 no metallic minerals were seen in the quartz, but it is reported that many years ago the best showings occurred on the crest of the mountain, and consisted of fine particles of native gold, a little galena, aggregates of arsenopyrite, and an unidentified steel-grey mineral. The quartz is in part vuggy and locally sheeted parallel with the walls of the vein.

The vein has been stripped for much of its length, and has been explored by a few prospect pits and adits, the latter now caved. A cabin on the north side of the mountain is in good repair. A camp, consisting of several buildings, was established on the south fork of Stryen Creek, where an adit, now caved, was driven in an attempt to find the extension of the vein.

It is reported that during the past 25 years about 1 ton of ore has been shipped.

IRON DEPOSITS

Toketic Deposit (16)

Reference: B.C. Minister of Mines, Ann. Rept. 1926, pp. 194-195.

As mentioned previously, the Guichon Creek batholith is traversed by two sets of fractures. In the Highland Valley copper camp, these fractures have been filled mainly with copper minerals and minor specular hematite. Four miles east of Toketic, at an elevation of about 3,800 feet, the fracture filling is mainly specular hematite, with minor chalcopyrite. The hematite occurs as narrow discontinuous stringers that lie along shear planes or as a cement between broken fragments of the wall-rock.

This occurrence of hematite was reported on briefly in the Annual Report of the B.C. Minister of Mines for 1926 under the name of the Dora Kay group of six claims. The report indicates that the hematite had, at that time, been prospected along a zone 3,000 feet long and 300 feet wide, and that the workings included an adit as well as several shallow open-cuts. No further work has been done on the occurrence since 1926. When it was visited in August 1945 the only working encountered was the adit, which had a length of 50 feet. This adit is driven along a series of narrow stringers of hematite that lie along shear planes striking north 65 degrees east and dipping 34 degrees southeast. The stringers are rarely more than 2 inches wide and few are continuous for more than 3 feet.

Index Molybdenite Prospect

References: Drysdale, C. W., 1917, p. 54. Stevenson, J. S., 1951, pp. 353-366. B.C. Minister of Mines, Ann. Rept. 1949, pp. 113, 114.

Molybdenite occurs in a granitic body, part of which lies within the western border of Ashcroft map-area, west of the north fork of Texas Creek. Although occasional flakes of molybdenite were noted here and there in the granitic body, the main showings, which have been described by Drysdale, lie about a mile west of the map-area, at the head of a cirque leading down to Cottonwood and Cayuse Creeks. The prospect, lying at an elevation of about 7,500 feet, is reached by trail via Texas Creek.

According to Drysdale: "The molybdenite ore is very clean and free from copper, tungsten, tin, bismuth, arsenic, and other deleterious elements. The highest grade ore is 76 per cent molybdenite and occurs sparingly in bunches up to one foot in width, along certain closely spaced joint planes in the fine-grained quartzose members of the granite stock, as well as impregnations in the intervening granite. The low grade ore could be readily concentrated, as the molybdenite occurs in rosettes and flakes that are uniformly distributed throughout the disintegrating granitic gangue. The latter consists of quartz, feldspar, and, in places, sericite flakes. Biotite mica occurs as an essential constituent in the blocky granite away from the ore zones. Molybdenite occurs less sparingly in rusty, vitreous, quartz veinlets cutting the granite. In the vicinity of the ore, the granite is much stained by the straw-yellow trioxide of molybdenum, molybdite, and this, along with a certain amount of kaolinization of the orthoclase feldspar serves as a good indicator of the ore zone". Development work apparently consists of a series of open-cuts. Eight tons of ore were shipped in 1916.

Specimens from the property are radioactive, but the radioactive mineral, uraninite, has not yet been found to occur in quantities of economic interest.

In view of the fact that radioactive minerals in some places occur in reddish or rusty igneous rocks, the region near the western edge of the map-area, south of Stein River, might be worth prospecting.

MOLYBDENUM-GOLD DEPOSITS

Martel Mine (11)

References: B.C. Minister of Mines, Ann. Repts.: 1935, p. G44; 1936, p. F63; 1937, p. F35; 1938, p. F68; 1939, p. A74; Bull. No. 9, pp. 9-11.

This property, operated by Martel Gold Mines, Limited, during the mid-thirties, included the Hat Nos. 1 to 11; Bug Nos. 12, 13, and 14; Axe, Boe, Boe No. 1, Dave, Matt, and Vernon mineral claims. It is situated on the eastern slope of Martel Mountain at an elevation of 2,400 feet and about 200 feet above the floor of Venables Valley. Two roads lead to the valley and the mine; one, an abandoned narrow wagon road climbs the slope behind Martel, and the other branches from the Cariboo Highway about 8 miles above Venables Valley. The latter is a good gravel road, suitable for truck haulage, and in 1945, when the property was visited, was in good repair.

