GEOLOGICAL
SURVEY
OF
CANADA

DEPARTMENT OF MINES
AND TECHNICAL SURVEYS

MEMOIR 243

GEOLOGY AND MINERAL DEPOSITS OF THE PRINCETON MAP-AREA, BRITISH COLUMBIA

H. M. A. Rice

Price, $2.00

1960

View looking east across the Interior Plateau from near Brodie.

GEOLOGICAL SURVEY
OF CANADA

MEMOIR 243

GEOLOGY AND MINERAL DEPOSITS OF THE PRINCETON MAP-AREA, BRITISH COLUMBIA

By
H. M. A. Rice

DEPARTMENT OF
MINES AND TECHNICAL SURVEYS
CANADA

FIRST PRINTING 1947

REPRINTED BY

THE QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1960

Price $2.00 Cat. No. M46-243

CONTENTS

CHAPTER IV

CHAPTER V

CHAPTER VI

CHAPTER VII

Illustrations

PREFACE

This report deals with the geology and mineral deposits of an area of some 3,100 square miles that lies mainly within the Interior Plateau region of south-central British Columbia. The area is readily accessible from the coast by rail or highway, and is traversed in various directions by numerous subsidiary roads and branching trails. It has been one of the most intensively prospected parts of the province, and this work has demonstrated a variety and wealth of metalliferous deposits characteristic of many of the better known parts of the Canadian Cordillera. Early discoveries were of placer deposits, in which platinum as well as gold was important, but since the beginning of the century lode mining has received most attention. Principal output has been derived from the arsenical gold ores of Nickel Plate Mountain and the bornite deposits of Copper Mountain, mining camps that are both still in active production. The area also includes the Tertiary coal measures of Princeton and Coalmont, from which more than 4,000,000 tons of coal have been mined since 1909.

Geological investigations have been conducted in various parts of Princeton map-area by many geologists, and numerous maps and reports have been issued, most of which are now out of print. No small part of the present author's task, has, consequently, been to correlate and reproduce much of this scattered information, and to reconcile inconsistencies on the basis of modern concepts and a complete survey of the area. More definite information has been gained on the age and distribution of the thick assemblages of Triassic and Tertiary volcanic rocks that constitute a large part of the bedrock of the area, and an important advance has been made in the recognition of two volcanic groups of Late Lower Cretaceous age. Further light has, in consequence, been thrown on the nature and sequence of the abundant associated intrusive bodies, and on their probable relationship to the working mines and numerous prospects of the area. Most of the mineral deposits can be classified into groups with certain specific features in common, and their occurrence and arrangement are thought to be largely controlled by structure.

GEORGE HANSON,
Chief Geologist, Geological Survey

OTTAWA, November 15, 1946

Geology and Mineral Deposits of Princeton Map-area, British Columbia

CHAPTER I

INTRODUCTION

GENERAL STATEMENT

Princeton map-area is in southern British Columbia between longitudes 120 and 121 degrees and latitudes 49 and 50 degrees, and covers roughly 3,100 square miles of mountainous terrain. The towns of Princeton, Hedley, Coalmont, and Tulameen lie within its borders.

Princeton, the principal town in the map-area, is about 120 miles due east of Vancouver, but is separated therefrom by the rugged Hozameen and Cascade Ranges. The deep valley of Coquihalla and Coldwater Rivers cuts through these mountains and is followed by the Kettle Valley Railway, which serves the district. The principal motor route into the area is by the branch road from the main highway at Spences Bridge through Merritt to Princeton, and from thence to Penticton via Hedley. The long awaited Hope-Princeton Highway was connected through during the summer of 1944, and, although much work remains to be done before it can be put into general use, a number of cars successfully made the trip from Hope.

The area is well served with roads and trails, especially in the cattle ranges in the northeast corner and the sheep ranges along the southern border.

Much of the area is unsuited for agriculture, and its prosperity depends largely on the profits gained from raising sheep and cattle, and from the produce of its mineral deposits. At present mining operations are continuing at the Nickel Plate and Hedley Mascot gold mines on Nickel Plate Mountain, and on the copper deposits of Copper Mountain. A little placer mining is undertaken each year, but has long since ceased to be a significant item.

ACKNOWLEDGMENTS

The following report is based on field work by the writer in 1939, 1941, and 1944. He wishes to acknowledge the generous co-operation of the residents of the area, especially the staffs of Kelowna Exploration Company, Limited, and Hedley Mascot Gold Mines, Limited, at Hedley, and of Granby Consolidated Mining, Smelting and Power Company, Limited, at Copper Mountain. In the field the writer was assisted in 1939 by M. J. Guiget, W. O. Williams, and C. S. Ney; in 1941 by C. S. Ney, J. W. Forrest, and B. P. Chernoff; and in 1944 by W. M. Sharp, H. B. Hilton, and J. W. Robinson.

PREVIOUS WORK

The earliest geological investigation in Princeton district was made by Bauerman when with the International Boundary Commission Expedition of 1859-1861. An account of this was published in the Report of Progress of the Geological Survey for 1882–83–84.

The real foundation for the geology of the area was, however, laid by G. M. Dawson, who, in 1877, explored a large part of southern British Columbia, including much of the Princeton area.

Between the years 1901 and 1906 R. A. Daly, working with the Boundary Commission, mapped a strip along the 49th parallel, part of which forms the southern border of the Princeton area. The principal results of this work were embodied in Memoir 38 of the Geological Survey, "North American Cordillera, Forty-ninth Parallel", published in 1912.

From 1906 to 1912 Charles Camsell investigated the geology of the southern part of the area, and his results may be found in the Summary Reports of the Geological Survey for that period, in Memoir 2, "Geology of the Hedley Mining District"; and in Memoir 26, "Geology of the Tulameen District".

C. E. Cairnes, between 1919 and 1923, mapped the Coquihalla area to the west, and made reconnaissance trips into the Princeton area. His findings appear in the Summary Reports for that period and in Memoir 139, of the Geological Survey, "Coquihalla Area, British Columbia".

From 1926 to 1930 H. S. Bostock investigated the geology of the part of the district near Hedley, the results appearing in the Summary Report for 1929, Part A. Later, following some additional work by D. A. McNaughton, geological maps of the Wolfe Creek and Hedley areas were published.

Victor Dolmage studied the geology of Copper Mountain during the summer of 1923 and part of that of 1926, and published his conclusions in Geological Survey Memoir 171, "Geology and Ore Deposits of Copper Mountain, British Columbia", in 1934.

Since then the only publications on this area by the Geological Survey were Preliminary Papers 42-6 and 45-5, both by the writer, but the results of a careful study of the geology of Nickel Plate Mountain by Paul Billingsley and C. B. Hume appeared in a bulletin of the Canadian Institute of Mining and Metallurgy in 1941. An important paper on the Hedley Mascot mine by Victor Dolmage and C. E. G. Brown was published in another bulletin of the Institute in 1944.

No small part of the task confronting the writer was to co-ordinate the information accumulated by these geologists, and to sift out that which had been rendered obsolete by advances in knowledge both local and general.

PHYSIOGRAPHY

Most of Princeton map-area lies within the Interior Plateau, but it includes near its southern and western borders parts of the Cascade Mountains, with a zone of transition separating the two physiographic areas. North of the International Boundary the Cascade Mountain System is divisible into three units: the Skagit Range on the west, the Hozameen Range in the middle, and the Okanagan Range to the east. The last two form the western and southern boundaries of the Interior Plateaux in the Princeton area, the Okanagan Range projecting north from the International Boundary for some 20 miles.

In southern British Columbia the Interior Plateau loses much of the table-like character it possesses farther north (*See* Plate I). Here dissection has to a great extent obscured the level surface, but from a suitable vantage point the general concordance of the summits and the long, level ridges can clearly be seen. The difference between the rugged crags of the mountain ranges and the broad, rounded, timber-covered peaks of the plateau region is very marked.

DRAINAGE

Drainage within the map-area is mainly by two systems, one predominantly east-west and the other north-south. There is evidence of recent disturbance in both systems, and it is of interest to consider some of their components in detail.

The most northerly member of the east-west system is a valley that can be followed east from Kingsvale to Wart Mountain. The western part is occupied by Voght Creek and the eastern part by Pothole Creek, but neither of these creeks is large enough to have cut the valley it now occupies, and in between is a section of the through valley unoccupied by any stream. The same is true of the valley immediately to the south that extends from near Brodie to Thalia and from there along a part of Otter Creek Valley to the north-south valley above Allison Lake. This valley is deep and narrow, and yet is occupied by the most insignificant of streams. East of it is the valley occupied by Chain Lake, Osprey Lake, and the lower part of Trout Creek. West of Mazama only a small sluggish stream flows down this valley. To the east it is occupied by turbulent Trout Creek, but the continuous nature of the valley and the abrupt bend made by Trout Creek on entering it suggest that this stream was deflected into a pre-existing valley rather than that it cut one for itself. It seems probable that these valleys must have been excavated by streams much larger than those now occupying them, and that the streams have either lost much of their volume or have been deflected into other channels. Lying, as they do, across the direction of principal ice movement, the effect of glaciation has been to fill them up rather than to deepen them. Dolmage (1934, p. 7)[1] suggests that the prominent valley of Whipsaw Creek, Smelter Lake, and Wolfe Creek was originally occupied by Whipsaw Creek throughout, and was later cut in two by the development of Similkameen Valley.

The valley of Tulameen and lower Similkameen Rivers is the master valley, controlling the drainage of the area. For its origin we need look no farther than the powerful rivers now occupying it. In common with the other east-west valleys, it has been but little modified by glacial erosion.

In the northern half of the area are five prominent north-south valleys. The most westerly is occupied by Otter Lake and the lower part of Otter Creek. To the east are two valleys, which join just above Princeton, one occupied by Allison Creek, Allison Lake, and upper Otter Creek, and the other by Summers Creek, Missezula Lake, and Alleyne Lake. East of these again are Hayes Creek and Siwash Creek Valley and McNulty Creek Valley. All of these are deep, narrow, comparatively straight valleys, the first two and the upper part of the third occupied by streams disproportionately small. These three follow lines of faulting and, in common with all the north-south trending valleys, have been deeply scoured by moving ice.

In the southern half of the map-area the valley of South Similkameen and Pasayten Rivers forms an extension of the Allison Creek and Summers Creek Valleys, and has also been deeply glaciated. Similkameen River, however, from near the junction of the Pasayten to the mouth of Whipsaw Creek, has cut a deep canyon in the floor of the glacial valley in post-Glacial time.

The discrepancy between the size of many of the valleys and the streams now occupying them indicates a very considerable disturbance in the drainage, with the abandonment of much of the east-west system in favour of the north-south system. As Matthews (1944) has pointed out, one of the results of this was the formation of a number of large, temporary lakes by the damming action of the ice or glacial detritus during late Glacial time.

Okwa Creek, the head of the Similkameen, and Chuwanten Creek, occupy a northwest-trending valley that fails to conform to either of the two systems mentioned. It is clearly controlled by the general trend of the folding and faulting in this part of the area, and, indeed, Chuwanten Creek actually follows a known fault.

Camsell (1913, pp. 21-22) has drawn attention to the difference in the topography below and above about the 4,500-foot level. Above this the hills

[1] References, in brackets, are to the Bibliography, pages 4, 5.

are rolling, with gentle slopes and broad valleys; below it the slopes are steep, many cliff-like, and the valleys are deeply incised.

The more recent physiographic history of the area includes the following events: (1) the erosion in pre-Glacial time of the land surface to that of a mature, gently undulating plain; (2) the elevation of the area as a whole, and rejuvenation of the drainage; (3) active erosion by the rejuvenated streams, resulting in the deepening of the main valleys but ceasing before all of the plateau area was affected; (4) the advent of the Ice Age with the consequent dislocation of the drainage, overdeepening of some of the valleys, and incomplete filling of others; and (5) re-establishment of the drainage, with active erosion of the bottoms of certain of the valleys, and the development, in places, of post-Glacial canyons.

GLACIATION

The entire map-area was at one time buried under the continental ice-sheet that covered most of British Columbia in Pleistocene time. The maximum thickness of this sheet is not known, but it was at least thick enough to erode the tops of mountains as high as 8,600 feet. The ice moved in a relatively broad sheet almost due south across the northern part of the area (*See* Map 888A, in pocket). The principal channel was between Otter Creek and Siwash Creek Valleys, with a tendency to spread out to the southeast and southwest on the two flanks. In the vicinity of Princeton this ice-sheet split around the northern end of Okanagan Range into two lobes. One of these turned to the southeast in a stream 3 or 4 miles wide parallel with the lower Similkameen Valley. The other lobe followed southwest across an area between Tulameen and upper Similkameen Rivers, riding over Granite and Three Brothers Mountains that lay across its path.

The waning of the continental ice-sheet and the emergence of the peaks and ridges initiated a period of valley glaciation. Only in a few places does erosion appear to have been active at this time. Mostly the result was to plane down the sides of the valleys, redistribute the detrital material, and cut out cirques in the higher peaks.

The most noticeable effect of the glacial period has been to cover the greater part of the area with a mantle of detritus—mostly from 2 to 6 feet deep, but in many places 30 or 40 feet thick or more. This is spread out more or less haphazardly, but here and there is in the form of drumlins or local terminal moraines. Drumlins occur principally in the northern part of the area, particularly round Pennask Lake; indeed the islands and points projecting into that lake are formed of partly submerged drumlins. Terminal moraines are rare, but a few have had a direct influence on local drainage. For example, the valley of Lawless Creek was blocked by a narrow, ridge-like moraine, and the creek, forced out of its regular channel, has cut a deep canyon through solid rock. This canyon is spanned by the bridge on the trail that skirts Mount Rabbitt.

BIBLIOGRAPHY

Bauerman, H. (1884): Report on the Geology of the Country near the Forty-ninth Parallel of North Latitude west of the Rocky Mountains; Geol. Surv., Canada, Rept. of Prog. 1882–83–84, pt. B, p. 18.

Billingsley, Paul, and Hume, C. B. (1941): The Ore Deposits of Nickel Plate Mountain, Hedley, B.C.; Can. Inst. Min. and Met., vol. XLIV, pp. 524-590.

Bostock, H. S. (1930): Geology and Ore Deposits of Nickel Plate Mountain, Hedley, B.C.; Geol. Surv., Canada, Sum. Rept. 1929, pt. A.

———(1940*a*): Map of Hedley area; Geol. Surv., Canada, Map 568A.

———(1940*b*): Map of Wolfe Creek area; Geol. Surv., Canada, Map 569A.

CAIRNES, C. E. (1923): Geological Explorations in Yale and Similkameen Mining Divisions, Southwestern British Columbia; Geol. Surv., Canada, Sum. Rept. 1922, pt. A.

———(1924*a*): Reconnaissance of Silver Creek, Skagit and Similkameen Rivers, Yale District, B.C.; Geol. Surv., Canada, Sum. Rept. 1923, pt. A.

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

———(1930): Serpentine Belt of Coquihalla Region, Yale District, B.C.; Geol. Surv., Canada, Sum. Rept. 1929, pt. A.

———(1940): Kettle River (West Half); Geol. Surv., Canada, Map 538A.

CAMSELL, C. (1907): Preliminary Report on a Part of the Similkameen District, British Columbia; Geol. Surv., Canada, Special Report No. 986.

———(1910): Geology and Ore Deposits of Hedley Mining District, B.C.; Geol. Surv., Canada, Mem. 2.

———(1912*a*): Note on the Occurrence of Diamonds at Tulameen, and Scottie Creek near Ashcroft, B.C.; Geol. Surv., Canada, Sum. Rept. 1911, pp. 123, 124.

———(1912*b*): Geology of Skagit Valley, Yale District, B.C.; Geol. Surv., Canada, Sum. Rept. 1911, pp. 1-15.

———(1913): Geology and Mineral Deposits of the Tulameen District, B.C.; Geol. Surv., Canada, Mem. 26.

———(1919): Platinum Investigations in British Columbia; Geol. Surv., Canada, Sum. Rept. 1918, pt. B.

DALY, R. A. (1912): Geology of the North American Cordillera at the Forty-Ninth Parallel; Geol. Surv., Canada, Mem. 38, pp. 443-506.

DAWSON, G. M. (1877): Report on Explorations in British Columbia; Geol. Surv., Canada, Rept. of Prog. 1875-76, pp. 233-265.

DOLMAGE, V. (1929): The Origin of the Copper Mountain Ores; Can. Inst. Min. and Met., Bull. No. 201, pp. 788-802.

———(1934): Geology and Ore Deposits of Copper Mountain, British Columbia; Geol. Surv., Canada, Mem. 171.

DOLMAGE, V., and BROWN, C. E. (1945): Contact Metamorphism at Nickel Plate Mountain, Hedley, B.C.; Can. Inst. Min. and Met., vol. XLVIII.

DOUGLAS, R. S. (1933): Mining Methods at Copper Mountain, B.C.; Can. Inst. Min. and Met., Trans., vol. XLVI, pp. 423-455.

DOWLING, D. B. (1915): Coal Fields of British Columbia; Geol. Surv., Canada, Mem. 69.

DRYSDALE, C. W (1913): Geology of the Thompson River Valley below Kamloops Lake, B.C.; Geol. Surv., Canada, Sum. Rept. 1912.

JONES, G. P. (1929): The Hedley Mine and Mill; B.C. Miner, Oct. 1929, pp. 16-20.

———(1936): History of the Hedley District; B.C. Miner, vol. 9, No. 10, Oct. 1936, pp. 54-56.

KEFFER, Frederick (1915): Notes on the Geology and Exploration of Copper Mountain in the Similkameen District of B.C.; Can. Min. Inst., Trans., vol. 18, pp. 192-201.

O'NEILL, J. J., and GUNNING, H. C. (1934): Platinum and Allied Metal Deposits of Canada; Geol. Surv., Canada, Econ. Geol. Ser. No. 13.

PEACOCK, M. A. (1944): Hedleyite, a New Bismuth Telluride from British Columbia, with Notes on Wehrlite and some Bismuth-tellurium Alloys; Univ. Toronto Studies, Geol. Ser. No. 49, Cont. to Can. Mineralogy.

POITEVIN, E. (1924): Platiniferous Rocks from Tulameen Map-area, Yale District, British Columbia, and Ural Mountains, Russia; Geol. Surv., Canada, Sum. Rept. 1923, pt. A.

RUSSELL, L. S. (1935): A Middle Eocene Mammal from British Columbia; Am. Jour. Sci., vol. 29, pp. 54-55.

SCHOFIELD, J. S. (1920): The Discovery of Fossils in the Mesozoic Rocks, Hedley, B.C.; Geol. Surv., Canada, Sum. Rept. 1919, pt. A.

SELWYN, A. R. C. (1873): Journal and Report of Preliminary Explorations in British Columbia; Geol. Surv., Canada, Rept. of Prog. 1871-72, pp. 54-66.

SPENCE, H. S. (1924): Bentonite; Mines Branch, Dept. of Mines, Canada, Pub. No. 626.

STAFF, Hedley Gold Mining Co., Ltd. (1929): The Hedley Mine and Mill; Can. Inst. Min. and Met., Bull. No. 201, pp. 1260-1270.

STEVENSON, J. S. (1940): Mercury Deposits of British Columbia; B.C. Dept. of Mines, Bull. No. 5.

WARREN, H. V., and CUMMINGS, J. M. (1936): Mineralogy at the Nickel Plate Mine; The Miner, vol. 9, May 1936, pp. 27, 28.

WARREN, H. V., and THOMPSON, R. M. (1945): Mineralogy of Two Cobalt Occurrences in British Columbia; Western Miner, vol. 18, No. 5, May 1945, pp. 34-41.

CHAPTER II

SEDIMENTARY AND VOLCANIC ROCKS

INTRODUCTION

Princeton map-area is underlain by a succession of volcanic rocks ranging in age from late Palæozoic to late Tertiary; by sedimentary rocks, mostly in minor amounts, interbedded with the volcanic groups; and by intrusive rocks ranging in composition from granite to peridotite and in age from Jurassic to late Cretaceous or early Tertiary. The age of many of the units, their relation to each other, and their separation and mapping in the field are not always clear, and many problems remain to be solved.

TABLE OF FORMATIONS

Era	Period or epoch	Group or formation	Lithology
Cenozoic	Pleistocene and Recent		Glacial till; silt, sand, and gravel
	Unconformable contact		
	Miocene or later	Valley basalt	Mainly brown, red, and grey, vesicular basalt
		Relationship not known	
		Plateau basalt	Mainly black and brown, amygdaloidal basalt
	Unconformable contact		
	Miocene or earlier	Princeton group	Mainly brown, black, red, and green basalt and andesite, rarely conspicuously porphyritic; grey, mauve, green, and buff, fissile, fossiliferous shale, buff sandstone, and conglomerate
Unconformable contact			
Mesozoic or Cenozoic	Upper Cretaceous or later	Otter intrusions	Pink granite and granodiorite, quartz generally inconspicuous and as microscopic intergrowths. Some bodies, notably porphyritic, grey granodiorite, not easily distinguished from phases of the Coast intrusions
		Probably correlative with above	
		Lightning Creek intrusions	Light grey quartz diorite stocks; grey to greenish grey diorite and quartz diorite sills and dykes; conspicuous needles of amphibole common. None of these types easily distinguished from phases of the Coast intrusions
Intrusive contact			
		Kingsvale group	Basal beds of agglomerate, greywacke, and volcanic breccia, mostly green or brown; green, purple, grey, and black andesite and basalt. Much of the group carries orange-coloured feldspar phenocrysts

TABLE OF FORMATIONS—*Continued*

Era	Period or epoch	Group or formation	Lithology
Mesozoic	Lower Cretaceous	Relations not known, but apparently of the same age	
		Pasayten group	Lower part mainly thick beds of greenish grit or greywacke; upper part dark brown, thin-bedded, fossiliferous argillite, yellowish sandstone with, near top, conglomerate, and a conspicuous horizon of purple tuff and lava
		Unconformable or disconformable with Kingsvale; not in contact with Pasayten	
		Spence Bridge group	Mainly hard, red, purple, buff, and grey rhyolite, dacite and basalt; in part spherulitic and porphyritic; pronounced flow-lines characteristic
	In faulted contact with Pasayten; not in contact with Spence Bridge		
	Upper Jurassic (?) and Lower Cretaceous	Dewdney Creek group	Division A: soft, crumbly, dark brown andesite or dacite tuff, breccia, and lava; Division B: argillite, brownish green greywacke, a little tuff, and buff-coloured sandstone; Division C: thick beds of conglomerate separated by much thinner beds of green grit or greywacke; Division D: sandy argillite, greywacke, and arkose
	Not in contact with any of the above except Princeton group, which overlies it unconformably		
	Jurassic or later	Copper Mountain intrusions	Mainly syenogabbro, augite diorite, and pegmatite; generally pink to red; quartz conspicuously absent
		Not in contact	
		Coast intrusions	In three colour phases referred to, from oldest to youngest, as "grey," "red," and "white" granodiorite respectively; the grey phase a very uniform, slightly gneissic biotite, occasionally hornblende granodiorite, or quartz diorite, with pegmatite and aplite dykes small and inconspicuous; red phase a variable textured, siliceous granite, granodiorite, and quartz diorite, mostly characterized by pink potash feldspar, and in places with orthoclase phenocrysts up to 3 inches long; white phase a white to light greenish grey granodiorite, quartz diorite, and gabbro characterized by dull white plagioclase crystals
		Intrusive contact in places, but in others possibly gradational	
			Deep green, coarse-grained pyroxenite; coarse-grained gabbro; grey, brownish weathering peridotite; quartz diorite
	Intrusive contact		
	Upper Triassic	Nicola group	Principally green andesite and augite or feldspar porphyry; locally abundant grey, mauve, purple, and brick-red andesite and andesite porphyry, and areas containing many beds of tuff, tuffaceous argillite, and argillite; occasional lenses of limestone. In a broad belt parallel with the east contact of the Eagle granodiorite the above rocks are sheared into chlorite and talc-sericite schist. In the vicinity of Hedley are thick beds of limestone, thin-bedded argillite, cherty quartzite, and calcareous quartzite

TABLE OF FORMATIONS—*Concluded*

Era	Period or epoch	Group or formation	Lithology
Contact not observed			
Palæozoic or later	Carboniferous or later	Bradshaw, Independence, Shoemaker, and Old Tom formations	Mainly green and grey chert, grey argillite and cherty argillite, limestone, and green andesite lava, locally altered to quartz mica schist and gneiss
		Fault contact with Dewdney Creek group	
		Hozameen group	Mainly green, cherty andesite, chert, and limestone

HOZAMEEN GROUP

Along Skagit River, close to the International Boundary, is a group of rocks to which the name Hozameen was given by Daly (1912, pp. 500-504). These rocks extend into the southwest corner of the Princeton area where they are terminated on the east by a strong fault. Although so little of the group is exposed, most of the principal types described by Camsell (1911, p. 118) are represented. Commonest of these are green, sometimes purple, andesites of volcanic origin. Many of these are brecciated, but, although Daly suspected their presence, neither pyroclastic nor amygdaloidal rocks were seen by the writer. White to grey-green chert and cherty quartzite are interbedded with the lava in considerable abundance. Camsell reports that argillite or phyllite is common throughout the Hozameen, but little was seen in the Princeton area. Pods or lenses of blue-grey, crystalline limestone are common. The largest seen was 10 feet thick, but Camsell reports beds several hundred feet thick to the northwest.

The predominant characteristics of the Hozameen group are its high degree of alteration and the fact that it is so criss-crossed by joints that it shatters to polygonal blocks at the touch of a hammer. Within the map-area the beds are steeply inclined and trend northeast.

The Hozameen group has always been correlated with the Cache Creek group on the basis of its close lithological similarity. No fossils have been found in it, so that its age is not definitely known.

BRADSHAW, INDEPENDENCE, SHOEMAKER, AND OLD TOM FORMATIONS

A group of rocks mapped by Bostock (1940) as the Bradshaw, Independence, Shoemaker, and Old Tom formations occurs in Similkameen Valley south of Hedley. These rocks were traced south of the Hedley map-area and for some distance up Ashnola River. Although Bostock's formations were recognized in the areas in which he worked, to the south it became impossible to distinguish them, and they have, consequently, been mapped as a group.

Dark and light grey chert, green chert, and hornstone are perhaps the most abundant rock types, but dark grey argillite, slate, and phyllite are very abundant, and massive green andesite is plentiful in places. Interbedded with these are occasional small lenses of limestone. All members of the group are more or less metamorphosed, and near the contact with the Coast intrusions the alteration becomes intense. As the contact is approached the argillaceous sediments, particularly, become coarser grained; feldspar and biotite develop; and the schistose texture gives place, with a further coarsening of grain, to a gneissic texture so that the sediments grade into the granitoid rock of the main intrusive body.

Some fragmentary plant remains were found in sandy argillite near the foot of the spur running into Similkameen Valley west of Ashnola River, but none could be identified. Bostock made two collections of fossils in the Olalla map-area to the east, one from the Independence formation, which contained only a few fragments of indeterminable crinoid stems, and the other from the Shoemaker formation, on which F. H. McLearn of the Geological Survey made the following report:

Location. Limestone bluff on the north side of a creek in the extreme southeast corner of Shoemaker Canyon, at an elevation of about 4,100 feet.

A belemnoid?

Crinoid stems.

Age; probably Mesozoic.

Nothing further can be said specifically about the age of this group, but Bostock found Permian fossils in a small body of limestone in a fault block that he believed to be underlying the Shoemaker. It seems clear that the group cannot be younger than the Nicola group. The volcanic members are identical with many of those in the Nicola, but the extensive chert members have no counterpart in the normal Nicola succession, although chert forms an important part of the sedimentary series at Hedley, which is definitely of Upper Triassic age. It is quite probable that some or all of the formations here grouped should be included with the Nicola, but it is also possible that the group may be in whole or in part older, perhaps even as old as Permian.

NICOLA GROUP

INTRODUCTION

The Nicola group covers a greater part of Princeton map-area than any other map-unit. It is a heterogeneous group, many components of which have, at different times, been given various names. The group was first named and described by Dawson (1877, p. 74B) in the following terms:

"East of the inner ranges of the Coast system of mountains, ... great areas are covered by rocks which may be correlated with little doubt with the green series of the upper part of Whipsaw Creek, and assigned with probability to the Triassic age. As being a characteristic exhibition of these rocks, the section found on the south side of Nicola Lake, from which it is proposed to designate these rocks as the Nicola series, will be first noticed.

"These rocks are exposed between the mouth of McDonald's River, and the bridge across the Nicola at the outlet of the lake, a distance of seven and one-half miles. With the exception of the limestone, they appear to be entirely of volcanic origin, consisting of agglomerates, with beds made up of fine volcanic debris, and others which have originally been sheets of molten matter. All these have been indurated, perhaps in some cases recrystallized by metamorphism, and have since suffered a greater or less amount of that alteration by decomposition of original constituent minerals, so common in the older volcanic rocks. Taken as a whole, the series is now distinctively felspathic, and in colour, green of various shades." (Dawson, a little later, amplified this statement to include purple volcanic rocks and beds of tuffaceous argillite.)

Members of this group were described by Camsell (1907, pp. 24, 25) from Similkameen and Pasayten Rivers, but he failed to correlate them with those described by Dawson on Whipsaw Creek and considered them to be of Palæozoic age. He, however, includes with the volcanic members, quartzite and argillite, which, although they cover a limited area, are important around Copper Mountain. Later, in his report on the Hedley Mining District, Camsell (1910, pp. 43-71) describes the sedimentary rocks in that locality, which both he and Dawson (1877, p. 87B) correlated on lithological grounds with the Carboniferous, Cache Creek series rather than with the Triassic, Nicola group. Dawson, however, suggests that some of the greenstones closely associated with the sediments should perhaps be correlated with the Nicola, and accounts for their intimate relationships by close infolding. He goes on to mention that "there seems to be further, in several places, a blending of materials originally volcanic, with quartzose sediments, which here greatly predominate." It is evident that he was not altogether satisfied with his correlation.

In 1919 fossils were found in the vicinity of Hedley (Schofield, 1920, p. 38B), which Frank Springer considered to be Triassic or possibly Jurassic in age. It appeared then as if Dawson's suspicions were correct, and that the sediments at Hedley were indeed part of the Nicola group. In 1925 and again in 1928 Bostock (1930, p. 204A) made collections of fossils from the Hedley sediments, and these were determined to be Upper Triassic in age. This and the information gained by mapping the Princeton area leave no doubt that the sedimentary series at Hedley is a rather unusual phase of the Nicola group.

In 1913 Camsell (1913, pp. 37-44) published a description of a belt of highly schistose rocks, which he called the Tulameen group. From them he collected some doubtfully Triassic fossils, and goes on to say, "the enormous preponderance of volcanic materials, together with the small proportion of interbedded sediments, suggests their correlation with Dawson's Nicola series." Work by the writer has established this correlation beyond doubt. Cairnes (1923, p. 52A) suggests that the Tulameen group might be divisible into two components, one predominantly volcanic and the other predominantly sedimentary. The writer's efforts to follow this suggestion were unsuccessful.

It can be seen that the Nicola group occurs in Princeton map-area in a number of localities, which, although later found to be connected, were studied separately. In some parts it was given a local name, and in some even subdivided into formations. On the scale on which the accompanying map is published it proved to be impossible to adhere to these subdivisions; indeed most of them were found to be of only local application, and the Nicola is mapped simply as a single group. The group term, however, includes the following units:

- Tulameen area
  - (Camsell, 1913, pp. 27-44)
    - Tulameen group
- Hedley area
  - (Camsell, 1910, pp. 43-72)
    - Aberdeen formation
    - Red Mountain formation
    - Nickel Plate formation
    - Redtop formation
  - (Bostock, 1940)
    - Wolf Creek formation
    - Henry formation
    - Hedley formation
    - Sunnyside formation
    - Redtop formation
- Copper Mountain area
  - (Dolmage, 1934, pp. 10-11)
    - Wolf Creek formation

DESCRIPTION

The Nicola group in Princeton map-area consists of a succession of lavas whose thickness is not known, but must be very considerable. Irregularly distributed through the lavas are lenses of tuffaceous and argillaceous rocks and occasional beds of limestone. Some of these lenses have been traced as much as 20 miles along strike and are as much as 2 miles wide, but most are of the order of a few hundred feet. In a few places, notably at Hedley, the sedimentary strata are relatively free from volcanic material.

The bewildering array of volcanic types met with in the Nicola group has always been a source of embarrassment to the field geologist. It has led to abortive attempts to subdivide the group and to more than one mistake in correlation.

The common type is a massive andesite porphyry, with a groundmass of medium sodic plagioclase, pyroxene, chlorite, epidote, actinolite, and some magnetite. Phenocrysts of either pyroxene or plagioclase are present, and many flows contain both. Mostly the rock is not at all striking in appearance, but in some flows augite phenocrysts stand out prominently, and in others the plagioclase phenocrysts are in laths up to an inch long. The common colour of these rocks is deep green, grey-green, or even blue-grey. Some that are most altered are a light green, and others are speckled through with spots of light green epidote. These are the common Nicola types described by Dawson and developed almost to the exclusion of all others in the western and southern parts of Princeton map-area. In the northeast, however, they give place to an array of highly coloured often spectacular appearing lavas. Here, too, the usual green types are met with, but in subordinate amount. Instead the following rock types are more common: green and purple, fine-grained, non-porphyritic andesite (a single specimen may be mottled with both colours); brick-red, fine-grained andesite; porphyries with a dark to light purple, mauve, or brick-red groundmass and feldspar phenocrysts; others with phenocrysts of bottle-green epidote; and still others with phenocrysts of actinolite; green andesite with pink feldspar phenocrysts; and many minor variants of the above types. Flow breccias are probably more common than massive lava, and in these any or all of the above types may be mixed together so that bombs or fragments of one occur in a groundmass of the other. Amygdaloidal lavas are scarce, but have been seen in both green and purple types, the vesicles being filled with chlorite or zeolite. A peculiar type occurs in the valley of Shrimpton Creek and at the outlet of Missezula Lake. It consists of a rather coarse-grained, greenish rock containing rounded fragments of what appears to be red syenite or granite. Examination of thin sections shows that the "syenite" is actually a feldspar porphyry, and the field evidence indicates that the rock is a flow breccia of unusual type. Another curious type occurs near the northern border of the area just west of the main road. The rock is a purple feldspar porphyry of normal composition, but the phenocrysts occur in large and striking clusters to form a glomeroporphyritic texture, and are accompanied by veinlets of a bright orange-red silicite mineral. Some exceedingly coarse-grained phases occur in places, many of which are feeders to later Nicola lava flows.

In spite of the diversity of appearance the types are quite similar in composition. They range from a fairly acid andesite to a basalt, but both extremes are rare. The plagioclase varies from oligoclase to labradorite (An_{25} to An_{65}), but in most it is andesite (An_{35} to An_{40}). In many specimens the plagioclase has a pronounced trachytic alinement, and in some it is colourless and is noticeable in the hand specimen only from glistening cleavage faces. Quartz was seen in only a few specimens, and even in these is partly or entirely secondary. Pyroxene is common; mostly it is augite, but occasionally diopside or some other related form. Amphibole is also common, usually some member of the actinolite family with a strong blue-green pleochroism, but common hornblende was identified in two specimens. In a few flows amphibole forms prominent phenocrysts. A few flakes of biotite were seen in one or two specimens, but were probably developed from foreign material picked up by the lava. Magnetite and pyrite are commonly present. Occasional specks of chalcopyrite have been seen. Apatite is not common. The usual secondary minerals are chlorite, calcite, epidote, and limonite.

The sedimentary beds of the Nicola group have a much more restricted distribution than the volcanic rocks. Small patches of fine-grained, well-bedded tuff or tuffaceous argillite, and small lenses of blue-grey limestone are met with all through the volcanic rocks, but in only some half dozen localities have sedimentary rocks any considerable extent.

A more or less continuous belt of mixed, fine-grained tuffs and argillaceous rocks extends southeast from north of Tulameen River to Whipsaw Creek, and a belt of similar rocks reaches from Copper Mountain up south Similkameen River to Pasayten River. Both belts are mixed with volcanic rocks, and it is not possible to set definite boundaries for them. North and west of Aspen Grove small lenses of limestone are unusually common, and some of these grade into brownish calcareous tuffs or greywackes, some of which are fossiliferous. At the northern end of the Tulameen belt and also in the belt south of Copper Mountain breccias are common. These are green, grey, or more rarely purple, with angular fragments half an inch to an inch in size. Most of the fragments are themselves volcanic rocks, but argillite fragments have been seen. These breccias are frequently associated with soft green or purple tuff or greywacke with subangular grains an eighth of an inch across. From near Pothole Creek to Missezula Lake is a belt of very fine-grained, well-bedded tuff and argillaceous tuff that is remarkable mainly for its uniform character. On Pennask Mountain is a thick series of thick- and thin-bedded, green tuff and fine breccia, with occasional interbeds of argillaceous tuff and one or two lenses of limestone. By far the largest belt of sedimentary rocks, as well as the most important economically and the most free of volcanic material, is that at Hedley. As already stated, this has been studied in detail, and the writer cannot do better than to follow the guidance of the geologists who did this work. Camsell divided the series into formations in 1910 (Table I) and these subdivisions were followed and amplified by Bostock in 1939. The Aberdeen formation had, up to this time, been considered to be on the downthrow side of the Bradshaw fault and, therefore, younger than the Redtop and Nickel Plate formations, but further work led Bostock to doubt the validity of this assumption, and he, therefore, introduced, in 1940, the term Hedley formation to include all of Camsell's formations above the Sunnyside limestone. A still younger formation above this he called the Henry formation.

In recent years a detailed study of the stratigraphy of Nickel Plate Mountain was made by geologists of Hedley Mascot Gold Mines, Limited. With the aid of diamond-drill holes driven for the express purpose, a clearer picture of the stratigraphy was obtained than was possible by the study of the surface and underground workings alone. Sections were obtained where metamorphism was much less intense than at Bostock's sections. As a result the following description (Dolmage and Brown, 1945, p. 38) is given of this section:

> "It is evident that it will be difficult to devise a scheme of subdivision which will be universally applicable to all parts of the mountain. Accordingly, it is suggested that the formation might be better described by simply dividing it into three members, as follows:
>
> Upper Member: quartzite and breccia; highly siliceous........... 300 feet
>
> Middle Member: thinly bedded, pure and impure limestones and quartzites, intercalated with massive limestone beds up to 80 feet thick.. 600-700 feet
>
> Sunnyside Limestone: Massive limestone beds with a small proportion of thinly bedded quartzite.. 150-200 feet"

The following table summarizes the section as it has been subdivided at different times by the different geologists referred to:

TABLE I

Camsell, 1910, p. 47	Bostock, 1930, p. 203	Bostock, 1930, p. 203	Bostock, 1940	Dolmage and Brown, 1945, p. 38
			Wolf Creek formation	
			Henry formation	
Aberdeen formation 3,000 ft.+	Aberdeen formation 3,000 ft.+			
		Feet		
Red Mountain formation, 1,200 ft. ±	Red Mountain formation, 1,200 ft.−	Red Mountain formation 300		
		Summit beds 300	Hedley formation	
		Upper siliceous beds........ 180		Upper member 300 ft.
(Kingston limestone) Nickel Plate formation, 900 ft +	Nickel Plate formation, 1,300 ft.	Nickel Plate productive beds 180		Middle member 600-700 ft.
		Lower siliceous beds 170		
		Sunnyside productive beds 200		
(Sunnyside limestone)		Sunnyside limestone 100	Sunnyside formation	Sunnyside limestone 150-200 ft.
Redtop formation, 1,200 ft. +	Redtop formation		Redtop formation	

REDTOP FORMATION

The Redtop formation includes the oldest sedimentary rocks known on Nickel Plate Mountain. It was named by Camsell, who says the beds of this formation "are best exposed on the north slope of Similkameen River in Redtop Gulch". They consist largely of siliceous rocks, occurring generally in thin beds, intercalated with bands of limestone at the top and bottom, and with argillaceous and volcanic bands toward the middle of the series. They are seen in the eastern part of the area to have as a base a massive limestone called, for the sake of convenience in describing it, the Stevenson limestone. This limestone is cut off by the eruptive granodiorite, and only a relatively small exposure of it appears.

> "The Redtop formation is strikingly banded, due to the rapid alternation of light and dark bands of rock. The light bands are generally white or greyish quartzite, while the dark bands are either black argillaceous quartzite or limestone, or beds of black volcanic material". (Camsell, 1910, pp. 43-44.)

The alternation of thin, light and dark grey quartzite beds is characteristic of the Redtop formation, and is the principal feature by which it may be recognized.

SUNNYSIDE FORMATION

The Sunnyside limestone is a clearly recognizable formation 150 to 200 feet thick. Where least metamorphosed it consists of alternating thin and thick beds of limestone, in places fossiliferous. Where more metamorphosed it is described by Bostock as a light blue-grey to white, crystalline, crumbly limestone in beds 6 inches to several feet thick.

HEDLEY FORMATION

This formation has been variously subdivided as indicated in Table I. The Middle member of Dolmage and Brown (1945, p. 38) consists of "thinly bedded pure and impure limestone, and quartzites intercalated with massive limestone beds up to 80 feet thick". This appears to conform to the Sunnyside productive beds, Lower Siliceous beds, and the Nickel Plate productive beds of Bostock's section. Bostock's description of his formations is similar to that of Dolmage and Brown, except that he stresses the presence of a group of rocks (Lower Siliceous beds) in the middle of the section that are distinctly less calcareous than those above or below. However, Dolmage and Brown point out that the section varies from place to place and that they were not able to follow any subdivision but the general one they suggest. The Upper member of Dolmage and Brown is described as highly siliceous quartzite and breccia. Bostock's descriptions of the Upper Siliceous beds, Summit beds, and Red Mountain formation conform to this general scheme. The Upper Siliceous beds consist essentially of thinly banded, fine-grained, black and white quartzite, much like that in the division below but with only a few thin beds of limestone. At the top of these are some beds of breccia. The succeeding Summit beds are composed of coarse breccia intercalated with thin-banded quartzite. The Red Mountain formation above that again is also composed of coarse breccias, but lacks the thinly bedded quartzite found in the Summit beds. Fragments of limestone are common in the breccias in both formations, but in the Red Mountain the matrix is, in places, calcareous. Some tuffaceous beds are also present.

HENRY FORMATION

The Henry formation is the uppermost in the sedimentary succession at Hedley, and is described by Bostock as consisting essentially of black argillite, tuff, and impure limestone. This passes conformably into the Wolfe Creek formation, which is typical of the Nicola group as previously described.

AGE OF THE NICOLA GROUP

The age of the Nicola group is in all probability Upper Triassic. Fossils have been found at the localities listed in Table II.

TABLE II

Fossils from the Nicola Group

	Fossil localities											
	1	2	3	4	5	6	7	8	9	10	11	12
Daonella cf. *Halobia*	x				x	x		x	x	x		
Pecten sp.		x	x	x								
Juvavites sp.			x	x								
Myophoria cf. *adornata*				x								
Oxytoma cf. *inaequivalve* var. *intermedia*							x					
Pecten cf. *oteanus*							x					
Myophoria sp.							x					
'*Arcestes*' sp.							x				x	x
Discotropites sp.								x				

F1.[1] Small lens of limestone in the draw between Mount Rabbitt and Mount Riddell.
F2. Lens of limestone about a mile west of highway, 1½ miles north of Aspen Grove.
F3. Lens of calcareous greywacke on the north slope of hill, about 2 miles northwest of F2.

[1]Locality as marked on the accompanying map, 888A.

F4. Lens of calcareous greywacke similar to that at F3. About ½ mile northwest of F3.
F5. Bed of fine-grained, green tuff near crest of ridge due east of trail bridge across Lawless Creek.
F6. Bed of fine-grained, green tuff ¾ mile north of Coalmont road about 4 miles west of Princeton.
F7. A bed of calcareous greywacke or tuff at the north boundary of Princeton map-area, on the break of the slope 100 or 200 yards west of the Kane Valley road.
F8. (Collected by H. S. Bostock.) Blocks of limestone in a coarse conglomerate 2½ miles west of Hedley on the south side of Similkameen River, elevation 3,850 feet on the west side of Henry Creek.
F9. (Collected by D. A. McNaughton from beds overlying Nickel Plate formation.) Fragments of limestone in a breccia on the north wall of Windfall Canyon near the town of Hedley.
F10. (Collected by D. A. McNaughton.) From talus slope about 1,000 feet below F9.
F11. (Collected by H. S. Bostock.) July fraction, Nickel Plate Mountain; Kingston limestone.
F12. (Collected by H. S. Bostock.) In talus, north side of Windfall Canyon, at elevation 5,900 feet, Nickel Plate Mountain. Probably Red Mountain formation.

From a consideration of the above fossil collections, F. H. McLearn, of the Geological Survey, concludes that the Nicola group is of Upper Triassic age, and that there is no palæontological evidence to indicate that rocks of any other age are included in the group as mapped in Princeton area. A more precise dating of the strata depends not so much on additional collections of fossils as on a more complete study of the Triassic fauna of southern British Columbia.

The Nicola group represents an epoch of widespread volcanism whose products were poured or ejected into a marine basin of great extent and, in the map-area at least, deep enough so that the only normal sediment formed is argillite and limestone, except for a little fine-grained quartzite at Hedley.

The Nicola group contains most of the known mineral occurrences in Princeton map-area.

DEWDNEY CREEK GROUP

The Dewdney Creek group was named and described by Cairnes (1924, pp. 56-66) from the Coquihalla area, and the type rocks can be traced directly into Princeton map-area, so that no question as to their identity can arise. The group is also described by Daly (1912, pp. 479-489), who places it in the upper part of his Pasayten series from which it is now known to be separated by a major fault.

The Dewdney Creek group occupies a belt covering most of the southwest corner of the Princeton area. It is bounded on the northeast by the fault referred to above, which, for purposes of reference, will be called the Chuwanten fault. Parallel to this fault and some miles to the southeast is another important fault that will be referred to as the Gibson fault. The block between these two has been little disturbed, and it has been possible to measure the thickness of the sediments in it with fair accuracy. Southwest of the Gibson fault the strata were too disturbed by folding and faulting to make satisfactory measurements possible.

The strata in the block between the two faults fall into four natural subdivisions, called, for convenience in reference, Divisions A, B, C, and D.

DIVISION A

The base of Division A is the Chuwanten fault, so that, although a thickness of 5,800 feet was measured at one place, its full thickness is not known. Rocks of this division are mostly soft, crumbly, and dark brown, and have the composition of andesite or dacite. Crystals of quartz and plagioclase are sprinkled through them, and pyroxene is the principal ferromagnesian mineral. Fragments, both angular and rounded, of chert, argillite, and lava are common, and so plentiful in some beds that the rock is a volcanic breccia or fine conglomerate. The bulk of the material is undoubtedly of volcanic origin, and apparently, from the scarcity of well-sorted and bedded material, most of it was deposited on land. Cairnes has described the rocks as crystal, lithic, and vitric tuffs, and no better terms can be applied. Interbedded with the fragmental rocks are some lavas, but even these are flow breccias, and, as they are of the same colour and composition as the tuffs, are not easily distinguished from the accompanying pyroclastic rocks.

DIVISION B

Division B rests conformably on Division A and is about 1,800 feet thick. This is a more varied division than the other, and consists of dark grey argillite, brownish grey, tuffaceous argillite, brownish green, soft greywacke, dark, crumbly argillite, massive, green, tuffaceous sandstone, and small beds of yellowish, soft sandstone. Occasional beds of crystal tuffs similar to those in the lower division occur, but are rare. Most of the rocks are well bedded, and evidently deposited in a body of water. A number of collections of fossils has been made from beds in this group.

DIVISION C

Division B grades upwards into massive conglomerate beds (*See* Plate II A) that combine to form Division C. As might be expected its thickness varies from place to place; at one place in the south it was 2,100 feet thick, and at another 1,300 feet. To the north it was not measured, but seemed considerably thinner. The conglomerate consists of well-rounded pebbles and cobbles from an inch or so to 1½ feet in diameter, set in a cement of greywacke or sandstone with a high proportion of soft volcanic material and crystals of plagioclase. The group as a whole is made up of beds of conglomerate up to 50 feet thick separated by beds of grit or greywacke. Most of the latter are thin, as compared with the conglomerate strata, but one bed 25 feet thick was seen. Fossils have been obtained from some of these interbeds. Pebbles and cobbles of many different rocks comprise the conglomerate, but noticeably abundant are those of biotite and hornblende granodiorite. Two statistical analyses of the conglomerate were made, and show both the various rock types present and the variations from place to place in the composition of the conglomerate:

	Per cent	Per cent
Groundmass	34·6	28·2
Granitic rocks	29·1	7·1
Slate or argillite	7·7	30·6
Volcanic rocks	17·3	11·8
Chert	4·0	11·7
Grit	4·7	0·0
Quartz	1·4	10·6
Schist	1·2	0·0
	100·0	100·0

A conglomerate as massive and continuous as that of Division C might be suspected of marking an unconformity, but the most careful study failed to reveal any signs of such at either contact. The degree of rounding of the boulders is more suggestive of stream than beach deposits, and yet the formation is so persistent it is difficult to see how such coarse material could have been deposited by streams alone over such a wide area.

DIVISION D

Division D rests conformably on Division C. It is cut off at the top by the Gibson fault, so that its full thickness is not known, but some 7,200 feet of sediments were measured at one place. These consist of sandy argillite, greywacke, and arkose, very similar to those of Division B, and require no further description. In this group, also, fossils have been found.

A. Dewdney Creek conglomerate (Division C), showing well rounded character of cobbles, several granitic cobbles, and, on the right, a mass of interbedded grit.

B. Outcrop of greywacke at base of Kingsvale group, showing fossil tree trunk.

The following are details of three partial sections measured between the Chuwanten and Gibson faults.

