John McGlynn

This document was produced by scanning the original publication.

Ce document est le produit d'une numérisation par balayage de la publication originale.

GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

MEMOIR 308

NELSON MAP-AREA, WEST HALF, BRITISH COLUMBIA (82 F W½)

H. W. Little

Price, $1.75

1960

NELSON MAP-AREA, WEST HALF, BRITISH COLUMBIA
(82 F W½)

No. 2556

3,000-1959-1444

Plate I *View of Valhalla Range from ridge west of Hela Peak, looking south.*

GEOLOGICAL SURVEY
OF CANADA

MEMOIR 308

NELSON MAP-AREA, WEST HALF, BRITISH COLUMBIA (82 F W½)

By
H. W. Little

DEPARTMENT OF
MINES AND TECHNICAL SURVEYS
CANADA

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

Price $1.75 Cat. No. M46-308

PREFACE

Mining has been an important factor in the economy of the Nelson area ever since the first lode deposit was staked in 1886. To assist this, various parts of the area have from time to time been mapped by many geologists.

In this report the author presents a unified and comprehensive picture built from the several concepts that grew out of his own studies and those of earlier and contemporary investigators.

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

OTTAWA, January 15, 1959

CONTENTS

PAGE

CHAPTER I

Introduction 1
Location and accessibility 1
Population and industries 2
Climate 2
Previous work 3
Acknowledgments 4

CHAPTER II

Physical features 6
Selkirk Mountains 7
Monashee Mountains 9
Drainage and drainage history 10

CHAPTER III

General geology 13
Table of formations ..... *In pocket*
Sedimentary and volcanic rocks 14
Proterozoic 14
Windermere 14
Toby formation 14
Irene Volcanic formation 16
Monk formation 18
Windermere (?) 20
Three Sisters formation 20
The base of the Cambrian system 23
Palæozoic 24
Lower Cambrian 24
Quartzite Range formation 24
Reno formation 27

PAGE

CHAPTER III—*Continued*

Laib formation 30
Middle Cambrian 35
Nelway formation 35
Ordovician 39
Active formation 39
Undivided Palæozoic 42
Devonian 45
Pennsylvanian (?) 45
Mount Roberts formation 45
Mesozoic 52
Triassic 52
Kaslo group 52
Triassic and (?) Lower Jurassic 53
Slocan group 53
Permian (?) Triassic (?) and Lower Jurassic (?) 57
Ymir group 57
Lower Jurassic 60
Sinemurian beds 60
Rossland formation 62
Middle and (?) Upper Jurassic 67
Hall formation 67
Early Mesozoic (?) 71
Upper Cretaceous (?) or later 73
Sophie Mountain formation 73
Cenozoic 74
Tertiary (?) 74
Pleistocene and Recent 75
Plutonic rocks 76
Ultrabasic intrusions 76
Rossland 'monzonite' 77
Bonnington complex 80
Nelson plutonic rocks 81
Age 85
Valhalla plutonic rocks 87
Age 90
Coryell plutonic rocks 90

PAGE

CHAPTER III—*Concluded*

Origin 93
Age 93
McGregor intrusions 94
Sheppard intrusions 94

CHAPTER IV

Structural geology 97
Structure of the Nelson batholith 97
Origin of the Nelson batholith 98
Faults 101
Ripple Creek fault 101
Unnamed fault 102
Laib Creek fault 102
Faults in Stagleap Creek 102
Weasel Creek fault 102
Baldy fault 102
Seeman Creek fault 103
Porcupine fault 103
Oxide fault 103
Pend-d'Oreille fault 104
Other faults 104
Folds 104
Slocan fold 104
Unnamed folds 105
Laib Creek syncline 105
Sheep Creek anticline 105
Western anticline 105
Baldy anticline 105
Unnamed folds in the Lower Cambrian rocks 106
Folds in the Rossland formation 106
Anticline near Paterson 106

CHAPTER V

Historical geology 107

PAGE

CHAPTER VI

Metalliferous deposits 111
History of mining 111
Description of properties 113
Placer deposits 114
Lode deposits 118
Lead-silver deposits 118
Silver-lead-zinc deposits 132
Silver-gold deposits 150
Gold-silver deposits 155
Copper-silver-gold deposits 176
Gold-copper-silver deposits 178
Zinc-lead-silver deposits 184
Tungsten deposits 192
Molybdenum deposits 193
Iron-oxide deposits 193

References 195

Index 201

Table I Chemical analyses of plutonic and volcanic rocks 78
Table II Chemical analyses of Valhalla granite 88
Table III Chemical analyses of Coryell rocks 91

ILLUSTRATIONS

PAGE

Map 1090A Geology of Nelson (west half) map-area ..... *In pocket*

Map 1091A Mining properties, Nelson (west half) map-area ..... *In pocket*

Plate I View of Valhalla Range from ridge west of Hela Peak, looking south ..... *Frontispiece*

II Ribbon quartzite in north end of belt of 'Palæozoic undivided' rocks ..... *facing page* 42

III Layered gneiss near Gwillim Creek ..... *facing page* 72

IV Fracture cleavage in gneiss near Slocan ..... *facing page* 72

V Drag-fold in gneiss near Hela Peak ..... *facing page* 73

Figure 1. Map showing physiographic divisions of southern British Columbia 6

2. Map showing physiographic divisions within Nelson map-area (west half) 7

3. Map of Hall formation in type locality 69

4. Diagrammatic sketch of termination of gneissic band 72

5. Setting of the Nelson batholith and some satellites 82

6. Intersection of bands of biotite-hornblende-feldspar gneiss as found on Kutetl Creek 100

7. Map showing relative size of mine and contained metals ..... *In pocket*

8. Geology of 5480 level, Carnation mine 121

9. Profile of workings of Bosun mine ..... *In pocket*

10. Plan of Nos. 4, 5 and 8 levels, Ottawa mine ..... *In pocket*

11. Plan of Little Tim mine 142

12. Plan of part of underground workings, Enterprise mine ..... *In pocket*

13. Longitudinal section of workings, Enterprise mine ..... *In pocket*

14. Plan of Maple Leaf (Porcupine) property 144

15. Plan of workings on Joan (Duplex) property 153

16. Plan of workings of Morning Star mine 160

17. Plan of workings of Chapleau mine 162

18. Hummingbird property ..... *In pocket*

19. Plan of Piedmont mine (Hope No. 2 claim) 190

Correlation chart ..... *In pocket*

NELSON MAP-AREA, WEST HALF, BRITISH COLUMBIA

Abstract

Nelson map-area embraces some 3,000 square miles of mountainous terrain in south-central British Columbia. It consists of generally severely folded and faulted sedimentary and volcanic rocks representing most systems from the Windermere (late Precambrian) to the Cretaceous. Within all these are emplaced plutonic rocks, mainly acidic, of two distinct ages. The more abundant are the Cretaceous (?) granitic bodies of the Nelson and Valhalla plutonic rocks. These are shown to be in large part of metasomatic origin although in places there is clear evidence of magmatic injection. The younger plutonic rocks are of Tertiary age, more alkaline in composition, and mainly of magmatic origin.

Mining has been active for many decades. The most important camps are the Rossland gold-copper camp in the southwest, the Slocan silver-lead camp in the northeast, and the Sheep Creek gold camp in the southeast. Elsewhere within the map-area other individual mines have been of importance, and small producers and prospects are numerous. Major production from the Rossland and Sheep Creek camps ended in 1928 and about 1942, respectively. In recent years most ore has been won from zinc-lead-silver mines in the Slocan camp and the limestone belt west and southwest of Sheep Creek camp. In this belt the Emerald, Feeney, and Dodger mines have been the largest producers of tungsten concentrate in Canada.

Résumé

La région représentée sur la carte Nelson couvre une superficie de quelque 3,000 milles carrés de terrain montagneux, dans le sud central de la Colombie-Britannique. D'une façon générale, on y trouve des roches sédimentaires et volcaniques très plissées et faillées qui représentent la plupart des âges géologiques depuis le Windermere (fin du précambrien) jusqu'au Crétacé. A l'intérieur de cet assemblage, on trouve des roches plutoniennes, en grande partie acides, qui appartiennent à deux époques distinctes. Celles qui prédominent sont les masses granitiques crétacées (?) des roches plutoniennes Nelson et Valhalla. La plupart de ces roches sont d'origine métasomatique, bien qu'en certains endroits il s'agisse clairement d'injection magmatique. Les roches plutoniennes plus récentes, qui remontent au tertiaire, sont de composition plus alcaline et, en grande partie, d'origine magmatique.

Dans cette région, l'industrie minière est active depuis des années. Parmi les plus importants champs d'action on compte le camp minier d'or-cuivre Rossland au sud-ouest, le camp d'argent-plomb Slocan au nord-est, et le camp aurifère Sheep Creek au sud-est. Ailleurs dans les limites de cette carte, d'autres mines particulières ont déjà eu de l'importance, et les petites exploitations ainsi que les gîtes prometteurs y pullulent. Dans les camps Rossland et Sheep Creek, le volume de la production a fortement décliné en 1928 et vers 1942, respectivement. Ces dernières années, le gros du minerai a été tiré des mines de zinc-plomb-argent du camp Slocan et de la zone calcaire située à l'ouest et au sud-ouest du camp Sheep Creek. A l'intérieur de cette zone, les mines *Emerald, Feeney* et *Dodger* ont été les plus importantes productrices de concentré de tungstène au Canada.

Chapter I

INTRODUCTION

Nelson map-area (west half) is in southeastern British Columbia and is about 3,110 square miles in area. It is bounded by the 49th (International Boundary) and 50th parallels of north latitude and by the 117th and 118th meridians of west longitude.

The entire map-area had been mapped geologically by the year 1900, but subsequent work adjacent to it and more detailed work within it indicated that revision of the original interpretations should be made. In particular, the integration of the structure into the regional picture was regarded as essential, and the more precise dating of many apparently unfossiliferous formations was desirable. Lastly, a study was made of the economic geology to relate the mineral deposits of the map-area to the regional picture.

Accordingly, the writer, after initiating the mapping of Ymir map-area the previous year, began in 1948 a study of Nelson map-area (west half) and field work on this project was continued during the field seasons of 1949, 1950, and part of 1952.

Location and Accessibility

The city of Nelson, from which the map-area derives its name, is 10 miles east of the geographic centre of the map-area studied. It is on the west end of the West Arm of Kootenay Lake, from which Kootenay River flows southwest some 20 miles to its junction with Columbia River. Nelson is a division point on the Kettle Valley Railway, the more southerly trans-provincial line of the Canadian Pacific Railway. It is 513 miles by rail from Vancouver and 450 miles from Medicine Hat, where the branch joins the main line.

Other principal cities within the map-area are Trail, on Columbia River, and Rossland, 7 miles west of Trail. The populations of the three cities according to the 1951 census are Nelson, 6,772; Trail, 11,430; and Rossland, 4,604. Smaller towns, in descending order of size, include Castlegar, Salmo, New Denver, Slocan City, Silverton, and Ymir.

The map-area in general is easily accessible, except for much of the northwest quarter and certain other parts. The Canadian Pacific Railway provides daily service through Nelson, with connecting bus service to Trail, in addition to freight service on the lines between Castlegar, Trail, and Rossland, between South Slocan and Slocan City, and between Kaslo, Sandon, and Nakusp. The Great Northern Railway provides freight service between Nelson and Spokane via Ymir and Salmo.

71994-8—2½

A paved highway extends from Kootenay Lake along the West Arm to Nelson; paved branches of this highway stretch via Castlegar and Salmo, to Trail. The highway is paved from Trail to Paterson via Rossland and links with the highway system of the State of Washington. The trans-provincial highway from Rossland west to Christina Lake is not paved, but from this point pavement continues to Vancouver. A new highway is planned, to avoid the mountains west of Rossland, that will ascend Blueberry Creek and continue west to join the main highway at Christina Lake.

Gravel highways link Salmo with Nelway, and South Slocan with Vernon, the latter via Slocan Lake, Nakusp, Burton City, and Monashee Pass. Several short public roads, together with mining and private logging roads provide access to many parts of the area. Pack-horse trails have been reopened in recent years by the British Columbia Forest Service along many of the less accessible valleys.

Population and Industries

The population of the area is perhaps 30,000, concentrated largely in the three main cities. Few Indians reside within the area. People of foreign origin form distinct groups within some communities. For example, people of Italian extraction form a group in Trail; and many of Japanese origin remained to reside in the towns of New Denver and Slocan City after being moved to interior towns from the coastal cities during World War II. These people now take part in the community life and industry of the district. Much of the farm land is owned and worked by Doukhobors, many of whom remain aloof from other ethnic groups.

The important industries include lumbering, mining and farming. Many residents are occupied in maintenance and operation of the railways. The most important single industrial employer is the Consolidated Mining and Smelting Company of Canada for whom thousands of residents of Trail, Rossland, and nearby communities work in the smelting and refining of ores, in the manufacture of chemical fertilizer, and in related duties.

The mining industry of the area is notable, not only for past production from such famous mining camps as Rossland, Slocan, Nelson, Ymir, and Sheep Creek, but for present and potential production. Gold, silver, copper, lead, zinc, and tungsten have been won in great quantities from the ores of these camps, and current production of lead, zinc, tungsten, and possibly silver remains at a high level. Relatively minor amounts of cadmium, antimony, molybdenum, and iron oxides, and some non-metallic materials, mainly building stone, have also been produced.

Climate

Because mountains are higher there than those to the west short of the Coast Mountains and because the prevailing winds are westerly, precipitation in the map-area is greater than anywhere to the west except in the Coast Mountains themselves. Weather records published by the Department of Transport are contained in the following table.

Station	Elevation (feet)	Years of Observation	Average Annual Precipitation[1] (inches)	Average Annual Snowfall (inches)	Average Annual Temperature (degrees, Fahrenheit)
Nelson	1,760	39	27.77	89.3	45
Crescent Valley	2,000	12	29.48	99.4	44
Rossland	3,410	10	30.75	132.2	42
Old Glory Mountain	7,700	6	23.90	162.2	26

[1] Including snowfall, of which 10 inches is equivalent to 1 inch of precipitation.

The climate of the area is moderate and healthful, and in the valleys the temperatures are not extreme. At Nelson, the average annual maximum and minimum temperatures are 96 degrees above and 4 degrees below zero Fahrenheit, respectively.

Previous Work

In this region the earliest geological work was done by H. Bauerman (1885)[1], who accompanied the International Boundary Commission expedition of 1859 to 1861. Because he descended Kettle River and made his way overland to Spokane via Colville, he did not actually examine any of the rocks exposed within the map-area, but he did see the lateral extensions of some of the formations and the equivalents of some of the intrusive rocks.

G. M. Dawson (1890) made a reconnaissance trip in 1889 down Arrow Lakes, and up Kootenay River and Lake. He examined the intrusive rocks, gneisses, and some of the formations, and described the copper-silver ores near Nelson.

In 1894, R. G. McConnell began the mapping of the West Kootenay sheet and a map of his initial work was published in 1897. In 1897 he was joined by R. W. Brock who completed the project in 1900. The West Kootenay sheet was published in 1904 under their joint authorship. More detailed descriptions appear in the Annual Reports of the Geological Survey for the years 1894 to 1900.

Detailed areal mapping of the Rossland mining camp was carried out by G. A. Young in 1906, in conjunction with the examinations by R. W. Brock (1906, 1907), of the ore deposits there. Their reports were subsequently expanded and revised by Drysdale (1915).

In 1908, O. E. LeRoy began a study of the Slocan mining camp which he continued for some years (LeRoy, 1909, 1910, 1911, and 1916). This work was continued by C. W. Drysdale (1917a) who published a report and map

[1] References in parentheses are to reports listed in the References at the end of this report.

of the area. Further work in this region, done in 1917 by M. F. Bancroft (1918) and continued by C. E. Cairnes (1926, 1927), culminated in the production of two memoirs with accompanying maps (Cairnes, 1934, 1935).

In 1911, LeRoy (1912a) examined the mineral deposits near Nelson and published a geological map of the area. Drysdale (1917b) in 1914 made a geological map of the Ymir area and reported upon the mineral deposits.

R. A. Daly, geologist to the International Boundary Commission, mapped geologically a narrow strip along the Forty-ninth Parallel across southern British Columbia during the years 1901 to 1906. The description of those parts along the south edge of the present map-area were published in preliminary form (Daly, 1904) and later incorporated in a memoir with geological maps dealing with the entire belt (Daly, 1912). In 1906, he initiated a geological investigation of Sheep Creek mining camp that was completed by LeRoy in 1909 (Daly and LeRoy, 1909).

During the field seasons of 1928, 1929, and 1931, a geological map and examination of the mineral deposits of Salmo map-area were made by J. F. Walker (1930, 1934). In 1935, W. E. Cockfield (1936) examined the mineral deposits of the Ymir-Nelson (Bonnington) area which adjoins Salmo map-area on the north. In 1947, the present writer began the geological mapping of Ymir map-area. This was completed by A. L. McAllister (1951) the following year. Bonnington map-area was mapped in 1949 by R. Mulligan (1952).

In addition to the above work by officers of the Geological Survey of Canada, detailed studies of structure and mineral deposits have been made by several geologists of the British Columbia Department of Mines. Among these are E. L. Bruce (1917) on Rossland camp, R. J. Maconachie (1940) on Upper Lemon Creek area, M. S. Hedley (Stevenson, 1943) on the Emerald tungsten deposits, M. S. Hedley (1952) on Sandon area, W. H. Mathews (1953) on Sheep Creek camp, and J. T. Fyles and C. G. Hewlett on the Salmo-Pend-d'Oreille Rivers area (report in preparation for publication). Other information regarding mineral deposits, as compiled by geologists and mining engineers of the British Columbia Department of Mines, is contained in the Annual Reports of the Minister of Mines for the years 1887 to 1956.

Geological maps have been published for areas adjacent and closely related to the Nelson (west half) map-area. Such areas are Ainsworth (Schofield, 1920; Rice, 1944), Lardeau (Walker, Bancroft, and Gunning, 1929), Nelson, east half (Rice, 1941), Metaline (Park and Cannon, 1943), Whitewater (Hedley, 1945), Northport (Campbell, 1947), and Orient (Bowman, 1950).

Acknowledgments

The writer wishes to express his appreciation for many courtesies extended by residents of the area, and particularly for the cooperation of the prospectors, mine managers and other mine employees, and many members of the British

Columbia Forest Service. Grateful thanks are also due to J. A. Mitchell, former resident mining engineer at Nelson, and J. W. Peck who succeeded him in that position, for their hospitality and cooperation.

Detailed mapping has been done in the eastern part of the map-area by mining and other geologists. Some such published works include those by McGuire (1942), White (Minister of Mines, B.C., Ann. Rept. 1949, pp. 169-174), Hedley (1952), and Mathews (1953). Other mapping which was made available to the writer and much of which was incorporated into the present map, was done by V. J. Okulitch for the Geological Survey of Canada, H. C. Gunning for New Jersey Zinc Exploration, Limited, G. Gilbert for the Consolidated Mining and Smelting Company of Canada, H. Lakes for Canadian Exploration, Limited, A. E. Buller for Pend Oreille Mines and Metals Company, P. J. Shenan for Day Mines, Limited, and J. T. Fyles and C. G. Hewlett of the British Columbia Department of Mines.

The writer is grateful to J. T. Fyles and the late C. G. Hewlett of the British Columbia Department of Mines for taking two days in June, 1956 to show him in the field some of the changes they had made in his reconnaissance mapping of Salmo map-area.

V. J. Okulitch also accompanied the writer to some fossil localities and assisted in the discovery and collection of fossils, and identified those of Lower Cambrian age. H. W. Frebold of the Geological Survey made a further collection of fossils from the Rossland group and identified all fossils of Jurassic age.

Willing and efficient assistance was rendered in the field by R. Mulligan, W. O. Pollock, and P. G. Hughes in 1948, by W. H. Dow, E. M. Wilson, L. E. Marjanen, and W. Panasiuk in 1949, by L. H. Green, P. J. Farrell, H. Benthin, and D. B. MacLennan in 1950, and by J. G. Souther, J. C. Davies, and R. C. Bland in 1952. Dr. A. B. Irwin was attached to the field party for some weeks in 1950 and examined mineral deposits in the Slocan area.

Chapter II

PHYSICAL FEATURES

Nelson map-area (west half) lies within the Columbia Mountains which form a great triangular area extending from the International Boundary between Rocky Mountain Trench and Interior Plateau northeasterly to the bend of upper Fraser River near Prince George (*see* Figure 1). The Columbia Mountains are subdivided into the Purcell, Selkirk, Monashee, and Cariboo Mountains. The map-area falls entirely within the Selkirk Mountains except for the small parts west of the Columbia River, which are in the Monashee Mountains.

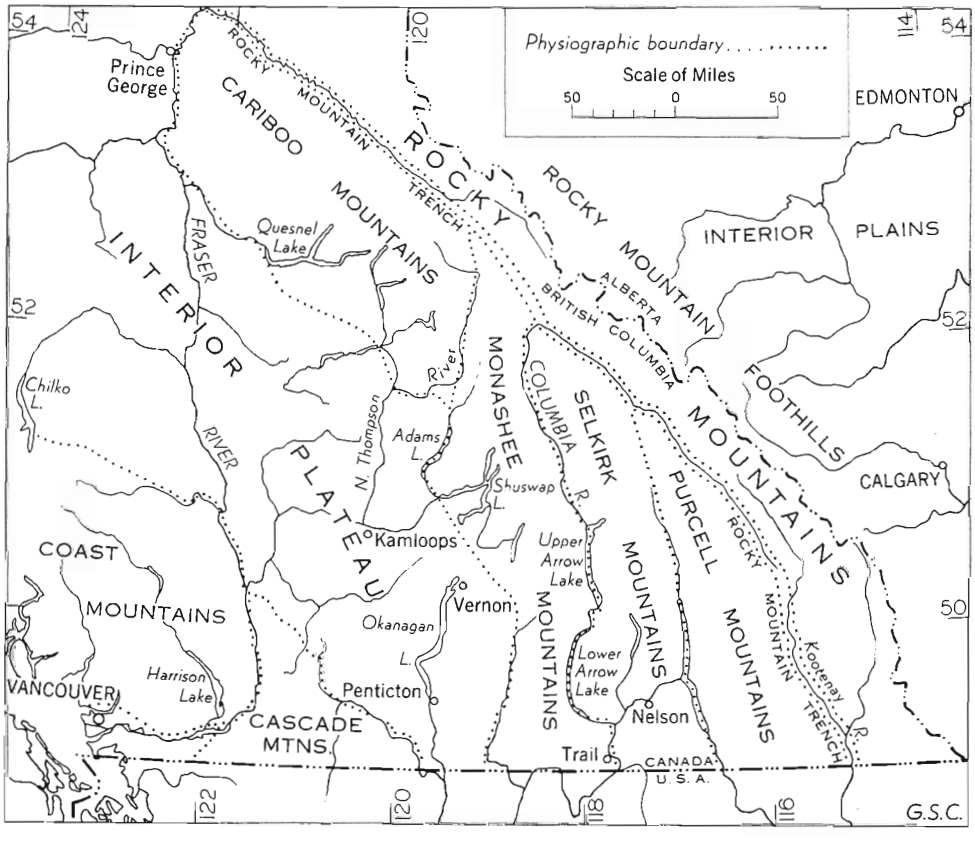


Figure 1. *Map showing physiographic divisions of southern British Columbia.*

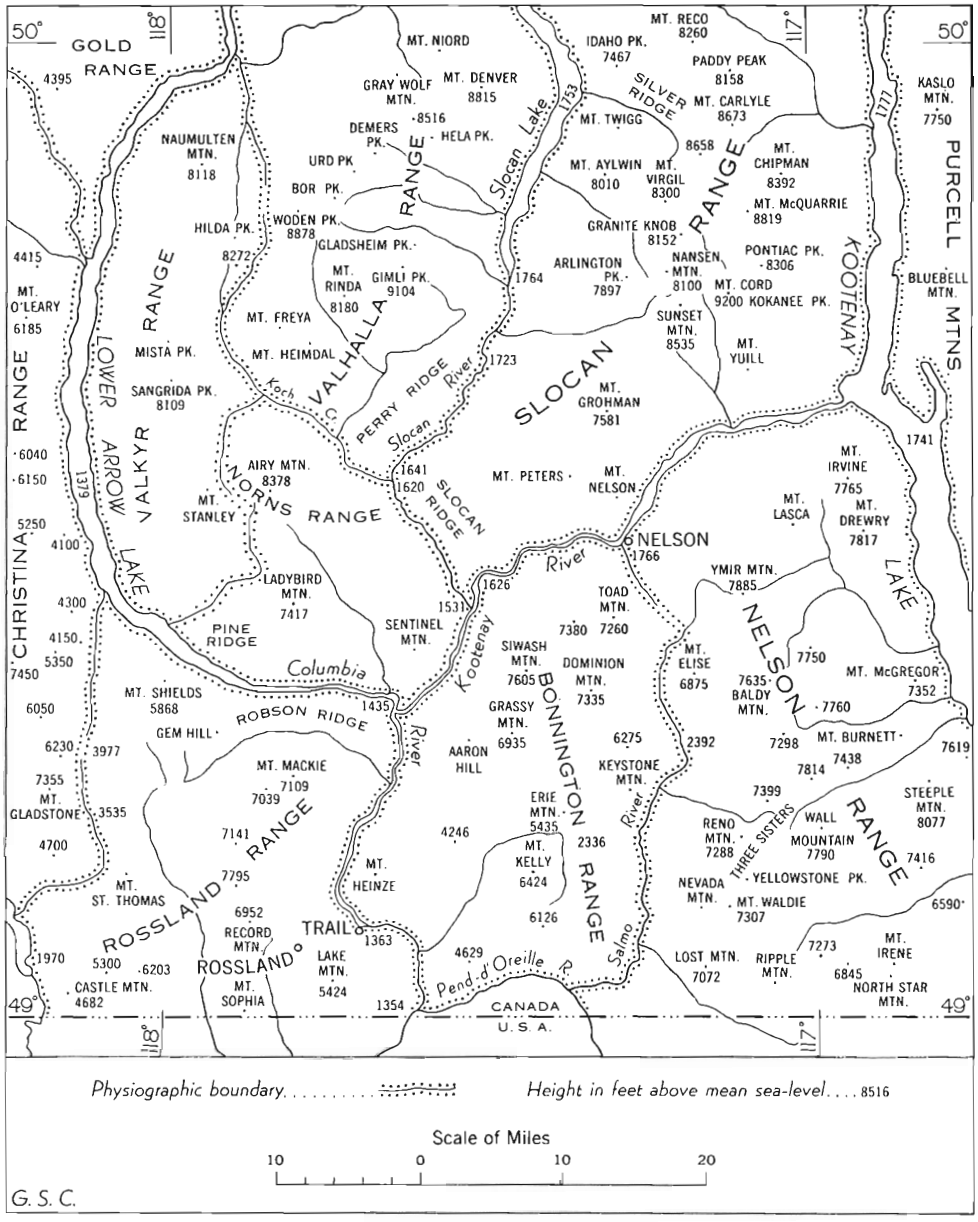


Figure 2. Map showing physiographic divisions within Nelson map-area (West Half).

Selkirk Mountains

The Selkirk Mountains form an imposing mountain barrier in the area, breached only by Kootenay River. Farther north there are two fairly low passes, the more southerly, immediately north of the map-area, being used by the Kaslo

and Nakusp branch of the Canadian Pacific Railway. Within this area the Selkirk Mountains contain parts of the following ranges: Nelson, Bonnington, Slocan, Norns, Valhalla, and Valkyr (*see* Figure 2).

Nelson Range

The crest of this range consists of rugged peaks mainly of Lower Cambrian quartzite, from which Nelson Range bears its former alternative name 'Quartzite Range'. The shapes of the mountains and ridges along the crest of Nelson Range are governed by the trend of these quartzites, and to a lesser extent, by their dip. Angular slabs of the quartzite form abundant felsenmeer on the higher ridges. In the north part of the range the peaks are more commonly of granite. Cirques are present on the northern slopes of many of the higher peaks. Ymir Mountain, elevation 7,885 feet, is the highest in the range and its peak, which forms a triangular pyramid, is an excellent example of a horn.

The eastern slope of the range is underlain by softer, more argillaceous late Proterozoic rocks intruded by granitic stocks. Much of the northwestern part is underlain by younger argillaceous and volcanic rocks.

Bonnington Range

This range is roughly oval in shape. The southern part, which is underlain largely by volcanic rocks, contains wooded, rounded mountains; but the north part, in which granite is more dominant, contains higher, more pointed peaks. The range is transected by the valley of Beaver Creek, which has been used by the Great Northern Railway to provide access to Salmo River valley and Nelson.

Slocan Range

Porphyritic granite is the principal rock forming the high and rugged mountains of Slocan Range. Mount Cond, in the centre of Kokanee Glacier Park, is the highest peak in the range, with an elevation of 9,200 feet. Kokanee Glacier, which covers more than 2 square miles and is the largest in the region, extends northward from Mount Cond and nearby peaks. A few miles to the northeast is Sawtooth Ridge which has two peaks nearly as high as Mount Cond. The Woodbury Glaciers are on the northeast slope of this ridge. A few other glaciers occur a little farther to the northeast, the largest of which is Caribou Glacier. On the West Kootenay sheet, published in 1904, a glacier was shown on the southwest slope of Mount Cond, but it no longer exists.

The effects of glaciation in the Slocan Range are manifest. Cirques are common and most are occupied by small tarns. Hanging valleys, truncated spurs and great accumulations of valley debris are testimony of glacial action.

Norns Range

The mountains of this range are composed of paragneiss and strongly foliated granite. The gentle southwesterly dip of the foliation, together with the strong jointing perpendicular to it, results in open meadows on the high southwest slopes and steep cliffs on the northeast faces. The highest peak in the range is Airy Mountain, elevation 8,378 feet, but the isolated positions of Ladybird and Sentinel Mountains make them more conspicuous features.

Valhalla Range

The peaks of Valhalla Range, which lies west of Slocan Lake, though not appreciably higher than those of Slocan Range are more spectacular owing to their extremely rugged nature (*see* Plate I). Although both ranges are composed of granite, the Valhalla Range granite is more strongly foliated and jointed, resulting in higher and steeper cliffs; where the foliation is horizontal, castellated peaks occur connected by tortuous, serrated cols.

Evidence of both continental and alpine glaciation is abundant, but the former is not seen at elevations much higher than 7,000 feet. The largest glacier in Valhalla Range is New Denver Glacier which is about one square mile and occupies a cirque on the northeast side of Mount Denver. The glacier on Woden Peak was not observed at close range by the writer, but those on the long ridge running eastward from Mount Bor are small. In his field notes of 1899, R. W. Brock described large glaciers in this locality.

Above the level of continental glaciation, horns and cirques are common features and the ridges have sharp crests formed by the weathering of the jointed granitic blocks. These blocks are perched precariously upon one another and are a barrier to easy passage on foot, either along the crests of the ridges or on the talus slopes. Below this level, the ridges and spurs have been bevelled and rounded to a marked degree.

Valkyr Range

This range is much lower than Valhalla Range immediately to the east, owing to the fact that it is largely composed of syenite that is less resistant to weathering than the granite comprising Valhalla Range. None of the peaks is much higher than 8,000 feet, but because the elevation of Lower Arrow Lake is less than 1,400 feet, they are an imposing sight when viewed from the west.

Except for the horns and cirques of the higher peaks such as Hilda and Sangrida the mountains and ridges are more rounded than those of Valhalla Range. No glaciers remain in the range.

Monashee Mountains

The Monashee Mountains are mainly west of Nelson map-area and extend from the International Boundary northward to North Thompson River. They are subdivided into several ranges, but only parts of the Gold and the Rossland Ranges are within the map-area.

Gold Range

Gold Range, which lies on the west side of Columbia River and Upper Arrow Lake, is high and rugged, with peaks nearly 10,000 feet high. Only the southern end of Gold Range is within the map-area, in the extreme northwest corner north of the upper end of Lower Arrow Lake.

Rossland Range

Like Bonnington Range, Rossland Range directly south of Lower Arrow Lake is characterized by more mature topography than the ranges to the north. The highest peak, Old Glory Mountain, elevation 7,795 feet, is a conspicuous feature, being several hundred feet higher than the surrounding peaks. It serves as a lookout point for the Forest Service, and is the site of a year-round meteorological observation station maintained by the Department of Transport, the highest such station in Canada.

Although lacking glaciers at the present time, the higher peaks show evidence of alpine glaciation and, in addition, the effects of continental glaciation are apparent everywhere within the range. Thick deposits of glacial till occupy the valleys, and in the valleys of Big Sheep Creek and its tributary Santa Rosa, thick accumulations of bedded silts and sands of Pleistocene age can be seen.

Drainage and Drainage History

Nelson map-area (west half) is drained by Columbia River and its main tributary, Kootenay River. Other streams tributary to the Columbia are Pend-d'Oreille-Salmo system and many creeks that empty directly into the main river. The main tributary of Kootenay River is Slocan River which drains Slocan Lake. Lower Arrow Lake is simply a widening of Columbia River which both empties into and drains it.

Earlier reports have remarked upon a peneplain surface in places at a general elevation of 6,000 feet. It was regarded as being of Eocene age, and this dating became so ingrained in the literature that Umpleby (1911, p. 26) used it as a basis for dating intrusions that are emplaced just below it. In the present map-area, however, the lack of pre-Pleistocene sedimentary deposits makes it impossible to date this peneplain, if such existed. The presence of conglomerate of probably Upper Cretaceous age on Lake Mountain and Mount Sophia suggests that a peneplain existed there at that time. In the adjoining map-area to the west, valley deposits of early Tertiary age occur. This would seem to indicate that rapid incision of the peneplain by the major rivers probably occurred at the close of the Mesozoic era. Yet these early Tertiary beds are intruded by bodies of syenite, some of which form peaks higher than 8,000 feet, well above the elevation of the presumed peneplain. It may be concluded that more than one local period of peneplanation occurred in the region.

Schofield (1946) has suggested that the West Arm of Kootenay Lake is a drowned river valley and that at one time the West Arm drained eastward in the opposite direction to which it now flows. This conclusion was based upon the premise that the West Arm widens and deepens eastward. That this is not so is clearly indicated upon Sheet M.S. 9 of the Columbia Basin Series, published by the Canadian Hydrographic Service, Surveys and Mapping Branch. Dawson's (1890, p. 23B) suggestion that the flooding of the West Arm was caused by blocking of the arm at its western extremity by outwash stream debris appears to be more valid.

The drainage pattern is not governed appreciably by geological structure except possibly the valleys of Koch Creek, Little Slocan River, and the lower part of Slocan River which follow the crests of anticlines of paragneiss banding and granite foliation. It is possible that jointing or fracturing along the crests of these anticlines rendered these regions more amenable to erosion.

Little direct evidence of earlier drainage patterns is apparent, but certain deep valleys culminating in low passes suggest that these may have been major river valleys. Such valleys are those of Slocan River and Lake, north of which a broad valley extends to Nakusp on Upper Arrow Lake, the valley of Little Slocan River, that west of Sentinel Mountain, and that of Beaver and lower Erie Creeks.

On the east side of Columbia River, at the mouth of Pend-d'Oreille River, is a buried channel that lies a few hundred feet from the present river bed. This was first commented on by Daly (1912, p. 589), who regarded it as an old channel of the Pend-d'Oreille. Drilling in connection with a dam built by the Consolidated Mining and Smelting Company of Canada has, however, established the presence of a buried channel north of Pend-d'Oreille River, and this suggests that the channel is an old bed of Columbia River.

The drainage pattern of Nelson map-area, then, appears to have been established early but may have been modified slightly, most probably during Pleistocene time.

Chapter III

GENERAL GEOLOGY

Sedimentary and igneous rocks, both intrusive and extrusive and ranging in age from Precambrian to Tertiary, occur within the map-area. (*See* Table of Formations, in pocket.)

The Windermere system, of late Proterozoic age, comprises a thick assemblage of sedimentary and volcanic rocks occupying the southeast corner of the map-area. These rocks trend slightly east of north and have been traced northward by Rice (1941) to the fiftieth parallel of latitude, which is a short distance south of the type area (Walker, 1926). In the type area and in Nelson area (east half) they overlie unconformably the Purcell series.

Cambrian rocks, consisting of schist, phyllite, quartzite, limestone, and dolomite, overlie with apparent conformity the late Proterozoic measures and are overlain disconformably by slate and argillaceous quartzite of Ordovician age.

The Ymir group, composed of argillite, slate, impure quartzite, and minor limestone, is believed to be roughly equivalent to the Triassic Slocan group of similar lithology, which outcrops in the northeast part of the map-area. There the Slocan group is underlain disconformably by volcanic rocks of the Kaslo group. This group in turn is underlain by the Milford group of Permo-Carboniferous to Triassic age that occurs northeast of the map-area (Walker, Bancroft, and Gunning, 1929; Cairnes, 1934; Rice, 1941).

In neither the Ymir group nor the Sinemurian beds, which are tentatively correlated with its upper part, is the base exposed. Both units are overlain conformably by the Rossland formation, of late Lower Jurassic age, which consists of volcanic rocks and minor shale. In the vicinity of Rossland, however, the Rossland rests on the Pennsylvanian (?) Mount Roberts formation with marked unconformity. The Rossland formation is overlain conformably by the Hall formation of Middle and possibly Upper Jurassic age.

Paragneisses that underlie large areas in the Nelson batholith mainly between Evans Creek and lower Slocan River are believed to have been formed by metasomatism of sedimentary rocks of probably early Mesozoic age.

Highly serpentinized dunite and peridotite bodies which intrude the Mount Roberts and Rossland formations occur in the southwest part of the map-area, with the largest body extending some miles southwest from Rossland.

The greater part of the area is underlain by granitic and related rocks of the Nelson and Valhalla plutonic rocks, which form the Nelson batholith and its satellites. Most of the peripheral bodies are of Nelson rocks, but a few in the northwest part are of Valhalla granite. The Nelson plutonic rocks cut all the formations mentioned above and the ultrabasic rocks. In the core of the batholith,

the contacts of Valhalla and Nelson plutonic rocks are commonly gradational, but nearer the periphery, dykes of Valhalla granite intrude the Nelson rocks.

In the southwest part of the map-area the Sophie Mountain formation, consisting largely of conglomerate, rests unconformably upon the Rossland formation and is not cut by Nelson intrusions. It has yielded fossil plants of Upper Cretaceous, or possibly Tertiary, age.

The Sophie Mountain formation is intruded by Coryell syenite which forms two large batholiths and some stocks along the west edge of the map-area. It is also cut by Sheppard granite which forms stocks and smaller bodies near the International Boundary south of Trail.

On the west side of Stagleap Creek in the southeast part of the area, about 10 feet of conglomerate of possibly Tertiary age are exposed, which probably represents a remnant of more extensive deposits once formed in the valley.

Sedimentary and Volcanic Rocks

Proterozoic

Windermere

The Windermere 'series' was defined by Walker (1926, pp. 13-20). In the type area it consists of two formations that Walker named "Toby" and "Horsethief"; the latter was later changed to Horsethief Creek as "Horsethief" had been used previously for another unit elsewhere (Evans, 1932, p. 116). These overlie unconformably the Purcell series and are overlain unconformably by Upper Cambrian strata. In several localities south of Windermere map-area, the Windermere rocks are succeeded unconformably by Lower Cambrian strata. Its two formations were traced southward to the International Boundary by Rice (1941), who found that the upper part of the Horsethief Creek formation, which he renamed Horsethief Creek series, grades laterally into the coarse clastic rocks of the Three Sisters formation of Nelson area (west half).

The present writer accordingly has placed the Toby, the Irene Volcanic, and the Monk formations in the Windermere system, and regards the Three Sisters formation as probably belonging to the same system, therefore being also of Precambrian age.

Toby Formation

The Toby formation was first described by Daly (1912, pp. 141-144) who named it the Irene conglomerate. Walker (1926, pp. 13-14) described a similar conglomerate in the Windermere map-area to which he applied the name Toby conglomerate. This formation was traced southward to the International Boundary by Rice (1941, pp. 14-15). Although the name Irene conglomerate has priority over others, the name Toby has become more widely accepted, and in order to avoid confusion with the overlying volcanic formation, the writer refers to the conglomerate as the Toby formation.

The Toby formation has been fully described by the above mentioned authors, as well as by Park and Cannon (1943, pp. 7-9) under the name Shedroof conglomerate.

Distribution and Thickness—The Toby formation occurs only in the extreme southeast corner of the map-area, where only the upper few hundred feet are exposed. Daly (1912, p. 141) has estimated a minimum thickness of 5,000 feet based on three complete sections near the International Boundary. To the south, Park and Cannon have estimated minimum and maximum thicknesses of the equivalent 'Shedroof conglomerate' as 3,000 feet and 11,000 feet respectively, near Shedroof Mountain. The formation thins greatly to the southwest where it apparently disappears within a distance of some 20 miles. To the north it also thins greatly over a distance of a few miles, and appears to be missing near the Bayonne batholith (*see* Rice, 1941, Map 603A). It appears again east of Kootenay Lake, and at Rose Pass is 250 feet thick. In the type area it ranges in thickness from 50 to 2,000 feet (Walker, 1926, p. 14).

Lithology—Both Rice and Walker have noted that the Toby formation varies greatly in character from place to place. The writer examined the upper part of the formation in the southeast corner of the map-area being considered. At this locality the roundstones vary in size from an eighth of an inch to 10 inches or more in diameter. They consist mainly of white quartzite, but buff weathering dolomite containing chert bands is also common. The roundstones of dolomite are more angular than those of quartzite, possibly due to their relative incompetence under stress. The roundstones are abundant in some places but relatively scarce in others; in one zone about 100 feet thick near the top of the formation they are entirely lacking. The matrix of the Toby formation consists of fine-grained, green, argillaceous schist.

Internal Structural Relations—Within the map-area the Toby formation forms part of a homocline that there trends N25°E and the beds dip vertically with tops to the northwest. No bedding planes were observed, but the schistosity is nearly parallel with the contacts between conglomerate and interbedded schist.

External Structural Relations—The Toby formation is said to rest unconformably upon the Mount Nelson and Dutch Creek formations of the upper part of the Purcell system (Rice, 1941, p. 14) but no angular discordance was observed. In the Metaline quadrangle to the south, the equivalent Shedroof conglomerate rests unconformably upon the underlying rocks, from which the roundstones were derived.

Daly (1912, pp. 142, 144) states that the top of the Toby formation consists of interbedded volcanic flows and conglomerate, but the writer found only interbedded green argillaceous schist and conglomerate. Because the basal flow of the Irene Volcanic formation was not observed, the contact shown on Map 50-19A (Little, 1950) was drawn at the top of the uppermost band of conglomerate. Park and Cannon (1943) found that the upper contact " . . . is marked by a zone of transition several hundred feet thick in which the matrix of the conglomerate

71994-8- -3

gradually changes from grey to green, (and) the proportion and size of fragments is smaller . . . This transition zone seems to pass gradually into schistose greenstone or greenstone without fragments."

Origin—The remarkable character of the Toby conglomerate is evidence of an unusual mode of deposition. Walker (1926, p. 15) regarded the rock as possibly a fanglomerate, formed along the edge of a piedmont basin, but pointed out that such a deposit should occupy only a narrow belt, while in Windermere map-area it occupies an area many miles broad. Rice (1941, p. 23) considered that "the Toby was laid down along the shoreline of a sea that spread rapidly over the land roughly reworking the loose, superficial deposits." This, in his opinion, would account for the variation in the character of the formation and in the degree of roundness of the pebbles, cobbles, and boulders. Park and Cannon (1943, p. 9) admitted the possibility that the formation may be a fanglomerate, but expressed uncertainty regarding its origin.

A glacial origin for the conglomerate has not been proposed. It does, in some respects, resemble a tillite, but the upper part as exposed in the present map-area contains argillaceous interbeds that appear to be the result of normal sedimentation. Rice (personal communication) has seen no evidence to support a glacial origin. G. B. Leech of the Geological Survey, who has recently made a careful study of the formation in the Canal Flats map-area of southeastern British Columbia, has discovered many striated boulders in the conglomerate, but he believes these striations to be a result of tectonic movement. Leech and the writer favour Rice's suggestion regarding the origin of the Toby formation.

Age and Correlation—The Toby is the basal formation of the Windermere 'series' which is of Late Proterozoic age. It is correlated with the 'Shedroof conglomerate' of the Metaline Quadrangle of Washington (*see* Correlation Chart, in pocket), and may also be equivalent to the 'Huckleberry conglomerate' of the Addy district, Washington (Bennett, 1941, p. 8). The Huckleberry conglomerate is older than the 'Addy quartzite', the upper part of which contains trilobites probably representative of the lower part of the Lower Cambrian (Okulitch, 1951, p. 405).

Irene Volcanic Formation

The Irene Volcanic formation was named and described by Daly (1912, pp. 144-147). Walker (1934, pp. 5-6) expressed doubt as to the volcanic nature of the formation and presented evidence suggesting that the formation is a complex intrusive mass. From Daly's columnar section of the formation he removed the two upper members, a 200-foot thick conglomerate and a 50-foot thick greenstone schist. Subsequent workers (Rice, 1941; Park and Cannon, 1943; and Little, 1950) agreed with Daly that the igneous rocks are extrusive, but followed Walker in placing the top of the formation at the base of the conglomerate.

The name Irene Volcanic formation was introduced by Daly and has been retained by Walker, Rice, and the writer. The equivalent formation in the Metaline quadrangle to the south is the 'Leola volcanics'.

Distribution and Thickness—The Irene Volcanic formation is west of the Toby formation within the same homocline and is likewise exposed only in the southeast corner of the map-area. Daly (1912, p. 145) presents a columnar section of the formation. According to him, the total thickness, reduced by the upper members subsequently placed in the Monk formation, is 5,730 feet. Details of a composite section of the formation within the map-area are as follows:

Top of section	Thickness (feet)
Greenstone, schistose, with minor interbedded green phyllite (poorly exposed)	2,700±
Limestone, black	30+
Greenstone, schistose	1,000±
Agglomerate	100±
Greenstone, schistose	1,800±
Phyllite, green, schistose	100±
Total thickness	5,730±

Park and Cannon estimate thicknesses of the equivalent formation to the south to be about 4,500 feet on the Salmo-Shedroof ridge, and apparently 9,000 feet on Green Mountain. Beyond this point the apparent thinning is mainly due to faulting for farther southwest the thickness again exceeds 5,000 feet. To the northeast the formation thins somewhat in the vicinity of Bayonne batholith, and is not present east of Kootenay Lake.

Lithology—The greenstone that predominates in the formation is schistose, and is composed of amphibole, saussuritized plagioclase, quartz, calcite, epidote, and sericite, with minor amounts of magnetite, pyrite, and ilmenite. The amphibole, according to Rice, is actinolitic, with a strong blue-green pleochroism, and resembles that in the quartz diorite of the Purcell sills. The plagioclase is about andesine-labradorite in composition. In one thin section, Walker noted phenocrysts of well-preserved augite.

Near the base of the formation in the present map-area, green chloritic phyllite is interbedded with flows and a volcanic flow breccia, and may represent fine-grained tuffaceous sediments. Near the middle of the formation is a band of fine-grained black limestone more than 30 feet thick.

Lenticular interbeds of dolomite and phyllite occur south of the map-area, and to the northeast, Rice has noted conglomerate also.

Internal Structural Relations—The Irene Volcanic formation forms part of a homocline that trends N35°E to N20°E. The strata dip vertically, the upper side facing northwest.

External Structural Relations—The base of the Irene Volcanic formation is interbedded with the upper part of the Toby formation, both within Nelson

71994-8—3½

map-area (west half) and Metaline quadrangle to the south. To the northeast, in the vicinity of the Bayonne batholith, the Irene Volcanic formation appears to rest upon the Dutch Creek formation of the Upper Purcell series (Map 603A). If so, then at this locality the contact is unconformable, as both the Toby and Mount Nelson formations are missing.

Origin—Daly regarded the Irene Volcanic formation as being composed essentially of volcanic rocks. Rice, Park and Cannon, and the writer agree with Daly's conclusions, although all admit the probability that some intrusive phases are present. The main outpouring of lava and pyroclastic rocks appears to have occurred near the International Boundary, pinching out to the northeast near Kootenay Lake, but probably extending much farther to the southwest. The possible presence of pillow structure (Park and Cannon, 1943, p. 10), and of lenticular interbeds of limestone and dolomite is suggestive of submarine vulcanism.

Age and Correlation—The Irene Volcanic formation underlies the Monk formation, which is regarded as being of Late Proterozoic age, and thus is probably Precambrian. It is correlated with the 'Leola volcanics' of the Metaline conglomerate and may also be equivalent to the 'Huckleberry greenstone' which Bennett (1941, p. 8) tentatively considered to be of Lower Cambrian age. Near the top of the overlying 'Addy quartzite', Okulitch (1951, p. 405) subsequently collected trilobites that probably represent the lower part of the Lower Cambrian, so that the 'Huckleberry greenstone' is probably Late Proterozoic.

Monk Formation

The Monk formation was first named and described by Daly (1912, pp. 147-150). Walker (1934, pp. 6-7) renamed the formation the Horsethief Creek series owing to its lithological similarity to the Horsethief series of the Windermere area (later renamed Horsethief Creek series because of preoccupancy of the name "Horsethief"). He included at the base a 50-foot band of schist and a 200-foot band of conglomerate that Daly had placed in the Irene Volcanic formation. Subsequent writers have followed Walker. Rice (1941, pp. 17-18) has shown that the Horsethief Creek series of Nelson area (west half) is not equivalent to that of Windermere area, where it also embraces beds that are stratigraphically equivalent to those of the Three Sisters formation. For this reason, and because it has priority, the writer has retained the name Monk formation originated by Daly.

Distribution and Thickness—The Monk formation is exposed along a belt in the southeast corner of the map-area, extending from the International Boundary northeasterly to the east edge of the map-area. It also occupies the core of a plunging anticline near the east edge of the area about 12 miles north of the International Boundary.

The soft, argillaceous rocks of the Monk formation are in general poorly exposed on both sides of the International Boundary. For this reason, Park and Cannon (1943, p. 11) have been unable to present a complete section. They

believe that the Monk formation, as they describe it, and the Horsethief Creek series of Walker, exclude the upper part of the type Monk formation of Daly. The writer, however, is inclined to regard the Horsethief Creek series of Walker as essentially the same as Daly's Monk formation except for the basal members.

Daly has presented a columnar section of the Monk formation totalling 5,500± feet, but Walker has shown that the upper part is highly folded so that Daly's section undoubtedly includes some repeated strata. Walker states that "the scarcity of outcrops, coupled with the knowledge that the (formation) is highly folded upon itself, renders it impossible to describe it fully or to estimate its thickness . . . The minimum width occupied by the (formation) is about 4,200 feet; the thickness is less than this due to the angle of dip and drag-folding."

Lithology—The basal member of the formation is a continuous band of conglomerate about 200 feet thick. Where examined by the writer on the ridge north of Monk Creek, the roundstones are largely of pisolitic magnesian limestone up to 6 inches or more in diameter, but many are of greenstone, dark quartzite, and argillaceous schist. The matrix consists of light brown, rusty weathering, argillaceous schist that has a pitted surface.