The buildings at the mine camp were in good repair, but all equipment had been removed. Mining operations were conducted at the property from 1934 to 1938, but in 1939 the entire operation was abandoned and the equipment sold. Nothing has been done since. In 1945, the property was restaked by Lester Starnes of Ashcroft.

The deposit consists of a group of small lenticular quartz veins in argillites, cherts, and minor tuffs of the Cache Creek group. The veins range in thickness from a fraction of an inch to 12 inches and from 2 to 60 feet in length. They strike north 35 to 40 degrees east, dip 70 to 75 degrees northwest, and are displaced a few feet by northwest striking faults.

The gangue is mainly quartz, with some calcite, and carries small amounts of molybdenite, pyrite, chalcopyrite, pyrrhotite, sphalerite, and arsenopyrite. The quartz has been fractured, allowing passage of mineralizing solutions. In 1937, a small shipment was sent to the Mines Branch at Ottawa for testing. This assayed 0·015 ounce gold and 0·04 ounce silver a ton, 1·48 per cent molybdenite, and 0·11 per cent copper. The molybdenite occurs in very thin seams that parallel the vein walls.

Underground work comprised 1,035 feet of drifting, crosscutting, and sinking in an effort to follow the veins. Most of the work was done on the main adit level, but two winzes were sunk, to depths of 88 and 55 feet respectively. Some short lateral workings were driven from these in an effort to find the veins on their downward extension from the main level, but with little success.

SILVER DEPOSITS

Paystreak Group (25)

Reference: Horwood, 1936, p. 5.

The Paystreak property is situated near the headwaters of a creek that empties into Kwoiek Creek about 3½ miles above its mouth. The claims show several small quartz veins that lie conformably in phyllite about 100 feet east of the main serpentine belt. Open-cuts in the phyllites have exposed several small veins that pinch and swell along strike, reaching a width of 7 feet in some places. No ore minerals were seen, but veins on the property have been reported to carry a little tetrahedrite and some silver.

ZINC DEPOSITS

Fairview Group (7)

The Fairview group of eight claims, situated west of the main highway about 14 miles east of Cache Creek, was, in 1944, held by Lestern Starnes of Ashcroft and J. W. Oakes of Calgary. It is believed that the claims have now lapsed. Some open-cut work and diamond drilling have been done on the property. All workings are in volcanic rocks of the Nicola group, which in this vicinity are intruded by a tongue of granite from the Guichon Creek batholith.

The lowest working just west of the highway exposes sphalerite in a gangue of quartz and calcite. Near the top of the north face of the pit, the vein comprises 3 feet of massive sphalerite on the foot-wall, about 2 feet of barren material in the centre, and 2 feet of well-mineralized stringers on the hanging-wall. The west wall of this pit is a definite slip face striking north and dipping 70 degrees east. The showing has not been traced beyond the limits of the pit, a distance of about 10 feet. Three thousand feet northwest of this lower showing a second pit exposes a 3-foot silicified zone carrying mineralized lenses consisting of sphalerite, chalcopyrite, and pyrite, 6 to 8 inches wide and up to 1 foot in length. This zone can be traced for 15 feet. Five hundred feet north, another open-cut exposes a similar deposit, which is less well mineralized. No intersections of economic importance were reported from the drilling.

Coronation Group (9)

Reference: B.C. Minister of Mines, Special Report by R. J. Maconachie, 1938.

The Coronation group of eight claims was held by A. J. Johnson of Ashcroft, but has now lapsed. It is situated on Barnes Creek between Thompson River and Barnes Lake and is about 3 miles east of Ashcroft. A good road leads to a point within ¾ mile of the showings, whence they are reached by trail over open country.

Between elevations of 1,800 and 1,850 feet on Barnes Creek, two narrow, easterly striking shears in volcanic rocks of the Nicola group carry sparse pyrite, sphalerite, galena, and lesser chalcopyrite in a gangue of quartz and calcite. Some exploratory work, including a 65-foot adit, met with little encouragement.

NON-METALLIC DEPOSITS

COAL

Although thin beds of lignite coal and coaly material were seen at many places in Ashcroft map-area, in both Tertiary and Cretaceous rocks, the large deposit on upper Hat Creek is the only one of economic significance.