1. *Section Measured on Spur between Castle Creek and Similkameen River*

Division C

Division B	Thickness Feet
Greenish black, crumbly argillite, small interbeds of sandstone	260
Massive, greenish arkose or tuffaceous sandstone; fossil collection 13A	550
Sandy, yellowish argillite; soft, crumbly, grey-green argillite; some massive, fine-grained sandstone or arkose	610
Brownish green, lithic tuff, some slaty fragments	140
Massive, fine-grained, compact greywacke	200
	1,760

Division A	
Gap in section	870
Interbedded agglomerate, massive crystal tuff, and tuffaceous argillite	230
Soft, dark brown, crystal-lithic tuff; conspicuous white feldspars and some rounded, pea-sized rock pebbles; a few thinly laminated beds	1,180
Soft, brown lavas, flow breccias, and pyroclastic breccia	410
Gap in section	2,090 ±
Chuwanten fault	4,780

2. *Section along the Spur on the Northeast Side of Similkameen River opposite Gibson Pass*

Division D

Division C	Thickness Feet
Massive conglomerate; many granite cobbles up to 8 inches in diameter	1,290
Massive conglomerate as above, but more interbeds of fine-grained, sandy argillite	790
	2,080

Division B	
Olive-green, sandy arkose or tuffaceous sandstone; some gaps	540
Crumbly, dark argillite and sandy argillite	1,110
Dark, brownish green, soft, fossiliferous greywacke	240
	1,890

Division A	
Gap in section	790
Soft, dark, greenish brown, crystal tuff with occasional interbedded lava flows; many gaps	3,040
Soft, dark brown, feldspathic flow-breccias alternating with bedded, sandy or tuffaceous argillite	290
Gap in section	1,500
Massive, soft, dark brown flow-breccia, considerably fractured	1,010
Chuwanten fault	6,630

3. Section some 3 Miles Southeast of Allison Pass

Gibson fault

Division D	Thickness Feet
Fine-grained, light to dark brown, feldspathic or tuffaceous sandstone with narrow partings of grey argillite; beds mostly more than 4 feet thick; several large gaps	3,710
Dark brown, soft, crystal tuff; some sandy argillite and arkosic sandstone	810
Thin-bedded, dark, sandy argillite; grey-green greywacke or tuffaceous sandstone; concretionary, sandy shale	2,660
	7,180

Division C	
Massive conglomerate except for occasional beds of sandy argillite or greywacke	1,300

Division B	
Fine-grained, greenish greywacke	300
Sandy argillite; tuffacous sandstone or arkose	600
Fine- to medium-grained, massive, brown, argillaceous sandstone or greywacke	200

The relationship between the part of the Dewdney Creek group southwest of the Gibson fault and the sections just described is not clear. The strata to the southwest resemble those of Division D except that they include beds of conglomerate at several horizons. Crossbedding and other features of sedimentation from which the upper side of beds can be determined prove that they are, in places at least, closely folded, and there is certainly some faulting. How extensive the faulting is or how much movement there may be on these faults is not known. It is at least possible that some of the conglomerate in this part of the area may be that of Division C, but the final solution of the problem must await more detailed mapping.

The age of the Dewdney Creek group has been reasonably well established by fossil evidence, although, as in the case of the Nicola group, much more information could be gained by further study of the palæontological history of the region. The following table lists the collections made:

Table III

Fossils from the Dewdney Creek Group

—	Fossil localities							
	13A	13	14	15	16	17	18	18A
Pleuromya sp.	x	....	....	....	....	x	....	....
Belemnites sp.	x	....	....	....	....	....	....	x
Pecten (Camptonectes) sp.	....	x	....	x	....	....	....	....
Pecten (Entolium) sp.	....	x	....	x	x	....	x	....
Trigonia sp.	....	x	x	x	x	....	....	....
Shasticrioceras ? sp.	....	x	....	....	....	....	....	....
Inoceramus colonicus Anderson	....	....	....	....	x	....	x	x
Aucella	....	....	....	....	....	x	....	....
Pecten	....	....	....	....	....	x	....	....
Trigonia (Quoiecchia) sp.	....	....	....	....	....	....	x	....
Lytoceras sp.	....	....	....	....	....	....	....	x

F13A. Nose between Similkameen River and Castle Creek. Elevation 5,180 feet. Division B 950 feet from base. Thirty-foot bed of yellowish, sandy argillite.

F13. Close to F13A, but about 300 feet higher in the section. Massive, greenish, arkosic sandstone or greywacke.

F14. Ridge due north of Allison Pass. Division B just below Division C.
F15. On the ridge about a mile southeast of F14. From upper part of Division C.
F16. Near 6,390-foot peak, about 4 miles west of Allison Pass. Massive, green greywacke or arkose in Dewdney Creek group west of Gibson fault. Horizon not known.
F17. A few hundred yards west of F16. Sandy argillite of Dewdney Creek group west of Gibson fault. Horizon not known.
F18. High peak on the north side of the head of Lightning Creek. Sandy argillite bed in Dewdney Creek group west of Gibson fault. Horizon not known.
F18A. A little east of F18, but probably the same horizon.

McLearn comments on the above collections as follows:

"The following collections contain the same fauna or at least faunas of similar age: F13, F16, F15, F14, and F18A. *Inoceramus colonicus* is present in F16 and F18A. The species of *Pecten* link F13 and F15, and F14 appears to contain the same species of *Trigonia* as F13. In California *I. colonicus* occurs in the two lower faunal zones of the Cottonwood beds, respectively correlated with the Hauterivian and Barremian of Europe. In California the Cottonwood beds are included in the lower part of the Horsetown group. *Shasticrioceras* occurs in the second faunal zone of the Cottonwood beds, the part correlated with the Barremian of Europe. So the above listed collections are of Lower Cretaceous age and are of the same time as the lower part of the Cottonwood beds of California and are later than the early Lower Cretaceous Paskenta beds of California.

"The occurrence of *Quoiecchia* in F18 would of itself, in the present state of our knowledge, suggest a correlation with the early Lower Cretaceous, equivalent to the age of the Paskenta beds of California, for *Quoiecchia* has only been dated in the Harrison Lake area. However, F18 also appears to contain *I. colonicus*, although poorly preserved. This suggests a Lower Cretaceous age later than the Peninsula formation or Paskenta group and more like that of our Hope collections with *I. colonicus* and *Shasticrioceras*. It may be later found that *Quoiecchia* has a longer range upwards than now known. For the present it seems best to date F18, tentatively as about equivalent in time to F13, F16, etc., but if of different age, somewhat earlier, but not earlier than Lower Cretaceous.

"The *Aucella* of F17 is of late Jurassic or early Lower Cretaceous age. It is probably earlier than the fauna listed above for F13, F16, etc., that is the beds with *I. colonicus* and *Shasticrioceras*. These Aucellas will be hard to date until more is known of the succession of Aucella-bearing faunas in the late Jurassic and early Cretaceous in British Columbia."

In summary then it can be stated that the Dewdney Creek group is in part definitely Lower Cretaceous in age, probably corresponding to the Barremian of Europe, and somewhat younger than the Lower Cretaceous of Harrison Lake. The Dewdney Creek, however, includes beds that may be of Upper Jurassic or very early Lower Cretaceous age, which correspond with the Peninsula formation of Harrison Lake. More detailed work will have to be undertaken to establish the relationship between the beds of the two ages, if there are indeed two.

PASAYTEN GROUP

The Pasayten group occupies a belt paralleling the Dewdney Creek in the southwest corner of the map-area, and is possibly related to it in origin and age. It rests unconformably on granodiorite and is cut off at the top by the Chuwanten fault. Rocks of the Pasayten group consist of massive green grit, dark argillite and sandy argillite, purple volcanic rocks, and conglomerate. They fall into five natural subdivisions, which will be called for convenience Divisions A, B, C, D, and E. All appear to be non-marine, and plant fossils have been collected from a number of beds.

DIVISION A

Division A comprises a narrow belt of rocks at the base of the Pasayten group overlying the Eagle granodiorite, which Daly (1912, pp. 489-490) called the Pasayten volcanic group. It was recognized by the writer west of Pasayten River near the International Boundary and north of Three Brothers Mountain. Whether it is present elsewhere is not known, as every attempt to find it was frustrated by lack of outcrops.

The group consists of lava, agglomerate, and flow breccia, the two latter types predominating. Mostly they are purple or grey andesite porphyries with conspicuous plagioclase, and in one specimen hornblende, phenocrysts. The agglomerates are composed of angular fragments of volcanic rocks set in a matrix of consolidated tuffaceous material. Daly estimates the thickness to be about 1,400 feet, but in the absence of bedding the writer was not able to verify this figure. It is probable, however, that the Pasayten volcanic group is in most places not so thick.

DIVISION B

Division B is a thick and uniform unit that comprises the bulk of the Pasayten group in Princeton map-area. It consists of about 12,000 feet of massive, generally coarse-grained arkose or greywacke lying conformably on Division A. The lower 10,000 feet consists of massive, light green, coarse-grained rocks made up mainly of fragments or whole crystals of andesine, quartz, and various ferromagnesian and secondary minerals such as biotite, chlorite, actinolite, epidote, and calcite, as well as a few crystals of zircon and titanite. The ferromagnesian constituents seldom comprise more than 10 or 15 per cent of the rock. The rock is a moderately siliceous arkose or greywacke, but appears to contain more than a little tuffaceous material, and differs from much of the Dewdney Creek mainly in a lower percentage of ferromagnesian minerals and in the presence of many relatively well-rounded grains. Thin beds of pebble-conglomerate appear all through the section, but bedding is mostly hard to discern.

The upper 2,000 feet of the unit is composed of similar rocks interbedded with dark grey or brown argillite and yellowish, sandy argillite. Beds as much as 5 or 6 feet thick show conspicuous coarse crossbedding. A number of the argillite beds of this unit are fossiliferous.

It is, perhaps, significant that neither the Pasayten nor the Dewdney Creek group contains any limestone nor more than a very little calcareous rock of any kind.

DIVISION C

Division B grades upwards into a group of rocks composed predominantly of pale buff, micaceous, arkosic sandstone, with dark argillite partings. A few small beds of conglomerate occur, with possibly some beds of tuff near the top, but on the whole the group, which is some 4,000 feet thick, is remarkably uniform in composition. It, too, contains fossiliferous beds.

DIVISION D

Division D lies conformably on Division C. The conspicuous feature of this unit, which is only some 900 feet thick, is the rather vivid purple colour of most of its members, which makes it an easily recognized horizon marker. In composition it is more heterogeneous than either of the two divisions below it, consisting of well-bedded, purple, occasionally green, tuff or tuffaceous greywacke, purple argillite or fine-grained tuff, purple and green andesite porphyry, and coarse and fine conglomerates, with many granite pebbles and a green or purple, coarse-grained matrix.

DIVISION E

Division E overlies Division D conformably, and is the highest recognized component of the Pasayten group, being cut off at the top by the Chuwanten fault. At one place, a section of 2,200 feet was measured, but its full thickness is, of course, not known. It consists mostly of soft, light brown to green arkose or greywacke interbedded with many thin beds of fine conglomerate.

ORIGIN OF THE PASAYTEN GROUP

In general it appears as if sediments of the Pasayten group were deposited on land and in shallow water near land where only a rude bedding would generally develop. The sediments are coarse grained and poorly sorted, and the coarse crossbedding in many places indicates deltaic conditions. That the body of water was not part of the ocean is suggested by the absence of marine fossils and the abundance of plant remains. The sediments apparently accumulated fast in fairly quiet waters, so that there was little weathering of the softer minerals such as feldspar, amphibole, and pyroxene, minerals seldom found in such abundance in normal sediments.

DETAILED SECTIONS

The following are details of three sections of the Pasayten group measured between its base on the Eagle granodiorite and the Chuwanten fault.

1. Section of the Pasayten Group along the Hillside above the Hope-Princeton Highway

Top not observed

	Thickness Feet
Division E	
Olive-green grit with a little pebble-conglomerate	400
Division D	
Purple tuff, fine conglomerate, sandstone; some purple beds 6 inches thick	340
Purple argillite or fine tuff and arkose, both coarse and fine grained, some conglomerate	560
	900
Division C	
Mainly yellowish brown, micaceous sandstone and arkose; some pebble-conglomerate; at least one bed of dark-coloured, basic tuffs	340
Mainly sandstone as above, but very poor outcrops	1,210
Coarse- and fine-grained sandstone and arkose as above; small interbeds of fossiliferous, greenish, sandy argillite and black argillite	2,320
Very similar to above, but with more black, carbonaceous argillite and massive beds of yellowish, biotite-bearing sandstone or arkose	700
	4,570
Division B	
Massive, light green grit (arkose and greywacke) conspicuously crossbedded; in places 1- to 2-foot beds of dark, fossiliferous argillite and sandy argillite, the latter crossbedded	2,210
Gap in section	2,200
Massive, mainly coarse-grained grit, with occasional fine pebble beds or narrow partings of argillite	6,040
Gap in section. Division A? could lie in this gap	1,000
	11,450

Eagle granodiorite

2. *Section of the Pasayten Group along the Southeast Side of Similkameen River*

Top not observed

	Thickness Feet
Division E	
Massive brown and green grits; some beds and lenses of conglomerate	1,000
Division D	
Alternating beds of purple, roughly sorted tuff and harder green grits	330
Gap in section	670
	1,000
Division C	
Gap in section	830
Brown to yellow, micaceous sandstone and arkose with pronounced crossbedding; occasional thin beds of argillite	2,050
	2,880
Division B	
Green grit (arkose and greywacke), many interbeds of dark-coloured argillite or sandy argillite	1,600
Massive, light green grit in very thick beds; occasional thin beds of fine pebble-conglomerate; a few thin argillite partings	9,880
Gap in section. Division A may lie in this gap	550
	12,030
Eagle granodiorite	
Gap in section	1,000
Granodiorite	

3. *Section of upper part of Pasayten Group on Mountain due North of the Mouth of Chuwanten Creek*

Chuwanten fault

	Thickness Feet
Division E	
Grit and fine pebble-conglomerate, poorly exposed	130
Gap in section	580
Crossbedded, light brown and green sandstones, arkose, and greywacke with thin beds of pebble-conglomerate	1,520
	2,230
Division D	
Purple, tuffaceous argillite and sandstone with occasional interbeds of green grit	1,150
Division C	
Green grits	

AGE OF THE PASAYTEN GROUP

The age of the Pasayten group is well established from fossils collected at a number of horizons. The following is a list of localities from which collections of fossils were obtained.

F19A, Lot 3128[1]. Northwest side of Hope-Princeton highway about 2 miles northeast of the mouth of Pasayten River. From sandy argillite bed in upper part of Division B, about 9,730 feet above base of the group.

F19B, Lot 3129. A little southwest of F19A and 10,180 feet above base of Pasayten group. Upper part of Division B.

F19C, Lot 3137. A little southwest of F19B and 10,920 feet above base of Pasayten group. Upper part of Division B.

F19D, Lot 3126. A little southwest of F19C and 11,490 feet above base of Pasayten group. Lower part of Division C.

F20, Lot 3127. At an elevation of about 6,700 feet on the northwest spur of the high mountain between Pasayten River and Chuwanten Creek. Probably from upper part of Division B.

F21, Lot 3139. Southeast side of Similkameen River about 1¾ miles northeast of the mouth of Chuwanten Creek. About the upper part of Division B.

These collections show so many similar species that in the present state of our knowledge of the Cretaceous palæobotany it is impossible to make any age distinction between them. They are, therefore, considered together.

The following species were identified by W. A. Bell of the Geological Survey, who reports as follows:

Ferns
- *Cladophlebis oerstedi* (Heer) Seward
- *Cladophlebis frigida* Heer
- *Cladophlebis munda* (Dawson) n. comb.
- *Gleichenites giesekiana* (Heer)
- *Sphenopteris foersteri* (Debey & Ettingshausen)
- *Sphenopteris newberryi* nom. nov. for
  - *Asplenium dicksonianum* Newberry (*non* Heer)

Conifers
- *Sequoia condita* Lesquereux
- *Cyparissidium? gracile?* Heer

Angiosperms
- *Araliaephyllum* cf. *geisleri* (Seward)
- *Araliaephyllum* sp.
- *Platanophyllum* (Sassafras?) sp.
- *Platanus heeri?* Lesquereux
- *Menispermites reniformis* Dawson

Bell concludes that this flora is of very late Lower Cretaceous age, equivalent to the Albian of Europe.

ORIGIN OF THE PASAYTEN GROUP

It is clear that the Pasayten group is somewhat younger than the Dewdney Creek group, and that it is non-marine, whereas the Dewdney Creek is marine. It is significant that the sediments of the two groups should show such similarity, that is, that they should both contain much material usually ground away by the normal processes of erosion, and that both include both tuffs and conglomerates. The similarity is most apparent in the field, and suggests a common or at least a similar origin for the two groups. It is possible that the sedimentary material of the Dewdney Creek accumulated rapidly from a nearby source in a relatively shallow arm of the sea not far from the shore, and that the water drained out of a part at least of this basin during Aptian time so that non-marine and deltaic sediments from the same source accumulated to form the Pasayten group in the succeeding Albian stage of late Lower Cretaceous time. The two groups are, as stated, separated by a fault, so that there are no means of knowing

[1] Permanent collection number, Geological Survey.

how important a time interval may have elapsed between their periods of deposition. It is indeed possible that the lower non-fossiliferous part of the Pasayten group may be of Aptian age and that the entire Lower Cretaceous epoch may be represented by the two groups.

SPENCE BRIDGE GROUP

Spence Bridge Volcanic group was the name given by Drysdale (1912, pp. 136-138) to a group of rocks in the vicinity of Spences Bridge that he describes as mainly lava, agglomerate, and tuff, and from which he collected fossils that recent restudy has shown to be of Lower Cretaceous (Aptian) age.

Until recently this group was correlated by the writer with what is, in this report, known as the Kingsvale group, and which was called the Spence Bridge group on Preliminary Map 45-5 of Princeton area. The Kingsvale group was underlain by an assemblage of reddish andesites and basalts figured in the preliminary map as the Spearing group, about which very little was known except that it lay unconformably beneath the Kingsvale and above the Nicola. Its age was, therefore, pre-uppermost Lower Cretaceous and post-Triassic. The correlation between the Spence Bridge and the Kingsvale was unsatisfactory in that the age of the latter was determined by fossil evidence to be Albian, that is, latest Lower Cretaceous, whereas the age of the Spence Bridge was known to be Aptian, which is slightly older. However, this small difference in age was not believed to invalidate the correlation. In 1945 S. Duffell of the Geological Survey commenced the mapping of the Ashcroft map-area, and while studying the Spence Bridge at its type locality was able to distinguish an upper group, which was of Albian age, and similar lithologically to the Kingsvale, and which conformably overlay the type Spence Bridge, which is of Aptian age. Comparison of Duffell's specimens of the type Spence Bridge with those obtained by the writer from the Spearing showed a close lithological similarity. As a consequence, the former Spearing group is now considered to be Spence Bridge and of Aptian age in spite of the fact that there is evidence of an unconformity between it and the Kingsvale group in Princeton area where none exists in the Ashcroft area.

DISTRIBUTION AND LITHOLOGY

Members of the Spence Bridge group are well exposed in bluffs by the side of the road near the junction of Spearing and Otter Creeks. They consist principally of lavas, which are brown, yellow-brown, reddish brown, mauve, purple, green, and grey. Mostly they are dense and cherty in appearance, very hard and brittle, and shatter readily at a blow. Many have small but conspicuous feldspar phenocrysts. Most conspicuous is the common occurrence of well developed flow-lines, which give the rock a finely banded appearance (See Plate III), and by which the Spence Bridge can be most readily recognized. Well-developed spherulites occur in some of the flows. Breccias are commonly developed both by fracturing of the rock in place and by volcanic activity preceding and during its formation. These rocks are similar in appearance to the lavas, and seem to be made up largely of fragments derived from them. They may be confused with the Kingsvale breccias, but for the most part they are easily recognizable as members of the Spence Bridge group.

The Spence Bridge lavas vary in composition from cherty rhyolite to soft dark brown basalt. Most of them are dacites, but many are comparatively free from quartz and are andesites.

Most of the rocks of this group occur in outcrops that, except for the flow-lines previously mentioned, are structureless. Columnar jointing is well developed on Shovelnose Mountain, but this is almost the only exception, and the flow-lines proved to be quite unreliable as a guide to the attitude of the flows in which they occur. As a consequence it has not been possible to estimate the thickness of the Spence Bridge at any place.

Specimen of Spence Bridge lava, showing characteristic flow banding.

AGE

No fossils have been found in the Spence Bridge group in Princeton map-area, so that its age can only be inferred from its relationship to older and younger units and by correlation with fossiliferous rocks at the type locality. At the top of the spur leading down to the intersection of Coldwater and Brookmere Valleys the contact between the Spence Bridge group and a small patch of Nicola group rocks is well exposed. The Nicola rocks are badly altered, are shattered and healed with veins of jasper, and blocks of them can be seen in the base of the Spence Bridge group. There is, therefore, no doubt that the Spence Bridge is resting unconformably on the Nicola and is, consequently, younger than Upper Triassic. Equally clear evidence is furnished as to its relationship with the Kingsvale group, for the basal beds of that group in many places contain blocks of unmistakable flow-lined Spence Bridge. The Kingsvale group is uppermost Lower Cretaceous (Albian) in age, and the Spence Bridge is clearly older than that. Its relationship to the granitic bodies is not so clearly understood. Granitic dykes cut the Spence Bridge in places, but it is not certain that these may not be related to the Otter granodiorite, which is known to be post-Lower Cretaceous. Although the Spence Bridge group is in contact with granitic rocks at a number of places the actual contact was nowhere observed by the writer. At two places, however, pebbles of granodiorite were found in lavas believed to be Spence Bridge, which suggests that it is younger than some at least of the granitic rocks. As mentioned before, restudy of the fossils collected by Drysdale from the Pimainus Hills near Spences Bridge determined them to be of Lower Cretaceous (Aptian) age, and this age is also accepted for the components of the Spence Bridge group in Princeton map-area.

Fossil plants from the type Spence Bridge, collected by C. W. Drysdale in 1912, were re-examined by W. A. Bell of the Geological Survey, who reports as follows:

Locality: from tuff beds at an elevation of 2,500 feet on the western slope of the Pimainus Hills about halfway between Nicola River and Pimainus Creek.

Ferns:
Gleichenites giesekiana 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 age is considered most probable.

KINGSVALE GROUP

As has been indicated in the section dealing with the Spence Bridge group, the group of rocks formerly considered to be its correlative, and so figured on Preliminary Map 45-5 of the Princeton area, is now believed to be somewhat younger. To this younger group the name Kingsvale group has been given, after the railway station of Kingsvale near which the only good fossil locality found in the group in Princeton map-area occurs.

The Kingsvale group in Princeton map-area was evidently deposited on a very rough terrain, and the older rocks break through the cover of Kingsvale at the most unexpected places. Furthermore, much of this older rock is very similar to members of the Spence Bridge group, so that great difficulty has been experienced in collecting a typical suite of rocks all of which belong without question to the younger formation. This difficulty has left the problem of the full range of lava types in the Kingsvale in some confusion. and has rendered the problem of mapping the group difficult. There is little doubt that a fuller knowledge of the exact composition of the Kingsvale group would lead to changes in the shape and extent of areas of this group as shown on the map.

The basal beds of the Kingsvale group are mostly massive agglomerate. In a matrix of andesitic lava or sometimes tuffaceous material are embedded pebbles, cobbles, and boulders, rounded or angular, of Nicola lava, Spence Bridge lava, and granodiorite. This material is so commonly met with in the areas of Kingsvale rocks that one is led to wonder if anywhere more than the lower part of the group is present.

The basal beds are in places interbedded with or replaced by coarse, olive-green greywacke, yellowish brown arkose or tuffaceous sandstone, and dark argillite (See Plate II B). This material is more or less well bedded, but is seldom more than 20 or 30 feet thick, and is in many places absent. Plant fragments and pieces of lignitized wood are common, and near Kingsvale station a fair collection of identifiable plant fossils was made.

Overlying the greywacke or basal agglomerate, or in part interbedded with the former is, in most places, a thick deposit of pyroclastic breccia. Most of this is highly characteristic of the group, and is green, pale buff, powdery mauve, or grey. It consists of sharply angular fragments of porphyritic andesite up to an inch in size in a matrix of crystal tuff. Conspicuous in many places are crystals of orange or salmon-coloured feldspar. The breccia is, in turn, overlain by purple, green, mauve, grey, and black or dark brown lavas. These may be with or without phenocrysts, and all but the black or brown varieties are andesitic in composition and very similar in appearance to many of the lavas in the Nicola group. The dark brown or black types are basalts, and are commonly characterized by the presence of small, amber-coloured feldspars. They resemble some of the basalt in the younger formations, but tend to break with a rough, crumbly surface instead of with a smooth conchoidal fracture.

No attempt can be made to present a type section, as the group varies enormously from place to place. Many hundreds of feet of breccia have been measured north of Kingsvale, whereas in other places this is entirely missing. Similarly, the basal agglomerate may be 50 or 100 feet thick or entirely absent.

The age of the Kingsvale group has been reasonably well established from the fossils collected at Kingsvale. These have been studied by W. A. Bell of the Geological Survey, with the following results:

F22. Lots 3125 and 3020: west side of Coldwater River, about 100 yards upstream from the bridge at Kingsvale.

Ferns
- *Cladophlebis oerstedi* (Heer)
- *Sphenopteris (Anemia?)* sp.
- *Gleichenites giesekiana* (Heer)
- *Sagenopteris* sp.

Equisetales
- *Equisetum* sp. (tubers)

Conifers
- *Pagiophyllum ambiguum* (Heer)
- *Elatocladus* sp. Seward
- *Sequoia condita* Lesquereux
- *Desmiophyllum* sp.
- *Mageiopsis longifolia?* Fontaine
- *Cyparissidium? gracile?* Heer

Angiosperms
- *Phyllites asplenioides* Berry
- *Sapindopsis?* sp.
- *Trochodendroides potomacensis* (Ward)
- *Menispermites potomacensis* Berry

Bell remarks, "The flora from the upper part of the Pasayten group and that from the Kingsvale are considered to be of the same approximate age, or late Lower Cretaceous (Albian)".

The evidence in Princeton map-area, therefore, points to the Kingsvale being a little younger than the Spence Bridge and separated from it by an unconformity. However, near Spences Bridge, the Spence Bridge group is overlain with apparent conformity by a narrow band of sediments containing Albian fossils similar to those found in the base of the Kingsvale group at Kingsvale[1]. These are in turn overlain by a thick series of volcanic rocks lithologically resembling those in the Kingsvale. The succession at the two places seems to be similar, and the absence of the unconformity between the two groups at Spences Bridge suggests that the one in the Princeton area is of local rather than regional importance, and represents only a minor interval of non-deposition.

PODUNK CREEK BODY

On Podunk Creek, near the head of Tulameen River, is a body of buff-coloured volcanic breccia lithologically so similar to the breccias in the Kingsvale group that it is correlated with them. The fragments of porphyritic andesite are set in a matrix of crystal tuff, and plant remains too fragmentary for identification have been found. The only noticeable difference between the Podunk Creek breccias and those in the Kingsvale is that the former carry small crystals of glassy quartz that show well-developed rhombohedral faces at both ends, but with the prism faces so short as to be barely visible.

YOUNG CREEK BODY

Another body of volcanic rocks occurs on Ashnola River in the vicinity of Young Creek. Some of these are volcanic breccias similar to those of the Kingsvale group, but the bulk of the formation consists of lava and unsorted or poorly sorted crystal tuffs, dark brown, buff, green, and purple in colour. The lavas all contain fragments of rocks and minerals, in some cases quite plentifully, but their presence is not always readily apparent. In composition they approximate dacite and are peculiar only in the presence of the fragments mentioned above. They are composed of lava through which is scattered abundant feldspar crystals and small rock fragments. It is as if fine volcanic fragmental material had fallen into molten lava. Most conspicuous throughout is the presence of glassy quartz crystals exactly like those described in the Podunk Creek body, and these and the general similarity between the breccias of the Young Creek body and those of the normal Kingsvale is considered sufficient evidence for including them in that group. Supplementary evidence is furnished by the stratigraphy. The Young Creek body rests unconformably on the nearby, main granitic mass, and is overlain unconformably by Tertiary volcanic rocks of the Princeton group. The stratigraphic evidence above suggests that it is of Cretaceous or very early Tertiary age, which tends to confirm its correlation with the Kingsvale. Furthermore, it is cut by dykes of similar composition and appearance to those that cut the Pasayten and Dewdney Creek groups. There remains the possibility, however, that it is an equivalent of the Spence Bridge group.

PRINCETON GROUP

Members of the Princeton group occur in many parts of the area. They fall into two divisions, one of lavas and the other of sediments. As, however, the lavas occur both above and below the sedimentary rocks, and as the latter

[1] Duffell, S.; Personal communication.

were quite clearly formed in discontinuous basins and probably at different times, it was found advisable to include the two in a single unit, to which the name Princeton group has been given.

PRINCETON SEDIMENTARY ROCKS

The Princeton sedimentary rocks occur in two large basins, the Princeton basin and the Coalmont basin, and as both basal and intraformational beds in a great many much smaller basins. They range in grain size from coarse conglomerate to extremely fine-grained shale. The conglomerate is mostly a light buff rock consisting of large and small, well-rounded boulders, cobbles, and pebbles in a cement of sandstone. Granite is the most conspicuous constituent, but any of the other rock types may be present. The strata grade into thick- and thin-bedded, coarse- and fine-grained sandstone of the same buff colour. Prominent bluffs of these rocks are common. Although at first glance the sandstone seems quite normal, actually it carries a considerable proportion of feldspar and small fragments of lava, and there is little doubt that the beds contain a considerable amount of tuffaceous material.

The fine-grained sediments show more variety than the coarse-grained types. They occur as sandy shale; as massive, soft shale that breaks with a conchoidal fracture, or as extremely thin-bedded shale, the individual laminæ of which split off into sheets as thin as paper. The common colour is light buff to light grey, but brick-red, brown, black, and green beds are plentiful. Quartz, feldspar (both orthoclase and plagioclase), and argillaceous material are the principal constituents. In the main Princeton body the rocks are mostly normal shales, but in many of the outlying bodies tuff beds or beds of tuffaceous shale are prevalent. Most of the sedimentary beds are both overlain and underlain by Princeton volcanic rocks, so that it is not surprising to find occasional lava flows interbedded with the sediments at many places. Some of these thin lava flows have produced interesting results. On Mount Jackson, for instance, sticks of wood buried in nearby sediments have been very completely silicified. Dawson (1877, p. 50B) describes a thin bed of lava at Vermilion Forks about a mile up Tulameen River from Princeton in the sediments near which silicified stems of grass occur.

Here, too, are certain ochre deposits that were used in the past by Indians for paint. Plant fossils are common in the Princeton sedimentary beds, and workable seams of coal occur in both the Princeton and Coalmont basins.

On the northern edge of Princeton map-area, outcrops of well-consolidated, brownish buff conglomerate occur west of the main road to Merritt. Although these are discontinuous they appear to line up as a long, narrow belt that may represent the course of a Tertiary river. A similar belt along Kane Valley road to the west is even more discontinuous, and the outline of this conglomerate area even more hypothetical. At its southern end the area widens out. The conglomerate is purple-red, and includes beds of red sandstone or arkose. It overlies and is interbedded with Princeton lava, so that there is little doubt as to its identity. This belt, too, is believed to represent the course of a Tertiary river. On the eastern boundary of the Young Creek body of the Kingsvale group, on the north side of Ashnola River, conglomerate outcrops in prominent bluffs. These conglomerates resemble the Princeton conglomerates closely and, although direct evidence could not be found, are believed to be younger than the Kingsvale group. They are, therefore, provisionally placed in the Princeton group.

The Princeton sedimentary rocks, on the whole, are normal, freshwater types and, although none of the sandstones is pure, they are very different from the greywackes and tuffs that compose the Cretaceous beds.

PRINCETON LAVAS

Although the Princeton sedimentary rocks are the more important economically, by far the bulk of the Princeton group is composed of andesite, dacite, basalt, and feldspar porphyry.

A common type is a very fine-grained, pale mauve to dove-grey andesite or basalt that is in places porphyritic, with phenocrysts of calcic or zoned plagioclase, pyroxene, biotite, and basaltic hornblende. Actually the porphyritic varieties are more common than is readily apparent, for in most places the phenocrysts are small and generally so inconspicuous as to pass unnoticed in the hand specimen. In this respect the Princeton lavas differ from those of the earlier volcanic formations, many of which are conspicuously porphyritic. Quartz is present in a few flows, but is not common; magnetite is almost always present. Many of the lavas show a pronounced trachytic alinement of the tiny feldspar laths in the groundmass. These rocks grade into various types of grey to pale purplish grey lavas. A common and easily recognizable type is a fresh-looking, pale purplish grey porphyry with widely separated, inconspicuous phenocrysts. This rock tends to break into slabs 6 inches to a foot across and half an inch to an inch thick. These slabs ring sonorously when struck with a hammer and have the appearance of being coated with a light powder or bloom. In some flows phenocrysts, although seldom conspicuous, may be sufficiently abundant to suggest that the rock is coarse grained, but in no specimen examined microscopically was the groundmass anything but exceedingly fine grained, with occasional glassy areas. Also common are rich purple to brick-red lavas, with many of which are associated thin tuffaceous beds. The colour is apparently derived from minute grains of hematite. Although many of the lavas described above are basalts, their basicity is not apparent in the hand specimen. However, typical dark brown or black basalts and basalt porphyry do occur, but are not common. They are fine-grained rocks with inconspicuous phenocrysts of yellowish labradorite, pyroxene (probably augite), and basaltic hornblende. Such rocks cannot be readily distinguished from the dark basalts of the Kingsvale group, or even from those of the younger basalt formations. An uncommon type, apparently confined to the Princeton lava, is a dark grey or greyish brown basalt with small closely spaced vesicles rimmed with some white mineral, probably a zeolite. These may be distributed uniformly through the rock or occur in bands and streaks. This type is well developed on the Similkameen side of the Hope-Princeton highway just south of Sunday Creek. Green lavas are uncommon, but occur in places. They are generally a much brighter green than those of the Nicola group, and are seldom porphyritic. The body of Princeton lava along McCullough Creek is composed of a dense, grey-buff, non-porphyritic andesite. It is not easily distinguished from a tuff, an illusion strengthened by the presence, in places, of flow banding. Under the microscope, however, its origin as a lava is clearly apparent.

AGE OF THE PRINCETON GROUP

The following fossils were collected from the sedimentary members of the Princeton group, and were identified by W. A. Bell of the Geological Survey:

TABLE IV

List of Fossils in Princeton Sediments

	Fossil locality					
	23	24	25	26	27	28
Ferns						
Azollophyllum primaevum Penhallow	x	x	x	....	....	....
Woodwardia maxoni Knowlton	....	....	....	x	....	....
Equisetalis						
Equisetum similkameenense Dawson	x	....	x	x	....	x
Ginkgoales						
Ginkgo adiantoides (Unger) Heer	x	....	....	....	x	....
Conifers						
Pinus sp.	x	x	x	....	....	....
Sequoia langsdorfii (Brongniart) Heer	x	x	x	x	x	x
Angiosperms						
Trochodendroides arctica (Heer)	x	x	x	x	x	x
Leguminosites ? archioides minor Berry	x	x	....	....	....	....
Castanopsis convexa (Lesquereux) Brooks	x	....	x	x	....	....
Alnus crispoides Berry = *Alnus hollandiana* Jennings	x	x	....	x	....	....
Alnus carpinoides Lesquereux	....	....	x	x	....	....
Alnus corallina Lesquereux	....	....	....	....	x	....
Ulmus colombiana Berry	x	....	x	....	....	....
Castanea orientalis Chaney	x	....	....	....	....	....
Ceanothus sp.	x	....	....	....	....	....
Porana cockerelli Knowlton	x	....	....	....	....	....
Cyperacites sp.	....	....	....	....	x	....
Myrica diforme (Sternberg) Chaney	....	....	....	....	x	....
Carpinus grandis Unger	....	....	....	....	x	....
Corylus hebridica (Seward and Holtton)	....	....	....	....	x	....
Betula sp. Oliver cf. *B. dryadum* Brongniart	....	....	....	....	x	....
Betula sp. (male aments)	....	....	....	....	x	....
Quercus sp. cf. *Q. appolinis* Unger	....	....	....	....	x	....
Castonopsis sp.	....	....	....	....	x	....
Fraxinus sp. cf. *F. flexifolia* (Lesquereux) Brown	....	....	....	....	x	....
Amelanchier sp.	....	....	....	....	x	....
Rhus sp.	....	....	....	....	x	....
Ilex ? sp.	....	....	....	....	x	....
Styrax curvatus ? Potbury	....	....	....	....	x	....
Sambucus sp.	....	....	....	....	x	....

F23, L3132: small hill about half a mile northwest of the mouth of Whipsaw Creek.
F24, L3133: Lamont Creek coal mine.
F25, L3143 and 3144: on main road a few hundred yards from bridge across Whipsaw Creek.
F26, L3145: railway to Copper Mountain about 1 mile south of Allenby.
F27, L3021: railway cut about 3 miles west of Princeton.
F28, L3365: head of Glacier Lake, Cathedral Mountain.

Bell reports on these collections as follows:

"The flora is considered to be contemporaneous with that of the Kitsilano formation of the Vancouver area. Berry considered the age of this latter to be Upper Eocene or Lower Oligocene. However, it would seem to be more nearly the age of the Bridge Creek flora of the John Day basin of Oregon which is now considered more probably to be Upper Oligocene or Lower Miocene. The climatic conditions indicated by the flora are warm temperate, with abundant rainfall, at least in the summer months, and a considerable degree of relative humidity."

A number of fossil insects were collected from localities F25 and F27. These were examined by Prof. F. M. Carpenter at Harvard College, Cambridge, Massachusetts, who identified the following: *Orthoptera; Blattidae* n.sp., *Homoptera, Jassoidae, Hymenoptera, Formicedae, Diptera, Bibionidae, Plecia, Homoptera,* and *Fulgoridae.*

Of these, Carpenter says "all are clearly Tertiary, and are almost certainly Oligocene or Miocene".

In 1933 B. R. MacKay of the Geological Survey obtained a mammal tooth found by C. Stubb in the W. R. Wilson coal mine on the south bank of Similkameen River at Princeton. This tooth was studied by L. S. Russell who referred it provisionally to *Trogosus minor* (Am. Jour. Sc., vol. 29, pp. 54-55). Russell comments that "the order Tillodontia, to which this genus and species belongs, is a primitive group of uncertain affinities, appearing first in the Late Paleocene and apparently becoming extinct in the Eocene.......It appears highly probable, therefore, that this family is confined to the Middle Eocene, and the British Columbia specimen is dated accordingly".

Some conflict, therefore, exists in attempts to fix the age of the Princeton group as between the evidence of the fossil plants and insects and that of the mammal tooth. There is the bare possibility that the Princeton coal basin contains sediments of both ages, separated by an unconformity that has not yet been recognized, but this explanation is improbable. The final solution of the problem will have to await further study, but in view of the cumulative evidence of the plant and insect material that has been made available, the younger age is provisionally accepted.

CORRELATION

The Princeton sedimentary beds have been correlated by Dawson and Camsell with the Coldwater beds at Merritt, but, in view of the fact that the latter are, by definition, the basal beds of the Tertiary and that most of the Princeton sediments are underlain as well as overlain by lavas, such a correlation is scarcely justified. From their stratigraphic position it seems more reasonable to correlate them with the Tranquille beds of Dawson. The fossils in the Tranquille are of the same age as those in the Princeton sediments, but this in itself is not conclusive, as fossils collected from the type Coldwater are so fragmentary they afford no reliable basis for the assumption that they represent an earlier age.

The Princeton volcanic rocks can be correlated with the Kamloops volcanic group of Dawson, as sediments of the same age are interbedded with each. W. E. Cockfield, in the Nicola area to the north, has included all the Tertiary rocks, both volcanic and sedimentary, in the "Kamloops group." The rocks of the Princeton group clearly belong within this larger group.

To the volcanic rocks underlying the sedimentary rocks in the Tulameen basin Camsell (1913, p. 82) gave the name Cedar volcanic series. As these rocks are included in the Princeton group the term is not used in this report.

PLATEAU BASALT

North of Princeton and at Blakeburn are two small areas of dark grey to brownish grey, unaltered olivine basalt. Most of it is massive, but large amygdules of zeolite or vesicles with a thick coating of zeolite occur in parts of some flows. Well-developed columnar jointing can be seen at some places. At Blakeburn these lavas overlie Princeton sediments unconformably, and as they are everywhere flat lying they are probably of late or post-Miocene age. A small patch of similiar basalt near Kingsvale is believed to belong to this group.

VALLEY BASALT

(*See* Plate IV A and IV B)

A number of patches of basalt occur along Quilchena Creek and the through valley to the head of Missezula Lake and appear to be remnants of a flow that at one time occupied that valley. They are all composed of basalt or olivine basalt, much of it very similar to the constituents of the Plateau basalt. In addition to the normal dark grey and brown types, however, many are red or purple. The main difference is in the abundance of highly vesicular, almost scoriaceous lavas, and in the almost complete absence of amygdaloidal types. They appear to be very young, and Cockfield[1] reports finding them in the Nicola area overlying unconsolidated material. Nevertheless, outcrops of them have been glaciated, and they are, therefore, of pre-glacial or interglacial age.

SUPERFICIAL DEPOSITS

Deposits of till and glacial silt are found throughout the map-area, and in places cover most of the bedrock. Recent alluvium occurs in many of the valley bottoms, and, in addition, a large part of the Princeton Tertiary basin is covered with a layer of sandy soil, probably in large part derived from the weathering of the Princeton sediments in post-Glacial time.

[1] Cockfield, W. E.: Personal communication.

A. Outcrop of Valley basalt, showing incipient spheroidal weathering.

B. Detritus from outcrop of Valley basalt, showing advanced spheroidal weathering.

CHAPTER III

INTRUSIVE ROCKS

Most of the plutonic intrusive rocks of Princeton map-area fall into two major groups, one older than the late Lower Cretaceous rocks of the area and one younger. To the latter belong several stocks and small batholiths of granite and granodiorite that have been named the Otter intrusions after one of the principal bodies called by Camsell the Otter granite. With this group, also, is included a number of large dykes and sills and a couple of small stocks of quartz diorite named by the writer the Lightning Creek intrusions. The pre-upper Lower Cretaceous intrusions include the main granodiorite batholiths that occur throughout the area and that may be correlated with the Coast Range intrusions on the west and with the Okanagan intrusions to the east, and to these the writer has given the name Coast intrusions. Of approximately the same age and, in part, probably related to them are a number of basic and ultrabasic bodies.

PRE-UPPER LOWER CRETACEOUS INTRUSIVE ROCKS

Intrusions of pre-upper Lower Cretaceous age form batholiths, stocks, and associated sills and dykes. They are far more widely spaced and diversified than those of later age, and represent nearly a third of the bedrock surface of the area. The principal component is granodiorite, presumably belonging to the general family of the Coast Range batholithic rocks, with associated more basic and more alkaline phases. Although it is most probable that all types are closely related genetically and in approximate time of intrusion, it has been possible to make certain subdivisions according to rock type. These types seem to have been introduced at somewhat different stages, but in places grade into one another. Certain possible exceptions will be referred to later. The following subdivision, arranged in sequence from oldest to youngest, makes use of descriptive names for identification purposes:

Basic and ultrabasic rocks

Coast intrusions
- Grey granodiorite
- Red granodiorite
- White granodiorite

BASIC AND ULTRABASIC ROCKS

Basic and ultrabasic rocks occur as stocks and small bodies at a number of places in Princeton map-area. The largest is the Olivine Mountain body to the southwest of Tulameen. This body has been studied and described in detail by Camsell (1913, pp. 49–76), who subdivided it into three main types, peridotite, pyroxenite, and augite syenite, which he mapped separately. It was not possible to map such small units on the scale of the Princeton map, and this and other ultrabasic bodies have been mapped together.

Olivine Mountain Body. The Olivine Mountain ultrabasic body varies in composition from peridotite to gabbro and, although considerable areas consist of a single phase, in places the various types are closely spaced. The most abundant type is a dark green, heavy, coarse-grained pyroxenite. It consists principally of crystals of pyroxene, mostly diopside, with minor amounts of olivine, serpentine, and magnetite. This grades into a peridotite composed largely of olivine, much of which is altered to serpentine. It is a fine-grained, dark grey to bluish grey, heavy rock that weathers dark reddish brown. In places the peridotite carries chromite either as individual grains or as minute veinlets. Native platinum is also present, but in small quantity, and can rarely be seen although it is evidently concentrated near stringers of chromite. There is little doubt that the two minerals were deposited from the peridotitic magma at about the same time during the cooling of the body. Nor is there any doubt that the peridotite has furnished the platinum of the placer deposits along Tulameen River. In places the peridotite has the appearance of a breccia, the fragments and the matrix of which have about the same composition. It would appear that the margins of earlier intruded bodies had cooled and been fractured by a later surge of the same magma, which then engulfed the fragments so produced.

The gabbro appears to be a more acidic, later phase of the ultrabasic body. It is a green rock with crystals of dark amphibole standing out against a matrix of lighter coloured plagioclase or its alteration product, epidote. The amphibole is common hornblende, much of which is altered to actinolite. Apatite and magnetite occur as accessories, and a little interstitial quartz may be present. Chlorite, sericite, and epidote are common secondary minerals. The plagioclase is, in most instances, too badly altered to identify, and although much of it is undoubtedly very calcic, some appears to be as sodic as andesine, in which case the rock should more properly be called a diorite than a gabbro.

A number of small, closely related bodies of similar rocks occur north up the valley of Lawless Creek and south to Whipsaw Creek.

The Olivine Mountain ultrabasic body is believed to be of Jurassic age, and probably represents the earliest phase of the pre-upper Lower Cretaceous period of plutonic activity. It is definitely younger than the Upper Triassic, Nicola group, and Camsell (1913, p. 65) believed it to be older than the Eagle granodiorite, which underlies the upper Lower Cretaceous unconformably. He based this belief on the fact that the peridotite near the Eagle granodiorite north of Grasshopper Mountain was bleached and metamorphosed, and that dykes probably related to the Eagle granodiorite were found cutting it. The writer has no more convincing evidence to offer.

Hedley Diorite-Gabbro. On Nickel Plate Mountain northeast of Hedley are two intrusive bodies, the Toronto "stock" and the Climax "stock", and a great many sills and dykes of intrusive rocks that vary in composition from quartz diorite to gabbro. Although they do not closely resemble the Olivine Mountain ultrabasic rocks they do, apparently, also represent an early basic phase of the nearby coast intrusions, and they are, therefore, grouped together.

These rocks have been described by Camsell (1910, pp. 72-94), Bostock (1929, pp. 213-218), Billingsley and Hume (1941, pp. 555-557), and Dolmage and Brown (1945, pp. 39-40). The following account is based on the work of these geologists.

> "The largest intrusion, an elongated body composed mainly of quartz diorite, known as the Toronto Stock, has been intruded into the western slope of Nickel Plate Mountain. The stock has a uniform width of 2,500 feet and has been unroofed by the erosion of Twenty Mile (Hedley) Creek for a length of 7,000 feet; its long axis strikes N 60° W" (Dolmage and Brown, 1945, p. 39).

The composition of the Toronto stock is not uniform, and quartz diorite in many places grades into diorite or gabbro. Both the diorite and the quartz are dark grey, medium-grained rocks consisting of andesine, some orthoclase, and abundant hornblende or actinolite as the primary constituents, and differ only in the presence or absence of quartz. Titanite, a few flakes of brown biotite, magnetite, arsenopyrite, and pyrrhotite are common accessory minerals. The gabbro and quartz gabbro differ from the above in that the plagioclase is labradorite, and in that the place of amphibole is taken by a pale green to colourless pyroxene, probably augite. The resulting rock is quite light coloured, and is readily distinguished from the diorite. Much of the augite in these intrusive bodies is derived from the amphibole, but Billingsley and Hume have found that some of the augite is a primary constituent. The Toronto stock gives rise to a great many apophyses, sills, and dykes composed of rocks similar to the parent stock, but in many of which hornblende, plagioclase, and augite occur as phenocrysts.

The Climax stock lies a little to the north of the Toronto stock, and is a sheet-like body connected to the main stock and probably better described as a large apophysis. For the most part it has the same composition as the sills and dykes of the Toronto stock.

The gabbroic phases of the Toronto stock have been seen to cut the diorite phases in places, and are, therefore, younger, but there is little doubt that both are derived from a common magma. Camsell suggests that the gabbro may have been intruded after differentiation had taken place. The gabbro is, however, cut by the nearby granodiorite, which is a member of the coast intrusions, and blocks of gabbro lie within the latter near the contact. It is, therefore, older than the granodiorite, and as it intrudes the Upper Triassic Nicola group, it is almost certainly of Jurassic age.

Selish Mountain Body. Another body of basic rocks occurs on the summit of Selish Mountain in the northwest corner of the map-area. Like the Hedley diorite-gabbro the Selish Mountain body varies in texture and composition from place to place. The bulk of the rock is a grey-green, medium- to coarse-grained, granitoid rock with the composition of a diorite or a gabbro. It is mainly composed of plagioclase (basic andesine or labradorite), pyroxene (probably diopside), and amphibole (mostly actinolite after the pyroxene). As much as 5 per cent quartz may be present. Magnetite and pyrite are common, and chalcopyrite was seen in some specimens. This rock grades in places into a light-coloured, coarse-grained rock composed largely of basic labradorite. A few large crystals of actinolite, and magnetite and pyrite constitute the rest of the rock. Another common phase is a dense, almost black dacite, much of which is noticeably banded. It consists of a very fine mosaic of sodic andesine, quartz, and pyroxene with considerable magnetite. In places this passes into a fine-grained gabbro porphyry with large phenocrysts of pyroxene.

The Selish body cuts the Upper Triassic Nicola group, but its relationship to the granodiorite is not known. Its general basic nature and resemblance to the Hedley diorite-gabbro suggest that it, too, is an early phase of the batholithic intrusions of the district, and it is provisionally grouped with the other basic bodies.

COAST INTRUSIONS

In this group of pre-upper Lower Cretaceous age belong all the plutonic rocks commonly correlated with the Coast Range intrusions. All members of this group are closely related and grade into one another, and all were intruded at about the same time. However, it has been possible to distinguish three types and to map them separately. These may be referred to broadly as the "grey", "red", and "white" granodiorite, though these colour distinctions are not everywhere strictly applicable.