Above this conglomerate, most of the exposures are of fine-grained, dark green to brown, argillaceous schist. Near the base, a band of grey limestone about 200 feet wide was traced by Walker for some distance south of Monk Creek. A band of grit occurs about 1,000 feet west of the limestone and grits become more abundant near the top of the formation where they are interbedded with talcose schist, dark argillite, and thin beds of limestone and limy slate. To the south, in Metaline quadrangle, the grit beds of the upper part of the formation give way to limy beds.

Internal Structural Relations—The structure of the southerly belt of the Monk formation is homoclinal and trends N20°E, but is offset by the Ripple Creek fault and complicated to the west by tight folds. In general the beds dip steeply.

Farther north no attitudes are available but the contacts with the younger Three Sisters formation indicate that the beds form an anticline that plunges about S25°W.

External Structural Relations—The base of the formation is marked by a conglomerate that rests upon greenstone of the Irene Volcanic formation. This conglomerate is not everywhere present in Metaline quadrangle to the south, where in places phyllite rests directly upon greenstone. Because the conglomerate contains material probably derived from the underlying greenstone, as well as other sources, the basal contact of the formation is regarded as unconformable, at least locally. To the northeast, beyond Kootenay Lake, the Irene Volcanic formation is missing and the Monk formation rests directly upon the Toby formation. If the basal conglomerate is present there it has probably been included in the Toby formation for, according to Rice (1941, p. 15), the Horsethief Creek series and the Toby are conformable, and basal Monk conglomerate could be identified only by the presence of roundstones of volcanic rocks.

The top of the Monk formation is interbedded with basal strata of the Three Sisters formation, but in the present map-area it is sharply defined where fine argillaceous schists give way to thick beds of coarse green grit containing a few thin beds of fine pebble-conglomerate. This is the contact established by Daly and followed by Walker and by Park and Cannon. To the northeast (Rice, 1941, p. 19) the overlying grits and conglomerates grade laterally into beds that cannot be distinguished from those of the Monk formation, which therefore loses its entity in this direction.

Origin—Variations in the conditions of deposition are reflected in the heterogeneous character of the sedimentary rocks of the Monk formation. Park and Cannon (1943, p. 13) have suggested a northerly source for the materials, owing to the change in character of the upper members from north to south from coarse clastics to fine-grained limy rocks. The reverse is true in Nelson area (east half), so that it seems more probable that the source was to the southeast, and that the ancient shoreline was near the southeast corner of the present map-area.

As pointed out by Park and Cannon the source material was probably derived from the Irene Volcanic and Toby formations, and, to some extent, from the older Purcell series.

Age and Correlation—The Monk formation is regarded by the writer to be of Late Proterozoic age for reasons presented in a subsequent section, "the Base of the Cambrian System". It is correlated with the lower parts of both the Horsethief formation of Windermere map-area (Walker, 1926) and the equivalent Horsethief Creek series of Nelson area (east half) (Rice, 1941). It is equivalent also to the Monk formation of Metaline quadrangle to the south.

Windermere (?)

Three Sisters Formation

This formation was named and described by Walker (1934, pp. 7-8). It forms a more convenient mapping unit than Daly's Wolf formation, which includes only the lower part of the Three Sisters formation.

Distribution and Thickness—The Three Sisters formation occupies a wide belt in the southeastern part of the map-area, and also the core of the Sheep Creek anticline and the Baldy anticline farther north, which is faulted on the east side.

The thickness varies more in a north-south direction than Walker believed. He estimated it to be 5,400 feet. Owing to folding and the intrusion elsewhere of granitic stocks, the only reliable measurements of the lower part of the formation

can be made near the International Boundary, but the upper part has been measured in several places. The following is a composite section of the entire formation along the eastern homocline:

Top of section	Thickness (feet)
Grits and quartzite, green; minor pink arkosic quartzite	500–1,230
Conglomerate	34–250
Grits, green, many crossbedded; minor quartzite, shale, and pebble conglomerate	3,800–4,600
Total thickness	4,334–6,080

The greatest thickness of all members is near the International Boundary, with a general thinning to the north. A more marked thinning, both of the formation and the individual beds occurs in a westerly direction. This is particularly apparent in Metaline quadrangle to the south, where the base of the formation is exposed in both the east and west parts. Measured sections at these localities are 4,475 and 1,455 feet, respectively. In the present map-area the base of the Three Sisters formation is not exposed where it occurs in the Sheep Creek and Baldy anticlines to the west of the monocline. In the Sheep Creek anticline Mathews (1953, p. 18) records 500+ feet of grey grit, white quartzite, and green schists representing the Three Sisters formation. From the western limb of the Baldy anticline McAllister (1951, p. 6) presents the following measured section:

Top of section	Thickness (feet)
Chlorite schist, grey weathering, grey-green, with numerous porphyroblasts of quartz and feldspar; narrow banded siliceous layers; some beds of white quartzite and mica schist	1,000
Gap	60
Quartzite, massive, grey-green	100
Schist and argillaceous quartzite	200
Quartzite, white and grey, massive	120
Quartzite, grey, grey-green, and white; minor mica schist	70
Schist, micaceous; some with cyanite or apophyllite; grey or grey-green	300
Limestone, grey, with pink and yellow tinges	35
Mica schist, grey or grey-brown, some garnet bearing, minor grey-brown argillaceous quartzite	140
Limestone, grey or grey-brown	30
Mica schist; interbedded with beds of white quartzite 2 to 3 inches thick	120
Quartzite, grey-brown, argillaceous	50
Quartzite and argillaceous quartzite, white, grey-brown, or greenish; minor mica schist	315
Quartzite, green-white, gritty, with some pebbles of white quartzite ½ inch long	5
Quartzite, white and grey-brown	25
Quartzite and chlorite schist	40
Total exposed thickness	2,610

McAllister states, "The exposed section of the eastern limb is much thinner than the one described above."

Lithology—The Three Sisters formation consists predominantly of coarse green grit but conglomerate is fairly abundant, mainly in the lower part of the formation except for one prominent band above the middle part. The lower

bands of conglomerate are intraformational and the pebbles are largely of grit from the underlying strata. The upper band contains roundstones that range in size from less than 1 inch to 18 inches at the International Boundary, but about 18 miles farther north, few roundstones exceed 3 inches in diameter. They consist of green grit, white and pink quartzite, vein quartz, and greenstone, in decreasing order of abundance.

The grits form thick, green, massive beds and are composed of quartz grains up to a quarter of an inch in diameter in a matrix of quartz and sericite. McAllister (1951, pp. 4, 5) notes also an 'arkosic' member "that in places contains up to 10 per cent alkali feldspar (microcline, orthoclase, and albite), and is pale pink-white in the hand specimen."

Farther east, in the cores of the Sheep Creek and Baldy anticlines, the beds are less massive; fine-grained impure clastic rocks are abundant at the latter locality. According to Mathews (1953, pp. 17-19), grey grit predominates in the Sheep Creek anticline, but white quartzite and green schist are also abundant. In the Baldy anticline, schist is even more abundant and two bands of limestone 30 to 35 feet thick are also present. In neither locality was any conglomerate observed.

Internal Structural Relations—The structure of the eastern band is a homocline, trending north to N20°E, and offset by the Ripple Creek fault in the south and an unnamed fault farther north. It is however complicated on the east side by tight folds north of Monk Creek. In the eastern band most of the beds dip steeply.

Farther west, where they form the cores of anticlines with the same trend as the homocline, the beds dip steeply east on both limbs.

External Structural Relations—The base of the Three Sisters formation is placed, following Walker's definition, where the fine clastic beds of the underlying Monk formation give way abruptly to the massive grits and conglomerate of the Three Sisters formation. To the northeast, in the adjoining map-area, this horizon rises stratigraphically northward, until finally the entire Three Sisters formation consists of fine clastic rocks. To the south, in Metaline quadrangle, the base as defined is recognizable everywhere.

The top of the formation is marked by a transition from grey grit to white quartzite, and, in most localities, has been placed at the top of the uppermost band of grey or green grit. It is possible, therefore, that this horizon does not represent the same time everywhere, particularly in the Baldy anticline where McAllister includes schists at the top of the Three Sisters formation. These schists may or may not be equivalent to grits to the south and west. Both the upper and lower contacts of the formation are conformable with the overlying and underlying formations, respectively.

Origin—The coarse clastic rocks of the Three Sisters formation in the eastern part of the area indicate a change from the conditions of sedimentation that prevailed in Monk time, and suggest an uplift of the landmass to the

southeast and a withdrawal of the late Precambrian sea towards the northwest. Near-shore environment is reflected in the massive nature of the beds and in the abundance of conglomerate and crossbeds. To the west, there is a marked decrease in grain size and in thickness of beds; conglomerate is lacking, and crossbeds are comparatively rare. In the Baldy anticline, some limestone appears in the formation. Some distance to the northeast, a similar gradation has been noted along the strike of the eastern band (Rice, 1941, p. 19).

Age and Correlation—The age of the Three Sisters formation is believed to be Late Proterozoic for reasons presented in the section that follows. The formation is correlated with the upper part of the Horsethief Creek series by Rice (1941, p. 19). It is equivalent also to the lower part of the 'Gypsy quartzite' of Metaline quadrangle to the south and to the same formation farther west in northeastern Stevens county, Washington (Campbell, 1947). It may also be equivalent to the lower part of the 'Addy quartzite' of the Addy district, central Stevens county (Bennett, 1941, p. 9; and 1944, pp. 30, 31).

The Base of the Cambrian System

It is necessary at this point to interpose a discussion on the boundary between the Precambrian and Cambrian in this region. The base of the Cambrian system cannot yet be accurately defined in Nelson area (west half), nor in the west part of the adjoining area to the east nor in that to the south. Daly (1912, p. 178, Table VIII) placed the base of the Cambrian system about 1,000 feet below the top of the Wolf formation or about 1,900 feet above the top of the Monk formation. This was based upon a lithological correlation of the 'Summit series' with the Purcell and Galton to the east, which he regarded as being of partly Cambrian age but which have since been shown to be Precambrian (Schofield, 1922). Walker (1934, p. 5), on lithological grounds, correlated the Monk formation with the Horsethief formation of the Windermere area, which he had shown to be of Precambrian age (Walker, 1926, p. 17). The Three Sisters, Quartzite Range, and Reno formations he correlated with the Hamill series which overlies conformably the Horsethief Creek series in Lardeau map-area (Walker, Bancroft, and Gunning, 1929), and the Pend-d'Oreille series with the Lardeau series which rests conformably upon the Hamill. Because no unconformity had been found between these rocks and rocks of proven Precambrian age, coupled with the fact that no fossils had ever been discovered in these rocks, which had been examined by many geologists, Walker assigned a Precambrian age to the entire succession.

Rice (1941, p. 24) followed Walker in placing these rocks in the Precambrian; but at Goat River the Lower Cambrian Cranbrook formation rests unconformably upon the Dutch Creek formation of the Purcell series, while only 13 miles west, the Dutch Creek is succeeded by the Mount Nelson formation and the entire Windermere 'series'. Thus if the Windermere is Precambrian, 35,000 feet of sediments are missing at Goat River. This anomaly was pointed out by Rice (1941, p. 30). If, as now seems probable, the Badshot formation is of about

the same age as the lower part of the Eager formation, then at Goat River only the Mount Nelson and Toby formations and the Hamill series are missing or are represented in part by the Cranbrook formation, so that the difference is reduced to about 18,000 feet.

Park and Cannon (1943, pp. 6, 13, 15) placed the base of the Cambrian system tentatively "at the hiatus below the Monk formation", which is the highest unconformity below the Cambrian trilobite fragments found in the upper part of the overlying 'Gypsy quartzite'. This is objectionable for two reasons. Firstly, the Cambrian rocks would extend some 12,000 to 14,000 feet below the lowest fossil horizon and secondly, Rice (1941, pp. 15, 18) has shown that this unconformity is relatively local, and indeed it may be so within Metaline quadrangle itself. If the Cambrian system were extended to the highest persistent unconformity, the base of the Toby, the base of the system would be extended to include an additional 11,750 feet of strata at the International Boundary.

In view of the paucity of fossils in this region, it is impractical to accept the lowest known fossil horizon as representing the base of the Cambrian system. The writer has, therefore, adopted the method of placing the Precambrian-Cambrian boundary at the base of the lowest formation bearing Lower Cambrian fossils even though fossils have not been found in the lower part of the formation.

The basal limestone of the Laib group has yielded abundant archæocyathids of Lower Cambrian age. Some hundreds of feet stratigraphically below this band, Park and Cannon obtained a slab of quartzite, which they believe was not more than a few feet from its original outcrop, that contained trilobite fragments of Cambrian age. Thus, fossils have been found at about the top of the Quartzite Range formation and the present writer tentatively assumes the base of this formation to represent the Precambrian-Cambrian boundary. This horizon has the advantage of having been traced northward nearly 150 miles to the 51st parallel of latitude, and could probably be traced for some distance southwest from the International Boundary.

Palæozoic

Lower Cambrian

Quartzite Range Formation

The Quartzite Range formation was defined by Walker (1934, p. 8). It probably includes the upper part of the Dewdney, the entire Ripple, and the lower part of the Beehive formations described by Daly.

Distribution and Thickness—Rocks of this formation are exposed only in the southeast part of the map-area. They occupy a zone along the homocline that lies along the east edge of the map-area and also occur on the limbs of the Laib syncline and the Sheep Creek and Baldy anticlines to the west. They were found by Mathews (1953) at low elevations in the core of a subsidiary anticline immediately west of the Sheep Creek anticline; they may also occur along the sides of Salmo River valley, on the east side near the mouth of Sheep Creek

and on the west side farther south, but could not be identified definitely there by the writer. Fyles[1] and Hewlett have recognized members of the Quartzite Range formation in upper Hidden Creek valley, Porcupine Creek near the mouth of Active Creek, Lost Creek near its mouth, and lower Salmo River valley. In the last three localities these members form the cores of overturned anticlines.

The formation is best exposed along the eastern band where Walker (1934, p. 8) measured the following section:

Top of section	Thickness (feet)
Quartzite, white, grey, or pinkish, and in places green, massive or locally platy; abundant cross-beds and some ripple marks	1,500
Quartzite, white, massive	1,100
Quartzite, argillaceous, and schist	200
Quartzite, white, green, or pinkish, massive; abundant crossbeds	1,600
Total thickness	4,400

A measured section in the same band just north of latitude 49°15′, recorded by McAllister (1951, p. 9), is as follows:

Top of section	Thickness (feet)
Quartzite, massive, white and pink-white	600
Quartzite, massive, pink and pink-white; some beds light grey to pale green	660
Quartzite, massive, pink-white and white	450
Quartzite, grey-green, massive	1,000
Sericite schists; some micaceous quartzite	215±
Quartzite, pink-white, platy to massive; minor amounts of grey quartzite	1,580
Total thickness	4,505±

To the west of this band the formation is much thinner. From the western limb of the Sheep Creek anticline, Mathews (1953, p. 18) gives the following section:

Top of section	Thickness (feet)
Quartzite, massive, white	20–160
Quartzite, dark, thin-bedded, and argillaceous quartzite	100–140
Quartzite, massive, white	135–375
Quartzite, white, grey, and dark; argillaceous quartzite, and argillite	175–300
Argillite and dark argillaceous quartzite	150–225
Quartzite, massive, white	370–450
Argillite, grey grit, and green schist	50
Quartzite, massive, white	500–700
Total thickness	1,500–2,400

The figures 1,500 to 2,400 feet represent the total variation in thickness of the composite section. Actually, where some members are thin others may be thicker than average, and Mathews found the formation as a whole to be fairly consistent in thickness, averaging about 2,000 feet.

[1] Personal communication, December 2, 1955.

Farther north, on the Baldy anticline, the east limb is faulted and the west limb is terminated against granite. A section of the Quartzite Range formation from the granite contact down to the Three Sisters formation, was measured by McAllister (1951, pp. 9-10) on the west limb near Baldy Mountain, as follows:

Top of section	Thickness (feet)
Quartzite, white; minor argillaceous quartzite and mica schist	70
Quartzite, fine-grained, pink-white and white, massive and platy	910
Schist, grey-brown, micaceous	30
Quartzite, grey-white, massive, coarser than those above	320
Gap	550
Quartzite, white with tinges of pink-green and yellow-brown	310
Total thickness	2,190

From these four sections, it is apparent that the Quartzite Range formation is remarkably consistent in thickness in a north-south direction, but thins greatly to the west, and the strata themselves are much thinner in this direction.

Lithology—The massive, white quartzite beds that predominate in the Quartzite Range formation are most striking, and have been traced for nearly 150 miles northward to the main line of the Canadian Pacific Railway. These beds are 15 to 20 feet thick, rather coarse-grained, and crossbeds are abundant. Near the International Boundary ripple-marks are common. Some 1,600 feet above the base is a band of impure argillaceous quartzite and schist 200 feet thick; but otherwise, in the eastern band, only pure quartzites are present.

Farther west, the quartzite beds are thinner and finer grained, and several argillaceous members appear. Except in the argillaceous beds, both grains and matrix consist almost entirely of quartz. In the impure beds, some sericite is developed.

Internal Structural Relations—The eastern band of the Quartzite Range formation trends north to N20°E and forms part of a homocline in which these beds dip steeply and face west. To the west the formation occurs on the limbs of the Sheep Creek anticline which is isoclinal, the axial plane striking N10° to 20°E and dipping 55° to 80°E. In the northern half of the anticline the Quartzite Range beds on the limbs are separated by the core of Three Sisters formation, but in the south part they themselves form the core of the anticline. They in turn finally disappear beneath younger formations beyond the Ripple Creek fault where the plunge of the anticlinal axis steepens.

To the north, the Quartzite Range formation occurs on the west limb of the Baldy anticline, the east limb of which is faulted. On this limb the strata strike north to N25°E. They are overturned and for the most part dip 45° to 75°E. To the east of this anticline a narrow band of Quartzite Range formation is present between the core of the Laib syncline and the Baldy fault. There most of the beds dip steeply east. The axis of the Laib syncline plunges southward so that the broad band of Quartzite Range formation on the east limb north of the Laib

Creek fault links with the band on the west limb at the north end of the syncline. The beds on the east limb dip steeply east and so for the most part are overturned, but probably they are isoclinally folded there though no detailed study was made to determine this.

External Structural Relations—The Quartzite Range formation exhibits conformable relations with the underlying Three Sisters and the overlying Reno formations. The base is defined in most places at the top of the uppermost grey or green grit bed of the Three Sisters formation. On the west limb of the Baldy anticline, the contact has been placed by McAllister at the base of the massive quartzite beds that overlie green schist and banded quartzite.

The top of the formation is placed at the transition of white quartzite to dark, argillaceous quartzite and mica schist of the overlying Reno formation. This transition is sharp within most of the map-area, but in the north part of the Laib syncline, according to McAllister, it extends across 200 to 300 feet of beds.

Origin—The clastic rocks of the Quartzite Range formation are less coarse than those of the underlying formation, and though conglomerate is lacking, massive beds and crossbeds are abundant in the eastern exposures. The formation likewise becomes thinner and finer grained to the west, but does not show any lateral change to the northeast where the beds have been traced for many miles and there rest on argillaceous rocks (Rice, 1941, p. 19). The remarkably constant character along the strike and the purity of the arenaceous sediments indicate stable conditions of sedimentation.

Age and Correlation—The Three Sisters formation is regarded as Lower Cambrian, for reasons set forth in a previous section. The formation has been correlated by Rice (1941, p. 20) with the lower and major part of the Hamill series to the northeast. It is also equivalent to the upper part, except the uppermost several hundred feet of beds, of the 'Gypsy quartzite' in Metaline quadrangle to the south and in the northeast part of Stevens county, Washington. The 'Gypsy quartzite' may be equivalent to the 'Addy quartzite' of Addy district, Washington (*see* Correlation Chart, in pocket).

Reno Formation

The Reno formation was defined by Walker (1934, pp. 9-10) from the type locality on Reno Mountain. It has been redefined by the writer (Little, 1950, p. 13) and by Mathews (1953, pp. 21-22) who examined it in detail at the type locality. In the words of Mathews,

> . . . it was defined (by Walker) by a measured section extending from the top of the Quartzite Range formation on the ridge of Reno Mountain about 1,000 feet northeast of the summit to the base of the Pend-d'Oreille series about a quarter of a mile north of the Reno mine. The beds in this section were thought to be part of a homoclinal succession on the western limb of the Eastern anticline. Later and more detailed studies by mine geologists indicated that the structure is by no means as simple as had been thought and that in the type section some of the beds have been repeated by folding at least three times. Moreover, in one place, . . . an infold of the younger calcareous and argillaceous sediments of the Laib group (Lower Pend-d'Oreille) is present. These

conclusions have been confirmed by the writer. Accordingly, the Reno formation is redefined, following Walker's original intent, as those beds lying between the top of the Quartzite Range formation, east of the summit of Reno Mountain, and the base of the infolded Laib (Pend-d'Oreille) beds, now known to be less than 50 feet west of the summit. The formation in the sense followed here includes only the lowest 662 feet of the former type section and excludes all calcareous beds. Even the eastern end of the original measured section is involved in several minor folds, and it is apparent that the Reno formation as revised has a stratigraphic thickness of considerably less than 662 feet at this locality.

Distribution and Thickness—Rocks of the Reno formation outcrop on both limbs of the Laib syncline which has been traced from the International Boundary northward to the Baldy fault near Seeman Creek. The formation also occurs on the limbs of the Sheep Creek anticline and a subsidiary anticline to the west. It forms the core of a faulted anticline near the United Verde property and also extends northward from Lost Creek to the Jersey mine. In addition, it may be present along the Salmo River valley, on the east side near the mouth of Sheep Creek and on the west side farther south. In these localities, however, detailed study of these rocks by J. T. Fyles and C. G. Hewlett of the British Columbia Department of Mines subsequent to the writer's examination have led them to believe that they may be in part the Laib formation (personal communication).

The thickness of the Reno formation in the Sheep Creek camp is extremely variable, ranging from 50 to 900 feet or more. Mathews attributes this almost entirely to thickening and thinning of these relatively incompetent beds as a result of folding. He presents the following section of the formation from average measurements near the Reno mine.

Top of section	Thickness (feet)
Impure quartzite, dark bluish or greenish; some grit beds	125
Argillite and argillaceous quartzite	450±
Total thickness	575±

To the east, along the east limb of the Laib syncline, the Reno formation, like those underlying it, is thicker than it is to the west. Near the International Boundary its total thickness is about 1,100 feet, but this decreases to the north and near latitude 49°15′ McAllister (1951, p. 12) measured the following section:

Top of section	Thickness (feet)
Quartzite and argillaceous quartzite, grey-green and grey-brown	115
Quartzite and siliceous argillite, grey-black to dark green; in part slaty and phyllitic	142
Quartzite, massive, yellow-brown to green	165
Quartzite, light grey-brown, argillaceous	60
Argillite and phyllite, light green, siliceous	80
Phyllite, light green, siliceous	60
Phyllite, quartzite, and calcareous argillite	47
Quartzite, light to dark green and dark grey; minor white quartzite	70
Total thickness	739

Farther northward the formation becomes more schistose. Just southeast of the Laib Creek plug it has an apparent thickness of 1,100 feet, consisting mainly of quartz-mica schist, but just north of the plug, the following section is poorly exposed:

Top of section	Thickness (feet)
Mica schist, grey-brown, in part chloritic	400±
Mica schist and white quartzite	200±
Total thickness	600±

On the west limb of the Laib syncline in this region the Reno formation, as in the south, is much thinner. McAllister (1951, p. 13) records a section just north of Porcupine Creek as follows:

Top of section	Thickness (feet)
Mica schist, grey-green, coarse	25
Quartz-mica schist, grey-green to brown	45
Quartzite, white with tinges of grey, pink, and green; interbedded with mica schist	60
Total thickness	130

McAllister states,

> Farther north, where the Reno outcrops in the trough of the syncline, it has a thickness of 300 feet. At this point the formation consists of well-banded schist and impure quartzite, and grades imperceptibly into the underlying Quartzite Range formation. The bands range from ½ to 1 inch in thickness, and are generally grey-brown, and grey or green-brown on the weathered surface . . .

In the vicinity of the Emerald mine the base of the Reno formation is not exposed, so far as is known. According to Ball (1954, p. 628) about 1,000 feet of the formation is exposed, of which the upper part is dominantly brown argillite and the lower part is mainly argillaceous quartzite.

Lithology—The Reno formation for the most part consists of dark, massive, argillaceous quartzite, argillite, and light brown, micaceous schist. In most localities argillaceous quartzite predominates in the lower part of the formation, whereas near the top, argillite and mica schist are the more common rocks. In a few places, as near the shonkinite plug on the Laib syncline, quartzite is missing and the formation consists almost entirely of quartz-mica schist.

Internal Structural Relations—The rocks of the Reno formation are almost everywhere exposed on the limbs of isoclinal folds that are overturned slightly to the west, so that the beds in general strike northerly and dip steeply eastward. Where they occur on the west limbs of anticlines the beds are overturned; on the east limbs they are not. The only important exception is at the south end of the Sheep Creek anticline, where the beds dip gently southwest on the nose of the fold.

External Structural Relations—The base of the Reno formation is conformable with, and in the more northerly exposures is transitional into, the underlying

Quartzite Range formation. The top is sharply defined in most localities against the overlying basal limestone of the Laib formation, with which the contact is likewise conformable.

Origin—The Reno formation consists of impure arenaceous sediments at the base, becoming more argillaceous in the upper part. It represents a transition from the pure quartzites of the Quartzite Range formation to the argillaceous and calcareous rocks of the Laib formation. Like the underlying formations, it exhibits a marked thinning to the west, and probably the source of the sedimentary materials was likewise to the southeast. The change in lithology upward probably indicates an advance southeastward of the Lower Cambrian sea.

Age and Correlation—The Reno formation is Lower Cambrian. The overlying limestone has yielded archæocyathids that, according to Okulitch[1] "usually occur . . . within the upper half of the Lower Cambrian". The beds some hundreds of feet stratigraphically below this limestone have yielded trilobite fragments of Cambrian age (Park and Cannon, 1943, p. 15) at a point only 2 miles south of the International Boundary.

The formation as now defined, is correlated by Rice (1941, p. 20) with the upper part of the Hamill series to the northeast. It is equivalent to the uppermost part of the 'Gypsy quartzite' and the lowermost members of the 'Maitlen phyllite' of Metaline quadrangle. Park and Cannon (1943, p. 13) placed the contact between the Gypsy and Maitlen at the top of a band, 50 to 300 feet thick, of alternating beds of quartzite and phyllite in which 'burrows' are abundant. This fucoidal band was not sufficiently extensive in the present map-area to serve as an horizon marker, being present mainly in the southern part of the eastern band of the Reno formation. The basal limestone of the Laib formation is some 200 feet above the fucoidal band.

Laib Formation

The Laib formation[2] was named and described by the present author (Little, 1950, p. 15) from Laib Creek in the east central part of Nelson area (west half), where the writer first examined the formation. It includes the upper part of the Beehive, and the entire Lone Star formations, and the lower part of the Pend D'Oreille group of Daly (1912, pp. 156-159, 271-277). It is also equivalent to the upper part of the rocks mapped as Reno by Walker (1934, pp. 8-10) and the lower part of his Pend-d'Oreille series. On lithological grounds, Daly correlated his Pend D'Oreille group with the Cache Creek 'series', and assumed the age to be Carboniferous to, possibly, Silurian. Walker, on the other hand, assigned his Pend-d'Oreille series to the Precambrian. More recent work by Park and Cannon (1943) showed that Lower and Middle Cambrian, and Ordovician strata are present, and the present writer has confirmed their findings and separated the rock units accordingly.

[1] Personal communication, November 7, 1955.

[2] Originally called 'Laib group'.

Distribution and Thickness—The Laib formation occupies the trough of the Laib syncline, and this band extends northward from the International Boundary almost to Seeman Creek. The basal limestone occurs in the core of the isoclinal syncline immediately west of the Sheep Creek anticline from Reno Mountain southward almost to Lost Creek (Mathews, 1953). These rocks may also be present in the vicinity of the Jack Pot property, south of Porcupine Creek, and occur in a belt between the Reno mine and the head of Aspen Creek. This belt extends southward to South Salmo River where it divides, one part passing southward across the International Boundary, and the other southwesterly across Pend-d'Oreille River where it passes under an overthrust plate of Active (?) formation; it may reappear on both sides of that river farther west, to its junction with Columbia River. In this southwesterly part, Fyles and Hewlett have made new stratigraphic interpretations. These are discussed in the following under Lithology.

At only two localities, between Ripple Creek and South Salmo River, and near the east edge of the map-area at latitude 49°15′, are sections of the entire formation exposed. At the former locality exposures are rather poor and there is some doubt as to the position of the upper boundary. There the apparent thickness is about 2,000 feet, but this figure may be too small owing to undetected strike faults. Elsewhere the group appears to be much thicker.

At latitude 49°15′ the only measured section of the Laib formation near the type locality is reported by McAllister (1951, p. 14) as follows:

Top of formation	Thickness (feet)
Argillite, light grey-green, darker near top, phyllitic	1,700
Limestone, light grey to brownish, siliceous	18
(Fault, displacement undetermined)	
Limestone, grey-buff, brecciated	3
Argillite and phyllite, grey-green; minor argillaceous quartzite	600
Phyllite, light grey-green, soft	90
Argillite, siliceous, grey-green	90
Limestone, buff, honeycombed	6
Argillite or phyllite, grey-green, massive	100
Quartzite, massive, grey-green, argillaceous	50
Phyllite and argillaceous quartzite, grey-black to grey-green	165
Quartzite and argillaceous quartzite, grey-brown, massive	180
Limestone, argillaceous	35
Limestone, white, massive, siliceous, magnesia, becoming less siliceous at the top; buff, honeycomb-weathered	135
Total thickness	3,172

Elsewhere the thickness of the formation appears to be much greater than the two figures given above. In Metaline quadrangle to the south, Park and Cannon (1943, p. 15) place the minimum apparent thickness of the 'Maitlen phyllite' at 5,000 feet, and this figure would appear to be a more probable average thickness for the Laib formation than those given above.

The thickness of the basal limestone of the eastern band of the Laib formation is about 200 feet at the International Boundary and is 65 feet where it passes

71994-8- -4

beyond the map-area near Laib Creek. In most places between these points the thickness is nearer the lower figure, and in some localities the band may be missing altogether. Farther west, on Sheep Creek anticline, the thickness is generally less. Mathews (1953, pp. 18, 23) found that the band was about 60 feet thick near the Reno mine; but above it are two additional bands of limestone, 150 to 300, and 300 to 500 feet thick, respectively, that are separated by bands of argillaceous rocks.

Still farther west the lower part of the Laib formation is dominantly calcareous and contains up to four bands of limestone of considerable thickness in which the major zinc-lead and the tungsten deposits of the region occur. At the H.B. mine the apparent thickness of the limestone is 3,200 feet (Little, 1950, p. 16), but detailed mapping by mine geologists has shown that there is much thickening there due to folding and possibly flowage. At the Jersey mine the basal limestone is thin (Whishaw, 1954). He presents the following section:

Top of section	Thickness (feet)
Argillite, and argillaceous quartzite	2,000
Argillite, black, carbonaceous	300
Limestone	1,000
Limestone and brown argillite, interbedded	100
Limestone	20
Total thickness	3,420

The top of the formation is not exposed.

To the southwest near the Reeves-Macdonald mine Okulitch (Little, 1950, pp. 16, 17) measured a section of the lower Laib formation totalling 3,225 feet, of which 1,950 feet are limestone. White (Minister of Mines, B.C., Ann. Rept. 1949, pp. 171 and 172) presents a composite section of the same part, based upon more detailed mapping, that totals 2,240 to 3,050 feet, of which 1,080 to 1,620 feet are limestone and limestone schist.

Fyles[1] and Hewlett in their detailed mapping in this vicinity have concluded that the above section is reversed, and that it is also complicated by isoclinal folds and by faults. According to them the south end of the section is bounded by a thrust fault, and the north end is overlain by upper Laib beds.

Lithology—The Laib formation is a thick assemblage of argillaceous schist, phyllite, argillaceous quartzite, and, in the lower part, limestone. In the eastern part of the map-area little limestone is present except for the basal band, whereas the western exposures contain abundant limestone throughout the lower part. In the basal part, schistose argillaceous quartzite and arenaceous mica schist predominate. These consist of quartz, sericite, and calcite in various amounts, with a little saussuritized feldspar, zircon, and tourmaline. In the upper part, the rocks are more argillaceous, representing a gradation into the overlying calcareous

[1] Personal communication, December 2, 1955.

beds of the Nelway formation. The upper members are largely micaceous schist and phyllite in which cleavage is strongly developed. They are mainly brown, but some beds, where chlorite is more abundant, are grey-green.

The major part of the rocks formerly mapped as Laib in the belt between the Reno and H.B. mines, and extending southward beyond South Salmo River, are regarded by Fyles[1] and Hewlett as probably Active formation, which forms a great, east-dipping thrust plate between Lower Cambrian formations. This conclusion is based upon stratigraphic and structural interpretation, no fossils having been discovered in this belt. It is accepted by the writer.

Furthermore, they regard the rocks bordering Salmo River from the mouth of Sheep Creek south and southwest to the mouth of Salmo River and westward down the Pend-d'Oreille, as mainly Laib formation with minor amounts of Reno and upper Quartzite Range. This interpretation has considerable merit; it not only overcomes the difficulties encountered in the previous interpretation (Walker, 1934, pp. 8-10; Little, 1950, pp. 14, 15), but confirms Okulitch's opinion that the rocks resemble those of the 'Maitlen phyllite' of Metaline quadrangle. Okulitch (1947) described these rocks as follows:

> The formation consists essentially of green chloritic schists, silvery grey sericite schists, and paragneiss. In places ... black micaceous and argillaceous phyllite is encountered. Interbedded with the schists and phyllites are bands of quartzite, and serpentinized limestone occurs close to the middle of the formation. Bands of actinolite schist or gneiss occur near the mouth of Salmo River. They probably represent metamorphosed basic sills or flows.

Internal Structural Relations—The rocks of the Laib formation for the most part occupy synclinal troughs. No detailed mapping of the eastern band has been done, but farther west, where there are mining properties, detailed mapping by company geologists has revealed faults and numerous folds, many of them isoclinal. In the vicinity of the Jack Pot property, rocks resembling those of the Laib formation exist in isolated panels separated by drift and cannot be accurately correlated.

External Structural Relations—The base of the Laib formation[2] is conformable with the underlying Reno formation, and where the basal limestone is present, is sharply defined against it. No certainty is felt, however, that the basal limestone as observed represents the same horizon throughout the map-area.

The top of the Laib formation is gradational into the overlying Nelway formation, and has been placed, by Park and Cannon (1943, p. 16) in the equivalent rock units, where limestone predominates over phyllite. For want of a better horizon marker the present writer concurs in this definition.

Origin—The fine-grained, argillaceous, calcareous, and arenaceous rocks of the Laib formation indicate deposition probably in a shallow, oscillating sea, far from the shore, and suggest relatively low relief in the adjacent landmass. There is little lateral facies change along the strike, but in the most westerly

[1] Personal communication, December 2, 1955.

[2] Fyles and Hewlett, in a bulletin published since this memoir went to press, show that the top of the Reno formation as defined by Mathews, is 100 to 300 feet below that defined by the present writer. They have followed Mathews.

71994-8—4½

exposures there is a greater abundance of limestone, suggesting that, as with the underlying formations, the source of the sedimentary materials lay to the east. The upper part of the formation, however, is predominantly argillaceous in both localities, becoming more calcareous near the top.

Age and Correlation—In 1948 the writer collected archæocyathids from the 200-foot limestone band at the base of the Laib formation in the southeastern part of the map-area, from a point 1,000 feet south of the International Boundary to a point nearly 5 miles to the north. Further collections were made from the more southerly localities by V. J. Okulitch in 1949. In 1951 an additional collection was made from the same band a mile north of Lost Creek. The presence of archæocyathids had previously been recorded in this band south of the International Boundary (Howell *et al.*, 1944, p. 996).

The writer's collection was examined by V. J. Okulitch[1] who identified the following species:

GSC Loc Cat Nos. 27118 to 27122

Ajacicyathus osilinka Okulitch and Roots
A. nevadensis Okulitch
A. purcellensis Okulitch
A. undulatus Okulitch
A. sp.
Archaeocyathus atlanticus Billings
A. taeniatus (?) Okulitch
Archaeocyathellus sp.
Claruscyathus cf. *obliquus* Okulitch
Copleicyathus laminosus Okulitch
Coscinocyathus cf. *miniporosus* Bedford
C. dentocanis Okulitch
C. sp.
Ethmophyllum americanum Okulitch
E. whitneyi Meek
E. sp.
Paracoscinus sp.
Protopharetra sp.
Pycnoidocyathus amomensis Okulitch
P. columbianus Okulitch
P. cf. *donaldi* Okulitch

The similarity to the Donald fauna is rather strong, but there are elements previously known only in Nevada, Mexico, and Australia . . . Your fauna is . . . in all probability, of the same age as the Peyto limestone of the Rocky Mountains.

The fauna of the Old Dominion limestone of Stevens county, Washington is likewise similar (Little, 1950, p. 18).

No fossils other than worm burrows have been found in the beds between the basal Laib limestone and those from which Middle Cambrian trilobites have been collected, nearly 6,000 feet above. On the basis of fossil evidence, the lower part of the Laib formation is probably late Lower Cambrian. The age of the upper part is assumed also to be Lower Cambrian, and the boundary between the Lower and Middle Cambrian has been drawn arbitrarily at the top of the Laib formation.

[1] Personal communication, November 7, 1955.

The Laib formation is correlated with the 'Maitlen phyllite' of Metaline quadrangle to the south, except for the lower 200 feet or so of the latter formation, which the writer has included in the Reno formation for reasons given previously. The Laib formation is also probably equivalent to the Badshot formation and the lower part of the Lardeau series to the northeast.

Middle Cambrian

Nelway Formation

The Nelway formation was named by the writer (Little, 1950, p. 18) from its occurrence near Nelway at the International Boundary south of Nelson. It is probably equivalent to the 'Metaline limestone' of Metaline quadrangle, but some parts of the latter formation are missing north of the International Boundary, probably largely due to faults.

Distribution and Thickness—Rocks of the Nelway formation occupy five separate areas within the map-area. The most northerly exposures are at the head of Porcupine Creek. Another band occurs east of Stagleap Creek both north and south of Ripple Creek. A greater thickness is exposed in the belt west of Stagleap Creek extending from the Ripple Creek fault southwest to the International Boundary, and in the belt extending from South Salmo River near Rosebud Lake southwest to the vicinity of Nelway and west a little beyond Pend-d'Oreille River. The fifth area, in which the rocks are doubtfully regarded as Nelway, is a belt north of, and parallel with Pend-d'Oreille River and extending from Tillicum Creek beyond Nine Mile Creek.

Because of faulting in these areas and the fact that the top of the formation is not exposed, no measurements of the thickness could be made. The equivalent 'Metaline limestone' to the south of the map-area, however, is comparatively well exposed, and, near Metaline Falls, provides the following section as measured by Park and Cannon (1943, p. 18).

Top of section	Thickness (feet)
Limestone, mottled, dense, grey; few chert nodules	150
Limestone, mottled, dense, grey; many chert nodules	450
Dolomite, fine-grained, cream coloured, particularly in upper part; alternating layers of black and white dolomite	1,200
Limestones and limy shales, interbedded; locally dolomitic	1,200
Total thickness	3,000

In the present map-area the lower part of the Nelway formation is best exposed at the head of Porcupine Creek, where McAllister (1951, pp. 17, 18) estimated that about 1,000 feet are exposed. About the same thickness of the lower Nelway is exposed in the belt east of Stagleap Creek. West of Stagleap Creek, north of South Salmo River, the entire lower part and much of the middle part of the formation are present. There the lower part is about 2,700 feet thick, and about 3,300 feet of the middle part is exposed, but it is not certain that these figures represent true thicknesses.

Farther west, owing to the paucity of outcrops and complexity of structure, no estimates can be made of the thickness of the lower part of the formation which in many places, as along Pend-d'Oreille River, is missing, apparently due to faults. The middle dolomite member is most widely distributed but the exposed thickness cannot be estimated with accuracy.

The uppermost, 150-foot member of the 'Metaline limestone' has not been recognized north of the International Boundary, but the down-faulted block of Nelway formation lying between Pend-d'Oreille River and the volcanic rocks to the north is regarded by Okulitch (1947) as consisting mainly of the 450-foot member of the 'Metaline limestone'. This limestone is almost entirely lacking in bedding planes, so that it is impossible to measure the thickness exposed.

Lithology—The lower part of the Nelway formation consists of predominantly calcareous rocks; limestone, phyllite, and calcareous schist. Most of these rocks are black but some of the limestones are grey, and some of these are locally dolomitic. Limestone is more abundant near the top. South of the International Boundary some of the limestone has been jasperized, particularly near orebodies, but this effect has not been detected in the present map-area.

The middle part consists almost entirely of cream weathering dolomite, but near the base a band up to 200 feet thick of black and white mottled dolomite has been seen at a few localities. One of these localities is on the Nelson-Nelway highway about a mile south of Rosebud Creek, another is east of Pend-d'Oreille River near the International Boundary, and a third is on the ridge west of Stagleap Creek. The cream weathering dolomite is regarded as being of primary origin owing to its great and consistent thickness and its broad lateral distribution. In many places it contains concentric chert concretions elongated along the bedding planes. On the ridge near the International Boundary between Boundary Monuments No. 190 and No. 191, the dolomite is clearly bedded in strata 1 foot to 3 feet thick. Alternate beds show wavy banding, the individual laminae being about 2 millimetres thick. Although this ribbed effect gives an appearance of organic origin, this was not confirmed in thin sections. More probably the rock has been mashed and recrystallized.

The exposures north of Pend-d'Oreille River, regarded as probably upper Nelway, consist of white limestone containing abundant irregular masses of chert, and exhibit very few bedding planes.

Internal Structural Relations—The black limestones and calcareous phyllites and slates of the Nelway formation at the head of Porcupine Creek occur in the trough of the Laib syncline, which there is isoclinal. The strata dip vertically; the easterly beds facing west and the westerly beds east. The strike is north to N20°E.

In the belt east of Stagleap Creek the lower Nelway strikes N20° to 40°E and dips 20° to 50°NW. West of Stagleap Creek, the lower and middle Nelway beds strike approximately N30°E and for the most part dip steeply southeast.

To the southwest, however, the beds curve around the nose of the southwest-plunging Sheep Creek anticline, and there strike about southeast and dip 35° to 45°SW.

The structure of the belt between Rosebud and Lomond Lakes is more obscure, but appears to take the form of a syncline plunging gently west-southwesterly. The axis of this syncline appears to extend from just north of the monzonite stock 2½ miles north of Boundary Monument No. 190 somewhat south of west to a point just north of Lomond Lake. The limbs of this syncline dip gently, for the most part, but at the eastern end the south limb seems to be overturned.

External Structural Relations—The base of the Nelway formation is gradational into the underlying Laib formation, and the contact, although poorly defined, has been placed where calcareous rocks predominate over argillaceous rocks. The top of the formation has been seen only in Metaline quadrangle where it is sharply defined against the overlying Ordovician slates. No angular discordance has been observed, but as Upper Cambrian strata are apparently missing, it seems probable that a disconformity exists.

Origin—The abundance of calcareous material and the fact that there is no discernible lateral gradation in any direction suggest that the sedimentary materials accumulated in a sea-basin far from any landmass. The lower part of the formation becomes less argillaceous toward the top, indicating a gradual change in conditions of sedimentation. At this horizon there is an abrupt change, and the thick middle dolomite member was deposited followed by dense grey limestone containing chert nodules. The reason for the sudden increase in magnesium carbonates and the equally sudden decrease is not apparent.

Age and Correlation—No diagnostic fossils have been obtained from the Nelway formation. In 1947 Okulitch found two poorly preserved trilobite pygidia, and in the following year Mulligan collected a fragment of *Conulites* from the lower Nelway north of South Salmo River west of Stagleap Creek.

The corresponding 'Metaline limestone' to the south has, on the other hand, yielded abundant faunas. The collections made by Park and Cannon (1943, p. 19) in the upper Lehigh quarry and from Threemile Creek, both near Metaline Falls, Washington, were identified as Middle Cambrian and approximately equivalent to the Stephen formation of British Columbia and the Cambrian formation of Libby quadrangle, Montana (Gibson, 1948, pp. 19, 20). Howell (1945) subsequently stated that these faunas were older than the *Ogygopsis* fauna of the Stephen formation, and correlated the Metaline with the Lakeview of Idaho, Damnation and Pagoda formations of Montana, and the lower part only of the Stephen formation.

McLaughlin and Enbysk (1950) reported upon collections from the upper and middle Lehigh quarries and one made in 1931 from Slate Creek. The latter two collections are characterized by *Olenoides, Elrathia,* and *Elrathina*, and the

first by *Taxioura, Bathyriscus,* and *Ogygopsis.* The faunas of the upper quarry were regarded as "at least as young as the *Ogygopsis klotzi* zone of the Stephen."

In 1947 Okulitch collected fossils from the Lehigh quarries and identified the following species (Okulitch, 1947):

GSC Loc Cat Nos. 15529 to 15540, 15549, 15703 and 15710.

Brachiopods
- *Acrothele* sp.

Trilobites
- *Elrathina cordillerae* (Rominger)
- *E. fecunda* Deiss
- *E. hydrida* Deiss
- *E. erecta* Deiss
- *E. oculineata* (?) Deiss
- *E. lickensis* Deiss
- *E. convexa* Deiss
- *E.* sp.
- *Elrathiella unisulcata* Deiss
- *E.* sp.
- *Ehmania* sp.
- *Ogygopsis klotzi* Rominger
- *Bathyriscus formosus* Deiss
- *Taxioura* (?) sp.
- *Olenoides* cf. *serratus* (Rominger)
- *Kootenia rugosa* Deiss
- *K. subequalis* Deiss
- *Pachyaspis typicalis* Resser
- *Zacanthoides romingeri* Resser

R. D. Hutchinson[1] of the Geological Survey re-examined the collection and stated:

> I agree with Dr. Okulitch's identifications except for the specimen labelled *Zacanthoides romingeri* Resser. This specimen has too narrow a glabella, and the eye lobes are too close to the axial furrow, to be referred to *Zacanthoides.* I believe it belongs in the genus *Kootenia,* but is not well enough preserved to permit specific identification.

Okulitch (1950) revisited the quarries and concerning the localities says:

> The trilobites occur in two zones in the . . . Metaline formation. The lower zone consists of thin-bedded shaly limestone, well exposed in the (middle) quarry. The dominant forms in this zone are *Elrathia, Elrathiella,* and *Elrathina.* This faunal zone is very similar to the Pagoda limestone described by Deiss in Montana. Some 200 feet above this zone in the upper operating quarry, in dark blue to black limestone, is the second trilobite zone containing *Ogygopsis, Neolenus,* and *Elrathia.* This zone is similar in contents to the Stephen formation of British Columbia.

All the above collections appear to have been made from the upper part of the lower, 1,200-foot member of the 'Metaline limestone' and are representative of the middle part of Middle Cambrian time. No diagnostic fossils have been found in the dolomites and limestones above this horizon, and, though these may in part be Upper Cambrian, Park and Cannon have referred the entire formation to the Middle Cambrian. The writer therefore regards the corresponding Nelway formation as Middle Cambrian.

[1] Personal communication, December 1, 1955.

The Nelway formation is correlated with the 'Metaline limestone' of Metaline quadrangle and the Northport area to the west on lithological grounds. Strata of the Nelway formation may be included in the Lardeau series to the northeast of the present map-area.

Ordovician

Active Formation

The Active formation was named by the writer (Little, 1950, p. 21) from Active Creek, where much of the formation is exposed. In this locality it bears a close resemblance to the Laib formation, and was mapped as lower Pend-d'Oreille series (Laib) by Walker. The writer would undoubtedly have done likewise had it not been for the fortuitous discovery of Ordovician fossils in the formation. As no fossils were found in the belt west of the Sheep Creek anticline, these rocks were mapped by the writer as Laib 'group' and presumed to form a syncline. Fyles and Hewlett subsequently showed that they are probably largely strata of the Active formation.

Distribution and Thickness—The Active formation forms a discontinuous belt extending from the International Boundary south of Pend-d'Oreille River, northeastward for about 25 miles to the head of Wren Creek. Only the north part of this belt, where it forms an annulus about a large granite stock on Porcupine Creek, was originally identified by the writer (Little, 1949). In 1950 detailed mapping south of Pend-d'Oreille River by P. J. Shenan of Day Mines Limited, revealed an overthrust of Ordovician (?) rocks and his conclusions were later verified by the writer (Little, 1951). Subsequent detailed mapping by Fyles and Hewlett showed that the part of the belt between Creggan and Hidden Creeks likewise comprised these rocks. Further it was shown that the belt was bounded by two thrust faults and that the Ordovician (?) rocks were bounded on both sides by plates of Lower Cambrian rocks and, in addition, on the southeast by some Middle Cambrian rocks.

Rocks of the Active formation elsewhere are known only in a narrow wedge in the valley of South Salmo River, east of Stagleap Creek.

The thickness of the Active formation within the map-area cannot be determined, as in no section are both the base and top exposed. Furthermore the structure is probably complex and bedding planes are obscured in many places by slaty cleavage. The maximum apparent thickness is in the valley of Active Creek where about 4,600 feet of beds are exposed. The minimum apparent thickness, in the valley of Porcupine Creek 2 or 3 miles to the northeast, is about 1,500 feet. In both localities the lowermost beds exposed are limestones, but whether these represent the uppermost Nelway limestone or limestone within the Ordovician succession is not known.

For the part of the formation in the Metaline quadrangle Park and Cannon (1943, p. 20) estimate the maximum apparent thickness as 2,500 feet, but the top is not exposed.

Lithology—The wedge of Active formation near Stagleap Creek most closely resembles the lithology of the 'Ledbetter slate' as described by Park and Cannon, except for the presence of a band of white quartzite exposed near the International Boundary. The strata of this wedge proved to be the northward extension of the fossiliferous band they had mapped at the head of Slate Creek. The rocks within the wedge are slates in which the cleavage transgresses the bedding at high angles, and it is probably for this reason that no graptolites have been found in them north of the International Boundary.

The rocks exposed in the type locality at Active Creek consist of three 100-foot bands of limestone separated by arenaceous slate, in contact with a large granite stock. A little farther north, in Porcupine Creek, the more easterly limestone band attains a thickness of 250 feet and is white or pinkish with grey bands. Farther from the stock the slates become more arenaceous and consist predominantly of argillaceous quartzite up to the contact with the white quartzites, schist, and crystalline limestone of map-unit 10. In the belt farther south, from Hidden to Creggan Creeks, the rocks are similar to those in Active Creek, but limestone, other than black, is rare.

Rocks of the Active (?) formation south of Pend-d'Oreille River comprise mainly black, sooty argillite and slate, with minor arenaceous argillite and black limestone. The outcrops toward the west, on the ridge north of Fish Creek, contain more slate and no black limestone was observed. The rocks there more closely resemble those of the 'Ledbetter slate' than those farther east.