Hat Creek Coal Deposit (5)

References: Dawson, G. M., 1896, pp. 207B-208B. MacKay, B. R., 1926, pp. 164-181. B.C. Minister of Mines, Ann. Repts.: 1899, p. 290; 1895, p. 668; 1897, p. 558; 1899, p. 728; 1901, p. 1092; 1913, p. K183; 1823, p. A159; 1924, pp. B145, 337; 1925, pp. A187, 308; 1933, p. A337; 1934, p. G31; 1936, pp. G4, 6, 42; 1937, pp. G5, 32; 1938, p. G34; 1939, p. A115; 1940, pp. A101, 126; 1941, pp. A96, 120; 1942, pp. A94, 96, 118; 1943, pp. A89, 115; 1944, pp. A86, 88, 89, 93; 1945, pp. A137, 163.

The Hat Creek coal deposit lies about a mile south of the road junction at the southeastern end of Marble Canyon. In 1946 it was held by St. Eugene Mining Corporation, who intended to explore the possibilities of the property as a stripping operation.

This coal occurrence was reported on by G. M. Dawson in 1877 and again in 1894. Various early attempts were made to work the deposit, during which three shallow shafts were sunk and two adits, one 188 feet long, were driven. In 1925, the property was acquired by the Hat Creek Coal Company, who drove another adit more than 100 feet in length, and drilled seven bore-holes in an attempt to explore the property. During the progress of this work, B. R. MacKay of the Geological Survey examined and reported on the property. It lay idle from 1925 to 1933, after which it was worked intermittently in a small way. The average production each year was only a few hundred tons, but reached a maximum of 1,978 tons in 1942. During this period Mr. L. D. Leonard held the property and operated it for only a few months each year, during the winter season. His markets were the local towns of Ashcroft, Kamloops, and Lillooet, and he trucked the coal direct from the mine to the customer. In 1943, Leonard sold to the Western City Company, who in 1944 optioned the property to the St. Eugene Mining Corporation. In 1946, when the property was visited, no work was being done either on the surface or underground, but there were evidences that a recent survey had been made. The conditions, therefore, are much the same as when reported on by MacKay in 1925, with the exception that the face of the adit has been advanced to about 500 feet from the portal.

The coal is contained in a basin of Tertiary sedimentary rocks that overlie unconformably the blue-grey Marble Canyon limestones of the Cache Creek group. The Tertiary beds are in turn overlain by basalt flows and breccias of probable Miocene age, all of which are covered by a heavy mantle of glacial drift. The extent of the sedimentary basin and the coal measures therein is not easily defined because much of the area is drift covered. According to MacKay (1947, p. 102), the area underlain by the coal measures is 3 square miles.

Hat Creek has eroded through the drift, and at the mine site has exposed coal along the creek for a distance of 1,500 feet. This is the only place where coal outcrops, but stripping has exposed coal at other points close to the creek in this vicinity. The coal is interbedded with clay seams and semi-indurated shales and sandstones. No fossils have been found to date these beds accurately, but about 1,000 feet to the west, light-coloured, yellow and red shales of the coal-bearing group are overlain, unconformably, by vesicular basalt of probable Miocene age.

Little is known of the structure of the coal measures, but near the coal outcrop they appear to be steeply folded and to have suffered some faulting. Along the creek the beds strike north 20 to 40 degrees west and dip 65 to 70 degrees west. According to MacKay (1926, p. 168A), this structure held throughout the length of the old adit. Evidence of folding was disclosed in the adit driven in 1925, and known as Adit No. 2. Here MacKay discovered two synclinal folds separated by a compressed and faulted anticline. The axes of these folds strike north 10 degrees west.

Of the seven holes drilled, only four encountered coal, and three of these were in the neighbourhood of the adits and open-cuts. On the basis of the work done at that time, MacKay (1926) estimated 16,800,000 tons of clean coal and 31,950,000 tons of combined shaly and clean coal. In his recent report on the "Coal Reserves of Canada", issued in 1947, MacKay revises his estimate to a probable tonnage of 28,000,000 tons plus a possible further 28,000,000 tons. Regardless, however, of estimates made, the work done to date is insufficient to delineate the coal basin properly. To do this a diamond drilling campaign of wide scope is necessary, and until this is done no accurate idea of reserves is possible.

To date, coal from this deposit has not been able to compete with higher grade coals on the open market, but some small success has been attained in supplying local markets, by delivering the coal direct from mine to consumer. The coal dries rapidly and disintegrates on exposure leaving very little lump, a feature adverse to stockpiling and long transportation. Therefore, under present conditions, it is not suitable for ordinary fuel purposes. On the other hand, should there be discovered some method of utilizing the coal, this deposit would attain economic importance.