Grey Granodiorite

The "grey" granodiorite is dominantly a light grey rock with a normal granitic texture. Much of it is distinctly foliated, although the foliation may not be obvious in a hand specimen. Porphyritic phases seldom occur, at least in the main bodies. One of the marked features of the grey granodiorite is its uniformity in texture, composition, and appearance, and the absence of associated large or numerous aplite and pegmatite dykes. In composition it varies from quartz diorite to granodiorite, the average being quartz diorite (Table V, figure 1). Its principal mineral constituents are: plagioclase (An_{13} to An_{39}) zoned in places, and rarely much altered; quartz, always present and in most outcrops abundant; orthoclase or, occasionally, microcline, as large crystals or, when in small amounts, interstitial; biotite, always present and in most specimens the principal ferromagnesian constituent; and amphibole, a member of the actinolite-tremolite series with a pronounced blue-green pleochroism, possibly all secondary. Accessory minerals comprise magnetite, apatite, titanite in small crystals, and occasional zircon.

Much of the grey granodiorite seems to have developed as the result of intense metamorphism of the intruded rocks. In places traces of bedding are distinctly preserved, and much of the rock has the confused texture of a metamorphic rock with impurities dusted through all the major constituents. Where evidence of relative age relations was observed the red granodiorite either cuts the grey or grades into it, and from this the latter is presumed to be the earlier phase of this period of igneous activity. It is possible that the emplacement of the grey type may have been accomplished, at least in part, by emanations rising from an encroaching magma, and may be the result of widespread granitization with little actual introduction of molten magmatic material.

Four bodies of grey granodiorite are known: The Eagle granodiorite, the Pennask Lake body, the Ewart Creek body, and the Similkameen body.

Eagle Granodiorite Body. The Eagle granodiorite was named and described by Camsell (1913, pp. 76–82). It is exposed in a narrow belt elongated in a northwest-southeast direction across the southwest corner of the map-area. Foliation is parallel with the elongation of the body, and near the International Boundary both swing abruptly to the northeast. There is evident conformity between the structures of the Nicola group and that of the granodiorite, and the writer feels that the intrusion has been introduced along the bedding of the Nicola, perhaps in large part by granitization. A possibility exists that the folding was accomplished after the introduction of the granodiorite, but there is no evidence of crushing in the granite to bear this out.

Pennask Lake Body. The Pennask Lake body lies along the northeast boundary of Princeton map-area. It is typical, uniform, grey granodiorite, but is only slightly, if at all, foliated. Aplite and pegmatite dykes are noticeably scarce. The contact with the body of light-coloured granodiorite to the east is in an area almost devoid of outcrops, and its exact position is uncertain.

Ewart Creek Body. The Ewart creek body is in the southeast corner of Princeton map-area. It is coarse grained and distinctly foliated, but otherwise in no way different from the other grey granodiorite bodies. East of Crater Mountain it grades into red granodiorite, but to the south its contact with the red Cathedral body is sharply defined. This contact is marked by a line of large inclusions against which both bodies show marginal features. Apparently the younger, red body was intruded along the margin of the Ewart Creek body. A narrow band of metamorphic and granitic rock, which parallels Ashnola River to the north, consists mainly of alternating layers of sugary, biotite schist, metamorphosed limestone and lava, and quartzite and sill-like bodies of granodiorite. Each layer is 10 to 20 feet thick, and dips south at low angles. Contacts in most places are gradational, and the granitic sills appear to be beds of sediments that have been more completely granitized than the neighbouring rocks; indeed it is difficult to escape the conclusion that this zone has, for some reason, escaped the full effects of granitizing processes that elsewhere have been carried to completion. There is little doubt the Ewart Creek body is continuous with the Eagle granodiorite beneath a cover of Cretaceous and Tertiary rocks.

Similkameen Body. The Similkameen intrusive body is probably the northern extension of the Ewart Creek body, but is separated from it by an area of Nicola group rocks. It is a normal grey granodiorite, and the location of its northwestern contact with the red granodiorite is only approximate.

TABLE V

Modes of Specimens from the "Grey" Granodiorite (Coast Intrusions)

Specimen No.	Eagle granodiorite body								Ave. 1–8	Pennask Lake body					Ave. 9–13	Ewart Creek body				Ave. 14–17	Ave. 1–17
	1	2	3	4	5	6	7	8		9	10	11	12	13		14	15	16	17		
Quartz	25·0	32·5	12·7	27·0	24·0	15·8	14·8	29·4	22·6	20·5	27·1	19·9	20·7	30·7	23·4	35·5	17·5	13·6	3·8	17·4	21·8
Plagioclase	57·0	58·0	68·6	60·0	67·0	70·4	84·0	56·9	65·2	67·0	48·7	55·0	61·2	40·2	55·1	49·5	38·8	67·7	70·2	56·1	59·8
Potash feldspar	1·0	0·7	1·7	0·0	0·0	0·0	0·0	0·0	0·4	4·6	2·4	7·3	6·4	15·3	7·1	2·5	18·2	8·6	6·1	8·8	4·4
Ferromagnesian and accessory minerals	17·0	8·8	18·0	13·0	9·0	13·8	1·2	13·7	11·8	7·9	21·8	17·8	11·7	13·8	14·4	12·5	28·5	10·1	19·9	17·7	14·0
Per cent An of plagioclase	25	28	29	30	35	35	13	28	27	27	33	21	30	31	28	39	36	35	31	35	30
Biotite	x	x	x	x	x	x	x	x		x	x	x	x	x		x	x	x	x		
Amphibole				x	x	x					x	x	x	x		x	x	x	x		
Magnetite	x	x	x		x	x	x	x		x	x	x	x	x		x	x	x			
Apatite	x	x	x	x	x	x		x		x	x	x	x	x			x	x	x		
Titanite and leucoxene		x			x	x					x	x	x	x			x	x			
Zircon		x		x	x		x			x						x					

1–6, quartz diorite (228 tonalite)[1]; 7, quartz diorite (128 leucotonalite); 8, quartz diorite (228 tonalite); 9, quartz diorite (227′ monzotonalite); 10, quartz diorite (228 tonalite); 11, 12, granodiorite (227′ monzotonalite); 13, granodiorite (227); 14, quartz diorite (228 tonalite); 15, granodiorite (227); 16, granodiorite (227′ monzotonalite); 17, diorite (2211′ monzonite).

[1] Names and numbers in parentheses are according to Johannsen's classification.

Red Granodiorite

The "red" granodiorite is generally quite distinct from the grey, although similar phases occur in both. Mostly it is coarser grained, much more variable in texture and grain size, and more plentifully associated with aplite and pegmatite dykes. Pegmatitic phases occur as well as distinct pegmatite dykes, and altogether the rock appears to have been derived from a magma more plentifully supplied with mineralizers. Characteristically it is a light-coloured rock composed largely of quartz, plagiocase, and pink orthoclase or microcline. In contrast with the grey granodiorite it is rarely gneissic, and then only locally. A darker and older porphyritic phase is in places cut by the normal pink phase, though generally they grade into one another and are so intimately associated that it is not possible to map them separately.

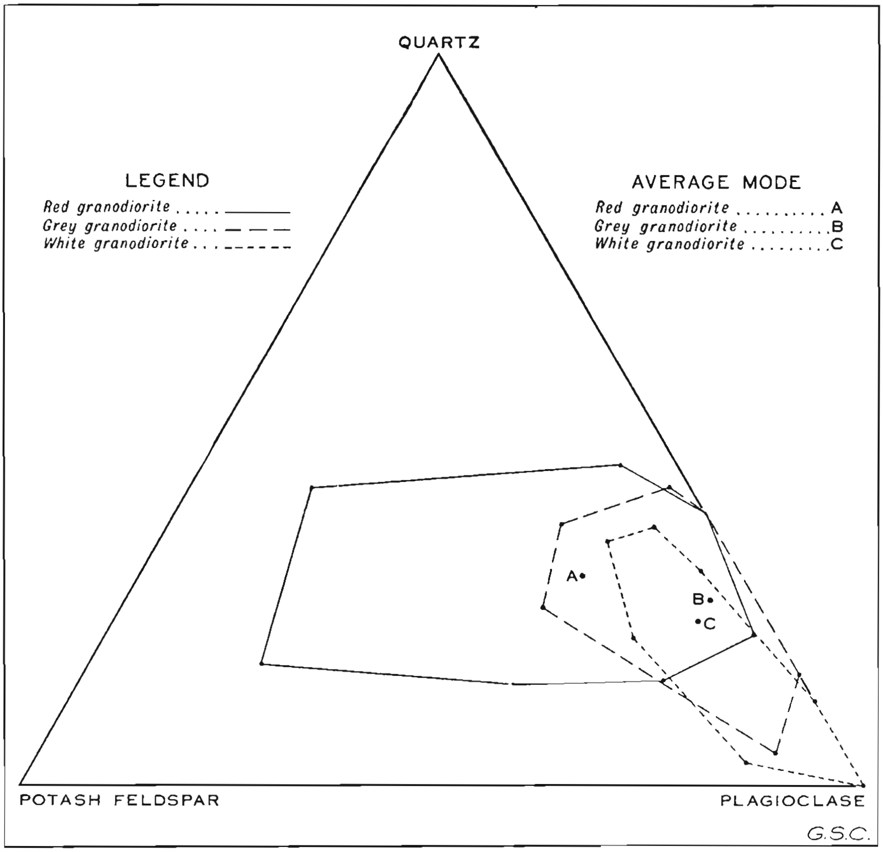

Figure 1. Graph to illustrate modes and average mineral composition of specimens of the Coast intrusions.

The groundmass of the porphyritic phase is a dark foliated granodiorite not unlike much of the "grey" granodiorite, but containing euhedral crystals of orthoclase as much as 3 inches long. These may be relatively scarce or, on the other hand, so closely spaced as to constitute 75 or 80 per cent of the rock. Zenoliths with a common orientation are also common in the porphyritic phase, and there is reason to suggest a relationship between the abundance of the zenoliths and the abundance of orthoclase crystals. However, statistical measurements of fair-sized areas will have to be made before such a relationship can be established. Some of the zenoliths also contain similar orthoclase crystals, and the writer has in more than one place seen such crystals cross the contact between a zenolith and the enclosing granodiorite. There can be little doubt that the orthoclase crystals have developed by a process of metamorphism, and are, therefore, porphyroblasts rather than true phenocrysts. Once again the question must be raised as to whether the porphyritic phase as a whole is not a result of granitization rather than magmatic injection.

The normal phase of the red granodiorite ranges in composition from a granite to a quartz diorite with the average composition of a granodiorite (Table VI, figure 1). It differs from the grey granodiorite in having a much higher content of potash feldspar and generally more quartz. The plagioclase ranges from acid oligoclase (An_{16}) to andesine (An_{45}). Biotite is present in most specimens, and is the most abundant ferromagnesian constituent. Amphibole, commonly a member of the tremolite-actinolite family, is common. The usual accessory minerals are magnetite, apatite, titanite, and zircon. In places the porphyritic phase of the granodiorite may contain titanite crystals as much as half an inch long.

The following is a brief description of the various bodies.

Osprey Lake Body. This body outcrops on both sides of the Kettle Valley Railway from Jura to the eastern edge of the map-area, and is the largest single body of the "red" granodiorite. It has been intruded by two bodies of the Otter intrusions and is in contact with "white" granodiorite on the north and "grey" granodiorite on the south; the position of neither contact has been accurately determined.

Allison Lake Body. This body extends along the main highway north of Princeton. It is more altered than the Osprey Lake body, in part due to the Allison Lake fault and in part at least to pre-Kingsvale weathering, as evidenced on the top of the mountain near the southwest end where the cover of Cretaceous rocks has been stripped off to expose the weathered granodiorite beneath.

Boulder Body. This intrusion, near Tulameen, has, as in the case of the Allison Lake body, been cut by a fault, the Otter Lake fault, and recently stripped of its mantle of Tertiary rocks. It has been described by Camsell (1913, pp. 44-49). In the present writer's opinion, the alteration exhibited by this intrusive rock is due to the presence of the Otter Lake fault and not to the proximity of the Olivine Mountain ultrabasic body. In view of the relationships found elsewhere the Boulder body is considered to be part of the "red" granodiorite and to be younger than the Eagle granodiorite, and, consequently, younger than the ultrabasic rocks. Camsell gives the following chemical analysis (1913, p. 45) of a sample taken from Collins Gulch and analysed in the laboratory of the Mines Branch by M. F. Connor:

	Per cent
SiO_2	73·10
Al_2O_3	12·78
Fe_2O_3	1·43
FeO	1·20
MgO	0·55
CaO	2·00
Na_2O	3·84
K_2O	3·08
H_2O+	0·87
H_2O	0·06
TiO_2	0·30
P_2O5	0·15
MnO	Tr.
	99·42

Kingsvale Bodies. Two bodies of "red" granodiorite occur near Kingsvale. The one to the northeast is normal in every respect, but the body to the west has profoundly affected the intruded Nicola rocks, so that it is not easy to trace the contact between them.

Table VI

Modes of Specimens from the "Red" Granodiorite (Coast Intrusions)

Specimen No.	Boulder body						Ave. 1–6	Osprey Lake body								Ave. 7–14
	1	2	3	4	5	6		7	8	9	10	11	12	13	14	
Quartz	27·8	32·3	40·4	39·6	39·3	12·6	32·3	21·5	18·9	16·5	36·6	28·1	11·9	10·1	16·5	20·2
Plagioclase	59·2	60·5	31·9	14·3	22·9	47·6	39·8	46·9	60·8	56·6	37·4	51·3	30·8	72·9	20·8	47·6
Potash feldspar	6·6	0·2	21·4	43·7	35·6	1·7	18·4	24·0	12·9	10·5	24·4	20·6	43·8	0·3	62·7	25·1
Ferromagnesian and accessory minerals	6·4	7·0	6·3	2·4	2·2	38·1	9·5	7·6	7·4	16·4	1·6	–	13·5	16·7	–	7·1
Per cent An of plagioclase	10	27	27	32	31	30	26	32	37	31	23	26	27	27	14	27
Biotite	x	?	?	?	?	x		?		x	x	x	x	x	x	......
Amphibole	–	?	?	?	?	x	......	x	x	x	–	–	x	x	x	......
Magnetite	x	x	–	–	x	x	......	x	x	x	x	–	–	x	x	......
Apatite	–	x	–	–	x	x	......	x	–	x	x	x	x	x	–	......
Titanite and leucoxene	x	–	–	–	–	–	......	–	x	–	x	–	x	x	–	......
Myrmekite	–	–	–	–	–	x	......	–	–	–	–	–	–	–	–	......
Zircon	–	–	–	–	–	–	......	–	x	–	–	x	–	x	–	......
Rutile	–	–	–	–	–	–	......	–	–	–	–	–	–	–	–	......

Specimen No.	Allison Lake body													Ave. 15–27	Cathedral body				Ave. 28–31	Kingsvale bodies				Ave. 32–35	Ave. 1–35
	15	16	17	18	19	20	21	22	23	24	25	26	27		28	29	30	31		32	33	34	35		
Quartz	18·2	33·8	30·7	19·1	23·7	25·0	23·7	27·1	38·8	22·1	19·8	34·2	20·6	25·8	18·3	13·9	21·7	36·2	22·7	33·8	40·3	24·8	27·1	31·3	16·7
Plagioclase	46·5	57·6	50·9	44·6	38·5	44·0	56·7	46·0	54·7	52·3	59·9	33·9	46·6	48·8	58·4	67·4	33·6	40·1	50·3	43·2	45·5	45·4	60·9	48·8	55·1
Potash feldspar	–	–	3·5	0·8	13·5	14·5	17·4	14·2	4·4	12·8	3·0	25·5	23·4	10·2	21·0	16·0	39·7	10·1	21·3	9·4	6·3	21·4	5·8	10·6	12·7
Ferromagnesian and accessory minerals	34·0	8·6	14·9	35·5	24·3	16·5	2·2	12·7	2·1	12·8	17·3	6·4	9·7	15·2	2·3	2·7	5·0	13·6	5·7	13·6	8·9	8·6	6·2	9·3	15·5
Per cent An of plagioclase	39	25	–	26	37	32	13	29	35	22	25	25	29	......	24	18	20	34	24	30	30	31	35	32	37
Biotite	x	x	?	–	x	x	x	x	x	x	–	x	?	......	x	x	x	x	......	x	x	x	x	......	......
Amphibole	x	–	?	x	x	x	–	x	–	x	x	–	x	......	–	–	–	x	......	x	x	x	x	......	......
Magnetite	x	x	x	x	x	x	x	x	x	x	x	x	x	......	x	–	x	x	......	x	x	x	x	......	......
Apatite	–	x	–	x	x	–	x	x	–	x	x	x	x	......	–	–	–	–	......	x	x	x	x	......	......
Titanite and leucoxene	x	x	–	x	–	x	–	–	–	x	–	x	–	......	–	–	x	x	......	x	x	–	x	......	......
Myrmekite	–	–	–	–	–	–	–	–	–	–	–	–	–	......	–	–	–	–	......	–	–	x	–	......	......
Zircon	–	–	–	–	x	x	–	–	–	–	–	–	–	......	–	–	–	–	......	x	x	–	–	......	......
Rutile	–	–	–	–	–	–	–	–	–	–	–	–	–	......	–	–	–	–	......	–	–	–	–	......	......

1, granodiorite (227′ monzotonalite); 2, quartz diorite (228 tonalite); 3, granodiorite (227′ adamellite); 4, granite (126 leucogranite); 5, granite (126″ leucoadamellite); 6, quartz diorite (228 tonalite); 7, granodiorite (227); 8, 9, granodiorite (227′ monzotonalite); 10, 11, granodiorite (127 leucogranodiorite); 12, granodiorite (226 adamellite); 13, quartz diorite (228 tonalite); 14, granite (126 leucogranite); 15, 16, quartz diorite (228 tonalite); 17, granodiorite (227′ monzotonalite); 18, quartz diorite (228 tonalite); 19, 20, granodiorite (227); 21, granodiorite (127 leucogranodiorite); 22, granodiorite (227); 23, granodiorite (227′ monzotonalite); 24, granodiorite (227); 25, quartz diorite (228 tonalite); 26, granodiorite (227″ adamellite); 27, granodiorite (227); 28, 29, granodiorite (127′ leucomonzotonalite); 30, granite (226′ adamellite); 31–34 granodiorite (227); 35, granodiorite (227′ monzotonalite).

Cathedral Body. The Cathedral body occurs in the southeast corner of the map-area, and was so named by Daly (1912, pp. 459-464). Near its northern boundary, close to the "grey" granodiorite, the rock is fine grained and light coloured, with a predominance of pink orthoclase. Near the International Boundary south of Cathedral Mountain, streaks and patches of slightly different composition occur, and were formed by the granitization or assimilation of the intruded rocks. One of these bodies Daly has called the "Salic phase". The Cathedral body, particularly on Red Mountain, carries much pegmatitic material in which are crystals of smoky quartz 3 or 4 inches long.

Daly (1912, pp. 457, 460) gives the following analysis of the Cathedral body, made by M. F. Connor of the Mines Branch:

	Per cent
SiO_2	71·27
TiO_2	0·16
Al_2O_3	15·38
Fe_2O_3	0·25
FeO	1·47
MnO	0·06
MgO	0·33
CaO	1·37
BaO	0·09
Na_2O	4·28
K_2O	4·85
H_2O at 105° C	0·02
H_2O above 105° C	0·43
P_2O_5	0·05
	99·95

Other small bodies of red granodiorite occur in various parts of the area, but require no special mention.

White Granodiorite

The "white" granodiorite is a distinctive rock, light grey to greenish grey in colour. Its principal characteristic is a porcellaneous appearance imparted by white feldspars. It is fine to coarse grained in texture, rarely foliated, and mostly unaltered. Characteristic also is the presence of needles of amphibole, often in clusters, that give the rock a glomeroporphyritic texture. The rock is fresh in appearance, but in part at least is derived by granitization of volcanic rocks. On the southeast side of Cathedral Lake textures of volcanic agglomerate can be clearly discerned in rock that in the hand specimen cannot be distinguished from the normal white granodiorite. Border phases, where present, and associated dykes and sills are fine-grained, greenish grey diorites or quartz diorites characterized by the plentiful development of long needles of amphibole. The composition grades from that of a basic granodiorite to that of a diorite or gabbro (Table VII, figure 1). On the average it is more calcic and less siliceous than either the grey or the red granodiorites previously described. The principal constituents are quartz, orthoclase, and plagioclase, the latter ranging in composition from oligoclase (An_{20}) to labradorite (An_{70}). Biotite is common, but less abundant than in the grey or the red varieties. Amphibole, mostly a member of the tremolite-actinolite series, is common, and in some specimens abundant. The common accessory minerals are magnetite, apatite, titanite, and zircon.

The contact relations between the "white" and "red" granodiorites are rather confusing. In places the white variety is clearly younger than the red, as it exhibits a chilled border against it, and dykes from it cut the red granodiorite. In other places, however, the two granodiorites seem to grade imperceptibly into each other. It is possible that some of the bodies mapped as "white" granodiorite should in reality be correlated with such post-Lower Cretaceous intrusions as the Castle Mountain stock and the Lightning Creek dykes and sills. The following is a brief account of separate bodies of white granodiorite.

TABLE VII

Modes of Specimens from the "White" Granodiorite (Coast Intrusions)

Specimen No.	Pike Mountain body						Ave. 1-6	Summers Creek body				Ave. 7-10	Park stock			Ave. 11-13	Lakeview body				Ave. 14-17
	1	2	3	4	5	6		7	8	9	10		11	12	13		14	15	16	17	
Quartz	8·3	0·2	26·2	3·2	17·8	...	9·3	33·7	64·5	22·7	11·7	33·1	21·9	20·0	2·8	11·4	18·4	7·6	14·3	14·6	13·7
Plagioclase	65·2	42·6	42·4	23·6	55·3	40·0	44·8	54·9	20·9	65·5	57·2	49·6	48·5	68·5	72·6	70·6	49·8	59·6	63·5	60·4	58·3
Potash feldspar	...	...	10·5	...	14·5	...	4·2	6·6	11·9	9·4	6·8	8·7	3·2	6·5	10·3	8·4	4·0	0·1	12·3	9·6	6·5
Ferromagnesian and accessory minerals	26·5	57·1	20·9	73·2	12·4	60·0	41·7	4·8	2·7	2·4	24·3	8·6	26·4	5·0	14·3	9·6	27·8	32·7	9·9	15·4	21·5
Per cent An of plagioclase	20	60	32	25	30	70	40	27	25	24	40	29	31	27	25	26	36	45	23	29	33
Biotite	...	...	x	...	...	...	...	...	x	x	x	...	x	x	x	...	x	x	x	x	...
Amphibole	x	x	x	x	x	x	...	x	...	...	x	...	x	x	x	...	x	x	x	x	...
Magnetite	x	x	x	x	x	x	...	x	x	x	x	...	x	x	x	...	x	x	x	x	...
Apatite	x	x	...	...	...	x	...	x	x	x	x	...	x	x	x	...	x	x	x	x	...
Leucoxene and titanite	x	x	x	...	...	...	...	...	...	x	x	...	x	x	x	...	...	x	...	...	...
Zircon	...	...	...	...	...	...	...	...	x	...	x	...	x	...	...	...	...	...	...	...	...
Pryoxene	...	x	...	...	...	x	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Myrmekite	...	...	...	...	...	...	...	...	...	...	...	...	...	x	x	...	...	...	...	...	...

1, quartz diorite (228 tonalite); 2, gabbro (3312 melagabbro or bozite); 3, granodiorite (227); 4, quartz diorite (328 melatonalite); 5, granodiorite (227′ monzotonalite); 6, gabbro (3312 melagabbro); 7, granodiorite (127 leucogranodiorite); 8, granodiorite (123 leucoquartz granodiorite); 9, granodiorite (127′ leucomonzotonalite); 10, granodiorite (227′ monzotonalite); 11, granodiorite (227); 12, granodiorite (227′ monzotonalite); 13, diorite (2211′ monzodiorite); 14, quartz diorite (227′ monzotonalite); 15, quartz diorite (228 tonalite); 16, granodiorite (227′ monzotonalite).

Pike Mountain Body. This body lies between the main Princeton-Merritt road and the Tulameen road up Otter Creek. It is quite typical of the white granodiorite, ranging in composition from granodiorite to gabbro. It is definitely younger than the red, Allison Lake body, but is cut by dykes from the post-Lower Cretaceous Otter granite. Several small bodies of similar rocks occur to the west and northwest of the Pike Mountain body.

Summers Creek Body. This body, a few miles due north of Princeton, is mostly a grey-green quartz diorite, very different in appearance to any phase of the "red" granodiorites. Its relationship to the red, Osprey Lake body is, however, not well known.

Kathleen Mountain Body. A large body of "white" granodiorite occurs near the headwaters of Trout Creek. The contacts of this body have not been observed, so that its relationships with the "grey" and the "red" granodiorites have not been established. It is similar in appearance to the white granodiorite elsewhere, and little doubt exists as to its identity. The rock exhibits two interesting features: a fracture zone well within the main body has been mineralized with chalcopyrite and molybdenite, indicating the presence of mineralizing solutions in the vicinity of the intrusion; elsewhere, a small, outlying, stock-like body, a mile or so west of the main contact, resembles the normal white granodiorite in the hand specimen, but in the outcrop clearly exhibits relic structures of bedded rocks, giving an indication of its metamorphic origin.

Lakeview Body. This body, lying to the north and west of Lakeview Mountain in the southeast corner of the map-area, presents several interesting features. It is typical of the "white" granodiorite, and much of it has the well-developed glomeroporphyritic texture previously mentioned. To the north its contact with the "grey" granodiorite has not been accurately determined, and there is more than a suggestion that the two may grade into each other. On the other hand, the southern contact with the "red" granodiorite is sharply defined. In part, they are separated by a narrow remnant of Nicola volcanic rocks, but to the east, where the two are in contact, the "white" granodiorite is dark, fine grained, and fresh looking close to the contact, and there seems little doubt that it is here intrusive into the other.

Park Stock. The Park stock was so named by Daly (1912, pp. 464–465). It is composed of very light-coloured, coarse-grained rock, and, though it varies a little from the typical white granodiorite, it has more the appearance and composition of that phase than of the normal red granodiorite. Its contacts with other plutonic rocks have not been seen, so that no direct evidence of its relationships to these bodies was obtained. Near the International Boundary the quartz diorite is in contact with Nicola volcanic rocks that have been partly granitized and are intruded by a number of diorite sills and dykes. Its effect on these rocks is similar to that elsewhere affected by intrusions of the white granodiorite.

Age of the Coast Intrusions

It has been pointed out that, although in certain instances a definite sequence of the intrusion of the "grey", "red", and "white" granodiorites can be determined, the three types, with the possible exception of some of the "white" granodiorite bodies, were all emplaced during one general period of intrusion, the age of which is known within certain limits. Intrusions of this period all cut the upper Triassic Nicola group, and are overlain by the late Lower Cretaceous groups. Their age is, therefore, definitely Jurassic or early Lower Cretaceous.

COPPER MOUNTAIN INTRUSIONS

A number of stocks, dykes, and irregular bodies of syenitic rocks occur in the vicinity of Copper Mountain. These are composed of several rock types of very different appearance, but evidently parts of a single petrographic suite, and doubtless all intruded at about the same time. They have been studied in detail by Dolmage (1934, pp. 12–17) and much of the following description and discussion of the several components is taken from his report.

Lost Horse Intrusions. This name was given to a number of irregular bodies that occur in Similkameen Valley northwest of Copper Mountain. There are two distinct types: 1, augite diorite; and 2, biotite monzonite or syenite. The augite diorite consists of large amounts of almost white plagioclase with lesser amounts of pale green augite, which together form a pale grey to almost white rock. A little orthoclase is present, and in some places apatite is an abundant accessory mineral. The biotite monzonite consists mainly of orthoclase and plagioclase, crystals of which contain numerous, small, scattered specks of black biotite. Augite is also present, but in small amounts. In places both types carry a little pyrite and chalcopyrite.

Voigt and Smelter Lake Stocks. These stocks, named and described by Dolmage, are similar in composition and appearance to several other small stocks that lie beyond the Copper Mountain map-area. All lie northeast of Copper Mountain and southeast of Princeton. They consist of dark grey, medium-grained augite diorite or gabbro composed essentially of plagioclase, augite, and amphibole with small amounts of biotite and orthoclase. The plagioclase is mostly zoned, and varies in composition from andesine to labradorite; orthoclase composes from 10 to 20 per cent of the rock. Pyrite, magnetite, and hematite are commonly present.

Copper Mountain Stock. This stock is the most interesting of the Copper Mountain intrusions, both economically and geologically. Since it was described by Dolmage its northern limits have been exposed in road cuts, and its western boundaries, which lie outside the Copper Mountain area, have been mapped. However, the description given by Dolmage cannot be improved upon, and it is repeated here.

> "The Copper Mountain stock is elliptical in plan, having a major axis of about 5 miles, extending in a northwesterly direction, and a minor axis of about 3 miles. . . . . Similkameen Canyon cuts through the centre of the stock, clearly exposing the wide range of rocks of which it is composed. The Copper Mountain ore deposits lie against the northeast side of the stock and several other similar, but less important, copper deposits are situated in the western and southern parts of the stock. All are believed to be genetically related to it.
>
> "The composition of the stock varies from a syenogabbro at its outer margin to, in a central core nearly a mile in diameter, nearly pure feldspar-orthoclase and albite. There is a marked change in texture from a fine-grained plutonic at the margin to, in the centre, a medium coarse pegmatite having crystals up to 3 inches in length. As a whole the stock consists of varying amounts of orthoclase, microcline, plagioclase, augite, biotite, hornblende, and also apatite, which occurs throughout the stock in large crystals, some of which are one-quarter inch long. The mineral composition of the rock varies in the following way: an increase in the amount of potash feldspar from 10 per cent to 60 per cent is accompanied by a decrease in the amount of plagioclase and by a change in its composition from andesine-labradorite to albite, and the amount of augite decreases from 36 per cent to less than 1 per cent. Biotite is irregularly distributed and is the principal iron-bearing mineral in the central pegmatitic core. Hornblende is absent from both the outer and the extreme central parts of the stock, but is present in small amounts in the intermediate portion where it appears to be an alteration product of augite. Quartz is absent from all phases, even the pegmatite. The chemical variation is well shown in the accompanying table.

Chemical Composition of the Various Rocks Composing the Copper Mountain Stock

—	1	2	3	4	5
SiO_2	43·12	50·60	54·40	62·86	61·84
Al_2O_3	18·19	16·15	19·05	20·41	19·35
Fe_2O_3	6·20	5·68	3·55	0·35	1·03
FeO	6·43	2·50	2·86	0·14	0·53
MgO	6·52	5·06	2·56	0·20	0·54
CaO	14·00	8·72	6·96	1·20	1·06
Na_2O	2·49	3·86	3·88	4·87	6·07
K_2O	0·81	4·54	5·34	7·35	7·12
H_2O-	0·10	0·14	0·04	0·04	0·24
H_2O+	0·65	1·36	0·66	0·59	0·76
TiO_2	0·50	0·35	0·30	0·35	0·10
CO_2	0·17	0·10	0·00	1·16	0.92
P_2O_5	1·00	0·58	0·36	0·34	0·17
S	0·05	0·02	0·02	0·05	Trace
MnO	0·12	0·14	0·11	0·01	0·03
F	....	Trace	....	....	....
Cl	....	Trace	....	....	....

"No. 1 is at the extreme edge of the stock at the end of the lower road on the west side of Similkameen River.

"No. 2 is 1,200 feet from contact and about 1,000 feet east of the crusher.

"No. 3 is 100 yards south of pumping station in Similkameen Canyon.

"No. 4 is pegmatite 14 inches from contact in Similkameen Canyon, 2,500 feet south of pumping station.

"No. 5 is the central part of pegmatitic core 1,500 feet from contact in Similkameen Canyon.

"The variations in the mineral compositions of the stock were determined by Rosiwal measurements made on powdered samples from two series of specimens taken at intervals along two radial lines, one extending in a westerly direction following the pipe-line leading from the water tanks to the pumping station, and the other extending southward along Similkameen Canyon. The powders were immersed in a liquid having a refractive index of 1·53 so that the potash and soda feldspars could be unmistakably distinguished from one another.

"The variation in mineral composition is gradual in some places and abrupt in others. At the two concentric boundary lines shown on the map, somewhat sudden changes in both composition and texture were marked, so that these boundaries could be mapped with little difficulty. Within each of the three zones marked off by these two concentric boundaries, the variation was found to be too gradual to permit mapping the various phases of which each is composed.

"The change in the mineral composition is shown in the following table:

—	1	2	3	4	5	6	7
Plagioclase	57·00	35·50	47·90	52·00	40·00	48·30	29·00
Potash feldspar	9·00	20·40	12·30	33·00	23·00	35·10	60·00
Augite	20·35	35·50	23·80	11·70	28·00	1·00	1·00
Biotite	10·10	1·80	10·50	0·00	4·00	4·00	3·00
Magnetite	3·10	5·00	4·10	2·80	4·00	4·00	0·00
Hornblende	....	....	....	....	....	6·00	....
Muscovite	....	....	....	....	....	....	4·00
Serpentine	....	....	....	....	....	....	1·90
Sulphides	....	....	....	....	....	....	0·10

Specimens 1 to 6 were secured along the pipe-line at the following places: (1) at eastern contact of stock; (2) 2,700 feet from contact and 800 feet from boundary of intermediate zone; (3) at contact of intermediate and outer zone; (4) outer part of intermediate zone; (5) central part of intermediate zone; (6) inner part of intermediate zone. Specimen (7) came from the central part of the pegmatitic core.

"The outer zone varies in grain from fine to medium fine, and in composition from a syenogabbro at the margin to an inner zoned syenodiorite. The syenogabbro consisto of about 50 per cent plagioclase, much of it zoned and varying from labradorite to andesine, of 10 per cent to 15 per cent orthoclase, 30 per cent to 40 per cent augite, 2 per cent to 11 per cent biotite irregularly distributed, and about 4 per cent magnetite. The syenodiorite consists of 12 per cent to 20 per cent orthoclase, about 50 per cent oligoclase-andesine and oligoclase, 25 per cent augite, 10 per cent to 12 per cent biotite, and 3 per cent to 4 per cent magnetite.

"The intermediate zone varies from a medium coarse to a coarse-grained rock with crystals averaging between a quarter and an eighth of an inch in length. The composition ranges from a syenodiorite having 25 per cent orthoclase, 50 per cent oligoclase, and 15 per cent augite to a rock approaching a monzonite and consisting of 35 per cent orthoclase, 55 per cent albite-oligoclase (85 Ab-15 An), and 7 per cent augite, the remainder consisting of biotite, hornblende, and magnetite.

"The change from this phase to the central core of pegmatite is sudden, the contact, in places, being knife-edge and strongly suggestive of intrusive relationships. Inside this contact the rock becomes coarser in grain and less grey and more pink in colour; augite disappears; and biotite is present in only minute quantities, the small amounts of iron and magnesia shown in the analyses being confined mainly to a soft, pale green, chloritic mineral thought from its optical properties to be penninite. Nearly 90 per cent of the rock consists of feldspar, and of this plagioclase forms about one-third, the remainder being made up of orthoclase, microcline, and microperthite. Apatite is an abundant accessory occurring in large, glassy crystals. Muscovite and sericite are present as alteration products and chalcopyrite and bornite are freely scattered through the pegmatite. Dykes of pegmatite exactly similar in mineral composition occur at many places in and adjacent to the stock.

"Some of the outstanding peculiarities of all the phases of this stock are: the absence of both quartz and feldspathoids, the great number of large apatite crystals, and the association of an abnormal amount of orthoclase with the gabbro and diorite phases. As a whole the rocks are massive, but near the southern contact distinct gneissic structures were observed over a considerable area in Similkameen Canyon and also on the west side of the Similkameen. At the former locality the strike of the foliation is north 75 degrees east and the dip 85 degrees to the south; at the latter the strike is north 85 degrees east and the dip 75 degrees north. The stock has been faulted in many places, though the amount of displacement is small. The long haulage tunnel of the mine, which passes through nearly 3,000 feet of the outer zone of the stock, intersects a large number of small fault zones having a north-south trend. In the vicinity of the ore deposits the stock is cut by a large number of minute, parallel fractures striking northeasterly and along which the feldspars and augite are decidedly bleached. Similar minute fractures were observed in the intermediate zone of the stock near the contact of the pegmatite. Here they are less numerous, strike north 30 degrees to 40 degrees east somewhat parallel to those in the outer zone, and contain a few scattered grains of chalcopyrite and bornite.

"The stock with its several components presents a pattern resembling a target of which the pegmatite core is the bull's-eye. The contacts of the whole mass with the surrounding formations and the boundaries of the concentric zones within the mass, are clearly shown by their intersections with the steep walls of Similkameen Canyon and by mine development work, to be nearly perpendicular over a vertical distance of 1,000 feet or more. There is no apparent tendency of the body to increase in diameter with depth, therefore it conforms closely in size and shape to the definition of a stock and may be so classified.

"The marked consanguinity of the widely varying components, the completeness of the series of components, their normal arrangement with the basic gabbro at the margin and the copper-bearing pegmatite in the centre, together with associate pegmatite dykes and mineral deposits outside the stock, all point to the conclusion that the stock represents a series of differentiated components from a single magma. The variations in composition and texture within the several components, the gradations between the different parts, excepting the pegmatite core, indicate with considerable clearness that the differentiation took place largely in situ."

Dolmage (1934, pp. 52-59) believes that the Copper Mountain intrusions are the products of differentiation of a common, deep-seated magma. The Copper Mountain stock has been further differentiated in place, with a relatively basic margin and a relatively acid core. The most noteworthy fact is the absence of quartz in all phases, even in the numerous associated pegmatite dykes.

The age of the Copper Mountain intrusions is fixed only within wide limits. The intrusions are known to cut the Upper Triassic Nicola group and to be cut by the intrusions of Upper Cretaceous or early Tertiary age. Their age is, therefore, Jurassic, Lower Cretaceous, or early Upper Cretaceous. They differ in the absence of quartz from all other plutonic intrusions in the area, and would, therefore, appear to be unrelated to any of them.

POST-LOWER CRETACEOUS INTRUSIVE ROCKS

Intrusions included in this group may be separated into two sub-groups: 1, the Lightning Creek intrusions, confined to the southwest corner of the map-area; and 2, Otter intrusions and related bodies. Apart from the fact that the two groups were intruded at about the same time there is little direct evidence of relationship between them.

LIGHTNING CREEK INTRUSIONS

The Lightning Creek intrusions include two or three stocks and a great number of sills, dykes, and irregular-shaped bodies. With one exception, they all cut members of the Pasayten or Dewdney Creek groups, and are, consequently, confined to the belt occupied by these rocks. There can be little doubt, however, that they occur elsewhere in the area, but cannot at present be distinguished from dykes and sills related to earlier plutonic intrusive rocks (Table VIII, figure 2).

The largest known member of this group is the Castle Peak stock, named and described by Daly (1912, pp. 492-500). This is a roughly elliptical body, part of which lies on the Canadian side of the International Boundary in the southwest corner of the map-area. It consists of a medium- to fine-grained, light grey granodiorite with a uniform granitic texture. The principal constituents are quartz, plagioclase (andesine), orthoclase, biotite, and amphibole, the last a member of the tremolite-actinolite series with a pronounced blue-green pleochroism. Daly reports seeing it with a core of pyroxene, and it may all be secondary after that mineral. Magnetite and apatite are common accessory minerals. In many respects the Castle Peak stock is quite similar to phases of some of the "white" granodiorite bodies, and, as has been previously suggested, it is possible that some of the latter should more properly be classed with the Lightning Creek than with the Coast intrusions.

Other bodies, smaller but of similar composition, occur cutting the Pasayten group near Skaist River, Podunk Creek, and Tulameen River.

The Lightning Creek sills, dykes, and irregular bodies occur all through the Dewdney Creek and Pasayten groups, and are, in places, so closely spaced as to constitute the bulk of the bedrock. They range from a foot to more than 100 feet in width, and vary considerably in composition. Some are light coloured and even grained, resembling the stocks except that quartz and orthoclase are both scarce, and the rock is a light-coloured diorite. Others are grey, fine-grained porphyries, with conspicuous phenocrysts of plagioclase in relatively equidimentional crystals. Actinolite or biotite forms less conspicuous phenocrysts. Quartz may or may not be abundant. Potash feldspar is generally absent, and the rocks are diorite or quartz diorite feldspar porphyries. The most abundant type, however, is a fine- to medium-grained, grey-green diorite or quartz diorite with abundant biotite or actinolite, or both. In some, lath-shaped crystals of common hornblende constitute the principal ferromagnesian mineral. Similar dykes are commonly associated with the Otter intrusions and may point to a relationship between the two groups. However, very similar dykes are known to be related to the Coast intrusions.

A large dyke of the normal Lightning Creek quartz diorite, as well as a number of smaller dykes and sills, cuts the Young Creek body of the Kingsvale group. From its position it may be suspected to have been injected more or less along the granodiorite-Nicola group contact underlying the Kingsvale volcanic rocks.

The age of the Lightning Creek intrusions is reasonably closely fixed. They cut the upper Lower Cretaceous Pasayten strata, and are believed to be overlain unconformably by members of the Princeton group. Their age is, therefore, Upper Cretaceous or early Tertiary.

TABLE VIII

Modes of Specimens of the Post-Lower Cretaceous Intrusions

Specimen No.	Otter intrusions															Ave. 1-15	Verde Creek body	Castle Peak stock		Lightning Creek intrusions			Ave. 17-21
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		16	17	18	19	20	21	
Quartz	21·4	29·1	24·9	13·4	30·8	26·0	4·3	8·8	4·9	7·5	11·8	13·0	10·0	1·8	20·9	15·5	29·8	9·0	18·2	1·8	8·2	11·2	9·7
Plagioclase	53·1	36·2	60·6	55·5	22·3	44·5	68·0	74·6	74·2	74·2	54·4	50·1	55·4	73·8	43·9	54·9	46·2	54·6	41·7	41·8	73·3	59·2	54·2
Potash feldspar	20·1	25·2	7·5	4·6	40·8	27·0	0·3	4·4	0·1	....	9·3	10·6	3·8	2·6	27·5	12·5	20·6	6·6	17·5	....	9·8	....	6·8
Ferromagnesian and accessory minerals	5·4	9·5	7·0	26·5	6·1	2·5	27·4	12·2	20·8	18·3	24·5	26·3	30·8	21·8	7·7	17·1	3·4	29·8	22·6	56·4	8·7	29·0	29·3
Per cent An of plagioclase	....	20	35	20	30	25	25	40	60	60	40	35	55	60	28	38	27	38	40	20	13	10	25
Biotite	x	x	....	x	x	x	....	x	....	x	x	x	....	....	x	......	x	x	x	....	....	....	......
Amphibole	x	....	x	x	....	....	x	x	x	x	x	x	x	x	x	......	x	x	x	x	x	x	......
Magnetite	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	......	x	x	x	....	x	x	......
Apatite	x	x	x	x	x	x	x	x	x	x	x	x	....	x	x	......	x	x	x	x	x	x	......
Leucoxene and titanite	....	....	x	x	....	....	x	x	....	x	....	....	....	x	x	......	x	....	x	x	x	x	......
Zircon	....	....	....	....	x	x	....	....	....	x	x	x	....	....	....	......	x	....	....	....	x	....	......

1, granodiorite (227); 2, granodiorite (227″ adamellite); 3, 4, granodiorite (227′ monzotonalite); 5, granite (226″ adamellite); 6, granodiorite (127″ leucoadamellite); 7, diorite (228 tonalite); 8, granodiorite (227′ monzotonalite); 9, 10, gabbro (238 quartz gabbro); 11, granodiorite (227′ monzotonalite); 12, granodiorite (227′); 13, gabbro (237 granogabbro); 14, gabbro (2312); 15, granodiorite (227″ adamellite); 16, granodiorite (127 leucogranodiorite); 17, 18, granodiorite (227′ monzotonalite); 19, diorite (2212); 20, granodiorite (227′ monzotonalite); 21, quartz diorite (228 tonalite).

OTTER INTRUSIONS

A number of large and small stocks and a profusion of dykes and sills may be correlated with the Otter intrusions. Many rock types are represented, but most of them fall clearly into a closely related suite. In composition, they range from gabbro to granite, with an average composition about that of a granite or adamellite, but throughout the suite there is generally less quartz than in corresponding members of the earlier intrusive rocks (Table VIII, figure 2). The consideration of rock types will be deferred to the description of individual bodies.

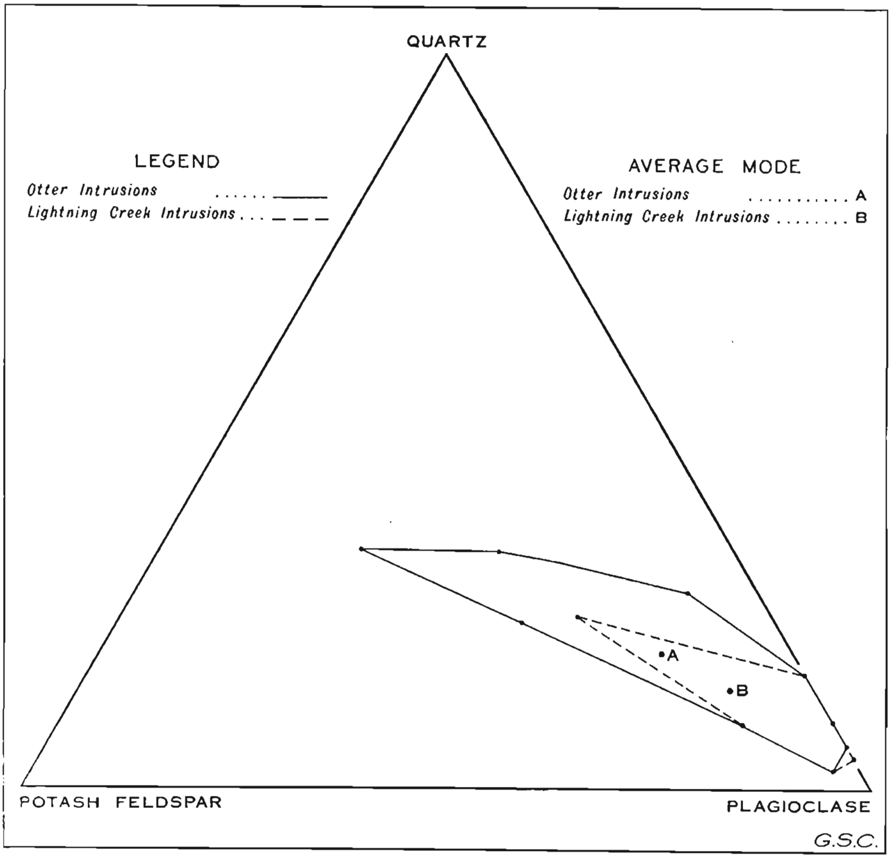

Figure 2. Graph to illustrate modes and average mineral composition of specimens of the Otter and Lightning Creek intrusions.

Otter Lake Body. This intrusion was named and described by Camsell (1913, pp. 99-105) and is the type for the group. It lies mostly on the east side of Otter Creek Valley north of Tulameen. Three rock types constitute the bulk of the body or are associated with it: 1, red granite; 2, grey granite; and 3, feldspar porphyry sills and dykes.

Most of the Otter Lake body is composed of a pinkish red, medium-grained, light-coloured granite or granodiorite. The principal minerals visible are pink and white orthoclase or microcline, white plagioclase, and small specks of black biotite. The white feldspar stands out so as to give the rock a pseudo-porphyritic texture. Quartz is present and can be seen on careful examination, but on casual inspection the rock looks like a syenite. Most of the quartz, indeed, is not visible to the naked eye, being in the form of a quartz-feldspar intergrowth. These intergrowths are quite characteristic of the Otter, and occur in almost all phases in far greater abundance than is commonly met with in rocks of similar composition. Magnetite, apatite, and titanite are common, but not abundant, accessory minerals. Occasional small crystals of actinolite occur in addition to the more common biotite. Some marginal phases are fine grained and truly porphyritic with euhedral pink orthoclase phenocrysts. Certain more basic phases are bluish pink, owing to the development of bluish grey instead of white plagioclase feldspar; in these amphibole is common, completely taking the place of biotite in some exposures, and developed in crystals as much as half an inch long.

Some of the Otter granite, particularly along certain marginal areas, is composed of light to medium grey, medium- to fine-grained rock varying in composition from granodiorite to gabbro. These rocks, though very different from the type just described, have certain features in common. Pink orthoclase, although quite subordinate, can be seen in nearly all specimens, and quartz, though always present, is never conspicuous, much of it being in the form of quartz-feldspar intergrowths. Biotite is the most common ferromagnesian mineral, but amphibole is usually present and may be abundant. In one specimen of the gabbro phase common hornblende occurs in striking, almost black, equigranular crystals. A closely related phase has no pink orthoclase, and the rock is composed principally of blue-grey labradorite and hornblende. Nearly 5 per cent of quartz is present, but the mineral cannot be seen with the naked eye. Along the margins of the grey granite phase the rock is a somewhat darker greenish grey and is fine grained. Amphibole is the usual ferromagnesian constituent, and occurs as lath-shaped or acicular crystals, sometimes in glomeroporphyritic masses. This phase bears a striking resemblance to some of the Lightning Creek dykes, and, it may be noted, to certain phases of some of the "white" granodiorite bodies, particularly those on Lightning Creek and Pike Mountain.

In attempting to describe the Otter feldspar porphyry dykes and sills the writer is confronted by a bewildering array of types no two of which are exactly alike. Some are clearly fine-grained phases of the red or the grey granite and need no further description, but these are in the minority. In general terms the usual type is a rock with a very fine-grained groundmass in some shade of red, buff, liver, mauve, or grey in which are set conspicuous phenocrysts of white or pink feldspar and in some specimens much smaller phenocrysts of biotite or amphibole. Quartz may or may not be present, but is never conspicuous. Occasionally clusters of small white or pink feldspar and biotite phenocrysts an inch or less across are characteristic of the Otter dykes. A less usual, although fairly common type, is a very fine-grained, buff-coloured rock either non-porphyritic or else with feldspar phenocrysts of so nearly the same colour as the groundmass as to be inconspicuous.