Internal Structural Relations—The structure of the Active formation in the type area is baffling and only by very detailed mapping might the solution of the problem be obtained. The formation appears to be completely 'wrapped around' the large granite stock on Porcupine Creek. A limestone band was traced almost continuously around the southern periphery of the stock and, although no such horizon marker could be found to the north, the strikes of the slate and quartzite are roughly parallel to the granite contact except, perhaps, at the most northerly point. The dips are steep and mainly are outward from the granite body but no reliable top determination could be obtained. The strata are bounded on the south and southeast by those of map-unit 10 (mapped as Palæozoic, undivided). The most probable explanation for the structure is that the forcible emplacement of the granite stock caused a doming of the strata around it.

The slates of the down-faulted wedge of Active formation near Stagleap Creek strike about N10° to 45° E and dip both easterly and westerly from 35 degrees to vertical.

The structure of the belt of Active (?) formation between Hidden and Creggan Creeks is not known to the writer. The strata in general strike roughly parallel with the thrust faults that define the east and west boundaries of the belt. The dips are extremely variable. Fyles and Hewlett contend that the easterly thrust fault is folded in the valley of Hidden Creek, and this would account for the puzzling fact that the Active formation appears to be conformable with the rocks mapped as map-unit 10, which here are regarded as largely Lower Cambrian.

The Ordovician (?) rocks south of Pend-d'Oreille River strike northwest to southwest and, except for a few reversals, dip gently westerly. Drag-folds are numerous and indicate that the plate has been thrust from the south-southwest.

External Structural Relations—All contacts of the Active formation with other formations are faults, and at no place within the map-area are either the base or the top exposed. To the south in Metaline quadrangle the basal slates of the 'Ledbetter slate' rest with no angular discordance on the uppermost limestone of the 'Metaline limestone' of Middle Cambrian age.

Age and Correlation—Only one fossil locality has been discovered in the Active formation. In 1947 the writer collected what appeared to be a poorly preserved gastropod from the slate talus east of Active Creek about half a mile north of Porcupine Creek, at an elevation of 4,000 feet. A tentative examination was made in the field by V. J. Okulitch who expressed the opinion that it might be *Hormatoma,* or similar gastropod of probably Trenton (Middle Ordovician) age.

In view of the importance of obtaining more information the writer revisited the locality in 1949 accompanied by Dr. Okulitch, and a number of specimens of graptolites were collected. These were initially examined by Dr. Alice E. Wilson, and at her suggestion were re-examined by R. Thorsteinsson of the Geological Survey, whose report is quoted below:

> Loc Cat No. 17206.
>
> The collection comprises numerous poorly preserved graptolites in which the following forms have been identified:
>
> ? *Tetragraptus* sp. indet.
> *Didymograptus* sp. indet.
> Diplograptid graptolites
>
> These forms permit provisional correlation with the Lower Ordovician Deepkill formation of northeastern United States. However, if the form identified questionably as *Tetragraptus* is not this genus the fauna could be as young as lower Middle Ordovician.

The determinations suggest that the age of the rocks of this horizon is Deepkill (Canadian) or Lower Ordovician.

The corresponding 'Ledbetter slate' of Metaline quadrangle has yielded abundant fossils, mainly graptolites, most of which are of Deepkill age, but "some collections contain elements of lower Dicellograptus fauna of Normanskill (Champlainian or Middle Ordovician) age" (Park and Cannon, 1943, p. 21).

As the fossils collected from the Active formation are probably of Lower Ordovician age and as Lower and Middle Ordovician strata are present immediately south of the map-area, the age of the Active formation is presumed to be Lower and Middle Ordovician.

The Active formation is correlated with the 'Ledbetter slate' of Metaline quadrangle, but may include beds higher than those of the latter (*see* Correlation Chart, in pocket). Beds of Ordovician age may be present in the highly metamorphosed Lardeau series to the northeast, or in the overlying Milford group. The latter conjecture is supported in Drysdale's (1917a, p. 58) report, in which a fossil collection, from rocks on strike with those later shown by Cairnes (1934)

to be Milford, contained gastropods. One of the gastropods "though preserved only in section is sufficiently preserved to leave little doubt that it represents a species of *Raphistoma* . . . Provisionally determined as Ordovician." As this locality is apparently near the top of the Milford—the part where Cairnes obtained fossils of Mesozoic age—the Ordovician (?) rocks must be faulted into their present position. If the determination is correct, it represents the nearest exposure of Ordovician rocks in British Columbia to those of the southern part of Nelson map-area.

The Active formation may be correlated, in large part at least, with the Glenogle shale of Windermere map-area (Walker, 1926, pp. 24-31), which Ruedemann (1947, pp. 101-106) has shown to contain fossils of both Deepkill and Normanskill age.

Graptolitic argillites of Ordovician age occur to the southwest in Stevens county, Washington, at Clugston Creek (Bennett, personal communication), near Addy (Bennett, 1944, p. 31), and 3 miles east of Rice, where graptolites were collected by J. P. Thomson of Colville. Ordovician beds have been reported in Skykomish basin, Cascade Mountains, by Smith (1916).

Undivided Palæozoic (map-unit 10)

A thick assemblage of metamorphosed quartzite, schist, and limestone at the head of Hidden Creek was originally mapped by Walker (1934) as doubtfully Quartzite Range formation. Subsequent mapping (Little, 1950; McAllister, 1951; Mathews, 1953) indicated that the assemblage differs greatly lithologically and structurally from Quartzite Range. Furthermore the assemblage appears to overlie the Active formation and underlie the Ymir group, in both cases without angular discordance. To this assemblage the name 'Seeman group' was applied.

More detailed work by Fyles[1] and Hewlett of the British Columbia Department of Mines has shown that the southern part at least of these rocks include members of the Quartzite Range, Reno, and Laib formations. In view of this recent work, the name 'Seeman group' is discarded, and the assemblage is mapped as undivided Palæozoic rocks.

Distribution—Two large areas and several smaller ones, the latter surrounded by granitic rocks, are underlain by rocks of map-unit 10. The more southerly of the larger areas is in the upper valley of Hidden Creek; the more northerly extends more than 16 miles northeasterly from the valley of Porcupine Creek and passes beyond the east edge of the map-area north of Seeman Creek. The smaller areas occur on both sides of the northerly belt.

Lithology—The rocks exposed in the valley of upper Hidden Creek consist of argillaceous quartzite, white massive quartzite, schist, and minor slate and crystalline limestone. White quartzite predominates near Hidden Creek, but crystalline limestone and schist are more abundant in other parts exposed in this region.

[1] Personal communication, December 2, 1955.

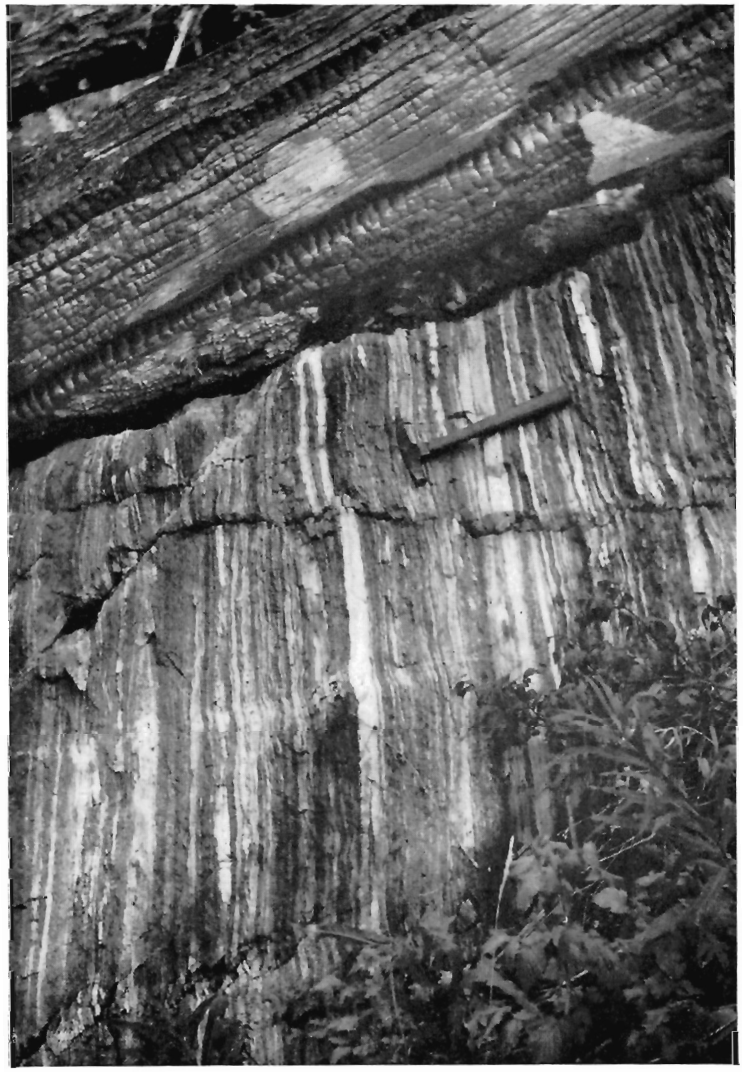


Plate II *Ribbon quartzite in north end of belt of 'Palaeozoic undivided rocks'.*
(Photo by A. L. McAllister, 1948.)

In the large area underlain by rocks of map-unit 10 extending northeasterly from the valley of Porcupine Creek, white quartzite with tints of pink, yellow, brown, and green is the dominant rock type. Argillaceous quartzite and schist, grey-black phyllite, and crystalline limestone are abundant, chlorite and graphite schist were observed, and ribbon quartzite is common in the eastern part.

McAllister (1951, pp. 22-25) has divided the assemblage there into an eastern, a central, and a western zone. Concerning their stratigraphy he says:

> The eastern zone is best exposed along the southeastern side of Seeman Creek Valley, along the upper reaches of Seeman Creek, and along the walls of Porcupine Creek Valley just east of Active Creek. The 'ribbon quartzites' are the most striking rocks of this zone. They consist of bands of nearly pure quartzite, generally less than 2 inches thick, separated by narrow bands of quartz-mica schists (*see* Plate II). The schists weather more readily than the quartzites, in many places resulting in a rough washboard effect on the weathered surface. This, together with the dark red, grey, and grey-brown colours of the schists contrasting with the pale quartzite gives the rock its strikingly banded appearance. Associated with the ribbon quartzites in this zone are bands of schists and quartzite, in some places up to 50 or 60 feet thick. Some of these thicker beds of white quartzite are well exposed and can be used as marker horizons for limited distances.
>
> The eastern zone contains at least two bands of limestone. One of these, a dolomitic limestone, is well exposed along the southern side of Seeman Creek Valley, near the fault separating this from the older Quartzite Range beds. At that point it has an outcrop width of 450 feet, but minor folds may account for some of this width. It is a white, buff-weathering rock with a sandy feel on the weathered surface, the carbonate forming crystals ¼ inch in diameter. The rock contains small amounts of talc, tremolite and muscovite. Apparently the same limestone band, with an outcrop width of about 300 feet, and associated with schists and 'ribbon quartzites', is found on the Ymir-Seeman Creek divide. If this band continues south it must change in character and become thinner, as it resembles none of the limestones found along Porcupine Creek.
>
> Seven hundred feet southeast of this band, on the Ymir-Seeman Creek divide, a second, 20-foot band of grey limestone is interbedded with banded quartzite and schists. Only one band of limestone was found in this zone along Porcupine Creek. This, a grey-banded limestone, lies near the junction of Active and Porcupine Creeks.
>
> The central zone consists of white quartzite, schists, and limestone. One calcareous band occurs in this zone. It is about 200 feet thick on Porcupine Creek, and consists of grey-banded limestone in beds up to 20 feet thick interbedded with calcareous schists.
>
> The western zone is poorly exposed. To the south, along Porcupine Creek, it has suffered extensive alteration. From here to the northeastern (part) it is traced mainly through small isolated roof pendants in the Nelson batholith. (Here) it is again highly altered and poorly exposed. In the southern part .... the zone consists dominantly of dark, grey-brown mica schist, with minor bands of white, feldspathized quartzite and paragneiss. To the north, this zone becomes more argillaceous and limestone is much more prominent. Along the ridge between Seeman and Kutetl Creeks, one band of sheared argillite, 500 feet thick, and five bands of limestone were recognized. In this area they occur in a group of hybrid rocks ranging from biotite-chlorite and muscovite schists through paragneiss into massive granitic rocks.
>
> Along the northwestern side of Ymir (Wildhorse) Creek Valley and the northwestern side of Seeman Creek Valley a band of limestone conglomerate is poorly exposed. It is grey-white to grey-black. Pebbles are of fine granitic material, quartz, and feldspar. The granitic pebbles are the most prominent, and stand out on the weathered surface as coarse nodules up to 2 inches in diameter. In thin section, these pebbles are seen to consist of highly altered alkaline feldspar, of which some at least is albite, together with biotite and quartz in a groundmass of calcite. Smaller, rounded pebbles of quartz are abundant. Flowage in the limestone has drawn the larger pebbles into irregular crenulated lenses, whereas the smaller pebbles have retained their well-rounded form.

Two isolated bodies of dioritic rocks occur in the vicinity of Kutetl Creek, near the upper (?) part of this zone. One of these is a black, grey-black weathering, medium-grained rock showing moderate schistosity. It consists of hornblende, biotite, andesine, and magnetite. The other is an altered augite-feldspar porphyry consisting of augite, biotite, andesine, microcline, orthoclase, and quartz. The rock has been extensively granitized. Both bodies are sill-like in form but may be flows.

Internal Structural Relations—Little is known of the structure of these rocks. In the upper part of Hidden Creek valley the strata strike generally east and dip steeply, but to the northeast across the ridge and toward Porcupine Creek they trend northeast to north.

The structure of these rocks elsewhere is similarly obscure. In Porcupine Creek the strata strike northerly and dip steeply east. There can be little doubt that isoclinal folds are present. To the north the strike is likewise northerly although the belt has a more easterly trend. The band at the head of Wren Creek between the Active formation and granite has a southeasterly trend and a northeasterly dip; it may represent the east limb of an anticline resulting from doming caused by intrusion of the granite stock on Porcupine Creek. If so, the anticline plunges steeply northward and terminates within a short distance. North of the latitude of Baldy Mountain, the strike is a little more easterly and the dips are mainly vertical to west, except on the southeast side of Seeman Creek where the dips are predominantly east.

External Structural Relations—The beds exposed near the contact with the Active formation north of the headwaters of Hidden Creek appear to be conformable with and gradational into those of the Active formation. If, however, the interpretation of Fyles and Hewlett is correct, these rocks must be separated by a strike fault. The exposures at the head of Wren Creek are very poor and the contact between these assemblages, though apparently not discordant, was not observed. In Porcupine Creek the rocks are separated by a fault, and north of Wren Creek, all contacts of this assemblage with rocks of older Palæozoic age are faults.

Age and Correlation—This assemblage is probably Palæozoic. No fossils have been found in the beds, nor, in view of the high degree of metamorphism, are they likely to be preserved. The apparent conformity of these rocks both with the Active formation and the Ymir group led the writer (Little, 1950) and McAllister (1951) to suggest that the age of these rocks is between Ordovician and Triassic. Recent detailed studies by Fyles and Hewlett "have shown that the rocks mapped as Seeman group in Hidden Creek and along Porcupine Creek belong mainly to the Laib, Reno, and Quartzite Range formations." If this is correct, the age of the rocks in these localities is Lower Cambrian.

Farther north, however, McAllister has noted the presence of 'ribbon quartzite' and this striking rock is a distinguishing feature of the Milford group west of Kootenay Lake (Rice, 1941, p. 31). According to McAllister it is probably the metamorphosed equivalent of the banded cherts of the Milford group described by Cairnes (1934, p. 40) in Sandon map-area. Such banded

cherts are common in the Permo-Carboniferous of British Columbia and are virtually unknown in formations of other ages. This suggests that the northern part of this belt of rocks may be, at least in part, equivalent to the Milford group. P. Harker of the Geological Survey re-examined the collection made by M. F. Bancroft from the head of Cascade Creek in 1917. In his original examination, E. D. Kindle reported "crinoid stems, three or more undetermined species of bryozoa, *Lithostrotion* ? sp. and *Athyris* sp. undet." Harker states that the questionable *Lithostrotion* is actually a *Michelinia*-like coral. The *Athyris* fragment gives no indication of age, but corals of *Michelinia* type have a long range extending well into the Permian. A fragment of a spiriferid brachiopod having the rib pattern of the *Spirifer* (*Spiriferella*) group occurs in the collection, and these have a wide distribution in the Permian, occurring in the Cache Creek group associated with *Neoschwagerina*. This indication of a Permian age must be regarded with considerable reserve.

Regarding the other collections from the base of the Milford group, which were not re-examined, Harker remarks that there is some confliction in Kindle's identifications, and, as Permian strata had not been identified in British Columbia at the time of Kindle's examination of the fossils, it would have been unlikely that he would suggest a Permian age from such fragmentary material. Thus, although the basal beds of the Milford group may be Carboniferous, it appears at least equally possible they may be Permian. The age of the upper part of the Milford group is discussed in a subsequent section, the Kaslo Group (Age and Correlation).

The rocks of map-unit 10 probably include strata of Lower Cambrian age and may also include rocks as late as Permo-Carboniferous.

Devonian

Although no beds of Devonian age have been identified within the map-area, fossiliferous limestone of this age occurs in a small fault block west of Pend-d'Oreille River only 2 miles south of the International Boundary. The minimum thickness was estimated by Park and Cannon (1943, p. 22) to be 700 feet. The age of the beds has recently been established as probably Middle Devonian (Onondagan) (Enbysk, 1956).

Limestone mapped as Devonian by Park and Cannon a few miles farther west, near the head of Russian Creek, was examined by the writer in 1949. It most closely resembles the Nelway (Metaline) formation.

Pennsylvanian (?)

Mount Roberts Formation

Rocks of the Mount Roberts formation were mapped and described by McConnell (1897a and 1897b; 1898, p. 22A) and Brock (McConnell and Brock, 1904; Brock, 1906, p. 14), who included the formation in their Rossland group. Daly (1912, pp. 320 and 321) separated part of the Mount Roberts formation

from the Rossland group. Drysdale (1915), on the basis of G. A. Young's detailed mapping in the Rossland camp, further delineated the formation and applied the name Mount Roberts formation to it. Gilbert (1948, p. 190) subsequently reduced the areal extent of the formation as shown by Drysdale, and transferred some tuffaceous beds to the Rossland group.

Distribution and Thickness—Rocks of the Mount Roberts formation occur on both sides of Little Sheep Creek for a mile or more north from the International Boundary. They also occur near the head of Little Sheep Creek in a narrow band extending some 4 miles northward along the east slope of Mount Roberts, in a broader band south and west of Red Mountain, and in one or two smaller areas nearby.

Greenstone, limestone, and argillaceous quartzite and their metamorphosed equivalents that extend eastward from Deer Park, just beyond the west central part of the map-area, and other smaller areas to the southeast are, on a lithological basis, tentatively mapped as Mount Roberts formation. Some other rocks mapped as probably Rossland formation, particularly in the region between Deer Park and Rossland, may also be Mount Roberts formation as these two map-units may be distinguished from one another with confidence only on the basis of palæontological evidence, which is lacking in this part of the map-area.

The formation is structurally so complex that no accurate estimate of the thickness can be obtained, unless, perhaps, very detailed mapping were to be done. Drysdale (1915, p. 23) estimated the minimum thickness to be 1,200 feet in the type area. In view of the fact that thick beds of limestone and volcanic flows are present elsewhere, at Paterson and possibly at Deer Park, it seems probable that the thickness recorded above represents only the upper part of the formation.

Near Paterson, at least three bands of limestone are exposed, the smallest being 20 feet thick and the largest at least 400 feet thick. Interbedded with the limestone are massive andesite flows and tuffaceous beds. Slaty argillite and argillaceous quartzite with a few interbedded flows and tuffs occur mainly to the southeast of the limestone and appear to be younger than the limestone, as determined by brecciated tops of lava flows. The apparent thickness of these younger beds is 4,000 feet, but folding in two distinct orogenies is known to have taken place, so that the actual thickness is probably much less. In all, the total thickness of the Mount Roberts formation near Paterson is estimated to exceed 2,000 feet and is possibly much greater.

A much less detailed study has been made of the supposed Mount Roberts formation near Deer Park. Some hundreds of feet of each of crystalline limestone, greenstone, and argillaceous quartzite are exposed.

Lithology—The lower (?) members of the Mount Roberts formation exposed near Paterson comprise mainly limestone, andesite, and banded tuff, in decreasing order of abundance. The limestone is rather crystalline and contains masses of white to light grey chert which are usually irregular in shape, lacking in discernible

bedding planes, and range in average diameter from a few inches to some tens of feet. In two localities the limestone has been quarried and the ruins of limekilns used in the past are still visible. The andesite is mainly extrusive and forms flows having brecciated tops, but some is intrusive and forms irregular, branching feeder dykes cutting the limestone. Banded tuffs are interbedded with limestone, but in some places grade into massive, black argillite.

The upper (?) members near Paterson consist principally of fissile argillite and massive argillaceous quartzite with minor interbedded lava flows, sills, and bedded tuff. The members that appear to overlie the limestone with conformity are black, massive argillite, banded tuff, and andesite, both intrusive and extrusive. Farther from the limestone, lava flows are not common, but argillaceous quartzite becomes more abundant, although argillite, which is locally cherty, predominates. At one locality, about half a mile west of the customs house, the argillite is highly contorted and contains bombs of andesite.

At a few localities east and north of the customs house, where argillaceous quartzite is most abundant, is a band about 20 feet thick of angular fragments of argillite, oriented with their long axes within a plane, and cemented with an argillaceous matrix; at one place some of the fragments are crinoidal limestone. Other thin bands of chert-pebble conglomerate up to a foot thick occur northeast of the customs house. East of the customs house, at an elevation of about 3,100 feet, is a band of white limestone containing numerous tuff fragments.

In the Rossland area the type Mount Roberts formation consists mainly of soft, dense, black slates that in places grade into more arenaceous facies. Much of the slate is, however, lighter coloured, harder, and generally finely banded. Much of this rock Drysdale regarded to be of tuffaceous origin.

A few miles north of Deer Park crystalline limestone bands several hundred feet thick occur in rocks regarded as Mount Roberts; but to the east, within the present map-area, limestone is much less abundant and none exceeds 100 feet in thickness. The limestone is everywhere coarsely crystalline and in many places is altered to skarn or tremolite rock.

Most of the rocks in this region that are mapped as probably Mount Roberts are dark grey to purplish, fine-grained, argillaceous quartzites. They are for the most part highly metamorphosed, with the development of sericite, biotite, and andalusite. These rocks grade into paragneiss. In some places, where the rocks are least metamorphosed, black, fissile argillites are present as well as finely laminated quartzites that may be bedded tuffs. Greenstone, though less abundant than quartzite, is common, and for the most part is massive and fine grained. Most of the flows are andesitic in composition but a few are basaltic. Many flows contain small phenocrysts of augite and a few have small phenocrysts of feldspar.

Internal Structural Relations—Near Paterson, the Mount Roberts formation appears to form an anticline whose axial plane strikes about northeast, and most of the beds dip steeply. Limestone forms the core of the anticline, and most of the northwest limb is covered by volcanic rocks of the Rossland formation. This broad structure is complicated by superimposed structures developed by at least

71994-8—5

one subsequent orogeny. Upon the southeast limb, subsidiary synclines and anticlines occur and on these, drag-folds were observed. The axes of the drag-folds plunge west, south, and northeast at steep angles. The ages of the drag-folds, relative to one another, are unknown.

In the Rossland area, according to Drysdale, the Mount Roberts beds dip west, commonly at angles of from 10° to 30°. The beds in many places are transected by faults.

East of Deer Park, little is known of the structure of the Mount Roberts formation. The strata there, for the most part strike roughly east and dip steeply south, but some northward dips were recorded.

External Structural Relations—The base of the Mount Roberts formation is not exposed. The top is overlain unconformably by basal agglomerates of the Rossland formation which rest upon various members of the Mount Roberts formation.

Origin—The older members of the Mount Roberts formation were deposited in seas distant from the shore or, if they were deposited near the shore, the adjacent landmass must have been of low relief. The presence of corals, crinoids. bryozoa, and brachiopods suggests deposition in shallow water. The occurrence of vulcanism at this time is indicated by the presence of tuffs and lava flows.

The upper members are largely argillaceous, becoming more arenaceous toward the top. Some marine fossils occur together with poorly preserved, shredded plant fragments. This indicates a change in source material, but probably shallow water conditions prevailed as is shown by the presence of corals and the intraformational argillite breccias that appear to have been formed by wave action.

Age and Correlation—Corals were collected by McConnell (1897a) near Paterson and identified by Whiteaves as "probably referable to the Carboniferous genus *Lonsdalia*." Brock in 1906 (Drysdale, 1915, p. 199) made a collection of poorly preserved fossils from the type area on the east slope of O.K. Mountain near Rossland, and these were identified by Ami as follows:

Zaphrentis sp.
Stenopera, or *Rhombopora* sp.
Productus semireticulatus
Productus sp.
Martinia sp.
Spirifer sp., cf. *Spirifer cameratus*

The age was given as Upper Carboniferous.

In 1949, several collections of fossils were made by the writer and his party from localities near Paterson. These were examined by P. Harker of the Geological Survey together with a small collection he made himself in 1955. The localities

are defined by bearing and distance from International Boundary post No. 175, 100 feet or more south of the Canadian customs house at Paterson. Harker reports as follows:

GSC Loc Cat No. 16853
From limestone at two localities:
1. Isolated outcrop 4,350 feet N22°W from post 175; elevation 2,280 feet.
2. Outcrop, 4,950 feet at N32°W from post 175; elevation 2,340 feet.

Localities are 1,000 feet apart.
Syringopora sp.
Fenestrellina sp.
Fragment of large brachiopod, probably an orthotetid.

GSC Loc Cat No. 17207
Limestone band 25 feet thick, interbedded with lava flows; 4,000 feet N40°W from post 175; elevation 2,400 feet.
Isolated small corallites, possibly
'Diphyphyllum' sp. A.
Neokoninckophyllum sp.
Schizophoria sp.

GSC Loc Cat No. 16857
Another limestone band interbedded with lava flows and 30 to 40 feet northwest of No. 17207, and stratigraphically lower as shown by brecciated tops of lava flows.
Schizophoria sp.
Echinoconchus sp.
Striatifera sp.
Punctospirifer sp.
Large productus of *"Dictyoclostus americanus"* type.

GSC Loc Cat No. 17211
Limestone band between lava flows, 4,500 feet N46°W from post 175; elevation 2,600 feet.
'Diphyphyllum' sp. A.
Neokoninckophyllum sp.

GSC Loc Cat No. 17212
From slaty argillite, 3,250 feet N7°W from post 175; elevation 2,350 feet.
Crinoid fragments?

GSC Loc Cat No. 17208
2,350 feet at S87°W from post 175, 100 feet south of International Boundary; elevation 2,400 feet.
Crinoid fragments.
Fenestellid bryozoa indet.
Brachiopod fragments.

GSC Loc Cat No. 17215
1,350 feet N52°E from post 175; elevation 2,980 feet.
Syringopora sp.
Coral fragment, possibly *'Diphyphyllum'* sp. A.

In addition to these, collections were made of fossiliferous limestone fragments in basal flow breccia of the overlying Rossland formation. The limestone fragments caught up in the lava appear to be from the Mount Roberts formation. Two of these localities are near Paterson and the third near Rossland. Harker reports as follows:

GSC Loc Cat No. 17214
Limestone fragments in flow breccia, 2,450 feet N8°W from post 175, 200 feet at N70°E from No. 16852; elevation 2,400 feet.

71994-8—5½

Syringopora sp.
Brachiopod fragment.
Bryozoa indet.

GSC Loc Cat No. 16852

Limestone fragments in volcanic flow breccia 2,400 feet N13°W from post 175, or 200 feet east of road junction; elevation 2,250 feet.

'Diphyphyllum' sp. A.
Neokoninckophyllum sp.
Bryozoa indet.

GSC Loc Cat No. 17213

Limestone fragments in flow breccia, southeast spur of Granite Mountain; elevation 5,600 feet.

Crinoid fragments.
Productid fragments.
Punctospirifer sp. cf. *P. kentuckyensis* (Shumard).

As pointed out previously, the limestone is regarded as the oldest member of the formation and if this is so the first four lots described would be older than the three that follow. However, there is no confirmation of this from the determinations; indeed some faunal elements are common to several collections. Harker reports that

> . . . it seems probable that all the collections are of approximately the same age, although this equivalence is not necessarily close enough to include some stratigraphic separation.
>
> Palæontological evidence of actual age is rather meagre. The collections are of Pennsylvanian or Permian age and in my opinion they are probably Pennsylvanian.

Daly (1912, pp. 322, 323, 802, 816, 820, and 822), in 1903 collected plant fragments from beds above the old railway grade, east of the present location of the customs house at Paterson. Although these beds in Daly's opinion dip east under the Rossland flows and must therefore be pre-Jurassic, Penhallow identified the specimens, though poorly preserved and pyritized, as probably *Gleichenia gilbert-thompsoni* of Lower Cretaceous age. A careful study of the beds by the writer showed that they are conformable with those yielding the invertebrate fossils, and collections were made of plants from Daly's localities and from a site some 800 feet in height above the customs house. These were examined by W. A. Bell of the Geological Survey who submitted the following report:

> GSC Plant Loc Cat No. 3892, north of International Boundary at Paterson, B.C. on east side of Little Sheep Creek.
>
> The collection consists of unidentifiable imprints of plant stems, which may be classified as follows:
>
> (1) Stems up to ¾ inch diameter; a few narrow stems branch dichotomously, others laterally. Generally a fractured, siliceous coating on the stems has destroyed any surface markings that may have been present, but in a few instances the stems are longitudinally striated.
>
> (2) One specimen is of a narrow, striated stem having small, linear, once-divided leaf-like organs, apparently arranged in whorls at nodal lines, recalling early forms of *Sphenophyllum*.

(3) A single specimen is of a branched (?) stem marked by minute, circular scars, which may be bases of spines or leaves.

(4) Stems, about ¾ inch diameter, having longitudinal ribs, somewhat calamitean in appearance, but no visible nodes.

The specimens are useless for refined age determination on account of their unidentifiable nature. There is no definite evidence for a Mesozoic age and on the plant evidence alone a Palæozoic post-Silurian age would be possible.

The writer returned to the lower locality in 1955 accompanied by W. L. Fry of the Geological Survey and a small but more diagnostic collection was made. Dr. Fry comments:

GSC Plant Cat No. 4790.

The carbonaceous remains represent the remnants of small branches and stems. Oftentimes they are slightly replaced with pyrite and little or no hydrocarbon is left. It would appear that these remains together with a fragment of *Lepidodendron* sp. represent pieces of plant debris that floated out from shore. Furthermore they appear to have partly decayed and fragmented prior to burial and preservation.

The material for dating is extremely meagre but the presence of *Lepidodendron* is indicative of the Permo-Carboniferous and possibly of Pennsylvanian age.

From the above palæontological information, the age of the Mount Roberts formation is most likely Pennsylvanian but a Lower Permian age cannot be entirely ruled out. The occurrence of plants in Palæozoic measures is rare in this part of the continent. Bancroft (1914, p. 14) collected a specimen near Covada, Ferry county, Washington, identified by David White as "*Bothrodendron* sp. (?) of Carboniferous age, most likely older Pennsylvanian."

The Mount Roberts formation may be correlated in part with the Milford group of Lardeau, Sandon, and Nelson (east half) areas (*see* Correlation Chart, in pocket). Its age lies within that of the widespread Cache Creek group, with which it may be correlated. It is also correlated in part with the Churchill formation of the Orient area to the southwest on lithological grounds. Bowman (1950) has, however, assigned a Permian age to the Churchill formation on the basis of two fossil collections. One, from about a mile south of Barstow, yielded corals identified by V. J. Okulitch as being of Devonian to Permian age; the other, from a mile farther south, contained two species of *Parafusulina* of Middle or Upper Permian age, identified by Lloyd Henbest. Near the International Boundary, Bowman found some unidentifiable mineralized impressions of plant fragments. The Churchill formation may, therefore, extend downwards in age into the Pennsylvanian, and conversely, the Mount Roberts formation, where the upper part has not been removed by pre-Jurassic erosion, may include beds as late as Middle or Upper Permian.

The Mount Roberts formation may also be correlated in part with the Anarchist series as described by Waters and Krauskopf (1941) in the Okanogan Valley of north central Washington. From the Anarchist, they obtained poorly preserved fossils of Carboniferous or Permian age.

Mesozoic

Triassic

Kaslo Group

The Kaslo group (formerly 'series') was originally described by McConnell (1896, p. 31A; 1897a, p. 24A) and though defined as the 'Kaslo schists', it was included in the Lower 'Selkirk series' on the West Kootenay sheet (McConnell and Brock, 1904). Drysdale (1917a, p. 57) believed that the 'Kaslo volcanics' are younger than the Slocan series and form the core of a syncline bounded on both sides by the latter. Cairnes (1934) subsequently showed that the Kaslo 'series' is underlain unconformably on the east by the Milford group, and overlain disconformably on the west by the Slocan series.

Distribution and Thickness—Rocks of the Kaslo group have been identified definitely only in the extreme northeast corner of the map-area, but may be present in roof pendants between Mount McQuarrie and Alwyn Creek.

A short distance south of the small lake at the head of Harrop Creek there is a large outcrop of amphibolite surrounded by gneissic, porphyritic granite. A little farther south paragneiss of uncertain age outcrops. The amphibolite may be the metamorphosed equivalent of Kaslo greenstone, and indeed is close to the position where it might be expected according to Rice's (1941) mapping in the adjacent map-area. McAllister (1950, pp. 100, 101) pointed out that some basic igneous members present in the rocks of map-unit 10, occurring a few miles farther south of the amphibolite mentioned above, may represent the most southerly extent of the Kaslo group.

The maximum thickness of the Kaslo group in the type area varies greatly from place to place. According to Cairnes (1934, pp. 47, 48), near Jardine Mountain it is about 6,200 feet thick, with only the upper half of this thickness exposed within Nelson map-area (west half). On Kaslo River it is 3,000 feet thick. From the latter point it apparently thins southward in which direction it has been traced along the west side of Kootenay Lake by Rice, and terminates at, or north of, the localities mentioned in the preceding paragraph.

Lithology—The lithology of the Kaslo group has been fully described by Cairnes and by Rice and, because relatively little of the group occurs within the present map-area, their remarks will be summarized only briefly.

The rocks of the group are almost entirely of volcanic origin. Volcanic breccias and tuffs predominate at the base, but extrusive and intrusive andesite and dacite also occur. Near the middle of the group, and also beyond the boundaries of the present map-area, two belts of serpentine and carbonate rocks are present. In the upper part of the group, flows and sill-like bodies of, mainly, andesite are common; some pyroclastic rocks are also present.

Internal Structural Relations—In the extreme northeast corner of the map-area the structure of the Kaslo group is a homocline in which the rocks strike roughly northwest and dip, according to the few attitudes obtainable, 45° to nearly

90°SW. The upper sides of the tuffs and flows face southwest. Elsewhere the structure of volcanic and metamorphic rocks that are possibly Kaslo is not known.

External Structural Relations—According to Cairnes (1934, pp. 30, 31, 42, 48) the Kaslo group rests unconformably upon the Milford group, as suggested by the weathered appearance of the uppermost Milford beds and because the basal members of the Kaslo group appear to rest, from place to place, upon different members of the upper part of the Milford group. Furthermore, intrusive members of the Kaslo group invade the Milford group near their usual contact.

The basal strata of the Slocan group overlie disconformably the Kaslo group as indicated by the presence of "erosion materials from the uppermost members of the Kaslo", but there is little discordance between the groups along their contact.

Age and Correlation—The age of the Kaslo group is probably Triassic. The underlying Milford group has yielded fossils from the upper part of the group that McLearn (Cairnes, 1934, p. 43) ascribed to the Mesozoic era. The collections were re-examined by E. T. Tozer and J. A. Jeletzky of the Geological Survey. Tozer reports that the ammonites are too poorly preserved and as sutures are lacking, the age cannot be placed with confidence in either the Triassic or Permo-Carboniferous. Jeletzky, upon sectioning the belemnites, identified the following species:

537 F.C. (8432). From limestone float, probably nearly in place; nearly ½ mile south of Schroeder Peak and 400 feet below summit of ridge:

Indeterminable organic remains.

Possibly Belemnoidea Stolley; family, genus, and species indet.

311 F.C. Fossiliferous limestone float from the south slope and near the summit of the divide between Jardine and Schroeder Peaks, probably nearly in place:

Aulacoceratidae Bernard, cf. *Atractites* sp. indet. B (somewhat abnormal).

536 F.C. (8431) from limestone float, probably not far out of place; about ½ mile south of Schroeder Peak and 400 feet below summit of Schroeder Ridge:

Aulacoceratidae Bernard, ? cf. *Atractites* sp. indet. C (somewhat abnormal and close to B).

Most probably Triassic. The family Aulacoceratidae Bernard has always been regarded as a safe indicator of the Triassic age of the containing strata. Unfortunately this point of view cannot be retained any longer since typical representatives of the genus *Dictyoconites* Mojsisovics were found recently in the Upper Permian of Greenland (Fisher, 1947) and genus *Atractites* Gumbel is known to range from Upper Permian to Upper Liassic (although the main range of distribution is Triassic).

As from the above information, the top of the Milford group is probably of Triassic age, and as fossils of similar age have been identified in the Slocan group overlying the Kaslo group, the age of the Kaslo group is probably Triassic.

The Kaslo group, in the light of present information, cannot be correlated with any other group or formation.

Triassic and (?) Lower Jurassic

Slocan Group

The Slocan group (formerly 'series') was first described by McConnell (1896, p. 31A; 1897a, p. 24A) and was provisionally named 'Slocan slates'. On the map published subsequently the rocks were described as the 'Slocan series', which name has been used until recently.

Drysdale (1917a, p. 57) included in the 'Slocan series' the rocks now known as the Milford group, that later (Walker, Bancroft, and Gunning, 1929; Cairnes, 1934) were again separated from the 'Slocan series'.

Distribution and Thickness—The Slocan group is exposed mainly in the northeast part of the map-area, where together with a few intrusive bodies, it underlies the entire region between Slocan Lake and Kaslo River north of the Nelson batholith. From there they extend northwesterly and occur in a broad belt, the southern part of which lies across the north edge of the map-area west of Slocan Lake. In this part of the belt the rocks are largely paragneiss intruded by bodies of granite and granodiorite.

Roof pendants of paragneiss, probably of the Slocan group, are present in the Nelson batholith for some distance south of its northern periphery. Rice (1941) has traced strata of the Slocan group southward from Kaslo River along the eastern edge of the batholith to the west central part of the adjoining map-area, at which point it appears to pass again into the present map-area.

The thickness of the Slocan group was estimated by Cairnes (1934, p. 58) as not more than 6,800 feet. On the basis of more detailed work, Hedley (1952, p. 23) has revised the thickness which he regards as being much greater and "may possibly be several times that figure." Irwin, (1951, p. 501) on the basis of carefully plotted cross-sections and after making allowance for the average dip, local thickening, and some repetition of the beds, concluded that the Slocan group is represented by some 37,000 feet of strata. Cairnes (Irwin, 1952) objected to this figure because it is much greater than the maximum thickness of any known Triassic section in the world and because the Slocan group is apparently confined to the Upper Triassic only as Lower and Middle Triassic are unknown in southern British Columbia west of the Rocky Mountain Trench. Furthermore, the strata are composed of limestone and fine clastic rocks that would be expected to accumulate very slowly. Cairnes suggested that major repetitions of the strata may have been unrecognized.

Irwin replied that in the lower part of the group, adjacent to the Kaslo group, Hedley (1945, p. 14) could find no repetition of the beds by folding, and in the upper part of the group 95 per cent of the beds face west, as indicated by top determinations. The middle part of the group contains few criteria for top determinations, but, where such could be made, all beds face west. He admitted, however, that further detailed studies would probably lead to a revision of the above figure.

Although only the Upper Triassic is represented in the greater part of British Columbia, the Spray River formation of the Rocky Mountains is Lower and Middle Triassic (McLearn, 1953) and the Lower and Middle Triassic sea may have extended as far west as the present map-area. If so, the entire Triassic system may be represented. Muller and Ferguson (1939) present measured sections of the Triassic of Nevada totalling some 24,445 feet, including some pyroclastic rocks. Thus, great thicknesses of Triassic rocks are possible.

In view of the foregoing, it appears likely that the total thickness of the Slocan group is very great but that an accurate figure cannot at present be given.

Lithology—The Slocan group consists predominantly of argillaceous rocks, but fine-grained quartzite and limestone are fairly abundant. Tuffaceous beds and a little conglomerate are also present.

The basal part of the group has been described by Hedley (1945, pp. 7-10) who refers to it as the 'slate belt' because of the predominance of fissile, argillaceous rocks. A number of bands of limestone occur in them, and some quartzitic strata are also present. The slates and phyllites are grey to black, and locally greenish. Evidence of lateral gradation of these beds toward the northwest into more arenaceous and less calcareous phases has been presented by Cairnes and confirmed by Hedley.

Several thousand feet of strata overlying the basal belt have not been examined everywhere in detail. In general they resemble the basal beds as far west as Zincton (north of the map-area), beyond which they are mainly grey argillaceous rocks that contrast sharply with the lower strata.

Higher still in the section the beds exposed between Mount Payne and Idaho Peak are more arenaceous, the dominant type being a dark, well-bedded, quartzitic argillite in which the alternating strata of various degrees of purity range in thickness from a fraction of an inch to 2 or 3 feet. These rocks are fine grained and silty. Less abundant are impure quartzites and limestones.

Rocks highest in the section outcrop between Idaho Peak and Slocan Lake. They are similar to those east of Idaho Peak but contain beds of tuffaceous origin. It is probable that these tuffs heralded the outpourings of lava of the 'Rossland group' which, according to McConnell and Brock (1904), overlies the Slocan group northwest of Slocan Lake, beyond the boundaries of the present map-area.

West of Slocan Lake, near the north edge of the map-area slates and impure quartzites of the Slocan group have been largely altered to paragneiss. This gneiss is similar in appearance and composition to that exposed farther south in the core of the Nelson batholith.

Internal Structural Relations—The structure of the Slocan group in the northeast part of the map-area has been worked out by Hedley (1945; 1952) and the reader is referred to his publications and to Irwin (1951) for further details. On a line through Silverton and Idaho Peak and extending beyond the north edge of the map-area to Whitewater, strata of the Slocan group outcrop for 12 miles across their strike. Nearly all these strata face southwest; in general those in the valley bottoms dip southwest, those of median elevation dip vertically, and those on the peaks dip northeast and are overturned. Thus they form a great recumbant syncline facing southwest with horizontal cleavage and axial plane. This Hedley has termed the 'Slocan fold'. Within it, particularly about Idaho Peak, are Z-folds of large dimension formed by crumpling within the trough. Faults of small displacement relative to the dimensions of the fold are common.

In the cross-section described, the axis of the Slocan fold is horizontal, but to the northwest it plunges gently northwest. To the southeast it plunges successively southeast, south, and southwest and the axial plane dips more and more steeply eastward until, near the contact with the Nelson batholith the dip is reversed to steeply west.

Much less is known of the structure to the northwest, beyond the boundary of Nelson map-area, but reconnaissance mapping by Cairnes (1929) shows that pyroclastic rocks overlie the Slocan group in a syncline whose axial plane strikes west and dips steeply. McConnell and Brock (1904) show that volcanic rocks of the 'Rossland group' are present farther west where they appear to rest on the Slocan group. From this general information it appears that to the northwest, the Slocan fold trends westerly and the dip of the axial plane steepens. This trend is observed in the sedimentary rocks and paragneiss of the Slocan group exposed near the north edge of the map-area west of Slocan Lake.

The structure of the roof pendants of rocks presumed to be Slocan group in the Nelson batholith south of the Slocan camp, is not known but they appear to have a general south to southeasterly trend that would seem to link them with the Ymir group to the south.

External Structural Relations—The presence of detritus of volcanic rock from the Kaslo group in the basal member of the Slocan group, as described by Cairnes (1934, p. 58), indicates that the latter rests disconformably on the Kaslo group. This fact has been confirmed by Hedley (1945, p. 7). The top of the Slocan group, so far as is known, is not exposed within Nelson map-area. Northwest of Slocan Lake, as has been pointed out above, the Slocan group is apparently overlain by 'Rossland group'. This contact however, has not been examined.

Origin—The tremendous thickness of the Slocan group presents a problem with regard to its origin. There must have been a deep, sinking basin of sedimentation throughout much of Triassic time, and the argillaceous material that predominates must have been derived from similar material or from volcanic rocks. The most probable source for this material is from the west where thick assemblages of such rocks accumulated in Cache Creek time. The paucity of conglomerate and the abundance of calcareous material suggest that the source area was rather distant or of comparatively low relief. Certainly the ancient watershed was of very great extent.

Age and Correlation—Fossils that are to some degree diagnostic have been discovered in the lower part and possibly near the top of the Slocan group. The first fossils were collected by Bancroft (1920, p. 42) and determined at that time to be Carboniferous. These were subsequently re-examined by McLearn (Cairnes, 1934, p. 60) and a Triassic age was regarded as equally probable. Later collections by Cairnes also from the lower part contained belemnites,

probably of Triassic age, and these were more recently examined by J. A. Jeletzky of the Geological Survey, who reports as follows:

Lot 218 F.C., Whitewater road.
Aulacoceratidae Bernard cf. *Atractites* sp. indet. A. Some supposed belemnoid remains were revealed, after sectioning, as indeterminable juvenile ammonoid shells.

Lot 569 F.C. (8441), from limestone bed at elevation 7,300 feet on ridge extending east from Texas Peak.
Indeterminable Belemnoidea Stolley; all evidence available suggests Aulacoceratidae Bernard, but not Belemnitacea (d'Orbigny) s. str. Part of supposed belemnoid remains were found on sectioning to be indeterminable juvenile ammonoid shells.

Lot 556 F.C. (8437), from limestone float along south slope of Texas peak within 600 feet of summit.
Aulacoceratidae Bernard cf. *Atractites* sp. indet. C. (somewhat abnormal, close to B in collections from Milford group).

Lot 197 F.C. (8427), Mount Holmes ridge about 1 mile southeast of Mount Holmes.
Aulacoceratidae Bernard? genus and species indet.

Age: Most probably Triassic. As a rule it is safe enough to regard all representatives of the family Aulacoceratidae Bernard as Triassic guide fossils as both Permian and Liassic occurrences are rare.

The ammonites in the collections were examined by E. T. Tozer of the Geological Survey but are insufficiently well preserved to be of value in this problem.

In 1948 J. A. Mitchell of the British Columbia Department of Mines gave the writer a slab of impure quartzite, containing the imprint of an ammonite, that he had collected on the mountainside north of Caribou Creek, some 6 miles northeast of Burton. McConnell and Brock (1904) show the contact between the Slocan and Rossland groups to be near this locality, so that the fossil may be from the upper part of the Slocan group. The fossil was examined by Frebold (1959) who reports:

Loc Cat No. 16183
Talus from top switchback on trail west of Independence Creek (*see* B.C. Dept. Lands, Map 4H, Arrowhead Sheet, pub. 1926).
Arnioceras sp. indet.
Age: Sinemurian (early Lower Jurassic).

From fossil evidence the age of the lower part of the Slocan group is almost certainly Triassic, although the possibility of an Upper Permian age exists. The top of the formation may be Sinemurian (early Lower Jurassic), but a study of the region north of Caribou Creek and eastward to Slocan Lake would be necessary to make certain of this.

Permian (?) Triassic (?) and Lower Jurassic (?)

Ymir Group

The Ymir group was first named by the writer (Little, 1950, p. 24) from the town of Ymir. It includes much of the beds mapped as Pend-d'Oreille group by Drysdale (1917b).

Distribution and Thickness—Rocks of the Ymir group occur in a belt extending from the ridge between Hidden and Porcupine Creeks northward to a point

due east of Nelson. To the east and north of this point roof pendants of paragneiss believed to be Ymir form a discontinuous chain that extends north of West Arm of Kootenay Lake.

Because of the complexity of structure within this belt and the difficulty of discerning bedding in the slaty rocks, as well as the uncertainty as to the position of the base of the group, it is impossible to accurately determine its thickness. McAllister (1951), who mapped the group in more detail than any previous geologist, was unable to give any estimate of thickness, pointing out only that it "outcrops along a band 1 to 3 miles wide." There can be little doubt, however, that the minimum thickness of the group is some thousands of feet.

Lithology—In view of the complexity of structure only the uppermost members can be reliably placed in proper stratigraphic position but in general the older beds appear to be towards the eastern part of the belt. There a prominently banded, argillaceous quartzite member with a minimum thickness of 400 feet occurs. According to McAllister the bands are uniformly 1 inch to 2 inches thick and are alternately light grey or grey-green and dark grey or dark green. This member has been traced from Porcupine Creek northeast for several miles through a number of roof pendants to a point northeast of Kutetl Creek, where it is more argillaceous and slightly darker than at Porcupine Creek.

West of this member, in the vicinity of Porcupine Creek, the overlying(?) strata consist mainly of argillaceous quartzite, argillite, and slate. Near the top of the group, east of Ymir and Apex, are sill-like bodies that may be either sills of Rossland andesite or thin flows that preceded the main outpouring of lava.

Farther north, the thickness of the Ymir group appears to increase, and some probably discontinuous bands of limestone appear. There the strata of the Ymir group more closely resemble those of the Slocan group. Parts of the southern part of the band resemble the Active formation.

Internal Structural Relations—Details of the structure of the Ymir group are not known, but McAllister (1951, p. 27) has stated that the beds were highly folded at the time of emplacement of the Nelson batholith.

External Structural Relations—The contact between the Ymir group and map-unit 10 is exposed along Porcupine Creek where it was studied both by the writer and by McAllister. The Ymir group appears to be conformable with the older rocks and gradational into them, but the exposures are in a zone of metamorphosed, hybrid rocks. If, however, Fyles and Hewlett's conclusion is correct—that the rocks of map-unit 10 are mainly of Lower Cambrian age—a strike fault that was missed by the writer and McAllister must separate these two groups.

The Ymir group is overlain conformably by basal flows of the Rossland formation, the writer's observations being confirmed by McAllister and Mulligan (personal communication). The contact is best exposed in Ymir Creek, at times of low water, about a quarter of a mile above its mouth.

Origin—The similarity of strata of the Ymir group to those of the Slocan group suggests similar conditions of deposition. Indeed, as will be pointed out in the following, these sediments were probably deposited at the same time and in the same geosynclinal trough.

Age and Correlation—No fossils have been found in the Ymir group. However, the similarity of the Ymir to the Slocan group, coupled with the fact that discontinuous roof pendants of paragneiss that probably represent metamorphosed rocks of the Ymir group appear to link up with those of the Slocan group, indicates that the groups are probably largely of equivalent age. Furthermore, the eastern part of the band of Ymir rocks links with Slocan rocks that Rice (1941) traced southward along the eastern border of the Nelson batholith from the Slocan area.