Miscellaneous Coal Occurrences

About 2½ miles south of Spences Bridge, light-coloured, partly consolidated sandstones of Tertiary age outcrop in a dry gully at an elevation of 2,200 feet. These rocks contain a lignite seam (18) about 6 feet thick that is exposed for 100 feet by two short adits driven into each side of the gully. The area of sedimentary rocks can be only of limited extent, as volcanic rocks of the Spences Bridge group outcrop on all sides near the coal seam.

Small occurrences of coal have been reported from Botanie Creek near Lytton.

GYPSUM

References: Cole, L. H., 1913, pp. 95-97. B.C. Minister of Mines, Ann. Rept. 1922, p. N153. Geol. Surv., Canada, unpublished report by W. E. Cockfield, 1941.

On the west bank of Thompson River, opposite Spatsum station and near the mouth of Inkikuh Creek, rocks of the Cache Creek group have been intensely altered by intrusion of the Guichon Creek batholith. They have suffered much silicification and pyritization, and locally contain nodules of gypsum and thin stringers of selenite.

In 1913, a 25-foot adit was driven into the outcrop oposite Spatsum and is reported to have intersected a 5-foot bed of pure gypsum, but nothing further has been done to develop the showing and little is known about the continuity of the bed as it does not outcrop.

The exposures near the mouth of Inkikuh Creek are reported to have been explored about 40 years ago, but the workings are now caved and buried in slide material. The highest assay obtained by Cockfield (1941) was 21·48 per cent gypsum, which is well below commercial grade. The stringers of selenite themselves are too small and too widely spaced to be of commercial value.

JADE

References: Dawson, 1887, pp. 364-370; 1895, p. 347B. Harrington, 1890, pp. 61-65.

Boulders of jade have been found in river gravels in Ashcroft map-area at Lytton and near Spences Bridge. They are reported also from Yale, in Hope map-area (Dawson, 1887). The local Indians used it in the manufacture of tools, and jade adzes or partly worked jade fragments are common in Indian burial grounds and camp-sites of the Ashcroft area. The jade, which is nephrite, has been described by Harrington (1890). So far as known, the source of the jade has never been found.

LIMESTONE

Reference: Goudge, M. F., 1946, pp. 181-183, 185, 221, 225.

Besides the great belt of limestone in the Pavilion Mountains, a few other small exposures, some of nearly pure limestone, were observed convenient to transportation. According to Goudge (1946), who examined the limestones in this area for purity, two such bodies outcrop along the road between Spences Bridge and Ashcroft. One, just north of Martel, could provide a large tonnage of high calcium limestone. His analysis of the limestone is as follows:

	Per cent
SiO_2	2·44
Fe_2O_3	0·07
Al_2O_3	0·14
$Ca(PO_4)_2$	0·11
$CaCO_3$	95·98
$MgCO_3$	0·46
	99·20

Near the road junction at Cornwall Creek, an oval-shaped mass of high calcium limestone forms a sharp bluff. This mass contains beds of shale and chert and includes siliceous patches of highly magnesian limestone that weathers brown. These impurities, however, do not greatly affect the quality of the limestone, from which the following analysis was obtained:

	Per cent
SiO_2	1·98
Fe_2O_3	0·10
Al_2O_3	0·48
$Ca_3(PO_4)_2$	1·27
$CaCO_3$	95·84
$MgCO_3$	0·29
	99·96

In the main body of limestone along Marble Canyon and Pavilion Mountains analyses of samples from various localities show one with a calcium carbonate ($CaCO_3$) content as high as 99·05 per cent, and many in which this content is more than 96 per cent. This great belt of limestone, though holding lenses of argillite and greenstone as well as siliceous streaks and patches, is one worth investigation for those interested in the production of lime and lime products. So far, the distance from consuming centres has militated against utilization of the deposit.

SALINES

As the greater part of Ashcroft map-area is in the dry belt region of British Columbia, it is natural that surface deposits of saline material would be preserved. Two such occurrences are known, of which one, the epsomite deposits at Basque, has been worked at intervals since 1919. The salt is leached from neighbouring Cache Creek rocks and concentrated in basins during the hot dry spells of the summer months. At Soap Lake on Nicoamen Plateau, near Spences Bridge, sodium carbonate (Na_2CO_3) accumulates during the dry summer seasons, but to date has attracted comparatively little attention.

Basque Epsomite Deposits (10)

References: Goudge, M. F., 1926, pp. 62-81. B.C. Minister of Mines, Ann. Repts.: 1918, pp. K237-238; 1919, pp. N180-181; 1920, p. N168; 1922, p. N153; 1923, p. A171; 1934, pp. F22-23; Bull. No. 4, pp. 42-50.