Camsell (1913, p. 101) gives the following chemical analysis of a typical specimen of Otter granite:

	Per cent
SiO_2	72·32
Al_2O_3	14·53
Fe_2O_3	0·67
FeO	1·37
MgO	0·58
CaO	1·52
Na_2O	4·46
K_2O	3·51
H_2O+	0·67
H_2O-	0·06
TiO_2	0·30
P_2O_5	0·17
MnO	0·02
	100·18

He points out that the amount of soda is slightly higher than the potash, suggesting the presence of a sodic orthoclase or else the presence of albite, which in thin section might be mistaken for orthoclase.

The description of the Otter body also serves for all the other bodies in the belt running from Copper Mountain to Coldwater River, as they differ in no material respect. The body at Copper Mountain was called Verde Creek granite by Dolmage (1934, p. 17), but is unmistakably related to the Otter granite, as, indeed, Dolmage points out.

The two bodies that occur in the northeast part of the map-area, one on Trout Creek and one on Siwash Creek, are somewhat different and warrant separate description.

Trout Creek Body. The greater part of the Trout Creek body consists of quartz-feldspar porphyry. The groundmass is fairly fine grained, greyish mauve to pink in colour, with little or no quartz visible to the naked eye.

As in most specimens of Otter intrusive rocks, the quartz of the groundmass is in the form of a quartz-orthoclase intergrowth. It differs from the type Otter, however, in having large, well-developed, euhedral phenocrysts of orthoclase, some as much as an inch or more long, and conspicuous euhedral quartz phenocrysts. The latter have well-developed rhombohedral faces and the prism faces so short as to be barely visible. Some of the rock is so decomposed that the phenocrysts may be picked out quite readily by hand.

Siwash Creek Body. The Siwash Creek body is very similar to the Trout Creek body and is clearly related to it. A considerable part of it has, however, been profoundly altered to a pale grey-green or buff rock, largely composed of secondary sericite, kaolin, carbonate, and pyrite. In some places, however, it bears a close lithological resemblance to the Otter Lake body, and there is little doubt as to their relationship.

AGE OF THE OTTER INTRUSIONS

The age of the Otter intrusions is reasonably well fixed. The type Otter Lake body and its associated dykes cut the Kingsvale group in many places, so that it is clearly post-Lower Cretaceous. On the other hand, Otter dykes have never been found intruding the Princeton volcanic or sedimentary formations, although they may occur in abundance in the older rocks a short distance from the contact. This seems to imply that the Princeton group overlies the Otter unconformably, even though no actual unconformable contact has been seen. The Otter is, therefore, assumed to have been intruded at some period in Upper Cretaceous or early Tertiary time.

Most of the Otter granite bodies are intruded along the line of the main Otter Lake fault, which follows lower Tulameen River and crosses to the Coldwater. Furthermore, apophyses from the Coldwater intrusive body have been injected along the fracture zones of this fault. It is clear, therefore, that the Otter granite was intruded after the present system of faulting was established. However, the Otter Lake body, particularly in the vicinity of Elliot Creek, has been sheared as a result of subsequent movements along the same fault zone.

A little pyrite and rare specks of chalcopyrite have been seen in the main Otter granite bodies, but otherwise no mineralization is known to be associated with them. The Trout Creek and Siwash Creek bodies, however, present a different picture. On Kathleen Mountain, where the Trout Creek body intrudes the "red" granodiorite, contact metamorphism is pronounced, and is accompanied by the introduction of manganese minerals and, locally, considerable pyrite and chalcopyrite. Parts of the Siwash Creek body carry veinlets of fluorite, and the intrusion is crossed by several fractures some of which carry pyrite, sphalerite, galena, and chalcopyrite. The source of these mineralizing solutions is quite probably related to the parent magma of the Siwash Creek intrusive body.

MISCELLANEOUS DYKES AND SILLS

Dykes and sills occur abundantly in many parts of Princeton map-area. Some of these, whose relations to their parent plutonic intrusions are well established, have already been described. Others, andesite, dacite, and quartz-feldspar porphyries, are undoubtedly related to one or other of the Coast intrusions, but show no special features that would serve to relate them to any particular body nor to distinguish between those related to the Coast intrusions and the Lightning Creek dykes and sills. Sills and dykes of quartz diorite at many places in the Nicola group rocks are clearly feeders to the Nicola lavas and are difficult to distinguish from them. In the same way feeders to the Princeton lava flows are particularly well exposed on the peak near the International Boundary south of Easygoing Creek. A distinctive group of dykes in the vicinity of Tulameen is in part intrusive into the Otter granite and its related dykes and sills, and is, therefore, of later age. It comprises soft, dark, greenish brown andesite and dacite dykes from a foot to 10 feet wide.

CHAPTER IV

STRUCTURAL GEOLOGY

As most of Princeton map-area is underlain by intrusive and extrusive igneous rocks, and as bedding in the latter can generally be recognized only from occasional tuffaceous interbeds, the structural geology of the area is imperfectly known. It is clear, however, that folding took place before Lower Cretaceous time, as well as between then and Lower Miocene time, and again in post-Lower Miocene time. The results of these periods of folding have been superimposed on each other, leading to highly complex structures.

Map 888A endeavours to show, in simplified form, the principal faults and fold axes in Princeton map-area. The general picture is apparently that of a broad and complex geosyncline extending in a northwest direction from the International Boundary to about the centre of the map-area. The central area of this geosyncline is occupied by a belt of irregularly distributed Triassic and Lower Cretaceous rocks. Associated intrusive rocks and Tertiary formations are disregarded in this connection as any relationship of the former to the structural pattern is obscure, and the latter appear to be superimposed here and there on the older rocks without regard to underlying structures. Late Palæozoic formations rest on either flank of this geosyncline. The eastern limb seems to be formed of a normal geological succession of formations, but this succession is interrupted on the western limb by the Hozameen fault system, so that the Hozameen strata are brought into direct contact with Lower Cretaceous formations. Most of Princeton map-area straddles the eastern limb of this geosyncline, and the formations are progressively older from west to east. The structure is far from simple, however, and much folding and faulting within the compass of the major structure has, therefore, led to many reversals in dip and abrupt changes from the general trend.

FAULT STRUCTURES

The major faults in Princeton map-area radiate in a general northerly direction like the spread fingers of a hand whose palm is in the centre of the southern half of the area. They resolve themselves into three groups: one in the southwest corner of the area, one that radiates from the vicinity of the town of Princeton, and one near the town of Hedley.

HOZAMEEN SYSTEM

The main fault in the southwest group is the Hozameen fault, only a small part of which is in the map-area. It is a westerly dipping thrust fault with sufficient displacement to bring the Carboniferous (?) Hozameen group in contact with Lower Cretaceous, Dewdney Creek beds. It has been traced for some 14 miles in Princeton and Hope map-areas, and the faults along Fraser River north of Boston Bar may represent extensions of this system, although the connection has not been definitely established. The Gibson and Chuwanten faults have smaller displacements, but probably resulted from the same crustal deformation that produced the Hozameen fault. Other faults of the same system are suspected to occur in the block between the Gibson and Hozameen faults.

OTTER SYSTEM

A spray of faults radiates northwest and northerly from the vicinity of Princeton. Its extension to the south could not be traced, as the area in which the faults may occur is largely covered with later Tertiary rocks or occupied by granodiorite intrusions in which they could not be traced. The principal fault of this system, the Otter Lake fault, follows Tulameen River from Princeton to Tulameen. It is well exposed at a number of points on the side of the road, and is marked by a wide zone of crushed, silicified, and leached Mesozoic rocks. It cuts through the Otter granite body, which is also crushed and leached, particularly on Elliot Creek. Its course across Thynn Mountain is not well known, but it can again be seen crossing the railway just south of Brodie. Here the zone of crushing and leaching is quite in evidence, but the structure is complicated by the presence of Otter dykes that have followed the fault zone and have also been crushed by subsequent movements along it. North of the railway the fault was lost in the highly metamorphosed zone bordering the granodiorite body. The displacement on this fault is not known, but the lateral component of the movement appears to have been northwest on the northeast side of the fault with respect to the southwest side.

A complicated zone of faulting, identified as the Allison Lake fault, follows the main road from Princeton to Merritt. Outcrops are generally poor in this vicinity, and the course of the fault is imperfectly known. It can, however, be seen at a number of places where the road skirts Allison and Gladstone Lakes. Clearly, the fault is not a single line of rupture, but rather an *en échelon* arrangement of closely related faults. The rocks along one of these faults were observed to be crushed, silicified, and leached, much as along the Otter Lake fault. Undoubtedly the faulting involved the Allison granodiorite body, which is in places much crushed and altered.

Faulting strong enough to suggest a major fault was observed at several places along Summers Creek, but this fault, if it exists, could not be traced for more than a few miles.

HEDLEY SYSTEM

Both fault systems described have a general northwesterly trend. Near Hedley, however, is a group of faults that strike mainly northeasterly. These are not large faults, and have not been traced beyond the area in which detailed work has been done. Their situation in the heart of the Hedley mining camp, however, gives them considerable significance. The principal fault, the one up Hedley Creek, was called by Camsell the Bradshaw fault, and has a throw of 800 feet (Camsell, 1910, p. 113).

Although northeasterly trending faults predominate in this region, there are some that strike northwest in conformity with the pattern elsewhere in the map-area.

In addition to the faults described there are many minor faults that do not necessarily fit into the main system outlined, and that probably originate from minor local disturbances.

AGE OF THE FAULT STRUCTURES

Faults of the main system cut nearly all formations up to and including the Otter granite, but are not known to intersect rocks of the Princeton group. It may thus be inferred that the last movement along them occurred in Upper Cretaceous or early Tertiary time. It is clear, however, that the faults originated at a much earlier date, for not only do apophyses from the Otter granite follow the fault zones, notably as on Coldwater River, but the position of the granodiorite bodies themselves is, in places, apparently influenced by pre-existing fault zones. For instance, apophyses from the granodiorite body near the northwest corner of the map-area appear to have been intruded into the zone of the Otter Lake fault, and apophyses from the Allison intrusion seem to have invaded the zone of the Allison Lake fault. From this it is evident that the period of faulting started early in Jurassic time and continued intermittently into an early Tertiary epoch.

FOLD STRUCTURES

As previously mentioned, the fold structures are both complex and difficult to determine because of the scarcity of reliable attitudes in most of the formations. However, the axial lines of enough folds have been roughly traced in both the Triassic and Cretaceous formations to give a general idea of the structures in which these formations are involved. A difference may be noted in the trend of the formations of these two ages, indicating the application of stresses in quite different directions. In Map 889A the axial lines of folds in the Triassic rocks are represented by sinuous curves that are actually much more complex than depicted, due to the superposition of cross-folding in Cretaceous time. Not enough data were available, however, to represent the true pattern accurately.

Folding occurs in the Triassic, Cretaceous, and Tertiary formations and will be treated in that order.

FOLDING IN THE NICOLA GROUP

The general trend of the Nicola rocks is roughly north and south, the general sequence of older rocks on the east and younger on the west being interrupted by a number of fairly steep folds (Map 889A). The continuity of these folds is broken by the Otter Lake and Allison faults. The only fold that deserves special mention is the anticline along Pasayten River. It plunges to the south, and is followed around the nose by the Eagle granodiorite.

FOLDING IN THE DEWDNEY CREEK GROUP

The entire block of sediments forming the Dewdney Creek and Pasayten groups has been tilted to the west, so that the constituent strata have a general westerly dip. In addition, beds between the Hozameen and Gibson faults have been severely folded. The axial lines of the anticlines and the synclines shown on Map 889A were readily recognizable and others may exist. However, it is clear that the western edge of the block has been dragged up by movements along the Hozameen fault, and probably all the folding can be attributed to these movements.

FOLDING IN THE KINGSVALE GROUP

Folds in the Kingsvale group trend east and west or northeasterly, in contrast with the north-south structures in the Nicola rocks. Mostly they are relatively gentle, but steep dips are not uncommon. Whereas folds in the Nicola group evidently resulted from an east-west compression, the forces producing the Kingsvale folding acted more nearly from the north and south. The former almost certainly resulted from northeasterly thrusting on a regional scale, whereas the latter is probably much more local in origin and extent.

FOLDING IN THE PRINCETON GROUP

Little is known of the folding in the Princeton group except such as is revealed in the sedimentary members. Outcrops in the large sedimentary basins were so scattered that an overall picture was not obtained. Considerable areas are undoubtedly underlain by relatively flat-lying beds, but in places the strata have been closely folded, and dips as high as 70 degrees were observed. The general trend of the folds in the Princeton basin seems to have been east and west, and in the Coalmont basin about northwest. The first corresponds with the folding in the Kingsvale group, which could, therefore, have been accomplished in post-Princeton time rather than earlier. Although direct proof is lacking, the general distribution of the Princeton formations with respect to those of the Kingsvale group suggests considerable erosion and some folding in the latter in pre-Miocene time.

CHAPTER V

HISTORICAL GEOLOGY

The earliest geological record in Princeton map-area is contained in the Carboniferous (?) rocks of the Hozameen group. These were deposited in a marine basin that most probably extended over the entire Princeton map-area. So far as can be determined from the limited area of exposures of the Hozameen rocks the sediments laid down in this marine basin were intercalated with a much greater amount of lava flows and other volcanic materials. Probably somewhat later, but possibly in a part of the same basin, very similar processes produced the rocks of the Bradshaw, Independence, Shoemaker, and Old Tom formations. The age of these formations is not definitely known, but it is improbable that they bridge the interval between the periods of deposition of the Hozameen and succeeding Nicola groups. It would appear, however, as if the conditions that produced the rocks of the above formations continued into Upper Triassic time, for the Nicola group also consists of marine sediments, among which were extruded tremendous volumes of lava and associated pyroclastic material that, falling into the water, formed well-bedded tuffs and breccias.

At the close of Upper Triassic time the sea drained from most, at least, of the area, and, commencing early in Jurassic time, a period of deformation was initiated. This was probably accomplished by strong pressure from the west, which threw the earlier formations into a series of north-trending folds. As the sea withdrew erosion commenced, and increased in intensity as the land rose. Into the heart of the deformed strata penetrated a succession of magmas and magmatic emanations producing a core of granitic and granitized rocks, with accompanying alteration and mineralization of the older rocks.

By Lower Cretaceous time erosion had exposed the earlier intrusive rocks. It was probably during this epoch, that the Copper Mountain intrusions were emplaced, to the accompaniment of further mineral deposition.

The earliest Cretaceous record is in the southwest corner of the map-area where the sediments of the Dewdney Creek group were laid down on the edge of a shallow marine basin. That vulcanism was active somewhere in the vicinity is clear from the great accumulation of volcanic fragmental material in the Dewdney Creek group. The local source of this material is, however, not known, and no great accumulation of lavas of this age has been found.

In upper Lower Cretaceous time, which immediately followed, the situation during the formation of the Pasayten, Spence Bridge, and Kingsvale groups is clearer. The Pasayten sediments were laid down in a body of water in which there is no record of marine life. Whether the basin had by this time been cut off from the sea and was no longer salt, or whether the conditions of deposition of the sediments (much of the Pasayten is of deltaic origin) were unsuitable to support marine life is not known. While the Pasayten sediments were being deposited along the margin of this body of water, and in part at an even earlier stage, active vulcanism resulted in the accumulation on land of considerable thicknesses of lava, breccia, and tuff along a parallel belt to the northeast. There can be little doubt that the volcanic material that forms a considerable part of the Pasayten came from this volcanic region, either being dropped directly into the water or washed into it from the shore. During this period the Spence Bridge and Kingsvale groups were deposited. In Princeton map-area an interval of erosion separates these groups, but farther north deposition seems to be nearly, if not quite, continuous.

Lower Cretaceous vulcanism and sedimentation was followed by another period of folding, faulting, and erosion during which the Otter and Lightning

Creek intrusions were first emplaced and later exposed by erosion. Intrusion was accompanied by the formation of some mineral deposits.

The next recognizable event was the outbreak of widespread vulcanism in or before early Miocene time, giving rise to the Princeton group of lavas associated, at intervals, with sediments laid down in local lake basins. This period of accumulation was succeeded by another of folding and erosion, followed in turn by the extrusion of the "Plateau" basalts. During the subsequent period of erosion most of this basalt was removed, and the basic pattern of the modern drainage system established. Down one of the valleys so formed the "Valley" basalt streamed late in Pliocene or early in Pleistocene time. This was probably an event of only local significance, and the processes of erosion already going on were not interrupted until the advent of Pleistocene glaciation.

There is no evidence in the map-area of more than one advance of the ice. The entire area was covered by a sheet of ice many thousands of feet thick that swept forward in a general southerly direction. Erosion was severe in places, but in others the effects were relatively slight. The retreat of the ice left a mantle of till over most of the area, and many of the valleys were choked by glacial debris. Local late-Glacial lakes were formed, and many streams diverted from their previous courses. Locally broad flood-plains were developed where streams re-worked the abundant loose material left by the ice, a process that is still in progress.

CHAPTER VI

METALLIFEROUS DEPOSITS

Several distinctly different assemblages of metalliferous deposits occur in Princeton map-area, but each type is, in the main, concentrated in particular localities so as to form distinct mining camps. It has, consequently, proved more convenient, in the descriptions that follow, to include all ore occurrences in each camp at the one time, rather than to select only those properties of the characteristic type.

CLASSIFICATION OF METALLIFEROUS DEPOSITS

- Placer deposits
- Lode deposits
  - Gold, arsenopyrite, pyrite deposits (Hedley camp)
  - Gold, telluride deposits (Grasshopper Mountain)
  - Galena, sphalerite deposits (Whipsaw and Siwash Creeks)
  - Gold, galena, sphalerite, pyrite deposits (upper Similkameen River)
  - Bornite, chalcopyrite deposits (Copper Mountain-Aspen Grove belt)
  - Chalcopyrite deposits (Laws Camp and Mount Rabbitt)
  - Chalcopyrite, molybdenite deposits (Copper King)

PLACER DEPOSITS

HISTORY AND PRODUCTION

The Princeton area was first brought to the attention of the mining public in the early sixties when placer deposits were found along Tulameen and Similkameen Rivers and their tributary creeks. It was not until 1885, however, when rich placer showings were revealed, that the region really came into prominence, and in the following year the value of the production amounted to $193,000, the peak figure. Production remained high for some time, however, and in 1891 the district was recognized to be the most important producer of platinum in North America. The bonanza period lasted in all for about a decade, and production then dwindled to a few thousand dollars a year. Activity has never, in fact, actually ceased: nearly every season a few men are to be found sniping along the creeks, re-working old tailings, and, as late as 1938, discovering small patches of virgin ground missed by the old timers. Concurrently with this period various attempts were made to reach deeply buried channels by tunnelling, or to work bench deposits and deep gravels by steam shovel or hydraulic methods. These efforts met with various, but never more than moderate, success.

Elsewhere in the area, in particular on Siwash and Shrimpton Creeks, placer gold has been found, but attempts to mine it have not proved profitable.

The following table of gold and platinum placer production from 1885 to 1909 is quoted from Camsell (1913, p. 143).

TABLE IX

Year	Gold	Platinum
	Dollars	Ounces
1885	114,000	....
1886	193,000	....
1887	118,000	2,000
1888	89,000	1,500
1889	31,800	1,000
1890	17,700	1,000

TABLE IX—*Concluded*

Year	Gold	Platinum
	Dollars	Ounces
1891	17,800	2,000
1892	16,750	500
1893	9,550	257
1894	5,630	160
1895	41,600	633
1896	9,000	125
1897	23,500	266
1898	7,560	100
1899	6,600	137
1900	4,800	....
1901	4,680	22
1902	2,700	10
1903	2,000	....
1904	2,500	20
1905	1,140	30
1906	2,500	....
1907	1,000	....
1908	1,000	....
1909	1,000	....
Total	724,860	9,860

The following statistics on placer production in the years following are taken from the Annual Reports of the British Columbia Minister of Mines.

Year	Gold	Platinum
	Dollars	Dollars
1910	1,000±	?
1911	1,000±	?
1912	2,000±	?
1913	3,000±	small
1914	3,000±	small
1915	12,000±	2,000
1916	9,000	1,700
1917	8,000	?
1918	5,000	?
1919	1,000	1,500
1920	500	400
1921	1,000	100±
1922	1,000	100±
1923	5,000	100±
1924	4,000	2,100±
1925	2,482	1,000±
1926	1,621	4,258
1927	1,003	960
1928	4,114	2,743
1929	1,275	1,699
1930	1,292	771
1931	4,454	1,783
1932	5,210	2,332
1933	7,093	1,400
1934	9,833	2,051
1935	5,173	1,046
1936	2,938	809
1937	2,302	388
1938	9,374	....
1939	7,341	....
1940	5,351	....
1941	18,268	....
1942	2,216	....
1943	570	....

DESCRIPTION OF PLACER DEPOSITS

The materials of the placer deposits are sand and gravel, nearly always containing many boulders of various sizes. Several attempts to mine by mechanical means have been frustrated by these boulders, but in one instance at least, they were confined to the upper, unprofitable layers and the underlying paystreak was relatively free of them. Some of the gravels are cemented, but not sufficiently so to be troublesome.

The heavy minerals concentrated by washing the gravels are principally chromite, magnetite, gold, platinum, and, occasionally, native copper. Of these gold has always been the most important. It occurs in rough, angular, or slightly flattened, rarely well-flattened, nuggets. Flour gold is comparatively scarce. The largest nugget reported weighed about 8 ounces, but nuggets over an ounce in weight are rare. Quartz can be seen adhering to occasional nuggets, and this and the general lack of flattening suggest that the gold has not moved far from its source. It is indeed most probable that the gold-bearing veins of Grasshopper Mountain and its vicinity supplied the gold concentrated in the placers.

The only other mineral of commercial importance in the placers is platinum. The ratio of platinum to gold is about 1 to 4 in the Similkameen and lower reaches of Tulameen River, but increases upstream to where, near the mouth of Olivine Creek, the platinum is about equal in amount to, or may even exceed, the gold. On the whole, however, the platinum is of lesser importance. Platinum nuggets are never flattened and rarely even subangular, but occur in small rounded grains resembling fine shot, and mostly of quite uniform size. These nuggets are smaller than the gold on the average, but at the same time the platinum does not occur in fine, flaky particles. Most of the pellet-like nuggets have a roughly pitted surface; many show adhering grains of chromite and magnetite; and olivine and pyroxene are occasionally attached to them. The platinum can be separated into magnetic and non-magnetic varieties, probably depending on the amount of attached magnetite.

A sample of platinum weighing 18·266 grammes from Granite Creek was assayed by G. C. Hoffmann of the Geological Survey.[1] It was separated into magnetic and non-magnetic parts, the former constituting 37·88 per cent of the whole. These parts were analysed separately, and the composition of the whole calculated.

—	Magnetic	Non-magnetic	Total
	Per cent	Per cent	Per cent
Platinum	78·43	68·19	72·07
Palladium	0·09	0·29	0·19
Rhodium	1·70	3·10	2·57
Tridium	1·40	1·21	1·14
Copper	3·89	3·09	3·39
Iron	9·78	7·87	8·59
Osmiridium	3·77	14·62	10·51
Embedded chromite	1·27	1·95	1·69
Total	99·97	100·29	100·15

In September 1925, a sample of platinum from the Tulameen district weighing 5 ounces was sent to Johnson and Son, London, England[2], for a complete analysis, and in 1930, 13·43 ounces of platinum concentrate from Tulameen River below Coalmont were shipped to Johnson, Matthey, and Company[3], also of London, England. The following are the returns made and the prices quoted in 1930:

[1] Ann. Rept., 1886, vol. II, pp. 5-9.
[2] Ann. Rept., B.C. Minister of Mines, 1926, p. 227.
[3] Ann. Rept., B.C. Minister of Mines, 1930, p. 212.

—	1926	1930	Price per ounce
	Per cent	Per cent	Dollars
Gold	3·5	0·58	19.40
Platinum	60·4	68·74	35 16
Tridium	16·0	2·22	194 00
Palladium	–	0·31	16·97
Osmium	6·8		
		8·10	97.00
Ruthenium	7·2		
Rhodium	6·1	0·48	43.65
	100·0	80·43	–

The origin of most of the platinum in the Tulameen and adjacent streams is the ultrabasic body that crosses Tulameen River below Grasshopper Mountain and continues to the southeast across the heads of Olivine and Granite Creeks. Not only are ultrabasic bodies the world over considered to be the primary source of platinum, but there is abundant direct evidence that this is true in Princeton map-area. The presence of olivine, pyroxene, and chromite in the platinum nuggets, all of which occur in the nearby ultrabasic rocks, is in itself suggestive, but, moreover, grains of platinum have been seen in the ultrabasic rock and particularly in the small seams of chromite that here and there cut it. Furthermore, assays of the rock and of the chromite have returned as high as 2 ounces a ton.

Platinum is reported to occur in shear zones in granodiorite on Siwash Creek and elsewhere, which suggests the possibility that some platinum in the area may have an origin other than that suggested above, but it is most unlikely that any important amount of platinum came from such sources.

ORIGIN OF THE PLACER DEPOSITS

The original source of the gold and platinum in the placer deposits is believed to be the gold-bearing veins of Grasshopper Mountain and vicinity and the Olivine Mountain body of platinum-bearing ultrabasic rocks. Erosion of these bodies has released their metal content, but it is evident that only the residue of a large amount of such rocks could have produced the rich deposits of Tulameen and Similkameen Rivers. Since glacial times canyons have been cut in the floors of some of the valleys, but over most of the area erosion has not succeeded in removing the mantle of glacial material, much less eroding any quantity of the underlying rock. It is, therefore, clear that the gold and platinum of the placers must have been released from the parent rocks by erosion in pre-Glacial time and deposited in pre-Glacial placers. It also follows that these placers must have partly escaped the dissipating effect of glaciation, and that the present deposits are mainly either remnants of pre-Glacial placers or those only slightly disturbed by the ice. There has, of course, been some reconcentration of the earlier deposits in the beds of the present streams, but it seems most unlikely that Glacial and post-Glacial streams could have formed the rich placer deposits of the Tulameen except by reworking deposits that were already rich.

DESCRIPTION OF OCCURRENCES

Gold and platinum placer deposits have been found for a distance of about 25 miles along Tulameen River and 40 or 50 miles along Similkameen River, as well as in many of the tributary creeks.

Similkameen River between Princeton and Hedley flows in a broad valley flanked on either side by gravel terraces, most of which are composed of glacial material more or less re-worked by the stream. As a result the gold and platinum scattered through the glacial material have been concentrated locally in small patches, some of which show fairly attractive values. None of these local concentrations has proved to be large enough to be mined by dredge or other large scale operations, nor rich enough for profitable hand mining. Some drilling was done on the flats near Princeton in the late twenties, but the results were not considered good enough to justify a large scale operation. Whether or not areas of gravel occur in this section of the river where dredging or some similar method could be successfully employed is doubtful. Most of the precious metal is in fine particles, and the deposits appear to be far from the source of supply.

Above Princeton the placer deposits on the Similkameen have been worked at intervals for some 30 miles, although production has nowhere been great. From the mouth of Whipsaw Creek to Princeton the river runs in a wide valley with deep gravel deposits in most places. Several attempts have been made to mine these, and have not been successful, but it is possible that systematic drilling might lead to the discovery of concentrations of sufficient value to be mined by large scale methods. From Pasayten River to Whipsaw Creek the Similkameen runs through a canyon where such methods could not be employed. Several attempts at small scale operations have been made without notable success.

Whipsaw Creek, a tributary of the Similkameen, is a small, fast stream. Gold and platinum placer deposits have been found on it, but attempts to mine them have not met with appreciable success.

Tulameen River, between its mouth and Granite Creek, has been generally productive. A considerable part of this stretch of the river is through a canyon, and extensive gravel deposits are relatively scarce. For about 3 miles above Princeton, however, the valley is open, and the river runs over a gravel bed with gravel benches on each side. Rich placer deposits have been mined along this stretch of the river. In 1941 R. L. and E. A. Ashley were working a small patch of virgin ground about 2 miles above Princeton that had been missed in earlier days. The paystreak consisted of 3 feet to a few inches of well-bedded, partly cemented gravels overlain by more than 10 feet of unsorted glacial material. From this paystreak five men were recovering about $900 worth of gold and platinum a week. Most of the nuggets were rough, and there was little fine gold. The ratio of platinum to gold was between 1 to 2 and 1 to 3.

Several attempts to mine bench gravels on a large scale in this stretch have not been too successful, although a drag-line operation by the Campbell brothers in 1941 recovered a fair amount of precious metal. For a short distance below Granite Creek, Tulameen Valley is also open, and from it a considerable amount of gold and platinum has been recovered. The valley here is wide, and between 1926 and 1941 several attempts were made to mine the gravel deposits with a steam shovel or drag-line. In each operation the presence of large boulders, spotty values, or other difficulties led to the abandonment of the enterprise. Methods may yet be devised to overcome these difficulties.

The richest deposits in the district were on Granite Creek, and a large proportion of the early production came from them. The readily accessible deposits were, however, soon exhausted and more recent successful mining has been confined to small, sniping operations involving the complete exposure of small patches of bedrock. In 1933 and 1934, 264 feet of drifts were run into an old channel of Granite Creek between that creek and Tulameen River, and 2,107 square feet of bedrock cleaned up to yield 172·58 ounces gold and 17·58 ounces platinum. In 1932 a patch of virgin ground was found on the south fork of Granite Creek on the Lambert lease. In spite of spring freshets, which washed out the dam and flooded the workings, and lack of water in the summer seasons, a considerable amount of coarse gold and platinum was recovered in the succeeding 2 or 3 years.

From Coalmont to near Olivine Creek Tulameen River flows along a wide valley over deep gravel deposits. No attempt has been made to mine these deposits, and their gold content is not known. In 1918 the gravels on the north side of the Tulameen were tested with a churn drill by the Mountains Resources Commission. Unfortunately, the work was discontinued before the project was completed, and the information is, consequently, inconclusive. The following results were, however, obtained, and are quoted from the Annual Report of the B.C. Minister of Mines for 1927, page 256. Gold is here valued at $22.67 an ounce and platinum at $105 an ounce.

No. hole	Depth of gravel	Depth of sample	Gold from assay of sample	Gold per cubic yard	Platinum from assay of sample	Platinum per cubic yard	Total gold and platinum per cubic yard for hole	Remarks
		Feet	Milli-grams	Cents	Milli-grams	Cents	Cents	
1	70′5″	0–50	5·37	7·13	8·35	5·62	–	Bedrock at 69·8′
		50–60	0·80	0·53	0·37	1·24		
		60–70·5	1·40	0·88	1·38	4·44	5·50	
2	14′6″	0–15·5	3·80	1·80	8·58	21·10	22·70	Bedrock 18·5′
3	61′0″	0–10	0·36	0·24	1·55	5·22		No bedrock
		10–20	1·41	0·93	0·85	2·86		
		20–30	0·36	0·24	0·18	0·60		
		30–40	0·32	0·21	0·18	0·60		
		40–50	Tr.	–	0·03	0·10		
		50–61	0·02	0·01	0·34	1·14	1·98	
4	23′6″	0–26	3·02	1·00	3·30	5·80	6·80	Bedrock 26′
5	38′0″	0–20	1·66	0·55	0·10	0·17		Bedrock 45′
		20–30	94·58	62·84	0·04	0·13		
		30–40	1·52	1·01	0·28	0·94		
		40–50	0·08	0·11	Tr.	–	14·50	
6	67′0″	0–20	0·08	0·26	0·06	0·10		Bedrock 72′
		20–30	0·86	0·57	0·07	0·23		
		30–40	0·96	0·63	1·60	5·39		
		40–50	5·80	3·85	3·46	11·66		
		50–60	0·42	0·28	0·07	0·23		
		60–67	1·56	1·48	7·30	24·60	6·70	
7	50′0″	0–10	0·10	0·07	0·20	0·67		No bedrock
		10–20	0·12	0·08	0·28	0·94		
		20–30	0·16	0·11	0·14	0·47		
		30–40	0·04	0·03	0·16	0·53		
		40–50	0·06	0·04	0·36	1·21	0·80	
8	59′0″	0–55·5	0·47	0·01	3·03	1·84		No bedrock
		55·5–59	1·36	3·49	0·02	0·26	2·72	
9	48′0″	0–20	0·96	0·318	0·94	1·58		Bedrock 48′
		20–30	0·72	0·47	0·17	0·57		
		30–40	0·12	0·08	0·04	0·13		
		40–50	0·20	1·66	0·60	0·25	1·47	
10	46′0″	0–20	19·25	6·39	1·22	2·05		No bedrock
		20–30	0·16	0·11	0·06	0·20		
		30–46	0·06	0·24	Tr.	–	3·44	
11	7′0″	0·7	Tr.	–	0·10	0·48	0·30	No bedrock

Collins Gulch and Cedar Creek are small streams that flow into Tulameen River just below and just above Tulameen village. Gold was recovered from these streams near their mouths, but it is more probable that the gold here was deposited by Tulameen River when at a higher level than by the smaller streams themselves. On Cedar Creek, some coarse gold was recovered as late as 1933.

Olivine Creek, formerly known as Slate Creek, is about 7 miles long. The upper part is in a fairly deep, flaring valley, but near the mouth it runs through a short canyon and enters the Tulameen over a series of falls. A considerable amount of gold was taken from this creek in the early years, mostly from the valley above the canyon. More recent attempts have been made to hydraulic the gravels at the mouth of the stream without much success. In 1926 an exploration of old channels both above and below the falls was commenced. Many difficulties were encountered, and in 1931 the main tunnel was flooded out and blocked. Although a new tunnel was started the next year, it, too, met with difficulties and the project was finally abandoned.

Above Olivine Creek the Tulameen flows through a narrow, rock-walled canyon, with nowhere more than a few feet of gravel. This had been one of the most productive stretches of the river, and gold was recovered from both bench and stream deposits. Since the gravel deposits are small, the creek was fairly well worked out early in the history of the district, but small parties of men have since been more or less successful in carefully cleaning up selected areas of bedrock that were missed by the old timers. One of the most successful of these operations followed a discovery by Garnet Sootheran in 1925 on leases about half a mile below the mouth of Britton Creek (formerly Eagle Creek). These leases were successfully mined on a small scale for the succeeding 8 or 9 years.

Lawless Creek flows through a narrow, deep valley and has never been particularly productive. Some gold and platinum have, however, been recovered from gravels near its mouth. In 1918 Tulameen River was dammed near the mouth of Lawless Creek, and an attempt made to mine the deep gravels in that part of the river. Bedrock was not reached, however, and the attempt was abandoned.

Britton Creek, like Lawless Creek, is a fast flowing stream with few gravel deposits of any size, and only a little gold and platinum have been recovered from them.

As in most of the streams tributary to the Tulameen, Champion Creek occupies a broad, flaring valley in its upper part, but runs through a steep-walled canyon before entering the Tulameen. There are few gravel deposits in this lower part, but both gold and platinum have been recovered from above the canyon. The gravels are deep, however, and attempts to work them have not been commercially successful. In 1931 a company was incorporated to work the gravels in what was believed to be an old channel of the creek near its mouth. Early attempts to ground sluice failed from lack of water, and when a hydraulic plant was installed the following year, the values recovered proved to be insufficient to make the operation profitable.

About 1920 John Marks encountered good values in a bench lease at the foot of Olivine Mountain, which he worked successfully on a small scale for the next 6 or 7 years. The gravels on this bench were relatively free of boulders, and a drag-line was used successfully. In 1927 a company was incorporated to take over his holdings, and a monitor and several thousand feet of flume and pipe-line installed. In 1928 about 9 ounces of gold and 30 ounces of platinum were recovered in about 18 days of operation; some recovery is also recorded for the following year. This large scale operation was, however, badly hampered by shortage of water and was eventually abandoned.

Prior to 1909 a considerable amount of placer gold and some platinum were recovered from the lower $1\frac{1}{2}$ miles of Elliot Creek (formerly Boulder Creek), which flows into Otter Creek just above Otter Lake.

Some attempts have been made to mine both bench and creek placer deposits on Siwash Creek, which enters Hayes Creek near Jellico station. Small lots of rough gold have been recovered from time to time, and in 1933 a group of men installed a hydraulic outfit and mined the gravels on a bench 7 miles up from the mouth of the creek. Values were reported to be as high as $3 a yard, but the attempt was abandoned the following year.

In 1939 Fred Keeling of Quilchena was working a placer deposit on Shrimpton Creek 4 or 5 miles above Missezula Lake. Flat, well-worn, flaky gold from $\frac{1}{16}$ to $\frac{1}{8}$ inch across occurs in unsorted glacial material, with most of the values near the surface and little or nothing on bedrock. He claimed to be making about $1 a day.

FUTURE OF THE PLACER DEPOSITS

The bulk of the recoverable gold and platinum has most probably been already won from the deposits of Tulameen and Similkameen Rivers, but two types of deposit may still develop into profitable undertakings. When the ice-sheet flooded the area, it undoubtedly filled up the valleys of the main rivers and their tributaries, and in certain instances these streams failed to reoccupy their original channels after the retreat of the ice. There is, therefore, a chance of finding placer deposits in some of these old channels buried beneath later glacial deposits. Attempts have been made to find and explore some of these buried channels but none has yet proved successful. Along several stretches of Tulameen and Similkameen Rivers are wide and deep deposits of gravel, some of which could possibly be mined profitably by a dredge or by other large-scale methods. The failure of attempts in the past is, however, a warning of the many difficulties to be expected in the way of such an enterprise and that it should only be undertaken by experienced men with enough capital to prospect the proposed area very thoroughly, by drilling or other means, before mining is started.

METALLIFEROUS LODE DEPOSITS

HEDLEY DISTRICT

Introduction

In the mining properties in this district the principal value is in gold, and arsenopyrite is the important carrier. Other minerals of common occurrence are pyrite, pyrrhotite, chalcopyrite, and sphalerite.

The most important locality is Nickel Plate Mountain, where the ore occurs in metamorphosed limestone associated with basic stocks, dykes, and sills. All commercial deposits found there to date lie in a single metamorphosed zone and near its contact with relatively unaltered limestone. Small deposits occur in minor metamorphic zones related to local intrusions outside the main zone, but these appear to be of limited extent, and in none has orebodies of commercial size been found. A full account of the geology of Nickel Plate Mountain is given in the section dealing with the Nickel Plate mine.

On Stemwinder Mountain, on the opposite side of Hedley Creek, are several properties that show close resemblance to those on Nickel Plate Mountain, but with important differences. Instead of the massive limestones and calcareous argillites the sediments are mainly argillite, and calcareous rocks are restricted to fairly narrow beds. Dykes and sills of the same type as those on Nickel Plate Mountain occur and have similarly affected the intruded rocks, but both the intrusions and related zones of metamorphism are small and few in comparison. The ore is, however, of the same type, and further exploration may lead to the discovery of more favourable conditions for the development of commercial deposits.

South of Similkameen River, opposite Stemwinder Mountain, conditions are similar to those just described except that calcareous strata are even less common and the principal host rock for the mineral deposits is argillite. The intrusions also, though probably related to those on Nickel Plate Mountain, are rather different in character, and metamorphism associated with them is much more restricted and somewhat different in type. Instead of the large, replacement orebodies north of Similkameen River the deposits south of the river are mainly vein-like in form, with quartz the principal gangue. Much the same minerals are present, but arsenopyrite does not appear to be as important a carrier of gold.

To the southeast of Hedley, on both sides of Similkameen River, are several deposits, either in or closely related to granodiorite of the Coast intrusions. These are quartz veins or mineralized shear zones. Arsenopyrite is present, but carries little gold, and copper minerals are common. Gold may or may not be important.

The above remarks are generalizations, and as such are subject to exception. In the Toronto and Galena prospect on Hedley Creek, for instance, the principal metallic minerals are chalcopyrite and sphalerite.

Nickel Plate Mine (60)[1]

References: Ann. Repts. Minister of Mines, B.C.: 1908, p. 118; 1909, pp. 135-136; 1910, p. 124; 1913, pp. 171-175; 1914, pp. 356-357; 1915, pp. 202-209; 1916, p. 254; 1918, pp. 212-213; 1920, p. 157; 1921, p. 177; 1922, p. 162; 1929, pp. 263-267; 1931, p. 133; 1932, pp. 138-139; 1933, p. 169; 1934, pp. D17-18; 1935, p. D11; 1936, p. D54; 1937, p. D30; 1938, p. D33; 1939, p. 74; 1940, p. 60; 1941, p. A59; 1942, p. 58; 1943, pp. 62-63. Camsell, 1910, pp. 190-198[2]. The Staff, Hedley Gold Mining Company, 1929, pp. 1260-1270. Bostock, 1929, pp. 198-252. O'Neill and Gunning, 1934, p. 103. Billingsley and Hume, 1941, pp. 524-590. Dolmage and Brown, 1945, pp. 27-67 and 69-85. Warren and Cummings, 1936, pp. 27, 28. Warren and Thompson, 1945, pp. 34-41.

Introduction. The Nickel Plate mine, owned and operated by the Kelowna Exploration Company, Limited, of New York, with mine offices at Hedley, British Columbia, is by far the most important gold producer in Princeton map-area, and one of the largest in the entire province. It is also a deposit of unusual geological interest, and one in which careful studies by several eminent geologists have directly resulted in prolonging the life of the mine by enabling the operators to discover and extract large bodies of ore whose existence had not been recognized before these studies were made.

Location. The Nickel Plate mine lies on Nickel Plate Mountain a mile or more northeast of Hedley, which is at the junction of Hedley (Twentymile) Creek, with Similkameen River. The mine buildings are situated near the top of the mountain, but the main administration office and the mill are at the foot of the mountain on the outskirts of Hedley, and are connected with the mine workings by an inclined gravity tram.

The sedimentary strata on Nickel Plate Mountain dip at a low angle to the west, and the orebodies roughly follow the bedding down from the top of the mountain. The tabular orebodies were opened originally by an inclined shaft, but more recent developments have been by adit and winze.

History. The discovery of placer gold in Similkameen River in the sixties led naturally to the search for lode gold deposits, and in 1894 some claims were staked on a deposit of gold-bearing sulphides on Nickel Plate Mountain. This particular showing did not prove commercial, but in 1897 the Nickel Plate claim was staked nearby, and with it the active history of Nickel Plate Mountain may be said to have commenced. In 1898 eight claims, including the Nickel Plate, were bonded by M. K. Rogers, and in the following year they were taken over

[1] Numbers in brackets are those that give the location of the property on the accompanying map (Map 889A, in pocket).
[2] These references are given in full in the Bibliography, pages 4 and 5.

by Marcus Daly, and the Daly Reduction Company formed to operate them. By 1904 a considerable reserve of ore had been blocked out, and a 40-stamp mill was erected at Hedley and put into operation the following year. The property was taken over by the Yale Mining Company in 1907, and by the Hedley Gold Mining Company in 1911. From 1904 until 1920 it continued to produce steadily. Up to 1916 the ore was concentrated and the tailings treated with cyanide, the products of both processes being sent to Tacoma, Washington, for further treatment. In 1916 the entire product was cyanided in an effort to eliminate the cost of shipping concentrates. In 1920 the mine was shut down, owing to the high cost of production, but the following year it was reopened and continued to operate until 1931. By that time the known ore reserves were exhausted, and efforts to find new bodies had resulted only in the discovery of some too low grade to be worked profitably. The mine was, consequently, considered to be worked out, and operations were closed. In 1932 it was bonded by the Mercer Exploration Company, and a subsidiary, the Kelowna Exploration Company, formed to take it over. A thorough geological examination by Paul Billingsley and August Locke resulted in definite recommendations for further exploration. This exploration was successful in finding more ore, and in 1934 milling was resumed and has continued to the present; indeed the known ore reserves are now as great or greater than at any time in the history of the mine.

Production. The following is a table of production taken from the Annual Reports of the Minister of Mines for British Columbia:

Year	Tons	Remarks
1904	10,200	
1905	33,000	$12 to $14 a ton
1906	35,000	
1907	31,756	$14 a ton (about)
1908	44,068	
1909	31,100	
1910	46,828	$11.09 a ton
1911	57,815	$11.99 a ton
1912	10,455	$11.19 a ton
1913	70,796	$12.03 a ton
1914	78,494	$10.80 a ton
1915	74,265	$11.65 a ton
1916	73,491	
1917	71,207	
1918	67,313	31,945 ozs. gold produced
1919	62,907	
1920	39,400	
1921	Shut down	
1922	41,286	
1923	44,090	$7.10 a ton
1924	48,300	
1925	50,870	
1926	49,656	
1927	44,910	
1928	45,410	
1929	?	
1930	39,670	
1931-1933	Shut down	
1934	2,865	
1935	54,032	
1936	64,854	22,613 ozs. gold produced
1937	77,887	29,929 ozs. gold produced
1938	88,636	
1939	90,204	
1940	82,660	
1941	97,476	38,881 ozs. gold produced
1942	99,219	32,425 ozs. gold produced
1943	67,640	23,344 ozs. gold produced
1944	88,491	32,526 ozs. gold produced

In addition to gold, the ore has, from time to time, yielded silver, arsenic, and copper. For example, production in 1944 included, in addition to the gold, 2,270 ounces of silver, 90,593 pounds of copper, and some arsenic. The ore also contains cobalt in recoverable quantities, but the present market conditions are not considered favourable to an attempt to produce this metal.

Geology. There are few mines in British Columbia in which a knowledge of the geology has played so important a rôle as at the Nickel Plate mine. Billingsley and Hume (1941) have outlined the progress of geological investigations on this property, and have given a clear picture of the known facts and of the deductions that may be made from them. Their paper illustrates the important point that no geological concept can be safely regarded as complete and final in all its details, but rather that all such concepts should be constantly revised as new information is gained. The authors do, however, make it abundantly clear that in spite of this need for revision some idea of the principal geological features of a deposit is essential at all stages of its development, in the intelligent search for ore.

The first real geological study of Nickel Plate Mountain was made in 1907 and 1908 by Camsell (1910). This was followed by detailed investigations by various geologists, and, in 1928, by the mapping of the mountain summit on 1 inch to 500 feet by Bostock (1929). During the shut-down of the mine between 1930 and 1933, Billingsley, with the assistance of Augustus Locke, made an exhaustive study of the deposits, resulting in a much clearer understanding of the structural control of the ore, and, eventually, in the discovery of large new orebodies. A further study was made by Dolmage and Brown (1945), geologists for Hedley Mascot Gold Mines, Limited, and their report contains the last published data on Nickel Plate Mountain. The following account is largely taken from this and the preceding reports mentioned.

Nickel Plate Mountain is underlain mainly by a succession of argillite, limestones, and volcanic rocks of the Nicola group. These rocks occupy the low-dipping west limb of a minor, asymmetric anticline that is itself on the east side of the syncline that forms the major structure of Princeton map-area. The stratified rocks are truncated to the west by the Bradshaw fault, which follows Hedley Creek, and are floored by a large body of granodiorite and intruded by gabbro stocks, dykes, and sills. The sedimentary succession has already been discussed under the section dealing with the Nicola group, but may be briefly recapitulated as consisting of some 9,600 feet of limestone, thin-bedded quartzite, argillite, tuff, and breccia, in part much silicified. The productive zone lying some 1,200 feet above the base has been subdivided into the Sunnyside limestone, the Middle member, and the Upper member, in all some 1,150 feet thick. The base of Nickel Plate Mountain consists of a large body of the Coast intrusions, whose upper margin roughly follows the bedding in the overlying intruded sediments. Dykes and sills from this body cut the sediments, but are not abundant, and only one of notable size cuts the ore zone.

The basic intrusions, on the other hand, are abundantly represented through the ore zone, and have played a paramount rôle in the origin and location of the ore shoots. The largest of them, known as the "Toronto stock", is exposed as an oblong body 2,500 feet wide extending northerly for some 7,000 feet along the east side of Hedley Creek. The north and south contacts dip steeply beneath the upturned sedimentary beds, but to the northeast and east the stock sends off a great array of dykes, sills, and irregular apophyses. The largest of these, known as the "Climax stock", occurs on the westerly summit ridge of Nickel Plate Mountain. As its name implies it was originally believed to be a stock, but the lower contact has been found to be in part at least concordant with the intruded sediments, so that the body more closely resembles a large, irregular sill. Sills also occur on the south side of the Toronto stock, but are much less plentiful than on the north side, where they are most abundant in three zones, one at or near the base of the Sunnyside limestone, another approximately 500 feet from the bottom, and a third group, mostly eroded away, in the upper 500 feet of the formation.

The basic igneous rocks of Nickel Plate Mountain are composed of gabbro, quartz gabbro, augite, diorite, quartz diorite, and porphyries; the last occurring only as part of the east end of the Climax stock and as sills and dykes. Dolmage and Brown described the igneous rocks very fully, and the following is abstracted from their paper.

Gabbro and quartz gabbro form the north side of the Toronto stock and the southwest and south side of the Climax stock, and have evidently developed at or near the upper contacts of these bodies. They are pale green to white, medium-grained rocks. The gabbro consists of labradorite and a pale green augite with the following optic properties: $n_\alpha = 1\cdot685$, $n_\beta = 1\cdot688$, $n_\gamma = 1\cdot705$ ($\pm\cdot003$), $Z \wedge C = 45°$. Orthoclase, biotite, pyrrhotite, and arsenopyrite are present in small amounts. The quartz gabbro is more abundant than the gabbro, and differs from it only in the presence of interstitial quartz. Its average composition is as follows: plagioclase, 45·8 per cent; augite, 20·6 per cent; and quartz, 26·1 per cent; the balance is composed of accessory minerals.