This correlation was first proposed by McConnell (1896, p. 31A), but was later revised (McConnell and Brock, 1904), and the rocks were assigned to the Lower Cambrian (Nisconlith); although Brock (1900, p. 84) had found a brachiopod, "probably *Chonetes*" in float near Nelson. He regarded the float as being from the Slocan group carried from the Slocan area by glaciers, but this seems improbable in view of the great height of the mountains north of Nelson.

The conception was revived by LeRoy (1912b) who wrote: "Though not definitely correlated with the Slocan series, the similarity in lithological character would favour the view that the Pend d'Oreille (Ymir) group is a more metamorphosed phase of the Slocan series." Walker (1934) later placed the "Pend-d'Oreille series" in the Precambrian and this view has prevailed until recently.

West of Kootenay Lake from the Slocan area to a point some miles south of West Arm, the upper part of the Milford group and the lower part of the Slocan group are lithologically identical, and may be distinguished only by the intercalation of the Kaslo group. Farther south the Kaslo group has not been identified, so that rocks mapped as Ymir group are probably partly equivalent to the Milford group, but mainly to the Slocan group. Further support for this correlation is presented by the probability that the tremendous thickness of the combined Milford and Slocan groups in the Slocan area would hardly be confined to such a small region as the Slocan area; the basin of sedimentation must have been extensive. Lastly, the Ymir group is overlain by the Rossland formation. McConnell and Brock (1904) show that the Slocan group also is overlain, northwest of Slocan Lake, by the Rossland formation. An ammonite collected from talus indicates there the presence of early Lower Jurassic strata, but whether the fossil is from sedimentary facies of the Rossland formation or from the upper part of the Slocan group is not known.

On lithological grounds the Ymir group has been correlated with the Slocan group and the upper part of the Milford group. If this correlation is correct, the age of the Ymir group is mainly Triassic, although the lowermost part may be as old as Permian and the uppermost part as young as early Lower Jurassic. Frebold's (1959) suggestion that the fossiliferous beds of Sinemurian age in the basin of Archibald Creek are equivalent to the upper part of the Ymir group supports the latter statement.

Lower Jurassic

Sinemurian Beds

Sedimentary rocks formerly included in the Rossland group, and more recently mapped as Hall formation (Little, 1950; 1957a) are exposed in valleys of Archibald and upper Beaver Creeks.

Distribution and Thickness—In Archibald Creek valley the rocks form an anticline whose limbs are exposed in the sides of the valley. The beds have also been identified on both sides of Beaver Creek from a point 1½ miles north of Fruitvale to the ridge 1 mile north of Parks. These rocks appear to be exposed almost continuously westward to the vicinity of Champion Lakes, and may also occur in the valley of Erie Creek. Some of the sedimentary beds mapped to the north and west may be of the same age, but without fossil evidence no correlations can be made. Such evidence has been obtained only from the north side of Caribou Creek, 2½ miles north of the map-area.

The base of the Sinemurian beds is not exposed. Mulligan (1951, p. 79) has estimated the exposed thickness as perhaps 3,500 feet, but the rocks are poorly exposed and only the general structure is known.

Lithology—The Sinemurian beds consist of impure grey sandstone in beds commonly 4 to 6 inches, rarely 4 feet thick, intercalated with argillite beds, massive sandstone with argillaceous partings, and some banded siltstone and bedded tuff. A few thin flows or sills of andesite or latite were noted. Elsewhere, banded, slaty argillite is more abundant, with thin beds of slaty quartzite. In some localities the argillite is limy. Near the top, interbedded flows and agglomerate are more abundant. Mulligan (1951, p. 80) states that "an agglomerate-conglomerate bed" on the slope northeast of Ross Spur, near the top of a 2,500-foot section of sandstones, siltstones, and argillites, contains well-rounded granite pebbles.

The rocks in the canyon of Erie Creek north of Erie Lake comprise thick beds of pebbly sandstones and interbedded tuffs. Exposed on the ridge to the west, are banded argillaceous siltstones and argillites, with interbeds of light-coloured greywackes, tuffaceous beds and thin flows. Similar rocks occur in the basin of upper Hall Creek and on the slopes of Red Mountain nearby. In the basin of Marsh Creek, argillaceous quartzite and argillite predominate, with some slate, banded argillite, and minor tuffaceous beds and flows or sills.

Internal Structural Relations—The Sinemurian beds in the basin of Archibald Creek appear to form a simple anticline whose axial plane strikes about N20°E. Within the core of this anticline the beds dip vertically, but on the limbs they dip generally steeply outward, with some reversals of dip. In some localities the beds are somewhat distorted, probably due to faulting.

In Beaver Creek valley the Sinemurian beds appear to form an anticline plunging southwest but flattening to the northeast. The structure of the beds in Erie Creek valley may be anticlinal. In the basin of Marsh Creek the structure is unknown.

External Structural Relations—The base of the Sinemurian beds is not exposed. The upper part is characterized by increasing proportions of lavas and pyroclastic rocks. The top of the section has been defined by Mulligan (1951, p. 80) on the long northeast ridge of Mount Kelly and on the ridge north of Parks, as a coquina a few inches thick within an agglomerate that is overlain by massive augite porphyry of the Rossland formation.

Origin—The abundance of tuffaceous sediments with a few flows and agglomerates indicates a volcanic-island environment during the time of deposition. The abundance of quartz beds and occasional granitic pebbles in agglomerate suggests a more distant source for these materials. Paragneisses of probably pre-Jurassic age occur to the west between Christina Lake and Grand Forks (Little, 1957b), so that this is the most likely source area.

Age and Correlation—Collections of fossils from the Sinemurian beds were made by Mulligan and by the writer and his field assistants in Salmo map-area and to the west in 1949. These were examined initially by McLearn and his conclusions were confirmed by Frebold (Little, 1950, pp. 27, 28). Further study of these collections has been made by Frebold (1959) and the results are as follows:

Loc Cat No. 16858. East side of Archibald Creek, at elevation 3,950 feet.
Imprints of small, indeterminable ammonites. Age: indeterminable.

Loc. Cat Nos. 16847 to 16850. West side Archibald Creek, between first and second tributaries, at elevations 3,700, 3,950, 4,000 and 4,100 feet respectively.

The ammonites collected at all four localities belong to the family Arnioceratidae and the form *Arnioceras* (*Melanhippites*) sp. indet. was found at the 3,700-, 3,950-, and 4,100-foot elevations. Age: The ammonite genus *Arnioceras* is characteristic of part of the Sinemurian stage of the Lower Jurassic.

Some additional fragments of Arnioceratids were collected from these localities by Frebold in 1957.

Loc Cat No. 16855. East side of Beaver Creek about 2 miles northeast of Fruitvale, at elevation 2,700 feet.

Arnioceras sp. indet. Age: Sinemurian.

Loc Cat No. 16854. West side of Beaver Creek about 2 miles north of Fruitvale, at elevation 3,000 feet.

Ammonites sp. indet. Imprint of an ammonite with undivided ribs. Affinities to some Lower Jurassic forms. Age: May be Lower Jurassic.

A coquina bed was discovered north of Parks by Mulligan in 1949. Additional collections from the locality were made in 1957 by Frebold, who reports upon the combined material as follows:

Loc Cat Nos. 17237 and 17240. South slope of the ridge 1¼ miles north of Parks, at elevation 3,500 feet.

Arnioceras sp. indet.
Trigonia littlei Frebold
Goniomya aff. *heteropleura* Agassiz
Cardinia aff. *regularis* Terquem
Lima aff. *compressa* Terquem
Gastropods, belemnite fragments, and corals. Age: Sinemurian.

From the same ridge the writer picked up a piece of talus containing a plant fragment which was examined by W. A. Bell of the Geological Survey.

> Plant Loc Cat No. 4792. Talus from a point about ¼ mile south of Loc Cat Nos. 17237 and 17240, at elevation 3,000 feet:
>
> > This is a small fragment of a cycadeoid either a *Pterophyllum* or a *Ptilophyllum*. It certainly denotes a Mesozoic age and resembles species found in the Lower Cretaceous or Upper Jurassic.

The ammonite collected from the Caribou Creek area northwest of Burton by J. A. Mitchell is reported by Frebold (*see* p. 57, this report) to be Sinemurian, and the strata in that locality are, consequently, correlated with the "Sinemurian beds".

According to Frebold (1959), "the *Arnioceras* beds in Archibald Creek, Beaver Creek, at Parks, and Caribou Creek can be correlated with beds of the same age widely distributed in other parts of British Columbia, in southern Yukon, in the Rocky Mountains and Foothills, and in the Canadian Arctic coast region". Some of these are the "Arnioceras" beds of the Fernie group (Frebold, 1957, pp. 7, 8) and parts of the Cultus formation of the Hope area, and upper Takla group of north central British Columbia, and the Harbledown formation of northern Vancouver Island (Frebold, 1953).

Rossland Formation[1]

The Rossland formation as here defined comprises volcanic and minor intercalated sedimentary rocks underlain within the map-area by the Ymir group and the Sinemurian beds, and overlain by the Hall formation. It includes most of the volcanic rocks mapped by McConnell and Brock (1904) as the "Rossland volcanic group". In the lowest sedimentary members Brock obtained fossils of upper Carboniferous age, but the remainder, because it resembles the Nicola group, was regarded as being of Triassic age. To this assemblage, McConnell and Brock applied the name "Rossland volcanic group". Within the area underlain by rocks of this group they also delineated an area about Beaver Mountain (now Mount Kelly) underlain by volcanic rocks that appeared to be much fresher. These they named the "Beaver Mountain volcanic group", to which they assigned a "post-Cretaceous" age. They suggested that the volcanic rocks on Record and Old Glory Mountains might be of the same age as this younger group.

Daly (1912, pp. 323, 324) redefined the "Rossland volcanic group" to exclude the Carboniferous strata, but included certain volcanic members interbedded with them in the group. He agreed (Daly, 1912, pp. 352-354) with Brock's observations concerning the Beaver Mountain volcanic group, but included at the base certain sedimentary beds that had yielded plant fragments. He called the assemblage the "Beaver Mountain group", and suggested that Brock's nomen-

[1] Field work in Salmo map-area by H. Frebold and the writer in 1959 has shown that some volcanic rocks there are equivalent in age to the Hall formation and are therefore younger than those farther northeast. It is probable that the Rossland will be reinstated as a group in a forthcoming publication.

clature "be extended to all the lavas and pyroclastics of the complex which are contemporaneous with those shown typically on and in the vicinity of Beaver mountain".

Drysdale (1915, p. 201) excluded the entire Mount Roberts formation from the rocks mapped as Rossland by McConnell and Brock in the vicinity of Rossland. Later, he (Drysdale, 1917b, pp. 27-29) separated a belt of sedimentary rocks that outcrop between Hall Creek and a point 2 or 3 miles southwest of Ymir from the "volcanic rocks of contemporaneous age" comprising the 'Rossland volcanic group'. These sedimentary rocks he named the "Hall series".

Walker (1934, pp. 10-13), in mapping the Salmo area, concluded that the 'Rossland and Beaver Mountain volcanic groups' formed an extrusive-intrusive complex that was inseparable on a scale of 1 mile to the inch.

Subsequent mapping by McAllister (1951), Mulligan (1952), and the writer (Little, 1950) appeared to make possible a threefold subdivision of the rocks mapped as Rossland and Beaver Mountain by McConnell and Brock. The lowest division is of volcanic rocks and was named Elise formation. This is overlain by a middle division of sedimentary rocks, the Hall "series", renamed Hall formation by Mulligan (1952, p. 6). The highest division, which is of volcanic rocks, was originally named Beaver Mountain group and redefined as Beaver Mountain formation (Little, 1950), and included in the Rossland volcanic group, as defined since 1915 to exclude the Mount Roberts formation.

Until recently, this threefold subdivision of the Rossland group appeared to be satisfactory. The sedimentary rocks of the Hall formation appeared to be traceable continuously from the type locality in Hall Creek some 12 miles south to Salmo, thence southeastward into the anticline in Archibald Creek. Walker (1934, p. 13), however, noted that the sedimentary rocks on Keystone Mountain do not closely resemble those of the 'Beaver Mountain-Rossland group', and Mulligan (1951, pp. 166-168) suggested that they may belong to the Ymir group overthrust upon the Rossland group.

The threefold subdivision was further complicated by the fact that in many places the Hall formation is missing. For example, the formation pinches out entirely a few miles north of the type locality in Hall Creek where it appears to be some 3,500 feet thick. Similarly, between Fruitvale, where Beaver Mountain formation is apparently exposed, and Rossland, which is apparently underlain by Elise formation, the Hall formation, which was thought to separate the volcanic formations, could not be identified.

Frebold (1959) has made recent studies of fossils collected from the 'Rossland group' by Mulligan and the present writer in 1948 and 1949, and of others collected by himself in 1956 and 1957. These have shown that the top of the Elise formation between Barrett and Hall Creeks is, as expected, older than the Hall formation on the ridge between Stewart and Barrett Creeks. However, Frebold has found that the upper beds of the strata mapped as Hall formation in Archibald Creek are older than the top of the Elise north of Barrett Creek.

In 1958, Frebold (personal communication) discovered near Arlington mine a shale bed intercalated with volcanic rocks mapped by Little (1950) as Beaver

71994-8—6

Mountain formation. This bed is similar to the one on the highway between Barrett and Hall Creeks that McAllister (1951) shows to be the upper part of the Elise formation. According to Frebold, the ammonites at both localities are identical and are of Toarcian (late Lower Jurassic) age. Thus, he has shown that the Beaver Mountain and Elise formations are mainly or entirely equivalent. This in turn greatly strengthens his suggestion that the Sinemurian beds may be equivalent to the upper part of the Ymir group.

From Frebold's work it is evident that the threefold subdivision of the Rossland group is no longer tenable unless it can be shown that the true Hall formation is overlain by lavas. In Hall Creek, Mulligan (1951, 1952) showed the lavas bounding the Hall formation on the west as Beaver Mountain formation which he had traced northward from the Salmo map-area. As Beaver Mountain lavas have been shown to be equivalent to the Elise, or nearly so, it follows that no lavas younger than the Hall formation have been identified.

It is, therefore, proposed that the term Rossland formation be applied to the volcanic rocks formerly mapped as Elise and Beaver Mountain formations.

Distribution and Thickness—The Rossland formation underlies much of the area from the north side of Kootenay River between Bonnington Falls and a point a little east of Nelson, southward to the mouth of Sheep Creek and Champion Lakes, thence southwestward to the southwest corner of the map-area. It has been identified also on Old Glory Mountain. Elsewhere, it is probably represented by roof pendants of highly altered greenstone north of Old Glory Mountain to Columbia River, at points several miles southwesterly from Castlegar, between Mount Peters and Slocan, and at two points in the northwest corner of the map-area.

The entire formation is best exposed south of Nelson where the base occurs on the east slope of Mount Elise and the top of the formation may be seen a short distance west of Salmo River. The maximum outcrop width there is about 3¼ miles; near Ymir it is about 2 miles. Allowing for average dip where determinable, the writer (Little, 1950, p. 26) estimated the maximum thickness to be about 9,000 feet. Mulligan (1951, p. 36), from exposures on Selous Creek south of Nelson, estimated 8,500 feet as the maximum thickness. Sections showing both the top and base of the formation are not exposed elsewhere in the map-area, but the thickness everywhere appears to be some thousands of feet.

Lithology—The Rossland formation on Mount Elise consists mainly of lava flows of andesitic to basaltic composition. Many of these flows which are referred to by all writers as "agglomerates", are in reality flow breccias, although some agglomerates are present, and in these the matrix is pyroclastic material. The flow breccias contain numerous rounded xenoliths, mostly 1 inch to 3 inches in diameter but a few up to 2 feet across, of volcanic rock in a matrix of similar composition. Locally, however, particularly near Rossland, rocks of foreign origin, mainly limestone, form some of the fragments. In places the normal flows and flow breccias are amygdaloidal and vesicular. The amygdules are generally of calcite and less commonly of quartz. McAllister (1951, p. 29) reports that pillows occur rarely,

and only in the fine-grained facies. The flows are predominantly dark green or grey-green, but some are black, brown, or light green. A few contain small phenocrysts of feldspar.

The next most abundant rock is augite porphyry, which appears to be mainly intrusive though some augite porphyry flow breccias occur. This rock is mainly fine grained and contains numerous small phenocrysts of augite up to 2 millimeters long that are partly uralitized. It is usually dark green, and on some weathered surfaces that are leached to a light green shade, the phenocrysts are conspicuous.

Minor lenticular bodies of bedded tuff and of argillite up to 10 or 15 feet thick, in one case 150 feet thick, occur in the formation. The argillite contains some semi-rounded grains indicating abrasion before deposition.

Thin sections of the lavas show that they consist of saussuritized plagioclase (oligoclase-andesine to, rarely, labradorite), partly uralitized augite, and some chloritized green hornblende. The alteration products, calcite, albite, green biotite, epidote, clinozoisite, zoisite, and chlorite, are typical of the 'green schist' metamorphic facies. The rocks are schistose in most localities. The augite porphyry is similar in composition, differing only in the greater abundance of augite which forms conspicuous phenocrysts.

Farther west, where the formation was formerly mapped as Beaver Mountain, it has been described by Mulligan (1952, pp. 9-10) as follows:

> The formation consists chiefly of dark green augite and augite-feldspar porphyry flows, breccias, agglomerates, and contemporaneous intrusives. Highly porous amygdaloidal flows are conspicuous in certain localities, and abundant coarse pyroclastic rocks are an outstanding feature of the formation. Some breccias are entirely autoclastic, with subrounded resorbed fragments of material practically identical with the matrix. Other breccias and agglomerates have rounded to angular fragments up to 2 feet in diameter, mostly composed of volcanic porphyries but including banded siltstone and quartzite, some limestone boulders, and occasional granite pebbles.
>
> In thin section the rocks are seen to be highly altered for the most part. Original augite has been mostly replaced by uralitic hornblende, and plagioclase feldspar by sodic plagioclase and epidote-group minerals. Further breakdown of uralitic hornblende is generally to actinolite; in some cases augite and/or uralitic hornblende have altered to biotite and epidote, rarely to chlorite and calcite. In a few flows, relict plagioclase is identifiable as labradorite, in others as andesine; most appears to be oligoclase. These rocks are andesites and basalts.
>
> Some exceptionally feldspathic flows have well-formed albite-oligoclase phenocrysts that appear to be primary. The association of augite with possibly primary sodic feldspar suggests affinity to the 'spilitic kindred'. Similar feldspar, with epidote, fills amygdules and is pseudomorphic after augite crystals in other flows. This records a segregation of either late-formed or secondary feldspathic components, and of epidote, subsequent to solidification of the flows, and suggests a deuteric or 'autometamorphic' process of alteration of these rocks.
>
> In the vicinity of Mount Kelly . . . the flows have remarkably fresh augite, although saussuritization of the feldspar is in most cases well advanced. Because of their appearance, these rocks were considered by early workers to be younger than the surrounding volcanic rocks. The freshness of the augite here, in contrast with its uralitized condition elsewhere, is attributed to the fact that these rocks lie in the flat trough of a syncline, and were subjected to lower shearing stresses than those on the limbs of the folds. Under such conditions augite may persist as a relict mineral in rocks even of the greenschist metamorphic facies.

71994-8--6½

Near Rossland the formation differs mainly from that at Mount Elise in that the basal member is invariably a flow breccia that in many places contains fragments of foreign rocks, mainly limestone. The remainder of the formation consists of andesite flows, flow breccia, and lesser interbedded agglomerate and tuff. Many of the flows contain microphenocrysts of augite. In contemporaneous intrusive bodies within the formation the augite phenocrysts are of megascopic size and in some bodies are as large as a quarter of an inch long. For further details regarding these rocks and their composition the reader is referred to Drysdale (1915, pp. 200-208).

Internal Structural Relations—In view of the present interpretation of the stratigraphic succession, some of the earlier conceptions of the structure must be modified. In the area south of Kootenay River the structure is now believed to be a syncline extending from Toad Mountain southward to Stewart Creek, south of which it divides into two synclines to the south, separated by an anticline. The core of the main syncline and its two southerly branches is occupied by sedimentary rocks of the Hall formation. To the west of the syncline the structure is not known and requires further study in the field.

On Mount Kelly, the rocks form a syncline whose limbs dip gently and whose axis plunges gently southwest. Immediately east of the syncline is a more tightly folded anticline, well exposed in the basin of Archibald Creek. The eastern limb of the anticline dips steeply and the axis plunges in a more southerly direction than that of the syncline. In the area surrounding these folds the attitudes of the bedding planes are random but the structure appears to be undulating.

Gentle undulations are characteristic of the Rossland rocks exposed north of lower Erie Creek and upper Beaver Creek.

In the region around Rossland the structure is too complex for interpretation on the present mapping scale, but the general trend is northerly with moderate dips to the west and gentle dips to the east. Many attitudes are erratic, however, and even in places such as the Rossland mining camp detailed mapping failed to delineate the major fold pattern (Drysdale, 1915; Gilbert, 1948), although the faults and fracture patterns were worked out.

In areas possibly underlain by Rossland volcanic rocks the structure has not been interpreted.

External Structural Relations—Between Nelson and Ymir the Rossland formation rests apparently with conformity upon the Ymir group. Elsewhere the character of the contact between these rock units is not known either because it is not exposed or because Ymir rocks have not been identified. In the region about Archibald Creek and upper Beaver Creek the Rossland formation rests, probably conformably, on the Sinemurian beds.

Near Rossland and Paterson, however, the contact with the underlying Mount Roberts formation, which is probably Pennsylvanian and therefore much older than the Sinemurian beds and, probably, the Ymir group, is unconformable. There

the basal flow breccias of the Rossland formation rest upon different members of the Mount Roberts formation and contain fragments of these members, particularly of limestone.

The Rossland formation is overlain by the Hall formation. The contact is not well exposed, but is described by Mulligan (1952, p. 6) as essentially conformable, but with locally, a suggestion of erosional unconformity.

Origin—The heterogeneous assemblage of lava flows, flow breccias, agglomerates, tuff, and minor intercalated marine shale beds indicates intensive volcanic activity in a marine environment. Frebold (1959) has pointed out that the presence of corals and coquina beds immediately below the Rossland formation northeast of Parks and on the long ridge northeast of Mount Kelly indicates near-shore environment at those localities. He further states that the shale beds in the Rossland formation that yielded harpoceratid ammonites are believed to have been deposited in a sea far from shore. These facts lead him to conclude that deposition occurred in a volcanic-island (eugeosynclinal) environment.

Age and Correlation—Frebold (1959) in 1956 and 1957 collected fossils from beds of shale intercalated with lavas and exposed on the highway between Barrett and Hall Creeks. These bands are placed near the top of the Elise formation by McAllister (1951) and the writer (Little, 1949). The following ammonites were identified by Frebold:

Harpoceras aff. *exaratum* Young and Bird
H. sensu lato sp. indet.

The ammonites probably indicate a Toarcian (late Lower Jurassic) age for the beds concerned.

As stated previously, identical ammonites were found by Frebold in 1958 near Arlington mine.

The age of the Rossland formation is therefore Toarcian (late lower Jurassic), but the basal part may be as old as Sinemurian (early Lower Jurassic) because fossils of this age were collected from the beds immediately below the formation northeast of Parks.

Middle and (?) Upper Jurassic

Hall Formation

The Hall 'series' was named and described by Drysdale (1917b, pp. 27-29) from Hall Creek, south of Nelson. It was renamed Hall group by the writer (Little, 1950, p. 26) and subsequently was referred to as the Hall formation (Mulligan, 1952; Little, 1957a).

Distribution and Thickness—Only a relatively small part of the map-area is at present known to be underlain by rocks of the Hall formation. Such rocks form a belt extending from a point 1½ miles north of lower Hall Creek southward to the basin of Stewart Creek. From there the belt divides, the more easterly branch terminating near a monzonite body 2 miles southwest of Ymir. The more westerly was thought to extend continuously southward to the basin of Archibald Creek (Little, 1950). However, Mulligan (1951, pp. 166-168) expressed doubt that

the rocks mapped as Hall formation south of Boulder Mill Creek were correctly designated. He remarked that the beds near Arlington mine and Keystone Mountain are black, well-indurated hornfelsic argillites almost devoid of banding or of coarse arenaceous material. Furthermore, north of the northwesterly-trending ridge of Keystone Mountain, exposures are lacking and the nature of the bedrock was inferred only from fine float in the soil cover. He suggested that the rocks there may comprise an overthrust plate of Ymir group and Rossland volcanic rocks. As the fossil collection made by Frebold in 1958 near Arlington mine shows that the rocks there are older than Hall formation, Mulligan's alternative suggestion, that north of Keystone Mountain the Hall formation terminates against a thrust fault, is plausible.

Sedimentary rocks that appear to overlie lavas on the ridge 2 miles southwest of Blizzard Mountain may be of the Hall formation.

Because the top of the Hall formation has not been recognized, its thickness is not known. If the structure in Hall Creek is a syncline, then the maximum thickness exposed there is less than 2,000 feet. Farther south the Hall formation is exposed across a belt some 12,000 feet wide, but folding has repeated many of the beds and, although a greater thickness may be present than in Hall Creek, no accurate figure for the thickness can be given.

Lithology—The lithology of the Hall formation has been described by Mulligan (1952, pp. 6-8) in the following terms:

> The Hall formation ... varies from place to place in thickness and lithology, and north of upper Noman Creek and Red Mountain apparently pinches out entirely. Lateral gradation is pronounced and rapid, especially in an east-west direction...
>
> Lithologically the formation consists of conglomerate, greywacke-sandstone, quartzite, banded siltstones and cherty quartzitic siltstones, and argillites, with minor intercalated flows, tuffs and agglomerates, and contemporaneous intrusions. Quartz-biotite and other types of schist, quartzite, and occasional conglomerate (north of Kootenay River) are also assigned to the Hall formation. The isolated limestone outcrops east of Taghum are tentatively included.
>
> In the vicinity of lower Hall Creek, the type area, and southward, conglomerates and conglomeratic greywackes make up a large part of the formation. Both intraformational and basal conglomerates occur. The former are characterized by light buff to reddish weathering colours, and by large and small lenticular squeezed mudstone fragments oriented parallel with the bedding. The basal conglomerates are in thin lenticular patches of restricted distribution made up chiefly of subrounded pebbles of volcanic rocks similar to those in the Elise formation.
>
> The greywackes contain from 10 to 50 per cent quartz in small rounded grains, feldspar and ferromagnesian minerals, and angular fragments of fine-grained volcanic and sedimentary material. The matrix contains some interstitial carbonate. A reddish iron stain emanates from decomposed ferromagnesian minerals. The proportion of quartz is statistically greater, that of rock fragments less, south of Hall Creek than north. This is analogous to an overall decrease in proportion of coarse clastics, and suggests a tendency to southward change from littoral to offshore conditions of sedimentation, though abundant intercalated argillite in the Hall Creek section indicates an oscillatory shoreline...
>
> Both primary and secondary small-scale structures are poorly developed in the Hall rocks although grain gradation, crossbedding, and slaty cleavage have been used in top determination. Cleavage at an angle to the bedding is erratic in development and in attitude, and no well-defined, consistent attitudes of lineation or foliation are recognizable. The grade of metamorphism is low, and the rocks appear to be insufficiently indurated for the development of such structures.

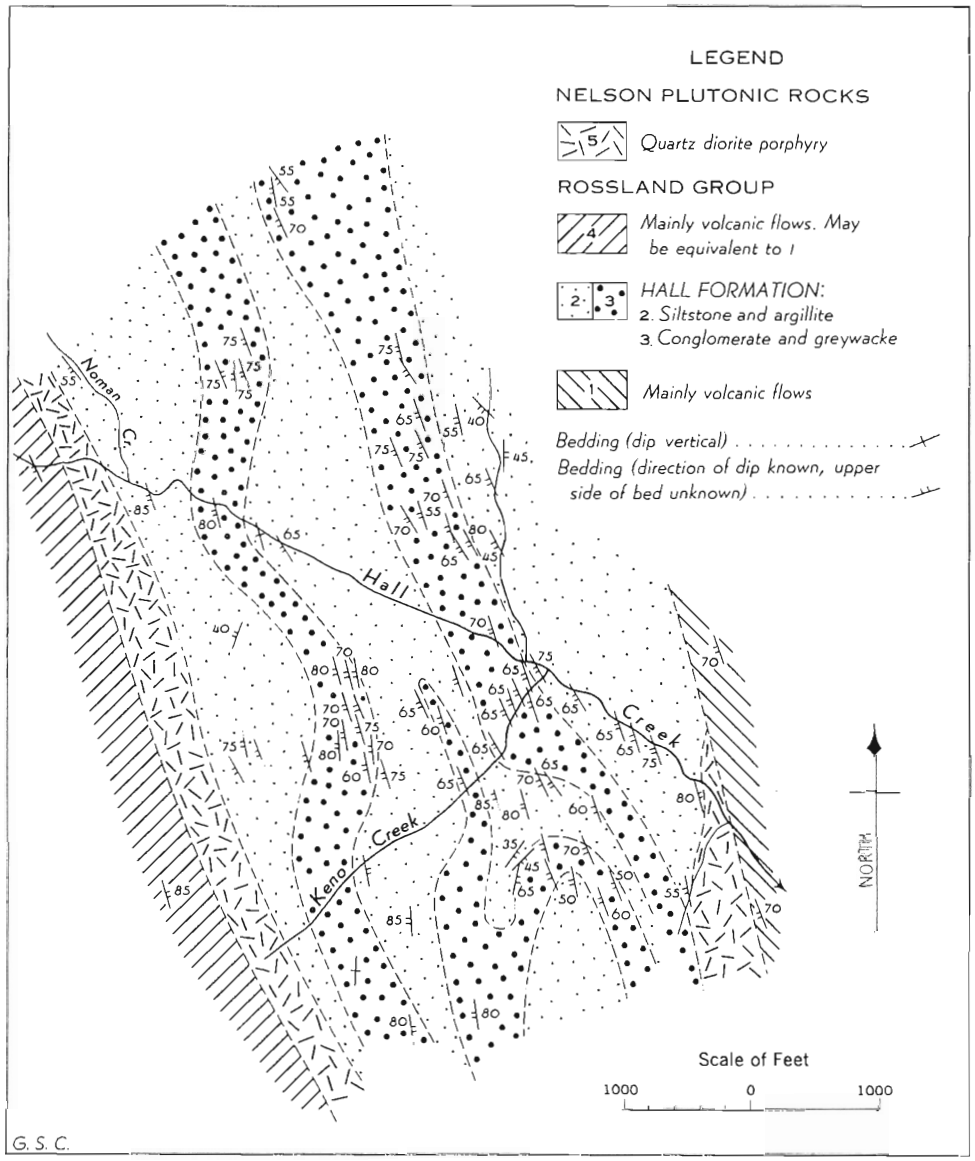


Figure 3. *Map of Hall formation in type locality (after R. Mulligan, 1951).*

Internal Structural Relations—Until recently it was believed that the Hall formation from Toad Mountain southward formed an homocline with the younger beds to the west. If, however, rocks formerly mapped as Elise and Beaver Mountain are equivalent, or nearly so, the structure of the Hall formation must be a syncline which, north of Hall Creek, plunges south. This interpretation is not incompatible with Mulligan's detailed mapping in lower Hall Creek valley (*see*

Figure 3), if it is assumed that a subsidiary fold developed on the west limb of the syncline. It would also solve the problem of the disappearance of Hall rocks only 2 miles north of Hall Creek.

This syncline appears to continue southward to Stewart Creek, but may contain other subsidiary folds. South of Stewart Creek two synclines appear to be present, separated by an anticline in which the core is occupied by Rossland volcanic rocks. The eastern branch ends near a monzonite body, but the western may plunge beneath overthrust Rossland rocks.

The sedimentary rocks exposed on the ridge southwest of Blizzard Mountain, if they are Hall, must form a syncline whose axis strikes northeast, unless these rocks are faulted into their present position.

External Structural Relations—The Hall formation rests with apparent conformity upon the Rossland formation, though Mulligan (1952, p. 6) states that "there is locally a suggestion of erosional unconformity between the formations."

Origin—Mulligan (1952, p. 7) has pointed out that the decrease in conglomerate roundstones and the increase in the quartz content of the sediments in a southward direction from the type area suggest a change from littoral to offshore conditions. The lack of volcanic flows or ejectamenta in the Hall formation indicates an abrupt cessation of volcanic activity in the region. Drysdale (1917b, pp. 20, 28, 29) assumed that the Hall formation was of continental origin and of Triassic age. Fossils have shown, however, that the beds are marine and that the age is Jurassic.

Age and Correlation—Beds near the top of the underlying Elise formation have yielded fossils of Toarcian (late Lower Jurassic) age. The only fossil collection obtained in beds definitely known to be Hall formation is that from a ridge about 2.7 miles southwest of Porto Rico station. It was made in 1948 by W. O. Pollock, one of the writer's field assistants. The collection was originally examined by F. H. McLearn of the Geological Survey and his preliminary conclusions were confirmed by Frebold (Little, 1950, p. 26). Recently, the collection was restudied by Frebold (1959) and his revised conclusions are as follows:

> Loc Cat No. 16181. From ridge between Barrett and Stewart Creeks, elevation 6,500 feet:
>
> *Sonninia* ? sp. indet.
> small Harpoceratids
> indeterminable pelecypod remains.
> The age of these beds is probably middle Bajocian (early Middle Jurassic).

Fossils collected by Frebold near the top of the underlying Elise formation are of Toarcian age. The basal strata only of the Hall formation could, however, also be of Toarcian age. The fossils of Bajocian age are believed to be from an horizon well above the base of the formation, but Frebold (1959) points out that the great thickness of Hall formation sediments above the fossil locality "indicates probable continuation of marine conditions in post Bajocian times". The uplift of the region to supply sediments to the Kootenay sea (Schofield, 1915, p. 97)

must have occurred in Portlandian (latest Jurassic) time (Frebold, 1957, p. 2), thus establishing a probable upper age limit for the Hall formation.

The age of the Hall formation then is Middle and possibly in part Upper Jurassic.

Early Mesozoic (?)

Paragneisses occurring in the core of the Nelson batholith were formerly regarded by the writer as probably equivalent in age to the Hall formation. In view of the revision of the Rossland group by Frebold it is now equally possible that they may be a metamorphosed facies of the Ymir group, which has been correlated with the Slocan group.

Distribution and Thickness—The paragneisses form a dome centred about the upper part of Gwillim Creek, the core of which is occupied by Nelson and Valhalla granites.[1] On the northwest side of the dome in lower Evans Creek, the northern limb of the dome grades eastward into granite. The western limb however, continues northward along the east shore of Slocan Lake, under which it disappears near the mouth of Enterprise Creek. Above the western limb is a thick zone of mylonite.

South of the dome the paragneisses form a simple anticline that follows the valley of Little Slocan River and the lower valley of Slocan River where it plunges gently southeastward under Nelson granite.

The paragneisses exposed in Norns Creek valley northwest of Sentinel Mountain are presumed to be part of the same assemblage, and it is possible that other such rocks to the south and west may be of similar age and origin.

The maximum thickness of the paragneiss, where it is exposed in the valley of Little Slocan River is about 5,000 feet.

Lithology—The paragneiss that outcrops in the valley of Norns Creek and between lower Slocan River and Slocan Lake is conspicuously layered. The layers are an inch to more than a foot thick and are alternately leucocratic and melanocratic (*see* Plate III). The dark layers contain abundant hornblende and biotite, and rounded porphyroblasts or *augen* of potash feldspar, mainly microcline, 1 inch to 2 inches long and commonly confined to them. Garnets are widespread in the gneiss and in some places graphite is present. Lenticular bands of pegmatite parallel with the gneiss bands are common. The gneiss nearly everywhere dips gently and contains drag-folds (*see* Plate V) and some of the melanocratic bands show fracture cleavage (*see* Plate IV). These features usually indicate that no overturning has occurred. Small fractures of no more than a few inches displacement are visible in some places.

As the gneiss is traced laterally northward, the conspicuous banding disappears; in the basin of upper Evans Creek it can scarcely be detected in outcrops but may be seen from nearby mountain peaks. The rock is essentially granite and its sedimentary origin is evident only from the presence of some garnets and a

[1] In 1958, J. E. Reesor (personal communication) found in upper Gwillim Creek, metaquartzites that underlie these granites.

few intercalated bands of crystalline limestone or skarn. These are more abundant in the north part, indicating a lateral gradation of the formation into a more calcareous facies in this direction. The total thickness of the gneiss decreases in a northerly direction and eventually is represented by a series of oriented xenoliths of gigantic dimensions separated by granite (*see* Figure 4). Between and beyond these xenoliths the granite contains zones of red garnets.

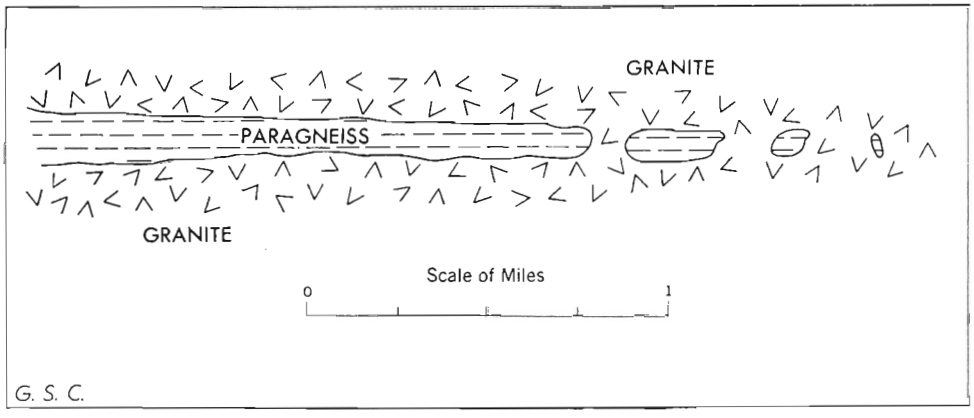


Figure 4. *Diagrammatic sketch of termination of gneissic band.*

Internal Structural Relations—The gneiss in Norns Creek valley appears to form an anticline whose axis strikes roughly west and whose limbs dip gently.

In the valleys of lower Slocan River and Little Slocan Lakes the gneisses form an anticline trending northwest to north with gently dipping limbs. Farther north the anticline becomes a dome that is breached on its northeast side.

External Structural Relations—The paragneiss in the vicinity of upper Gwillim Creek is underlain on the east side of the dome by porphyritic Nelson granite and on the west side by Valhalla granite. In those same localities it is overlain by Nelson and Valhalla rocks respectively, but to the south it is overlain everywhere by Nelson porphyritic granite.

Origin—The sedimentary rocks from which the paragneisses were derived were, in the southern part, argillaceous and arenaceous in character. To the north, however, intercalations of limestone occur, suggesting that the sediments there were deposited farther from the shore than those in the south.

These sedimentary rocks appear to have been altered to paragneiss and granite by metasomatic processes.

Age and Correlation—The paragneiss in lower Slocan Valley plunges under Nelson granite and appears to emerge a few miles southeastward, beyond Kootenay River, where the rocks are less highly metamorphosed; there, they were previously mapped as Hall formation (Mulligan, 1952). It now appears equally possible that these rocks could be the upper part of the Ymir group. The age of the rocks from which the paragneisses were formed is possibly Triassic or Jurassic, and is tentatively referred to the Lower Mesozoic.

Plate III *Layered gneiss near Gwillim Creek.*

Plate IV *Fracture cleavage in gneiss near Slocan.*

Plate V *Drag-fold in gneiss near Hela Peak.*

Upper Cretaceous (?) or Later

Sophie Mountain Formation

The conglomerate, with minor interbedded argillite, of the Sophie Mountain formation was first mapped by McConnell (1897b) on Lake Mountain southeast of Rossland and also by McConnell and Brock (1904) on Mount Sophia, formerly known as Sophie Mountain. It was correlated by them with beds farther west, later named Kettle River formation, and correlated also with the Coldwater beds near Kamloops which were regarded as of Oligocene age.

Daly (1912, pp. 350-351), on the basis of poorly preserved plant fragments, believed that these rocks were younger than the Kettle River beds. He correlated the conglomerate on Mount Sophia with that on Lake Mountain and with two smaller areas of conglomerate 5 and 10 miles west of Mount Sophia.

The name "Sophie Mountain conglomerate" was first applied to the formation by Bruce (1917, pp. 214-216) and he assigned an Eocene-Oligocene age to it. The present writer refers to it as the Sophie Mountain formation.

Distribution and Thickness—The largest area underlain by Sophie Mountain formation is at the type locality where more than a square mile of these beds outcrop. About a quarter of a square mile of it occurs also on Lake Mountain. Daly also mapped as Sophie Mountain a small patch of conglomerate near Boundary Monument No. 172, about 5 miles west of Mount Sophia. This locality was examined by one of the writer's assistants who described it as a chert conglomerate in which the chert pebbles are highly deformed. It is a roof pendant surrounded by Coryell syenite and is probably part of the Mount Roberts formation.

The thickness of the formation is uncertain owing to the marked folding and faulting and subsequent erosion it has undergone. It is probable that at least several hundred feet of beds remain, both at Mount Sophia and at Lake Mountain.

Lithology—On Mount Sophia the Sophie Mountain formation consists almost entirely of coarse conglomerate; intercalations of impure sandstone and arenaceous argillite are not abundant. The roundstones in the conglomerate vary in size from place to place, being up to 6 inches in diameter in some places and up to only 1 inch or 2 inches in others. Most are well rounded and consist of black chert, grey quartzite, and argillite, with some of greenstone and fine-grained granite. The matrix is mainly of sandy or argillaceous material. Interbeds of argillite up to several feet thick occur near Boundary Monument No. 174, and elsewhere lenses of impure sandstone up to 2 feet thick are present.

On Lake Mountain the roundstones in the conglomerate are generally larger than on Mount Sophia, especially in the more easterly exposures where some are 2 or 3 feet in diameter. Elsewhere the maximum size of roundstones is about 9 inches. The matrix is highly ferruginous and weathering has imparted a brownish purple colour to most of the formation. The largest and most abundant roundstones are of brownish purple, highly altered granitic rock, but many are of white to grey, fine- to medium-grained granite different from local phases of the Nelson

plutonic rocks. Other roundstones consist of grey or purplish quartzite, white, coarse grit, chert, vein quartz, and argillite, and are less well rounded than on Mount Sophia. A few interbedded lenses of sandstone were seen.

Internal Structural Relations—On Mount Sophia near Boundary Monument No. 174, dips are 10° to 20°N-NE. On the east side of the ridge the dip is 35°W. At the Douglas mine, near the most westerly exposures, the beds strike N20°E and dip 70°SW. Daly (1912, p. 350) states that on Lake Mountain the average dip of the beds is 20°NE. In the most northwesterly exposure, however, the strike is N20°E and the dip is 60°NW.

External Structural Relations—The basal contact of the formation has not been observed, but there can be no doubt that it is an unconformity. The top of the formation has been removed by erosion.

Origin—The heterogeneous assemblage of roundstones, of which few if any have a local source, together with the generally high degree of rounding indicates a rather distant source. Daly (1912, p. 350) suggests that they may have been derived from the Palæozoic and Precambrian terrains that lie to the east and believed them to represent river gravels.

Age and Correlation—Fossils were collected by Daly (1912, p. 351) near Boundary Monument No. 174 on Mount Sophia. These were examined by Penhallow who assigned a tentative age of Tertiary, possibly Miocene, based upon the determination of *Ulmus speciosa* Newberry. Further collections were made in 1949 by the writer's party from Daly's locality and another nearby. W. A. Bell of the Geological Survey reports on these collections as follows:

> Plant Loc Cat No. 3890. From the top of Mount Sophia, 300 feet N20°E of Boundary Monument No. 174, and an additional 660 feet north of this point, elevation 5,000 feet.
>
> In addition to imprints of rootlets and stems this collection has a number of fragments of dicotyledonous leaves and several of a sphenopterid fern. All the material is unidentifiable, although some of the leaves are apparently platanoid. Although a Tertiary age is not ruled out an Upper Cretaceous age seems more probable.

From the stratigraphic point of view this determination is more satisfactory than Penhallow's, for the Sophie Mountain formation is invaded by dykes of Coryell syenite and Sheppard granite that were almost certainly emplaced before the extrusion of undeformed basalt farther west. The latter is generally regarded as being of Miocene age.

The age of the Sophie Mountain formation is, therefore, probably Upper Cretaceous, possibly early Tertiary.

Cenozoic

Tertiary (?)

Conglomerate of possible Tertiary age was observed on the west side of Stagleap Creek half a mile from the mouth, at an elevation of 3,140 feet. About 10 feet of the conglomerate is exposed. The roundstones, which are up to 6

inches in diameter, consist of quartzite, black argillite, and fine-grained granite, and are moderately well rounded, but not well sorted. The matrix consists of a hard, limy cement. The conglomerate rests unconformably upon dolomite of the Nelway formation. It has a northerly strike and a dip of 20°E and probably represents an erosion remnant of more extensive deposits formed in the valley.

Pleistocene and Recent

During Pleistocene time all of Nelson (west half) map-area with the exception of the higher peaks and ridges, was covered by the Cordilleran ice-sheet.

The accompanying map of mineral deposits shows many glacial striae recorded on published maps as well as those observed in the field by the writer and his assistants. On the map these are more plentiful in the southern half of the area than in the northern half, partly because more geological work has been done there, and partly because glacial striae are rarely preserved in the granitic rocks of the northern part.

The highest glacial striae observed by the writer that could not be attributed to alpine glaciers were found at an elevation of 7,100 feet, near the head of Beatrice Creek. Cairnes (1934) observed striae at a similar elevation on the south side of Selkirk Peak, but Brock (1902) recorded striae in a saddle west of Woden Peak, elevation 7,300 feet, and on the divide between Snow and Nemo Creeks, elevation 7,800 feet. The positions of these striae appear to be open to question for no erratics were seen above 7,300 feet by the writer or his assistants.

Further evidence of the upper limit of glaciation is seen in the Valhalla Range, where, above 7,500 feet or so, most of the ridges are serrate and sinuous and are composed of blocks of jointed granite perched precariously upon one another. These could hardly have survived the movement of an ice-sheet. In contrast, below this level, the ridges are rounded and bevelled, with truncated spurs and U-shaped valleys.

The general movement of the ice-sheet is slightly east of south, towards the lower ground of Columbia Plateau, but variations to S25°W and S60°E are recorded. Some marked variations beyond these limits occur, one on Mount Waldie where a trend of S55°W has been recorded by Mathews (1953) and two that strike due west on Ladybird Mountain and Selkirk Peak respectively, recorded by others. In the vicinity of Rossland also some striae indicate movement toward the east, and this probably represents the final, valley glaciation stage in the recession of the ice-sheet.

Much of the upland surface to an elevation of 7,000 feet or more is covered by a thin mantle of glacial till; above this point only talus and felsenmeer cover the bedrock. The effects of both alpine and ice-sheet glaciation are manifest; horns, cirques and moraines being testimony of the former, and truncated spurs, U-shaped and hanging valleys, *roches moutonnées,* kame terraces, and, in the broader valleys, small drumlins and eskers giving evidence of the latter. Terraces are common at elevations to 2,000 feet or so, and some have been noted well above 4,000 feet.

Damming by the ice of some of the larger valleys during the final stages of glaciation has resulted in the deposition of thick deposits of bedded silt, sand, and gravel, and in a few places, varved clays. Crossbeds are evident in the deposits of coarser material. Such deposits are present in the valleys of Columbia River and Lower Arrow Lake, Salmo River and some of its larger tributaries, Slocan River, Big Sheep and Santa Rosa Creeks, and in some others. These deposits are covered by outwash alluvial fans which are common at the mouths of nearly all creeks draining into the major valleys, and in particular into the larger lakes. In the latter case, there is generally evidence of older, higher deltas some hundreds of feet above the present ones.

In Nelson map-area there is no good evidence of more than one stage of continental glaciation. At one place only, on South Salmo River, till was observed to overlie varved clay, but this may have resulted from slumping of the upper layers subsequent to deposition.

White volcanic ash is widely distributed in valley bottoms where it forms a layer one-eighth of an inch to perhaps 2 inches thick at or near the surface of the soil. It is best exposed in fresh cuts of roads and stream banks. A petrographic examination of this material was not made by the writer, but it is presumably similar to that described in Washington State (Rigg and Gould, 1957), which consists mainly of glass shards of acidic composition, and some generally euhedral crystals of andesine, hypersthene, hornblende, magnetite, and augite. Rigg and Gould have shown that this ash was erupted from Glacier Peak, west of Lake Chelan. Carbon-14 age determinations of peat immediately below the ash layer from two localities in Washington gave averages of 6,950±200 and 6,500±200 years, respectively.

Plutonic Rocks[1]

Ultrabasic Intrusions

The ultrabasic bodies that occur in the southwest part of the map-area represent the most easterly extent of a belt of such rocks that extends westward intermittently to Fraser River, though it is not known if all the bodies within this belt are of the same age.

The largest body of ultrabasic rock within the area is an elongated stock about 4 miles long and more than a mile wide extending southwest from the south slope of O.K. Mountain to Record Ridge. Southwest of this stock are three smaller bodies of serpentinite, in one of which the Velvet copper-gold deposit occurs. Another small body occurs on the west edge of the map-area a short distance north of the International Boundary. The second largest stock of ultrabasic rock occurs on the east side of Little Sheep Creek, a short distance southwest of Rossland, and is well exposed in rock cuts along the highway to Paterson. One other small

[1] The term 'plutonic rocks' is used in this report to include with igneous rocks formed at great depth, rocks of metasomatic origin that are similar in composition and texture to igneous rocks.

body occurs at an elevation of about 3,500 feet, 2½ miles southeast of Fruitvale. Dykes of dunite were reported on Record Ridge by Daly (1912, p. 334), but none of these was seen by the writer or his assistants.

The ultrabasic rocks have been almost completely serpentinized and along their contacts have been altered to quartz-talc-carbonate rocks. Small remnants of olivine, seen in some thin sections, led Daly to conclude that the rocks were originally dunites. In one or two cases, however, one can discern what appear to be pseudomorphic outlines of pyroxene crystals, so that some of the rocks at least were probably peridotites.

The rock now consists of a felt-like aggregate of antigorite crystals with a little talc, carbonate, and magnetite. A few euhedral crystals of chromite are also present. No aggregations of chromite have been reported within the map-area, but from the Mastodon claims a few miles to the west, small shipments of chromite were made from a similar serpentine body (Minister of Mines, B.C., Ann. Repts., 1918, p. 204; 1920, p. 24; 1931, pp. 121-122) and low values in platinum were obtained by assay.

Rossland 'Monzonite'

The Rossland 'monzonite' was first mapped by McConnell (1897b) and subsequently described by G. A. Young (Daly, 1912, pp. 337-344; Drysdale, 1915, pp. 219-227), Bruce (1917, pp. 222-223), Gilbert (1948), and others. The rock is possibly of metamorphic origin, evidence for which will be presented later, but it is described here under the heading 'plutonic rocks'.

The monzonite body is irregular in shape, about 2 miles wide and 5 miles long, and extends eastward from Rossland. In view of the scale of mapping only a cursory examination of the body was made by the writer and in the following description much has been obtained from the earlier more detailed reports.