The epsomite deposits at Basque are situated in a small valley midway between Venables Valley, on the west, and the gorge of Oregon Jack Creek, on the east. The salts have accumulated in four small ponds that lie along the now dry valley, but are concentrated mainly in the two upper ponds. Overburden is light or lacking, and in many places bare rock walls form part of the borders of the ponds. These ponds are caused by dams of boulder clay and drift that cross the narrow valley. The elevation of the highest and largest pond is about 2,500 feet above sea-level, and the lowest pond is 164 feet lower and 1 mile farther down the valley. A good road, 2 miles long, leads to the property, and branches from the main Spences Bridge-Ashcroft highway at a point ¾ mile south of Oregon Jack Creek.

The deposits were first staked in 1917 by Messrs. Hammond of Basque, and in 1919 the Basque Chemical Company was formed to ship crude salts to its refinery in Vancouver. This company ceased operations in 1923 after removing 2,300 tons of salts. In 1926, the deposits were carefully examined by M. F. Goudge of the Bureau of Mines, Ottawa, who published a full report in the Bureau of Mines Publication No. 642. It was not, however, until 1933 that interest was again taken in the deposits, and in 1934 Epsom Refineries, Limited, took over the property. From then until 1938 about 3,000 tons of salts were removed. In 1938 the property was acquired by the Ashcroft Epsom Salts Company of Winnipeg, which carried on operations during the winter of 1938-39. Since then little has been done except that in 1942, 65 tons of salts were shipped from the refinery at Ashcroft, by Canadian Industries, Limited.

Rocks in the immediate vicinity of the epsomite deposits consist of sheared andesite, impure highly folded argillites, and minor limestone of the Cache Creek group.

The salt crystal in the ponds occurs in circular basins or bowls, separated from each other by a ring of mud, rising 2 to 8 inches above the surface of the crystal. The mud between the crystal bowls contains 45 to 60 per cent salts plus a little organic matter, the remainder being silt. When viewed from the shore the ponds appear to consist of numerous shallow bowls, the bottoms of which are composed of crystal. The salts are evidently leached from the adjacent Cache Creek rocks and fed into the pool by underground channels or springs. Surface water during periods of run-off also raise the water level of the ponds and carry in silt and organic matter. During the long, hot, dry spells characteristic of the region, the brine is concentrated by evaporation and crystallization takes place in the crystal bowls.

The Basque deposits are hydrous salts of magnesium, sodium, and calcium, and consist mainly of hydrous magnesium sulphate (epsomite), some hydrous sodium magnesium sulphate (bloedite), and minor amounts of other soluble salts. When the main deposit was first worked, the top layer of crystal, about 3 feet thick, was high-grade hydrous magnesium sulphate that only needed to be free from the small amount of mud mixed with it to provide, according to the company's statement, epsom salts over 98 per cent pure.

The highest and largest of the deposits, known as Basque No. 1, is oval in shape, about 650 feet long and 450 feet wide, and occupies an area of between 5 and 6 acres. The aggregate area covered by the crystal bowls is slightly less. Some of these bowls have a diameter of as much as 60 feet, and the deposit persists with little diminution in size to a depth of 5 feet. The average depth of the bowls is in excess of 10 feet, and one was as much as 14 feet deep. Goudge calculated that this pond held approximately 64,800 tons of mixed salts to a depth of 10 feet. Tests indicated that the uppermost 3 feet were of almost pure hydrous magnesium sulphate, giving a reserve of this material of about 20,000 tons.

The second pond, known as Basque No. 2, is 2,800 feet farther down the valley and 76 feet lower in elevation than the Basque No. 1. It occupies an area of about 2 acres, and is covered by a 1-foot layer of top crystal. This top layer represents run-off from No. 1 pond, where the brine interfered with the mining operations and was pumped into a launder leading to No. 2 pond. Below the top layer, crystal bowls occur similar to those in the No. 1 deposit, but occupy only an area of about 1 acre. Goudge estimated an available 8,500 tons of mixed hydrous salts in this basin.

The third pond, situated about 85 feet below, and 1,000 feet farther down the valley from, No. 2 pond, contains considerably less salts than either of the others. Though it is roughly the same size as the No. 2 pond, only the southern half contains crystal bowls, which have an average depth of 3 feet. Tonnage estimated for this pond is 3,000 tons.

No. 4 pond contains only about 200 tons of material, and another, known as No. 5 pond, carries nothing that could be utilized.

The total amount of salts in the Basque deposits then is as follows:

		Tons
Basque No. 1	Epsomite	20,000
	Combined sodium and magnesium salts	44,800
Basque No. 2	"	8,500
Basque No. 3	"	2,000
Basque No. 4	"	200
	Total	75,500

Since this estimate was made by M. F. Goudge in 1924, about 3,000 tons of the salts have been removed.