The gabbro and quartz gabbro grade downwards into a comparatively narrow zone of augite diorite that has much the same composition as the gabbro except that the plagioclase is andesine ($An_{45\text{-}50}$) instead of labradorite, and the pyroxene is dark green or black augite with the following optic properties: $n_\alpha = 1\cdot685$; $n_\beta = 1\cdot690$; $n_\gamma = 1\cdot709$ ($\pm\ \cdot003$), $Z \wedge C = 45°$. The rock, in contrast with the light-coloured gabbro and quartz gabbro is dark green and is with difficulty distinguished from the quartz diorite that underlies it. Quartz is almost always present, but in lower amounts than in the overlying quartz gabbro.

The augite diorite grades downward into quartz diorite, which forms the base and bulk of the Toronto stock. It has an average composition of 56·2 per cent andesine ($An_{40\text{-}48}$); 12·2 per cent quartz; 8·9 per cent orthoclase; 16·5 per cent amphibole; and 6·2 per cent biotite. Apatite, magnetite, and pyrrhotite are accessory minerals. The amphibole appears to be a member of the pargasite-hornblende series about intermediate between the two and having the following optic properties: $n_\alpha = 1\cdot640$; $n_\beta = 1\cdot645$; $n_\gamma = 1\cdot661$ ($\pm\ \cdot003$); $Z \wedge C = 26°$.

The porphyries, which constitute the sills and dykes and the eastern part of the Climax stock, vary considerably in appearance and colour, but show little mineralogical difference where examined in thin section. Dolmage and Brown (1945, p. 57) studied two hundred and fourteen specimens taken systematically and conclude that "no fundamental difference can be detected on petrological grounds between members of the sill groups or between cross-cutting dykes and sills". Phenocrysts range in size from $\frac{1}{4}$ to 2 mm. and consist of plagioclase, two kinds of augite, and a dark and a light-coloured amphibole. The plagioclase consists of labradorite varying in composition from An_{55} to An_{60}. The dark-coloured amphibole appears to be common hornblende with the following optic properties: $n_\alpha = 1\cdot650$; $n_\beta = 1\cdot660$; $n_\gamma = 1\cdot668$ ($\pm\ \cdot003$), $2V = 90°$; $n_\gamma\text{-}n_\alpha = \cdot016\text{–}018$; $Z \wedge C = 25°$. The hornblende is partly replaced by a colourless amphibole that appears to be a member of the tremolite-actinolite series near the tremolite end, having the following optic properties: $n_\alpha = 1\cdot605$; $n_\beta = 1\ 620$; $n_\gamma = 1\cdot630$ ($\pm\ \cdot003$); $2V = 80°$; $n_\gamma - n_\alpha = \cdot020\text{–}025$; $Z \wedge C = 20°$. Light green augite also occurs, presumably as a primary constituent of the rock. It has the following optic properties: $n_\alpha = 1\cdot685$; $n_\beta = 1\cdot688$; $n_\gamma = 1\ 705$ ($\pm\cdot003$); $2V = 60°$; $n_\gamma\text{-}n_\alpha = \cdot022$; $Z \wedge C = 42\text{-}45°$. The augite, hornblende, and occasionally even the plagioclase are in part replaced by colourless pyroxene. This has nearly the optic properties of augite, but is more probably a member of the diopside-heddenbergite series. The following are its optic properties: $n_\alpha = 1\cdot679$; $n_\beta = 1\cdot685$; $n_\gamma = 1\cdot700$ ($\pm\ \cdot003$); $2V$ = large, about 75°; $n_\gamma\text{-}n_\alpha = \cdot020$;

$Z \wedge C = 43°$. The groundmass consists of an aggregate of andesine (An_{35}), hornblende, augite, and orthoclase, the latter intergrown with quartz as micropegmatite. Both the hornblende and augite in the groundmass are largely replaced by the same secondary amphibole and pyroxene found replacing the phenocrysts.

Normal processes of differentiation of an intruded magma, involving the settling out of the earliest formed, heavy minerals, result in the formation of an intrusive body with relatively acid phases at the top and basic phases below. The fact that the normal order is reversed in the Toronto stock calls for a different explanation. The gradation of one type into another excludes the idea that each phase was derived by differentiation from some deep-seated magma and intruded at different times. Dolmage and Brown (1945, pp. 60–62) conclude that quartz diorite is the normal composition of the stocks and that the upper, more calcic gabbro and augite diorite were developed by the assimilation of limestone from the sediments into which the magma was intruded.

Structure. As has already been mentioned, the sediments on Nickel Plate Mountain form a west dipping wedge, the lower side of which is the contact with the body of granodiorite that forms the base of Nickel Plate Mountain and the upper side the Bradshaw fault. Both planes dip west, but converge to form the apex of the wedge somewhere under Hedley Creek.

The sedimentary series consists principally of quartzite, argillite, limestone, and tuff, but also includes beds of coarse and fine breccia to which the names Climax and Copperfield have been given. These breccias consist of fragments of limestone and finely banded sediments in a groundmass of approximately the same composition, all more or less metamorphosed. The nature of these breccias puzzled geologists until Billingsley, in 1932, found evidence that proved them to be clastic breccias developed along low-angle thrust faults subsidiary to the main Bradshaw thrust. Billingsley and Hume (1941, p. 551) summarize the structure of Nickel Plate Mountain as follows:

> "The Climax and Copperfield breccias and the Bradshaw fault are common members of a thrust-zone which converge northwestward like leaves of a book to a single steep structure in depth. The granite floor has the attitude of a flatter leaf of the same book. . . . . The ore-bearing portion of Nickel Plate Mountain is limited, so far as is now known, to the lowest slice of the three, that is, to that one with a granodiorite floor and a roof of Climax breccia."

As seen from across the valley the beds on Nickel Plate Mountain seem to have a more or less uniform westerly dip, and the intruded sills appear to follow the bedding closely. Billingsley and Hume found, however, that although the beds do indeed have a general westerly dip, they are actually greatly contorted, and that the all-pervading structure is a sheeting that follows the bedding where it has a regular attitude but cuts across it in other places. It is this sheeting that has, to a large extent, controlled the position of the sills.

Metamorphism. Both the dykes and sills and the sedimentary rocks on Nickel Plate Mountain have locally been highly metamorphosed. The alteration of the former has already been described, but as this alteration may occur where such dykes and sills cut unaltered limestone and the alteration shows no relation to any local structures, and as the groundmass of certain porphyries shows much more alterations than the phenocrysts, Dolmage and Brown conclude that the alteration of the porphyries was due to neither thermal nor hydrothermal agencies, but is rather an end product of the consolidation of the magma in place.

A much more extensive and commercially important phenomenon is the alteration of the calcareous and siliceous sediments, the former to a massive aggregate of pyroxene and garnet known as skarn, and the latter to a light-coloured, flinty, cryptocrystalline rock resembling chert. In the skarn the pyroxene is light to dark green, and appears to be a member of the diopside-heddenbergite series with the following optic properties: $n_\alpha = 1 \cdot 702$; $n_\beta = 1 \cdot 710$; $n_\gamma = 1 \cdot 727$ ($\pm \cdot 003$); $Z \wedge C = 46°$. The garnet is brownish red grossularite, with $N = 1 \cdot 735$ ($\pm \cdot 002$) and S.G. = $3 \cdot 550$. Minor amounts of epidote, wollastonite, and sulphides make up the rest of the rock.

The transition between the garnet-pyroxene rock, or skarn, and the unaltered limestone is abrupt, and bears no relationship to the bedding. On the other hand, it marks the limits of mineralization so closely that Billingsley introduced the special term "Marble line" to designate it. The "Marble line" outlines a shallow, bowl-like structure, tipped up to the northeast, and with its deepest part to the northeast of the Toronto stock.

The relationship between the skarn and the basic intrusions is clear. A thin layer of skarn envelopes all the porphyry bodies, even those occurring in otherwise unaltered limestone, showing that the intrusion produced the metamorphosis. The main body of the skarn, however, occurs around the periphery of the Toronto stock, with the greatest development in the region of transverse folding and crumpling to the north and northeast. The minerals of the skarn appear to have been formed from the limestone and its impurities, with the addition of considerable quantities of silica and the loss of some CO_2. The logical source for this silica is the Toronto stock and its related intrusions. The preponderance of free quartz in the upper parts of the stock suggests that the late differentiates of this body were indeed rich in silica. Dolmage and Brown (1945, pp. 64, 65) summarize the sequence of events leading to the production of the skarn as follows:

> "Subsequent to the original folding of the sediments into the main anticline and the transverse folds, the stock was intruded into the fresh limestones with the accompaniment of further folding and crumpling as the beds were arched and thrust aside to make room for the incoming magma. Simultaneously, or shortly after this event, part of the magma, which ultimately crystallized as porphyry, was squeezed out of the stock into the surrounding rocks to form sills and dykes. . . . . . . During the crystallization of the porphyries deuteric reactions, which resulted in the changes in the femic minerals, also caused the formation of a thin skin of silicate minerals on the surface of the sills, leaving the remainder of the limestone still unaltered. The greatest period of skarn production came late; when crystallization in the stock had proceeded far enough to cause concentration of silica and volatiles in the cupola; these were forced out into the limestones which had already been heated by the intrusion of the sills, a fact which helped to promote reaction between the limestone and the fluids.
>
> "As the temperature of the cupola declined as crystallization proceeded, the residual liquid changed in character, becoming lighter and less viscous due to the increasing proportion of water which it contained; at this stage, its characteristics approached those of a hydrothermal solution. A gas phase may have been present, depending entirely on the pressure, and concentration. In this condition, the liquid was able to be forced out into the limestone where it penetrated into small openings and capillary spaces. Considerable assistance was probably given to this process by slight orogenic movements which brecciated the first generation of skarn, previously formed as a skin on the surface of the sills by deuteric reactions in the porphyries; this brecciation and fracturing of the brittle coverings of the sills supplied channels of easier access to the fluids. Evidence for this is furnished by the extensive development of coarse garnet and pyroxene, formed without regard for bedding planes, which occurs adjacent to the sills, particularly on the axes of the folds. In the course of the passage of the fluid through the rocks, material was constantly being abstracted by reaction with limestone to form silicates, which reduced the concentration of the system and therefore probably increased the vapour pressure, since the temperature declined only gradually in accordance with the gradient predetermined by the thickness of the cover rocks. Therefore, the solutions may have partially supplied their own motive power since the increased vapour pressure seemed to disperse them still further through the rocks. In this way, limestone was replaced by lime silicates for a maximum distance of 6,000 feet from the stock. However, since the supply of material available for the reaction was not inexhaustible, metamorphism ended, with surprising abruptness, at the Marble Line."

Mineralization. The ore of the Nickel Plate mine consists of sulphide minerals, some gold bearing, that replaced the earlier minerals in the skarn. Consequently, the principal gangue minerals are those that have already been described. In addition to these, however, the sodic scapolite, dipyre, and the rare mineral chloropal occur in considerable abundance in certain of the ore-bodies, both apparently as a product of the mineralizing solution. The following metallic minerals were identified by Warren and Cummings (1945): arsenopyrite ($FeAsS$), lollingite-safflorite ($FeAs_2$–$CoAs_2$), cobaltite ($CoAsS$), unknown grey mineral (possibly a bismuth telluride), pyrrhotite, sphalerite, chalcopyrite, gold, pyrite, and marcasite. Of these, arsenopyrite is the most abundant and most important mineral, as arsenic is being recovered from it and nearly all the gold occurs as minute specks in it. Pyrrhotite is also plentiful, and also carries some gold but in much less amount than the arsenopyrite. Chalcopyrite is abundant locally, but, although it is recovered from the ore, it is of minor economic importance. A process has been devised to recover the cobalt from the ore, but under the present market conditions it is not considered profitable to install it. The gold is believed to be present entirely as the native metal in microsocopic specks in the arsenopyrite and, to a less extent, in pyrrhotite. Pyrite is rare. Warren and Cummings suggest the following paragenesis: "(1) formation of silicates; (2) introduction of arsenopyrite (cobaltite occurs as tiny inclusions completely in, and surrounded by, arsenopyrite); (3) introduction of pyrrhotite, chalcopyrite, and sphalerite; and (4) fracturing and veining of ore by calcite stringers."

Most of the gold occurs as fine specks in the arsenopyrite. These may be as large as 30 microns, but are generally much smaller. Warren and Cummings (1945, p. 37) say:

> "Although some of the gold appears to have been deposited contemporaneously with the arsenopyrite, some is now known to be later and may be observed in fractures in arsenopyrite and cobaltite . . . . The association of gold with it (calcite) is interesting, because if this gold were introduced in colloidal form, the deposition of the calcite may well have been the cause of the deposition of the gold. Calcite is known to have dispersive properties and its removal from the solutions containing the colloidal gold may well have been related to the deposition of the precious metal. After etching, what appears on casual inspection to be a gold-free surface of arsenopyrite, reveals the presence of gold particles, nearly always bounded in part by a crater which presumably held calcite prior to etching."

It appears, therefore, that the gold was in two generations; one early accompanying the deposition of arsenopyrite, and one later than most if not all of the sulphide deposition and accompanying the calcite.

Origin and Control of the Ore. Dolmage and Brown concluded that the ore was formed from hydrothermal solutions originating in the same magma that produced the Toronto stock and related intrusions. These solutions they believed to contain considerable amounts of silica as well as the metallic elements found in the ore. The presence of Na_2O is believed to have assisted in keeping these elements in solution. The silica in the solutions reacted freely with the limestone to form the skarn, and the exhaustion of the silica is marked by the position of the "Marble line". At or near this point the Na_2O entered into composition with the lime to form the scapolite of the skarn, and at the same time and in the same place, the solutions being enriched by the abstractions of the silica began to deposit metallic minerals. In accord with this hypothesis is the fact that all known ore shoots occur in the skarn not more than 250 feet from the "Marble line". This then appears to be one of the factors controlling the location of ore shoots and is, for reasons given above, a chemical rather than a structural control.

Under continued stress the altered rocks were further deformed and fractured, and this deformation, together with the damming effect of the sheets of porphyry, still further localized the deposition of metallic minerals to form ore shoots. Billingsley and Hume (1941, p. 567) suggest the following sequence of events:

> "First was the introduction of the sill-like sheets of hornblende-diorite porphyry, coupled closely in time with the dykes of hornblende-andesite porphyry. Essentially

contemporaneous with the crystallization of the primary porphyry minerals was the development of calcite in the adjacent argillites, converting them in part to marble. With the coarsening of grain throughout the rock-pile came increased perviousness, permitting the hot fluids to reach and recrystallize entire masses of the formation, making the widespread garnet-leuc-augite alteration and further coarsening and stiffening the rocks.

"The Nickel Plate formation, when this stage was reached, was no longer plastic. Deformation took place mainly on thrusts and fractures instead of by crumpling. True, the crumples continued to grow and the porphyry sheets are bent on them, but these bends are far less acute than those in the argillites, and they are accompanied by flattish shearing between beds and porphyry, by axial faulting, and by crackling and brecciation on the axes. These grosser breaks provided the channels for the next stage of recrystallization, in which arsenopyrite and gold came in with dipyrite, calcite, and clinozoisite. Continued deformation cracked the arsenopyrite, etc., and the later sulphides—chalcopyrite, sphalerite, pyrrhotite, and pyrite—followed and, with gangue minerals, occupied the cracks and completed the mixture now mined as ore. The structural control of the orebodies, the reason 'why gold is where it is', is therefore a resultant of the combined processes of persistent deformation, intrusion, recrystallization and precipitation in progressively limited channels."

The last and most detailed control is formed by the intersection of the sills and dykes, ore shoots often occurring in the crotches between the two, and also in small drags or crumples. The position of these crumples is, however, governed largely by the position of the dykes and sills, which have, consequently, a primary as well as a secondary control. Dolmage and Brown point out that as yet no ore has been found unless all three controlling factors are present, that is: (1) proximity to the "Marble line"; (2) proximity to dykes and sills; and (3) suitable folds.

Hedley Mascot Gold Mines, Limited (60)

References: Ann. Repts., Minister of Mines, B.C.: 1934, p. D19; 1935, p. D11; 1936, p. D54; 1937, p. D30; 1938, p. D33; 1939, p. 75; 1940, p. 60; 1941, p. A59; 1942, p. 57; 1943, p. 62. Arsenical Gold ore from the Hedley Mascot Mine, Hedley, B.C.; Mines Branch, Dept. of Mines, Canada, Pub. 748, 1936, pp. 179-190. The Miner: 1941, vol. 14, July, pp. 50-52; 1942, vol. 15, May, p. 49; 1944, vol. 17, June, p. 66; 1945, vol. 18, June, p. 112. B.C. Dept. of Mines, Bull. 20, No. 3, p. 20. Dolmage and Brown, 1945, pp. 27-67.

Introduction. The Hedley Mascot mine, owned and operated by the Hedley Mascot Gold Mines, Limited, of Vancouver, British Columbia, is also situated on Nickel Plate Mountain, and most of the ore is being won from the same orebodies as those of the Nickel Plate mine. The mine buildings are perched precariously halfway up the steep west face of Nickel Plate Mountain, from whence the ore is dropped down to the mill in the valley of Hedley Creek by a short, steep, aerial tramway. The main entry to the mine is by means of a crosscut adit from the mine camp, but at the time of the writer's visit an adit had been started at the level of the mill.

History. The Mascot fraction, a triangular claim in the heart of the Nickel Plate orebody, was staked in the early part of the century and Crown granted in 1908. Although orebodies of the Nickel Plate mine were known to pass through the Mascot fraction, the owners of the Nickel Plate were never able to come to suitable terms with Duncan Wood, its owner. In 1934 Hedley Mascot Gold Mines, Limited, was formed to take control of the Mascot fraction, and a group of claims adjoining the holdings of Kelowna Exploration Company. Active development was at once initiated, and a mill built that by 1936 was in operation. The following tables give the production of the Hedley Mascot, as recorded in the Annual Reports of the British Columbia Minister of Mines, since that time:

Year	Tons	Ounces gold
1936	30,265	13,524
1937	59,115	21,422
1938	63,868	
1939	67,572	15,848
1940	62,812	22,819
1941	66,088	22,477
1942	66,099	19,844
1943	47,848	13,122
1944	42,285	13,343

In addition to gold, silver, copper, and arsenic are recovered from the ore. For instance, in 1941, 2,755 ounces of silver, 1,300,000 pounds of copper, and 2,250,000 pounds of arsenic were produced in addition to the gold recovered.

The geology of the Hedley Mascot orebodies is the same as that at the Nickel Plate mine, which has been fully discussed; indeed the owners of the two properties are mining parts of the same group of orebodies, and, consequently, no further reference to geology need be made here.

Canty Gold Mines, Limited (60)

References: Ann. Repts. Minister of Mines, B.C.: 1938, p. D34; 1939, p. 75; 1940, p. 60; 1941, p. A60; 1942, p. 57. The Miner, vol. 18, No. 3, 1945, p. 61.

The claims of Canty Gold Mines, formerly owned by Duncan Wood, are located on Nickel Plate Mountain 1½ to 2 miles northeast of the Nickel Plate mine at an elevation of 6,000 feet. Exploration was commenced in 1939, and by 1940 enough ore was blocked out to warrant the construction of a mill. Owing to difficulties attending construction during the war, however, an agreement was reached whereby Hedley Mascot Gold Mines, Limited, a majority shareholder, would treat the Canty ore in its mill. In 1941, accordingly, 1,606 tons of ore averaging 0·31 ounce a ton in gold was trucked to the Mascot mill. Subsequently, however, labour conditions were such that it was no longer expedient to continue working the property, and it was shut down. The money for development work had been loaned by Hedley Mascot Gold Mines, and, when payment of this loan was defaulted, the Mascot took over the Canty and later removed much of the mining equipment for use elsewhere.

The ore in the Canty mine is similar in nature to that of the Nickel Plate, and also occurs in similarly metamorphosed rocks. A granitic dyke 400 to 600 feet wide has intruded Nicola sediments similar to those at the Nickel Plate mine, and is cut at an acute angle by a fault of considerable size. In the angle between the dyke and the fault is a zone of folded and intensely crushed sedimentary rocks that have been metamorphosed to a rock very similar to the skarn at the Nickel Plate mine, except that it contains much less garnet. Along a fold within this zone occur several ore shoots, the largest some 50 feet long by 20 feet wide. These shoots are apparently developed in local fracture zones along the fold.

Duffy Group (59)

Reference: Ann. Rept., Minister of Mines, B.C, 1926, p. 217.

The Duffy group of eight claims and fractions lies to the northwest of the Nickel Plate mine beyond the Bradshaw fault. The ore consists of a replacement by sulphides of limestone in the Nicola group. The principal values are in gold. Some short adits and open-cuts exposed mineralized zones, but most of the samples carried only low values. No work has been done for many years.

Florence Group (59)

Reference: Camsell, 1910, pp. 202-203.

The Florence group of seven claims lies on either side of Bradshaw Canyon from Hedley Creek to near the top of Aberdeen Mountain. The ore occurs in sedimentary rocks of the Nicola group that have been intruded by porphyry dykes and crushed and folded by the Bradshaw fault. No work has been done for many years.

Horse Fly Group (62)

Reference: Ann. Rept., Minister of Mines, B.C., 1937, pp. D11-D14.

This group of five claims is located on the south side of Nickel Plate Mountain at an elevation of from 4,000 to 5,500 feet. Beds of the Sunnyside and overlying formations, intruded by many porphyry sills and dykes belonging to the basic series, underlie the claims. Locally these rocks have been sheared, folded, and metamorphosed, but all the known structures are small, and there is no counterpart of the extensive skarn development as at the Nickel Plate mine. Ore is of a similar type to that of the Nickel Plate, and selected samples of arsenopyrite run as high as 1·78 ounces in gold a ton. There is, however, a noticeable lack of the secondary minerals, such as scapolite, that accompany the Nickel Plate ores. The ore shoots are of two kinds. On the Horse Fly claim are several narrow mineralized shear zones, from which the ore minerals diverge here and there to follow for a short distance narrow favourable beds. Ore shoots also occur in the metamorphic zone close to porphyry intrusions. The most important of these follows a low-angle fold crossing the Rollo claim, but is of limited extent, and none has yet been found to contain a commercial quantity of ore.

The Rollo, the oldest claim on Nickel Plate Mountain, was staked in 1897; the others were staked the following year. In 1937 the group was optioned by the Trethewey Syndicate, of which the Hedley Mascot is a part owner, and some diamond drilling was done. Attempts to find commercial ore were unsuccessful, the option was dropped, and since then the claims have lain idle.

Kingston Group (61)

References: Billingsley and Hume, 1941, p. 551, Fig. 16. Camsell, 1910, pp. 198-202. Ann. Rept., Minister of Mines, B.C., 1926, p. 218.

The Kingston group of five claims lies on the southwest side of Nickel Plate Mountain about three-quarters mile southwest of the Mascot camp. The orebodies occur in limestone and quartzite of the Nicola group in a northwesterly plunging fold close to a large granitic dyke. These sedimentary rocks have been metamorphosed locally to skarn, but the principal skarn body of the Nickel Plate mine lies to the north. Ore is similar to that at the Nickel Plate, although some phases are rich in chalcopyrite and relatively poor in arsenopyrite. No commercial ore has been found, although considerable surface exploration has been done and several short adits driven.

Good Hope Group (63)

Reference: Ann. Rept., Minister of Mines, B.C., 1944, pp. A57-58.

The Good Hope group of claims is situated about 4 miles southeast of Hedley, and is reached from a road branching off the Hedley-Nickel Plate mine road. The original claim was staked in 1943 by W. R. Wheeler, and was taken over by Hedley Mascot Gold Mines, Limited.

A series of tuffs, argillite, and limestone is intruded by a basic sill, and the limestone partly altered to skarn. This complex has been intersected by a major fault, branching from which are minor fractures. The ore has developed along these minor fractures, and is not unlike that on Nickel Plate Mountain except that the gold is associated with a recently identified bismuth telluride to which the name "hedleyite"[1] has been given. The skarn on the good Hope group is unusual in that it carries considerable quartz.

Hedley Amalgamated Gold Mines, Limited (57)

References: Ann. Repts., Minister of Mines, B.C.: 1920, p. 158; 1923, p. 187; 1928, p. 258; 1930, p. 217; 1933, p. 171; 1934, pp. D18-19; 1937, p. D30. Cairnes, 1922, pp. 124-125A.

This group of nine claims is at an elevation of around 3,400 feet on the divide between Hedley Creek and Similkameen River about $1\frac{1}{2}$ miles northwest of Hedley. The claims were staked many years ago, but it was not until 1919 that much serious exploration was undertaken. Since then exploration work has continued more or less steadily until 1938. The property was optioned and diamond drilled by the Consolidated Mining and Smelting Company in 1926. In 1933 Stemwinder Mountain Mines, Limited, was formed to take over the group and the following year ownership was transferred to Hedley Amalgamated Gold Mines, Limited. The claims are underlain by thin-bedded limestone and quartzite with some interbedded tuff and volcanic breccia of the Nicola group. These bedded rocks strike north and dip at various angles to the west. They are intruded by dykes and sills of the basic group of Nickel Plate Mountain and by diorite dykes related to the granitic intrusion, a large body of which appears at the base of Stemwinder Mountain. The sedimentary beds have been altered by both the basic dykes and the diorite to a rock resembling the skarn on Nickel Plate Mountain, but this alteration is restricted to the proximity of the intrusions. Arsenopyrite, pyrrhotite, chalcopyrite, and sphalerite are the ore minerals. Gold, as at the Nickel Plate, is chiefly in the arsenopyrite. Calcite and scapolite occur as gangue minerals in addition to the normal silicates of the altered sediments. High gold values are reported in places, but as yet no orebody of workable size has been found.

Hedley Consolidated Gold Mines, Limited (57)

Reference: Ann. Rept., Minister of Mines, B.C., 1935, p. D12.

"This Company was formed during 1935 to explore a group of claims adjoining the Hedley Amalgamated Gold Mines holdings on Stemwinder Mountain, 2 miles northwest of Hedley. A crew of three men was employed stripping and open-cutting different mineral zones in replaced limestone and other sediments close to the diorite contact."

Toronto and Galena Group (58)

Reference: Ann. Rept., Minister of Mines, B.C., 1936, pp. D12-13.

The Toronto and Galena group lies between elevations of 3,000 and 4,000 feet on the west side of Hedley Creek, 3,000 feet below the forks. The showings occur partly in calcareous, argillaceous, and cherty beds of the Nicola group close to the main body of granodiorite and partly in the granodiorite, and are of a different kind to those on Nickel Plate and Stemwinder Mountains. In the sedimentary rocks the mineralized zone consists of veinlets of quartz and associated streaks of pyrite with a little chalcopyrite and galena. In the granodiorite are two sparsely mineralized quartz veins from 1 to 5 feet wide. The gold content of both types of ore is apparently low. The property was optioned and explored in 1937 by the Trethewey Syndicate without notable success, and the option was dropped.

[1] Peacock, M.A., 1944.

Gold Mountain Mines, Limited (56)

References: Ann. Repts., Minister of Mines, B.C.: 1908, pp. 118-119; 1913, p. 233; 1927, p. 240; 1932, p. 138; 1933, p. 122; 1934, p. D19; 1935, p. D12; 1936, pp. D5-9; 1937, p. D31. Camsell, 1910, pp. 207-209.

The properties of Gold Mountain Mines, Limited, lie between elevations of 2,000 and 4,000 feet on the west bank of Henry Creek, a tributary of Similkameen River from the south, about 2 miles above the town of Hedley.

The original claims were staked in the early days of the district, and were known as the Pollock group. By 1908 a considerable amount of surface exploration had been done. From then to 1927, when it was bonded to H. Guernsey and associates, little was done. They, however, initiated a period of increased activity, and in 1933 the present owners obtained control. In 1934 the property was diamond drilled, and the following year it was optioned by Consolidated Mining and Smelting Company, who did some further diamond drilling before dropping their option. In 1936 Gold Mountain Mines built a 50-ton mill, which operated only a short time the following year before all the developed ore was exhausted. Since then the property has been idle.

The geological conditions on this side of Similkameen River are rather different from those that obtain on the north side. Here sedimentary beds of the Nicola group are predominantly argillites, with some cherty members, and in place of the thick limestone members of the north side of the river are a few thin beds of calcareous argillites. Diorite similar to that on Nickel Plate Mountain occurs as an irregular, stock-like body, and occasional small andesite dykes appear in places. The complex of basic intrusions, so pronounced a feature of Nickel Plate Mountain, is absent on this side of the river. No metamorphism is apparent, except locally in the immediate vicinity of the intrusions. Translucent quartz forms veinlets along, and cements the fragments in, breccias developed in shear zones in the argillites close to the diorite contacts. The most common minerals associated with the quartz are arsenopyrite, pyrite, sphalerite, and, more rarely, chalcopyrite and galena. As at the Nickel Plate mine, gold is associated with the arsenopyrite, and has been seen with the naked eye in exceptional specimens.

Four shear zones are known on the property, the principal one being on the Maple Leaf claim. This is an irregular, branching zone striking north and dipping 60 degrees to the west, with ore shoots developed at intervals along it. The zone itself is as much as 30 feet wide, but the greatest width of quartz is 12 feet.

The ore minerals occur in the quartz, but are not evenly disseminated. The shear meets the diorite at an acute angle, and is best mineralized in the metamorphic rocks near the contact, but is barren in the diorite. The length of the part explored is about 240 feet out from the contact. Gold values are erratic, varying from 0·02 ounce to 0·80 ounce a ton, according to samples taken in 1936 by the Resident Engineer.

Hedley Sterling Gold Mines, Limited (54)

References: Ann. Repts., Minister of Mines, B.C.: 1927, p. 240; 1928, p. 257; 1931, p. 133; 1933, p. 173; 1934, pp. D21, 22; 1935, p. D12; 1937, pp. D4-D8.

The property of Hedley Sterling Gold Mines, Limited, consisting of eight claims and a fraction, lies along the west side of Sterling Creek south of Similkameen River, between elevations of 2,000 and 4,500 feet. It is reached by a narrow road 2½ miles long from the Princeton Hedley road 4 miles from Hedley.

Some work was done on the property prior to 1927, but active development started in 1931 when it was optioned by Sterling Gold Mines, Limited. In 1933 the work was financed by Canada Lode Gold Mines, Limited, and the following year Hedley Sterling Gold Mines, Limited, was formed to take it over.

That year and the next saw active development and a considerable amount of diamond drilling, but the work was stopped in July 1935 and has not been resumed.

On the claims a thick series of steeply tilted argillites is intruded by dykes and irregular masses of diorite. Most of this argillite is massive and black, but across the Patsy No. 2 claim extends a band, not less than 200 feet thick, of light-coloured rocks consisting of calcareous argillite, chert, some limestone, and possibly some tuffs. Metamorphism is nowhere extensive, even in the calcareous beds. The rocks have been fractured here and there and some of these fractures have been filled by quartz carrying pyrite, arsenopyrite, sphalerite, and a little chalcopyrite and pyrrhotite. The quartz stringers are all small and the zones of fracturing generally weak, but some of these small stringers carry more than 2 ounces of gold a ton. In spite of these attractive values no success has as yet attended efforts to find commercial sized ore shoots. In the Annual Report of the British Columbia Minister of Mines for 1937 Dr. Hedley concludes with the following summary:

"On the Patsy No. 1 claim a narrow zone of shattering and shearing in argillite is mineralized in widths from a fraction of an inch to a maximum of 8 inches, and other narrow zones carry slight amounts of mineral. The mineralization, when strong, carries good gold values, but these are more than offset by the smallness and irregularity of the deposit.

"On the Patsy No. 2 claim are five shear-zones which tend to follow the bedding of light-coloured, in part calcareous and cherty sediments. The zones are not strong, mineralization is discontinuous, and values over minable widths are not commercial. . . . . The belt of (light-coloured) sediments is interesting, because in these arsenopyrite, containing variable gold values, seems to occur in preference to the darker argillites. The mineralization so far encountered, however, is weak and discontinuous. Exploration of the belt might, if it is found to pass across or into an area which is more structurally active, lead to the discovery of more worthwhile mineralization."

Hedley Gold Hill Mining Company, Limited (56)

References: Ann. Repts., Minister of Mines, B.C.: 1934, pp. D19, 20; 1936, pp. D9, 10.

The holdings of the Hedley Gold Hill Mining Company, Limited, consisting of a group of eight claims, lie on the south side of Similkameen River at an elevation of about 4,500 feet, 3½ miles southwest of Hedley, and adjoin the claims of Gold Mountain Mines, Limited, on the south. They are reached by a pack-trail 2½ miles long from Sterling Creek. The deposits occur in argillite and minor calcareous beds intruded by irregular bodies of diorite, or in fracture zones in the diorite. The deposits of the former type occur in sharp, westerly plunging folds in the sedimentary rocks or occur in brecciated zones resulting from such flexures. The principal mineral is calcite carrying pyrite and small amounts of arsenopyrite, chalcopyrite, sphalerite, and galena. At one place veins of vuggy quartz occur, and are somewhat better mineralized than the calcite ores. In 1936 the Resident Engineer took four samples, the best of which carried 0·19 ounce of gold a ton. Selected sulphides would doubtless run higher, but the amount of sulphide present is nowhere great. Development consists of a number of open-cuts, a shallow shaft, and a crosscut adit.

Snowstorm Claim (55)

References: Ann. Rept., Minister of Mines, B.C., 1924, p. 169. Geol. Surv., Canada, Ec. Geol. Ser. No. 4, p. 67 (1927).

The Snowstorm claim, owned by J. A. Robinson of Hedley, is at an elevation of 4,200 feet on the east side of Sterling Creek about 2 miles from its mouth and 4 miles southwest of Hedley. Bedrock on the claim is largely obscured by a thin mantle of drift, so that the geology is far from clear. The deposit appears to have formed by the replacement of grey, cherty limestone, probably along some sort of a fissure or fracture zone, by arsenopyrite and pyrite with calcite about the only introduced gangue mineral. The shallow trenches and pits or small shafts, all the work done so far, have failed to penetrate the zone of oxidation; even in a 23-foot shaft, the deepest working, the sulphides are much oxidized. In this shaft the mineral zone is 6 to 12 inches wide; 90 feet to the north the same or another zone is 18 to 24 inches wide. Samples of this material have assayed from ¼ to ½ ounce of gold a ton.

Mission Group (64)

Reference: Ann. Rept., Minister of Mines, B.C., 1936, pp. D11, 12.

The Mission group of six claims is owned by H. D. Barnes of Hedley and associates. It lies at an elevation of between 4,300 and 4,500 feet, 2¾ miles southwest of Hedley on the west side of Jameson Creek, and is reached by a pack-trail that follows the creek up from its junction with the Similkameen.

The showings occur in a tongue of granodiorite that projects northwest from the main batholith and cuts a series of argillaceous sedimentary rocks, and the granodiorite is crossed by three prominent and several small shear zones. The main shear, known as the Barnes zone, strikes northeast, and two subsidiary zones, the Walker and Winkler, diverge from it in a westerly direction. Outcrops are poor, and the zones have been followed largely by open-cuts and shallow shafts. On the Barnes zone the shear is 10 to 15 feet wide, and the granodiorite is crushed and altered to a whitish granular material largely composed of quartz and white mica with a little chlorite, epidote, and calcite. This zone has been traced for 250 feet and probably extends for 800 feet. It is generally well mineralized with pyrite, arsenopyrite, and dark brown sphalerite, with minor amounts of chalcopyrite and tetrahedrite. The Walker zone has been traced for some 300 feet and is similar to but not as strong as the Barnes. The Winkler zone is also similar, but had not been as carefully explored when last reported on.

The three principal shear zones are all well mineralized and persistent, but the gold values are low. Samples taken by the Resident Engineer in 1936 ran from 0·04 to 0·08 ounce in gold a ton, except for a picked sample that assayed 10·8 per cent zinc and carried 0·20 ounce of gold a ton.

Oregon Group (65)

References: Ann. Repts., Minister of Mines, B.C.: 1913, p. 177; 1917, pp. 205-206; 1928, p. 257.

The Oregon group of eight claims lies about 4 miles southeast of Hedley and about a mile east of the highway. Here a tongue of the Coast intrusions cuts limestones of the Nicola group close to the Bradshaw fault. The ore consists of bornite, chalcopyrite, arsenopyrite, and pyrrhotite in a gangue of metamorphosed limestone consisting of quartz, garnet, and epidote. No work to speak of has been done since 1917. At that time three adits had been driven to explore the mineral deposit. The upper adit, 35 feet long, was in ore most of the way, but the two lower workings failed to pick up its downward extension. Two samples taken by the Resident Engineer returned: copper, 1 per cent, silver, 0·9 ounce a ton, and gold, 0·06 ounce a ton; and copper 3·90 per cent, silver, 3·40 ounces a ton, and gold, 0·12 ounce a ton.

Victoria Group (66)

Reference: Ann. Rept., Minister of Mines, B.C., 1936, p. D12.

The Victoria group of seven claims is owned by T. C. McAlpine of Summerland, and associates. It lies at an elevation of about 3,550 feet about 1½ miles east of the highway 4 miles south of Hedley. The showing consists of a narrow irregular quartz vein cutting through blocky argillite and argillaceous quartzite of probably the Bradshaw formation. A considerable post-mineral movement has occurred along several faults that are possibly offshoots from the nearby Bradshaw fault. The vein has been explored over a vertical range of 410 feet by three adits totalling 312 feet in length. It varies in thickness from 1 inch to 26 inches, and consists of vitreous, crystalline quartz with arsenopyrite, pyrite, pyrrhotite, and chalcopyrite irregularly distributed along it. A chip sample taken across a 26-inch width of the vein by the Resident Engineer ran 0·28 ounce of gold a ton. A selected sample of arsenopyrite, however, assayed only 0·13 ounce in gold a ton, indicating, apparently, that this mineral is not the principal gold carrier in this property as it is on Nickel Plate Mountain.

Lost Horse Group (68)

Reference: Ann. Rept., Minister of Mines, B.C., 1936, pt. D, Special Rept. by M. S. Hedley, pp. 1, 2.

The Lost Horse group of six claims, formerly owned by Hedley Mascot Holdings, Limited, was taken over by Hedley Shamrock Gold Mines, Limited, in 1936. It lies between elevations of 6,000 and 6,400 feet near the summit of the mountain north of Paul Creek, about 4 miles west of Similkameen River, and is reached by a trail that follows Paul Creek for part of its course. Regarding the geology, Hedley says:

"Steeply tilted, banded sediments strike north-south and are intruded by dykes and sills of augite and/or hornblende andesites and diorites. Just northwest of the claims are banded purple and green andesite flows and some breccias, and to the west to at least as far as the 6,616-foot summit (1 mile to the northwest) is a light grey intrusive dacite. Cherty (probably sedimentary) breccias lie between the sediments and dacite on the west. The sediments are argillaceous to quartzitic rocks, all metamorphosed, and are in many respects similar to those encountered on Nickel Plate Mountain; the average strike is 5 degrees west of north, and the dip is nearly vertical. An anticlinal fold occurs in the centre of Lost Horse Nos. 2 and 4 claims, immediately to the west of which are chert breccias grading northerly into banded andesites and intruded on the southwest by dacite. The dacite is a fresh, variable rock of considerable area and contains phenocrysts of quartz and feldspar. . . . .

"Mineralization includes, besides primary (?) pyrrhotite, arsenopyrite, pyrite, and pyrrhotite. It is found almost entirely in the sediments and appears to occur selectively in a fine dense brownish rock which is probably an altered shale. Sulphides, particularly arsenopyrite, are closely associated with green to whitish alteration of this rock in a system of fine interlocking and coalescing veinlets, an inch in width to paper thin. The green colour is due to diopside and less actinolite in one thin-section studied . . . . . .

". . . . . Alteration of brownish fine sediments in reticulating veinlets, is accompanied by scattered crystals and thin seams and blebs of arsenopyrite. . . . . The total amount of sulphide is low. Two picked samples returned 0·01 ounce gold per ton and a trace of silver."

Shamrock Group (74)

Reference: Ann. Rept., Minister of Mines, B.C., pt. D, Special Rept., by M. S. Hedley, 1934, p. D17.

The Shamrock group of eight claims, formerly held by Hedley Mascot Holdings, Limited, was taken over by Hedley Shamrock Gold Mines, Limited, in 1936. It is situated immediately above the alluvial floor of Similkameen River at the foot of the spur between it and the Ashnola.

The deposits consist of irregularly spaced quartz veinlets cutting a set of intersecting granodiorite dykes intruded into argillite and intercalated andesite lava. Arsenopyrite and pyrite occur spotted and in bunches along the veinlets. The veinlets range from a fraction of an inch to 16 inches in width, but average less than 8 inches. Three adits have been driven for short distances in an effort to find a sufficient concentration of well-mineralized veinlets to make ore, but without success.

Speculator Group (67)

References: Ann. Repts., Minister of Mines, B.C.: 1934, p. D17; 1936, pt. D, Special Rept. by M. S. Hedley.

The Speculator claim was Crown granted by Duncan Wood in 1908, and a certain amount of trenching done to explore the showings. In 1935 it and seventeen other claims forming the Speculator group were taken over by the Osoyoos Mining Syndicate. The following year Hedley Dome Gold Mines, Limited, assumed control. The group is situated on the high ridge south of John Creek, 2 miles east of the Lost Horse group.

The mineral deposit consists of pyrite, pyrrhotite, and arsenopyrite in a sheared and altered zone crossing a 20-foot granitic sill that cuts argillite and limestone, and is essentially confined to the sill. The unaltered host rock is a normal amphibole granodiorite or quartz diorite related to the nearby batholith. When altered it becomes light coloured and fine grained, and consists largely of quartz, epidote, calcite, pyroxene (probably diopside), zoisite, and apatite. Although restricted in extent the sulphides are locally massive with much arsenopyrite. However, two samples of this material taken by Hedley only returned 0·02 and 0·01 ounce of gold a ton, respectively.

COPPER MOUNTAIN AREA

Introduction and General Geology

Copper Mountain area lies some 8 miles south of Princeton. It includes the crest and both flanks of a broad spur extending north to Similkameen River, and a small part of the area west of that stream. The region is thickly dotted with mineral deposits, all with many features in common and all distinctly different from those of the Hedley camp some 20 miles to the east.

The principal geological feature of this mining camp is the occurrence of two fair-sized stocks and a number of irregular-shaped bodies of coarse-grained plutonic rock. These bodies are known respectively as the Copper Mountain stock, the Voigt stock, and the Lost Horse intrusions. They vary in composition from syenite to gabbro, and are all conspicuously devoid of quartz. Not only do copper deposits occur with all of them but primary copper minerals can be seen in them and in their associated pegmatite dykes. They intrude, and have variously metamorphosed, volcanic rocks of the Nicola group.

The structure of the Copper Mountain area is, so far as is known, comparatively simple. Nicola volcanic rocks form the western limb of a north-trending anticline and dip steeply to the west. Along the eastern border of the Copper Mountain stock these rocks have been extensively sheared in a direction roughly parallel with the bedding. They have also been intersected by many small faults that strike about east and dip steeply north, and by a series of small tension cracks that lie roughly normal to the shearing in the area between the Copper Mountain stock and the main belt of Lost Horse intrusions. In certain localities these cracks are very plentiful, and, although from the structural point of view they are insignificant, they are of great economic importance because most of the ore deposition occurred along them. Three major faults are recognized in the northern half of the Princeton area, and these converge towards Copper Mountain. Large areas of drift and of Tertiary rocks cover the southern extension of these faults, so that it is not known if they actually meet, nor where, if they continue to the south, they lie. It seems fairly certain that they pass through the Copper Mountain district, and, if so, they may have a bearing on the location of the ore deposits.

Economic Geology

The ore deposits of Copper Mountain are of three principal types, which may be designated by their mineral content as : (1) bornite deposits; (2) chalcopyrite-pyrite deposits; and (3) chalcopyrite-hematite deposits. The bulk of the ore at present being mined is of the first type, the ore minerals consisting of bornite, chalcopyrite, a little chalcocite, and some secondary copper minerals. The sulphides occur as disseminated grains and, more plentifully, as narrow veinlets in the tension cracks referred to above. The tenor of the ore depends rather on the spacing of these cracks than on their size, which varies but little from place to place. The deposits occur mainly in the metamorphosed volcanic rocks along the east and northeast margin of the Copper Mountain stock. A notable feature of these deposits is the scarcity or absence of pyrite, so common in most copper deposits.

Ores of similar composition occur as an integral part of some of the pegmatite dykes that are so commonly associated with the stocks. West of Similkameen River the mineral content of some of these dykes is sufficiently high to suggest the occurrence of deposits of commercial size and grade. As yet none has, however, been found.

The chalcopyrite-pyrite deposits occur in a wide belt extending west from the Copper Mountain stock across Similkameen River. Near the Lost Horse intrusions ore minerals occur in veinlets and disseminated grains in the same way as in the bornite deposits, and differ from them only in the scarcity of bornite and the abundance of pyrite. Ore has been mined from these deposits, but they are of much less importance than those carrying bornite.

East and west of the main body of Lost Horse intrusions are deposits of the chalcopyrite-pyrite type, but these are more generally related to local shear or fracture zones and are of limited extent.

The chalcopyrite-hematite ores occur only in the Voigt stock, where they are known along west-striking shear zones, in particular one that occupies a central position in what is known as the Voigt camp. The ore minerals are principally hematite, pyrite, chalcopyrite, and magnetite, and feldspar occurs both in pegmatite dykes and as a common gangue mineral. As yet none of these deposits has proved commercial, but one or two are promising prospects. It was noted that the hematite deposits are confined to the Voigt stock, and that some of the chalcopyrite-pyrite deposits, of which they seem a phase, carry large amounts of magnetite near or at the contact of the stock.

It seems clear that the copper deposits of Copper Mountain are closely related to the Copper Mountain and Voigt stocks, and that the mineralizing solutions probably originated in an underlying magma from which the stocks were derived. Mineralization, however, followed the intrusion of the stocks, as is evident from the fact that the mineral deposits occur in fractures in the stocks and in the surrounding metamorphosed rocks. Attention is called both to the similarity of the solutions throughout the area, as illustrated by the presence of copper and the absence of quartz, and to differences as exemplified by the development of bornite and the scarcity of pyrite near the Copper Mountain stock, the scarcity of bornite and the abundance of pyrite in the belt north of that stock, and the presence of abundant hematite and magnetite in deposits in the Voigt stock. No evidence is available to suggest that the various types of deposits were formed at notably different times, and it seems rather that differentiation within the parent magma gave rise to solutions of somewhat different composition at one place than at another.

The deposits are evidently somewhat younger than the intrusions, but as the age of the latter is imperfectly known all that can be said is that the deposits themselves are of late Jurassic or, probably, Cretaceous age. They will be dealt with more fully in the section of the report describing the ore deposits of Copper Mountain.

Copper Mountain Mine (45)

References: Ann. Repts., Minister of Mines, B.C.: 1908, pp. 123-126; 1913, p. 242; 1914, pp. 365, 367; 1915, pp. 200, 240; 1916, pp. 261, 262; 1917, pp. 207-208; 1918, pp. 215-219; 1920, p. 159; 1923, p. 191; 1925, p. 209; 1926, pp. 219-222; 1927, p. 241; 1928, p. 269; 1929, pp. 269-276; 1930, p. 212; 1937, pp. D33-34; 1938, p. D38; 1939, p. 98; 1940, p. 83; 1941, p. A77; 1942, pp. A68, 69; 1943, pp. 67, 68; 1944, pp. A64-65. Keffer, 1915, pp. 192-202. Dom. Bur. Mines, No. 617, pp. 16-21, 1925, and pp. 144-147, 1926. Dolmage, "Flotation Tests of Copper Mountain Ore, Copper Mountain, B.C.": 1929, pp. 788-802; 1934, pp. 1-69. Nelson, Walter I., and Buckle, F.: "Mining Methods at Copper Mountain"; C.I.M.M., Trans., vol. XLIV, 1941, pp. 213-229. Douglas, R. S.: "Mining Methods at Copper Mountain, B.C."; C.I.M.M., Trans., vol. XLVI, 1943, pp. 423-455.

Copper Mountain is on the east side of Similkameen River 9 miles south of Princeton. It is reached by auto road and by a spur line from the Kettle Valley Railway.

History. The first discovery of copper ore was made by a trapper in 1884, but it was not until 1892 that the showing was staked by R. A. Brown. In 1900 the Sunset Copper Company was formed to explore the claims, and in 1905 the property was optioned by F. Keffer, who formed the South Yale Copper Company. A considerable amount of exploratory work was done by this company, but a disagreement over the terms of the option resulted in its being dropped. The South Yale Copper Company continued to explore the properties at Voigt camp, a mile or so to the northeast, and in 1911 renewed their option on the Copper Mountain properties. The period of active development that ensued was brought to an abrupt end by the beginning of the war in 1914. With the increase in the price of copper in 1915 attention was again turned to Copper Mountain, and in 1916 development was recommended and work started on the construction of a 2,000-ton concentrator and a spur railway. Strikes and failure of supplies delayed the completion of the work until 1918. By this time the price of copper was again very low, so when the test run failed to be entirely satisfactory, the property was again shut down. In 1922, the holding company was reorganized as Allenby Copper Company, which was controlled by Granby Consolidated Mining, Smelting, and Power Company, Limited. The railway was reconditioned and certain changes made in the mill, and by 1924 the property was ready to go into production, but hopes were again frustrated by the very unfavourable price of copper, and the property was once more shut down. The following year, however, production was at last commenced and has continued ever since except for the period between 1931 and 1936, inclusive, when the property was closed owing to the low price of copper. The following, as far as are available, are the production figures:

Year	Tons ore milled	Pounds copper	Ounces gold	Ounces silver
1925	122,996			
1926	655,508	18,001,637	4,019	146,211
1927	757,628	17,694,121	4,024	134,030
1928	889,020	21,387,728	5,268	150,775
1929	919,752			
1930	703,232			
1931-1936	Shut down			
1937	452,352	7,692,756	2,102	58,436
1938	1,223,200	29,652,613	8,730	214,676
1939	1,450,352			
1940	?			
1941	?			
1942	?			
1943	1,363,346	22,892,724	6,464	156,507
1944	1,383,796	22,242,642	5,603	147,695

The earliest geological work done in the district was by H. Bauerman, who examined the formations along the International Boundary between 1859 and 1861, and reported on them in the Reports of Progress of the Geological Survey for 1882–83–84. In 1877 Dawson examined the area during his preliminary investigations of the area between Harrison and Okanagan Lakes. The first real contribution to the geology of Copper Mountain was made by Camsell in 1906. He mentioned the intrusive body, later known as the Copper Mountain stock, and pointed out the genetic relationship of the ore minerals and the intrusion. He found evidence of mineralization over the whole mountain and in workable ore shoots along fracture zones within the intrusion and in contact metamorphic bodies. In 1915 Keffer presented a paper on Copper Mountain to the Canadian Institute of Mining and Metallurgy. He followed Camsell closely, describing the various phases of the intrusion and the intruded "Palæozoic" volcanic and sedimentary rocks. He also described a series of "cream coloured" quartz porphyry, rhyolite, and syenite dykes that cross the ore zone in a direction a little west of north and with a steep easterly dip. He believed that the ore minerals were primary constituents of the intrusion, and that they were concentrated into workable ore shoots under two sets of conditions: (1) "in the neighbourhood of the contacts of the batholith with the original Palæozoic rocks where fracturing both of the batholithic mass and of the partly or wholly digested Palæozoics has afforded ingress to copper-bearing solutions, derived from the deeper lying batholith"; and (2) "along lines of fracturing between and usually at right angles to the porphyries," the host rock being a phase of the batholith. He believed the evidence favoured the probability that the dykes were intruded before the deposition of the ore. He also noted that the ore minerals in the deposits within or close to the batholith (in the vicinity of the Sunset claim) were bornite and chalcopyrite, whereas in those in the Princess Camp, a little to the north of the edge of the main batholith, the principal mineral was chalcopyrite. At that time no ore had been found deeper than 500 feet, and it was believed that the orebodies bottomed at that depth. Keffer recognized that a strong, roughly east-west fracture system controls the location of the orebodies at Voigt Camp, but made no suggestion as to the control at Copper Mountain other than by the position of the main intrusion and the porphyry dykes. The next important contribution to the geology of Copper Mountain was by Dolmage (1929 and 1934), who made a detailed study of the area in 1923 and a part of 1926. His conclusions, with certain modifications, to be pointed out later, made by the mine geologists, are currently accepted.