The monzonite seen by the writer is fine to medium grained, mostly 1 to 2 mm. but in some parts the grain size is as coarse as 4 mm. Drysdale (1915, pp. 220-221) states that on Monte Cristo Mountain and along the southwest border of the mass, there are some coarse phases. The rock is dark green to greenish grey and is inequigranular. It consists of andesine, orthoclase, small stout prisms of augite, hornblende, and biotite, which in the coarser phases is poikilitic. Magnetite and apatite, and locally titanite are present as accessories.

Daly (1912, p. 344; *see* also Table I, column F) presents a chemical analysis of the rock, and by comparison with analyses of four specimens of latite from the Rossland formation, shows it to be similar in composition to the surrounding rocks. He followed McConnell in suggesting that it represents a volcanic vent from which the nearby latite flows were extruded. Young (Drysdale, 1915, p. 225) and Gilbert (1948) believed it to be an early phase of intrusion of the Nelson granodiorite (quartz diorite), but Bruce (1917, p. 223) regarded it as younger than the latter.

Table I

Chemical Analyses of Plutonic and Volcanic Rocks

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
SiO_2	54.54	59.06	58.67	52.17	50.89	54.49	65.50	56.46	62.08	67.70	62.59	60.51	52.38	50.66	77.09
Al_2O_3	18.10	16.24	15.67	16.59	17.00	16.51	17.23	15.34	16.61	16.30	17.23	16.71	15.29	16.91	13.04
Fe_2O_3	1.14	0.43	2.85	8.32	0.97	2.79	1.50	1.68	1.53	0.58	1.51	1.72	2.99	1.71	0.82
FeO	4.63	4.88	3.28	not det.	7.60	5.20	1.40	1.83	3.72	1.74	2.02	3.34	5.53	6.17	0.26
CaO	5.85	5.59	5.33	8.25	9.82	7.06	3.04	3.43	5.20	3.74	1.99	3.62	7.30	8.26	0.63
MgO	4.56	3.51	3.86	3.87	5.41	3.55	1.00	1.11	2.44	0.96	1.30	2.53	5.84	5.50	0.12
Na_2O	3.38	2.84	4.77	3.91	3.35	3.50	5.35	4.86	3.18	4.26	5.50	4.64	3.68	2.89	3.11
K_2O	5.44	3.95	3.08	4.00	1.31	4.36	3.40	4.58	3.29	2.19	6.74	5.20	3.84	4.45	4.50
H_2O+	0.50	0.19	0.54	1.17	1.14	1.18	0.74	} 0.29	1.00	} 1.13	} 0.30	0.27	0.63	1.06	0.07
H_2O-	0.10	0.21	0.02	0.13	0.06	0.07	0.06		0.16			0.03	0.21	0.14	0.03
TiO_2	0.96	1.08	1.00	0.80	0.80	0.70	0.20	0.27	0.73	0.43	0.54	0.60	1.10	1.32	0.05
P_2O_5	0.46	0.21	0.16	0.24	0.19	0.20	—	0.08	0.30	not det.	0.11	0.16	0.75	0.91	0.10
MnO	0.10	0.20	0.11	0.11	0.14	0.10	0.12	not det.	0.11	"	tr.	0.10	0.10	0.16	tr.
CO_2	not det.	—	not det.	0.56	0.28	0.10	not det.	"	not det.	0.65	tr.	not det.	not det.	not det.	not det.
S	"	—	"	1.37	0.43	0.23	0.04	"	"	not det.	tr.	"	"	"	"
SrO	0.15	0.12	0.09	0.05	not det.	not det.	not det.	"	0.03	"	not det.	0.12	0.15	0.08	nil
BaO	0.21	0.11	0.11	0.15	not det.	"	"	"	0.09	"	"	0.10	0.25	0.23	nil
Totals	100.12	99.32	99.54	101.69	99.39	100.04	99.58	99.93	100.47	99.68	99.83	99.65	100.04	100.45	99.82

Key to Table I

A. Augite latite (Rossland group). At elevation 6,000 feet on east side of Grey Mountain. (Daly, 1912, p. 325.)

B. Augite-biotite latite (Rossland group). On crest of Record Ridge about 2½ miles south of Record Mountain. (Daly, 1912, p. 327.)

C. Augite-olivine latite (Rossland group). On crest of Record Ridge about 2½ miles south of Record Mountain. (Daly, 1912, p. 328.)

D. Hornblende-augite latite (Rossland group). At elevation 3,100 feet on slope due east of Columbia Gardens. (Daly, 1912, p. 329.)

E. Augite porphyrite (Rossland group). From 4th level of War Eagle mine, Rossland. (Drysdale, 1915, p. 205.)

F. Monzonite ("Rossland"). From 700-foot level of Le Roi mine, Rossland. (Daly, 1912, p. 343.)

G. Porphyritic granite (Nelson). From the head of the north fork of Montezuma Creek, Slocan area. (Cairnes, 1934, p. 63.)

H. Porphyritic (?) granite (Nelson). From near Molly Gibson mine, near Kokanee Peak. (Cairnes, 1934, p. 63.)

I. Quartz diorite (Nelson). From railway cutting 2 miles west of Trail. (Daly, 1912, p. 347.)

J. Biotite granodiorite (Nelson). From a small stock in the upper valley of Robb Creek, Slocan area. (Cairnes, 1934, p. 70.)

K. Syenite (Coryell). From a point north of Record Mountain. (Daly, 1912, p. 359.)

L. Porphyritic syenite (Coryell). From the crest of the ridge south of Santa Rosa Creek, near Boundary Monument 172. (Daly, 1912, p. 364.)

M. Monzonite (Contact phase of Coryell). From railway cutting about 2 miles southwest of Coryell. (Daly, 1912, p. 361.)

N. Monzonite (Coryell). From the stock ½ mile east of Salmo River, between Lost and Sheep Creeks. (Daly, 1912, p. 305.)

O. Granite (Sheppard). From the crest of the ridge north of Sheppard Creek. (Daly, 1912, p. 355.)

71994-8—7

The present writer agrees with all except Bruce that it is older than the Nelson quartz diorite, but suggests that it may be of metamorphic origin for the following reasons:

1. Unlike other monzonitic phases of the Nelson plutonic rocks, it is earlier than the quartz diorite.

2. In view of its great dimensions it is remarkably fine grained.

3. As Young and Bruce have remarked, there are few apophyses from the body into the surrounding volcanic rocks, and these Bruce describes as "dyke-like", that is presumably not like normal dykes.

4. All contacts observed by the writer, of the monzonite with volcanic rocks, are gradational and cannot be determined accurately.

On the other hand Young noted xenoliths of fine-grained monzonite in the coarser phases.

It is possible that the volcanic rocks have been recrystallized and, locally, even mobilized in the coarser phases by aqueous solutions. Such solutions could have originated in quartz diorite that may underlie the monzonite body at no great depth, in view of the presence of the Trail batholith to the east and north of the body, and of cupolas of granodiorite and quartz diorite at its western end. More detailed study of the monzonite body would be required to verify this hypothesis.

Bonnington Complex

The Bonnington complex is exposed a few miles west and southwest of Nelson. It is described by Mulligan (1952, pp. 10-13) as follows:

> Rocks of this complex, comprising pseudodiorite, pyroxene-hornblende-biotite rock, and syenite, underlie an extensive terrain about Eagle Creek and the western part of Kootenay River Valley.
>
> The pseudodiorite is a streaky, dark-coloured, medium-grained hornblende-feldspar gneiss. Along the Kootenay River it grades imperceptibly into light-coloured pink hornblende-syenite in some places, in others it is cut by syenitic dykes. The contact with surrounding volcanic augite-porphyries is marked in places by coarsely recrystallized, heavy, pyroxene-hornblende-biotite rock with large, interlocking, composite ferromagnesian crystals and blurry interstitial patches of fine feldspathic material. This rock grades into both the pseudodiorite and the volcanic rocks. In Eagle basin the pseudodiorite body appears to be contained within a syncline in (Rossland) volcanic rocks. Bands of limestone lie within the body at Eureka mine. The pseudodiorite appears to be concordant with bedded rocks, and nowhere shows crosscutting relationships. It is definitely cut by Nelson granodiorite.
>
> Thin sections of pseudodiorite show the essential mineral constituents to be saussuritized plagioclase feldspar largely reduced to granular albite and zoisite-epidote minerals, and pale uralitic hornblende with occasional identifiable augite cores. This mineral assemblage is practically identical with that of the volcanic augite porphyries. There is some suggestion that the 'dioritic' texture has arisen from a segregation of ferromagnesian and feldspathic components. Further 'segregation' results in a pronounced coarsening of grain towards contacts (e.g., the 'coarse diorite' in the Kenville mine), and reaches its culmination in the coarse pyroxene-hornblende rock where this contact facies is developed. The latter is basically identical with the pseudodiorite in mineral constitution but shows definite evidence of extensive recrystallization and grain growth of ferromagnesian mineral, particularly augite.

Several sections of pseudodiorite and one of pyroxenite show fresh new andesine-labradorite cutting through and including albite-epidote saussuritization assemblages in poikiloblastic fashion. One section consists exclusively of fresh calcic andesine, brownish green hornblende, and brown biotite, with abundant coarse sphene, and looks igneous.

Pseudodiorites in the vicinity of the Kenville mine show extensive replacement of plagioclase, preferentially relict oligoclase, by fresh soda- potassic feldspar. Sericitization seems to be a preliminary stage, and alteration of original ferromagnesians to biotite and epidote is a concomitant process.

Similar replacement of plagioclase by soda-potassic feldspar, with decreasing proportion of ferromagnesian minerals, marks the transition from pseudodiorite into syenite. Here the change is accompanied by replacement of pyroxene and uralitic (?) hornblende by a deep blue-green alkali and/or iron-rich amphibole with distinctive optical properties: low 2V about X, with strong dispersion r greater than v, low gamma minus beta. This amphibole replacement extends beyond the transition zone, in places well into typical pseudodiorite and even into pyroxene-rock. Sphene is a prominent accessory in the syenite, but except for the igneous-looking phase noted above is not seen in pseudodiorite. The latter may, however, have ilmenite or titaniferous magnetite. Apatite, abundant in the syenite, is also widely distributed throughout the metadiorite.

The exact relationship between these rocks is a matter of conjecture. The pseudodiorite is a hybrid rock, derived by either assimilation or metasomatic reconstitution of (chiefly) altered volcanic rocks. Evident lack of severe disturbance attendant on reconstitution (e.g., unreplaced limestone bands) and absence of a definitely intrusive basic rock, favour the latter mode of origin. The field and petrographic data at hand suggest a metasomatic sequence from syenite through pseudodiorite and pyroxene-hornblende rock to unreconstituted volcanic rocks, with pyroxene-hornblende rock representing an ultimate 'basic front'. However, the presence in places of uralite-like borders and patches in the large recrystallized individuals of the pyroxene-hornblende rock, and doubt as to the age of the syenite raise the possibility of a considerable time break in the above hypothetical sequence.

The pseudodiorite, in its existing state, is younger than the (Rossland) formation, and older than the Nelson batholithic rocks. It is the host rock for important gold-quartz fissure veins. The syenite is also younger than the typical pseudodiorite; it differs in appearance and composition from the Nelson rocks. The possibility is not wholly excluded that it is related to younger alkaline batholiths of the district.

Nelson Plutonic Rocks

The greater part of the map-area is underlain by Nelson plutonic rocks, originally named "Nelson granite" by McConnell and Brock (1904), that comprise the Nelson batholith and its satellites. In that part of the batholith that lies within the map-area, porphyritic granite is the predominant phase, but to the west of the present map-area granodiorite is more common. Other phases that have been identified are, in approximate order of abundance, quartz diorite, quartz monzonite, diorite, monzonite, and syenite. All these phases are present in the satellites, but in different degrees of abundance. The satellites will be dealt with later in this section.

The Nelson batholith was first examined by Dawson (1890); its north, east, and south boundaries were shown by McConnell and Brock (1904), and are indicated in Figure 5. On the west it merges into the Okanagan batholith, which consists of rocks of similar type and probably of the same age.

The major part of the Nelson batholith within the map-area consists largely of porphyritic granite, but a large area east of Slocan River south of Lemon Creek is underlain by pinkish, rather leucocratic, non-porphyritic granite. Much

71994-8—7½

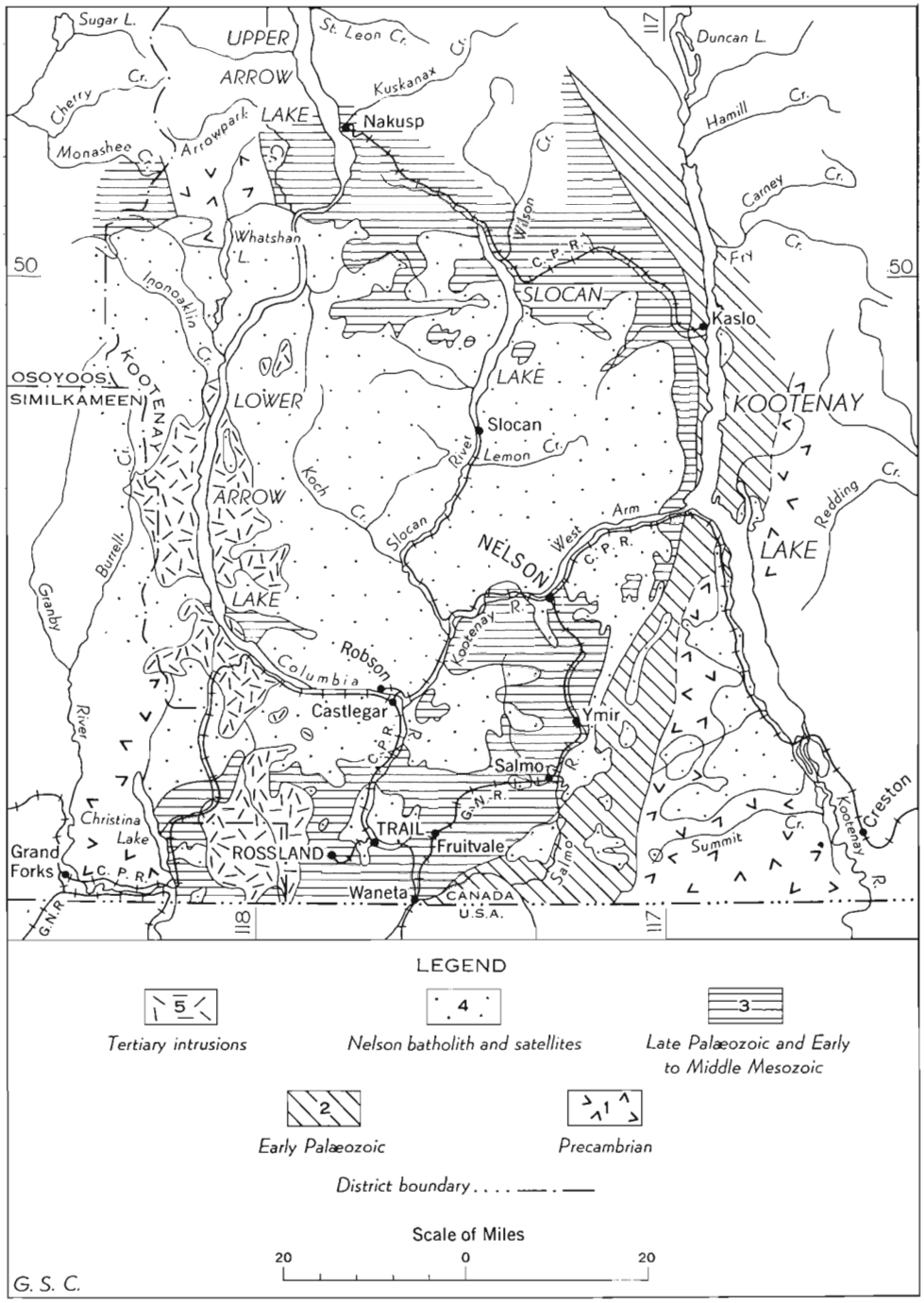


Figure 5. **Setting of the Nelson batholith and some satellites.**

of the batholith west and south of Castlegar consists of non-porphyritic granodiorite. Similarly along the lower part of Kootenay River most of the valley is flanked by more basic phases, largely quartz diorite and diorite. Elsewhere within the batholith non-porphyritic zones ranging in composition from granite to diorite occur within the porphyritic granite. No sharp contacts were observed between these phases. As the contacts are approached, the phenocrysts of the porphyritic granite decrease in both number and size. A similar phenomenon is commonly seen near contacts between porphyritic granite and older sedimentary and volcanic rocks.

Nelson porphyritic granite is a coarse, grey rock that generally contains numerous white to flesh-coloured phenocrysts of twinned alkali feldspar. In a few localities the phenocrysts may make up 50 per cent of the rock, but usually much less. On the other hand some zones were observed in which only a few phenocrysts could be seen in a single outcrop. In size, the phenocrysts range from scarcely larger than the groundmass crystals to 5½ inches in length, the average length being perhaps 2 inches or a little less. In general, the size of the phenocrysts bears a rough ratio to their abundance.

The groundmass of the porphyritic granite is mostly coarse, hypidiomorphic, and it consists essentially of potash feldspar, plagioclase, sometimes zoned, and quartz, with accessory hornblende and biotite. These accessories comprise 5 to 10 per cent of the rock but locally may be somewhat more abundant. Hornblende commonly predominates over biotite, and in some specimens no biotite is visible in the hand specimen.

The phenocrysts are mainly sodic orthoclase, though, as Cairnes (1934, p. 63) points out, they are locally replaced by microcline, particularly where the rock has been deformed. Under the microscope the groundmass is seen to consist of orthoclase and microcline, plagioclase (generally oligoclase, but in places andesine), and quartz, with hornblende, biotite, and minor apatite, titanite, magnetite, zircon, and rutile. Pyrite occurs locally, especially in and near small, irregular bodies of pegmatite that are commonly encased in porphyritic granite. The composition of the groundmass is quartz monzonite to granodiorite, but the overall composition of the rock, including the phenocrysts, is granite. Analyses of this rock are given in Table I, columns G and H.

The presence of zones of non-porphyritic phases within the large areas of porphyritic granite, together with the decrease in size and number of the phenocrysts near the contacts of the batholith indicates that the phenocrysts were largely formed after emplacement of the batholith either by crystallization from a cooling magma or by later metasomatism by deep-seated alkaline solutions. Microclinization, at least, appears to support the latter.

The granodiorite, the other important phase in the batholith, is a greenish grey, coarse- to medium-grained quartzose rock in which the feldspar is largely plagioclase, and biotite is much less abundant than hornblende. The texture is hypidiomorphic. The plagioclase is mainly andesine, and is commonly zoned. Less abundant are orthoclase, quartz, hornblende, and biotite. Accessories are

apatite, magnetite, and titanite. Secondary minerals are epidote and chlorite, and even in the freshest specimens the plagioclase has been partly saussuritized.

The pinkish, rather leucocratic, medium-grained granite that occupies a large area east of Slocan River and a few small areas to the south, differs greatly from typical Nelson rocks. It contains less quartz, in places grading into syenite, little or no hornblende, and a greater abundance of orthoclase and microcline. Accessory minerals are biotite, muscovite, apatite, titanite, and magnetite. In some specimens the orthoclase has been kaolinized. It is possible that the rock was formed by metasomatism of Nelson granite or granodiorite by underlying Tertiary plutonic rocks. Along the shores of Lower Arrow Lake, west of the map-area, Nelson rocks have been similarly affected near the contacts of Coryell bodies, and there have assumed a pinkish colour due apparently to the introduction of orthoclase. The Nelson rocks also appear to have been somewhat desilicated near the contacts. In Trozzo Creek, several miles from its mouth, abundant float resembling Coryell syenite was observed, and more closely spaced traverses might reveal the source of this rock.

An unusual phase of the Nelson granite occurs in a large, isolated outcrop between the highway and Kootenay River, 4 miles south of the mouth of Slocan River. It is a medium-grained grey rock consisting of quartz, orthoclase, plagioclase (albite-oligoclase), and microcline, with a little hornblende and biotite, and accessory magnetite, titanite, and apatite. The hand specimen is almost identical to many of those collected from the Kuskanax batholith along Upper Arrow Lake by A. G. Jones of the Geological Survey. It differs, however, by having rather more quartz and orthoclase, and less microcline than the Kuskanax.

Some of the more basic phases of the Nelson, which occur mainly along the lower Kootenay River valley, may be more highly metasomatized equivalents of the pseudodiorite near Eagle Creek, described previously.

The rocks comprising the satellites of the Nelson batholith are more varied in composition than those of the batholith. Except in the southwest part of the map-area, the rocks forming the large apophyses of the batholith and the larger satellites near the periphery of the batholith are mainly of porphyritic granite, as also are a few more distant or small ones. Stocks of non-porphyritic, coarse- to medium-grained granite are most common in the southeast part of the map-area. The larger ones occur in Salmo River valley from Salmo to Hidden Creek, west of the mouth of South Salmo River, and in Lost Creek valley. Others are near Erie Lake, in Sheep Creek valley, at the head of Hidden Creek, and elsewhere. These granites contain abundant white to flesh-coloured orthoclase and quartz, with oligoclase, and microcline, and accessory biotite, hornblende, muscovite, apatite, titanite, magnetite, and pyrite. Walker (1934, p. 14) has identified ilmenite and pyrrhotite also in these rocks. He remarks that the border phases are more melanocratic, finer grained, and are cut by tongues of the leucocratic granite of the core.

Like adjacent parts of the Nelson batholith, the Trail batholith (Daly, 1912, pp. 346-349) comprises coarse- to medium-grained quartz diorite. The rock is greenish grey and consists of zoned plagioclase (andesine), orthoclase, microcline,

and quartz, with dark green hornblende and brown biotite. Accessory minerals are magnetite, titanite, apatite, and some zircon. The orthoclase is commonly somewhat sericitized, and a little epidote, zoisite, and chlorite have formed. An analysis, compiled by Daly, is reprinted in Table I, column I.

Other stocks of quartz diorite, quartz monzonite, and granodiorite occur in the southern part of the map-area. Two large, irregular, sill-like bodies of pale green, medium-grained albite porphyry that outcrop on the west slope of Mount Elise north of Ymir are believed to be Nelson plutonic rocks (McAllister, 1951, p. 31). Other porphyritic bodies occur near the Silver King mine. These have been defined as granite porphyry and appear similar to those on the west slope of Mount Elise, but Mulligan (1952, p. 13) states that they are porphyritic quartz diorite and are older than the Nelson batholithic facies, although probably an early phase of the Nelson.

Smaller, irregular plugs of feldspar porphyry, ranging in composition from granite to diorite, are known locally as 'bird's eye' porphyry. They are numerous in the northeast (Slocan) part of the map-area and have been described by Cairnes (1934, pp. 69, 70).

It has been remarked previously that pegmatitic facies of the Nelson are confined mainly to small, irregular masses encased in porphyritic granite. A peculiar body of pegmatite has however been mapped and described by Mulligan (1952, p. 18). It is about half a mile wide and 1½ miles long and is exposed on the ridge about 2 miles west of Ymir. It consists of very large crystals and irregular masses of pink potassic feldspar and coarse quartz. Mulligan pointed out that it differs from both the observed facies of Nelson plutonic rocks and from the younger plutonic rocks, but may be a facies of Sheppard. In view of the fact that no known bodies of Sheppard granite have been discovered nearby, it is tentatively correlated with the Nelson.

Hosts of dykes of acid to basic composition related to the Nelson plutonic rocks occur throughout the map-area. They intrude both Nelson and older rocks but are more common in the latter. These were not studied by the writer but many have been described by previous writers in their more detailed examinations. Lamprophyre dykes also are numerous, particularly in the mining camps where they appear to be structurally or genetically related to some ore deposits, at least in the Slocan area (Cairnes, 1948, p. 203).

Age

Earlier writers provisionally assigned the age of the Nelson plutonic rocks to the Jurassic because of their similarity to the Coast plutonic rocks which had traditionally been regarded as of Jurassic age. By 1934, it was realized that the main body of the Coast plutonic rocks is Lower Cretaceous, and Cairnes (1934, p. 74) suggested that, as the Nelson plutonic rocks are largely granite, they may represent a more acidic differentiation of that magma and their age might be Upper Cretaceous. Rice (1941, p. 37) also favoured this suggestion and stated that the age is probably Cretaceous, possibly Upper Cretaceous.

There is little direct evidence to establish the age exactly. The youngest fossils collected from sedimentary rocks of the Hall formation are of early Middle Jurassic age and above this horizon are at least several hundred feet of sedimentary and possibly volcanic rocks, all of which are cut by Nelson rocks. With some confidence then, it can be stated that the lower limit of the age of the Nelson plutonic rocks is post Middle Jurassic.

The Sophie Mountain formation rests unconformably upon the Rossland formation, and probably also upon serpentinites that both intrude the Rossland and are cut by the Nelson. Pebbles of granitic composition that may be derived from Nelson granite were observed in the Sophie Mountain conglomerate. Plant fossils from the Sophie Mountain formation are probably Upper Cretaceous, possibly Tertiary. Thus, the upper limit of the age of the Nelson rocks can be set, with rather less confidence, as pre-Upper Cretaceous.

Indirect evidence of the age of the batholith is provided from the fact that since Tyrrell (1887, p. 135E) first suggested it, this region is regarded by most geologists as the geanticline from which the Kootenay and later formations to the east were largely derived. The basal Kootenay beds have yielded fossils of Portlandian (late Upper Jurassic) age (Newmarch, 1953, pp. 46-48; Frebold, 1954, p. 1), and the orogeny that was accompanied or closely followed by the emplacement of the Nelson batholith must have occurred at that time. Further evidence is provided by the fact that feldspar is lacking in the Kootenay strata but is abundant in the Blairmore above the basal conglomerate, as first pointed out by Allan and Rutherford (1924, p. 26) although they incorrectly identified the beds as Kootenay (Sanderson, 1939, p. 434). Beveridge and Folinsbee (1956, p. 41) have also shown that igneous pebbles from the McDougall-Segur conglomerate of the Blairmore formation contain a heavy mineral suite identical with that of the Nelson plutonic rocks. This indicates that erosional unroofing of batholithic rocks, almost certainly the Nelson, took place shortly after deposition of the basal Blairmore conglomerate. The age of the lower flora of the Blairmore is given as Aptian, but possibly Barremian (Bell, 1956, pp. 11-12). The batholith was, therefore, apparently unroofed in the middle or late Lower Cretaceous. If this line of reasoning is valid, the limiting times of emplacement of the Nelson batholith are latest Upper Jurassic to perhaps middle Lower Cretaceous.

Radioactive age-determination of the Idaho batholith to the southeast of the map-area is given as 105 million years (Larsen *et al.,* 1954). That of the Nelson batholith, based on zircon from a specimen of a gneissic phase near Whatshan Lake, about 10 miles west of Burton, is identical with that of the Idaho batholith, and is latest Lower Cretaceous or Albian (Beveridge and Folinsbee, 1956, p. 41). In view of the fact that the batholith appears to have been denuded before this stage, and as, according to Beveridge and Folinsbee, the Blairmore which is pre-Albian, contains heavy minerals common to the Nelson rocks, the figure of 105 million years seems to be too small.

An age of 86 million years was obtained by the potassium-argon method by R. K. Wanless of the Geological Survey (personal communication, October 2,

1958). The determination was made on biotite obtained from a specimen of Nelson granodiorite collected by the writer from the quarry just west of Nelson. This figure, which of course also appears to be too small, may be incorrect because of recrystallization of the biotite by metamorphism long after emplacement of the batholith.

Valhalla Plutonic Rocks

The Valhalla plutonic rocks are in part contemporaneous with, and in part younger than the Nelson. They were first recognized by Brock (McConnell and Brock, 1904) who observed the latter relationship. Because of this and because of their fresher appearance, he regarded them as "post Cretaceous". McConnell and Brock named these rocks "Valhalla granite" after the Valhalla Range where they are widely distributed. Cairnes (1934, pp. 65-68), although he recognized that the Valhalla rocks cut the Nelson, realized their intimate relationship and regarded them as a late differentiation of a common magma. He consequently dropped the name "Valhalla". Farther west, near Okanagan Lake, Cairnes (1939, pp. 265-272) found that bodies of granite similar to the Valhalla, which he calls "Shuswap granite", are encased in paragneisses of the "Shuswap terrane" with which they form indistinct borders. He regarded this granite as the end product of palingenesis. The present writer has retained the name "Valhalla" for these rocks, which can be separated from the Nelson. The Nelson and Valhalla together could be regarded as "Coast intrusions", as defined by Rice (1947, p. 35).

The Valhalla plutonic rocks are generally white, foliated rocks of plutonic habit composed of granite or closely related rocks. Within the Nelson batholith the rock is characterized by closely spaced joints, giving rise in rugged terrain to fluted cliffs that can with some confidence be distinguished at a distance from the massive, shear cliffs of Nelson porphyritic granite.

The Valhalla granite consists of orthoclase, quartz, oligoclase, and microcline in rough order of abundance, with a little biotite and muscovite and minor accessory titanite, apatite, zircon, allanite, and magnetite. Hornblende is rare, but red garnets (grossularite) are quite common, and range from 1 mm. to nearly 1 cm. in diameter. The rock is in most places fresh; chlorite (after biotite) is the most common alteration mineral. Nearly everywhere the Valhalla granite is non-porphyritic. The most extensive area underlain by the porphyritic phase is about 5 miles southeast of Airy Mountain; it is more than half a mile wide. This, however, is the dip-slope of a relatively thin porphyritic zone that dips gently southwest, and would be much less conspicuous on northeast slope. The phenocrysts, which are plentiful, are of microcline and range from one half to three quarters of an inch in length. These are much smaller than those commonly found in the Nelson porphyritic rocks. Elsewhere, porphyritic phases of the Valhalla are confined to small zones and these, so far as observed, occur near zones of pegmatite.

As no chemical analyses of Valhalla granite have been published, two samples were secured for analysis (*see* Table II). These samples are composite, obtained by

splitting a number of hand specimens of Valhalla granite taken by the writer and his assistants. Sample No. 1 is from various localities in western Valhalla Range and in Valkyr Range. Sample No. 2 is from more widely distributed localities between Slocan Lake and Granby River, which is about 20 miles west of the map-area.

Table II

Chemical Analyses of Valhalla Granite

Chemical	Sample No. 1	Sample No. 2
SiO_2	70.78	72.13
Al_2O_3	15.64	14.71
Fe_2O_3	0.56	0.58
FeO	1.02	1.16
CaO	2.06	1.61
MgO	0.52	0.46
Na_2O	4.31	3.93
K_2O	3.82	4.45
H_2O+	0.44	0.37
H_2O-	0.08	0.17
TiO_2	0.27	0.26
P_2O_5	0.14	0.12
MnO	0.05	0.05
CO_2	0.04	0.01
Totals	99.73	100.01
Analysts	M. McGahey	G. Bender

Comparison of these analyses with those of the Nelson granite (*see* Table I, columns G and H) shows that the Valhalla contains more free quartz, more potash in relation to soda, and less calcium and magnesium, as would be expected from the observed mineral compositions.

An interesting and puzzling feature of the Valhalla granite is the presence of abundant quartz that is almost invariably smoky, in contrast to the Nelson which only contains distinctly smoky quartz west of Slocan River between Hoder and Norns Creeks. A specimen of Valhalla smoky quartz was heated to 1,000°C and was completely bleached to a milky colour. The milky colour is due to fractures produced by sudden heating; clear quartz would be produced only if the smoky quartz were heated very slowly. Milky quartz is common in the Valhalla granite along Lower Arrow Lake near dykes and larger bodies of the later Coryell plutonic rocks. Daniels and Saunders (1953, p. 11-6) have found that the bleaching of smoky quartz under prolonged heating takes place at 290°C. The effect of hydrostatic pressure is not known, but Primak, Fuchs, and Day (1953) have shown that irradiation of quartz results in an increase in space-lattice constant and a decrease in density, and, conversely, annealing causes decrease in volume. It is therefore apparent that under the confining pressure at great depth, greater intensity of radiation is required to cause quartz to become smoky than at shallow depth.

The bleaching of Valhalla smoky quartz by Coryell plutonic rocks shows that the quartz became smoky before intrusion of the Coryell, that these were emplaced at temperatures probably much above 290°C, and that the intruded rock was heated rapidly.

The fact that the smoky colour of the Valhalla quartz is due to radioactive emanations and not due to the presence of minute inclusions of graphite (Boyle, 1953), suggests that the Valhalla granite should have a higher intensity of radiation than the Nelson. Accordingly, a number of specimens of each rock suite was submitted to H. R. Steacy of the Geological Survey for radiometric tests. The average for all readings of all specimens was only slightly above 0.003 per cent U_3O_8 equivalent, which is the activity of the average granite. The average activity of the Valhalla specimens was only 5 per cent greater than that of the Nelson and, as this figure is much less than the accuracy of the determinations, the two suites must be regarded as essentially equivalent. If the smoky colour of the quartz was produced by relatively more intense radioactive emanations the source of these is no longer present in the Valhalla granite. It is possible that radioactive materials, once present, were removed by rising hydrothermal solutions in the late stages of crystallization or metasomatism of the rock. Another possibility is that over a long period of time, say 50 million years, the normal radioactivity of the granite is sufficient to produce smoky quartz, provided the rock is not too deeply buried. In support of this conjecture is the fact that within the core of the batholith the Nelson rocks lie below the Valhalla, and the former contain smoky quartz only near the Valhalla contact. Elsewhere, on the other hand, the Nelson rocks appear to have reached as great elevations as the Valhalla. It is also possible that all the quartz of both Nelson and Valhalla rocks was once smoky and that rising isotherms caused most of the former to become clear. Finally, it is possible that radioactive emanations may not be the only cause of the smoky colour in quartz.

In most places, Valhalla granite may be readily distinguished from the Nelson by the following characteristics:

(1) The texture is allotriomorphic rather than hypidiomorphic.
(2) Quartz is more abundant and is mostly smoky.
(3) Phenocrysts are rare.
(4) Hornblende is rarely present, the ferromagnesian mineral being generally biotite.
(5) The Valhalla granite is generally lighter coloured than the Nelson.

In many localities, however, Valhalla granite does not display all these characteristics, and there it is separated from Nelson by only some of them. Where the two rock types were mapped separately, it was found that they were for the most part, distributed so as to form a pattern that will be discussed in the chapter on structure (Chapter IV).

Pegmatite is much more abundant in the Valhalla plutonic rocks than in the Nelson. These bodies are commonly dyke-like, but many are larger, irregular in shape, and up to a hundred feet or more across. They consist of white potash

feldspar and quartz, in part showing graphic intergrowth, with some albite-oligoclase and muscovite in books up to 2 or 3 inches in diameter. In some places, a little biotite and small red garnets are present, and in a few dykes small crystals of beryl occur. As Cairnes (1934, p. 67) observed, the pegmatites in the main do not appear to have been emplaced by mechanical injection, but form vague boundaries against the enclosing Valhalla granite or paragneiss. Xenoliths of the latter within the pegmatite do not appear to have been rotated as would be the case had mechanical intrusion occurred. The quartz in the pegmatite is almost invariably smoky.

Less abundant than the pegmatite are dykes of aplite that in places grade into pegmatite. Lamprophyre dykes that may be related to the Valhalla granite are uncommon.

Age

The Valhalla granite cuts the Nelson plutonic rocks, but over large areas the contacts are gradational. The Valhalla is therefore so slightly younger in age than the Nelson that the two may be assumed to be contemporaneous, with an age that is latest Upper Jurassic to perhaps middle Lower Cretaceous.

Coryell Plutonic Rocks

These rocks were first observed by Dawson (1890) who described them as "younger red granites". Their distribution was later shown by McConnell and Brock (1904) who called them the "Rossland alkali granite and syenite". The name "Coryell syenite" was given to them by Daly (1912, pp. 358-362) after the station of that name several miles west of Nelson map-area on the Kettle Valley branch of the Canadian Pacific Railway. The name "Coryell" has been retained for these rocks by the writer because the name "Rossland", although it has priority, was also applied by McConnell and Brock to an assemblage of volcanic and sedimentary rocks for which it has been used by subsequent writers.

The Coryell plutonic rocks consist dominantly of syenite, but with some granite, shonkinite, and apparently related monzonite. It is a typically alkaline suite of rocks.

The syenite is a coarse- to medium-grained, inequigranular, reddish to pale buff rock. The reddish phase tends to grade into granite in some places, particularly along Big Sheep Creek valley and in Valkyr Range. The pale buff phase, on the other hand, tends to grade into shonkinite.

The red syenite consists of orthoclase, microperthite, and andesine, all of which are commonly much altered. Less abundant are quartz, chloritized hornblende, and biotite. Magnetite and titanite are unusually abundant accessories. There is also a little apatite.

The pale buff syenite is more widely distributed, and is generally more coarse grained. It consists largely of orthoclase, with lesser microperthite, microcline, oligoclase, biotite, augite, and hornblende. Quartz is rare, and in small quantities.

Some phases have been identified by earlier workers as pulaskite, although they do not mention the presence of nepheline in the rocks, and none has been identified by the present writer. Accessories are apatite, magnetite, titanite, and zircon.

Composite specimens of the most typical Coryell rocks were obtained by splitting hand specimens taken during the course of the mapping. These were submitted for chemical analysis to the Mineralogy Division. (*See* Table III.) Sample No. 1 is from many localities in Nelson map-area and the adjoining map-area to the west. For the most part it comprises red to pink syenite with hornblende and biotite, and a little visible quartz. Sample No. 2 is from various localities in the map-area west of Nelson map-area, mainly in the valley of Granby River, and consists mainly of pale buff augite-biotite-hornblende syenite, rarely with visible quartz.

Table III

Chemical Analyses of Coryell Rocks

Chemical	Sample No. 1	Sample No. 2
SiO_2	64.58	59.25
Al_2O_3	16.31	16.67
Fe_2O_3	1.38	2.08
FeO	1.90	3.02
CaO	2.05	3.53
MgO	1.26	2.82
Na_2O	4.77	4.29
K_2O	5.69	5.28
H_2O^+	0.61	0.76
H_2O^-	0.17	0.41
TiO_2	0.44	0.67
P_2O_5	0.22	0.45
MnO	0.07	0.08
CO_2	0.51	0.28
BaO	not det.	Trace
Totals	99.96	99.59
Analysts	G. Bender	M. McGahey

The analysis of the red syenite agrees closely with that recorded by Daly (*see* Table I, column K) for typical Coryell syenite, whereas the analysis of the buff syenite is close to that of Daly's porphyritic syenite (Table I, column L).

The granite phase differs from the reddish syenite phase only in the amount of quartz and was not observed to cut the syenite. Within the map-area the free quartz content scarcely exceeds 10 per cent, but to the west at Edgewood on Lower Arrow Lake quartz forms more than 20 per cent of the coarse-grained red granite.

Shonkinitic phases similarly differ from the pale buff syenite by local concentration of the mafic content of the rock, and generally contain a little more augite.

The above rocks occur in bodies of batholithic size but in addition many of the stocks and plugs that have been mapped as Coryell consist of syenite similar to that of the batholiths. Others, however, especially those some distance from a batholith, consist of monzonite, many of which contain short euhedral phenocrysts of augite. Those in the Rossland camp are of the porphyritic variety and have been studied in some detail by G. A. Young (Drysdale, 1915, pp. 233-236). Only one thin section of the rock has been examined by the present writer and it is from a rock essentially similar to that described by Young.

The porphyritic monzonite is a grey, coarse-grained rock in which stout, euhedral phenocrysts of dark green augite up to one quarter of an inch long and flakes of brown biotite up to one tenth of an inch in diameter are embedded in a groundmass of feldspar. As seen in thin section, the augite is in some cases zoned, partly uralitized, and commonly rimmed by a narrow zone of hornblende. The biotite is dark brown and pleochroic. Orthoclase is more abundant than plagioclase which varies in composition from oligoclase to andesine. Apatite is unusually abundant as an accessory and is most commonly encased in the augite phenocrysts. Magnetite and fine needles of rutile are also present.

A large body of porphyritic monzonite is exposed on the ridge south of Hanna Creek about 2 miles northwest of Trail. A plug that is partly composed of similar rock outcrops on the highway about 2 miles south of Ymir, and has been described by Drysdale (1917b, pp. 38-40) and McAllister (1951, p. 32). Macroscopically the rock resembles the porphyritic monzonite in the Rossland camp and Drysdale identified it as such, but as McAllister points out, the proportion of plagioclase to orthoclase is so small that the rock should more properly be called a basic syenite. He states:

> It consists of euhedral augite, olivine, labradorite, soda orthoclase, and biotite, with accessory apatite, amphibole, magnetite, hydrous iron oxide, and certain alteration products. The pulaskite core of the body is well exposed in a small quarry along the railway. It is a coarse, mauve-coloured, leucocratic rock, with a pronounced trachytoid, texture, and consists of orthoclase, cryptoperthite, augite (sodic), biotite, and amphibole, with accessory oligoclase, apatite, magnetite, and alteration products believed to have formed from nepheline. The contact between the pulaskite and basic syenite, where examined by the writer (McAllister), was found to be gradational across a width of 5 or 6 feet. Angular fragments of basic syenite are found in the pulaskite, and small stringers of pulaskite, with gradational boundaries, cut the basic syenite.

Another small plug containing two facies of alkaline rock similar to that near Ymir is exposed on the north side of Stewart Creek about half a mile above its mouth (Mulligan, 1952, p. 17).

A few miles southwest of Ymir a body of porphyritic augite monzonite grading to syenite has been described by Drysdale (1917b, pp. 36-38), in part by McAllister (1951, pp. 32-33), and by Mulligan (1952, pp. 16-18). It is irregular

in shape, and has been described by them as a chonolith. Another body of identical rock occurs about 2½ miles to the west. The monzonite in both bodies has a peculiar texture and is described by Mulligan as follows:

> In these bodies, thin brown biotite lamellae nearly an inch across give a distinctive facetted appearance and lacy pattern to the rock, otherwise fine grained and medium to dark grey in colour. Thin sections show small augite, olivine, and possibly alkaline pyroxene phenocrysts embedded in a uniform, fine, felted mass of lath plagioclase feldspar. Biotite is mostly confined to the thin lamellae, which probably mark a complex system of shrinkage cracks.

In the east part of the more easterly body, McAllister found the composition to be more like that of the basic syenite phase of the plug south of Ymir.

Another small stock of porphyritic monzonite is exposed on the east side of Salmo River valley, about 3 miles south of Sheep Creek. It has been described by Daly (1912, pp. 304-306) and Walker (1934, pp. 16, 17). The rock contains euhedral crystals of augite and is almost identical to that near Rossland, except that the plagioclase is labradorite rather than oligoclase or andesine. An analysis, compiled by Daly, is reprinted in Table I, column N. Porphyritic augite monzonite comprises also a small plug a short distance east of a larger body of augite syenite between South Salmo River and Creggan Creek, described by Walker (1934, p. 16). Another such plug occurs on the ridge southwest of Erie Mountain.

A small body of olivine syenite at the head of Tillicum Creek has been examined by Daly (1912, pp. 356, 357) and Walker (1934, p. 16). It is composed of olivine, augite, biotite, orthoclase, plagioclase, and minor quartz, apatite, and magnetite, and appears to be related genetically to the Coryell syenite.

Some bodies of biotite monzonite are exposed in the valley of Blueberry Creek. These differ from most of the rocks described above in that augite is not visible in the hand specimen, but is present as small crystals within the medium-grained rock. Dykes and other small bodies of monzonite and porphyritic syenite mineralogically similar to those mapped as Coryell are common throughout the map-area, particularly in the south and west parts.

Origin

In most places, the Coryell rocks bear an intrusive relationship to the older rocks, as shown by the numerous offshoot dykes from Coryell bodies. In some localities, however, especially near Renata, which is on the west shore of Lower Arrow Lake, west of the map-area, criteria for intrusion are lacking. It is therefore possible that some of the Coryell rocks are of metasomatic origin, but evidence for this is by no means as certain as in the core of the Nelson batholith.

Age

Within the map-area the age of the Coryell plutonic rocks cannot be defined accurately. They cut Nelson and Valhalla rocks and also intrude the Sophie Mountain formation which on fossil evidence is probably Upper Cretaceous, possibly Tertiary in age.

The writer is indebted to S. Muessig, R. A. Parker, and J. A. Calkins of the United States Geological Survey for informing him that Coryell rocks are younger than lavas equivalent to Daly's Midway volcanic group. In 1958 these geologists also helped the writer to confirm this relationship in the Kettle River[1] map-area (east half). There Daly's Midway group has yielded plant fossils of Paleocene or Eocene age (Little, 1957b). The Coryell rocks would therefore be younger than this group and the age is probably Eocene or later.

McGregor Intrusions

The McGregor intrusions were described and named by Rice (1941, pp. 42-47) from McGregor Mountain, which is west of Kootenay Lake in the east half of Nelson area. They form a group of small stocks, believed by Rice to be volcanic necks, and related dykes, all which are distinctly alkaline in composition, ranging from syenite to shonkinite. A small, elliptical plug of similar rock, less than half a mile across at the widest, occurs near the east boundary of the present map-area between Cultus and Laib Creeks. It has been described by McAllister (1951, p. 33) as follows:

> The chilled border of the plug is almost black, but with a faint mauve tint, and weathers grey-black. It consists of phenocrysts of aegirine-augite up to one-quarter inch in length, together with finer phenocrysts of olivine, set in an aphanitic groundmass.
>
> The coarse, grey-black central part of the plug is more amenable to study in thin section. It is composed of orthoclase, biotite, augite, amphibole, and fine-grained alteration products of olivine, and (?) nepheline, with accessory apatite, magnetite, and calcite, and fine grains of pyrite and angular inclusions of quartzite.

This rock is mineralogically similar to that in other plugs and stocks to the west that have been mapped as Coryell, and to the Coryell itself. There is little doubt that the rock is Tertiary, as Rice and McAllister have suggested, and it is probably early Tertiary.

Sheppard Intrusions

The Sheppard intrusions were first mapped by McConnell and Brock (1904) as "Rossland alkali granite and syenite". Daly (1912, pp. 354-356) later separated them from the generally less quartzose Coryell, and named them "Sheppard granite" from Sheppard Creek, south of Trail.

The Sheppard intrusions comprise a group of small stocks, plugs, and dykes in the southern part of the map-area between the lower reaches of Pend-d'Oreille River and Big Sheep Creek. The rock is uniform in composition and is a medium-grained, non-porphyritic, pinkish granite, commonly stained with limonite along the surfaces of joints. In some localities it contains small phenocrysts of oligoclase, and there the composition of the rock trends towards granodiorite.

The granite consists of quartz, microperthite, orthoclase, and oligoclase, with a little biotite, more or less chloritized. Daly observed one stock that contained

[1] This name has recently been changed to Penticton.

augite, rather than biotite. Accessory minerals are magnetite, titanite, zircon, and rutile. An analysis of a hand specimen collected by Daly is reprinted in Table I, column O.

Daly suggested that the Sheppard granite bears a genetic connection to the Trail granodiorite, regarded by him as being of Mesozoic age, despite the fact that the Sheppard cuts the conglomerate at Lake Mountain which all workers have correlated with the Sophie Mountain formation, then stated to be probably Miocene but now regarded as probably Upper Cretaceous. The present writer agrees with all except Daly, that the Sheppard is probably genetically related to the Coryell. Gilbert (1948, p. 189) suggested that it is a young phase of that plutonic suite, possibly because it is more acid, or possibly because, in the Rossland camp, granite porphyry dykes cut those of pulaskite. On the other hand, a dyke of biotite monzonite resembling Coryell cuts the largest body of Sheppard granite on Pend-d'Oreille River. However, as unquestioned Coryell and Sheppard intrusions have not been seen in contact their relative ages cannot be determined definitely. In the meantime the Sheppard may be tentatively regarded as roughly equivalent to the Coryell, and therefore of Eocene or later age.

71994-8—8

Chapter IV

STRUCTURAL GEOLOGY

Throughout the Canadian Cordillera the regional trend of the structures is almost everywhere roughly northwest. The region within and about the present map-area is unique in that the structure does not follow the common trend, but appears to be in some way related to the Nelson batholith. South of the batholith the rocks strike northeast; east of it they strike north; northeast of the batholith they strike northwest, and north of this point some of the youngest rocks depart from the northwest trend and strike west along the north border of the batholith. This structure has been named by Hedley (1955) the "Kootenay Arc". Within it for the most part the more detailed structures are extremely complex and include many faults and isoclinal folds, in marked contrast to the relatively simple structure of the rocks that comprise the core of the batholith.

Within the map-area most of the major structures, both folds and faults, were formed before the emplacement of the Nelson batholith and its satellites. The shapes of some of the latter in the southeast part of the map-area appear to some degree to be controlled by the early faults.

Structure of the Nelson Batholith

The paragneiss that is exposed in the core[1] of the Nelson batholith along the valleys of Slocan and Little Slocan Rivers, and, to a smaller extent, elsewhere, has been tentatively correlated with the Ymir group or the Hall formation. Along these valleys it forms an anticline with limbs that dip at low angles and contain numerous drag-folds that indicate no overturning of the strata. The anticline plunges gently under the Nelson granite to the south, and to the north forms a dome centred about Gladsheim Peak. North of this dome along Beatrice Creek is a zone of disturbance that may represent a pre-Nelson fault separating the paragneisses there from the older(?) Slocan gneisses to the north. Some movement perhaps occurred along this zone during the emplacement of the Nelson and Valhalla rocks.

Lying above the paragneiss and gradational into it is mainly Nelson porphyritic granite in which the foliation is parallel with that of the paragneiss. For many miles along the western limb of the anticline the porphyritic granite is of nearly constant thickness and is overlain in turn, with gradational contact, by Valhalla non-porphyritic granite in which the foliation is likewise parallel with the contact and with the foliation of the Nelson below. Near Mount Heimdal, however, the

[1] The core of the batholith underlies an area extending roughly 12 miles north, 8 miles east, and 25 miles south of Gladsheim Peak, and to the western edge of the map-area.

71994-8—8½

Nelson porphyritic granite appears to finger out laterally into Valhalla granite, which, on the west side of the dome north to the head of Evans Creek, is in direct contact with the paragneiss.

The gradational contact between the Nelson and Valhalla, which is parallel with the foliation, is observed almost everywhere in the Norns and Valkyr Ranges and in the Valhalla Range except near the north edge of the map-area. In many places, however, dykes of Valhalla granite do cut the Nelson, particularly those of pegmatitic or aplitic Valhalla which also transgress the normal Valhalla, usually without exhibiting any injection phenomena. Elsewhere, particularly along the northern periphery of the batholith and to the west beyond the map-area, gradational contacts of Valhalla with Nelson are uncommon, and the normal Valhalla granite is almost invariably intrusive into the Nelson.

The structure of the core of the batholith is more complex in the Valkyr Range due to the intrusion of a batholith of Coryell syenite along Lower Arrow Lake. East of Slocan River and Slocan Lake, little Valhalla granite has been found and the Nelson granitic rocks comprise a large proportion of this part of the batholith, possibly owing to mobilization of the porphyritic material which may have flowed out from the autochthonous core, pushing the eastern peripheral rocks into their present arc-like position.