Soap Lake Sodium Carbonate Deposit (19)

References: Cole, L. H., 1928, pp. 25-28. B.C. Dept. Mines, Bull. No. 4, pp. 32-35.

Soap Lake lies at an elevation of about 3,000 feet in an east-west trending valley about 3 miles southeast of Spences Bridge, and is reached by a good trail from Nicola River.

In flood time, the lake probably has a length of more than a mile and a maximum width of ¼ mile. When the deposit was visited, in July 1945, the eastern end of the lake bed was almost dry; only a few small shallow ponds remained, separated by mud-flats that carried a white encrustation of salts not more than an inch thick. The main basin of the lake was toward the western end of the valley, where a pond covering an area of about 60 acres was filled with a greenish brine. These conditions were similar to those encountered by Cole (1928), who tested the deposit in 1926. At that time he estimated that the brine in the main basin was about 3 feet deep and would yield about 15,000 tons of mixed sodium salts to each vertical foot of depth. No crystal bed was encountered.

A sample of the brine taken by Cole at a depth of 2 feet below the surface gave the following analysis:

	Per cent
Sodium carbonate (Na_2CO_3)	81·42
Sodium bicarbonate ($NaHCO_3$)	10·03
Sodium chloride ($NaCl$)	2·17
Sodium sulphate (Na_2SO_4)	5·93
Magnesium chloride ($MgCl_2$)	0·45

The rocks in the vicinity of the lake are volcanic flows and agglomerates of the Spences Bridge and Kingsvale groups.

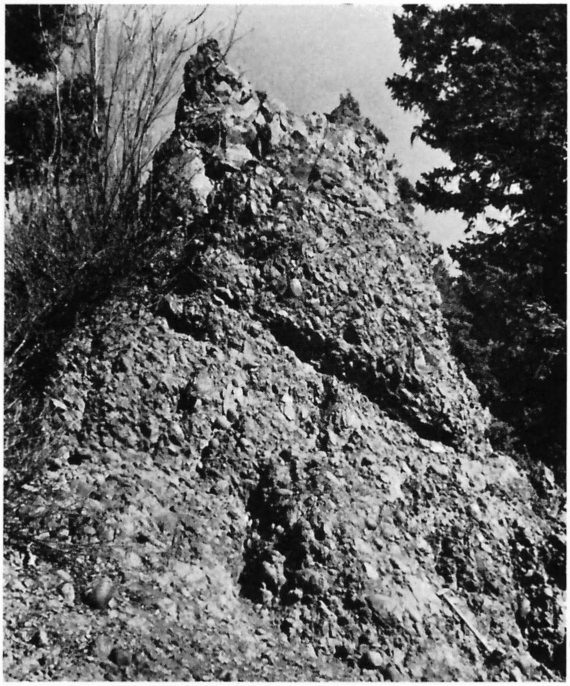
The lake has no apparent outlet, and the salts are evidently leached from the surrounding volcanic rocks, carried into the basin by springs and run-off waters, and concentrated there during the hot dry summer seasons. Though no attempt has been made to collect and ship these sodium salts on a commercial scale, it is reported that sacks of the salt have been transported to Spences Bridge and used locally.

VESUVIANITE (23)

Green Gold Jade Claims

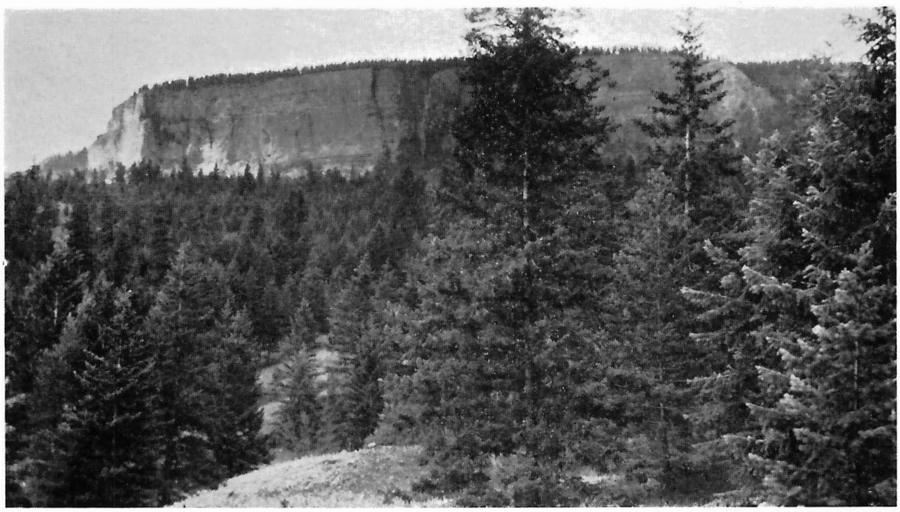
Occurrences of vesuvianite were staked by Messrs. Ray and Malcolm Dunstan of Lytton in 1945. Vesuvianite is found in the large serpentine body on the ridge some 2 miles southwest of Skihist Mountain, and in float for some distance to the west. The mineral occurs as an extremely fine-grained aggregate. Colours are brown, grey, yellow-green, and apple-green; much of the material is nearly opaque, but some apple-green varieties are translucent and attractive in appearance. The pure vesuvianite was seen in place at only one locality, and here it had been almost completely extracted. It occurred, apparently, as an irregular mass, perhaps 6 inches across, associated in the serpentine with a white rock flecked with green that consists of chlorite, clinopyroxene (probably diopside), and minor vesuvianite. The pure vesuvianite is similar to californite, a variety found in serpentine (Kunz, 1903). Large, unfractured specimens of the translucent green variety would probably be of some value as semi-precious stones.