General Geology. The oldest rocks in the area belong to a volcanic formation of the Nicola group called by Dolmage the Wolfe Creek formation. In the vicinity of the mine, these have been subdivided by the mine geologists into an upper and a lower member. The upper member is mainly dark green flow breccia consisting of andesite, augite porphyry, and some basalt. The lower member is mainly breccia, with fragments of brown, biotitized lava and, more rarely, green amygdaloidal andesite in a pale green to black matrix.

On both sides of the Similkameen north of Copper Mountain the Nicola volcanic rocks have been intruded by a number of irregular bodies of light-coloured rocks with a granitic texture, named by Dolmage the Lost Horse intrusions. To the south of these is the main Copper Mountain stock, and to the east is the Voigt stock. All of these intrusions have already been described in detail. In part, the Lost Horse intrusions form a body lying along the north-east margin of the Copper Mountain stock and separated from it by several hundred feet of Nicola rocks.

At both Copper Mountain and Voigt Camp a number of very light-coloured granophyre and felsite porphyry dykes cut the stock and the volcanic formations. They are locally known as the "Mine" dykes, and are from a foot to 150 feet wide. They have a general north and northwesterly trend and many split and join again enclosing lens-shaped masses of the intruded rock. Two closely associated types have been recognized, differing mainly in the presence or absence of quartz. In both the groundmass is very fine grained. In one type there are small quartz phenocrysts and a fine intergrowth of quartz and feldspar in the groundmass; in the other are small phenocrysts of oligoclase. These dykes cut the orebodies and all adjacent rocks except some small andesite dykes that are probably related to the Princeton volcanic rocks of Tertiary age.

It has already been pointed out that three main faults, recognized in the northern half of the Princeton area, converge and probably meet near Copper Mountain. The actual juncture of these faults has not been seen, nor can any of them be recognized in the vicinity of Copper Mountain. There is, however, a pronounced zone of foliation several hundred feet wide trending northwesterly close to the margin of the Copper Mountain stock, and also at least four minor faults with northeasterly strikes, steep dips, and as much as 30 feet of gouge. It is not known if these are related to the major faults.

Metamorphism. The volcanic rocks adjacent to the intrusions have suffered extensive alteration. Dolmage distinguishes three stages. In the first, large amounts of biotite have formed in the fractured volcanic rocks adjacent to the Copper Mountain stock, due, he believed, to the emanation of large quantities of aqueous, hot solutions from slowly crystallizing magma, either that which formed the stock or its parent magma at greater depth. During a second stage, of less importance, epidote, zoisite, scapolite, and andesine were deposited in rocks that had already suffered metamorphism by the earlier process. The third stage was characterized by the introduction of large amounts of orthoclase, albite, green biotite, and iron and copper-iron sulphides. This was also the principal period of mineralization.

Since the period of Dolmage's examination, the mine geologists have distinguished two types of alteration, one related to the Lost Horse intrusions and the other to the Copper Mountain stock. They describe the former as a halo around the intrusions composed of a coarse-grained metamorphic rock consisting essentially of altered plagioclase and augite. In appearance the rock is hard, pale green, and cherty, but it may be almost impossible to distinguish this rock from phases of the intrusion itself. This coarse-grained phase obviously grades into the unaltered volcanic rock. Many orebodies, formerly believed to lie within the intrusive mass, are actually in this metamorphic rock. The halo around the stock is developed principally along the northeast margin in the shear zone previously mentioned. Zoning is well defined. First, the margin of the intrusion has been altered for a few feet by assimilation of the intruded volcanic rocks to a medium- to coarse-grained, light-coloured rock consisting essentially of plagioclase and pyroxene with minor amounts of quartz, biotite, titanite, ilmenite, pyrite, bornite, and chalcopyrite. Outside this a second zone, 10 feet or more in width, consists essentially of recrystallized andesite with a little biotite. It has a granular, gabbroic look with crystals of pyroxene in a matrix of feldspar. The outermost zone, which has a width of some 300 feet, is similar to the second but is characterized by the abundant development of biotite.

Economic Geology. There are three distinct, although related, types of ore deposits: bornite-chalcopyrite deposits; chalcopyrite-hematite deposits; and chalcopyrite-pyrite deposits. These are similar in mode of occurrence, but differ in their mineral content and in distribution. The bornite-chalcopyrite deposits are closely associated with the Copper Mountain stock, and are economically the most inportant at present. The chalcopyrite-pyrite deposits are associated with the Lost Horse intrusions, and include some orebodies. The chalcopyrite-hematite deposits are chiefly related to the Voigt stock and will be discussed in the section dealing with Voigt camp.

Dolmage gives the following list of minerals found in the Copper Mountain ores:

Metallic	Gangue
Bornite (Cu_5FeS_4)	Augite
Chalcopyrite ($CuFeS_2$)	Orthoclase
Pyrite (FeS_2)	Albite
Magnetite (FeO, Fe_2O_3)	Oligoclase
Chalcocite (Cu_2S)	Biotite
Covellite (CuS)	Epidote
Malachite ($CuCO_3$, $Cu(OH)_2$)	Zoisite
Azurite (2 $CuCO_3$, $Cu(OH)_2$)	Sericite
Hematite (Fe_2O_2)	Quartz
Galena (PbS)	Scapolite
Sphalerite (ZnS)	Apatite
Native copper (Cu)	Garnet
	Piedmontite

Bornite is the most important ore mineral in the deposits. It occurs in veinlets, blebs, and disseminated grains, and is a primary mineral in the Copper Mountain stock and its associated pegmatite dykes. *Chalcopyrite* is the most abundant metallic mineral in the ores and is the most important ore mineral in the deposits related to the Lost Horse intrusions. *Pyrite* is usually scarce for so ubiquitous a mineral. Dolmage estimated that it rarely forms as much as 1 per cent of the sulphides in the ore. *Magnetite* is present in all phases of the Copper Mountain ores; although it is more plentiful than the pyrite it is by no means abundant in any of them. Some of it is doubtless a primary constituent of the rocks involved, but some is unquestionably of hydrothermal origin, occurring in small veinlets associated with the ore minerals. *Chalcocite* occurs in only small amounts in the ores. Some of it is associated with copper carbonates and is clearly of secondary origin, but a little is found in even the deepest parts of the mine and is considered by Dolmage to be primary. *Hematite* occurs principally in the Voigt stock, but some occurs in the ore-bearing pegmatite veinlets associated with the Copper Mountain stock. It appears to be of primary origin and to have been formed early in the sequence of mineralization. *Galena* and *sphalerite* occur in extremely small amounts as microscopic constituents of the bornite ores. Gold and silver occur in small but important amounts. A little native silver and electrum have been seen, and are the only precious metal minerals known. The average tenor of the ore is about 0·01 ounce a ton in gold and 0·24 ounce a ton in silver.

Orthoclase is an abundant gangue mineral. It occurs in the intrusive and granitized rocks, and is introduced into the less altered phases of the volcanic rocks in the form of pegmatite veinlets. *Albite* and *oligoclase* occur in the pegmatite dykes and veins and also in the ore veinlets. *Quartz,* a mineral so commonly met with in ore deposits, is absent from all the rocks and most of the ores at Copper Mountain. In the few ores in which it does occur it is in microscopic amounts only. This surprising fact is of importance as an indication of the nature and origin of the ore-bearing solutions.

A spectrographic analysis of the Copper Mountain ore made by F. J. Fraser of the Geological Survey revealed the presence of vanadium in all specimens. In an effort to isolate the vanadium-bearing mineral the components of the ore were examined separately, and as the biotite seemed to be the most probable source a selected specimen was submitted to the Mineralogical Division for assay. A volumetric analysis of this material returned 0·36 per cent vanadium.

The paragenesis of the ore and gangue minerals is rather confused by overlapping, but Dolmage believed the following to be roughly the order of deposition:

Biotite
Pyroxene
Bornite
Chalcocite
Orthoclase
Albite
Sericite and chlorite, etc.
Malachite, etc.

He recognizes four distinct stages: (1) the development of the zone of metamorphism; (2) the main period of ore deposition initiated by the principal development of ore fractures; (3) a late phase during which the residual solutions reacted with earlier formed minerals to produce chlorite, etc.; and (4) a final stage of superficial alteration largely accomplished by surface waters. Dolmage makes it clear that the succession of events is by no means as definite as the table appears to indicate, but that all phases, including the fracturing, were of long duration and that there has been much overlapping.

In all types of deposits the minerals occur both as grains disseminated through the rock and as veinlets following small, steep-dipping tension fractures. The disseminated type is of little importance as a factor in producing ore; indeed, so sparse is the development of disseminated grains that Dolmage concludes that the unfractured host rock must have been extremely impervious to the movement of the mineralizing solutions. It is the mineral in the fractures, then, that makes the ore, and the amount of fracturing is, therefore, of paramount importance. The general shearing in the volcanic rocks is roughly parallel with the margin of the intrusions; the tension cracks are at right angles to this, and, consequently, normal to the margins of the intrusions. They are straight, parallel, and average a few millimetres in width. Fractures as much as an inch wide are rare. Some have been traced for 20 feet, but mostly they are shorter. It can readily be seen that the grade of the ore is principally determined by the spacing of these ore fractures, and that ore shoots occur in the zones that contain the greatest number of fractures. The control for the location of ore shoots is, then, the control for the zones of most fracturing. For this the mine geologists offer the following explanation. They regard the Copper Mountain stock as the west boundary of the ore zone, and the Lost Horse intrusions as lying in a belt to the northeast. Between these two is a band of volcanic rocks. Forces acting in opposite directions on these two intrusive bodies have, they suggest, developed a couple that subjected the volcanic rocks between them to considerable stress. This stress has been localized, by embayments in the Lost Horse intrusions, into areas where it is more intense than elsewhere. If the principal of the strain ellipsoid be applied to these local areas, shearing should develop roughly parallel with the contacts and tension cracks normal to them, and such are the conditions actually encountered.

The ore associated with the Lost Horse intrusions occurs as long, narrow, irregular lenses, associated with a great deal of pegmatitic material in dykes and irregular patches. The ore minerals, mainly chalcopyrite, follow a well-developed fracture system both parallel with and at right angles to the contact. The host rock is the granitized volcanic rock, and the more massive and brittle rock close to the contact is the most fractured and contains the best ore. Few of these deposits have, however, as yet proved commercial.

The ore associated with the Copper Mountain stock consists mainly of bornite and occurs in three distinct zones: (1) in well defined fractures in the granitized volcanic rocks close to the contact; (2) in the adjoining zone of gabbroic rocks, which are relatively incompetent and in which the minerals occur mainly in disseminated grains; and (3) in the outer biotite zone in which the rock is brittle and well fractured and the ore minerals once again occur mainly in the fracture. Throughout all three zones are many pegmatite dykes and patches of pegmatitic material, most of which carry some bornite.

The mine geologists suggest the following sequence of events: (1) two periods of volcanic activity, forming the two components of the Wolfe Creek (Nicola) formation; (2) emplacement of the Lost Horse intrusion and Copper Mountain stock, resulting in the folding and metamorphism of the relatively soft volcanic rocks, converting them into hard, brittle, cherty types; (3) a period of strain developed in the metamorphosed rocks between the Lost Horse intrusions and the Copper Mountain stock from stresses developed by movements of the two bodies as a couple with respect to each other. The stresses so developed were concentrated in areas near embayments in the Lost Horse intrusions, and in these local areas the brittle rocks were shattered and the softer rocks sheared.

Voigt Camp

The mineralization found on the groups of claims forming what has come to be known as Voigt camp is similar to that of Copper Mountain proper, but differs from it in some important respects. Voigt camp is a little more than a mile northeast of the Copper Mountain camp. It is on the east margin of the Voigt stock of similar composition to the Copper Mountain stock and evidently closely related to it in origin and age. Some of the deposits are in the volcanic rocks of the Wolfe Creek (Nicola) formation and some in the intrusive rock itself.

The main controlling structure is a prominent shear that strikes nearly due east through both volcanic and intrusive rocks. The principal deposits are in this shear or in subsidiary parallel shears to the north and south.

The ore minerals in the volcanic rocks consist essentially of chalcopyrite, pyrite, and a little magnetite, disseminated along these shears. Bodies of pegmatite are common, and feldspar is freely developed all through the ore zones. As yet no orebody of this type has shown much promise, the average grade being very low.

To the east, near the margin of the Voigt stock, the amount of magnetite increases, and here and there are occasional bunches of hematite in which chalcopyrite is, apparently, more abundant than in the deposits farther from the intrusion. These deposits are apparently transitional to those in the Voigt stock, which carry large quantities of hematite as well as some pyrite. The former mineral, which is not commonly found in this association, does not occur elsewhere in the Copper Mountain area. Dolmage (1934, p. 22) gives the following list of minerals in their relative order of abundance: hematite, pyrite, orthoclase, albite-oligoclase, quartz, calcite, magnetite, chalcopyrite, chlorite, epidote, and sericite. The hematite occurs both massive and as specularite, and constitutes more than 50 per cent of the vein material. The feldspars occur in the veins and in the country rock adjacent to them. Orthoclase also forms the principal constituent of the many pegmatite veinlets associated with these deposits. Magnetite is abundant in certain deposits and rare in others. The relative order of deposition of the hematite, magnetite, feldspar, and quartz is not known, but they were all deposited before the chalcopyrite, and the calcite is definitely later still.

Following is a description of some of the more important of the properties constituting the Voigt camp.

Number 18 Claim and Fraction (46)

Reference: Dolmage, 1934, pp. 37-38.

These claims are among the most westerly of the camp. They are entirely in volcanic rocks, except for some felsite and andesite dykes. The mineralized rocks exposed by trenches and short adits consist of volcanic breccia carrying disseminated pyrite and chalcopyrite. Mineralized areas are small and irregular, and even the richest deposits rarely carry more than 1 per cent copper.

Olympia Claim (47)

Reference: Dolmage, 1934, p. 38.

The Olympia claim lies to the southeast of the Number 18, close to the margin of the Voigt stock. Drift covers most of the claim, and the only rock visible is exposed in two long trenches. It is andesite breccia of the Wolfe Creek formation (part of Nicola group) sparsely mineralized here and there with chalcopyrite and pyrite. In one or two places, however, magnetite is abundant, and there the copper content may be 2 per cent or more. Dolmage did not, however, consider it likely that ore in commercial quantity would be found.

R.S. Claim (47)

Reference: Dolmage, 1934, p. 43.

The R.S. claim lies to the east of the Olympia. Most of the workings are in the Voigt stock, but, from the large number of outcrops of andesite lava in the vicinity, Dolmage concluded that the showings were just about at the margin of the stock, that the contact was here flat-lying, and that most of the cover of volcanic rocks had been stripped off. The mineral showings are low grade and of little commercial interest, but magnetite is an important constituent, in contrast with deposits remote from the stock.

Automatic Fraction, Frisco, and Number 14 Claims (42)

Reference: Dolmage, 1934, pp. 41-43.

These claims lie a little to the north of the Olympia and R.S. in a line roughly from west to east in the order named. The contact between the Voigt stock and the volcanic rocks is in the Automatic fraction, so that the two other claims are entirely within the intrusion. A pronounced shear zone runs through all three claims, and has been mineralized throughout, although in varying amounts. On the Automatic fraction, where it intersects volcanic rocks, pyrite and chalcopyrite are the only metallic minerals and the ore is very low grade. On the Frisco, where it passes into the intrusion, hematite is also present and the ore is of better grade, but still probably carries less than 1 per cent copper. Farther within the stock, on the Number 14 claim, the shear is still better mineralized, and Dolmage reports values as high as 6 per cent copper and $10 a ton in gold with an average of 3 per cent copper and $4 a ton in gold across widths of from 30 to 50 feet. He considered this to be the most promising property in the Voigt camp.

Falum Claim (50)

Reference: Dolmage, 1934, p. 43.

The Falum claim lies nearly a mile to the east of the Number 14 and well within the Voigt stock. The ore is quite similar to that on the Number 14 claim and is probably on the extension of the same easterly striking shear zone. In addition to pyrite, chalcopyrite, and hematite, magnetite is common and minute amounts of bornite can be seen.

Azurite and Copper Glance Claims (49)

Reference: Dolmage, 1934, p. 43.

The Azurite and Copper Glance claims are on the southwest margins of the Voigt stock about a mile southeast of Voigt camp. The workings are mostly in the intrusive rock, but some are in basalt and basalt breccia of the Wolfe

Creek formation (part of Nicola group). The mineral showings consist of finely disseminated pyrite and chalcopyrite and appear to be of low grade.

Other Properties in the Vicinity of Copper Mountain

The area underlain by the Copper Mountain stock and for some distance around its margin was all staked following the development of commercial ore. These are described by Dolmage (1934) and few give promise of commercial importance. The attempt to describe them all will not be made, but certain ones that show features of interest have been selected for illustration.

Red Buck Mines, Limited (43)

References: Ann. Repts., Minister of Mines, B.C.: 1927, p. 253; 1928, p. 265; 1936, p. D58; 1937, pp. D24-26; 1938, p. D37; 1939, p. 89. Dolmage, 1934, p. 36.

The Red Buck group of seven claims lies on both sides of Similkameen River Canyon about 1½ miles north of the main Copper Mountain adit. It was staked prior to 1908, and explored intermittently until 1927, when a shipment of 40 tons of picked ore was made by pack-horse. The following year it was optioned by Fred Foster of Spokane, who later formed Red Buck Mines, Limited. Development was continued by hand until 1938 when it was felt that there was enough ore in sight to warrant the installation of a power plant and the erection of a 100-ton mill. Unfortunately, the hope of developing further ore failed to materialize, and the mill was shut down early in 1939, since when the property has been inactive.

The ore consists of irregular disseminations of pyrite and chalcopyrite in a complex of Nicola volcanic rocks cut by dykes and irregular masses of the Lost Horse intrusions, the whole impregnated with pegmatite material and small pegmatite dykes. The orebodies are small and irregular, and as yet no structural control has been recognized.

Hamilton, Fraser, and Fraser Fraction (43)

References: Ann. Rept., Minister of Mines, B.C., 1915, p. 37. Dolmage, 1934, p. 48.

The above claims are in the northern part of the Copper Mountain stock and extend west from Similkameen River. The workings are all in the intrusion from 1,000 to 2,000 feet from the contact. The host rock is the normal gabbro phase of the stock, with occasional fine veinlets of pegmatitic material. The ore minerals consist of bornite and chalcopyrite, and a little chalcocite occurs in disseminated grains or minute veinlets. It is doubtful if this type of mineral deposit will anywhere make ore, but Dolmage points out that the volcanic rocks adjacent to this enriched part of the stock deserve careful prospecting.

Kennedy Mountain Prospects (42)

Several mineral showings have been prospected on the north slope of Kennedy Mountain between the angle of Similkameen River and Whipsaw Creek. The area is mainly underlain by Nicola volcanic rocks cut by occasional small bodies of Lost Horse intrusions. The volcanic rocks have been locally fractured in a general north and south direction, and the resulting breccia cemented by calcite carrying bornite, chalcopyrite, and a little quartz. The brecciation is not pronounced; one mineral zone near Kennedy Lake, for instance, has been exposed by trenching, and appears to be from 10 to 15 feet wide and about 100 feet long.

Friday Creek Prospects (44)

References: Ann. Rept., Minister of Mines, B.C., 1929, p. 277. Dolmage, 1934, p. 47.

Friday Creek is a small tributary of the Similkameen from the west, a little to the south of the Copper Mountain mine. In its lower part it crosses the western margin of the Copper Mountain stock. Mineral deposits occur at several places along the creek, the principal one being on the Wheeler group, situated a short distance up from the mouth of the creek. Here the Nicola volcanic rocks and the hybrid, marginal phase of the stock are cut by a number of pegmatite dykes, all of which carry bornite, chalcocite, and chalcopyrite in bunches and disseminated grains. At no place, however, were these minerals found in the intruded rock adjacent to the dykes. As the ore is confined to the pegmatite dykes, and as these dykes are small, it follows that no larger orebodies can be expected. Dolmage, however, points out the possibility of finding large bodies in either the stock or the volcanic rocks in the vicinity, for it is evident that the residual magmatic liquids were rich in copper. Prospecting is greatly hampered by lack of outcrops.

Princeton Mining and Development Company, Limited (53)

References: Ann. Repts., Minister of Mines, B.C.: 1918, p. 214; 1920, p. 159; 1921, p. 179; 1922, p. 168; 1923, p. 189; 1924, p. 174; 1925, p. 210; 1926, p. 222; 1927, pp. 242-244; 1928, pp. 261-263.

The property of Princeton Mining and Development Company, fourteen claims in all, is situated on the south side of Similkameen River 4 miles east of Princeton. The original staking was done prior to 1908. In 1917 the present company acquired the Copper Farm group of three claims and the remaining eleven claims were added later. From 1918 to 1928 the property was developed continuously; three main adits and several raises and crosscuts were driven, and a considerable amount of surface trenching done. This work, however, failed to develop commercial sized orebodies, and the property was shut down and has remained inactive since.

The claims are underlain by a body of diorite cutting Nicola volcanic rocks, both formations being cut by a large, pink, quartz porphyry dyke. Both intrusions and volcanic rocks have been sheared so as to produce a series of north-striking, steeply dipping, narrow, lenticular lenses of breccia. Although these lenses may be 10 feet or more wide their mineralized parts consist of stringers, seldom more than a few inches wide, of chalcopyrite, pyrite, and occasionally tetrahedrite. These veins may occur along one or other side of the breccia zone, and though chalcopyrite and pyrite commonly also form disseminated grains in the breccia, nowhere is this dissemination sufficiently concentrated to constitute ore. The mineral stringers are of good grade, but explorations have revealed few places where they occur over mineable widths. Where tetrahedrite occurs the silver values may run to 50 ounces a ton or more, but this mineral is rare in most of the mineral deposits.

PRINCETON-ASPEN GROVE COPPER BELT

North from Copper Mountain to the border of Princeton map-area is an area several miles long along which copper prospects, including those of the Aspen Grove Copper camp, are numerous. At the southern end of this belt, just northeast of Princeton, are three prospects, the Shamrock, Lucky Strike, and Dry Creek, that occur in or close to large granitic bodies or close to apophyses from them, and are clearly related to these bodies. The deposits are in part of the contact metamorphic type, and chalcopyrite and pyrite with, in the Dry Creek prospect, galena and sphalerite, are the ore-bearing minerals. One other property of this type, the King George, occurs to the southeast of Missezula Lake. The remaining deposits consist of chalcopyrite, bornite, chalcocite, and, rarely, pyrite, occurring in fractures and disseminated grains in Nicola volcanic rocks. No intrusive rocks are known to be related to them, and their only structural connection seems to be their common occurrence along the trend of the faults up Allison Valley and Summers Creek. These faults if projected to the south across the area covered by the Princeton lavas and sediments would extend into the Copper Mountain area. It is surely more than a coincidence that deposits whose mineral constituents should be so conspicuously like those of Copper Mountain should occur dotted along a line of faulting extending north from Copper Mountain. If, as is suggested by these considerations, the Aspen Grove copper deposits originated from solutions genetically connected with those that produced the Copper Mountain ores, and that these solutions entered the host rock through channels afforded by the fault zones mentioned above, it is odd that no member of the Copper Mountain intrusions, to which the mineralizing solutions would also be related, has been seen along this belt. Perhaps such intrusions are present, but are covered by rock or drift.

Shamrock Group (Blue Ridge) (52)

References: Ann. Repts., Minister of Mines, B.C.: 1915, pp. 241-243; 1919, p. 171.

The Shamrock group of six claims is on or near the summit of Holmes Mountain, some 4 miles northeast of Princeton and just north of Similkameen River, not far from the property of Princeton Mining and Development Company. The claims occupy an area extending south and east from the top of the mountain.

The southwest contact of the main Osprey Lake body of granodiorite with the Nicola group of rocks passes through the claims. The granodiorite is intruded by large and small quartz porphyry dykes, and contains also inclusions and small roof pendants of the older sedimentary and volcanic rocks. The dykes strike northerly, and seem to have acted as loci for the development of zones of brecciation. Some of the small pendants have been largely altered to garnet and epidote and carry chalcopyrite and pyrite. The sulphides also occur in some quantity as cementing materials in the breccia zones, which range from ½ inch to 3 feet only in width. One vein, at least 10 inches wide, was traced for 20 feet and from it 10 tons of 15 per cent copper ore were shipped. Several adits and open-cuts have failed to reveal commercial sized orebodies, and the group has been idle since 1919.

Regal Group (51)

References: Ann. Repts., Minister of Mines, B.C.: 1918, p. 214; 1929, p. 278.

The Regal group of ten claims is about 2½ miles northeast of Princeton, not far from the Kettle Valley Railway. The mineral deposits, consisting largely of copper carbonates, occur in heavily brecciated Nicola volcanic and sedimentary rocks, and evidently lie in the fault zone that follows down Allison Valley or Summers Creek, possibly near or beyond their junction.

No work is recorded since 1929, and few of the old open-cuts penetrated the oxidized zone. Some diamond drilling reported to have been done by A. G. Trites is said to have suggested a considerable area of brecciation and mineralization with values too low for profitable mining.

Lucky Strike Group (36)

References: Ann. Repts., Minister of Mines, B.C.: 1927, p. 248; 1928, p. 263.

The Lucky Strike group of eight claims is situated close to the Kettle Valley Railway some 5 miles northeast of Princeton on the Hayes Creek-Summers Creek divide. The claims are near the western contact of the Osprey Lake body of granodiorite with the Nicola volcanic and sedimentary rocks, which are also cut by granitic and pegmatitic dykes and are much fractured and altered. The ore minerals are chalcopyrite and pyrite in a gangue of quartz and epidote. Exploratory work, done many years ago, comprises some surface stripping and three short adits.

Dry Creek Group (34)

Reference: Ann. Rept., Minister of Mines, B.C., 1922, p. 168.

The Dry Creek group of three claims is situated about a mile up Dry Creek, a tributary of Summers Creek, some 10 miles north of Princeton. Members of the Nicola group, including beds of limestone, have been intruded and altered by the Summers Creek body of light-coloured granodiorite and its accompanying apophyses. The mineral deposits consist of chalcopyrite, pyrite, sphalerite, and galena in a siliceous gangue, all very much crushed and broken. Work consists of open-cuts and surface stripping and one 50-foot adit, all done many years ago.

Shamrock Group (Summers Creek) (8)

Reference: Ann. Rept., Minister of Mines, B.C., 1929, p. 278.

The Shamrock group (Summers Creek) of six claims is about a mile south of Missezula Lake at an elevation of 3,500 feet on the west side of Summers Creek. It is underlain by Nicola volcanic rocks, much of which is of that peculiar type previously referred to that resembles a red granitic rock. It is, however, clearly a volcanic breccia, and here strikes north and dips 45 degrees west. The rock is intersected by a fracture striking north 20 degrees east and dipping 75 degrees northwest. This fracture has been traced by six open-cuts for about 250 feet, in which distance it pinches from about 10 feet wide at the south end to a foot or two at the north end. It is mineralized in zones with chalcocite and some pyrite and chalcopyrite, all of which occur in finely disseminated grains and tiny veinlets. At the south end an open-cut exposes a 3-foot mineralized zone on the foot-wall and a 1-foot streak along the hanging-wall.

Very little work has been done on this property, but a small shipment was made by J. Armstrong of Princeton and associates in 1929, which is reported to have carried 5·78 per cent copper.

On the rim of Summers Creek Valley almost directly opposite the Shamrock group similar breccias occur in the Nicola volcanic rocks over a considerable area. In several places the rocks are stained with copper carbonates, and at one place two shallow open-cuts were seen. No primary copper mineral was observed.

King George Group (9)

The King George group of claims is owned by William Johnson, Arthur and Thomas Smitherin, and Andy Ericsson, all of Princeton. It lies between elevations of 4,220 and 4,340 feet on the slope of the hill about 1½ miles southeast of the south end of Missezula Lake. The original four claims in this group were staked in 1937 and just prior to the writer's visit in 1941 eight additional claims were staked.

North of a small camp in a timbered flat, where the hill rises slowly to the east, fifteen or twenty open-cuts, pits, and areas of stripping have exposed a belt of fracturing striking a little west of north and about 40 feet wide in fine- to coarse-grained, green, volcanic rocks of the Nicola group. The resulting breccia has been silicified and mineralized with pyrite and chalcopyrite. The copper sulphide is, however, mostly altered to copper carbonates. Neither the fracturing nor the mineralization is pronounced, and few exposures will carry more than 1 per cent copper.

Southwest of the camp the ground rises in a low, flat ridge before dropping into a little gully. Along the ridge some twenty open-cuts have exposed a mineralized area in Nicola volcanic rocks. These rocks are finer in grain than those of the workings north of the camp and are more generally grey than green. The mineral association, too, is a little different; both pyrite and quartz are scarce, and the principal introduced gangue mineral is calcite, in veinlets and fine stringers. Although evidence of mineralization is exhibited over a wide area it is all very sparse, nor was the writer able to discern any definite patterns that might serve as a guide in the search for richer deposits.

Aspen Grove Copper Camp

References: Ann. Repts., Minister of Mines, B.C.: 1901, pp. 1179-1189; 1913, pp. 222-223; 1915, pp. 224-227; 1917, p. 233; 1918, pp. 238-239, 244; 1919, p. 189; 1920, p. 168; 1928, pp. 222, 223; 1929, p. 245.

The Aspen Grove copper camp covers an area some 8 miles long extending northerly from a couple of miles north of Missezula Lake to the boundary of Princeton map-area. The camp lies roughly parallel with the main Princeton-Merritt highway, and extends east from it for a width of from 2 to 2½ miles.

The mineral deposits consist of chalcopyrite, bornite, chalcocite, and some pyrite and hematite in shear zones in volcanic rocks of the Nicola group. None of these shear zones is large, and the better deposits are restricted to small shoots within them. On a few properties two shear zones intersect, and the zone of intense fracturing at the juncture is well mineralized. The ore minerals also occur as grains disseminated more or less at random through the lava in the interstices between the fragments of flow breccias. This type of mineralization is widespread but has not been found to be sufficiently high grade to be economically interesting.

Copper Star Claim (1)

References: See Aspen Grove copper camp.

The Copper Star claim lies some 7½ miles north of Aspen Grove post office at the northern end of the Aspen Grove copper camp and a little to the east of the main Merritt-Princeton road. The showings occur in a brecciated zone in augite andesite porphyry of the Nicola group. The rocks in this zone are somewhat altered to epidote and jasper, and are mineralized with chalcopyrite, chalcocite, and secondary copper carbonates and a little native copper. Most of the work on the claim was done before 1915, and consists of surface stripping and open-cuts. These expose a mineralized area as much as 30 feet wide and of undetermined length from which a shipment of some 45 tons of hand-sorted ore was made. This is reported to have returned 2·2 ounces a ton in silver and 8·7 per cent copper.

Copper Standard Group (2)

References: See Aspen Grove copper camp.

The Copper Standard group of six claims is about 2 miles south of the Copper Star claim and just north of the road leading to Alleyne Lake from the north. It is owned by Isaac Eastwood of Merritt, and associates. An open-cut has been excavated along a fissure zone exposed in a bluff, and from the end of it a 50-foot shaft has been sunk. From these workings 25 or 30 tons of sorted ore was mined and stock-piled, a grab sample from which returned 1·0 per cent copper and 0·4 ounce a ton in silver. A general sample of the fissure zone, however, is said to have run 8·8 per cent copper.

Big Sioux Group (2)

References: See Aspen Grove copper camp.

The Big Sioux group of claims is about in the centre of the Aspen Grove camp just north of the Alleyne Lake road from the north and about a mile along it from the main Princeton-Merritt highway. The first ore to be seen in the camp was found on the Big Sioux claim in 1899 and since then this property has received considerable attention. In 1919 it was taken over by Aspen Grove

Mining Company of Vancouver, who, apparently, devoted their efforts to an unsuccessful attempt to find commercial sized bodies of shipping ore. In 1918 some sixty claims were taken over by Aspen Grove Amalgamated Mines, Limited, and between then and 1920 considerable diamond drilling was done. In 1929 thirty-two claims, including the Big Sioux, were purchased by Morgan Copper Mines, Limited, of Vancouver, but the depression put a stop to any plans they may have had for developing the property.

During the various periods of activity a number of adits, shallow shafts, and open-cuts have exposed zones of mineralization over a wide area. The host rock everywhere consists of volcanic rocks of the Nicola group: at some places these are porphyritic flow breccias; at others they comprise coarse-grained rocks with a granitic texture and at first glance look like intrusive diorites, but in which volcanic structures can still be recognized. One type of ore occurs in small shear zones none of which appears to have been traced very far. The ore minerals in this type consist chiefly of chalcopyrite, chalcocite, and bornite, and the dump from one of the shafts averages about 11 per cent copper. Mostly, however, the ore is of lower grade, and carries only small amounts of precious metal. In another type the ore minerals fill interstices in relatively unaltered flow breccia. Although none of this type of ore seems to be high grade, it gives some promise of considerable extent.

Golden Sovereign Group (2)

References: See Aspen Grove copper camp.

The Golden Sovereign group adjoins the Big Sioux to the northeast, and conditions are approximately the same on the two properties. The principal showing is in a big open-cut in a fracture zone formed, apparently, at the intersection of two shear zones. From the bottom of this cut a winze has been sunk, but it is now filled in. Native copper is common in this showing, and lumps weighing as much as 100 pounds are said to have been encountered.

Big Dutchman Group (3)

References: See Aspen Grove copper camp.

The Big Dutchman group of claims adjoins the Golden Sovereign group to the northeast and continues the belt of claims over the summit of the hill to the slope down to Quilchena Creek. Mineralization on this group is of a similar type to that on the preceding groups, but seems to be all very low grade, with little shearing in evidence. No work has been done since 1901, and most of the workings are inaccessible.

Cincinnatti Group (2)

References: See Aspen Grove copper camp.

The Cincinnatti group adjoins the Big Sioux to the southwest. Geological conditions are similar on the two properties, but no large concentrations of good grade ore are exposed on the Cincinnatti claims. Mine samples from surface workings, taken by the Provincial Mineralogist or members of his staff, range in copper content from 1·1 to 2·3 per cent. A 400-foot adit driven into the hill to test the deposit at depth failed to reveal any evidence of significant mineralization. No work has been done on the property since 1913.

Bluebird, Giant, Georgia, and June Bug Claims

References: See Aspen Grove copper camp.

These claims all lie in the northern part of the Aspen Grove copper camp. On all of them copper minerals occur disseminated through volcanic rocks of the Nicola group and along joints and fractures in them. The occurrences are similar to those already described, but are generally less attractive.

Tom Cat Claim (5)

Refcrences: See Aspen Grove copper camp.

The Tom Cat claim is in the southern part of the Aspen Grove copper camp. Geological conditions are essentially similar to those of the deposits in the northern part. The ore minerals consist principally of bornite, hematite, and native copper, and occur in fractures and as disseminated grains in Nicola lavas. A sample of the mineralized lava ran 0·2 per cent copper, and some of the ore from fractures exposed in an open-cut ran 2·8 per cent copper.

Portland Mining Company, Limited (5)

References: See Aspen Grove copper camp.

The property of Portland Mining Company adjoins the Tom Cat to the south. A considerable amount of development work was done, including a 115-foot shaft and a 106-foot drift off it to the north. These workings are now filled with water, but low-grade mineralized rock is exposed on the dump.

Bunker Hill Claim (5)

References: See Aspen Grove copper camp.

The Bunker Hill claim is $1\frac{1}{2}$ miles north and $\frac{3}{4}$ mile east of the Tom Cat. On it a zone of crushing and shearing in andesite lava carries considerable epidote but very little copper minerals.

Daisy Group (7)

References: See Aspen Grove copper camp.

The Daisy group of four claims is in the south end of the Aspen Grove copper camp some 2 miles north of Mizzezula Lake. An adit and two open-cuts in Nicola lava expose a shear zone 80 feet wide that is fairly uniformly mineralized with copper sulphides and carbonates. One sample taken across 30 feet by the Resident Engineer returned 0·8 per cent copper.

Vancouver and Victoria Claims (6)

References: See Aspen Grove copper camp.

The Vancouver and Victoria claims lie about 2 miles north of the Daisy. Conditions are generally the same except that one of the shear zones crosses a lens of Nicola limestone in which is exposed a considerable amount of copper carbonate.

MOUNT RABBITT AND VICINITY

To the northwest of Tulameen are several groups of claims on which the principal feature in common is the prevalence of chalcopyrite. All lie within an area of Nicola rocks, and with one exception the prospects are along shear zones carrying quartz veins or silicified rock. Pyrite and chalcopyrite are the commonest minerals, but galena and sphalerite occur in some and are the principal ore minerals in one. These deposits differ from those in the Copper Mountain-Aspen Grove belt in the common occurrence of quartz and the absence of bornite or chalcocite. They, therefore, appear to have had a different origin. Gold is present, but is unimportant except in the Cousin Jack property where it occurs with sphalerite in amounts up to 0·34 ounce a ton. The deposits of Laws camp are replacement bodies in lenses of limestone enclosed in sheared Nicola rocks. They have provided small shipments, but neither they nor any other deposits of this group have provided ore in economic quantity. No extensive development has, however, been attempted, and the true worth of several of the properties remains to be determined.

Red Bird Group (21)

References: Ann. Repts., Minister of Mines, B.C.: 1913, p. 235; 1924, p. 170; 1928, p. 268; 1929, p. 279.

The Red Bird group of four claims is situated on the east slope of Mount Rabbitt some 3 miles northwest of Tulameen village. It was staked before 1913 and taken over by Federation Copper Mines, Limited, in 1929, but has received no attention since.

The showings consist of a number of north-striking shear zones in green andesite lava, bedded tuffs, and argillite of the Nicola group not far to the west of the Boulder granite body. These shear zones have been silicified and mineralized with pyrite and chalcopyrite. The mineral zones are as much as 20 feet wide, but average about 2 feet in width.

The principal mineral zone has been explored by two crosscut adits and a short winze sunk from the upper one. The upper crosscut was extended for 400 feet into the hill, but is still about 100 feet short of the downward projection of a second mineral zone seen on the surface. The average copper content of the mineral zone is about 2 per cent, with gold and silver values generally low.

Spokane-Motherlode Group (21)

References: Ann. Repts., Minister of Mines, B.C.: 1928, p. 268; 1929, p. 279.

The Spokane-Motherlode group adjoins the Red Bird, and is owned by John Osborne of Tulameen. Conditions are similar to those on the Red Bird, but less work has been done.

Lloyd George Group (22)

Reference: Ann. Rept., Minister of Mines, B.C., 1937, pt. D, special report by M. S. Hedley, p. 2.

The Lloyd George group lies on the south slope of Rabbitt Mountain near its summit. It is owned by Harry Lowe of Tulameen.

The area of the claims is underlain by volcanic and sedimentary members of the Nicola group, all more or less sheared in a northwesterly direction. The resulting chlorite and sericite schists contain more intensely sheared zones that have been somewhat silicified and are mineralized with pyrite and a little chalcopyrite. Occasional zones show massive pyrite, but chalcopyrite is nowhere abundant and the copper content is quite small. Several showings, explored by open-cuts, short adits, and pits or shallow shafts, are scattered over an area half a mile or so wide, but none appears to be promising.

Cousin Jack Group (20)

References: Ann. Repts., Minister of Mines, B.C.: 1901, pp. 1088, 1178; 1922, p. 168; 1933, pp. 173, 174; 1934, pp. D22, 23; 1937, pp. D27-29.

The Cousin Jack group was staked before 1901, and has been explored intermittently since. It is owned by John Osborne, W. D. Vallance, and associates of Tulameen and Blakeburn. The property lies on the bench above the steep Otter Valley on the east slope of Rabbitt Mountain just south of Elliot Creek. It is reached by a short, steep trail up the hill from Otter Valley or by one on a better grade 4½ miles long from the Lawless Creek road.

The showings occur in volcanic, tuffaceous, and argillaceous rocks of the Nicola group not far from their contact with the Boulder granodiorite body. The rocks have been subjected to regional shearing, which has largely altered them to chlorite and sericite schists. These schists have a general northwesterly strike and dip at various angles to the west. In them are four or more zones of more intense shearing in which irregular veins and bodies of quartz have been deposited. Both the quartz bodies and in places the schists themselves have been mineralized with pyrite, sphalerite, galena, and chalcopyrite, but so irregularly that, although the zones have been traced for considerable distances, it is difficult to determine the continuity or grade of the orebodies. The principal value is in zinc, which is also accompanied by significant amounts of gold. A number of chip samples taken across widths of from 2 to 6 feet by the Resident Engineer returned from 2·3 to 19·1 per cent zinc and from a trace to 0·32 ounce a ton in gold.

Zone No. 1, lying to the south and west of the cabin, has been traced on the surface for some 1,200 feet, and is opened up by two crosscut adits and a number of open-cuts. So irregular has mineral deposition been in this zone that its limits have not been defined. Zone No. 2, immediately north of the cabin, has been traced by open-cuts for 550 feet, and much resembles the first. Zone No. 3 lies some 500 feet to the north and east of No. 2 zone, and has been traced for 350 feet by four open-cuts. These have exposed ribs of quartz and irregularly disseminated sulphides. Zone No. 4, 100 feet or so to the northeast of No. 3 zone, has been traced for some 200 feet by three open-cuts, a short adit crosscut, and a shaft. It is mineralized quite irregularly, but in places the occurrences are of good grade. Several open-cuts and at least one short adit prove the existence of other zones intermediate between the four mentioned, but as yet none of these has been explored to any extent.

The showings are difficult to evaluate, owing to the irregular distribution of the ore minerals within the comparatively regular zones. Locally, at least, the deposits are of promising calibre, but further development and bulk sampling will be required to demonstrate the true size and grade of the orebodies.

Totem Pole Group (17)

Reference: Ann. Rept., Minister of Mines, B.C., 1916, p. 261.

The Totem Pole group is located on the trail up Mount Thynne about 3 miles from the Otter Lake road. The area is underlain by sheared rocks of the Nicola group, which have been intruded and metamorphosed by dykes from a nearby small body of light-coloured granodiorite, and also by dykes and sills of Otter granite. In the rocks of the Nicola group small shear zones or fracture zones have been silicified and cut by irregular stringers of quartz and calcite, and some pyrite, chalcopyrite, and galena have been deposited. These showings have been explored by open-cuts and a 10-foot shaft, but have nowhere proved to be either extensive or of high grade.

O'Henry Group (19)

The O'Henry group is owned by H. Y. Lowe of Tulameen. It is situated on the summit and west flank of the ridge on the west side of Lawless Creek 1½ miles from the trail bridge. A good branch trail leads to the cabin on the property situated near a creek tributary to Lawless Creek.

Several types of deposits are represented on the property. On the summit of the ridge between Lawless Creek and the tributary stream, four open-cuts and some stripping exposed one or more quartz veins at least 3 feet wide in Nicola, green, andesite lava. Much of the vein material is white, barren-looking quartz, but in places it carries pyrite, chalcopyrite, and a few specks of galena and sphalerite. Nowhere is the evidence of mineralization extensive enough to be of much interest.

In the bed of the creek below the cabin a quarter of a mile or so from the above workings, an open-cut has exposed a vein of barren-looking quartz more than 20 feet wide.

A little downstream from the above the creek has cut through a small ultrabasic stock. In several places narrow but strong shear zones intersect this body, and these are locally mineralized with abundant pyrite and magnetite. The showing, however, seemed to have little economic significance.

Law's Mining Camp (23)

References: Ann. Repts., Minister of Mines, B.C.: 1908, p. 132; 1913, p. 236; 1916, p. 261; 1922, p. 107; 1926, p. 228; 1927, pp. 255-256; 1928, p. 269; 1929, p. 279. Camsell, 1913, pp. 162-166.

General Statement. Law's Mining Camp is situated on the west side of Lawless (Bear) Creek about 3 miles from Tulameen River. The principal claims on which most of the work has been done, fall into two groups, one including the St. Lawrence and St. George claims, and the other, the Liverpool. The first named claim was staked in 1900 by Charles L. Law and associates, and on it and the nearby St. George claim all the early work, consisting of two shafts, an adit, and open-cuts, was done. By 1916 Law had developed enough ore to ship a carload, which is reported to have returned him $600. Since that time, however, nothing further has been done. The second group of claims is owned by Louis Marcotte of Coalmont, who in 1922 sank a 60-foot shaft on the Liverpool claim. Encouraged by the results, he extended an adit, already started near the collar of the shaft, until, by 1926, it was 110 feet long. The following year a group of twelve claims, including the Liverpool, was taken over by Hope Range Copper Company, Limited, and exploration was continued on a small scale for the next 2 years. Since 1929 the claims have lain idle.

Geology. The rocks underlying both groups of claims are limestones interbedded with mica, dolomite, and talc schists, all sheared members of the Nicola group. A short distance to the west lies the Eagle granodiorite body, and it and apophyses and dykes from it have cut and metamorphosed the Nicola rocks. The ore, consisting of pyrrhotite, pyrite, chalcopyrite, small amounts of galena and sphalerite, and, in places, magnetite, replaces beds of limestone or their contact-metamorphosed parts consisting of garnet, epidote, and amphibole. In even those parts of the ore that consist of massive sulphides, however, the amount of chalcopyrite is not usually great, and the gold and silver values, although significant, are not high. The area is largely covered with drift, and exploratory work to date has not been sufficient to determine the size of the limestone bodies or the associated mineral deposits. It is, however, clear that the latter, though they may replace a limestone bed across its entire width, are more generally confined to a band along the hanging-wall side. Two samples were taken in 1929 by the Resident Engineer in a stub drift off the bottom of the shaft sunk on the Liverpool claim. One of these, across 6 feet, returned 0·06 ounce in gold and 0·50 ounce in silver a ton, and 1·26 per cent copper. The other, a general sample from the face of the drift, assayed: 0·14 ounce in gold and 0·60 ounce in silver a ton, and 1·31 per cent copper. This ore consists of massive pyrite containing streaks of chalcopyrite.

GRASSHOPPER MOUNTAIN GOLD DEPOSITS

Grasshopper Mountain, which lies in the angle between Lawless Creek and Tulameen River, is traversed by the broad zone of sheared Nicola rocks that follows along the northeast side of the Eagle granodiorite body. The southwest half of the mountain is, however, composed of rocks of the Olivine Mountain ultrabasic body. Mineral deposits occur within the sheared Nicola rocks as quartz veins or as breccia zones in which quartz veinlets constitute up to 75 per cent of the vein matter. The wall-rocks of most of these are carbonatized lavas, but in the Sunrise group they are argillite and limestone. The principal metallic mineral is pyrite, but chalcopyrite occurs in small amounts and, more rarely, galena, sphalerite, and hematite. Gold is present, but does not appear to be associated particularly with these minerals, and much of the vein is barren of precious metals. Much of the gold occurs in pockets in which native gold and a telluride mineral, probably petzite, can be seen. It seems probable that the gold-bearing solutions were introduced separately from those that deposited the quartz and sulphides. On the Sunrise claim gold seems to be associated with banded, comb quartz, which is apparently younger than the high-temperature, glassy quartz forming most of the veins. It is, therefore, probable that the gold in all the deposits is of somewhat later origin than the veins themselves and the sulphides they carry.

Rabbitt Property (25)

References: Ann. Repts., Minister of Mines, B.C.: 1938, special report; 1940, p. 60.

Location and History. The Rabbitt property, owned by P. and T. Rabbitt of Tulameen, is at an elevation of about 4,000 feet on the northeast slope of Grasshopper Mountain overlooking Lawless Creek at a point a mile from its junction with Tulameen River. It was located in 1938 by the Rabbitt brothers, who the same year shipped 5 tons that returned $724 in gold. In the following year Grasshopper Mines, Limited, was incorporated to work the property, and in 1940, 1,361 tons of ore was mined from which 924 ounces of gold and 514 ounces of silver were recovered.