Origin of the Nelson Batholith

The origin of the Nelson batholith may be deduced from observations of its components, the paragneisses and the Nelson and Valhalla plutonic rocks, and the structure of the batholith—all of which have been described in foregoing sections of this report.[1]

Evidence that the core of the Nelson batholith is autochthonous is manifest. The paragneiss and Nelson and Valhalla granitic rocks form successive layers of great lateral extent, fairly uniform thickness, and with gradational borders. The structures formed by these layers are gently dipping. Paragneiss layers grade laterally into granite, but beyond these boundaries oriented xenoliths of paragneiss may be seen for great distances (*see* Figure 4, p. 72). Similarly the Nelson and Valhalla granites in places grade laterally into one another. Dykes of Valhalla granite and pegmatite in some places traverse the Nelson porphyritic granite, but commonly do not show dilation, nor are xenoliths within them disoriented.

It is evident, therefore, that the rocks of the core of the Nelson batholith were formed by metasomatism of pre-existing rocks, at least some of which were sedimentary. Little or no mechanical injection could have occurred. Further it is apparent that these rocks were in some way rendered more competent than those beyond the periphery of the batholith, such as those of the Slocan group which are highly contorted.

[1] For a more complete account the reader is referred to a paper presented by the writer at the 20th International Geological Congress, Mexico, 1956. It is understood that publication of this paper is forthcoming.

The region now occupied by the Nelson batholith must have been deeply buried. Evidence that this could be so was found by Hedley (1952, p. 31) in Sandon area where the structure of the Slocan group is a huge recumbent syncline, the plane of which is horizontal and which opens toward the southwest. This he regarded as part of "a gigantic drag-fold in which the higher, overriding strata moved relatively southwestward, and the lower strata relatively northeastward. . . . Only the lower arc has survived erosion. . . ." An overfold of such dimensions, moving from the northeast, could have buried the region of the Nelson batholith deeply, without greatly disturbing the strata beneath it.

The mylonite zone extending along the east shore of Slocan Lake and southwesterly along Slocan River may represent the final thrust movement. The weight of this overfolded and overthrust material could also account for the fact that the region about the Nelson batholith is depressed relative to that to the north, east, and south. In these directions, the rocks become progressively older (*see* Figure 5, p. 82).

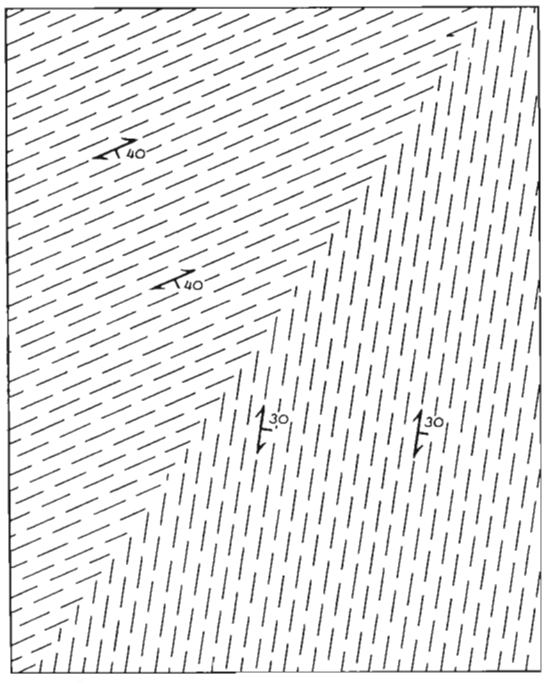
Indirect evidence for the deep burial of this region may be obtained from a study of the Cretaceous sedimentation in the Rocky Mountain geosyncline and the Plains to the east. As has been pointed out in the section on the age of the Nelson plutonic rocks, the source region of the materials comprising the Kootenay and later formations is regarded as the ancestral Purcell and Selkirk mountains. Further, the presence of feldspar and granitic pebbles above the basal Blairmore conglomerate gives a measure of the erosion necessary to unroof the batholith. The Kootenay formation extends from the Rocky Mountain Trench to the Foothills. It is assumed that the crest of the geanticline was near Slocan Lake (Williams, 1932) and that the Rocky Mountain geosyncline, before folding, was double its present width. Assuming that the volume of sediments deposited was equal to the volume of rock eroded, the average erosion on the geanticline was some 5,200 feet before denudation of the granitic rocks began.

In carrying the calculation farther to embrace as well, all the post-Kootenay Cretaceous sediments which also extend across the Plains, it is assumed that 10 per cent of the sediments there were derived from the Precambrian Shield and 30 per cent from ancestral mountains in Montana. The volume of these sediments was calculated from isopach maps supplied by the Fuels and Stratigraphic Geology Division. This calculation provides an additional 30,000 feet of erosion from the entire source region. As the vicinity of the Nelson batholith was on or near the crest of the geanticline, it is probable that erosion would be greater there than the average of the region as a whole. Thus 35,000 feet of erosion represents a minimum estimate for erosion during the Portlandian stage of the Upper Jurassic and the entire Cretaceous epoch. In this connection it is interesting to note that this provides a measure of the rate of erosion. Assuming the time to be 65 million years, the minimum average rate of erosion would have been about 1 inch per 150 years.

As the Cenozoic era represents some 70 million years, there may have been an equal amount of erosion in the region as there was in the upper Mesozoic. No estimate of the amount can be made, however, because the record of Tertiary sedimentation is so fragmentary.

From the foregoing it is apparent that the surface now exposed in the vicinity of the Nelson batholith was deeply buried at the time the batholith was emplaced. Furthermore, the autochthonous core of the batholith is typical of Read's (1951) deep-seated batholiths.

East of the core of the batholith, the weight of evidence favouring a metasomatic origin of the Nelson rocks is not so great. Between Slocan mining camp and latitude 49°30′, the most striking feature is the parallel alignment of roof pendants, each of which falls into its own zone so that the formations can be traced south across the batholith by this means. Furthermore, foliation in the granite adjacent to the roof pendants is parallel with the gneissic banding in the roof pendants.



G. S. C.

Figure 6. Intersection of bands of biotite-hornblende-feldspar gneiss as found on Kutetl Creek. Interpreted as a relict structure formed by replacement of discordant bedding in sedimentary rocks (after A. L. McAllister, 1950).

Evidence to support widespread granitization farther south has been presented by McAllister (1950, pp. 199-200) as follows:

1. Gneissic banding in the batholithic rocks is almost always parallel to the structure of surrounding sedimentary rocks or enclosed roof pendants.

2. Migmatitic zones are gradational into massive granitic rocks; many pre-granitization structures can be mapped with a good deal of assurance from an examination of structures in the gneisses.

3. Certain structures as outlined by gneissic banding can only be interpreted as relict. For example, along Kutetl Creek, two sets of gneissic banding were found truncating each other along a sharp contact, and is interpreted as a relict structure formed by replacement of discordant bedding in sedimentary rocks (*see* Figure 6).

Near Ymir Mountain narrow bands of sedimentary rocks, ranging in thickness from 50 to 100 feet, were traced several thousand feet along their strike, and through several hundred feet vertically. These bodies, lying in granite and granite gneiss, are thus seen to be not merely the bottom fringes of ordinary roof pendants, but great tabular bodies with the same beds persisting throughout. Their attitude as well as the bedding within them, conforms with the structure in other roof pendants in the area and with gneissic banding in the enclosed rocks.

On the other hand, elsewhere, particularly around the periphery of the batholith, the evidence for mechanical intrusion is abundant. Crosscutting relationships between the batholithic rocks and those they intrude are common; dykes are of the rheomorphic type, exhibiting dilation and rotation of xenoliths. Mulligan (1951, pp. 92-145) for example, in Bonnington Range, concluded that the parts of the Nelson batholith he examined exhibit crosscutting relationships to the folded, bedded rocks. He observed definite signs of assimilation on a small scale in apophyses of granite and diorite, but widespread effects of granitization, although looked for, were not seen. Similar injection phenomena were observed by the writer along the northern periphery of the batholith. In the peripheral region Valhalla granite does not exhibit gradational contacts with the Nelson, but is always intrusive into it. It is evident, therefore, that the plutonic rocks about the periphery of the batholith, unlike those of the core, have been mobilized and injected into older rocks.

In most of the bodies of Nelson rocks peripheral to the batholith the above features are common, as well as chilled margins at the intrusive contacts.

Faults

The longest faults known in the map-area and on which movements are of the greatest magnitude, are strike faults that for the most part follow the trend of the Kootenay Arc. They are, therefore, tangential to the Nelson batholith and in most places are very difficult to detect. Much fewer, but more conspicuous, are the transgressive faults that are radial to the batholith and to the Kootenay Arc. All major faults are, so far as is known, earlier than the Nelson plutonic rocks.

Ripple Creek Fault

Ripple Creek fault, the largest of the radial faults, was first observed by Daly (1912) and noted independently by Calkins and MacDonald (1909). Walker confirmed the presence of this fault, but Park and Cannon (1943, pp. 33, 34) expressed doubt concerning its existence. The present writer, however, agrees with the earlier writers. The fault strikes roughly N70°W, dips steeply, and causes an apparent right-hand displacement of the strata of about 3,500 to 4,000 feet along the 7 or 8 miles that the fault has been traced in the map-area. From the west end of Ripple Creek fault a branch fault follows South Salmo River for perhaps 3 miles. The wedge-shaped block between the two faults has moved westward relative to the rocks that lie north and south of it. This appears to suggest stress in an easterly direction, north of Ripple Creek fault, but the presence of an east-dipping thrust fault to the west renders this interpretation unlikely.

Unnamed Fault

Another radial fault, parallel with the Ripple Creek fault occurs east of the head of Porcupine Creek. McAllister (1951, p. 37) states that it has a left-hand displacement of about 1,500 feet, and does not cut the Laib Creek fault.

Laib Creek Fault

The Laib Creek fault has been observed near Laib Creek where it offsets the Quartzite Range, Reno, and Laib formations. There, according to McAllister (1951, p. 37), it has a left-hand displacement of about 10,000 feet. Farther south it marks the contact between Laib and Nelway formations, where the apparent displacement is some 2,000 feet. It strikes southward into the granite stock in upper Hidden Creek, beyond which point it has not been detected.

Faults in Stagleap Creek

Two faults striking northeasterly and seemingly with steep dips extend from the International Boundary to the Ripple Creek fault. They mark the boundaries of a down-faulted wedge of Active formation in contact with Nelway and upper Laib formations. North of Ripple Creek fault, a fault of unknown magnitude separates the Nelway and upper Laib formations, and may be the extension of one of the faults south of Ripple Creek fault.

Weasel Creek Fault

Repetition of strata on the east limb of the Sheep Creek anticline is caused by the Weasel Creek fault, mapped by Mathews (1953). This fault strikes about N15°E, parallel with the axial plane of the anticline, and dips steeply. The east side moved up relative to the west side. A similar fault was seen by the writer east of Lost Mountain.

Baldy Fault

The Baldy fault is believed to cut off much of the east limb of the Baldy anticline in the north part, and all but part of the west limb in the south. McAllister (1951, pp. 37-38) describes it as follows:

> The Baldy fault was observed at only one place along the north wall of Porcupine Creek valley, where strata of the Quartzite Range formation have been faulted into contact with those of the Three Sisters. Here, recent movement has thrust the west side up, producing a small fault scarp.
>
> The fault has been extended from this locality northward to join the Seeman Creek fault, where similar scarps were observed, although at only one intermediate point, east of Baldy Mountain, was any evidence of faulting noted. There abundant dragfolds were observed in quartzites.
>
> Throughout much of its length the attitude and position of the fault are unknown. Accordingly it is mapped along the western boundary of the Quartzite Range formation to the point where it joins the Seeman Creek fault.

Seeman Creek Fault

The Seeman Creek fault, marked by small fault-scarps, is just south of Seeman Creek, and brings the Quartzite Range and Three Sisters formations in contact with younger(?) Palæozoic rocks. On the south end it terminates against granite, and may emerge farther south as the Porcupine fault.

Porcupine Fault

The Porcupine fault may be seen in the Wren Creek-Porcupine Creek divide, where it forms a deep notch in the ridge. Originally it was shown by McAllister (1950) as a folded thrust fault, but later (1951) was described as a steep-dipping fault because McAllister's interpretation was incompatible with the present writer's stratigraphic interpretations to the south. Since then Fyles[1] and Hewlett have shown the contact of Active formation with older (?) rocks in Hidden Creek valley to be a thrust fault. Accordingly, McAllister's original interpretation is accepted and is shown on the accompanying map of Nelson area. Further, the Porcupine fault is assumed to continue southward from Porcupine Creek, thence westward around the elliptical granite stock in Porcupine Creek, to terminate against the stock in lower Hidden Creek valley.

Fyles and Hewlett contend that this same fault emerges from the granite on the south side of Hidden Creek and is bent sharply from an east trend to a southerly trend just northwest of Reno mine. From this point it strikes about S15°W to the stock in the valley of Lost Creek and from the south side of that stock may be traced westerly, south of Reeves-Macdonald mine, to the point at which Pend-d'Oreille River crosses the International Boundary. It is a thrust fault dipping east to southeast, and along it, Lower and Middle Cambrian strata are thrust upon the Active (?) formation.

Oxide Fault

The Oxide fault, so named because it is well exposed in the workings of the Oxide property, has been traced by McAllister (1951, pp. 38, 39) from that locality northward to Oscar Creek and some distance farther along a north tributary. From this point the fault appears to swing sharply eastward and thence north to terminate against the granite body there (McAllister, 1950).

Southward from the Oxide mine, where it strikes N10°E and dips steeply east, the fault has been traced southward until it terminates against the large granite body in lower Hidden Creek valley. It has brought rocks of map-unit 10 into contact with younger(?) Active formation.

What may be the continuation of this fault farther south has been traced by Fyles and Hewlett from the head of Aspen Creek southward across Lost Creek, thence eastward to Salmo River and westward across Pend-d'Oreille River, to leave the map-area eventually at the International Boundary south of Church Creek. Throughout its length it dips at moderate angles to the east, southeast, or south, and Active strata rest upon the older Laib formation. It is displaced in some places by younger faults.

[1] Personal communication, December 2, 1955.

Pend-d'Oreille Fault

Pend-d'Oreille fault was, before the building of Waneta dam, best exposed in the lower reaches of Pend-d'Oreille River, where greenstones of the Rossland formation are in fault contact with graphitic schist of the Laib(?) formation. Fyles and Hewlett have found that this fault is not steep dipping as believed by the writer (Little, 1950, p. 32) but instead dips gently southeast. Its strike varies so that the plane of the fault undulates. Fyles and Hewlett have found this fault on the east side of Salmo River, both north and south of Sheep Creek. The northward continuation of the fault may mark the contact between the Ymir group and rocks of map-unit 10 in Porcupine Creek and Kutetl Creek valleys, where these contacts are now assumed to be faulted.

Other Faults

Numerous other faults occur throughout the map-area, particularly in the areas underlain by Slocan and Ymir groups. These are for the most part strike faults and their magnitude is unknown but presumed to be relatively small.

The only major post-Nelson fault known in the map-area is that marked by the mylonite zone overlying the band of paragneiss on the east side of Slocan Lake. This zone strikes N20°E and dips 20° to 25°SE. It disappears to the north under the waters of Slocan Lake and to the south appears to feather out into several smaller faults on the slopes of the southeast side of Perry Ridge.

Folds

The anticlinal and domal structure of the autochthonous core of the Nelson batholith has been described previously. The known folded structures elsewhere, are mainly confined to the Kootenay Arc, particularly in those parts that have been mapped in detail.

Slocan Fold

The northern part of the Kootenay Arc has been shown by Hedley (1952) to be a huge recumbent syncline facing southwest, which he named the "Slocan Fold." Within this syncline, however, the local structures are complex with intricate minor folds and abundant faults. To the northwest, beyond the map-area, the dip of the synclinal plane appears to steepen and the strike swings to the west, so that northwest of Slocan Lake there appears to be a syncline plunging gently west in the trough of which sedimentary rocks of Lower Jurassic age occur. Hedley (1952, p. 33) describes a similar change in structure southeastward from Idaho Peak. The dip of the axial plane of the fold increases from horizontal to vertical and the strike swings from southeast to nearly southwest. This structural unit is much smaller than the Slocan fold, however, of which the older strata (lower Slocan group, Kaslo group, and Milford group) have been traced by McConnell and Brock (1904) to West Arm of Kootenay Lake. This was confirmed by Rice (1941) who traced these strata some miles farther south where they appear to correspond, in part at least, with those of the Ymir group.

Unnamed Folds

In the southeast part of the map-area the structure of the rocks near the east border is for the most part homoclinal, but from Monk Creek northward, the Monk and Three Sisters, near the contact of these formations, appear to be folded. This is particularly evident east of Three Sisters Peaks where the core of the anticline is occupied by Monk formation. Farther south, on the ridge north of Monk Creek, there appear to be several smaller folds.

Laib Creek Syncline

The Laib Creek syncline, named by McAllister (1951, p. 35) in Laib Creek, is at that locality overturned steeply to the west. From a point 2½ miles farther south to the granite stock in upper Hidden Creek valley most of the west limb has been removed by the Laib Creek fault. South of this stock the syncline can be traced to the Ripple Creek fault. Although no strike faults have been detected in this part there can be little doubt that they exist, but both limbs expose rocks of lower Laib formation. South of Ripple Creek fault the west limb is again cut off by faulting.

Sheep Creek Anticline

The Laib Creek syncline is, in the south, succeeded on the west by the Sheep Creek anticline, which was discovered by Walker (1934) and is referred to by Mathews (1953, pp. 36-38) as the "Eastern anticline". The anticline is overturned to the west, and the axial plane strikes N10° to 20°E and dips 65° to 70°E. The axis plunges gently, locally north but mainly south. In the vicinity of Lost Mountain the Sheep Creek anticline is still overturned to the west, and the axis plunges about 10°S; the strike of the axial plane is N30°E. South of the Ripple Creek fault the plunge increases to 25 degrees and the anticline there is neither isoclinal nor overturned.

Western Anticline

The western anticline (Mathews 1953, p. 37) lies to the west of the Sheep Creek anticline, from which it is separated by a tight syncline. It has been recognized only in Sheep Creek camp and was first described by McGuire (1942). According to Mathews, the Western anticline is complex and somewhat faulted, but, like the Sheep Creek anticline, is overturned to the west. The axis throughout Sheep Creek camp plunges about 10°S.

Baldy Anticline

The Laib Creek syncline in the north is succeeded on the west by the Baldy faulted anticline, which is quite closely aligned with the Sheep Creek anticline. The Baldy anticline is cut off on the north by the Seeman Creek fault. McAllister (1951, pp. 35-36) states that it is a fan fold overturned to the west, but that he was unable to correlate members on opposite limbs.

The ground between the Sheep Creek and Baldy anticlines is now mapped as map-unit 10, for Walker's (1934) conclusion that strata of the Quartzite Range

formation occur there has been confirmed by Fyles[1] and Hewlett. These workers state that "rocks . . . in Hidden Creek and along Porcupine Creek belong mainly to the Laib, Reno and Quartzite Range formations". North of Sheep Creek camp these strata bend sharply along a line previously shown by the present writer (Little, 1950, 1957a) as an assumed fault, and terminate against the granite body in lower Hidden Creek valley. On the north side of the valley these rocks are presumably bent back to link with those of the Baldy anticline. The bending and faulting of these previously folded and faulted rocks has resulted in an extremely complex structure in this part of the area.

Unnamed Folds in the Lower Cambrian Rocks

Three unnamed folds are known in the Lower Cambrian rocks west of the thrust slice of Active formation. The most northerly is in the valley of Porcupine Creek. It was discovered by Fyles and Hewlett, who show it as overturned to the west. The core contains strata of the upper part of the Quartzite Range formation.

The second fold is seen in Lost Creek and was shown by Walker (1934). It is likewise overturned to the west and contains Quartzite Range beds. The third anticline, which is overturned to the north, was discovered by Fyles and Hewlett, and was traced by them from Salmo River north of Creggan Creek westward past Reeves-Macdonald mine to the head of Harcourt Creek, where it disappears under overthrust Active (?) rocks. This represents a new interpretation of the structure of this region that differs from that of all previous writers.

Folds in the Rossland Formation

Various interpretations of the structure of the Rossland formation have been discussed in the description of these rocks in an earlier section. The major structure appears to be a syncline, the trough of which is occupied by the Hall formation, that divides south of Stewart Creek. At present, however, the only folds that are known with confidence are the anticline that has been traced northward from Archibald Creek some distance up Erie Creek valley, and the syncline west of it that passes through Mount Kelly. The anticline plunges north from Archibald Creek and must also plunge south from the monzonite stock at the head of Archibald Creek, for the sedimentary rocks of the core were not seen south of this stock either by Walker (1934) or the writer. A small window of sedimentary rocks may exist in the west fork of Tillicum Creek, as shown by Daly (1912).

The syncline on Mount Kelly has gently dipping limbs formed of flows and pyroclastic rocks of the Rossland formation. The axis of the syncline plunges about 20°SW.

Anticline Near Paterson

The Mount Roberts formation, exposed as a window in the valley of little Sheep Creek, appears to be folded into an anticline trending northeast. This has been peneplaned and covered by the basal flow breccias of the Rossland formation.

[1] Personal communication, December 2, 1955.

Chapter V

HISTORICAL GEOLOGY

In a discussion of the historical geology of a region, it is almost essential to be well armed with palæontological datings. Within this region, however, there are many gaps in the record of these rocks, which range in age from Late Precambrian to possibly Early Tertiary. Further, except in the sedimentary rocks of Jurassic age, fossil collections have been of little value in stratigraphic correlations. Nevertheless, if it is borne in mind that the piecing together of the historical geology is based upon meagre fossil evidence, such a discussion can serve the useful purpose of drawing an overall picture from observations of the stratigraphy and structure.

The earliest geological record in the map-area is contained in the Proterozoic rocks of the Windermere system. The basal formation (Toby) is of great lateral extent and locally of great thickness and, being composed of large angular masses of various rocks in an argillaceous matrix, indicates peculiar conditions of deposition. Rice's (1941, p. 23) proposal that it represents a shoreline deposit formed by a sea spreading rapidly over the land is accepted as being most probable.

Subsequent volcanic activity, probably centred near the International Boundary where the formation is thickest, spread lava and pyroclastic material of the Irene Volcanic formation upon the Toby conglomerate. Some weathered volcanic material may have contributed largely to the green argillaceous sediments of the Monk formation which overlies the Irene Volcanic formation locally, but several miles to the northeast the Monk (lower Horsethief Creek) rests directly upon the Toby.

Local uplift of the landmass to the southeast must have occurred after deposition of the Monk, because coarse, arenaceous clastics of the Three Sisters formation were spread upon the Monk. Farther northeast (Rice, 1941, p. 19) and apparently farther from the shore, rocks equivalent to the Three Sisters (upper Horsethief Creek) are much finer grained and similar to the Monk.

At what the writer regards as the beginning of the Cambrian period, conditions of sedimentation were much more uniform. White quartzite of the Quartzite Range formation, which is equivalent to the lower part of the Hamill series, was deposited uniformly from Addy, Washington northward to the main line of the Canadian Pacific Railway, and probably beyond. Like the Three Sisters formation, thickness of beds and crossbeds, and grain size, decrease to the northwest, and the conglomerate in the eastern exposures does not occur a few miles farther west. This proves that the source of the sediments, in the present map-area at least, was from the southeast. North of the fiftieth parallel (Reesor, 1957; Okulitch, 1949, p. 10) the source of the Hamill sediments was to the east.

The more argillaceous sediments of the Reno formation suggest retreat of the ancient shoreline after deposition of the Quartzite Range formation. By late Lower Cambrian time the environment had changed from miogeosynclinal to eugeosynclinal conditions and the limestone of the lower Laib formation was laid down. The deposition of calcareous and argillaceous rocks continued into Middle Cambrian time with the accumulation of the Nelway formation. During this time the shore must have been far from the map-area, and the direction of the source of these materials is not known. The occurrence of Middle Cambrian calcareous formations resting upon Proterozoic strata at Pend Oreille Lake, Idaho shows that by this time the landmass in northern Idaho (Montania) had subsided.

No record of Upper Cambrian rocks occurs within the map-area, and it is not known whether some of the unfossiliferous limestones of the Metaline Quadrangle in Washington represent this epoch, or whether there was no deposition at that time. The argillaceous sediments, with minor calcareous and arenaceous components, of the Lower and Middle Ordovician Active formation indicate renewed uplift of the distant landmass resulting in an influx of fine-grained argillaceous material. How far northward these slates extend is not known, but they may comprise a part of the Lardeau series.

Between Middle Ordovician and Permo-Carboniferous time there is a gap in the geological record that may be partly filled by the upper part of the Active group. Middle Devonian limestone (Park and Cannon, 1943; Enbysk, 1956), probably at least 700 feet thick, forms an isolated fault block only 2 miles south of the International Boundary. It is apparent that sedimentary rocks at least of Devonian age were deposited in the map-area, but have since been either buried or removed by erosion.

The late Palæozoic era is represented within the map-area by the fossiliferous Pennsylvanian(?) assemblage of the Mount Roberts formation, and possibly by the lower part of the Ymir group which may in part be equivalent to the Permo-Carboniferous to Triassic, Milford group. In both cases the rocks are mainly argillaceous and limy, and in the Mount Roberts formation, lava flows and pyroclastic materials are common. Sedimentation appears to have been continuous from late Palæozoic time into the Triassic east and northeast of the present location of the Nelson batholith, but to the south, near Paterson, local folding and erosion has occurred. There the basal lavas of the Rossland formation rest upon different horizons of the Mount Roberts formation. Permian strata are apparently missing at Paterson, but are exposed some miles to the southwest in the State of Washington (Bowman, 1950).

In the northeast part of the map-area the Triassic assemblage, comprising the upper part of the Milford group and the entire Kaslo and Slocan groups, is of enormous thickness, possibly some tens of thousands of feet. Rocks presumed to be mainly Triassic and largely equivalent to the Slocan group comprise the Ymir group. The base of this group is not exposed but the thickness may be much less than that of the Slocan group. It was probably not deposited at all in the vicinity of Rossland. The western shore of a Triassic sea is thus established within fairly narrow limits.

Sedimentation apparently continued into the early part of the Jurassic period with deposition of the Sinemurian beds and possibly the upper parts of the Ymir and Slocan groups. This was followed in late Lower Jurassic time by widespread vulcanism, and the volcanic material, largely deposited in marine waters, formed the Rossland formation. At Paterson, however, these volcanic rocks lapped onto a land surface of eroded Pennsylvanian(?) rocks. To the east and northeast they spread over marine sediments of the Sinemurian beds and Ymir groups. Similarly at the north end of Slocan Lake (Cairnes, 1929, p. 99, and Map 232A) a lava flow and abundant pyroclastic rocks occupy what seems to be a syncline plunging west. A few miles farther west, Rossland lava flows rest on fossiliferous sediments mapped as Slocan group north of Caribou Creek (McConnell and Brock, 1904). The late Lower Jurassic Rossland formation was deposited in a volcanic island environment, as is indicated by the irregular intercalation of marine sediments with lava flows and pyroclastic rocks. Palæontological evidence has shown that sedimentary rocks may grade laterally into volcanic rocks. Frebold (1957, pp. 2-4, 39-41) has pointed out that the supposed extensive Jurassic landmass in this part of British Columbia, variously referred to as the "Central Cordilleran geanticline", "Jurozephyria", and "Cordillerische Zwichenschwelle", did not exist as such, but that small or even large islands may have occupied this region at that time.

Probably in latest Jurassic (Portlandian) time a major orogeny occurred, in which the pre-Portlandian strata were highly folded and faulted. Ultrabasic rocks, now almost completely serpentinized, were emplaced, followed by the emplacement of Nelson and Valhalla rocks. During Cretaceous time these ancestral mountains supplied sediments to the Rocky Mountain geosyncline to the east. Probably deposited during Upper Cretaceous time was the alluvium of continental origin that now comprises the isolated remnants of the Sophie Mountain formation.

A second major orogeny that apparently affected the western part of the map-area more than the eastern, occurred in the early Tertiary. This was accompanied by the emplacement of batholithic masses and satellitic bodies of Coryell and Sheppard alkaline rocks. Except for a small remnant of conglomerate of possibly Tertiary age that was found in the valley of Stagleap Creek, these alkaline rocks represent the latest record of pre-Pleistocene geological history. The present drainage pattern may have been established fairly early in the Tertiary.

No evidence of more than one major advance in Pleistocene time has been found in the map-area. A continental ice-sheet that accumulated in the higher ranges to the north in the Selkirk and Monashee Mountains swept southward to the lower regions of the Columbia Plateau in the State of Washington. This thick ice-sheet modified the topography, and its retreat left a mantle of till over much of the area. Local late-glacial lakes, formed by the damming of pre-existing river channels by alpine glaciers, caused deposition of glacio-fluvial material in those valleys. The final stage of alpine glaciation has continued to the present time, although few alpine glaciers remain and these are currently decreasing in size.

Chapter VI

METALLIFEROUS DEPOSITS

In value of mineral production the west half of Nelson map-area is probably the second most important area of this size in British Columbia, the most important being the adjoining east half, which contains nearly all of the Sullivan orebody mined to date. This mine alone has produced nearly one half of the metal wealth of British Columbia. Within the present map-area are the Rossland camp, which still leads the province in total amount of gold produced; Sheep Creek camp which ranks sixth in gold production; and most of Slocan camp which ranks second to the Sullivan mine in silver production. In addition, outside these mining camps there are many major precious metal mines, such as the Yankee Girl, Ymir, Silver King, Second Relief, Arlington (Erie Creek), I X L, Molly Gibson, Arlington (Springer Creek), Van Roi, and several others. Most of these mines have produced important amounts of base metals that in some cases slightly exceed the value of the precious metals. Other important mines that have produced primarily zinc and lead are the Cork-Province, Mammoth and Standard, Galena Farm, H. B., Jersey, and Reeves-Macdonald. The Emerald, Feeney, and Dodger tungsten mines, owned by Canadian Exploration Company Limited, have produced at least 80 per cent of the tungsten concentrates of the province. Other metals produced in lesser amounts within the area, in approximate order of value of the amount produced, are cadmium, iron oxides, molybdenum, and antimony.

History of Mining

Placer gold is reported to have been discovered in 1855 at the mouth of Pend-d'Oreille River by ex-servants of the Hudson's Bay Company from Fort Colville (Hazlitt, 1858, p. 128). This was the first discovery of gold on the mainland of British Columbia. In 1865, an attempt was made by men of the Hudson's Bay Company to recover placer gold near the mouth of Salmo River (Walker, 1934, p. 21), but it was not until 1886 that the first placer claims were staked on Pend-d'Oreille River. Intermittent placer mining has been done within the map-area until recent years, but production of placer gold has not been great.

Interest in lode deposits was not aroused until after the relocation in 1882 of the Blue Bell mine on Kootenay Lake, known since the 1820's, and the staking in 1883 of new discoveries on the west shore at Hot Springs, later known as Ainsworth. According to Drysdale (1917b, p. 2) the first locations within the present map-area were made by the Hall brothers in 1885 near the headwaters of Ymir Creek. In the autumn of 1886 the Hall brothers staked the Silver King, Kootenay Bonanza, and American Flag claims, on the rich silver-copper veins of

71994-8 9

Toad Mountain near Nelson (Dawson, 1889, p. 60R). By August 1, 1888, 228 claims had been recorded in this camp. Four years later the first mill, of 10 stamps, was erected at the Poorman mine to treat its gold-silver ores. In 1896, Hall Mines Company built a smelter at Nelson to treat copper and silver-lead ores. No copper ores were treated after 1900 when production from the Silver King mine became spasmodic, but silver-lead ores were shipped to the smelter until 1904 and perhaps later.

The discovery of these and other deposits brought about the building of railways, which in turn encouraged the development of the mines and the erection of smelters. The first railway to be constructed was the Columbia and Western, built in 1892, to connect Nelson with the navigable waters of the Columbia at Robson. The following year, completion of the Nelson and Fort Sheppard Railway gave access to Spokane. In 1894 the Nakusp and Slocan branch of the Canadian Pacific Railway provided transportation between Nakusp and Three Forks, and was later extended to Sandon. The narrow gauge Kaslo and Slocan Railway, built by the Great Northern Railway Company in 1895, linked Cody and Sandon with Kaslo. The greatest expansion of rail facilities occurred in 1896, when branches of the Columbia and Western Railway were extended from South Slocan to Slocan City, and from Robson to Trail. In the same year a narrow gauge railway was built by the B. C. Smelting and Refining Company to transport ore from Rossland to their new smelter at Trail.

In 1897 the Great Northern Railway Company extended a branch line, known as the Red Mountain Railway, from Northport to Rossland. The next year the smelter at Northport and the Le Roi mine at Rossland were purchased by the British American Corporation. In 1898 also, the Canadian Pacific Railway Company acquired the railway between Rossland and Trail, and the Trail smelter, and immediately reduced the smelter charges. Later the road-bed was expanded to wide gauge and incorporated with the Columbia and Western system. By 1900, all the railways within the map-area were in operation.

The interest aroused in lode deposits along Kootenay Lake and on Toad Mountain spread first to the Rossland camp. There the Lily May claim on the Dewdney Trail was located in 1887. It was however allowed to lapse and was not relocated until 1889 (Drysdale, 1915, p. 5). In the summer of 1890 two prospectors, Bourgeois and Morris, who had been working in the vicinity, located five claims in one day on Red Mountain. Three of these claims were the Le Roi, Centre Star, and War Eagle that were to produce 88 per cent of the ore from the Rossland camp (Gilbert, 1948, p. 189). By the spring of 1892, 67 mining claims had been recorded, and production, other than trial shipments, began in 1894 when the Josie shipped 1,856 tons of ore, which returned $75,510. By 1895, several mining companies were paying dividends and production increased to a peak in 1903. It declined somewhat from then until 1916 and then fell off sharply until the principal mines closed in 1928. The relatively small production since that time has been of ore mined by lessees.

In 1906 the Consolidated Mining and Smelting Company of Canada was formed, and it acquired in that year the Centre Star and War Eagle mines and the smelter at Trail. In 1911 the Le Roi mine and other claims were added to its holdings. In 1916, electrolytic refining of copper and zinc was begun at Trail and other metals were produced subsequently: bismuth in 1930, tin and magnesium powder in 1941, and indium in 1942. The plant installed in 1931 to produce commercial fertilizer from flue gases has since been a large source of income for the company.

Before the Rossland camp became established as a productive camp, the Slocan camp came into prominence. On September 9, 1891, the Payne vein was discovered and staked, as was the Noble Five group, later that month. These discoveries were followed by such a rush of stakings that in the following year, 750 locations were recorded. The first shipment of ore was made from the Freddie Lee mine in 1892.

Rail facilities accelerated the development of the camp, which in the mid-nineties was the most productive in the province. Peak production was reached in the period 1912 to 1919, and subsequent periods of renewed activity occurred from 1925 to 1928, and since 1945.

Ymir camp first became very active in 1896, and, with the exception of a depression in 1899 to 1901, it continued to be an important camp in the region until about 1904, when attention was shifted to Sheep Creek camp. A revival of mining activity was experienced in 1934 to 1940, caused by the increase in the price of gold.

Sheep Creek camp aroused interest in 1899 when gold ore was first mined at the Yellowstone property, and later at the Queen. The camp came into prominence however, in 1934, and by 1941, when production fell off, it ranked sixth in gold production in the province. Sheep Creek Gold Mines Limited, Reno Gold Mines Limited, Kootenay Belle Gold Mines Limited, and Gold Belt Mines Limited were the principal producers.

Since 1945 the demand for base metals and the consequent enhancement in price has resulted in a shift of interest to these from gold. The production of several mines in the Slocan camp and elsewhere has increased greatly, but it is overshadowed by that from mines of the Salmo area, the Jersey, Reeves-Macdonald, and H. B., as well as by the tungsten production from the Emerald, Feeney, and Dodger mines.

Description of Properties

Nelson map-area (west half) contains some 441 properties that have produced 1 ton or more of ore (B.C. Dept. of Mines, Ann. Rept. 1955, Table I). This list includes claims and groups of claims that have since been incorporated into other groups and in some cases separated from other groups, so that the above figure cannot be regarded as accurate. Nevertheless, it indicates that about one third of the properties in the province that have produced metals are within the map-area.

71994-8—9½

On the accompanying map of mining properties (Map No. 1091A) only properties that have produced are listed, and an effort has been made to plot all those whose locations are accurately known. Twenty-eight such properties could not be plotted, probably due to the fact that they had never been Crown-granted, but nearly all of these are of minor importance.

The properties are plotted according to (*a*) metal content of their ores, and (*b*) relative magnitude of production (*see* Figure 7, in pocket). In nearly all cases this information was obtained from the list of producing mines referred to above. In some cases corrections have been made from other sources and where the mineral production of two or more properties has been combined in the table, an estimate of the relative production from each has been made.

During the course of geological mapping of the area there was insufficient time to examine more than a small proportion of the numerous properties. Accordingly, an effort was made not to duplicate the more detailed observations made on properties examined by Hedley (1952), Mathews (1953), Green (1954), and Fyles and Hewlett (B.C. Dept. of Mines, bulletin in press).

Placer Deposits

Placer gold production in Nelson map-area (west half) is comparatively small. From 1855, when placer gold was first discovered near the mouth of Pend-d'Oreille River, until 1874, when the provincial Department of Mines was formed, no record of gold production in this region was kept. Even as late as 1925 some gold was believed to have been unreported, and in the official production figures a factor of one tenth to one third was added to the reported production during the period from 1874 to 1925 in order to present a more probable amount.

The total recorded production of placer gold from Nelson, Slocan, and Trail Creek mining divisions up to and including 1955, is 4,702 ounces, valued at $119,865.[1] Of this perhaps 90 per cent was obtained from streams that are within the map-area.

Details of a part of this production, which have been compiled by Holland (1950, pp. 14 and 15) for the years 1886 to 1945, are presented below:

Year	Pend-d'Oreille River		Salmo River		Tillicum Creek	
	ounces	$	ounces	$	ounces	$
1886–1890	.....	.....	.....	.....	.....	.....
1891–1895	15	250.	28	500.	.....	.....
1911–1915	.....	.....	.....	.....	.....	.....
1931–1935	.....	.....	.....	.....	.....	.....
1936–1940	56	1,535.	27	814.	14	435.
1941–1945	213	6,186.	50	1,502.	.....	.....
Totals	284	7,971.	105	2,816.	14	435.

[1] Minister of Mines, B.C., Ann. Rept. 1955, p. 29.

Year	Erie Creek		Hall Creek		Fortynine Creek		Lemon Creek	
	ounces	$	ounces	$	ounces	$	ounces	$
1886–1890	.....	.....	.....	.....	48	900.	.....	.....
1891–1895	.....	.....	126	2,250.	241	4,500.	.....	.....
1911–1915	.....	.....	.....	.....	7	130.	.....	.....
1931–1935	1	30.	.....	.....	78	2,126.	13	361.
1936–1940	.....	.....	2	41.	94	3,064.	18	511.
1941–1945	.....	.....	57	1,726.	24	833.	.....	.....
Totals	1	30.	185	4,017	492	11,553.	31	872.

The above figures account for a total of 1,112 ounces of placer gold, which is perhaps 25 per cent of total production. In the period 1946 to 1955, a total of 41 ounces valued at $1,067 is reported; the source is only given as Nelson mining division. Although details are lacking most of this came from Tillicum Creek and Salmo River.

Placer gold has also been reported in several other streams within the map-area. Some of these are Burton, Falls, and Rover Creeks (Holland, 1950, p. 14), Bird Creek (Minister of Mines, B.C., Ann. Rept. 1890, p. 364), Ymir Creek (Drysdale, 1917b, p. 2), Enterprise Creek, and tributaries of Kaslo River that drain the area underlain by the Kaslo group (Cairnes, 1934, p. 109). Dawson (1889, pp. 132R, 133R) reports placer gold in Slocan River, Cottonwood Creek, and Columbia River a short distance above the mouth of Pend-d'Oreille River.

Pend-d'Oreille River

References: Minister of Mines, B.C., Ann. Repts.: 1893, p. 1041; 1894, pp. 742, 743; 1895, p. 686; 1902, p. 154; 1903, p. 142; 1926, p. 282; 1934, p. E24; 1935, p. E36; 1938, p. E34; 1939, p. 110; 1940, p. 97. Holland, 1950, pp. 14, 15. Walker, 1934, pp. 21, 90.

Early placer operations on the Pend-d'Oreille were small, but pumping machinery was first used, with little success, by the Kootenay Hydraulic Company in 1895. In 1926 a small suction dredge was tested on the sand of Pend-d'Oreille River before being moved up Salmo River. Similar operations were attempted in 1938 and 1939. In the 1938 operation, a raft equipped with an air-lift pipe, owned by River Placers Syndicate, raised gravel from the river-bed. The 1939 operation, sponsored by the A. H. Green Company of Nelson, worked bench gravels about a mile below the Red Bridge (now collapsed) with a half-yard shovel, a bulldozer, and two trucks with which the gravel was brought to sluice boxes. Neither operation was very successful with respect to the amount of gold recovered.

One- or two-man operations have been active intermittently for many years, particularly at times of low water.

Except near its mouth, Pend-d'Oreille River valley does not contain buried channels of the main river, so that placer operations must be confined to the present river gravels. Near the mouth, above Waneta dam an old channel apparently exists

north of the present course of the river. This channel is deeply buried, and the gravel is undoubtedly heavily impregnated by water, due to the rise of the river level caused by the construction of the dam.

Salmo River

References: Minister of Mines, B.C., Ann. Repts.: 1893, p. 1041; 1894, pp. 742-3; 1895, p. 686; 1902, p. 154; 1903, p. 142; 1926, p. 282; 1935, p. E36. Holland, 1950, pp. 14, 15. Walker, 1934, pp. 21, 90.

Salmo River has yielded comparatively little placer gold. In the period 1893 to 1903 placer leases were being held, but the only reported production year is 1894, when some $500 in gold was said to have been produced. In 1926 a small suction dredge was operated for a short time about a mile above the mouth of the river, but this was wrecked in a sudden flood. In 1935 much interest was aroused when two men recovered 27 ounces of gold in a short time from two 250-foot leases. Holland reports a production of 50 ounces in the period 1941 to 1945.

Tillicum Creek

References: Minister of Mines, B.C., Ann. Rept. 1902, p. 154; Holland, 1950, p. 14.

Although only 14 ounces of gold have been reported from Tillicum Creek probably many times that amount has been recovered, for in 1949, one operator was still active. This working was about half a mile above the Nelway-Waneta road. At this point the stream deposits of gravel, sand, and clay are thin and easily worked.

Erie Creek

References: Minister of Mines, B.C., Ann. Repts.: 1902, p. 154; 1904, pp. 130, 143; 1915, p. 137; 1921, p. 173; 1935, p. E36. Holland, 1950, p. 14. Walker, 1934, p. 90.

Placer gold was discovered on Erie Creek in 1902 by the Peterson brothers while digging a well for water. They staked the ground and operated the lease for some time before their discovery became known. Thirty-five claims were staked during that summer and the Petersons' ground was acquired by Wild Duck Placer and North Fork Placer, but no record of production has been kept. In 1904 two claims just below Hooch Creek were worked. A small amount of coarse gold was said to have been obtained from gravel in an old stream channel on the north side of the creek. Farther down the creek the Erie Placer Company did preliminary work and found some coarse gold. No further activity is reported.

In 1915 some work was done near the mouth of Hooch Creek and good returns were said to have been obtained. In 1921 an attempt was made to work the ground about 2 miles above Erie, but progress was hampered by the presence of large boulders and a layer of clay that carried much gold through the sluice boxes. A little coarse gold was obtained. In 1935 one ounce of gold was recovered from Erie Creek, but the locality is not given.

Hall Creek

References: Minister of Mines, B.C., Ann. Repts.: 1890, p. 363; 1892, p. 533; 1893, p. 1042; 1894, pp. 742, 743; 1895, p. 686; 1904, p. 143; 1908, p. 107; 1938, p. E35; 1939, p. 110; 1940, p. 97. Holland, 1950, p. 15.

The first recorded activity on Hall Creek was in 1890, when 50 placer claims were recorded. Coarse gold was reported in a bench a short distance from the creek. The gold was found at a depth of 6 feet, and was said to have been deposited in an old channel of the creek. Some work continued intermittently for many years, and in 1894 a rich pocket yielded $500 in gold from only 60 cubic yards.

In 1904 the American and B.C. Hydraulic Mining Company began hydraulic mining. This appears to have been continued at least until 1908, but production is not recorded.

No activity is reported until 1938 when the J. D. Mining and Prospecting Company, Limited, installed a small concentrating plant consisting of a jig and 1-ton amalgam-barrel ball-mill. Several tons of black sand from gravel moved by monitors were recovered, but the content of this material was not recorded. Some coarse gold was obtained at and near the base of a 3-foot bed of hard-pan that rests on bedrock and is overlain by 8 feet of bluish boulder clay and gravel, in turn succeeded by 10 to 15 feet of reworked boulder clay.

Owing to financial difficulties this property reverted to T. E. Levasseur, but the equipment was retained by the company. The following summer some leasers operated occasionally, leasing the equipment from the company and the ground from the owner. In 1940 several small operations were reported but no subsequent activity is recorded.

Fortynine Creek

References: Minister of Mines, B.C., Ann. Repts.: 1890, p. 364; 1892, p. 533; 1893, p. 1041; 1894, pp. 742, 743; 1895, p. 686; 1914, p. 330; 1915, p. 137; 1916, p. 206; 1921, p. 173; 1928, p. 323; 1933, p. 240; 1934, pp. 24, 26; 1935, p. E36; 1938, p. E34; 1939, p. 110; 1940, p. 97; 1942, p. 90. Holland, 1950, p. 15.

Fortynine Creek is apparently the most productive in the map-area. A hydraulic operation was reported as early as 1890 and activity was reported each year to 1895, the principal operator in 1894 and 1895 being Nelson Hydraulic Company, Limited. In 1914, tests were started by a syndicate of men from Nelson. By 1916 a tunnel that was to explore an old channel had been advanced 230 feet, in spite of quicksand that caused grave difficulties. No work other than one small operation in 1921 is reported until 1928. In that year Fortynine Creek Placers, Limited, acquired the leases upon which tunnelling had been carried out. The company cleared out the tunnel, which had been filled with mud, and advanced the face to encounter gravel of an old channel believed to be about 1,700 feet long. No further reports of the success of this venture are given nor does Holland record any placer gold production in this period.

In 1933 the Black Watch Syndicate, under the direction of H. A. McKen, removed by drag line and sluiced 8,000 cubic yards of gravel from a bench on the east side of the creek about half a mile upstream from the road to the power-

plant on Kootenay River. The syndicate continued work in 1934 with a small crew of men. A little activity occurred the following year when 5¾ ounces of placer gold were recovered.

In 1938 H. A. McKen sunk a shaft to a depth of 28 feet on one of sixteen claims, but it is not known if placer gold was obtained from this operation. In the same year Nelson Placers, Limited reworked marginal gravel on ground that had been hydraulicked between 1890 and 1900. Eleven ounces of gold were recovered. This company continued operations in 1939 and the following year the property was operated under lease.

In 1942, a shaft was sunk on the creek-bed in the Acorn group to a depth of 110 feet to prove the existence of an old channel of supposed Tertiary age. Gravel from the shaft which was said to penetrate to within a few feet of bedrock, was hoisted to the surface and dumped onto a grizzly over sluice boxes. Encouraging amounts of gold and some scheelite were recovered.

Lemon Creek

References: Minister of Mines, B.C., Ann. Repts.: 1935, p. E36; 1938, p. E45. Holland, 1950, p. 15.

Only small production of placer gold has been recorded from Lemon Creek, probably mainly due to the presence of large boulders in the creek-bed. The exact localities that yielded the gold are not known.

Lode Deposits

Lead-silver Deposits, With or Without Some Zinc and Minor Gold

Mineral deposits containing lead and silver, in that order of value, are with few exceptions confined to a single broad belt extending from the Mountain Chief mine near New Denver southeastward through the Slocan mining camp to the Scranton mine on the watershed of Woodbury Creek. Within this belt, exceptions to this order of value are the Black Colt, Elkhorn, Gibson, and Scranton properties, where the value of zinc produced exceeds that of silver but is less than that of lead. This is also true of the Ruth lode and parts of many other lead-silver veins. The Victoria vein has yielded lead and zinc, but no silver. The Silversmith-Slocan Star and Noble Five mines have produced in addition, a little cadmium.

Within the lead-silver belt are a few zinc-lead-silver and silver-lead-zinc deposits, but the latter appear to be largely peripheral to the belt. Cairnes (1948, p. 203) has stated that the ore deposits in the Slocan camp commonly grade downward from silver-lead ores through silver-lead-zinc ores to predominantly zinc ores. Hedley (1952, pp. 59-61) however, after more detailed mapping of the deposits, concluded that such orebodies show a similar zoning laterally, so that "the lead tends to be central and the zinc peripheral". These effects are not apparent from the more general study based on mine production, but as indicated on the accompanying map showing mineral properties there seems to be a broad zonal distribution of the different types of orebodies. This conclusion may in

some cases be invalidated, as Hedley pointed out, by such economic considerations as metallurgical practices of the times and the relative values of lead and zinc ores.

The lead-silver deposits of this belt are all fissure-filled lodes, but in a few veins on such properties as the Comstock and Chambers, there occurs minor dissemination of ore minerals in the wall-rocks. The host rocks for the lead-silver deposits in this belt are principally argillite, quartzite, minor limestone, and gradations between these rock types, which are all of the Slocan group. In some cases the argillaceous rocks are metamorphosed to form slate and andalusite schist. A few veins are partly in quartz porphyry, as are those of the Last Chance and Chambers properties. Several other deposits, however, such as the Comstock, Fisher Maiden, Comstock-Virginia, Flint, Martin, and Silver Cup, are in coarse-grained, mainly porphyritic, Nelson granite, which on the Comstock property is greatly crushed. The Scranton veins, though mainly in granite, are in part in a huge xenolith of quartzite encased in granite. The Shady fraction (Gem) has yielded only float ore.

The gangue in these deposits, aside from brecciated wall-rock which in some veins is abundant, is quartz, siderite, or calcite, or combinations of two or more of these. In general, carbonates appear to be more common where the host rocks are calcareous and quartz more common in veins in granite. Ankerite may be present in the Silver Bell and Hustler vein and tourmaline has been identified in the quartz veins of the Flint property.

Galena is the predominant ore mineral, but sphalerite is common in most deposits and indeed appears to exceed galena in the New Springfield, Ruth, and Bell lodes. On the other hand, sphalerite is not reported in the veins of the Comstock, Sapphire, Freddie Lee, Chambers, and Home Rule properties. Some silver minerals have been identified in the ores, but these are of course much less abundant than in the silver-lead-zinc deposits. Such minerals are grey copper, ruby silver, native silver, and argentite, one or more of which have been reported in the ores of the Echo and Graphic, Fisher Maiden, Wakefield, Hope, Wonderful, Silversmith-Slocan Star, Ajax, Last Chance, Noble Five, Number One, Fourth of July and Texas, Mohawk, Comstock-Virginia, and Silver Bell properties. Pyrite is present in many of the veins and is abundant in a few. Chalcopyrite is present in fewer of these veins than in those rich in silver, and occurs only sparingly.