PLATE II



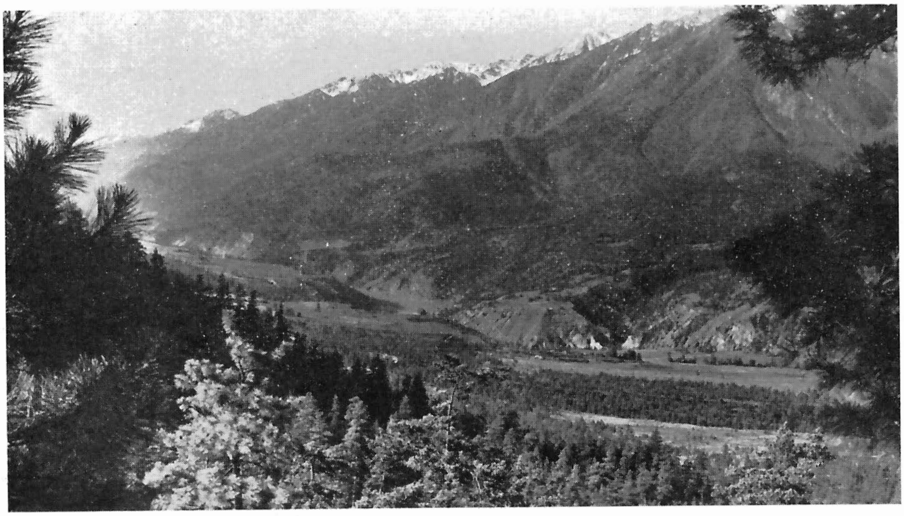
K.C.McT. 9-3-1947

A. Conglomerate near the base of Jackass Mountain group, showing a suggestion of imbricate structure. The hammer is about 15 inches long. (Page 41.)