Geology. The mineral deposits occur in volcanic rocks of the Nicola group, which are traversed by a wide, intensely sheared zone that follows the east margin of the Eagle granodiorite. The situation is further complicated on the Rabbitt property by the intrusion of the Olivine Mountain ultrabasic body, the contact of which lies about a mile southwest of the workings. On the property are several quartz veins with a general northerly strike and a steep dip. The veins are composed of glassy quartz, and vary in width from a few inches to 6 feet, averaging 3 or 4 feet. They are not composed entirely of quartz, the wider sections becoming lodes rather than veins and consisting rather of highly brecciated wall-rock cemented with quartz, which constitutes around 75 per cent of the vein material. The volcanic rock forming the fragments has been largely carbonatized, and a similar carbonatization extends into the walls of the veins for distances up to 10 feet. The quartz carries free gold, an undetermined telluride mineral, chalcopyrite, pyrite, galena, and sphalerite, but all in very small amounts, and much of the veins is quite barren.

Adits and a deep surface cutting have developed a section 85 feet long of the vein on which most work has been done. It was from this section that most of the ore had been shipped. At the northern end of this section the vein swings from north 45 degrees east to about north 25 degrees west for about 275 feet. It varies from 1 foot to 6 feet in width, but is reported to be low grade where it is widest. Several other veins have been exposed by open-cuts, but the average values in them are low.

Old Glory Group (25)

The Old Glory group, owned by R. J. Marks of Tulameen, lies just to the southeast of the Rabbitt property and at about the same elevation.

At the time of the writer's visit in 1939 the showing had only recently been discovered, and the only exposure was in a single small open-cut. This was made in a zone of crushed quartz and carbonatized volcanic rock about 10 feet wide. Apparently a vein or breccia zone, similar to those on the properties described above, has been crushed as a result of more recent fault movements. No mineralization of importance was seen.

Ace Group (24)

Reference: Minister of Mines, B.C., special report, 1938.

The Ace group is owned by the Hamilton brothers of Tulameen. It is nearly on the summit of Grasshopper Mountain at an elevation of about 4,800 feet, and is about a mile nearly due west from the Rabbitt property and near the contact with the Olivine Mountain ultrabasic body.

The mineral deposits on the Ace group are very similar to those on the Rabbitt property. Five roughly parallel quartz veins that strike northwest and dip steeply southwest are exposed within a distance of 200 feet. Open-cuts have been excavated in all these veins, and some have been explored for several hundred feet. They vary in width from a few inches to 4 feet and, as on the Rabbitt property, are in part formed of rock breccia cemented by quartz. Metallic minerals are pyrite, chalcopyrite, hematite, pyrrhotite, the silver-bearing telluride petzite, and free gold, but are usually scarce. The values are evidently in the last two minerals, for samples taken by the Resident Engineer in which neither could be seen ran uniformly a trace in gold. Some small pockets of rich ore have, however, been found.

Marcotte Claims (24)

Reference: Minister of Mines, B.C., special report, 1938.

Louis Marcotte of Tulameen and associates own two claims immediately south of the Ace group. Geological conditions are the same as on the Ace, and a vein similar in appearance and mineral content to those on that group has been traced by open-cuts for 125 feet. It is as much as 7 feet wide and averages about 3 feet. Some 300 feet to the west of this vein is another about 5 feet wide that consists of barren-looking quartz..

Sunrise Group (Max Hanson's Claims) (27)

Reference: Minister of Mines, B.C., special report, 1938.

The Sunrise group of four claims was leased by Max Hanson in 1938, and was being worked by him in 1939 at the time of the writer's visit. It is on the southern slope of Grasshopper Mountain, and extends from the Tulameen road to the southern boundary of the Marcotte and Ace groups.

The principal workings are some 400 feet vertically above the road. They consist of three open-cuts and a short adit, all driven on a single quartz vein striking north 15 to 20 degrees west and dipping steeply southwest. In all, from 200 to 250 feet of the vein is exposed. It varies in width from 1 inch to 23 inches, except at one place where it is intersected by a cross fissure and is 4 feet wide. The quartz is quite different from that of the other claims on Grasshopper Mountain. It is well banded, and was evidently deposited after the carbonatization of the wall-rock. Many of the rock fragments caught in the vein have a coating 2 or 3 millimetres thick of some iron-bearing carbonate. These coated fragments have been surrounded by quartz and, in at least one instance, a small veinlet of quartz extends from the main mass through the carbonate coating into the rock of the fragment itself. The wall-rock in the upper open-cuts is slaty argillite, whereas that at the lower workings is slaty argillite and interbedded limestone. The vein is sparingly mineralized with pyrite, chalcopyrite, and a little galena, sphalerite, and free gold. The gold values are erratic, but in places high, and some small shipments of high-grade ore have been made by the lessees.

Britton Claim (28)

References: Ann. Rept., Minister of Mines, B.C., 1937, pt. D, special report by M. S. Hedley.

The Britton claim, owned by William Britton, is on the south side of Tulameen River about 300 yards below Lawless (Bear) Creek. The showing consists of a mineralized shear zone 10 to 15 feet wide in argillite of the Nicola group close to its contact with andesite lava. The shear zone is traversed by irregular stringers of quartz and calcite carrying free gold. No work has been done for some time.

COPPER DEPOSITS OF OLIVINE MOUNTAIN AND VICINITY

The properties grouped together under this heading all occur in or near the Olivine Mountain ultrabasic body. Within this body are two sets of shear zones, one set striking north and the other east. The north-striking set contains quartz veins or groups of quartz stringers mineralized with pyrite, chalcopyrite, galena, and sphalerite. The east-striking set carries chalcopyrite in minute veinlets following the shear planes, or as disseminated grains within the body of the rock. The latter type of mineralization, which seems to have its origin within the ultrabasic magma, is the more important on the top of Olivine Mountain, whereas the former is more important farther north.

Near the northern end of the ultrabasic body shear or breccia zones that have involved both the intrusive rock and the intruded members of the Nicola group follow both east and west contacts. Both zones carry deposits of pyrite and chalcopyrite, but none of the deposits shows much high-grade copper ore, and precious metal values are uniformly low. Further exploration, however, might prove them to be of considerable size.

Jenson's Claims (33)

References: Ann. Repts., Minister of Mines, B.C.: 1917, pp. 208-210; 1918, p. 214; 1917, p. 172. Camsell, 1913, pp. 159, 160.

Several claims have been staked by Andy Jenson of Tulameen covering parts of the summit and west, south, and east slopes of Olivine Mountain. The exploratory work is confined to open-cuts and areas of stripping. The claims are all underlain by members of the Olivine Mountain ultrabasic body. These ultrabasic rocks have been intersected by two sets of shear zones, one striking northerly and the other easterly. In the northerly set are small stringers of veins of quartz, sparingly mineralized with pyrite, chalcopyrite, and pyrolusite. The easterly striking shear zones are not as strong as those of the other set, and carry no quartz, but chalcopyrite occurs as fine stringers in the cleavage planes of the shear zone and as disseminated grains through the mass of the adjacent rock. Some of the disseminated chalcopyrite occurs embedded in crystals of pyroxene, and is probably a primary constituent of the rock, possibly of late, deuteric origin. None of this ore is high grade, although general samples carrying as much as 2 and 3 per cent copper have been obtained. Precious metal values are uniformly low.

Sootheran's Claims (31)

Reference: Ann. Rept., Minister of Mines, B.C., 1937, pt. D, special report by M. S. Hedley.

Garnet Sootheran of Tulameen owns two claims on the south side of Tulameen Canyon, about a quarter mile below the pack-horse bridge near the mouth of Britton (Eagle) Creek. Concerning this property Dr. Hedley states:

> "The showing is a quartz vein-zone in peridotite, strike N10° W, dip steep westerly. It strikes right up the hill but is obscured by slide rock and is opened up in only one place. In this open-cut it is 6 feet wide, containing a total of 2 feet of quartz (the rest being country rock and sheared oxidized material); the quartz is lightly mineralized with pyrite, galena, chalcopyrite, and sphalerite, and in a 4-inch band on the east wall is a fair quantity of galena. Three samples chipped across sections of the main quartz and schistose material each returned traces in gold and a fraction of an ounce in silver. . . . . . . This mineralization is interesting in spite of these low values."

Britton Mountain Claims (30)

References: Ann. Repts., Minister of Mines, B.C.: 1908, p. 132; 1913, p. 234; 1917, p. 208; 1937, pt. D, special report by M. S. Hedley. Camsell, 1913, p. 160.

Britton Mountain lies in the angle between Britton (Eagle) Creek and Tulameen River. It is crossed by a band of sheared Nicola rocks from ½ to 1 mile wide between the Eagle granodiorite on the west and the Olivine Mountain ultrabasic body on the east. The claims, which were staked originally in 1899 and restaked by William Britton in 1937, cover a zone of brecciation following along the west contact of the ultrabasic body. This brecciation has involved both the ultrabasic rocks and the intruded and metamorphosed Nicola group, and the breccia so produced has been mineralized with pyrite, chalcopyrite, and magnetite. Exposures are not sufficient to determine either the size of the breccia zone or the extent of the mineralization. Indeed most of the earlier work has been done on a bed of pyritized white quartz schist, paralleling the breccia zone, from which Camsell failed to obtain any precious metal values.

Bonanza Group (26)

Reference: Ann. Rept., Minister of Mines, B.C., 1928, p. 268.

The Bonanza group is owned by Frank Bailey of Tulameen, and occupies a similar position on the east side of the Olivine Mountain ultrabasic body to the Britton Mountain claims on the west. Here several open-cuts have been made in a breccia zone some 200 feet wide that follows the contact between the ultrabasic body and the Nicola group. In the cuts on the west side, nearest the ultrabasic intrusion, the crushed rock has been mineralized with pyrite, chalcopyrite, and calcite.

WHIPSAW CREEK LEAD-ZINC DEPOSITS

A group of properties on either side of Whipsaw Creek lies in the belt of shearing that follows the west side of the Eagle granodiorite, the same as that in which the Grasshopper Mountain deposits occur. The host rocks consist of chlorite-sericite and quartz-mica schists, metamorphosed members of the Nicola group. These, and particularly the quartz-mica schists, are cut by many granitic dykes and sills. This assemblage has been fractured in such a way as to produce narrow, lenticular zones of breccia. These zones have been re-brecciated, and have been mineralized with quartz, carbonate (ankerite and calcite), and the sulphides pyrite, sphalerite, and galena, as well as with small amounts of chalcopyrite, and some gold and silver. The breccia-zones are narrow and discontinuous, and mineralization is generally restricted to certain parts of them, rarely across widths of more than a few inches.

On the Marion claim the conditions are a little different. The deposits there occur in limestone beds or lenses near the Eagle granodiorite and are of the contact metamorphic type. In addition to the sulphides already enumerated, pyrrhotite and magnetite are common and some molybdenite was seen. As in most contact metamorphic deposits these are quite irregular in outline and mineral content, and none has as yet proved to be of commercial size and grade.

S. and M. and Copper Basin Groups (39)

References: Ann. Repts., Minister of Mines, B.C.: 1915, pp. 245, 246; 1920, p. 160; 1927, pp. 251-253; 1928, p. 264; 1929, p. 276; 1930, p. 214. Camsell, 1911, p. 123. Cairnes, 1922, pp. 119, 120.

Location and Ownership. The S. and M. and Copper Basin groups adjoin each other and there is some doubt as to the area occupied by each. As the writer was not certain on which of the two groups some of the workings were, they are described together. The properties are on the north side of

Whipsaw Creek about 12 miles from its junction with Similkameen River, and are accessible by a narrow road along which a car may be driven precariously. The claims extend from the creek up the hillside to an elevation of more than 5,700 feet. The Copper Basin group is near the creek and the S. and M. group above it.

Geology. The showings are in the belt of sheared Nicola volcanic and sedimentary rocks along the east side of the Eagle granodiorite body. These rocks, particularly the argillite and tuffaceous argillite members, have been metamorphosed to micaceous schists, and in places intruded by many dykes and sills of granitic rocks. The whole complex has been fractured and mineralized with various sulphides. The fracture zones are small and irregular and their history complicated. At least six distinct stages of development can be recognized: (1) silicification and pyritization by solutions clearly emanating from the nearby intrusions; (2) brecciation along restricted and irregular lens-shaped zones, producing angular fragments an inch or so across; (3) fragments mineralized and cemented with ankerite and with ore minerals. In places little or no brecciation is apparent, and mineralization followed closely on silicification; (4) further brecciation of the vein material, followed by cementation of the fragments so produced with well-banded, comb-like ankerite; (5) and (6) entire complex once again brecciated and cemented with dolomite or, in part, by calcite.

Description of Workings. The main workings are on the S. and M. group where several open-cuts and short adits and one long adit have been driven on small lenses of ore, the long adit being the only important working still open. It is 570 feet long, with a number of short crosscuts on each side totalling 415 feet. In this working are several showings consisting of lenses of quartz and carbonate carrying galena, sphalerite, and minor amounts of pyrite and chalcopyrite. One of these lenses is 6 feet long and 1 foot wide, and another 40 feet long and about 6 inches wide. On the dump are a few tons of ore that runs about 10 per cent zinc, 1 or 2 per cent lead, and 3 or 4 ounces a ton in silver. The wall-rocks for these deposits are mainly chlorite schist derived from various types of volcanic rocks.

Below the road, on what may be ground owned by Copper Basin Mines, Limited, are four adits in talc and mica schists cut by granitic dykes and sills. One of these adits, 40 feet long, follows a fracture zone from 1 to 4 feet wide that is irregularly mineralized with sphalerite, galena, pyrite, and a little chalcopyrite. Similar but smaller showings occur in some of the other adits. There is a possibility that the gold values may be better in the deposits in the mica schist, as one picked sample from a 6-inch stringer returned 0·44 ounce a ton in gold and 8·4 ounces a ton in silver.

Marion Group (39)

References: Same as for S. and M. group.

The Marion group adjoins the S. and M. group to the west, and the two were grouped together for some time as the property of Pacific Slope Mines, Limited. The contact between the Eagle granodiorite and the Nicola group passes across the claims. The Nicola rocks here consist of talc-chlorite schists and intercalated small beds or lenses of limestone. Cairnes (1922, p. 120A) describes the occurrences as follows:

> "The ore deposits are associated with limestone beds and are of contact metamorphic origin. A variety of mixed sulphides occur, including pyrrhotite, pyrite, sphalerite, galena, and molybdenite. Magnetite is also conspicuous. The gangue includes calcite and quartz, together with an abundance of garnet, epidote, pyroxene, and other lime silicates. . . . .

"The occurrence of the ore is, as is characteristic of this type of deposit, very irregular. The total zone of mineralization includes a belt 300 to 400 feet wide adjoining the granodiorite. Only in relatively small sections of this, however, is mineralization sufficiently heavy to be of economic importance and even in these the values are low. The zone of mineralization follows the intrusive contact for a mile or more and is confined chiefly to the different limestone beds within this belt. The orebodies, even within these beds, are very irregular in outline and variable in mineral composition."

Lucky Pair Group (40)

References: Ann. Repts., Minister of Mines, B.C.: 1915, p. 247; 1920, p. 160; 1928, p. 264.

The Lucky Pair group is owned by Chas. Day of Princeton, and is situated about three-quarters mile due south from Whipsaw Creek opposite the S. and M. group. It lies just over the summit of a low saddle and is reached by a good trail about $1\frac{1}{4}$ miles long. The showings consist of three or more strong shear zones in Nicola tuffaceous rocks now largely altered to chlorite schist. The main shear zones have been explored by adits, but only one of these is still open. This adit is 225 feet long, driven along a zone of fracturing striking north 30 degrees west and dipping 75 degrees northeast. The zone is from 2 to 5 feet wide, and the wall-rock on each side has been silicified and is traversed by quartz veinlets. The fractured zone itself consists of a band of gouge on each wall between which the rocks have been thoroughly brecciated, silicified, and carbonatized, and the fragments, in part, cemented with quartz and carbonate. Pyrite, chalcopyrite, galena, and sphalerite occur unevenly distributed along the zones. The best mineralized parts are usually confined to a foot or so along the hanging-wall, but are formed in places along the foot-wall. A sample taken across 18 inches of one of the ore shoots was reported by the Resident Engineer to have assayed: gold, 0·2 ounce a ton; silver, 0·6 ounce a ton; copper, nil; lead, trace; zinc, 3·0 per cent.

PASAYTEN CAMP

Still another group of properties occurs where the belt of shearing following the Eagle granodiorite is crossed by Similkameen River near the mouth of Pasayten River. The deposits consist of silicified shear zones in part occupied by quartz veins and mostly containing the same suite of ore minerals as the deposits on Whipsaw Creek. The principal metal contained in the deposits is copper, but zinc may be important. Gold varies in amount, but is usually fairly low. It is highest in the Silver Moon group where arsenopyrite occurs. Apart from a little high-grade gold ore from this property, no ore has been shipped from this camp.

Red Star Group (71)

References: Ann. Repts., Minister of Mines, B.C.: 1901, p. 1173; 1917, p. 208; 1920, p. 160; 1921, p. 179; 1923, p. 192; 1927, pp. 249, 250; 1928, p. 265; 1938, pt. D, special report.

Location and Ownership. The Red Star group of six claims is owned by Charles Bonnivier and Gus Pouwels of Princeton, and is situated on the west side of Similkameen River about 2 miles above the mouth of Pasayten River. It is an old property, and many of the workings are so caved that a full examination was not possible.

Geology. The showings are in the zone of sheared Nicola rocks along the east border of the Eagle granodiorite. Here they consist of chlorite schist and quartz-sericite schist that have probably been derived from green andesite lava and impure tuff. Locally these rocks are all reduced to highly fissile schist with a persistent strike and dip.

The history of the mineralization is apparently involved and has resulted in four types of ore: (1) general pyritization of the silicified and crushed schists, resulting in much rusty stain but not in itself of any probable value; (2) further silicification of the fracture zones, resulting in the production of white, sugary quartz carrying pyrite, sphalerite, chalcopyrite, and galena; these deposits are more than 3 feet wide in places, and are the only ones of possible commercial value; (3) small but persistent and distinct veins of white quartz, nowhere more than 12 inches wide, fairly well mineralized with pyrite, chalcopyrite, sphalerite, and galena; and (4) small, highly irregular pods or lenses, seldom more than a few feet long and 18 inches wide, of glassy, high-temperature quartz; these pods carry occasional patches or blobs of pyrite and chalcopyrite, but not enough to constitute ore.

It seems as if the glassy quartz lenses were the first formed, for they have been more shattered by movements along the fissures than either of the other types of deposit, although these, too, have suffered some fracturing.

The mineralogy is comparatively simple, nor did spectrographic analysis reveal the presence of any unusual elements. There was a trace of cadmium in all samples and of molybdenum in one, but neither element is present in important amounts. Four samples taken at different times by the Resident Engineers assayed as follows:

Sample	Gold	Silver	Copper	Zinc	
	Oz. a ton	Oz. a ton	Per cent	Per cent	
(1)..................	0·06	7·3	17·0	4·0	Grab from dump of caved adit
(2)..................	0·14	5·7	19·0	2·5	Grab from dump of caved adit
(3)..................	0·04	1·0	0·8	18·0	Drift in adit No. 3
(4)..................	0·04	2·0	5·5	....	Outcrop of same shear zone as (3)

Workings. The workings consist of three adits, caved some distance in, and two caved at the portal. Adit No. 1 is driven along an irregular quartz vein 6 to 12 inches wide, mostly well mineralized with sulphides. It is blocked about 100 feet from the portal. Adit No. 2 is driven as a crosscut for some 400 feet. About 100 feet from the portal a short drift has been driven along a highly pyritized zone and at about 230 feet a longer drift has followed the downward extension of the vein in No. 1 adit. Much of this drift is in badly crushed ground, and close timbering has hidden long sections of the walls. It is caved some 200 feet from the crosscut intersection, but, where visible, conditions appear to be much as in the drift above. There a zone of crushed rocks, developed along a strong fault, is mineralized, silicified, and followed by a quartz vein with a maximum width of 12 inches. This drift is connected with the adit above by a raise driven on the vein.

Adit No. 3 is driven as a long crosscut. It is caved towards the face, but is reported not to have reached the downward projection of the main vein in Nos. 1 and 2 adits. The crosscut, however, intersected four, small, high-temperature veins or lenses and a strong crushed zone 5 feet wide, which was followed by a drift for 60 feet. This zone carries sugary quartz and sulphides, mainly confined to two bands each a foot wide on the foot- and hanging-walls.

Roche and Pasayten Claims (72)

References: Ann. Rept., Minister of Mines, B.C., 1927, p. 250. Cairnes, 1923, p. 77A.

The Roche and Pasayten claims are owned by John Crowley of Princeton, and lie on the northwest side of Similkameen River nearly opposite the mouth of Pasayten River. Development consists of an adit 168 feet long, another 25 feet higher and 130 feet long, and some shallow open-cuts and shafts. The showing consists of a narrow quartz vein following a fissure in green to grey chlorite and sericite schist. The original rocks were volcanic members of the Nicola group, consisting of tuff, lava, and argillaceous tuff. In addition to the alteration induced by the shearing, small spots of ferruginous carbonate are developed freely through the schist in the vicinity of the vein. The vein itself is from 2 to 12 inches wide, and carries pyrite and chalcopyrite as its principal primary metallic constituents. The presence of native gold and a telluride is reported but not confirmed. Two samples taken by the Resident Engineer assayed as follows: gold, 0·14 ounce a ton; silver, 0·60 ounce a ton; copper, 4·5 per cent; and gold, 4·14 ounces a ton; silver 1·8 ounces a ton. The first was a picked sample from the lower adit, and the second a sample of sorted ore from the upper adit.

The structure of the vein is complicated by post-mineral faults that have offset it in places and, in the lower adit, have followed the vein and shattered it into a series of lenses.

Knobhill Claim (70)

References: Ann. Repts., Minister of Mines, B.C.: 1920, p. 159; 1921, p. 179; 1923, p. 192; 1927, p. 250. Cairnes, 1923, p. 77A.

The Knobhill claim is owned by John Bowman of Princeton and lies on the northwest side of Similkameen River about 1,000 feet higher in elevation than the Red Star group and about 1½ miles southwest of it. The principal workings consist of a crosscut adit 157 feet long and some open-cuts. The showings occur in the general zone of sheared Nicola rocks along the east margin of the Eagle granodiorite body and only a few hundred feet from it. Shearing is accentuated along two zones, one about 10 and the other 6 feet wide. These zones have been to some extent silicified with sugary quartz, which is accompanied by abundant pyrite and some chalcopyrite, all in distinct grains or crystals. The larger of the two zones crosses the adit not far from its portal, and is also exposed in an open-cut above. A peculiar feature of this zone is a centrally located, bluish layer 6 inches or so wide. This layer is not itself particularly well mineralized, but the most massive sulphides in the zone occur immediately below it. The blue colour is apparently imparted by a thin coating of chalcocite on the other sulphides. Assays from the massive pyrite zone below the blue layer are reported to have returned 4 per cent copper. An assay made by the Department of Mines, Ottawa, of a specimen from the blue band itself showed no gold, 4·20 per cent copper, and 23·57 per cent iron.

Silver Moon Group (73)

Reference: Ann. Rept., Minister of Mines, B.C., 1938, p. D24.

The Silver Moon group, owned by E. N. Fredling and Alex Wagenstein of Princeton, is in Similkameen Canyon and extends downstream for half a mile from 400 feet below the mouth of Copper Creek.

The showings consist of shear zones in volcanic rocks and less commonly argillite of the Nicola group. These shear zones are from a few inches to several feet wide and are generally pyritized. In addition, cleavage planes are commonly followed by quartz stringers that may be so closely spaced that the assemblage resembles a sheeted zone. Three sets of these shear zones were recognized. The most important has a northerly strike and is vertical. Quartz stringers are numerous and occur both following and crossing the schistosity, so that in places they form a reticulated zone. A second set strikes north 70 degrees west and dips 60 degrees northeast. With rare exceptions these zones are barren of quartz stringers. A third, flat-lying set intersects the other two and is commonly followed by quartz stringers, but less abundantly so than in the first set.

All quartz stringers are in places mineralized with arsenopyrite, and, to a less extent, with sphalerite, galena, chalcopyrite, and pyrite. Native gold can occasionally be seen as tiny veinlets cutting the arsenopyrite, but values on the whole are low. Three samples taken by the Resident Engineer assayed nil, 0·18 ounce a ton, and 32·76 ounces a ton in gold respectively. He points out that gold occurs principally in the flat, mineralized shears, which, unfortunately, are neither numerous nor large.

PROPERTIES ON SIWASH CREEK

The lower part of Siwash Creek, which joins Hayes Creek near Jellico on Kettle Valley Railway, flows over rocks of the Osprey Lake granodiorite body. Just north of Tepee Creek the granodiorite has been intruded by a stock-like body of granite that has been called the Siwash Creek body and correlated with the Otter intrusions. This body is clearly younger than the Osprey Lake granodiorite, and is believed to be a member of the Otter intrusions of post Lower Cretaceous but pre-Miocene age. Apart from a few small dykes of Miocene age or younger, the Otter intrusions are the youngest known in the area, and it is rather surprising, therefore, to find that not only is a large part of the Siwash Creek body profoundly altered by hydrothermal solutions but that mineralized quartz veins occur along fractures in it. On Trout Creek, some 8 miles east of the Siwash Creek body, another similar stock, known as the Trout Creek body, has profoundly altered and mineralized the granodiorite on its eastern margin, and it is clear that its parent magma contained the necessary mineralizing solutions. It seems most probable, therefore, that the Siwash Creek stock was consolidated before the underlying magma, and that the alteration of the exposed granite and the mineralization in it and in the adjacent older rocks may thus have been affected by mineralizing solutions escaping from this magma. It is certain that the mineralization took place during Upper Cretaceous or early Tertiary time.

The Siwash Creek deposits consist of quartz veins following fractures in the Osprey Lake granodiorite body, the Siwash Creek granite body, and, in one instance, in volcanic rocks of the Nicola group near the granodiorite contact. These quartz veins are mineralized with pyrite, sphalerite, and galena, and the latter mineral sometimes carries high silver and substantial gold values. Some of the silver may be carried in argentite and tetrahedrite, which have been reported in places. Chalcopyrite and arsenopryite are rare. One property differs from the others in that the principal metallic mineral is specular hematite. Development work to date has failed to reveal sizable ore shoots, although a few small shipments of high-grade ore have been made.

Mabel Claim (13)

Reference: Ann. Rept., Minister of Mines, B.C., 1927, p. 247.

The Mabel claim, owned by F. Bailey and G. Price of Jellico and Princeton, is on Siwash Creek some 8 miles above its junction with Hayes Creek and just above Tepee Creek. Workings consist of open-cuts, shallow shafts, and short adits, all but the first being caved and inaccessible. The showings consist of strong mineralized shear zones in granodiorite, with a general easterly strike and a steep dip. They occur well within the Osprey Lake intrusive body, but not far from the contact of the younger Siwash Creek body of the Otter intrusions. Several large dykes related to the Siwash Creek body occur near the showings.

The shear zones carry quartz veins, and the crushed granitic rock is abundantly altered to chlorite. The principal metallic mineral is specular hematite, which occurs as veinlets and patches and is accompanied in places by a little pyrite and chalcopyrite. One such mineralized zone is exposed on the west side of Siwash Creek opposite the cabin. It is 10 feet wide, is exposed for about 50 feet, and contains some nearly massive hematite that is said to carry gold. A spectrographic examination revealed a trace of manganese.

Iron Duke and Fisher Maiden Claims (13)

These claims are on Siwash Creek about half a mile above the Mabel claim and may form part of the Mabel group.

The showings consist of mineralized shear zones in granodiorite, and are similar to those on the Mabel claim. Here, too, Otter intrusive dykes occur. The shear zones are silicified and mineralized with hematite, but more pyrite and chalcopyrite can be seen than on the Mabel claim, and in one place the shattered granodiorite shows small amounts of copper carbonate over an area of 30 square feet or more.

Claremont Group (possibly Argentite) (12)

References: Ann. Repts., Minister of Mines, B.C.: 1917, p. 206; 1927, p. 248.

The Claremont group is on Siwash Creek about a mile north of Tepee Creek. Several adits, now caved, have been driven into the steep bank of the main creek and have exposed several mineralized shear zones in the southern margin of the Siwash Creek body of the Otter intrusions, which in this vicinity have been profoundly altered to a soft, kaolin-sericite-quartz-carbonate rock. The shear zones have a general easterly strike and steep dips. They are in part silicified and carry considerable pyrite. Sphalerite and galena are also present, but very little could be seen. The galena is apparently argentiferous, for a selected sample of the mineral taken by the Resident Engineer assayed 0·10 ounce a ton in gold and 269·8 ounces a ton in silver. Apparently, however, such high-grade material is scarce, for in spite of the fact that between 400 and 500 feet of underground development has been done, no substantial shipments have been made. The writer found a number of fine seams of fluorite occupying joints in the altered granite.

Renfrew Group (11)

References: Ann. Repts., Minister of Mines, B.C.: 1925, p. 210; 1927, p. 247; 1928, p. 264; 1929, p. 277.

The Renfrew group, formerly known as the Snowstorm, consists of the E.J.A., B.H., H.J.B., and other claims, and is owned by Frank Barber *et al.* of Princeton. It is on Siwash Creek about 1½ miles above Tepee Creek. More development work has been done on these showings than on any others in the vicinity, and in 1926, 27 tons were shipped by pack-horse 9 or 10 miles to Jellico Siding. From this 3 ounces of gold, 3,379 ounces of silver, and 1,578 pounds of lead were recovered.

The deposits consist of fairly strong mineralized shear zones from a few inches to 5 feet wide striking northeasterly across granitic rocks of the Siwash Creek body of the Otter intrusions. This body has been profoundly altered in the vicinity of the claims to a soft, watery green or buff rock, the only recognizable original constituents being rounded crystals of quartz the size of peas. The sheared and altered rock has been silicified and well banded, and crystalline vein quartz, with both comb structures and vugs, has developed along the shear zones. Both the veins and silicified areas are generally well mineralized with sulphides, the following being observed: pyrite, sphalerite, galena, chalcopyrite, and arsenopyrite. Tetrahedrite and argentite are reported, but were not seen by the writer. In addition to the normal constituents of the minerals mentioned above, the spectrograph revealed traces of cadmium, manganese, antimony, and tin. Several of these veins have been explored by four or five adits, most of which are now caved. The following samples were taken by the Resident Engineer.

Gold	Silver	Copper	Zinc	Lead	—
Oz. a ton	Oz. a ton	Per cent	Per cent	Per cent	
Tr.	1·6	1	13·4		Across 6-inch vein, No. 2 adit
Tr.	1·8	Tr.	24		2½-foot vein, No. 2 adit
Tr.	1·6	1·4	16·2		14 inches of ore from open-cut
Tr.	5	0·7			3 feet of ore from open-cut
Tr.	2	0·6	2·4	Nil	2 feet of ore in No. 1 adit
0·44	20·4		16·0	5	2 feet of ore in No. 1 adit
0·20	63			24	Selected samples of galena ore

Blue Stone Claim (11)

Reference: Ann. Rept., Minister of Mines, B.C., 1927, p. 248.

The Blue Stone claim, owned by F. Barber and W. Cunningham of Princeton, lies on Siwash Creek about three-quarters mile northwest of the Renfrew group. The showing consists of a quartz vein, much like those of the Renfrew, in an easterly striking shear zone cutting the Siwash Creek granite body. The vein is 1 inch to 4 inches wide where seen, and is mineralized with tetrahedrite, pyrite, and some galena and sphalerite. Exploratory work consists of an open-cut and an adit, now caved, driven 50 feet below it.

El Paso Group (10)

The El Paso group is on the northeast side of Siwash Creek some 3 miles north of the Renfrew group. Unlike the properties on Siwash Creek already described, all of which occur in intrusive bodies, the deposits of the El Paso group are in volcanic rocks of the Nicola group near the northwest contact of the Osprey Lake granitic body. The workings seen were two adits, both caved, and some open-cuts. These have exposed one or more veins of banded quartz, carrying arsenopyrite, pyrite, sphalerite, and galena. The walls of the veins consist of crushed and carbonatized volcanic rocks and the quartz veins themselves have been brecciated and healed with veinlets of carbonate. One open-cut exposes a small dyke of the Otter intrusions that has been much brecciated and later healed with barite. No sulphides could be seen in association with the barite. Manganese is the only element revealed by the spectrograph whose presence could not be inferred from the mineralogy.

GRASSHOPPER MOUNTAIN CHROMITE DEPOSITS (29)

References: Ann. Repts., Minister of Mines, B.C.: 1917, pp. 27, 210; 1918, p. 214. Camsell: 1913, pp. 168-170; 1918, p. 29. Cairnes, 1922, p. 96. Poitevin, 1923, pp. 84-101. Cairnes, 1929, pp. 185, 186. Stevenson, 1940.

As is true of so many ultrabasic bodies, those of Olivine Mountain in places carry chromite. The occurrence of this metal is largely restricted to the southern slopes of Grasshopper Mountain, where thirty-two claims, known as the Girl group, were staked by Wm. M. Shaw, of Tulameen, and associates. The chromite occurs as disseminated grains and small veinlets within more or less restricted zones, and was evidently deposited before the final consolidation of the magma, as even when the chromite veinlets follow small fractures in the peridotite, these are, in turn, cut by dykelets of fine-grained peridotite a fraction of an inch wide.

Even the best zone found to date has, unfortunately, proved neither large enough nor rich enough to warrant mining for chromite. However, the clearly demonstrated association of platinum with the chromite has more than once aroused interest. In the first place the very considerable amount of platinum recovered in the placer deposits evidently had its source in the ultrabasic rocks. Also, small grains of platinum can occasionally be seen in or near chromite veinlets, and samples taken of such veinlets and adjacent rock commonly reveal substantial amounts of platinum when assayed. Occasional assays as high as 0·35 ounce a ton of platinum, and even higher, have led to repeated unsuccessful attempts to find areas with a sufficiently high average content of platinum to permit profitable extraction. There is no doubt that both the chromite and the platinum originated in the ultrabasic magma, nor that the two were deposited at about the same time and in the same places. No significant amount of platinum has been found except in rocks carrying chromite, but samples of chromite may, on the other hand, carry little or no platinum.

MISCELLANEOUS DEPOSITS

Earncliff Claim (4)

The Earncliff claim was staked in 1938 by Matilda Keeling and associates. It is on Quilchena Creek about 1½ miles above Pothole Creek. The showings occur in a short adit driven along a crushed zone in a small granodiorite stock near its western contact with rocks of the Nicola group. This crushed zone has no definite trend. It consists of broken and decomposed granite partly cemented with gypsum, and in places carries a little quartz and pyrite.

Copper King Group (14)

The Copper King group is on the eastern boundary of Princeton map-area about 9 miles south of the northeast corner. A small creek flowing east towards Okanagan Lake has here cut a small canyon in a body of light-coloured granodiorite. The showings are in the north wall of this canyon, three-quarters mile in from the western intrusive contact. A deep open-cut has been driven for some 30 feet along a steep-dipping quartz vein. The face of the open-cut is a vertical wall of rock 20 feet high, and from it a winze, now flooded, has been sunk. The vein consists of white, ribbon quartz carrying bunches and streaks of chalcopyrite. It is 3 to 4 feet wide, except in the face of the open-cut at the top where little or no quartz can be seen. The granodiorite on the walls of the vein has been partly silicified, and is mineralized with chalcopyrite, pyrite, and streaks of molybdenite.

Fifty feet lower down the bluff below the open-cut a crosscut adit has been driven for 70 feet. At that point it encountered the same fractures as that in the open-cut above. This was followed into the hill by a drift for 60 feet. A quartz vein varying from an inch or two to 2 feet in width occupies the fracture, and in places carries massive pyrite and a little chalcopyrite. The wall-rocks, as in the open-cut above, are altered and mineralized, and scarcely a piece of rock on the dump but carries disseminated grains or fine veinlets of chalcopyrite. Many of them also contain an appreciable amount of molybdenite, although this mineral was not observed in the vein quartz. No unexpected constituents were revealed by the spectrograph. It appears that the alteration and mineralization of the granodiorite was affected by different and probably earlier mineralizing solutions than those forming the quartz vein. The vein, though locally well mineralized, is small, and could hardly be expected to provide sufficient ore for a profitable base metal operation. The widespread mineralization in the wall-rock, however, suggests the possibility of a very considerable tonnage of low-grade ore, and deserves further investigation.

Kathleen Mountain Property (15)

The Kathleen Mountain property is at an elevation of some 5,000 feet on the east side of upper Trout Creek, about 2 miles north of Mazama. There the Trout Creek body of the Otter intrusions cuts the Osprey Lake granodiorite body.

At one place where a tongue of Trout Creek granite cuts the granodiorite the latter has been fractured and silicified. Close to the contact are small irregular bodies of a manganese-bearing carbonate carrying small specks of chalcopyrite. A hundred feet or so from the contact an adit 200 feet long has been driven northerly to follow a strong, silicified and sheared zone exposed at the surface. There it is 15 or 20 feet wide, and consists of brecciated and silicified granodiorite sealed with sugary and vuggy quartz. No sulphides could be seen. Quartz veins occur in the fracture only near the portal of the adit and crosscuts to both sides fail to disclose anything but relatively unaltered granodiorite. On the opposite side of a small gully on or very close to the contact with the Trout Creek granite, several open-cuts have explored the carbonate deposits referred to above, but no copper ore of commercial grade was seen. A spectrographic analysis failed to reveal the presence of any unusual elements.

Jessie Claim (16)

Reference: Ann. Rept., Minister of Mines, B.C., 1928, p. 264.

The Jessie claim, owned by E. H. Holes and Dan McDonald of Coalmont, is near the Kettle Valley Railway just east of Thirsk. The showings consist of one or more quartz veins in the Osprey Lake granodiorite. Workings consist of an open-cut and two short adits, all probably on a single quartz vein that varies from an inch to 8 inches in width and carries pyrite, chalcopyrite, sphalerite, and galena. The following assays are reported by the Resident Engineer:

Gold	Silver	Copper	Zinc	—
Oz. a ton	Oz. a ton	Per cent	Per cent	
0·56	0·70	0·30	54	Picked sample from lower adit
Tr.	1·20	1·8	10 (about)	General sample from lower adit

Hematite Claim (35)

Reference: Ann. Rept., Minister of Mines, B.C., 1928, p. 263.

The Hematite claim, owned by W. C. Wilkins and associates of Penticton and Princeton, is about 1 mile up Finnigan Creek, which flows into Hayes Creek about 6 miles from Jellico Siding on the Kettle Valley Railway. Here a zone of fracturing in the Osprey Lake granodiorite carries hematite and some galena and sphalerite. The extent of the fracture zone is not known, but an exposed area of some 30 feet by 40 feet of sheared granodiorite carries hematite.

Independence Group (18)

References: Ann. Repts., Minister of Mines, B.C.: 1906, p. 180; 1907, p. 144; 1908, p. 132; 1913, p. 237; 1924, p. 139; 1926, pp. 196-197; 1927, p. 208; 1928, p. 227. Camsell, 1913, pp. 166-168. Cairnes, 1924, pp. 160-163.

The Independence group, owned by Y. Holmes of Princeton, is situated on the west edge of the map-area near the headwaters of Lawless Creek. The camp is at an elevation of some 5,400 feet on the divide between Lawless Creek and Coldwater River, and is reached either by a short steep trail from Coquihalla Siding on the Kettle Valley Railway or by a more gently graded trail, roughly paralleling Lawless Creek, from Tulameen River.

The deposits were discovered in 1901, and explored by a New York syndicate. In 1906, the property was optioned by the Granby Company of Phoenix who excavated more than 1,000 feet of adits and drifts, 265 feet of shafts, and numerous open-cuts. In 1927, the property was bonded from the original owners by the Consolidated Mining and Smelting Company, but the option was dropped the following year.

The claims cover an area that includes part of the eastern margin of the Eagle granodiorite. This body intrudes volcanic members of the Nicola group, but is separated from them for about 3 miles by a body of feldspar porphyry with a maximum width of 1,000 feet that cuts the other rocks. Camsell notes that the porphyry

> "contains phenocrysts of quartz, feldspar, and biotite in a fine-grained groundmass. The thin section shows the feldspars to be both orthoclase and plagioclase, and the quartz exhibits a corroded outline. Much pyrite is also present. The composition of the rock is by no means uniform, being more siliceous in some parts than in others. It is traversed by little veins of quartz which are barren and appear to have been formed previous to formation of the ore bodies. The structure of the rock is massive, and when not affected by mineralizing solutions is quite fresh. It is only slightly sheared, and shows fracturing in two directions, the most pronounced of which is about N 25° W."

This porphyry is cut by dykes of Otter granite and is believed to be a late phase of the main Eagle granodiorite. Mineralized fractures in the feldspar porphyry strike northwesterly. The chief ore minerals are chalcopyrite, pyrrhotite, and pyrite, but molybdenite is not uncommon and sphalerite and tetrahedrite also occur. Secondary enrichment has given rise to chalcocite and cuprite in places. The gangue is altered granite porphyry, with the addition of calcite, quartz, and sericite. Mineralization is fairly widespread, the sulphides replacing the shattered constituents of the porphyry. Camsell distinguished two periods of fracturing and mineralization.

> "...During the first period chalcopyrite, pyrrhotite, and blende were introduced along with calcite, so that we find all those minerals in the fissures. Pyrite was also introduced, and often migrated farther into the wall-rock where it formed crystalline individuals by metasomatically replacing the country rock. In the second period of fracturing there was a very limited introduction of sulphides, but a greater influx of gangue minerals, so that we find veinlets of calcite cutting the previously formed ore minerals, and geodes filled with quartz, calcite, and sericite."

The presence of secondary copper minerals makes it difficult to arrive at a true figure for the tenor of the primary ore. Assays as high as 32·85 per cent copper have been obtained, but Camsell concluded that the average grade of the primary ore was probably about 3 per cent copper with about $1 in gold to the ton.

Nickel Plate Group, Champion Creek (32)

Reference: Camsell, 1913, pp. 170, 171.

The Nickel Plate group is owned by Dolph Galarneau, and is along Champion Creek from its mouth on Tulameen River to a point nearly a mile up stream. Here the Eagle granodiorite has intruded and metamorphosed volcanic rocks of the Nicola group, now altered to chlorite and mica schist, and limestone. Camsell has described the deposit as follows:

> "Much contact metamorphism has been effected by the granodiorite intrusion and with an abundant development of the usual contact metamorphic minerals in the intruded rocks. Some quartz veins, generally of small size, also traverse the schists and limestones.
>
> "The molybdenite occurs in small flakes and scales, having a bright metallic lustre and a lead-grey or slightly bluish colour. It is scattered plentifully in small particles throughout a gangue consisting of quartz, garnet, epidote, hornblende, and pyroxene. It is seen, in this section, to be intergrown with these minerals in such a way as to indicate a contemporaneous origin.
>
> "The deposits are clearly of contact metamorphic origin, and were formed by and at the time of the intrusion of the Eagle granodiorite. The associated minerals indicate that the rock in which the molybdenite occurs was originally a limestone which, on the intrusion of the granodiorite, had its constituents altered from carbonates to silicates by a process of metasomatic replacement, the molybdenite being introduced into the limestone along with the silica which went to form the lime silicates."

Rio Grande Group (38)

Reference: Ann. Rept., Minister of Mines, B.C., 1928, p. 267.

The Rio Grande group was staked by T. Smitheran and R. Jameson on the south fork of Tulameen River. Most of the western contact of the Eagle granodiorite is with overlapping Cretaceous rocks, but in the vicinity of Podunk Creek a triangular-shaped area of Nicola rocks is exposed between the Cretaceous beds and the intrusion. The rocks in this area are locally heavily sheared and brecciated, and in many places bleached to a pale yellowish brown. The deposits of the Rio Grande group occur in a 5-foot zone of kaolin, sericite, crushed quartz, and partly oxidized pyrite. Through this mass run stringers of galena and sphalerite from 1 to 4 inches wide. The workings comprise some surface stripping and open-cuts, and supply but little information as to the size, grade, or continuity of the zone. The following are assay returns from two samples taken by the Resident Engineer:

Gold	Silver	Lead	Zinc	——
Oz. a ton	Oz. a ton	Per cent	Per cent	
Tr.	0·40	Nil	1·2	Average across the vein
0·02	13·5	28	2	Picked galena ore

Newton Creek Property (37)

References: Ann. Repts., Minister of Mines, B.C.: 1929, p. 279; 1933, p. 173.

The Newton Creek property, owned by W. R. James and associates of New Westminster, was held by Coalmont Gold Mines in 1929. It is on Granite and Newton Creeks near their junction. The deposits are in volcanic and argillaceous members of the Nicola group and are of two types. Two or more quartz veins up to 8 feet wide have been explored by several adits. These carry some scattered pyrite, and high but erratic gold values are reported. In addition to these are several rusty and leached pyritized shear zones that have been exposed in open-cuts. These carry low values in gold and silver.

Virginia Group (41)

References: Ann. Repts., Minister of Mines, B.C.: 1928, p. 265; 1931, p. 130.

The Virginia group, owned by W. S. Wilson of Princeton, is on Whipsaw Creek about $2\frac{1}{2}$ miles from Similkameen River. The ore deposit consists of a zone of brecciated Nicola volcanic rocks that has been silicified and oxidized, and mineralized with pyrite and, more sparingly, with arsenopyrite. This has been exposed by several large open-cuts, in one of which is a mineralized area 25 feet wide and 30 feet long. Some faulting is suggested, but neither the size nor the trend of the deposit could be determined. One sample of the arsenopyrite-bearing material taken by the Resident Engineer assayed 0·54 ounce a ton in gold.

Big Ben Group (69)

References: Ann. Repts., Minister of Mines, B.C.: 1925, p. 112; 1927, p. 248; 1928, p. 265.

The Big Ben group, originally known as the Sparkler group, owned by Charles Richter and associates of Keremeos, was restaked recently by Ben Williams, also of Keremeos. It lies near the headwaters of Similkameen River from 1 to 2 miles north of the main valley, just southwest of Allison Pass. It is reached by a trail from the Hope-Princeton highway. The showings occur over a wide area in the upper volcanic division of the Dewdney Creek group. They consist of streaks, bands, and lenses of disseminated sulphides in fracture zones in basic lava and volcanic breccia. Pyrite, arsenopyrite, pyrrhotite, chalcopyrite, stibnite, and sphalerite have been noted, an assemblage of high- and low-temperature minerals that suggests an involved history and a long, or perhaps more than one, period of mineralization. As the Dewdney Creek group is at least in part of Lower Cretaceous age, the mineralization must be younger than that, and is probably related to the Lightning Creek dykes, some of which occur nearby. The showings have been explored by a number of open-cuts and shallow drifts, mostly put in by the original owners. A sample taken by the Resident Engineer ran: gold, 0·34 ounce a ton; silver, 0·60 ounce a ton; arsenic, 16·2 per cent. Other samples reported by him ran: gold, trace to 0·40 ounce a ton; silver, trace to 0·80 ounce a ton; and as much as 5 per cent zinc.

Prince Claim (75)

Reference: Ann. Rept., Minister of Mines, B.C., 1920, p. 158.

The Prince claim is owned by Ben Williams of Keremeos, and is on Ashnola River about 4 miles up from the Similkameen. A short adit has been driven under the road along a quartz vein from ½ inch to 18 inches wide. This cuts through volcanic rocks of the Bradshaw or Independence formations. A few grains of galena and chalcopyrite were seen in the quartz.

Forks Claim (76)

The Forks claim is on the southeast side of Ashnola River above the mouth of Ewart Creek. Here a quartz vein from 2 to 6 feet wide follows the contact between a granite dyke and badly altered sediments, now quartz-mica schist and gneiss of the Bradshaw or Independence formations. Faulting and fracturing have occurred along this contact, so that both the dyke and intruded rocks are traversed with veinlets of quartz. Finely disseminated pyrite, molybdenite, and some chalcopyrite occur in the main quartz vein and veinlets, and in the adjacent wall-rocks. A little carbonate is also present.

Other Occurrences

In addition to the showings described above, the following small mineral occurrences were seen. Chalcopyrite occurs in Nicola volcanic rocks, or in related andesite or diorite intrusions, on the ridge at the head of Coral Creek, a tributary flowing into Whipsaw Creek from the north some 3 miles above Similkameen River.

Several small zones of fracturing occur in the volcanic rocks of the Nicola group along the east side of Missezula Lake. These zones show copper stain at a number of places, and small amounts of pyrite, chalcopyrite, and bornite can be seen.

Small amounts of molybdenite and chalcopyrite were seen in the granodiorite of the Osprey Lake body on the ridge between Summers and Hayes Creeks some 6 miles north of Jura.

CHAPTER VII

NON-METALLIC DEPOSITS

COAL

Since the early part of the century coal has been an important product of the Princeton area. It is interbedded with the Princeton sediments of Tertiary age and occurs in both of the main areas in which they were deposited, namely the Princeton and Tulameen basins.

Although the only coal mined from these Tertiary sediments, coal also occurs in the Lower Cretaceous sedimentary rocks at the base of the Kingsvale group, and can be seen along Coldwater River at Kingsvale and in a couple of short adits along Voght Creek, within half a mile of Kingsvale. This area of sediments is, however, extremely small, and there is little likelihood that the occurrence of coal is commercially significant, except to call attention to the possibilities of such larger areas of the Kingsvale group as may be encountered outside the Princeton map-area.

PRINCETON BASIN

The Princeton sedimentary basin is some 15 miles long by 2½ to 4½ miles wide. The thickest measured section is 1,000 feet, but in most parts of the basin the thickness is imperfectly known.

The strata consist of conglomerate, sandstone, shale, and coal. The conglomerate may contain granitic cobbles 8 inches to a foot in diameter, although most of it consists of pebbles less than an inch across, and beds with pea-sized pebbles are common.