The few lead-silver deposits within the map-area outside the belt described above are scattered sparsely in belts of other types of ores, or else occur isolated from other deposits. Of these only the Howard is a comparatively large producer.

The Silver Leaf, White Hope, and Speculator deposits occur within the arcuate belt of 'dry ores' east of the southern end of Slocan Lake, and all differ from the deposits typical of the main lead-silver belt. In the Silver Leaf and White Hope veins the value of zinc exceeds that of silver. The Silver Leaf vein lies in Nelson porphyritic granite, the White Hope vein in gneiss apparently derived from the granitization of quartzite, and the Speculator deposit in crushed granite or granodiorite in which sulphides are disseminated. In these deposits the gangue is quartz, with, in the Silver Leaf only, siderite. Galena and sphalerite are the ore minerals, but the latter is not abundant in the Speculator. Pyrite occurs in the White Hope veins.

The Silver Reef mine, which is between the forks of Anderson Creek a short distance east of Nelson, the Willcock on Ymir Creek, the Nevada on Porcupine Creek, and the Howard on Active Creek—all have produced more zinc and gold than silver. The Silver Reef, Willcock and minor parts of the Howard veins are in porphyritic Nelson granite or granodiorite. The greater part of the Howard veins are however, in slate and quartzite of the Active formation. The Nevada veins are in schist and argillaceous quartzite of the Ymir group. The gangue in the veins of this group of properties is quartz that in the Howard bears tourmaline, and in the Silver Reef locally exhibits ribbon structure and is accompanied by a little siderite and calcite. The ore minerals are galena and sphalerite with pyrite, which is most abundant in the Howard. The Silver Reef vein also contains a little chalcopyrite.

The Iron Cap deposit on Sheep Creek differs from all other lead-silver deposits within the map-area in that it comprises sulphides disseminated in silicified limestone of the Laib formation and contains pyrrhotite. The International, near Pend-d'Oreille River, may have been of this type, but apparently due to secondary alteration perhaps by ground waters, it now consists of nodules of galena encased in oxides of iron, locally encrusted with cerussite.

The United Verde on South Salmo River, the Union north of Rossland, the Sunset on Little Sheep Creek, and the Douglas on Mount Sophia, are all fissure-filled veins. The first three occur in argillaceous quartzite or argillite, but the Douglas is in conglomerate of the Sophie Mountain formation. Quartz is the gangue mineral, accompanied by a little calcite in the Douglas vein. The ore minerals are galena and sphalerite, with pyrite in the United Verde and Douglas veins; the latter also contains a little chalcopyrite.

Carnation (35)[1]

References: Minister of Mines, B.C., Ann. Repts.: 1921, p. 135; 1926, p. 250; 1927, p. 269; 1929, p. 307; 1930, p. 248; 1946, p. 161; 1948, p. 144; 1949, p. 188; 1950, p. 145; 1951, pp. 42, 171. Cairnes, 1935, pp. 28-30. Hedley, 1952, pp. 27, 70-74.

The Carnation group of fourteen Crown-granted claims represents part of the fifty-five claims owned by Kelowna Exploration Company Limited.[2] The property comprises an irregular strip of claims that crosses the divide between Carpenter and Silverton Creeks. It was purchased by the present owners in 1946.

According to Hedley production from 1895 to 1928 was 677 tons of ore that yielded 224,597 pounds lead, 21,433 ounces silver, 36,491 pounds zinc, and 6 ounces gold. In 1951, 2 tons of ore picked from the dump were shipped to the Trail smelter. This contained 2,132 pounds lead, 153 ounces silver, and 276 pounds zinc.

The only work in 1950 was that done in the 5,480 tunnel, which was examined by A. B. Irwin of the Geological Survey in June, 1950.

[1] Numbers in parentheses are those that give the locations of the properties on the accompanying map.

[2] Ownerships mentioned in the description of properties are from the latest record available to the writer.

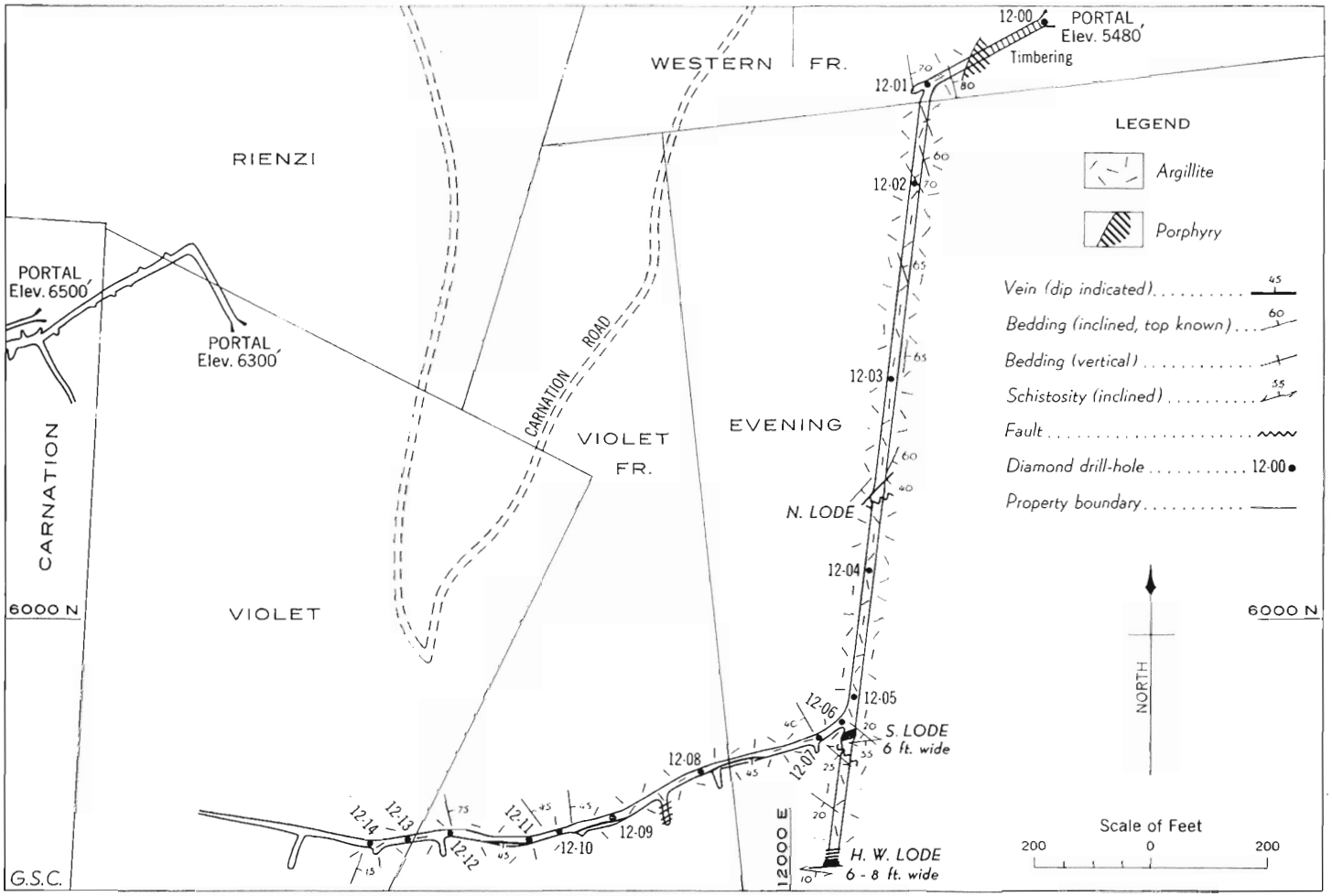


Figure 8. Geology of 5,480 level, Carnation mine (geology by A. B. Irwin, 1950).

The country rock is mainly banded argillite which in general strikes N20° to 40°W and, on the 5,480 level, dips mainly northeast (*see* Figure 8). Hedley states that this represents the principal overturned panel of the great Slocan fold. The bands in the argillite range from a fraction of an inch to 1 foot thick. North of the north lode they vary in colour from brown through green to grey but south of the north lode they are more commonly black and veined by calcite and quartz.

The north lode consists of small lenses of coarse- and fine-grained galena and sphalerite in a vein of quartz and carbonate up to 1½ feet wide, within a shear zone about 6 feet wide that strikes N45°E and dips 40°SE. The south lode comprises sparsely disseminated galena and sphalerite in the calcite gangue of a brecciated zone that strikes N80°E and dips 55°S. The south lode has been traced intermittently westward for nearly 700 feet by drifting in or near the foot-wall, with short crosscuts southward to the shear zone. It ranges in width from a few inches to 3 feet.

The hanging-wall lode, which is exposed only at the face of the main crosscut, consists of brecciated wall-rock cemented largely by calcite; it is also sparsely mineralized. This lode is 6 to 8 feet wide and dips 10°S.

A description of the earlier workings is given by Cairnes (1935), and a detailed description of the structure of the bedrock on the property is contained in Hedley's (1952) report.

Fourth of July and Texas (90)

References: Minister of Mines, B.C., Ann. Repts.: 1890, p. 367; 1918, p. 159; 1926, pp. 263, 264; 1933, p. 209. Cairnes, 1935, pp. 218, 250, 251.

The Fourth of July and Texas property, comprising the Fourth of July, Texas, Cowboy, San Antonio, Minnie, Toronto, Garland fraction, and Lucky Ed Crown-granted claims and four others held by location, is owned by L. N. Garland of Ainsworth, B.C. The group is in the upper basin of Robb Creek, a tributary of Kaslo River. It is reached by a trail about 3 miles long from Blaylock station, which is about 14 miles by road or rail from Kaslo.

The Fourth of July claim was one of the first staked in the region and by 1890, 100 feet of tunnelling had been done. In 1898 it was Crown-granted to Columbia Mining Company Limited and an initial shipment of ore was made. In 1918 the property was bonded and some 50 tons of ore was said to have been mined, but no record of shipment is published. In 1926 the workings on both the Texas and Fourth of July groups were examined and sampled by A. G. Langley, the resident mining engineer. Intermittent development work was done on the Texas until 1933.

The production from the Fourth of July group, for which complete records are available from 1898 to 1937 inclusive, is 6 tons of ore containing 4,357 pounds lead, 444 ounces silver, and 851 pounds zinc. The property was examined by A. B. Irwin of the Geological Survey in July 1950.

The rocks underlying the claims are slaty argillite and andalusite schist, limestone, and minor quartzite, intruded by a large dyke-like body of medium-grained porphyritic granodiorite. The sedimentary rocks in general strike northwest and dip about 55°SW.

On the Texas claim, the workings comprise a shaft and three adits, of which only the lowest was mapped by Irwin. The shaft was driven southwest in fine-grained granodiorite for 65 feet. It passes through 20 feet of argillite and quartzite and continues through limestone to the face, 110 feet from the portal. The limestone is distinctly laminated and strikes northwest, dipping 75°SW. At the face is a vein occupying a narrow fissure that strikes N40°W and dips 70°SW, roughly parallel with the bedding. From this point the drift follows the fissure 25 feet southeast and 160 feet northwest. The vein is narrow and irregular and consists of quartz and siderite with bands of galena and sphalerite. Euhedral crystals of pyrite up to one eighth of an inch across are disseminated in the vein and adjacent wall-rock.

On the Texas claim the lower two tunnels are caved but the upper adit is partly open. The surface showing near the lower tunnels reveals a contact between limestone and fine-grained granite along which a weathered vein more than 2 feet wide is visible. This vein strikes N60 W and dips 60°SW. The upper tunnel starts in limestone in a direction N65°W but is caved at a raise 100 feet from the portal.

Scranton (118, 119)

References: Minister of Mines B.C., Ann. Repts.: 1898, p. 1080; 1899, p. 701; 1904, pp. 156, 157; 1930, p. 256; 1939, p. 79; 1947, p. 167; 1948, p. 139; 1949, p. 183; 1950, p. 137; 1951, p. 163; 1952, p. 170; 1953, p. 134; 1954, p. 134. B.C. Dept. of Mines, Bull. 1 (1932), p. 118. Cairnes, 1935, pp. 241-244.

The Scranton property comprises eleven claims, of which the Scranton, Pontiac, Grandview, Sunrise, Granite, and Tecumsie are Crown-granted, and the Scranton fraction, Scranton extension, Grandview fraction, Snowflake, and Clearwater are held by location. The property is near the head of Pontiac Creek, a tributary of Woodbury Creek, and is accessible by private road 11 miles long from the Balfour-Kaslo highway. The claims are owned by Scranton Mines Limited, 444 Pacific Building, Portland, Oregon.

Initial production in 1898 was from the Pontiac and Tecumsie claims, and in 1901 exploration was begun on the Scranton. Ore shipments were made intermittently from the Pontiac and Tecumsie until 1905, but except for minor development from 1906 to 1908 the property remained idle until 1930 when the Pontiac, Scranton, and Sunrise groups were acquired by the Scranton Consolidated Mining Company Limited. In that year and in 1932 the workings were rehabilitated, and in 1939 and 1940 extensive development work was carried out. To solve the transportation problem a road was begun in 1945 and completed in 1947. In 1948, mine buildings were erected and 9½ tons of ore was shipped. Further shipments direct to the smelter at Trail were made in 1949 to early in 1952, but from mid-1952 to 1954 the ore was concentrated at the Kenville and

Kootenay Florence mills. The name of the company was changed from Scranton Consolidated Mining Company Limited to Scranton Mines Limited on December 31, 1951.

Total production of ore from the property from 1898 to 1954 inclusive is 6,881 tons, containing 1,426,150 pounds lead, 1,108,852 pounds zinc, 73,227 ounces silver, 1,359 ounces gold, and 5,539 pounds cadmium. The property was examined in July 1950 by A. B. Irwin of the Geological Survey.

The country rock is coarse-grained porphyritic Nelson granite in which a few inclusions of quartzite occur. These are small with the exception of one encountered in the main tunnel. There the drift is in quartzite from 300 to 800 feet from the portal and a crosscut is almost entirely in quartzite for 275 feet to the face.

The workings examined by Irwin consisted of a main tunnel and a higher, west tunnel. The main tunnel, now called the Pontiac, was driven eastward from the east side of Pontiac Creek for about 1,100 feet with a crosscut 275 feet long. The west tunnel, now called the Sunset, was driven westward from the west side of the creek and followed a vein for about 60 feet.

On the east side of Pontiac Creek there seem to be at least two veins, which are roughly parallel and are explored by the Pontiac tunnel.

The sinuous course of this tunnel, however, makes it difficult to decide if some of the veins encountered are continuations with a changed attitude of veins exposed farther back in the tunnel. The strikes of the veins range from northeast to east, but average N60°E. The dips range from 10° to 70°SW averaging about 30°. The vein on which the Pontiac tunnel enters is 6 inches to 2 feet wide and continuous in the granite, but as the contact with quartzite is approached the vein appears to pinch out. In the quartzites the veins are fairly regular and continuous where they cross the beds, but where they become concordant with the beds in most places the veins become narrow and split. An exception to this was noted in the drift about 750 feet from the portal where a vein, which is nearly parallel with beds that are almost flat-lying, is locally 5 feet wide.

On the west side of Pontiac Creek the vein strikes NE and dips 60°SE. It is probably the same vein as that on which the Pontiac drift enters. The vein in the Sunset tunnel has an average width of about 3 feet. The wall-rock in the tunnel, which is 60 feet long, is porphyritic Nelson granite.

The veins are of quartz containing streaks of fine-grained pyrite and clusters and individual cubes of pyrite. A little chalcopyrite is also present. Galena is widely disseminated in the veins and in addition forms streaks and pods of fine-grained, gneissic, and coarse cube galena. Sphalerite is less noticeable than galena, but as shown by smelter returns, is abundant.

The older workings on the Sunrise, Pontiac, and Tecumsie claims were not active, and so were not examined by Dr. Irwin.

International (Lomond) (273)

See Iron Oxide Deposit (p. 193).

Douglas (329)

References: Minister of Mines, B.C., Ann. Repts.: 1900, p. 862; 1901, p. 1048; 1950, p. 119. Brock, 1903, p. 75A.

The Douglas Crown-granted claim, owned by the Godfrey brothers of Northport, Washington, is on the west side of Mount Sophia adjacent to the International Boundary, and about a mile south of the Velvet mine from which it is accessible by road.

The earliest development of the mine was in 1900 and 1901, when some 790 feet of tunnelling was done. No further activity was reported until 1948 to 1950 when the present owners shipped 10 tons of ore that contained 1,305 pounds lead, 1,058 pounds zinc, and 19 ounces silver. The property was examined by the writer in 1949.

The country rock is conglomerate of the Sophie Mountain formation in which a lenticular bed of coarse-grained, faintly stratified sandstone strikes N20°W and dips 70°NE. The conglomerate is cut by several dykes of pink or greenish porphyritic syenite that are related to the Coryell batholith, the contact of which is several hundred feet northwest of the claim. There is also a dyke of sheared lamprophyre exposed underground.

The workings, consisting of three adits at elevations (barometric) of 3,950, 4,060, and 4,180 feet, explore a shear zone that strikes S60°E and dips 70°NE. This shear zone occurs along the contact of conglomerate and hypabyssal syenite, both of which are sheared. Masses of serpentine, most of them small but one at least 30 feet in diameter, occur along the shear zone and appear to have been emplaced during faulting as cold intrusions, probably from an underlying mass of serpentinite.

The shear zone is from a few inches to 10 feet wide and contains abundant gouge. Individual lenses and branching veins of quartz with minor calcite, up to a foot wide, occur at intervals along the lowest tunnel, which is 750 feet long. The veins are locally fractured and the fractures are filled with gouge, indicating movement along the fault subsequent to the emplacement of the vein.

Pyrite is the most abundant metallic mineral in the veins and has been oxidized and hydrated locally. In a few places along the veins are concentrations of galena, sphalerite, and a little chalcopyrite.

In 1949 the middle adit was caved and the upper adit was accessible for only a short distance. Judging by the size of the dump, the upper adit is long. Vein matter on the dump consisted of quartz containing euhedral crystals of pyrite one eighth of an inch or more in diameter. No other sulphides were seen. A higher adit at the International Boundary was reported by one of the writer's assistants. This is probably on the same shear zone but must be beyond the boundary of the Douglas claim.

Other deposits of this type, together with selected references, are listed below.

Mountain Chief (3)

Minister of Mines, B.C., Ann. Repts.: 1921, p. 136; 1929, pp. 316, 317.
Cairnes, 1935, pp. 14, 15.

California and Clipper (5)

Cairnes, 1935, p. 23.

Marion (6)

Minister of Mines, B.C., Ann. Repts.: 1900, p. 827; 1904, p. 202.
Cairnes, 1935, pp. 78, 79.

Hartney (7)

Minister of Mines, B.C., Ann. Rept., 1946, pp. 165, 166.
Rept. of Zinc Commission, 1906, pp. 208, 209.
Cairnes, 1935, p. 51.

Silver Bell and Hustler (9)

Minister of Mines, B.C., Ann. Rept.: 1896, p. 55.
Cairnes, 1935, p. 123.

Echo and Graphic (11)

Minister of Mines, B.C., Ann. Repts.: 1915, p. 126; 1916, p. 197; 1917, pp. 157-158; 1918, p. 169; 1926, pp. 256, 257.
Cairnes, 1935, pp. 37, 38.

Alpha (12)

Minister of Mines, B.C., Ann. Repts.: 1893-1938.
Cairnes, 1935, pp. 136-141.

Noonday and Curley (18)

Minister of Mines, B.C., Ann. Repts.: 1896, p. 69; 1904, p. 173; 1918, p. 171; 1955, p. 64; 1956, p. 98.
Cairnes, 1935, p. 97.

Comstock (23)

Minister of Mines, B.C., Ann. Repts.: 1898, p. 1074; 1904, pp. 176, 177.
Cairnes, 1935, pp. 33, 34.

Fisher Maiden (24)

Minister of Mines, B.C., Ann. Repts.: 1896, p. 68; 1904, pp. 177,178; 1926, p. 257; 1956, pp. 97, 98.
Cairnes, 1935, pp. 41-43.

Ivanhoe and Elgin (25)

Minister of Mines, B.C., Ann. Repts.: 1893-1952.
McConnell, 1897a, p. 29.
Cairnes, 1935, pp. 63, 64.
Hedley, 1952, pp. 82-84.

Canadian and Adams (26, 27)

Minister of Mines, B.C., Ann. Repts.: 1896-1952.
Cairnes, 1935, pp. 24-27.
Hedley, 1952, pp. 69, 70.

Boss Fraction (28)

Minister of Mines, B.C., Ann. Rept.: 1923, p. 227.
Cairnes, 1935, p. 79.

Wakefield (30)

Minister of Mines, B.C., Ann. Repts.: 1903, p. 137; 1904, pp. 175, 176; 1929, p. 315; 1947, p. 170.
Rept. of Zinc Commission, 1906, pp. 215-219.
Cairnes, 1935, pp. 157-159.
Hedley, 1952, pp. 120-126.

Read and Tenderfoot (34)

Minister of Mines, B.C., Ann. Repts.: 1921, p. 135; 1926, p. 250; 1927, p. 267.
Cairnes, 1935, p. 28.

Sunshine and Yakima (36)

Minister of Mines, B.C., Ann. Repts.: 1938, pp. E25, 26; 1946, p. 163.
Cairnes, 1935, pp. 145, 146.
Hedley, 1952, p. 116.

Corinth (37)

Minister of Mines, B.C., Ann. Repts.: 1896, p. 55; 1938, pp. E25, 26; 1950, pp. 145, 146.
Cairnes, 1935, pp. 34, 35.
Hedley, 1952, pp. 75, 76.

Queen Bess (38)

Minister of Mines, B.C., Ann. Repts.: 1892-1951.
Cairnes, 1935, pp. 100-103.
Hedley, 1952, pp. 98-102.

Palmita (39)

Minister of Mines, B.C., Ann. Repts.: 1936, p. E53; 1937, p. E51; 1951, p. 172.
Hedley, 1952, pp. 95, 96.

Victor (40)

Minister of Mines, B.C., Ann. Repts.: 1900-1956.
Cairnes, 1935, pp. 153-155.
Hedley, 1952, pp. 117-120.

Cinderella (41)

Minister of Mines, B.C., Ann. Repts.: 1924, p. 196; 1952, p. 176.
Cairnes, 1935, pp. 30, 31.
Hedley, 1952, p. 74.

Lone Bachelor (42)

Minister of Mines, B.C., Ann. Repts.: 1952, p. 177; 1956, p. 95.
Cairnes, 1935, pp. 68, 69.
Hedley, 1952, pp. 85, 86.

Hinkley (43)

Minister of Mines, B.C., Ann. Repts.: 1924, p. 197; 1955, p. 63.
Hedley, 1952, p. 79.

71994-8- -10

Silver Ridge (44)

Minister of Mines, B.C., Ann. Repts.: 1946, p. 164; 1951, p. 172.
Hedley, 1952, p. 68.

Black Colt (45)

Minister of Mines, B.C., Ann. Repts.: 1926, p. 251; 1929, p. 308; 1930, pp. 248, 249; 1949, p. 187.
Cairnes, 1935, pp. 16, 17.
Hedley, 1952, pp. 68, 69, 117.

Silverite (46)

Minister of Mines, B.C., Ann. Rept., 1949, p. 187.
Cairnes, 1935, pp. 16, 17.
Hedley, 1952, pp. 116, 117.

Elkhorn (47)

Minister of Mines, B.C., Ann. Repts.: 1907, p. 99; 1927, p. 274; 1951, p. 166.
Cairnes, 1935, pp. 39, 40.
Hedley, 1952, p. 78.

New Springfield (48)

Hedley, 1952, p. 93.

Wonderful (49)

Minister of Mines, B.C., Ann. Repts.: 1892-1956.
Cairnes, 1935, pp. 163-165.
Hedley, 1952, pp. 122-126.

Ruth-Hope (51)

Minister of Mines, B.C., Ann. Repts.: 1895-1956.
Cairnes, 1935, pp. 116-122.
Hedley, 1952, pp. 103-107.

Sapphire (55)

Cairnes, 1935, p. 122.

Majestic and Unexpected (56)

Minister of Mines, B.C., Ann. Repts.: 1896, p. 85; 1904, p. 202; 1929, p. 307.
Cairnes, 1935, p. 75.

Victoria (58)

Minister of Mines, B.C., Ann Rept., 1925, p. 244.
Cairnes, 1935, pp. 155, 156.

Silversmith-Slocan Star (61)

Minister of Mines, B.C., Ann. Repts.: 1892-1956.
Cairnes, 1935, pp. 124-129.
Hedley, 1952, pp. 108-116.

Slocan King (62)

Minister of Mines, B.C., Ann. Repts.: 1926, p. 247; 1927, pp. 271, 272; 1928, p. 286; 1953, p. 138.
Cairnes, 1935, pp. 130, 131.
Hedley, 1952, p. 111.

Freddy Lee (63)

Minister of Mines, B.C., Ann. Repts.: 1892, p. 531; 1893, p. 1060; 1928, p. 294.
Cairnes, 1935, pp. 31-33.

Colonial (64)

Minister of Mines, B.C., Ann. Rept., 1928, p. 294.
Cairnes, 1935, pp. 31, 33.

Chicago (65)

Cairnes, 1935, pp. 31, 33.

Leadsmith (Noonday) (66)

Minister of Mines, B.C., Ann. Repts.: 1893, p. 1066; 1926, p. 250; 1929, p. 306; 1951, p. 170.
Cairnes, 1935, pp. 64, 65.

R. E. Lee (68)

Minister of Mines, B.C., Ann. Repts.: 1896, p. 60; 1898, p. 1074; 1923, p. 224.
McConnell, 1897a, p. 31.
Cairnes, 1935, pp. 112, 113.

Ajax (69)

Minister of Mines, B.C., Ann. Repts.: 1896, p. 58; 1898, p. 1074; 1911, p. 144.
Cairnes, 1935, pp. 1-3.

Last Chance (70)

Minister of Mines, B.C., Ann. Repts.: 1896-1956.
McConnell, 1897a, pp. 30, 31.
Cairnes, 1935, pp. 5-11.

American Boy (71)

Minister of Mines, B.C., Ann. Repts.: 1922, p. 199; 1923, p. 224; 1956, p. 94.
Cairnes, 1935, pp. 5-11.

Noble Five (72)

Minister of Mines, B.C., Ann. Repts.: 1892-1956.
Rept. of Zinc Commission, 1906, pp. 256-258.
Cairnes, 1935, pp. 91-97.
Hedley, 1952, p. 57.

Slocan Sovereign (73)

Minister of Mines, B.C., Ann. Repts.: 1907, p. 99; 1951, p. 170.
Cairnes, 1935, pp. 131-133.

Omega (75)

Cairnes, 1935, p. 107.

Number One (76)

Cairnes, 1935, pp. 107, 111.

71994-8—10½

Blue Bird (Bluebird) (79)

Minister of Mines, B.C., Ann. Repts.: 1928, p. 287; 1952, p. 175.
McConnell, 1897a, p. 34.
Cairnes, 1935, pp. 17-20.

Chambers (80)

Minister of Mines, B.C., Ann. Repts.: 1904, p. 191; 1922, p. 200.
Cairnes, 1935, p. 30.

Shady Fraction (Gem) (81)

Minister of Mines, B.C., Ann. Repts.: 1925, p. 224; 1950, p. 145.
Cairnes, 1935, pp. 48, 49.

Vulture (83)

Minister of Mines, B.C., Ann. Rept., 1952, p. 175.

Home Rule (84)

Minister of Mines, B.C., Ann. Repts.: 1928, p. 288; 1949, p. 189.
Cairnes, 1935, pp. 49, 50.

Bell, Sunset, and Trade Dollar (87, 86 and 85)

Minister of Mines, B.C., Ann. Repts.: 1896-1948.
Rept. of Zinc Commission, 1906, pp. 181, 182.
Cairnes, 1935, pp. 141-145.

Echo and Almeda (88)

Rept. of Zinc Commission, 1906, pp. 182, 183.
Cairnes, 1935, pp. 214, 215.

Boadicea (91)

Minister of Mines, B.C., Ann. Repts.: 1926, p. 265; 1937, pp. A38, E50.
Cairnes, 1935, pp. 198, 199.

Keno (92)

Cairnes, 1935, pp. 227, 228.

Rainbow (94)

Minister of Mines, B.C., Ann. Rept., 1926, p. 265.
Cairnes, 1935, pp. 242, 243.

Mohawk (Ten Day Man) (95)

Minister of Mines, B.C., Ann. Repts.: 1921, p. 133; 1926, p. 266.
Cairnes, 1935, pp. 235, 236.

Comstock-Virginia (96)

Minister of Mines, B.C., Ann. Rept., 1948, p. 141.
Cairnes, 1935, pp. 203, 204.

Flint (98)

Minister of Mines, B.C., Ann. Repts.: 1906, p. 143; 1911, p. 132; 1916, p. 196; 1917, p. 157; 1929, p. 322; 1953, p. 137.
Cairnes, 1935, pp. 217, 218.

Martin (99)

Minister of Mines, B.C., Ann. Rept., 1923, p. 212.
Cairnes, 1935, p. 234.

Montezuma (100)

Minister of Mines, B.C., Ann. Repts.: 1898, p. 1085; 1899, p. 701; 1904, p. 158; 1906, p. 143; 1908, p. 93; 1950, p. 138.
McConnell, 1897a, p. 33.
Rept. of Zinc Commission, 1906, p. 169.
Cairnes, 1935, pp. 237, 238.

Black Bear (101)

Minister of Mines, B.C., Ann. Rept., 1920, p. 123.
Cairnes, 1935, p. 195.

Liberty (102)

Minister of Mines, B.C., Ann. Rept., 1899, p. 703.
Cairnes, 1935, pp. 228, 229.

Gold Cure (106)

Cairnes,1935, p. 220.

Gibson (Daybreak) (107)

Minister of Mines, B.C., Ann. Repts.: 1917, p. 186; 1926, pp. 260, 261; 1927, p. 286.
Cairnes, 1935, pp. 218, 219.

Silver Bell (109)

Minister of Mines, B.C., Ann. Repts.: 1899, p. 704; 1919, pp. 120, 121; 1952, p. 165.
Cairnes, 1935, pp. 245, 246.

Index (111)

Minister of Mines, B.C., Ann. Repts.: 1919, p. 121; 1949, p. 184.
Cairnes, 1935, pp. 223, 224.

Silver Cup (115)

Minister of Mines, B.C., Ann. Rept., 1949, p. 183.

Silver Leaf (130)

Minister of Mines, B.C., Ann. Rept., 1947, p. 173.
Cairnes, 1935, pp. 88, 89.

White Hope (Paystreak) (132)

Minister of Mines, B.C., Ann. Repts.: 1928, pp. 296, 297; 1950, p. 150.
Cairnes, 1935, pp. 190, 191.

Speculator (164)

Minister of Mines, B.C., Ann. Repts.: 1904, p. 166; 1951, p. 177.
Cairnes, 1935, pp. 185, 186.

Silver Reef (Rover) (197)

Minister of Mines, B.C., Ann. Repts.: 1921, p. 143; 1927, pp. 315, 316; 1929, pp. 344, 345.

Willcock (Ymir-Wilcox) (229)

Minister of Mines, B.C., Ann. Repts.: 1903, p. 147; 1904, p. 124; 1910, p. 106; 1915, pp. 152-154; 1933, p. 226; 1934, p. E13; 1943, p. 64.
Drysdale, 1917b, pp. 75-89.
Cockfield, 1936, pp. 42, 43.

Nevada (240)

Minister of Mines, B.C., Ann. Rept., 1915, p. 154.
Drysdale, 1917b, pp. 120, 121.
Cockfield, 1936, pp. 13-16.

Howard (Durango) (242)

Minister of Mines, B.C., Ann. Repts.: 1926, pp. 276-278; 1927, pp. 303-307; 1928, pp. 339-342; 1929, pp. 350, 351.
Drysdale, 1917b, p. 121.
Walker, 1934, pp. 70-73.

Iron Cap (Revell) (257)

Minister of Mines, B.C., Ann. Repts.: 1924, p. 193; 1952, p. 146.
Walker, 1934, pp. 69, 70.

Union (327)

Minister of Mines, B.C., Ann. Rept., 1946, p. 138.

Sunset (328)

Minister of Mines, B.C., Ann. Rept., 1952, p. 143.

Silver-lead-zinc Deposits, With or Without Minor Gold and Cadmium

Mineral deposits yielding the above metals approximately in the order of value listed occupy two major and two minor zones within the map-area. The most important of these zones extends from the vicinity of New Denver southeastward to the Ontario No. 2 and Baltimore properties. This zone is to a degree peripheral to the major lead-silver deposits zone, particularly in the northwestern part. In this silver-lead-zinc zone there are some exceptions to the general order of value

of metals. In the Buster, Hewitt, and B.N.A., sphalerite is more abundant than galena, but, conversely, the Apex, Alamo, Evening and Jennie, Jennie Lind, Mercury and Silver Bell, Redress, Madison, Reco, Grey Copper, Mountain Con, Ontario No. 2, and Baltimore have yielded little or no zinc. In the cases of the minor producers this may be because zinc exacted a penalty on the smelters, particularly in the early years of mining, and was not reported. Only in the Bismark, Ontario No. 2, Violet, and Dayton properties has sphalerite not been observed. The Utica has produced a minor amount of antimony.

The host rocks in this zone, except for the Mountain Con, Revenue, Violet, and Ontario No. 2 deposits which are in Nelson porphyritic granite, are sedimentary rocks of the Slocan group, and comprise one or more of quartzite, argillite, slate, and minor limestone, and calcareous or argillaceous facies of these. The Surprise lodes are partly in quartz porphyry. All the deposits are fault-fissure lodes except in those like the Bismark where there is a minor amount of replacement of the wall-rocks, if they are limestone. The gangue minerals in the veins vary from place to place, and comprise quartz, siderite, or calcite, or combinations of these in various orders of abundance. All four deposits in this zone that occur in granite, however, contain only quartz as the gangue. The ore minerals are galena and sphalerite with, usually, one or more of the silver minerals grey copper, ruby silver, native silver, and others that have not been identified. In the Evening and Jennie, however, only galena and oxidized products are reported. Many of the veins contain pyrite and some contain a little chalcopyrite. Those of the Hewitt mine contain some pyrrhotite.

The second major zone extends from the Hamilton westward through the Molly Gibson to the Olsen. These deposits occur in coarse-grained porphyritic granite of the Nelson batholith, crushed or mylonitized on the Hamilton, Happy Medium, and Arlington properties. All deposits in the zone are fault-fissure lodes except the Arlington where the ore is disseminated in crushed granite or granodiorite. In most of the veins quartz is the dominant gangue mineral, but in a few some calcite is also present. In the upper levels of the Enterprise mine quartz predominates, but in the lower levels siderite and calcite are more abundant. In the Ottawa mine barite is a fairly abundant gangue mineral, and is present also in the nearby Tamarac, Anna, and Little Tim properties. Some chalcedony is reported in the Bondholder vein. Ore minerals are commonly galena and sphalerite, generally with grey copper, ruby silver, native silver, and, at the Anna, stephanite. Pyrite and a little chalcopyrite are present in several of the veins, but only on the Anna has any copper been produced.

Many of the properties in the above two zones have been classified as 'dry ores', that is they are composed mainly of quartz, and contain abundant silver, but little or no lead and zinc. Among these are the Apex, Madison (in part), Violet, Ontario No. 2, Ottawa, Arlington, Slocan Prince, Alice S., and Lily B. The last five of these fit most nearly into the category of 'dry ore', and are adjacent to the truly 'dry ores' of the silver-gold mineral deposits zone.

In the southeast part of the map-area only two deposits of the silver-lead-zinc type have produced ore. The Maple Leaf in Porcupine Creek valley is typical of the group. It comprises veins of quartz in quartzite and schist, and contains argentiferous galena, sphalerite, and pyrite. On Aspen Creek, to the south, the Aspen mine has produced silver, lead, zinc, and gold in that order of value. The deposit, however, appears to contain much more sphalerite than galena, and should more properly be classified as a zinc-lead-silver deposit, of which it is typical; it comprises disseminated sulphides in dolomitized limestone.

The remainder of the silver-lead-zinc deposits form a small cluster of four properties on the south side of the Rossland camp. These are the Nature Boy, Mayflower, Red Eagle, and Hattie Brown. The last two have yielded no zinc. Of the four, only the Mayflower has been adequately described. It differs from the type deposit in containing more sphalerite than galena, and by the presence of pyrrhotite and arsenopyrite. It is a fault-fissure vein of quartz and calcite in augite andesite in which some ore minerals are disseminated, one of which has been identified as boulangerite. The four properties in this group are the only ones of this type that occur in volcanic rocks.

Bosun (1)

References: Minister of Mines, B.C., Ann. Repts.: 1898-1956. Rept. of Zinc Commission, 1906, pp. 209-213. Cairnes, 1934, p. 86; 1935, pp. 20-23.

The Bosun mine is on the east shore of Slocan Lake, about 1½ miles south of New Denver. It is owned by New Santiago Mines Limited, formed in 1951 by reorganization of Santiago Mines Limited, who acquired it in 1945 from Colin J. Campbell of New Denver, B.C. The property consists of eight Crown-granted claims and fractions.

Production, which began in 1898, totalled 69,516 tons of ore up to the end of 1952. This ore yielded 1,938,812 ounces silver, 10,795,026 pounds lead, 6,873,851 pounds zinc, 101 ounces gold, and 928 pounds cadmium. The property was examined in June 1950 by A. B. Irwin of the Geological Survey.

Along the shore of Slocan Lake north of the compressor-house the rocks are well exposed and comprise impure quartzite and slate, some tuffaceous, and a few beds of limestone. These strike about N65°W and dip 45° to 75°SW, with some reversals of dip. This trend continues across the Bosun property. The beds, according to Cairnes, are transected by dykes of melanocratic biotite quartz monzonite from 2 or 3 feet to 85 feet in width.

The vein has been developed by six main adits, several intermediate levels, and two levels (Nos. 7 and 8) reached by shafts. (*See* Figure 9, in pocket.) Two intermediate levels have been driven between No. 7 and No. 8 levels and since 1950 others have been driven above No. 7 level. The main working level, No. 6, is about 3,700 feet long and passes beneath the highway about 40 feet above the high water level of the lake.

The vein matter occupies a fracture that strikes on the average N60°E and dips from 35° to 65°SE. The gangue consists of quartz and siderite, with a little

calcite, and the metallic minerals are galena, sphalerite, tetrahedrite, ruby silver, native silver, possibly other silver minerals, and a little chalcopyrite.

The vein is discontinuous, varying in width from a few inches to more than 5 feet. It is intersected by several cross-faults that strike N45° to 55°W, nearly parallel with the bedding planes. In the eastern part of the mine there is a strong shear that strikes N60°W and dips 50° to 85°SW, from which one sharply defined branch shear dips 75° to 80°NE. Cairnes has pointed out that the "lode was most difficult to follow, for it presented numerous small irregularities, the footwall lacked definition, and slips or faults leading off into the hanging wall were common . . . the structure . . . is further complicated . . . by a split commencing a little below No. 4 level."

Along the vein from west to east are three orebodies known as the West, Central, and Third, respectively. The West orebody rakes westward at a low angle, but the Central and Third do not show this trend. The company operated the West orebody on No. 6 level in 1947, where the zinc content was high. In 1950 and subsequently, the Central orebody was worked between No. 5 and No. 8 levels. The Central orebody has a high zinc content on and above No. 5 level but on No. 8 level galena is much more abundant than sphalerite. Smelter returns show that the silver content of ore rich in zinc is only slightly less than that rich in lead.

On No. 8 level southwest of the Pilot shaft, the vein is clean and about a foot wide. It contains galena in coarse cubes and lenses, and irregular strands of fine-grained galena that cut small bunches of sphalerite. There the vein strikes N25° to 50°E and dips about 60°SE, and is exposed for 15 feet to where it pinches out to the southwest. East of the shaft the vein strikes N50°E and dips 45°SE. It is composed of irregular stringers of quartz and siderite with small bunches of galena. Above, in the 730 sublevel, the vein is 1 foot wide but contains brecciated wall-rock.

The company ceased work in 1953 and allowed the lower levels to flood. Unwatering was begun in 1955 but operations were suspended before the lower levels were accessible. In 1956 a lease was given to W. H. McLeod of Silverton who, with two partners, attempted to locate a vein reported in a diamond-drill hole many years previously.

Metallic (Midnight) (17)

References: Minister of Mines, B.C., Ann. Repts.: 1918, p. 171; 1923, p. 228; 1924, p. 199; 1929, p. 314; 1948, p. 147; 1949, p. 190; 1950, p. 149. Cairnes, 1935, p. 82.

The Metallic property, comprising five claims held by location, is owned by A. E. MacAulay, L. S. MacAulay, and R. S. White of Silverton. It is about 2 miles from Silverton and is served by a short branch road from the Hewitt mine road.

The Midnight claim, Crown-granted in 1900, subsequently reverted to the Crown and was incorporated into the group. Initial production, in 1909, was from the Metallic claim. Further shipments were made in 1922 to 1927, in 1929, 1935, 1938, 1940, and from 1948 to 1950, mostly by lessees. In all 230 tons of

ore was shipped containing 15,810 ounces silver, 56,933 pounds lead, 51,259 pounds zinc, and 3 ounces gold. The property was examined in June 1950 by A. B. Irwin of the Geological Survey.

The country rock is massive argillite that forms a large pendant surrounded by Nelson granite. The vein is a fissure filling of quartz and calcite that cements brecciated fragments of argillite. It varies in width from a few inches to perhaps 10 feet and has been explored for 600 feet in the lower tunnel and 350 feet in the upper, which is 65 feet above the lower. The two levels are connected by a raise. The vein strikes from N60°E to N80°W, the average strike being N75°E. The dip varies from 35° to 50°N. The walls of the vein are sharply defined. The vein is terminated in the east against a wide fault zone that dips gently east.

In 1950 the upper adit was partly caved, but in one of the faces a seam of sphalerite about 6 inches wide occurs with some sparsely disseminated galena. In the lower adit four stopes were noted; of these the three nearest the portal were being worked. Metallic minerals in the vein are sphalerite, galena, and tetrahedrite. Cairnes observed under the microscope, a little ruby silver associated with the galena.

Van Roi (22)

References: Minister of Mines, B.C., Ann. Repts.: 1893-1956. Cairnes, 1935, pp. 149-153.

The Van Roi property consists of the following Crown-granted claims: the Vancouver No. 2, Mountain Boomer, Ziler, Humboldt, Van Roi fraction, El Camino No. 2, Moccasin fraction, Vancouver fraction, Pelly, Ricardo, Burr, Tramway fraction, Mackinaw, Silver Star, and Napier. In addition it includes the eastern half of the Prior claim held jointly with the owners of the Hewitt property. These claims are owned by Slocan Van Roi Mines, Limited, in which Transcontinental Resources Limited has directional control. The mine is on the south side of Silverton Creek between Maurier and Twigg Creeks, and is accessible by two roads from Silverton, each about 6 miles long. The older road follows Silverton Creek but the newer road, which has more gentle grades and curves, is via the Hewitt mine.

The original claims were staked in 1892 and the initial production of ore was in 1893. The property has changed hands many times and has been operated spasmodically, sometimes by lessees. The present company was formed in 1955 by a reorganization of Van Roi Consolidated Mines Limited, who purchased the property in 1950 from Van Roi Mines (1947) Limited. A mill was built in 1950 and began operation in September 1950 but it was closed from 1952 to March 1956.

Total production of ore from 1893 to 1955 inclusive was 299,949 tons containing 2,609,573 ounces silver, 16,962,409 pounds lead, 15,161,368 pounds zinc, 26,817 pounds cadmium, and 276 ounces gold. The property was examined in July 1950 by A. B. Irwin of the Geological Survey but only a part of more than 5,000 feet of horizontal workings was seen.

The country rock is largely quartzite, with some limestone and argillite and gradations between these rock types, all of the Slocan group. These sedimentary

rocks are somewhat metamorphosed and silicified, particularly the more calcareous facies. In the vicinity of the mine they vary in strike from N35° to 75°E and dip from 55° to 80°NW, but locally have been deformed beyond these limits. Examination of ripple-marks at two places near the portal of No. 4 level showed that the beds there were not overturned, but elsewhere there may be isoclinal folds that were unrecognized, due to the dirty condition of the walls. The strata are intersected by a few dykes, up to 50 feet wide, which range in composition from felsite to diorite.

The vein system occupies a complex zone of shears or faults that trend roughly N60°E and dip 70°NW. The system has been divided by Cairnes into the "North and South lodes" but other veins exist that cannot be classified thus. These are in branching shears and are sufficiently well mineralized to be worth exploring.

On both main lodes the direction of movement indicated by mullion is predominantly dip-slip with a smaller strike-slip component, so that the net movement is probably normal and left-handed. One determination of movement on slickensides on the South lode showed a predominant strike-slip displacement, but Irwin regarded this as probably representing late movement of minor importance. A few bedding faults occurring in the Van Roi No. 4 west crosscut also show strike-slip movement, indicated by small drag-folds.

According to Cairnes the North and South lodes are perhaps 3,000 feet long and have been explored vertically for 1,200 feet. They range in width up to 10 feet, and in one place to 20 feet. Within the lodes are ore-shoots that may be more than 300 feet in greatest dimension. These rake steeply west, are erratically distributed, and have vague boundaries established by assay.

The vein matter consists of quartz with minor siderite and calcite, in many places cementing brecciated wall-rock. Metallic minerals present in the veins are galena, sphalerite, grey copper, ruby silver, some native silver, pyrite, and a little chalcopyrite.

Utica (93)

References: Minister of Mines, B.C., Ann. Repts.: 1892-1956. Cairnes, 1935, pp. 252-256.

The Utica property is near the headwaters of Utica Creek, a tributary of Twelve Mile Creek which enters Kaslo River about 12 miles above Kaslo. It may be reached by a road about 5 miles long from the Kaslo-New Denver highway. The property comprises eleven Crown-granted claims—the Sol, Sol No. 1, Pay Ore fraction, Alice No. 5, Hercules, Colorado, Andrew J., Utica, Rock Bolder, Minerva fraction, and Time and Tide—and 13 other claims held by location. It is owned by Utica Mines (1937) Limited.

The first claims were staked in 1892 but no ore was shipped until 1909 when a shipment of 34 tons of silver-lead ore is recorded. Shipments of both silver-lead and zinc ore, which commenced in 1913, were almost continuous until 1922.

From 1923 to 1925 and in 1927 the owners were engaged in development work, and it appears that little or no ore was shipped. In 1928 the ownership changed hands and after further development in 1929 on the lowest level, on which the lead was said to be intersected, the mine was closed. Small amounts of ore were produced in 1935, 1937, and in 1938 when the property was under lease. In 1940 the mine was reopened by the present company, which was formed by a reorganization of the previous owners; ore mined during the summer months was shipped from 1946 to 1951 inclusive as well as in 1953. In 1956, 193 tons of ore was shipped.

Total production from 1909 to 1956 inclusive is 6,508 tons of ore containing 772,928 ounces silver, 1,786,440 pounds lead, 419,252 pounds zinc, 7 ounces gold, and 186 pounds antimony. The mine was examined in July 1950 by A. B. Irwin of the Geological Survey, who confined most of his observations to the west vein on No. 5 sublevel, where mining was in progress.

The property is underlain by argillite and limestone that have been highly deformed and metamorphosed, much of the argillite being altered to andalusite schist. These beds strike roughly northwest and dip 25° to 60°NE, but they are complexly folded as can be seen on the upper slopes of Paddy Peak. The sedimentary rocks there are intruded by three small, irregular stocks of medium-grained biotite granite and by a number of dykes, mainly of acidic composition.

The workings include the five adits ranging in elevation from about 6,150 to 7,670 feet that were described by Cairnes and a raise from No. 7 level (formerly known as No. 5) to No. 4 level. This raise was driven in 1947 as an ore-pass and provides access to a sublevel (No. 5).

Two veins are developed. Early production was largely from the East vein, which is nearly parallel with the West vein and 90 to 130 feet from it. The strike of the veins is roughly N40°E and the dip 60° to 70°SE. The East vein varies in width from a few inches to 7 feet and has been stoped for a length of about 700 feet on No. 4 level; it was continuous for 264 feet on the dip above that level. The West vein ranges in width from 3 to 20 feet and contains an ore shoot more than 600 feet long.

The gangue minerals are, in decreasing order of abundance, calcite, siderite, and quartz. These form lenses, pockets, and stringers cementing sheared and brecciated wall-rock between well-marked, narrow zones of gouge. Much of the argillite has been converted to graphite schist. Slickensides in No. 5 sublevel indicate dip movement, but this appears to be the latest movement, as small drag-folds suggest a strike-slip, left-handed displacement. Calcite is later than siderite and fills interstices in brecciated siderite.

The metallic minerals in the vein are galena and sphalerite. Presumably silver minerals are present because the zinc ore is said to have a higher silver content than the lead ore. No silver minerals were however seen by Cairnes and none was observed in the single ore specimen that was available to the writer.

B.N.A. (108)

References: Minister of Mines, B.C., Ann. Repts.: 1904, pp. 295, 297; 1908, p. 93; 1909, p. 106; 1950, p. 138; 1951, p. 163; 1952, p. 172. Rept. of Zinc Commission, 1906, pp. 268, 269. Cairnes, 1935, p. 198.

The B.N.A. property consists of the B.N.A., Humming Bird, Onoka, and Lynx fraction claims, all Crown-granted in 1904 to B.N.A. Mines Limited. Since 1950 it has been operated by B.N.A. Mines Limited Liability, 620 View Street, Victoria, B.C. The mine is on the north side of Kyawats Creek, a tributary of Keen Creek, and is served by a tractor road 2 miles long, that branches from the Keen Creek road about 14 miles from Kaslo.

Production from the mine was small and intermittent from 1900 to 1909; the mine remained inactive until 1949 when the present owners reopened No. 6 adit and in 1950 started to build the road to the mine. A small amount of ore was shipped in 1950, 1951, and 1952. Total production of ore from 1900 to 1952 is 99 tons, which yielded 13,032 ounces silver, 21,533 pounds zinc, 18,587 pounds lead, and 3 ounces gold. A brief examination of the mine was made in July 1950 by A. B. Irwin of the Geological Survey.

Bedrock on the property is banded argillite and quartzite of the Slocan group that forms a narrow belt flanked by porphyritic Nelson granite. The sedimentary rocks are metamorphosed and silicified. The strike of the beds is about N55°E, roughly parallel with the trend of the belt. The beds dip steeply for the most part, more commonly southeast than northwest. No top determinations were made.

In 1950 only No. 6 tunnel was accessible, having been reopened the previous year. In this working argillite and quartzite strike on the average N40°E and dip 75° to 80°SE, but locally variations in this attitude were noted. The lode is nearly parallel with the bedding and strikes from N30° to 50°E and dips steeply southeast. It is a fissure filling 5 to 25 feet wide, and consists of fragments of wall-rocks and gouge cemented with calcite and a little quartz. It contains irregular streaks and pockets of sphalerite and galena, with some pyrite and native silver.