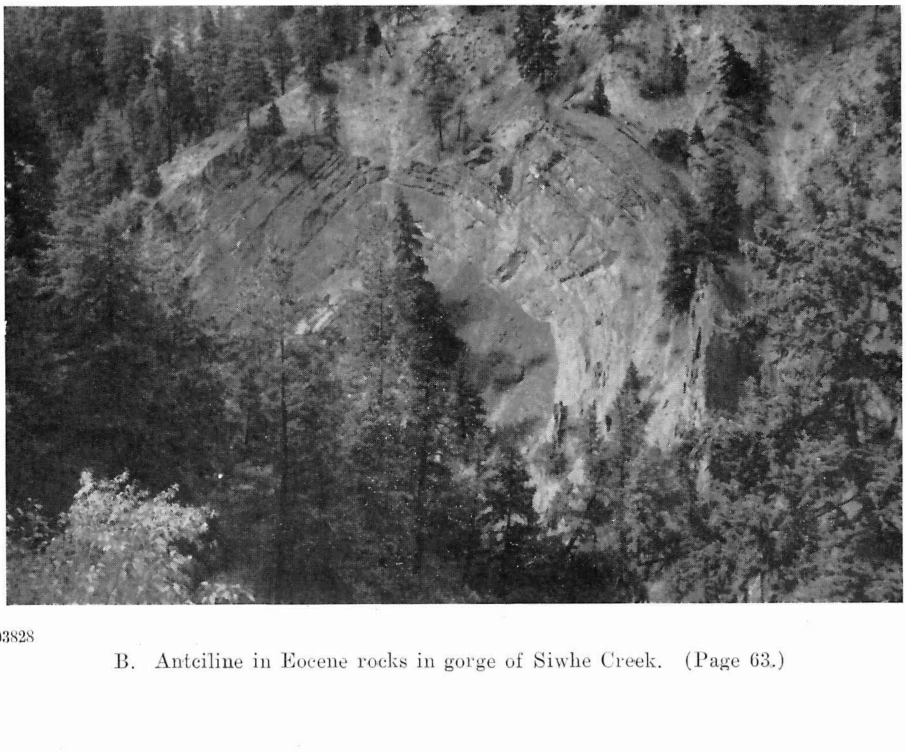
100862

B. Tertiary lavas and agglomerates, Pass Valley at eastern boundary of map-area. (Page 66.)



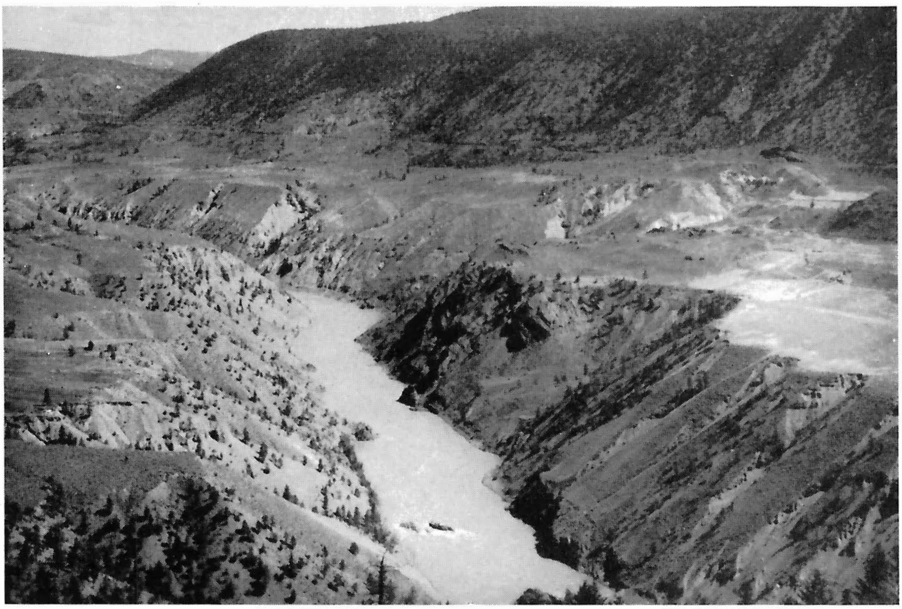
103751

A. View southeast of Fraser River, showing mouth of Siwhe Creek. Eocene rocks form spurs above which rises the eastern edge of the Coast Mountains. Note dissected fans at mouths of creeks. (Page 61.)



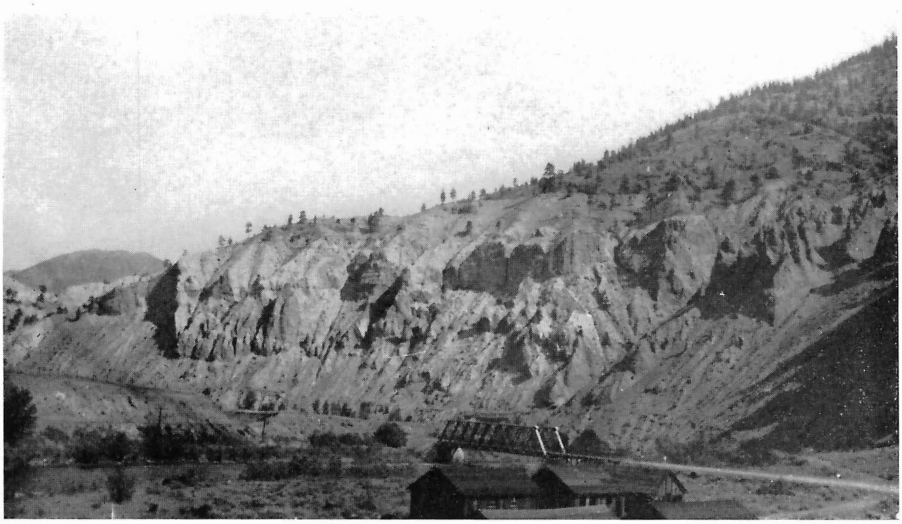
103828

B. Antciline in Eocene rocks in gorge of Siwhe Creek. (Page 63.)



103802

A. View northeast across Fraser River toward mouth of Fountain Creek (left background) showing glacio-fluvial till. (Page 71.)



96746

B. Pleistocene silts 3 miles up Nicola River from its mouth. (Page 71.)

INDEX