Production of Coal from the Princeton and Coalmont Basins

	Princeton Coal and Land Co., Ltd.	Tulameen Collieries	Pleasant Valley Mining Co., Ltd.	Princeton-Tulameen Coal Co., Ltd.	Granby Collieries	Black coal mine	Jackson's coal mine	Blue Flame Collieries	United Empire Colliery	Coalmont Collieries
1909	150	...	...	...	...	...	...	...	...	...
1910	11,868	...	...	...	...	...	...	...	...	...
1911	23,396	...	...	...	...	...	...	...	...	...
1912	28,174	...	...	...	...	...	...	...	500	...
1913	27,206	...	...	...	...	...	...	...	1,752	...
1914	19,535	...	...	...	...	...	...	...	...	...
1915	15,548	...	...	...	...	...	...	...	...	...
1916	29,458	...	...	...	...	...	...	...	...	...
1917	48,926	...	...	...	...	...	...	...	...	...
1918	38,673	...	...	...	...	...	...	...	...	...
1919	24,702	...	...	...	...	...	...	...	...	10,189[1]
1920	24,211	...	...	...	...	...	...	...	...	8,983[1]
1921	16,865	...	...	...	...	...	...	...	...	70,343
1922	23,880	...	...	...	...	...	...	...	...	159,954
1923	20,264	...	...	...	...	...	...	...	...	146,537
1924	11,875	1,581	...	...	...	...	...	...	...	166,971

[1] Figures from Ann. Rept., Minister of Mines, B.C.

Production of Coal from the Princeton and Coalmont Basins—Concluded

	Princeton Coal and Land Co., Ltd.	Tulameen Collieries	Pleasant Valley Mining Co., Ltd.	Princeton-Tulameen Coal Co., Ltd.	Granby Collieries	Black coal mine	Jackson's coal mine	Blue Flame Collieries	United Empire Colliery	Coalmont Collieries
1925	7,725	7,350	....	....	....	....	....	....	....	132,021
1926	911	14,558	....	....	....	....	....	....	....	136,034
1927	....	15,800	....	....	....	....	....	3,343	....	170,907
1928	....	20,148	....	....	....	....	....	20,855	....	184,594
1929	....	41,773	5,874	....	....	....	....	5,530	....	167,921
1930	....	45,765	21,663	....	....	....	....	12,248	....	116,485
1931	....	64,671	14,112	....	....	....	....	13,037	....	111,789
1932	....	57,965	16,346	....	411[1]	....	....	11,780	....	107,412
1933	....	54,061	9,479	....	1,062[1]	....	....	10,373	....	86,345
1934	....	21,529	10,147	....	1,060[1]	....	....	13,030	....	88,216
1935	....	9,601	5,799	....	786[1]	....	....	26,603	....	93,821
1936	....	12,362	7,202	899	1,298	....	....	21,576	....	104,942
1937	....	....	5,255	16,477	22,480	....	....	6,730	....	105,433
1938	....	....	....	18,513	74,164	....	....	....	....	89,394
1939	....	....	....	21,856	93,742	....	....	....	....	83,842
1940	....	....	....	26,434	94,030	....	....	....	....	22,428
1941	....	4,152	....	29,250	79,448	....	30[1]	....	....	....
1942	....	10,617	....	30,620	83,981	70[1]	....	....	....	....
1943	....	15,699	....	30,375	62,255[1]	2,254[1]	....	....	....	....
1944	....	47,687	....	18,038	....	....	233[1]	....	....	....
Total	375,367	443,319	95,877	192,462	516,717	2,324	263	145,115	2,252	2,364,561

[1]Figures from Ann. Rept., Minister of Mines, B.C.

All of these conglomeratic beds are light buff, with a groundmass composed mainly of quartz and feldspar grains. The sandstone beds are also buff coloured and grade from sandy shale to rocks transitional to the pebble-conglomerate. In some places coaly material occurs in the finer phases of the sandstone. Together the conglomerate and sandstone constitute less than half the material of the Princeton basin. The shales are normal soft rocks, coloured buff, grey, red, and brown. Most of them split along planes parallel with the bedding into flat plates, in part no more than a fraction of an inch thick. Some beds contain abundant plant fossils, and interbedded with them are seams of coal from a fraction of an inch to 18 feet thick. This coal is limited to sub-bituminous rank as indicated in the following table of analysis:

TABLE XI

	1	2	3	4	5	6	7	8	9	10	11	12	13
Moisture %	16·17	11·97	16·97	......	......	18·0	16·6	3·04	4·34	2·97	3·26	4·62	4·87
Volatile combustible matter %	37·58	30·49	56·37	56·44	56·50	32·7	33·0	31·88	31·08	31·28	43·33	41·16	36·86
Fixed carbon	41·67	49·21	21·76	39·71	39·73	42·8	43·0	51·11	48·89	52·49	49·70	49·04	50·99
Ash %	4·58	8·33	4·90	3·85	3·77	6·5	8·4	13·97	15·69	13·26	3·71	5·18	7·28
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

TABLE XI—*Concluded*

	1	2	3	4	5	6	7	8	9	10	11	12	13
Per cent coke.....	46·25	......	......	......	......	......	......	65·08	64·58	65·75	53·41	54·22	
Fuel ratio........	1·08	1·61	......	......	......	......	......	1·60	1·57	1·68	1·15	1·19	
B.T.U...........	......	......	12,630	12,200	12,100	9,850	9,850						
Sulphur %........	......	......	0·65	0·34	0·44	0·6	0·6						

1. Sample from 18-foot seam at Princeton, assayed by Geological Survey. Dowling, 1915, p. 261.
2. Sample from 8-foot seam at Princeton. Ann. Rept., Minister of Mines, B.C., 1902.
3. Sample from Tulameen Collieries. Idem., 1931.
4. As above. Idem., 1930.
5. As above. Idem., 1930.
6. From No. 1 mine, Princeton Coal and Land Co. Idem., 1923.
7. From No. 2 mine, Princeton Coal and Land Co. Idem., 1923.
8. Coalmont Collieries; No. 2 mine; 6½-foot seam. Camsell, 1913, p. 179.
9. " " " 5-foot seam. " " "
10. " " " " " " "
11. " " Collins Gulch; Camsell, 1913, p. 179.
12. " " " " " " "
13. " " " " " " "

Most of the beds in this basin are relatively flat lying, but in places they have been folded and dips as high as 70 degrees can be seen along the railway northwest of Princeton. Outcrops are poor over most of the basin, and the general structure is obscure. Until this has been worked out by detailed geological investigation a satisfactory estimate of the coal reserves is not possible.

Coal has been mined from several parts of the basin, principally from near Princeton and on Bromley and Lamont (Ninemile) Creeks. Other occurrences are known and some coal has been mined from north of Tulameen River.

Following are the logs of boreholes drilled at various times, the positions of which are indicated on Figure 3:

1. Drilled by Vermilion Forks Mining and Development Company. Borehole No. 1. Reported by Camsell, 1907, p. 27.

Material	Thickness		Depth	
	Ft.	In.	Ft.	In.
Gravel	14			
Shale	21	6		
Coal	4	6		
Sandstone	0	5½	40	5½
Coal	6	7½		
Clay	1	10	48	11
Coal	18	5½		
Shale	3	1		
Carbonaceous shale	4	6		
Clay	0	5		
Carbonaceous shale	0	8		
Sandstone	1	7		
Fire-clay	2	1		
Coal	0	2		
Shaly coal	1	1		
Shale	1	0	81	11½
Coal	1	8		
Clay	1	4		
Coal	1	6		
Shaly coal	1	2		
Coal	1	6		
Clay, shale, etc	26	4½		
Sandstone	31	0		
Clay, shale, etc	79	6	227	0
Sandstone	44	6		
Clay, shale, etc	8	6	280	

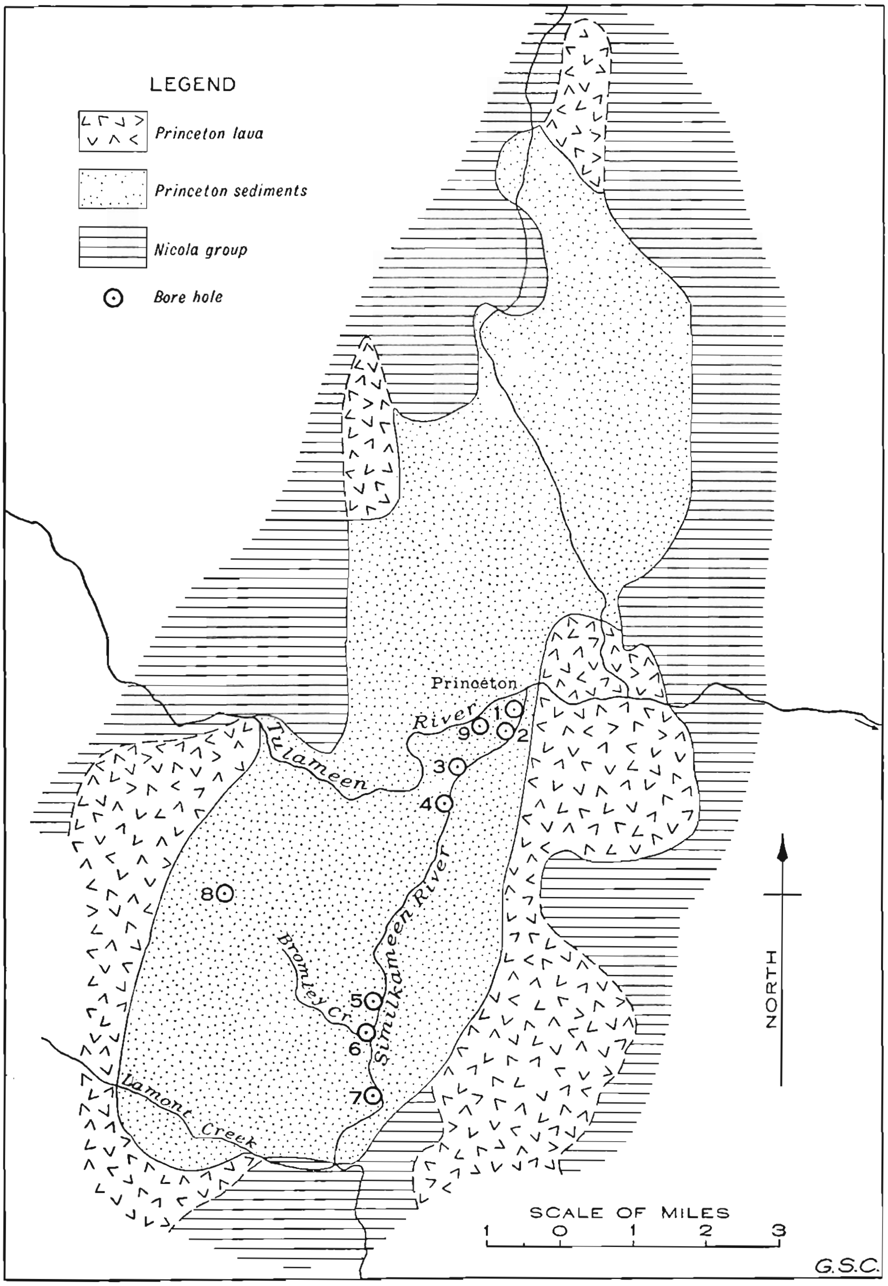

Figure 3. Princeton coal basin.

2. Drilled by Vermilion Forks Mining and Development Company. Borehole No. 3. From Camsell's notes.

Material	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Gravel	10	0		
Shale	83	8		
Sandstone	23	10		
Shale	84	6		
Sandstone	56	0		
Shale	34	0		
Sandstone	7	5		
Shale		10		
Coal	5	0	305	3
Shale	6	1		
Coal	8	0	319	4
Fine clay	2	0		
Coal	17	0	338	4

3. Drilled by the Vermilion Forks Mining and Development Company. Borehole No. 2. From Camsell's notes.

Material	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Clay	17	0	17	0
Shale, clay, etc	56	9	73	9
Clay	2	9		
Coaly shale	3	0	79	6
Coal	1	0	80	6
Clay	7	4		
Coal	0	2	88	0
Coarse and fine sandstone	28	11		
Shale and clay	20	7		
Sandstone	60	7		
Shale with coal	4	0	202	1
Clean coal	5	0	207	1
Coaly shale	3	6		
Shale	3	6		
Coal	1	7	215	8
Shale and clay	13	6		
Sandstone	9	11		
Shale	2	8		
Coal	3	0	244	9
Sandstone	14	9		
Coaly shale	1	3	260	9
Coal	0	9	261	6
Shale	21	11		
Sandstone	15	11		
Shale	3	9	303	1

4. Drilled by Blackmore. Borehole No. 2. From Camsell's notes.

Material	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Gravel	30	0	30	0
Clay	20	0	50	0
Sandstone	5	0	55	0
Brown shale and yellow clay	15	0	70	0
Sandstone and conglomerate	25	0	95	0
Coal	0	1	95	1
Hard rock with coal markings	0	3	95	4
Coal	0	1	95	5

4. Drilled by Blackmore. Borehole No. 2. From Camsell's notes—*Continued*

Material	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Coal shale	0	7	96	0
Hard, fine conglomerate	20	0	116	0
Greasy shale	4	0	120	0
Light sandstone	10	0	130	0
Shale	7	6	137	6
Mostly sandstone	8	2	145	8
Coal shale	1	4	147	0
Greasy shale	3	6	150	6
Sandstone	9	6	160	0
Coal shale	12	8	172	8
Dark shale	3	4	176	0
Light sandstone	3	0	179	0
Shale and clay	26	0	215	0
Light sandstone	5	0	220	0
Shale	7	0	227	0
Coal	8	0	235	0
Light sandstone	10	6	245	6
Coal shale	2	0	247	6
Light sandstone	7	4	254	10
Coal shale	7	10	262	8
Light sandstone	2	10	265	6
Shale and clay, some stringers of coal	23	0	288	6
Coal shale	2	6	271	0
Light sandstone	3	0	274	0
Dark shale and coal shale	20	10	314	10
Fine conglomerate	2	2	317	0
Sandy shale	3	0	320	0
Dark shale and coal shale	13	6	333	6
Mainly sandstone	10	0	343	6
Black shale	3	6	347	0
Conglomerate	7	0	354	0
Coal shale	1	6	355	6
Mainly sandstone	28	0	383	6
Dark shale and coal shale	5	4	388	10
Sandstone	3	2	392	0
Dark shale	3	8	395	8
Coal	0	2	395	10
Shale with a little conglomerate	8	2	404	0
Coal	0	2	404	2
Greasy shale	5	10	410	0
Light sandstone	6	0	416	0
Mainly shale and coal shale	11	6	427	6
Coal	0	8	428	2
Greasy shale with coal markings	2	4	430	6
Sandstone and conglomerate	7	2	437	8
Mainly dark greasy shale, a little coal	11	10	449	6
Sandstone and conglomerate	1	6	451	0
Mainly shale, a little coal and some sandstone	24	6	475	6
Coal	0	6	476	0
Dark shale	3	0	479	0
Coal	0	4	479	4
Dark shale, some coal shale	29	5	508	9
Coal	0	3	509	0
Shale and coal shale	9	8	518	8
Mainly sandstone, a little conglomerate and sandy shale	59	8	578	4
Dark shale	1	0	579	4
Coal	0	2	579	6
Sandy shale	0	2	579	8
Coal	0	2	579	10
Shale and coal shale	73	8	653	6
Sandstone and conglomerate	17	0	670	6
Shale and sandy shale	6	2	676	8
Coal	5	10	682	6
Dark shale	0	6	683	0
Coal	4	3	687	3
Mainly shale	7	3	694	6
Coal	0	1	694	7
Shale and coal shale	4	8	699	3
Coal	1	3	700	6
Mainly shale	43	6	744	0
Sandstone and conglomerate	17	6	761	6
Dark shale	4	0	765	6

4. Drilled by Blackmore. Borehole No. 2. From Camsell's notes—*Concluded*

Material	Thickness		Depth	
	Ft.	In.	Ft.	In.
Light sandstone	7	2	772	8
Dark shale and coal shale	6	4	779	0
Light sandstone	3	8	782	8
Dark shale	4	2	786	10
Fine conglomerate	4	2	791	0
Dark shale	2	2	793	2
Coal	1	0	794	2
Alternating shale and sandstone	5	4	809	6
Light sandstone	16	6	826	0
Fine conglomerate	3	0	829	0
Shale	9	0	838	0
Coarse sandstone	3	0	841	0
Shale	4	0	845	0
Loose conglomerate	3	0	848	0
Coal and shale	1	0	849	0
Interbedded shale, clay, and sandstone	84	6	933	6
Sandstone, coaly sandstone, and conglomerate	66	6	1,000	0

5. Drilled by the Vermilion Forks Mining and Development Company. Borehole No. 5. From Camsell's notes.

Material	Thickness		Depth	
	Ft.	In.	Ft.	In.
Sandstone	4	0		
Shale	86	9		
Clay	4	3		
Shale	5	3		
Shale with coal markings	6	9	107	0
Clay	5	0		
Shale	22	0		
Sandstone	5	0		
Shale	5	0		
Coal	0	8	144	8
Shale	8	8		
Sandstone and conglomerate	4	0		
Shale	5	0		
Coarse sandstone	2	6	164	10

6. Drilled by Vermilion Forks Mining and Development Company. Borehole No. 4. From Camsell's notes.

Material	Thickness		Depth	
	Ft.	In.	Ft.	In.
Gravel	5	0		
Clay	97	0		
Sandstone	8	6		
Shale	22	0		
Coal	1	8	134	2
Shale	11	4		
Sandstone	0	9		
Shale	36	2		
Coal	0	3	582	8
Shale	2	10		
Coal	0	6	586	0
Shale	39	0		
Clay	4	6		
Shale with thin seams of coal	10	0	639	6
Shale	9	6		
Coarse sandstone	7	9		

7. Drilled by Blackmore. Borehole No. 1. From Camsell's notes.

Material	Thickness		Depth	
	Ft.	In.	Ft.	In.
Wash	12	0	12	0
Clay, shale, and coal	83	0	95	0
Sandstone with a little coal	32	10	115	10
Shale with some coal markings	32	2	148	0
Sandstone, some shale	5	0	153	0
Dark shale, coal markings	6	3	159	3
Light sandstone	5	3	164	6
Black shale	3	3	167	9
Sandstone, some fine conglomerate	27	3	195	0
Coal shale	1	0	196	0
Sandstone, some conglomerate	13	6	219	6
Clay	1	6	221	0
Sandstone, some with coal markings	34	0	255	0
Clay	4	0	259	0
Sandstone, a little conglomerate	16	10	275	10
Shale, a little dark sandstone	4	6	280	4
Sandstone, a little shale	17	10	298	2
Dark shale and coal shale	3	10	302	0
Sandstone, a little conglomerate	19	0	321	0
Shale and coal shale	3	6	324	6
Dark and light sandstone	5	6	330	0
Shale and coal shale	12	0	342	0
Sandstone, a little shale	11	6	353	6
Interbedded shale and sandstone, a little conglomerate and coal shale	26	10	380	4
Sandstone, some conglomerate	17	8	398	0

8. Sharp's borehole, Bromley Creek.

Material	Thickness		Depth	
	Ft.	In.	Ft.	In.
Gravel	—		—	
Sandstone	—		7	6
Coal	9	0	16	6
Shale	—		—	
Coal	1	6	—	
Shale	—		—	
Coal	1	0	—	
Shale	—		36	0
Coal	2	8	—	
Shale and sandstone	—		460	0
White clay with dark spots	76	0	536	0
Coal	7	6	—	
Clay or shale	—		—	
Coal	2	0	—	
Clay or shale	—		—	
Coal	2	0	—	
Shale	—		—	
Coal	1	6	—	
Shale	—		—	
Coal	1	0	—	
Shale	—		—	
Coal	3	0	—	
Shale	—		—	
Coal	3	0	—	
Shale	—		—	
Coal	3	10	—	
Clay	—		—	
Coal	3	0	—	
Shale	—		—	
Coal	3	6	630	0
Shale	—		—	
Coal	1	0	—	
Shale and sandstone	—		712	0
Coal	3	0	—	
Shale and sandstone	—		—	
Coal	3	0	—	
Shale and sandstone	—		863	0

9. Drilled by the Vermilion Forks Mining and Development Company. Borehole No. 6. From Camsell's notes.

Material	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Clay and shale	9	0	9	0
Coal	0	10	9	10
Clay	1	0	10	10
Coal	3	6	14	4
Shale	3	9	18	1
Coal	0	7	18	8
Shale	1	0	19	8
Coal	2	0	21	8
Clay and shale	13	0	34	8
Coal	1	0	35	8
Shale	11	0	46	8
Sandstone, some conglomerate	28	9	75	5
Clay	13	0	88	5
Shale, some coal	13	10	102	3
Sandstone	4	0	106	3
Shale and clay	2	2	108	5
Mainly sandstone, some shale	51	2	160	7
Shale and clay	61	8	222	3
Sandstone	8	0	230	3
Coal	0	6	230	9
Clay and shale, some sandstone	74	0	304	9
Coal	2	6	307	3
Shale	7	0	314	3
Sandstone	6	0	320	3
Coaly shale with 4 feet of clean coal	8	0	328	3
Sandstone and shale	14	0	332	3
Coal	0	9	333	1

Princeton Coal and Land Company

References: Ann. Repts., Minister of Mines, B.C.: 1909, pp. 249, 250; 1910, pp. 204, 205; 1911, pp. K187, K247; 1912, pp. K289-291; 1913, pp. 242, 378-380; 1914, pp. K367, 475-479; 1915, pp. K237-240, 415-417; 1916, pp. K488, 489; 1917, pp. F421-423; 1918, pp. K214, K442, 443; 1919, pp. 340, 341; 1920, p. N160, N317-319; 1921, pp. G324-326; 1922, pp. N331-334; 1923, pp. A357-359; 1925, pp. 344, 345; 1929, p. C477; 1933, p. A337; 1935, p. G26.

The first coal area to come into prominence was that in and around the town of Princeton. As early as 1901 the Vermilion Forks Mining and Development Company started to bore for coal at Princeton and along Similkameen River. It was soon established that there were two promising coal seams, the upper known as the Gem and the lower or Number 1 seam. The latter was the better of the two, and early work was confined to it. Exploration revealed it to be from 18 to 24 feet thick, of which the upper 6 to 10 feet was good clean coal. The following is a typical section of the seam, from top to bottom:

	Feet	Inches
Top coal	2	0
Coal	3	0
Clay	–	6
Coal	5	0
Clay	–	9
Coal	1	0
Claystone	1	0
Coal	3	4
Clay and bone	–	10
Coal	6	0

Of this only the uppermost 10 feet contained coal of good quality, the remainder carrying partings of clay and bone from $\frac{1}{8}$ to $\frac{3}{4}$ inch wide. In 1909 the Princeton Coal and Land Company was formed to take over the assets of Vermilion Forks Mining and Development Company.

Number 1 mine was opened opposite the junction of Similkameen and Tulameen Rivers, on the right bank of the former, and that year the first coal to be produced on a commercial scale was extracted. From then until 1920 the mine continued to ship steadily. Number 1 seam was found to pitch south at 12 to 14 degrees, and was followed down for about 1,100 feet. In the early stages little care was taken to clean up the working faces, and in 1914 fire broke out in the old workings. Efforts to seal these off were only partly sucessful, and the fire continued to burn but was fairly well under control.

By 1921 reserves in Number 1 seam were nearing exhaustion, and an effort was made to open up the Gem seam 4,300 feet south of Number 1 mine. In 1922 a new section of the Number 1 seam 1,500 feet southeast of Number 1 mine was discovered and opened up as the Number 2 mine. It was found to be separated from Number 1 mine by a faulted and crushed zone. Work on the Gem seam, known as the Number 3 mine, was continued. This seam was 3½ feet thick and the coal not very clean, so that the attempt to develop it was abandoned in 1923. By that year the fires in Number 1 mine were causing great difficulty and, as efforts to work the deeper levels were unsatisfactory, in 1924 the mine was abandoned. In the same year the Number 2 mine was shut down, as the coal was found to be of poor quality.

In 1925 a new company, known as Princeton B.C. Colliery Company, Limited, was organized to take over the assets of the older company, and a shaft was sunk to the Number 1 seam on the north side of Similkameen River just above Tulameen River. The new company produced some coal, but it, too, shut down in 1926.

In 1929 Washington Coal Company, Limited, explored a 6-foot seam with a 15-degree pitch on the north side of, but close to, Tulameen River near its junction with Similkameen River. This was believed to be the Number 1 seam, but carried too much bone to be commercial. In the same year the Gem Domestic Coal Company commenced a small operation on a 42-inch seam 1 mile west of the railway station in Princeton. This seam pitched 15 degrees west and its quality was apparently unsatisfactory, as there is no further record of the company. Finally, in 1933, some exploration east of the Number 1 mine was attempted by the Sunblaze Coal Company.

Tulameen Collieries, Limited

References: Ann. Repts., Minister of Mines, B.C.: 1924, pp. B345, 346, 175; 1927, p. C445; 1928, pp. 481-483; 1929, pp. C473, 474; 1930, p. 405; 1931, pp. A225, 226; 1932, p. A270; 1933, p. A334; 1934, pp. G29, 30; 1935, p. G25; 1936, pp. 41, 42; 1941, p. A121; 1942, p. A120; 1943, pp. A118, 119; 1944, pp. A122, 123.

In 1924, when the property of the Princeton Coal and Land Colliery was nearly exhausted, a new discovery of the Princeton Number 1 seam was made on the north bank of Tulameen River some 2 miles west of Princeton. It was taken over by the Tulameen Valley Coal Company, and brought into small-scale production the same year. The seam here, as at Princeton, was some 24 feet thick, of which the uppermost 8 to 10 feet was essentially clean coal. When first discovered near the surface, it pitched at 8 degrees, but as it was followed down the pitch steepened to 15 degrees.

In 1929 the company was reorganized as Tulameen Coal Mines, Limited, and the production doubled. The original workings of the Tulameen Valley Coal Company were known as the Number 1 mine. Early in 1930, a new slope, known as Number 2 mine, was started 800 feet south of the Number 1 mine. This slope encountered the No. 1 seam 600 feet from the portal, and continued to develop it, leaving a 150-foot pillar between the Number 1 and Number 2 workings. During this time work in Number 1 mine was confined to extracting pillars, and in 1931 it was finally abandoned as worked out.

Number 2 mine continued to produce until 1935 when it was allowed to flood. Late in the year an unsuccessful attempt was made to pump it out, since when it has been inactive. In this mine the seam had been followed along strike for some 1,700 feet and pitched at 20 degrees at the deepest point.

By 1941 a new entry to the seam known as Number 3 mine, was driven close to Number 2, and later the workings were connected. The holding company had, in the meantime, been reorganized as Tulameen Collieries, Limited. By 1944 this new section of the mine had also been nearly worked out, the only remaining reserve being a little coal between Number 1 and Number 2 mines, which was being rapidly extracted. The soft nature of the roof made it impracticable to mine below a certain depth.

Pleasant Valley Mining Company, Limited

References: Ann. Repts., Minister of Mines, B.C.: 1928, pp. C485, 486; 1929, pp. C474, 475; 1930, pp. A406, 407; 1931, p. A226; 1932, p. A271; 1933, pp. A334, 335; 1934, p. G30; 1935, p. G25; 1936, p. G41.

In 1928 active development was started on the south bank of Tulameen River 1½ miles from Princeton, by Pleasant Valley Mining Company, Limited. A tipple and surface plant were erected on a large flat near the river, and an entry driven 1,500 feet east of the tipple. This working was known as Number 1 mine, and encountered a thick seam of coal pitching at from 12 to 20 degrees. Only the upper 3½ to 4 feet of this seam was clean enough to mine.

At the same time, work was commenced at the Number 2 mine 2,000 feet west of the tipple, where a 6-foot seam with from 3 to 5½ feet of clean coal was developed. This seam lay 800 feet stratigraphically lower than that at the Number 1 mine, and was the Number 1 seam of the Princeton Coal and Lands Colliery. Near the surface the pitch of this seam was 15 degrees, but at the deeper levels was as high as 25 degrees.

Work in both mines continued into 1933 when the Number 1 mine was considered worked out and was abandoned. Number 2 mine continued to operate until 1937 when it too was abandoned. Since 1937 no work has been done on the property.

Princeton Tulameen Coal Company, Limited

References: Ann. Repts., Minister of Mines, B.C.: 1937, p. G31; 1938, p. G34; 1939, p. A142; 1940, p. A126; 1941, pp. A120, 121; 1942, pp. A120, 121; 1943, pp. A117, 118; 1944, p. 122.

The Princeton Tulameen Coal Company, known originally as the Lind mine, was organized to exploit a showing of the No. 1 seam of the Princeton Colliery found in 1935. The mine lies close to Tulameen River about 1 mile west of Princeton, between it and the Tulameen Collieries mine. The seam here, as elsewhere, was thick, but with good coal restricted to about the uppermost 7 feet of the seam. The mine worked steadily, and by 1944 approximately 180,000 tons of coal had been extracted. The seam pitched at almost 16 degrees, and was followed down for a distance of some 1,280 feet, when, in 1943, extensive squeezing set in and the deeper workings had to be abandoned. In 1944 the mine was shut down, and allowed to flood. A typical section of the seam measured 9 feet 6½ inches, including three clay partings ¼ inch thick and two ½ inch thick.

Granby Consolidated Mining, Smelting and Power Company, Limited

References: Ann. Repts., Minister of Mines, B.C.: 1932, p. A272; 1933, p. A336; 1934, p. G31; 1935, p. G26; 1936, p. G42; 1937, p. G31; 1938, p. G34; 1939, pp. A141, 142; 1940, p. A126; 1941, p. A118; 1942, pp. A121, 122; 1943, pp. A116, 117; 1944, pp. A121, 122.

Coal has also been mined from seams exposed near Bromley Creek some 5 or 6 miles southwest of Princeton. This is on the western edge of the Princeton basin, where the beds dip east at inclinations of from 20 to 65 degrees. The original discovery was made early in the century, but it was not until 1932, when Bromley Vale Collieries, Limited, commenced operations on a seam on the north bank of Bromley Creek near the south boundary of lot 385, that production started. The seam proved to be from 12 to 14 feet thick, and pitched east from 20 to 35 degrees. The upper part of the seam contained many layers of bentonite, bone, and clay, and only the lower 5 to 7 feet could be mined profitably.

In 1934 the mine was taken over by Cascade Coal Company, Limited, and in 1936 the control changed to Black Diamond Collieries, Limited. Finally, in 1937, it was taken over by Granby Mining, Smelting and Power Company, Limited, and operated as Number 1 mine. In 1939 a new operation, Number 2 mine, was started 800 feet east of Number 1 mine. This was developed during the next year, but was shut down in 1941 and maintained as a reserve. In the meantime Number 1 mine had been producing steadily, fulfilling all the requirements of the Granby Company's steam plant. By 1942 two diagonal slopes had been driven, the north diagonal to a depth of 1,660 feet and the south diagonal to a depth of 1,230 feet. Seven levels were driven off the north diagonal, of which No. 6 level north was 1,480 feet long. Five levels were driven off the south diagonal, No. 4 south being 1,380 feet long. Squeezing became pronounced in the lower levels, and eventually they had to be abandoned. Finally, in 1943, mounting costs and labour troubles led to the closing down of the Number 1 mine. By that time some 464,368 tons of coal had been produced.

The squeezing, which was so troublesome a feature of this mine as well as in the properties near Princeton, is in part to be accounted for by the weight of the overlying sediments and the incompetent nature of the beds enclosing the coal. However, this condition may well have been aggravated by the swelling of the beds of bentonite adjacent to the coal seam when exposed to moisture in the workings. Beds of this material commonly accompany the coal seams, but their true nature was not recognized until comparatively recent times.

Black Coal Mine

References: Ann. Repts., Minister of Mines, B.C.: 1929, p. C476; 1942, p. A119; 1943, p. A119; 1944, p. A123.

The occurrence of coal on Finlay Creek, a tributary of Bromley Creek, had been known for some time, and sporadic, small scale attempts made to explore it, but it was not until 1942, when Inland Collieries, Limited, took over operations, that it was finally brought into production. Several seams from 5 to 10 feet thick were exposed, separated by a few feet of shale, bentonite, and bony coal. These seams pitched at 50 degrees. Work continued during the following year, but in 1944 the mine was once more shut down.

Jackson's Coal Mine

References: Ann. Repts., Minister of Mines, B.C.: 1941, p. A121; 1942, p. A117; 1943, p. A119; 1944, p. A123.

In 1941 Charles Jackson discovered a coal seam on Finlay Creek about half a mile north of the Black mine. This was taken over in 1943 by British Lands, Limited, and brought into small scale production the following year. Little work was done, but at least one seam of coal, 4½ feet thick, was developed.

Blue Flame Collieries, Limited

References: Ann. Repts., Minister of Mines, B.C.: 1927, pp. C447, 448; 1928, pp. C483, 484; 1929, p. C475; 1930, pp. A407, 408; 1931, p. A227; 1932, pp. 271, 272; 1933, p. A335; 1934, pp. G30, 31; 1935, pp. G25, 26; 1936, pp. G41, 42; 1937, p. G30.

In 1927 Lynden Coal Company, Limited, commenced to explore an outcrop of coal on Lamont (Ninemile) Creek, a tributary of Whipsaw Creek not far from its junction with Similkameen River. This working is about a mile up the creek from the Whipsaw Creek bridge on the Hope-Princeton highway, and is reached by a short branch road. The seam is about 24 feet thick, but only the upper 7 to 9 feet was clean enough for profitable extraction. Near the surface the seam pitched west at 12 to 15 degrees, but at depth was found to steepen to 30 degrees.

The first shipment was made in 1927, but operation was intermittent and not very successful, and in 1929 Lynden Coal Company was reorganized as Blue Flame Collieries, Limited. It was not, however, until 1933, when the property was acquired by Wilson Mining and Development Company of Vancouver, that the mine was efficiently operated. From then until 1936 active mining was maintained, by which time the face of the main level was 4,000 feet from the portal and extraction of the pillars was well under way. The following year the property was shut down.

In 1943 a little prospecting in the area to the east of the Blue Flame was undertaken by Pleasant Valley Mining and Development Company, but the project was abandoned before results could normally be expected.

United Empire Colliery

References: Ann. Repts., Minister of Mines, B.C.: 1910, p. K132; 1912, pp. K191-193; 1913, pp. K380-382; 1914, pp. K367, 479; 1915, p. K418; 1917, p. F423; 1932, p. A273; 1933, p. A336; 1935, p. G26.

The only coal produced from the north side of Similkameen River came from Allison (Hunters) Creek about 1½ miles northeast of Princeton. Here in 1910 the United Empire Mining Company commenced explorations and development of some coal prospects, and by 1912 had brought them into small-scale production. The following year the property was active, but none of the coal appears to have been of very good grade and in 1914 the mine was shut down. Two seams of coal were found and developed to some extent, the upper seam some 9 feet thick and the lower 4 feet thick. These were found to pitch at from 45 to 60 degrees. The following section of the productive measures is taken from the Annual Report of the B.C. Minister of Mines for 1913:

	Feet	Inches	
Coal	4	0	Upper seam, 9 feet
Clay	–	6	
Coal	4	6	
Sandstone and clay	21	0	
Coal and slate	5	0	
Clay	4	0	
Sandstone	1	4	
Coal	4	0	Lower seam
Coal and clay	7	0	
Sandstone	11	0	

In 1917 the property was taken over by the Tulameen Coal Company and a little indecisive prospecting done. In 1932 it was acquired by the Red Triangle Coal Company, and a new entry to the developed sections of the seam was driven to replace the old one, which had caved. The unsatisfactory nature of the coal, however, caused the work to be discontinued the following year. In 1935 the same company did a little further prospecting, but since then the property has been inactive.

Other Occurrences

No other properties in the Princeton basin have been worked, but other occurrences of coal are known at several places, notably on Summers Creek.

TULAMEEN COAL BASIN

References: Ann. Repts., Minister of Mines, B.C.: 1908, pp. J138, 139; 1910, p. K133; 1911, pp. K186, 187, 248, 249; 1912, pp. K293, 294; 1913, pp. K225, 226, 237-239, 382, 383; 1914, pp. K367, 480, 481; 1915, pp. K417, 418, 249; 1916, p. K491; 1917, p. F423; 1918, pp. K444, 445; 1919, pp. N342, 343; 1920, pp. N314-317, 160; 1921, pp. G320-324; 1922, pp. N328-331; 1923, pp. A353-356; 1924, pp. A353-356; 1925, pp. B340-343; 1927, pp. C441-445; 1928, pp. C477-481; 1929, pp. C468-471; 1930, pp. A401-403, 339-354; 1931, pp. A222-224; 1932, pp. 268-270; 1933, pp. A331, 332; 1934, pp. G27, 28; 1935, p. G24; 1936, pp. G37-40; 1937, pp. G30, 31; 1938, p. G33; 1939, p. A140; 1940, p. A125; 1943, pp. A119, 120; 1944, pp. A123, 124. Camsell, 1913, pp. 172-180.

The Tualmeen coal basin is an oval-shaped area of Tertiary sedimentary rocks of the Princeton group some $3\frac{1}{3}$ miles long by $2\frac{1}{4}$ miles wide. It forms a hill, actually an easterly extension of Olivine Mountain, west of Tulameen River at Coalmont. Granite Creek Valley is cut immediately to the southeast of the basin, and has partly exposed the strata at this point. Two small, steep valleys, Collins Gulch immediately south of Tulameen and Fraser Gulch west of Coalmont, are also important in exposing the coal measures. Camsell (1913, pp. 174-176) describes these measures as follows:

"The total thickness of the coal bearing rocks, as measured in a section along Collins Gulch, is less than 2,500 feet. . . . . In this section the whole series can be divided roughly into three groups. The lowest group, measuring 600 feet in thickness, is composed of sandstones, with which are interbedded a few thin bands of shale. The middle group is made up of 460 feet of very fissile shale, and in this group lie the principal coal seams. The upper part of the section contains a preponderance of sandstones, with which are associated some thin shale bands and beds of conglomerate. (On the south side of the basin there is a seam of coal 120 feet or so thick. Much of this is, however, very impure so that only a part 10 to 12 feet thick has been mined successfully.) The coal bearing rocks (Camsell, 1913, p. 176) are essentially sedimentary in origin, and must, therefore, have been deposited in a horizontal or approximately horizontal attitude. Their structure now, however, is that of a synclinal basin having its larger axis running almost northwest and southeast. On the southwest side of the basin the dips of the beds are in general towards the northeast; and on the northeast side they are towards the southwest. These dips vary from 20 degrees up to 70, and are apparently greatest on the outer edge of the basin. The average dip, however, is about 40 degrees.

"The structure of the beds does not always conform to the general structure of the syncline, and many discordant dips are noticed. In such cases pressure has been exerted in a different direction to produce dips and minor folds which strike in directions other than northwest and southeast."

These sediments lie conformably on lavas of the Princeton group, and are in part overlain unconformably by lavas of the Plateau basalt type, which at one time, no doubt, covered a comparatively much larger area.

The coal of the Tulameen basin is somewhat higher in rank than that of the Princeton basin: four analyses are given in Table XI. It is probable that the capping of younger lava there may have had the effect of converting it to bituminous rank. The section includes several mineable seams of clean coal, but unfortunately much of it is so badly crushed that it is of little use except for making briquettes.

Coalmont Collieries

Coal was known on Collins Gulch at the beginning of the century or earlier, and in 1906 coal was also found outcropping on the north fork of Granite Creek. It was not, however, until 1910, when the B.C. Coke and Coal Company obtained control of almost the entire Tulameen basin, that intensive exploration commenced. The following year the company was reorganized as Columbia Coke and Coal Company, Limited, and work was undertaken in two areas, one on the north and one on the south side of the basin.

The earliest work on the north side was done in Collins Gulch where three short adits demonstrated the presence of several seams of coal. The difficulty of transporting this to the road and railway, at what is now Coalmont, was so great that a successful attempt was made to trace the outcrops of the coal seams east to Frasers Gulch, directly above Coalmont. In order to develop the seams there, and at the same time avoid the badly crushed coal near the surface, a long crosscut was driven and intersected a 10- to 12-foot seam 2,000 feet from the portal. This seam was followed by drifts 250 feet to the east and 850 feet west. Unfortunately, even at this depth the coal was found to be badly crushed, apparently by strike faulting, and the work was, accordingly, abandoned. A last

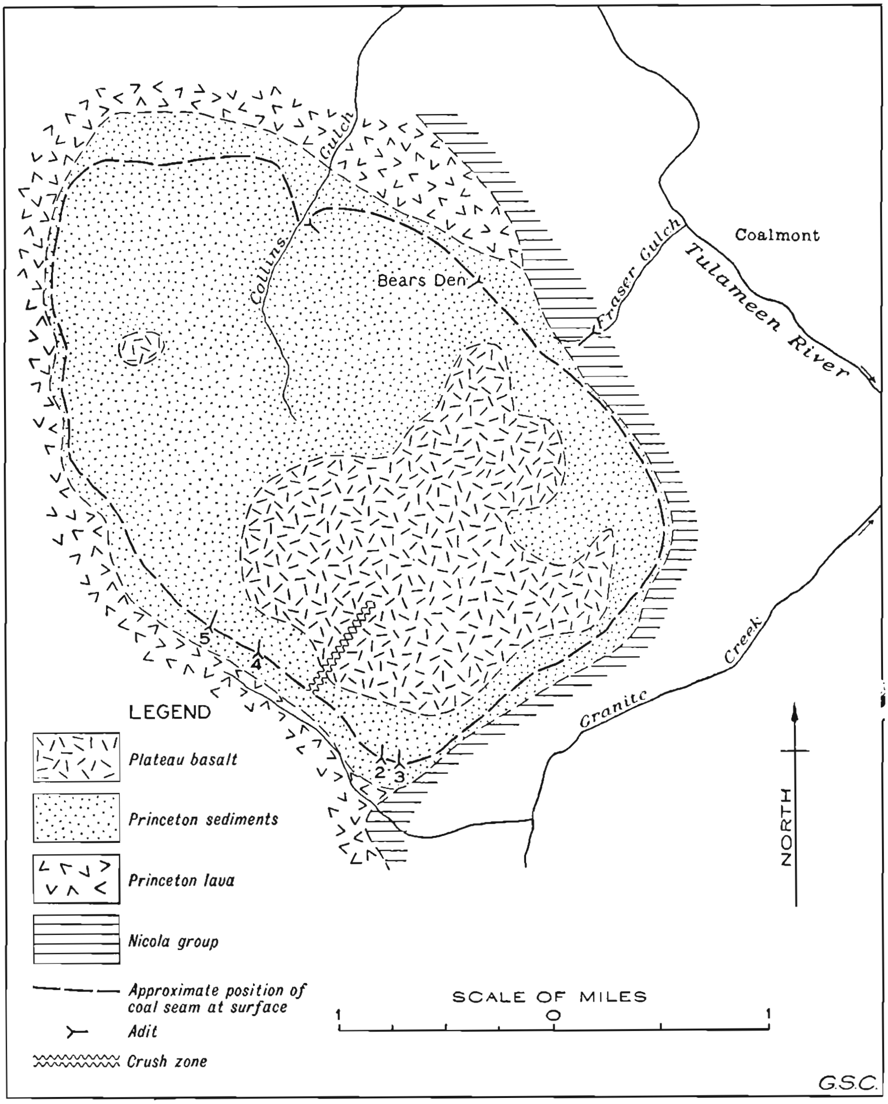

Figure 4. Tulameen coal basin.

effort to develop mineable coal on the north side was made at what was known as the Bear's Den showings halfway between Frasers and Collins Gulches. Here, two seams were cut underground, but also proved to be too crumbly to be of commercial value. All work on that side of the basin was, therefore, abandoned.

Development in the Number 1 workings on the north fork of Granite Creek on the south side of the basin was more satisfactory, and it became apparent that a workable seam of coal existed. However, it was also evident that the building of an adequate transportation system to Coalmont, which had by that time been reached by the railway, was beyond the financial resources of the holding company. Late in 1913, accordingly, the property was sold, and Coalmont Collieries was organized to assume control. For the next 2 years the owners actively developed the showings on the south side of the Tulameen basin. The original Number 1 workings were abandoned, and work concentrated on developing the Number 2 mine a little to the west of Number 1. In 1916 the work was stopped, but was resumed in 1918 and the following year the first production was recorded.

The seam worked was about 10 feet thick and the pitch at this point 18 degrees. It was followed by a drift 3,250 feet long to the northwest to a faulted and crushed zone occupied by a dyke. From 1919 to 1924 coal was mined from this level, mostly up the rise. In 1920 Number 3 mine was opened by a working known as Wilson's tunnel, on the same seam of coal as in the Number 2 mine but 400 feet to the east. This working was extended to the dyke encountered in the Number 2 mine at a distance of 3,300 feet. A pillar was left between these workings and those of Number 2 mine so that most of the coal extracted was below the adit level, and three main slopes, 1,100, 800, and 600 feet long, respectively, were driven to give access to it. Further extension at depth was prevented by heavy squeezing. In 1925 a fire broke out in Number 3 mine, which was promptly sealed off and flooded. Later in the year it and Number 2 slope were reopened and coal was mined from both these workings until 1935 when, with their exhaustion, the mine was shut down.

In 1927 Number 4 mine was opened by a drift on the same seam as that in Number 2 and Number 3 mines, but 5,400 feet northwest of the Number 3 and to the west of the dyke and faulted zone met with in these two mines. The seam in Number 4 mine had about the same thickness, but pitched at from 20 to 30 degrees. The main slope was driven 2,400 feet and was served by a crosscut adit driven to it at a lower elevation than the original entry. The small amount of coal below the level, between it and the fault, was mined out by 1928 and these workings sealed off. From then on active work was confined to the rise of the seam. Various difficulties were encountered: in 1930 an explosion resulted in the death of forty-five men, and in 1932 a section of the workings began to heat up and had to be sealed off. In 1935 this abandoned section was dewatered, and extraction of the developed coal in it resumed. Several attempts had been made to develop a workable seam of coal below the main seam both in Number 3 and Number 4 mines. In 1932 some coal was extracted from a seam 9 feet thick stratigraphically below the main seam. Extraction of the coal from the pillars in Number 4 mine continued until 1939 when the mine was abandoned.

In 1931 Number 5 mine was opened up on coal outcrops 2,800 feet north of Number 4 mine. A slope some 2,600 feet long was driven down the pitch of the same seam as that of the other mines. In view of the difficulties that attended the opening of the seam in the other mines, no lateral work was done here until 1935, by which time the slope had reached its maximum practical depth. Lateral development of the seam was then commenced at the deepest point and worked upwards closely followed by the extraction of the pillars. Sealing off and flooding the worked areas was in this way possible and all danger of fire avoided. By 1940 all the coal in Number 5 mine was extracted and the mine shut down. No other reserves were known, and the Coalmont Collieries, after 24 years of operation, during which more than 2,000,000 tons of coal were produced, passed out of existence, and the plant was dismantled and sold.

In 1943 and 1944 J. Delprato and a partner prospected along the line of the old Coalmont Collieries tramway, but this is the only recorded activity in the Tulameen coal basin since the closing down of the Coalmont Collieries.

BENTONITE

References: Spence, 1924. Ann. Repts., Minister of Mines, B.C.: 1923, p. 190; 1924, p. 175; 1931, p. 132.

Bentonite is the name given, according to the United States Geological Survey, to a "transported, stratified clay, formed by the alteration of volcanic ash, shortly after deposition". It consists essentially of silica, alumina, and water in the ratio of 61:18:10. In addition, there are minor amounts of iron, magnesia, lime, soda, and potash. Considerable doubt exists as to whether bentonite is a definite mineral or a mixture of colloids, authorities disagreeing on the matter. In appearance bentonite is a pale buff to olive-green or chocolate-brown clay; it is generally massive, and breaks with a pronounced conchoidal fracture. Its principal property is to swell enormously, as much as 16 times its normal volume when moistened. Spence (1924, p. 15) says:

> " . . . . . the bentonites of the Western United States and Canada are characterized in the field by their exceedingly sticky nature when wet. The great majority of ordinary clays exhibit plastic qualities in some degree, but bentonite may be termed 'hyperplastic'; that is, it does not possess working qualities even when mixed with the minimum amount of water necessary to thoroughly wet it, but passes at once from the 'short' state to a sticky, unworkable condition.
>
> "Bentonite outcrops always exhibit very characteristic weathered surfaces, having a crinkled, coral-like appearance, due to the alternate swelling and shrinkage of the material upon repeated wetting and drying out."

Several seams of bentonite up to 10 inches thick occur interbedded in the coal measures at the Princeton colliery on Bromley Creek and elsewhere in the Princeton basin. In particular, a 6-foot seam outcrops just south of Princeton about ½ mile from the railway, and a 14-foot seam is exposed in a nearby railway cut. H. Knighten of Princeton has explored the possibility of exploiting these deposits commercially, but although the material appears to be entirely satisfactory the problem of finding a market has not been solved. The following analysis of bentonite from Princeton is quoted from Spence, p. 14:

	Per cent
Silica	68·60
Alumina	12·10
Ferric oxide	2·00
Ferrous oxide	0·32
Lime	1·84
Magnesia	1·84
Titanium oxide	0·14
Phosphoric acid	0·17
Soda	0·50
Potash	0·23
Sulphur	Nil
Sulphuric acid	0·61
Carbon dioxide	0·17
Carbon	0·08
Water at 105° C	7·71
Water above 105° C	3·24
	100·01

A few carloads of bentonite have been shipped from time to time, largely as an experiment, but there has been no regular production.

The uses and possible uses of bentonite are many and varied (Spence, 1924, pp. 21, 30), depending largely on its absorptive and emulsifying powers. Actually its use is greatly curtailed by the costs of purifying and shipping to industrial centres.

GYPSUM

References: Ann. Repts., Minister of Mines, B.C.: 1913, p. 240; 1923, p. 188. Dom. Bur. Mines: 1913, Pub. No. 245, pp. 98, 99; 1930, Pub. No. 714, pp. 70, 71.

Several small deposits of gypsum occur on Granite Creek and on Tulameen River below this creek. Several of these have received a little attention, but none has been brought into production. As early as 1913, a few small trial shipments were made from the deposits on Granite Creek. A group of six claims on Tulameen River about a mile below the mouth of Granite Creek were owned in 1923 by A. S. Black of Princeton. All the gypsum deposits in this district seem to be discontinuous and small, Black's deposit being, apparently, the largest known. A limited number of open-cuts suggest a body of gypsum not less than 400 feet long, 100 feet wide, and some 6 feet deep. There is no record of any work having been done here since 1923.

INDEX