Myrtle (Alma) (137)

References: Minister of Mines, B.C., Ann. Repts.: 1901, p. 1027; 1903, p. 138; 1907, p. 101; 1924, pp. 201, 202; 1941, p. 75. Cairnes, 1935, pp. 166, 167.

The Myrtle group of claims, known for a time as the Alma, is near the head of Memphis Creek at an elevation of about 5,400 feet and is owned by Roy F. Ainslee of Slocan City. The Alma and Myrtle claims were Crown-granted in 1906 and 1907 respectively, but subsequently reverted to the Crown. The present claims are held by virtue of assessment work. The property was developed in the years 1901 to 1907 inclusive, and subsequently in 1924, 1935, 1940, and 1941. Ore shipments, made in 1907 and 1935, totalled 15 tons containing 1,597 ounces silver, 496 pounds zinc, and 329 pounds lead. The property was examined in August 1950 by A. B. Irwin of the Geological Survey.

The country rock is porphyritic Nelson granite that is bleached and silicified adjacent to the vein. The vein is in a sheared and brecciated zone that strikes

N40°E and dips 35° to 40°SE. This zone is encountered in the 100-level, which is 520 feet long and is driven S73°E. In this crosscut a small pegmatite dyke, a felsic dyke, three shear zones 2 to 4 feet wide, and a number of slips of small displacement occur. At 440 feet from the portal is a 5-foot shear zone followed by a breccia zone 15 feet wide and the main shear zone. From this point there is a short drift to the north from which an inclined raise has been driven up 46 feet to the 50-level. No vein material was noted in the shear zone to this point.

On the 50-level the shear zone is developed along 86 feet of drift and on a 40-foot inclined raise from the south end. The shear zone on this level contains small, lenticular masses of quartz and some calcite. These in turn contain small pods of galena and sphalerite with a little chalcopyrite. Cairnes reports that grey copper and native silver are also present.

Ottawa (149)

References: Minister of Mines, B.C., Ann. Repts.: 1896-1956. Cairnes, 1934, p. 88; 1935, pp. 182, 183.

The Ottawa property, consisting of thirty-one Crown-granted claims, is owned by the Ottawa Silver Mining and Milling Company Limited. It is on the northern slope of Springer Creek and is reached from Slocan City by a road 6 miles long.

The Ottawa claim was located in 1896 but development work was meagre until 1902 when it and some adjoining claims were acquired by a syndicate. Production of high-grade ore was steady until 1910. The property was purchased in 1913 by the Consolidated Mining and Smelting Company of Canada, Limited, which carried out more extensive development work until 1918. Shipments were made by the company and during some years by lessees until 1926.

In 1935 the property was obtained by the present owners who built a 100-ton flotation mill in 1937, but production never equalled that of 1904. Much of the work after 1938 was done under lease or option. Options were held in 1950 and 1951 by Violamac Mines (B.C.) Limited, and later in 1951 and in 1952 by Harrison Drilling and Exploration Company Limited, which continued the option the following year under the name Hardex Mines Limited. The owners resumed operations in 1956 and shipped 10 tons of ore.

Production of ore between 1903 and 1952 totalled 8,628 tons, containing 1,094,843 ounces silver, 755,489 pounds lead, 3,662 pounds zinc, and 15 ounces gold.

The lowest level (No. 8), which was active in 1950, was examined by A. B. Irwin of the Geological Survey in June 1950.

The property is underlain by coarse-grained, porphyritic Nelson granite cut by small dykes of felsite and lamprophyre.

The ore occurs in a broad, sheared and brecciated zone in granite. It strikes roughly north and dips 20° to 45°E. Within this zone are two lodes known as the West or Noble and the East or Ottawa veins that are 20 to 150 feet apart

(*see* Figure 10, in pocket). According to Cairnes most of the production from the higher levels has come from the East lode. In No. 8 level the West lode is wider and more continuous than the East lode.

The gangue of the veins is chiefly quartz and contains various amounts of native silver, argentite, tetrahedrite, galena, sphalerite, pyrite, and a little chalcopyrite. Cairnes states that barite is a common gangue mineral and that it is reported to be most abundant where the silver values are the greatest.

Irwin noted that in the West vein on No. 8 level, where stoping was being done in 1950, the vein strikes N25° to 40°E and dips 20° SE and that the foot-wall is marked by a few inches of gouge. In contrast the hanging-wall is irregular. The lode there is 1 foot thick and 30 feet long, but rakes S25°E at an angle of 15°. This ore contained an average of 250 ounces silver a ton. At the face of the main drift the vein is only 1 inch to 2 inches wide but is sharply defined.

The East lode on No. 8 level is strong and is composed of 2 to 3 feet of gouge and breccia cemented by quartz. It strikes N10°W and dips 30° to 40°E.

Little Tim (153)

References: Minister of Mines, B.C., Ann. Repts.: 1918, p. 195; 1919, p. 126; 1951, p. 177; 1952, p. 180. Cairnes, 1935, pp. 178, 179.

The Little Tim (L.T.) property, at the head of Little Tim Creek a tributary of Springer Creek, is owned by D. B. O'Neail of Slocan City. It is accessible by a road 2.7 miles long from the Ottawa mine, which is 5 miles from Slocan City. The property consists of the Victory V, V-day, Ute fraction, Radar No. 1, and Radar No. 2 claims, all held by location.

The property was staked in 1918 by the present owner who worked it intermittently until 1947. In 1951 and 1952, it was optioned by Harrison Drilling and Exploration Company Limited, later known as Hardex Mines Limited. Total production of ore from 1918 to 1952 inclusive was 136 tons, which yielded 22,838 ounces silver, 31,838 pounds lead, and 7,432 pounds zinc. The property was examined in August 1950 by A. B. Irwin of the Geological Survey.

The country rock is coarse-grained, porphyritic Nelson granite. The workings explore two veins and there is probably a third vein southeast of the main vein and parallel with it. The upper workings, comprising two adits and a shaft, explore the vein that is 300 feet northwest of the main vein. These workings are now inaccessible but were described by Cairnes.

The main vein (*see* Figure 11), called by Cairnes "the southeast lode", is developed by three adits, Nos. 1, 3, and 4, that range in elevation from 6,783 to 6,624 feet respectively. On all three levels the main vein strikes N55° to 65°E and dips 45° to 70°SE. It occupies a fissure mainly 6 inches, but in places up to 2 feet, wide. In the wider parts it contains brecciated wall-rock but elsewhere contains only gouge. The vein is largely quartz and ranges in width from 2 to 6 inches, averaging 3 inches. On No. 2 level, which is the longest, the vein has been followed for 235 feet, but it is offset about 30 feet to the left, 65 feet from the portal.

The metallic minerals in the main vein are galena, sphalerite, tetrahedrite, and a little chalcopyrite. Gangue minerals are quartz, calcite, and, according to Cairnes, some barite.

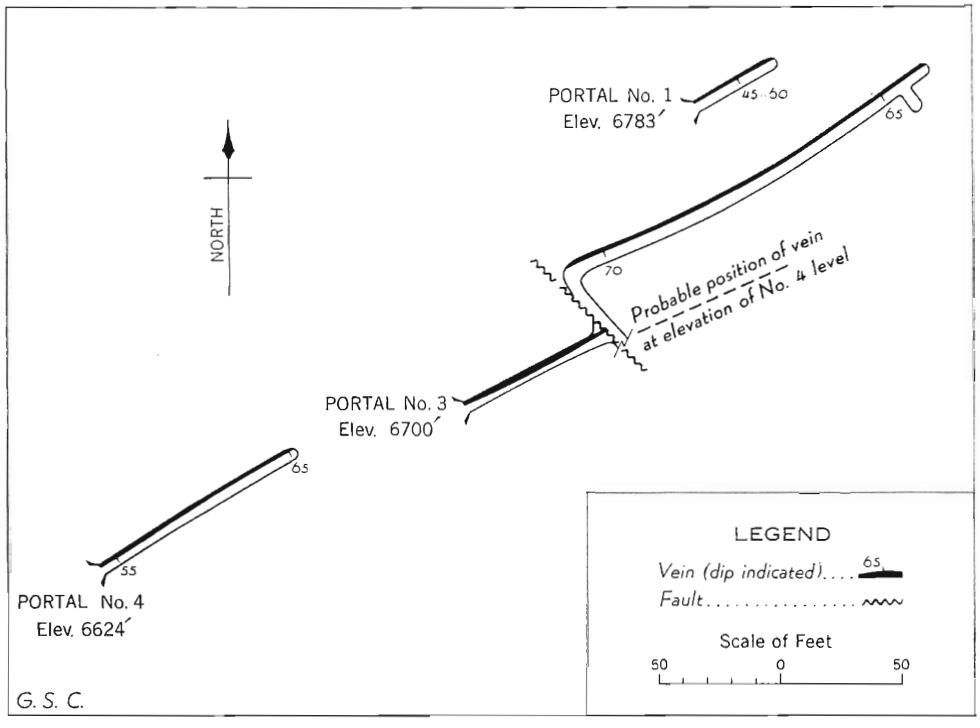


Figure 11. *Plan of Little Tim mine (geology by A. B. Irwin, 1950).*

Enterprise (157)

References: Minister of Mines, B.C., Ann. Repts.: 1894-1956. Rept. of Zinc Commission, 1906, p. 225. Cairnes, 1934, p. 99; 1935, pp. 172-174. Hedley, 1952, p. 122.

The Enterprise property consists of the Enterprise, Enterprise fraction, Slocan Queen, Empress fraction, Rainbow, Iron Horse, No. 2, Sunset, Millsite, Montezuma, and Sunrise Crown-granted claims. It is on the south side of Enterprise Creek and may be reached by road, about 7 miles long, from the Slocan City-New Denver highway. The main vein was discovered in 1894 by R. Kirkwood and J. McKinnon, who sold it a year or two later. It was soon acquired by the Enterprise (B.C.) Mines Company Limited which operated it until 1901 and subsequently for many years it was operated by lessees. In 1928 it was purchased by Yankee Girl Consolidated Mines Limited, which was obliged to close it in 1930. From 1941 to 1943 the property was leased by S. N. Ross and associates of Nelson, who were engaged mainly in the treating of the old tailings dump. In

1944 Western Exploration Company Limited purchased the property and operated it until early in 1953. It was leased for a short time in 1953 but has since remained inactive.

Production from the property began in 1896 and 10,198 tons of ore had been mined up to the end of 1942. This yielded 1,004,395 ounces silver, 3,454,806 pounds lead, 1,817,018 pounds zinc, and 5 ounces gold. The property was examined in June 1950 by A. B. Irwin of the Geological Survey.

The country rock is mainly coarse-grained, porphyritic Nelson granite containing numerous irregular bodies of more basic material of various sizes that appear to be older than the porphyritic granite. These rocks are cut by small dykes up to 5 feet wide ranging in composition from hornblende porphyry to olivine-bearing lamprophyre. Cairnes states that two of the lamprophyre dykes cut the lode, but that others are pre-mineral and are disrupted by faults that likewise displace the vein.

Two veins are known on the property, the main Enterprise vein being by far the more important. The smaller vein has been explored by a single adit. The main vein has been developed by nine adits and several raises serving eight levels and several sublevels (*see* Figure 13, in pocket). In 1950, the levels above No. 5 were largely caved but the lower levels were active.

The main vein is continuous over a horizontal distance of more than 2,000 feet and is developed over a vertical distance of more than 1,000 feet. The vein strikes N50°E and dips 60° to 85°SE. It varies in width, with a maximum of 2 feet and an average of less than a foot.

The vein is offset along its strike by three faults and several small slips of very little displacement. The faults are numbered successively toward the southwest (*see* Figures 12 and 13, in pocket). No. 1 fault was encountered only in No. 5 and No. 7 levels; No. 6 and No. 8 levels were not sufficiently advanced at the time of examination and the upper levels are above the surface trace of the fault. The strike of No. 1 fault is N50° to 70°W and the dip about 75°N. The fault contains 6 inches to 1 foot of gouge. The apparent displacement is to the right. No. 2 fault is intersected on Nos. 4, 5, and 7 levels and is a shear zone 20 to 30 feet wide. It strikes north to N20°W and dips from 75°E to nearly vertically. The apparent displacement of the vein is about 90 feet to the left. No. 3 fault may be seen on the same levels as No. 2 fault and has very little gouge. It strikes N15°W and dips 75° to 80°E. The apparent displacement is about 10 feet to the right.

The vein on the upper levels was, according to Cairnes, largely of quartz containing galena, grey copper, and other silver-bearing minerals. Where it was examined by Irwin on the lower levels, carbonates, consisting of about equal proportions of calcite and siderite, are more abundant than quartz. Sphalerite is also more abundant in the lower levels. Most of the silver is contained in tetrahedrite but a fair proportion is derived from ruby silver.

The ore shoot is remarkably continuous and along the sixth level the vein has been stoped for 325 feet. The vein is widest in 616-stope on No. 6 level

71994-8—11

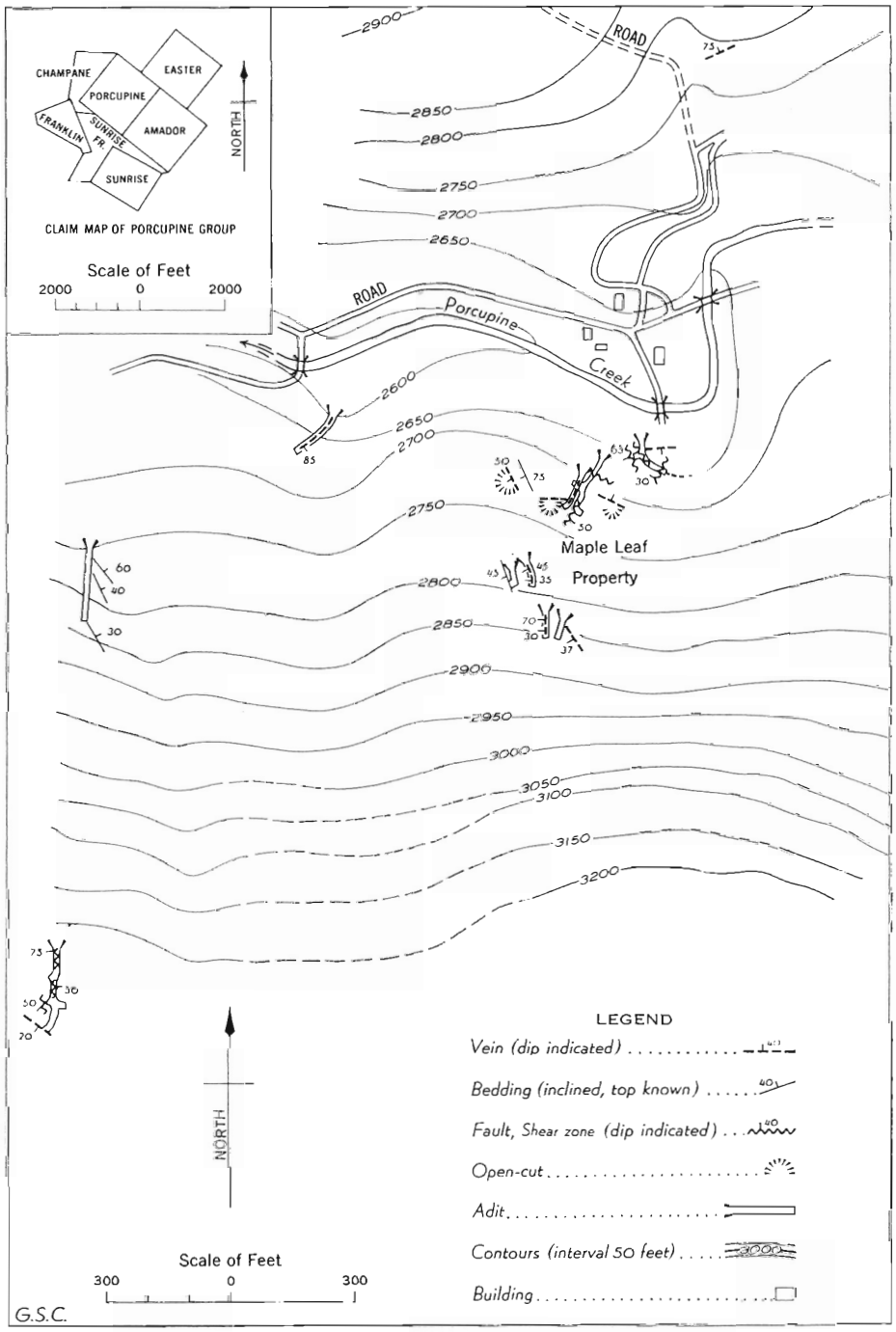


Figure 14. *Plan of Maple Leaf (Porcupine) property (after A. L. McAllister, 1951).*

where sphalerite occurs on the foot-wall and galena on the hanging-wall. Along the vein on No. 8 level, Irwin noted some bleaching of the dioritic wall-rock but not of the porphyritic granite. The ore shoot plunges northeast and so tends to be roughly parallel with the present topographic surface.

Maple Leaf (Porcupine) (239)

References: Minister of Mines, B.C., Ann. Repts.: 1925, p. 249; 1930, p. 273; 1939, p. 81; 1944, p. 61; 1948, p. 133. Drysdale, 1917b, pp. 3, 133. Cockfield, 1936, pp. 16, 17. McAllister, 1951, p. 40.

The Maple Leaf property, originally known as the Porcupine group, in 1926 and 1948 shipped a total of 44 tons of ore containing 405 ounces silver, 3,747 pounds lead, 3,832 pounds zinc, and 3 ounces gold. The property was examined by the writer in 1947, and is described by McAllister (1951, p. 40) as follows:

> The Maple Leaf property is on Porcupine Creek about 2 miles east of the Ymir-Salmo road. It embraces three full claims and four fractional claims of the Porcupine group (as shown on Figure 14). It is a lead-zinc prospect carrying a little gold and silver, copper, and traces of tin, in a quartz gangue. During the past few years the Maple Leaf Gold Mining Company has carried out intermittent exploration work.
>
> The rocks are highly silicified and granitized quartzites, argillaceous quartzites, and schist cut by numerous acidic, fine-grained dykes. Lamprophyre dykes in places cut the veins. The general trend of the structure is southeast.
>
> The showings on the property are exposed by ten short adits and several open-cuts (*see* Figure 14).
>
> The principal ore minerals are galena and sphalerite. These occur in several narrow, irregular quartz veins, some of which are rich in pyrite, which in places is also found in the wall-rocks well out from the veins. Pockets rich in silver have been mined. Several small shear zones are exposed in the workings.

Mayflower (283)

References: Minister of Mines, B.C., Ann. Repts.: 1896-1953, (especially 1949, pp. 157-163). Drysdale, 1915, pp. 168, 169.

The Mayflower Crown-granted claim is on the Canadian Pacific Railway, about a mile south of Rossland and is one of many claims in the vicinity owned by the Rossland Mining Company Limited. It is at an elevation of about 3,000 feet and is accessible by road from Rossland.

The claim was staked in 1890 and changed hands many times until it was acquired by the present owners in 1946. Total production of ore from 1907 to 1953 inclusive was 965 tons, which contained 12,114 ounces silver, 108,885 pounds zinc, 56,844 pounds lead, 133 ounces gold, and 164 pounds cadmium. The workings were examined by the writer in June 1950.

The workings comprise three adits and two shafts. Only one adit was accessible at the time of examination. In this adit, which is 300 feet long, the vein is encountered 75 feet from the portal, and is explored each way by drifts totalling nearly 400 feet in length.

The country rocks are porphyritic and non-porphyritic augite andesite intruded by dykes of porphyritic diorite and granite, and numerous dykes of lamprophyre.

71994-8—11½

According to White (Minister of Mines, B.C., Ann. Rept. 1949, p. 159) these rocks are overlain unconformably to the east of the property by a belt of conglomerate that is likewise cut by porphyritic granite.

Early work appears to have been concentrated upon a smaller vein that is parallel with the main vein and is exposed above the railway track. The main vein occupies a shear zone 2½ to 5 feet wide that strikes N50° to 60°W and dips 50° to 65°NE. This shear zone is less marked where it crosses the porphyritic diorite, but contains small veins of calcite with abundant pyrite. It has been traced underground for nearly 400 feet and, according to White, anomalies obtained by the self-potential method suggest that it is continuous to the northwest for 3,000 feet to the Blue Bird property.

The ore consists of sulphides disseminated in wall-rock traversed by veinlets and stringers of calcite and quartz. White places the metallic minerals in the following order of abundance: pyrite, pyrrhotite, sphalerite, arsenopyrite, galena, and boulangerite. Locally the ore is rudely banded, and is younger than the dyke-rocks, including lamprophyre, but it occurs only sparingly in these rocks.

Other properties of this type, together with selected references, are listed below.

Apex (2)

Minister of Mines, B.C., Ann. Rept., 1911, p. 134.
Cairnes, 1935, p. 14.

Idaho-Alamo (8, 10)

Minister of Mines, B.C., Ann. Repts.: 1892-1955.
McConnell, 1897a, p. 28.
Cairnes, 1935, pp. 59-62.
Hedley, 1952, pp. 11, 79, 80, 99.

Hewitt (20)

Minister of Mines, B.C., Ann. Repts.: 1896-1956.
Rept. of Zinc Commission, 1906, pp. 219-225.
Cairnes, 1935, pp. 51-58.

Buffalo (31)

Cairnes, 1935, p. 23.
Hedley, 1952, p. 69.

Jenny Lind (33)

Cairnes, 1935, pp. 28-30, 158.

Mercury and Silver Bell (53)

Minister of Mines, B.C., Ann. Repts.: 1902, p. 148; 1904, p. 202.
Cairnes, 1935, pp. 81, 82.

Redress (54)

Cairnes, 1935, p. 112.

Madison (59)

Cairnes, 1935, p. 74.

Richmond-Eureka (60)

Minister of Mines, B.C., Ann. Repts.: 1893-1956.
Cairnes, 1935, pp. 113-115.
Hedley, 1952, p. 102.

Surprise (67)

Minister of Mines, B.C., Ann. Repts.: 1895-1952.
Cairnes, 1935, pp. 146-149.
Hedley, 1952, pp. 82, 91.

Reco (74)

Minister of Mines, B.C., Ann. Repts.: 1892-1956.
Cairnes, 1935, pp. 107-112.

Grey Copper (77)

Rept. of Zinc Commission, 1906, pp. 259, 260.
Cairnes, 1935, pp. 50, 51.

Goodenough (78)

Minister of Mines, B.C., Ann. Repts.: 1896, p. 59; 1904, p. 192; 1907, p. 100.

Oro (82)

Cairnes, 1935, p. 98.

Mountain Con (97)

Minister of Mines, B.C., Ann. Repts.: 1900, p. 827; 1904, pp. 193, 194; 1930, p. 250.
Cairnes, 1935, pp. 89, 90.

Bismark (105)

Minister of Mines, B.C., Ann. Repts.: 1900, p. 851; 1904, pp. 158, 198; 1951, p. 166.
Rept. of Zinc Commission, 1906, pp. 266, 267.
Cairnes, 1935, pp. 194, 195.

Silver Bear (110)

Minister of Mines, B.C., Ann. Repts.: 1919, p. 121; 1923, pp. 211, 212; 1924, p. 189; 1931, p. 146; 1951, p. 165; 1954, p. 138.
Cairnes, 1935, pp. 244, 245.

Revenue (112)

Minister of Mines, B.C., Ann. Repts.: 1920, p. 122; 1928, p. 306; 1929, p. 321.
Cairnes, 1935, p. 243.

Violet (113)

Minister of Mines, B.C., Ann. Repts.: 1921, p. 133; 1931, p. 142.
Cairnes, 1935, pp. 256, 257.

Ontario No. 2 (Jessie-Bluebird) (116)

Minister of Mines, B.C., Ann. Repts.: 1906, p. 143; 1921, pp. 131, 132.
Cairnes, 1935, pp. 239, 240.

Baltimore (117)

Minister of Mines, B.C., Ann. Repts.: 1904, p. 156; 1953, p. 136; 1954, p. 137.
Cairnes, 1935, p. 192.

Olsen (120)

Minister of Mines, B.C., Ann. Repts.: 1901, p. 1031; 1939, p. 96.

Molly Gibson (121)

Minister of Mines, B.C., Ann. Repts.: 1896-1950.
Rept. of Zinc Commission, 1906, pp. 262-266.
Alcock, 1930, pp. 352, 353.

Hamilton (133)

Cairnes, 1935, p. 175.

Happy Medium (134)

Cairnes, 1935, p. 176.

Dayton (144)

Cairnes, 1935, p. 172.

Tamarac (148)

Minister of Mines, B.C., Ann. Rept. 1921, p. 139.
Cairnes, 1935, p. 186.

Anna (150)

Minister of Mines, B.C., Ann. Repts.: 1919, p. 126; 1927, pp. 277-280.
Cairnes, 1935, pp. 167, 168.

Cub (151)

Cairnes, 1935, p. 179.

V Day and Victory V (Graphic-Rosebud) (152)

Minister of Mines, B.C., Ann. Repts.: 1896, pp. 70, 71; 1952, p. 180.

Bondholder (155)

Minister of Mines, B.C., Ann. Repts.: 1896, p. 70; 1952, p. 180.
Cairnes, 1935, pp. 169, 170.

Mabou and Ohio (156)

Minister of Mines, B.C., Ann. Repts.: 1919, p. 130; 1947, p. 172; 1949, p. 191.
Cairnes, 1935, p. 179.

Dumac (158)

Minister of Mines, B.C., Ann. Repts.: 1947, p. 172; 1952, p. 180.

Neepawa (Peg Leg) (159)

Minister of Mines, B.C., Ann. Repts.: 1896, p. 70; 1919, p. 129; 1947, p. 172; 1949, p. 191.
Cairnes, 1935, pp. 180, 181.

Westmont and Eastmont (160)

Minister of Mines, B.C., Ann. Repts.: 1919, p. 128; 1956, pp. 97, 98.
Cairnes, 1935, pp. 189, 190.

Riverside (161)

Minister of Mines, B.C., Ann. Rept. 1919, p. 130.
Cairnes, 1935, p. 185.

Snowstorm (Slocan Chief) (162)

Minister of Mines, B.C., Ann. Rept. 1928, p. 307.
Cairnes, 1935, pp. 247, 248.

Hampton (163)

Minister of Mines, B.C., Ann. Rept. 1922, p. 203.
Cairnes, 1935, p. 176.

Arlington (Slocan-Arlington) (165)

Minister of Mines, B.C., Ann. Repts.: 1896-1951.
Cairnes, 1935, p. 168.

Slocan Prince (Black Prince, Two Friends) (166)

Minister of Mines, B.C., Ann. Repts.: 1896, p. 71; 1904, pp. 166-168; 1919, pp. 127, 128.
Cairnes, 1935, pp. 187, 188.

Alice S. (167)

Minister of Mines, B.C., Ann. Repts.: 1915, p. 132; 1916, p. 198.
Cairnes, 1935, p. 166.

Lily B. (168)

Minister of Mines, B.C., Ann. Rept. 1918, pp. 171, 195.
Cairnes, 1935, p. 178.

Aspen (251)

Minister of Mines, B.C., Ann. Repts.: 1896-1951.
Walker, 1934, pp. 65-67.
Green, 1954, pp. 18, 19.

Nature Boy (281)

Minister of Mines, B.C., Ann. Rept. 1949, p. 156.

Red Eagle (284)

Minister of Mines, B.C., Ann. Rept. 1908, p. 105.

Blue Bird (286)

Minister of Mines, B.C., Ann. Repts.: 1908, p. 105; 1950, p. 119; 1952, pp. 142, 143; 1953, p. 112.
McConnell, 1896, p. 34A.
Drysdale, 1915, pp. 160, 161.

Hattie Brown (291)

Minister of Mines, B.C., Ann. Rept. 1909, p. 129.

Silver-gold Deposits, With or Without Some Lead and Minor Zinc

Twenty-six deposits that have produced silver and gold in that order of value occur within the map-area. Of these, only three, the Mowitch, Lone Silver, and Republic No. 2, have also produced lead. The value of the lead produced by the Lone Silver is about equal to that of gold, the Mowitch much less, and the Republic No. 2 only small. The Mowitch and Lone Silver have produced some zinc and the Republic No. 2 only a little.

The silver-gold deposits are the truly 'dry ores'; the Kalispell, Highland Light, Silver Nugget, Colorado, Elise, Norway, and Gold Hill have produced only silver, and the Meteor has yielded only a minor amount of gold with the silver. Only the Meteor, and Hunter V and Double Standard properties are of more than minor economic importance.

All the deposits, except the Hunter V and Double Standard, and Lone Silver, which are replacement deposits in dolomitic limestone, are fissure-filled lodes. The host rocks of these deposits are of many types. The Mowitch, Kalispell, Highland Light, and Silver Nugget veins are in argillite or quartzite of the Slocan group. The Commodore and Elise veins are in argillaceous schist of the Ymir group, although the former is also partly in porphyritic granite. The Hunter V and Double Standard deposit is in limestone of the lower Laib formation, and the Lone Silver is in dolomite of the Nelway formation. The Birdseye and Curlew veins are in porphyritic augite andesite of the Rossland formation, and the Gold Hill in argillite and banded tuff (?) of the Mount Roberts formation. All the remaining deposits are in porphyritic Nelson granite or, to a lesser extent, in granodiorite as in the Norway, or partly in gneiss as are the V and M, Senator, and Skylark and Ranger veins. In a few deposits, the granite in the vicinity is strongly sheared as in the Republic No. 2, Meteor, and Crusader properties.

The gangue mineral in the silver-gold veins is invariably quartz, with some siderite in the Mowitch and Curlew veins, some calcite in the Highland Light and Gold Hill veins, minor barite in the Highland Light, and minor scheelite in the Meteor veins.

In the two replacement deposits carbonates are of course abundant. Tremolite occurs in the Hunter V and Double Standard ore, and quartz veins intrude the disseminated sulphide deposit of the Lone Silver.

On the other hand the assemblages of ore minerals in the veins are highly divergent. In only half of these deposits have such silver minerals as grey copper, ruby silver, native silver, argentite, and stephanite been identified. Galena is reported in ten of the deposits, in some cases associated with silver minerals, but it is generally of minor importance. In most veins where galena is present a little sphalerite is also reported. Pyrite is the most widespread metallic mineral and in the V and M, Meteor, and Elise it is accompanied by chalcopyrite. Pyrite is the

only metallic mineral reported in the Highland Light vein, and pyrrhotite is the only metallic mineral in the Gold Hill. Both pyrite and free gold occur in the Birdseye vein.

The most important belt of silver-gold or 'dry ore' deposits forms an arc east of the southern end of Slocan Lake from the Get There Eli and Silver Nugget southward to the Republic No. 2 and thence southeastward to the Crusader property. This arcuate belt is in a general way bounded on the concave or east side by silver-lead-zinc deposits and on the convex or west side by gold-silver ores. As has been pointed out several of the veins in this belt produced only silver.

Three silver-gold properties are peripheral to the Rossland mining camp. These are the Curlew to the south of the camp, the Norway to the southwest, and the Gold Hill to the north.

The remaining six silver-gold deposits do not appear to bear zonal relationships to other types of deposits. The Mowitch is surrounded by silver-lead-zinc properties; the Birdseye, Elise, and Commodore lie within the main gold-silver belt; and the Hunter V and Double Standard, and the Lone Silver are replacement deposits, a type that most commonly yields zinc-lead-silver ores.

Republic No. 2 (138)

References: Minister of Mines, B.C., Ann. Repts.: 1896, p. 73; 1898, p. 1077; 1904, p. 170; 1951, p. 77; 1952, p. 181. Cairnes, 1935, p. 184.

The Republic No. 2 property, previously known successively as the Republic, and Bell No. 2, is owned by C. B. Tipping of Slocan City. It is about 3 miles north and a little east of Slocan City, from where it is accessible by road, and lies west of the headwaters of Climax Creek a tributary of Springer Creek. The property in 1950 included the Erin, Erin fraction, and Republic No. 2 Crown-granted claims; the American Eagle and Bell No. 2 claims reverted to the Crown.

The claims were located in 1895 and developed between 1896 and 1904; shipments of ore were made each year in that period. The property lay idle until 1918, and from then to 1920 further mining was carried out. The present owner made shipments in 1935, 1939, 1941, 1951, and 1952; in 1940 separate shipments were made from the Republic No. 2 and Bell No. 2 claims by lessees. Complete records of early shipments of ore are not available but from 1902 to 1952 inclusive 242 tons of ore were mined. This yielded 13,299 ounces silver, 107 ounces gold, 268 pounds lead, and 171 pounds zinc. The property was examined in August 1950 by A. B. Irwin of the Geological Survey.

The rock underlying the claims is mainly coarse-grained porphyritic Nelson granite that is strongly sheared locally. Felsic and mafic dyke-like bodies intrude the granite.

The workings comprise two inclined shafts of which the lower and more westerly is flooded, three adits, and one open-cut. Several veins occur on the property, but only two are important. The Republic vein is explored by No. 2 shaft, the more easterly of the two. This shaft is collared at an elevation of about 4,375 feet and has been sunk on the vein for about 60 feet. The vein there is

2 to 3 feet wide, strikes east and dips 15° to 20°N. It is offset up to 2 feet by each of several small normal faults that strike N25° to 45°E and dip 65° to 85°NW. From this shaft, short, irregular drifts and stopes have been driven.

No. 1 shaft, about 700 feet west of No. 2, is probably also on the Republic vein. There the vein is about 2 feet wide, strikes N50°E and dips 35°NW. This shaft is flooded, but small normal faults that displace the vein perhaps a foot, can be seen near the collar. Two tunnels below and to the west of No. 1 shaft did not intersect the vein. To the west, 600 feet beyond the draw and probably on the Bell No. 2 ground, an adit follows for 60 feet a discontinuous vein that strikes N20°E and dips 45°SE. Beyond this point the ground is complexly faulted.

In general the veins vary in attitude; those on the east side of the property strike about east and dip gently north, whereas those on the west strike about northeast and dip gently northwest, except for the one described above. The ore shoots in these veins are erratically distributed and are elongated down the dip.

The veins are of quartz and contain pyrite, a little argentite and native silver, and according to Cairnes, possibly free gold.

Joan (Duplex) (173)

References: Minister of Mines, B.C., Ann. Repts.: 1901, p. 1028; 1902, p. 151; 1904, p. 168; 1922, p. 204; 1947, p. 173.

The Joan claim, formerly known as the Duplex, lies about half a mile northeast of the junction of Chapleau Creek and the third tributary east of Cameronian Creek. It adjoins the Fourth of July No. 6 and Teuro Crown-granted claims on the south. In 1950 ownership was held by W. Parker of New Westminster, B.C., by virtue of assessment.

The Duplex claim, staked prior to 1901, was worked under lease in that year and in 1902. Six tons of ore was shipped, containing 520 ounces silver and 7 ounces gold. The value of this ore was much greater than that estimated from samples collected by the resident mining engineer in 1922. These assayed 0.06 ounce gold and 3.7 ounces silver a ton.

The property appears to have been idle until 1946, when W. Parker and H. Parker mined 4 tons of ore from the Joan claim, as it was then named. This ore, shipped in 1947, yielded 121 ounces silver and 1 ounce gold.

The property was examined in 1950 by A. B. Irwin of the Geological Survey.

The workings consist of two adits, the lower by aneroid barometer being at an elevation of about 5,750 feet and the upper some 44 feet higher. About 50 feet from the portal of the lower tunnel a raise has been driven up the vein to the surface (*see* Figure 15).

The property is underlain by porphyritic Nelson granite that is sheared and fractured near the vein. The vein is encountered in the lower tunnel about 25 feet from the portal where it enters the right wall. From this point it is followed in the drift for a distance of about 140 feet to a narrow fault near the face.

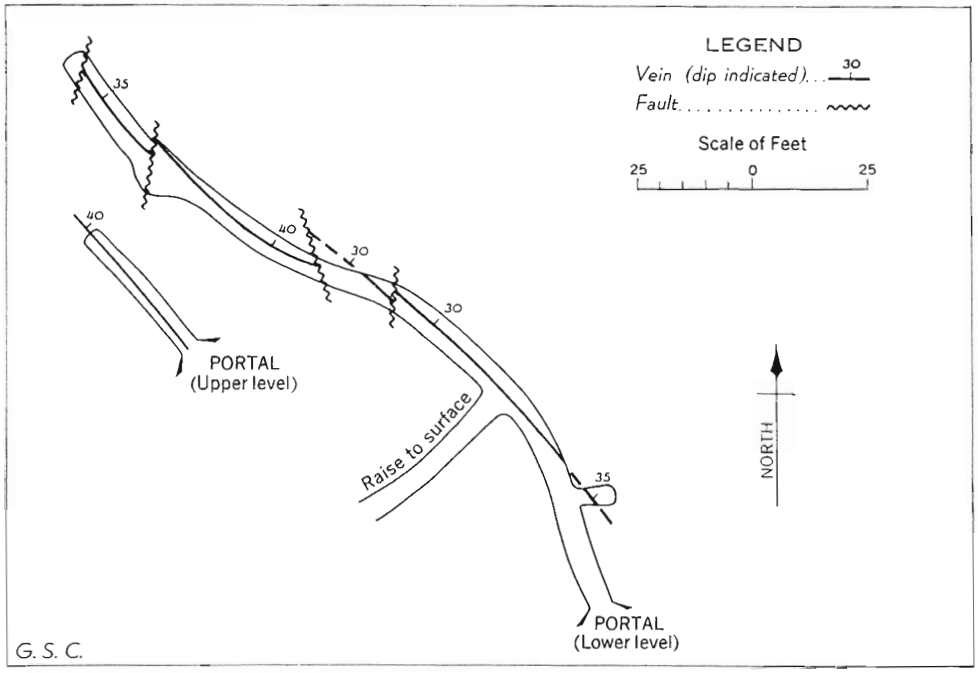


Figure 15. *Plan of workings on Joan (Duplex) property (geology by A. B. Irwin, 1950).*

Along the drift the vein is offset by three small faults with slight left-hand displacements. These strike roughly north and dip 70° to 80°W. The vein strikes N40° to 50°W and dips 30° to 40°NE. It is 1 foot to 2 feet wide on both levels.

The vein matter is quartz that in many places shows coarse crystal faces; no carbonates were observed. Narrow streaks and disseminations of galena occur in the vein together with a little pyrite and argentite.

Other silver-gold properties together with principal references except where these are numerous, are listed below.

Mowitch (4)

Minister of Mines, B.C., Ann. Repts.: 1904, p. 180; 1920, p. 125; 1949, p. 189.
Cairnes, 1935, pp. 90, 91.

Kalispell (127)

Minister of Mines, B.C., Ann. Rept. 1896, p. 71.
Cairnes, 1935, p. 177.

Highland Light (128)

Cairnes, 1935, pp. 176, 177.

Silver Nugget (129)

Cairnes, 1935, p. 124.

V and M (134a)

Cairnes, 1935, pp. 188, 189.

Senator (Batchelor) (135)

Cairnes, 1935, p. 169.

Colorado (136)

Cairnes, 1935, pp. 170, 171.

Mable (Cripple Stick) (139)

Cairnes, 1935, p. 185.

Port Hope (140)

Cairnes, 1935, p. 184.

Exchange (145)

Cairnes, 1935, p. 175.

Evening Star (147)

Cairnes, 1935, pp. 174, 175.

Meteor (169)

Minister of Mines, B.C., Ann. Repts.: 1896-1940.
Cairnes, 1935, pp. 179, 180.

Howard Fraction (172)

Minister of Mines, B.C., Ann. Repts.: 1896, p. 72; 1919, p. 127; 1950, p. 150.
Cairnes, 1935, p. 177.

Crusader (174)

Minister of Mines, B.C., Ann. Rept. 1896, p. 72.

Skylark and Ranger (177)

Minister of Mines, B.C., Ann. Repts.: 1899, pp. 689, 690; 1904, p. 168; 1938, p. E5.

Birdseye (195)

Minister of Mines, B.C., Ann. Rept. 1920, p. 134.

Commodore (226)

Minister of Mines, B.C., Ann. Repts.: 1910, p. 107; 1915, p. 155; 1940, p. 67.
Drysdale, 1917b, pp. 68, 69.

Elise (227)

Minister of Mines, B.C., Ann. Repts.: 1896, p. 75; 1933, p. 227.
Drysdale, 1917b, p. 94.

Hunter V and Double Standard (241)

Minister of Mines, B.C., Ann. Repts.: 1902, pp. 160, 161; 1904, pp. 127, 128; 1927, p. 303; 1928, p. 332.
Drysdale, 1917b, pp. 55, 116-118.
Walker, 1934, pp. 64-65.

Lone Silver (Hope) (272)

Minister of Mines, B.C., Ann. Repts.: 1936, pp. E16-18; 1937, p. E49.

Curlew (285)

Minister of Mines, B.C., Ann. Rept. 1896, pp. 17, 31.
Drysdale, 1915, p. 163.

Norway (295)

Minister of Mines, B.C., Ann. Rept. 1929, p. 363.

Gold Hill (301)

Drysdale, 1915, pp. 149, 150.

Gold-silver Deposits, With or Without Some Lead and Zinc

Gold-silver deposits are as numerous within the map-area as those containing lead-silver ores. However, there are a great many that have produced only minor amounts of ore. The overall gross value of production from the gold-silver deposits is therefore probably less than that from the lead-silver deposits.

In the gold-silver deposits the value of gold is in most cases greater than that of silver. From the Golden, Gold Viking, Referendum, Fawn, and R. E. Lee (near Rossland), no silver production is recorded; from the Star and Alma N., Second Relief, Harriet, Porto Rico, Tamarac, Jumbo, and Columbia-Kootenay, silver is only of minor importance. In the Alpine, Ymir, and Casino Red Cap deposits, the value of lead exceeds that of silver; in the California (near Nelson) the value of zinc exceeds that of silver; and in the Hummingbird, Catherine, Perrier, Golden Eagle, Canadian Belle, Protection, Blackcock, Yankee Girl, Centre Star (near Ymir), Ore Hill, and Sumit, the values of both lead and zinc are greater than that of silver. In all, twenty-eight gold-silver deposits have produced important or significant amounts of lead and zinc, and an additional twelve have yielded minor amounts of either or both of these metals. The Granite-Poorman, Athabaska, Canadian Belle, Second Relief, Porto Rico, Tamarac, Arizona, and Golden Drip have produced also a little copper and the Protection and Yankee Girl ores, both carrying more than normal amounts of zinc, have yielded also minor amounts of cadmium.

Except for a few relatively isolated deposits of little importance, the gold-silver ores of the map-area are contained in one major and two minor belts. One of the latter contains the L.H., Golden, and Little Daisy properties grouped about the northern end of the arcuate belt of 'dry ores' described previously. The remainder, in the southeastern part of this belt, extend from the Lakeview near the south end of Slocan Lake eastward to the Alpine and Oro Fino properties. The gold-silver deposits of this belt in a general way appear to lie on the convex side of the belt of 'dry' or silver-gold ores. They are with two exceptions,

fissure-filled veins. In the Lakeview some dissemination of sulphides occurs in the wall-rocks adjacent to the lenticular veins, and in the L.H. deposits, a most unusual type, the ore is composed entirely of disseminated sulphides in a shear zone that has been abundantly silicified.

The country rocks of the gold-silver properties of this belt vary greatly. The Oro Fino, Alpine, Goldstream, Kilo, Chapleau, and Lakeview deposits are in coarse-grained porphyritic Nelson granite which, on the Lakeview property, is highly crushed. Other phases of the Nelson such as medium-grained biotite-hornblende diorite and fine-grained granite are the host rocks of the Morning Star and Little Daisy veins, respectively. The L.H. deposit is in argillite and quartzite of the Slocan group. The gangue is quartz, with, in the Alpine, Lakeview, and Morning Star veins, minor carbonates. In all except the L.H., where pyrrhotite and arsenopyrite predominate, pyrite is the most abundant metallic mineral, and, except again in the L.H., it is accompanied by some galena and sphalerite. The Little Daisy, L.H., Chapleau, and Lakeview ores contain a little chalcopyrite and, in the Little Daisy and Lakeview, a little pyrrhotite and chalcocite respectively. Silver minerals are rare; minor tetrahedrite (?) is reported in the Morning Star ore, and possibly ruby silver with free gold in the Chapleau.

The major belt of gold-silver deposits is oval in shape and extends from the Good Hope, and Nevada and Royal Canadian properties west of Nelson southeastward to the Sheep Creek camp. This belt may be divided into three smaller ones, a northwest division of irregular shape, and central and southeast divisions of elongate shapes, arranged *en échelon*. Within each of these divisions are mines of considerable economic importance but the most important is the southeast division which embraces the Sheep Creek camp.

Within the entire major belt the gold-silver deposits are all fissure-filled veins with, in the Canadian Belle, Blackcock, Ore Hill, and Sumit deposits, more or less disseminated sulphides adjacent to the vein, particularly in the last two named. Many kinds of country rock enclose the various deposits. The Good Hope, May and Jennie, Star and Alma N., Perrier, Daylight and Berlin, Starlight, Golden Age, Euphrates, Harriet, Porto Rico, Spotted Horse, Myrtle, and Clubine-Comstock veins are in greenstone, augite porphyry, or chlorite or sericite schists of the Rossland formation, and the Whitewater, Venus and Juno, Athabaska, Bear, and Fern veins lie partly within these rocks and partly in granodiorite or porphyritic granite. The Nevada and Royal Canadian, Venango, and Granite-Poorman veins are in pseudodiorite; the Catherine, and Blackcock are in granodiorite; the Golden Eagle, and Pilot-Good Hope are in porphyritic granite; and the Tamarac is in albite porphyry.

The remaining deposits in this belt occur in sedimentary rocks. These, with the exceptions of the Ore Hill and Sumit which occur mainly in limestone, are in quartzite, argillaceous quartzite, or in brittle, metamorphosed argillaceous rocks. Some of the gold-silver deposits in the western part of the belt are in argillaceous quartzite and related sedimentary rocks. The Canadian Belle, Second Relief, Second Chance, Keystone, Gold Hill, and Arlington are of this type, and it appears

significant that the most productive mines in this part of the belt are those in which the country rock is hard, brittle quartzite. Similar rocks of the Ymir group contain the important veins of the Protection, Ymir, Yankee Girl, and Centre Star properties. The most important gold-silver deposits, those of the Sheep Creek camp, occur within brittle, mainly white quartzites of the Quartzite Range formation, except in the Reno vein which contains extensive orebodies in argillaceous rocks of the Reno formation that have been rendered brittle by metamorphism (Mathews, 1953, pp.20,23). At the south end of the camp, however, as has been stated previously, the greater parts of the Ore Hill and Sumit deposits consist of disseminated sulphides in limestone.

The gangue in the deposits of this belt is quartz with, in the Fern, Second Relief, Myrtle, and Yankee Girl veins, some crushed country rock. In the Daylight and Berlin, Spotted Horse, and Protection, some ankerite or calcite is present and scheelite has been reported in the Royal Canadian and Nevada, Golden Age, and Porto Rico veins. The veins of Sheep Creek camp contain minor calcite and scheelite as well as a little wolframite. Tourmaline occurs in the gangue of the Protection veins.

Pyrite is the predominant metallic mineral in many of the veins of the major gold-silver belt. Galena and sphalerite have been seen in most veins and are abundant in some, such as in the Hummingbird, Catherine, Perrier, Golden Eagle, Protection, Ymir, Blackcock, Yankee Girl, and Centre Star. On the other hand, neither is reported in the veins of the May and Jennie, Starlight, Bear, Fern, Second Relief, Harriet, Porto Rico, Spotted Horse, Tamarac, and Gold Hill properties. Chalcopyrite, mainly in minor quantity, occurs in the Nevada and Royal Canadian, Venango, Granite-Poorman, Star and Alma N., Daylight and Berlin, Fern, Canadian Belle, Golden Age, Euphrates, Clubine-Comstock, and Gold Hill ores, as well as in all those of the Sheep Creek camp which also contain a little marcasite and arsenopyrite. Arsenopyrite is reported also in the veins of the Canadian Belle and Euphrates, and pyrrhotite in those of the Hummingbird, Daylight and Berlin, Canadian Belle, Second Relief, Centre Star, and Clubine-Comstock mines. Free gold occurs in the Granite-Poorman, Athabaska, Catherine, Perrier, Bear, Fern, Harriet and Porto Rico. Only the Second Relief deposit contains molybdenite, and there, only in small amounts.

A minor belt of gold-silver deposits is peripheral to the gold-copper ores of the Rossland camp. In this belt all but three mines, the Midnight, Jumbo, and Columbia-Kootenay, are of minor importance. All deposits in this belt, except the Columbia-Kootenay which comprises only massive and disseminated sulphide ore, are fissure-filled veins, although in the Jumbo there are minor disseminated sulphides adjacent to the vein. The R. E. Lee, Richmond, and Columbia-Kootenay deposits occur in greenstone or augite porphyry of the Rossland formation, but the last mentioned is also partly in biotite monzonite. The Hattie vein is entirely in fine-grained monzonite. The Snowdrop, Midnight, and Jumbo veins are in fine-grained andesite with associated tuff or chert of the Mount Roberts formation. The Golden Drip vein is in serpentine.

The gangue in the Midnight, Snowdrop, and Jumbo veins is quartz, with some ankerite or calcite. Calcite is present also in the Columbia-Kootenay ores. Pyrite is most abundant in the Midnight veins, and minor galena together with free gold is also present. The R. E. Lee, Richmond, and Hattie ores contain abundant arsenopyrite and pyrite, with marcasite in the first and chalcopyrite in the latter two. Pyrrhotite predominates in the Columbia-Kootenay and Jumbo deposits, accompanied by minor chalcopyrite and arsenopyrite in the former, and in the latter, by some arsenopyrite, chalcopyrite, and molybdenite, and minor pyrite, bismuthinite, and sylvanite(?). The Golden Drip vein comprises soft gouge with minor quartz.

The remaining seven properties, scattered between Sheep Creek and Rossland camps, are of little importance and on three of them there is no geological information. The Lucky Strike and Davne veins occur in phyllite and dolomite of the Nelway formation, and comprise galena, sphalerite, pyrite, and tetrahedrite in a quartz gangue. Chalcopyrite also is reported in the Lucky Strike vein. The Bunker Hill quartz veins are in argillaceous quartzite, argillite, and minor limestone of the Laib formation and contain pyrite, molybdenite, minor galena, sphalerite, and possibly bismuth telluride. The Casino Red Cap quartz vein is in greenstone of the Rossland formation. Metallic minerals, if present, have not been reported.

Alpine (122)

References: Minister of Mines, B.C., Ann. Repts.: 1896, p. 72; 1927, p. 319; 1938, pp. E13-E15; 1942, pp. 61, 62; 1946, p. 150; 1947, pp. 158, 159. Stevenson, 1943, p. 156.

The Alpine group comprises the Kootenay Pass, Rocky fraction, Berne, Highland Chief, Swiss, Nelson, and Crown Point No. 6 Crown-granted claims and others held by location. The group is owned by Alpine Gold, Limited. It is situated at the head of Sitkum Creek on the divide marking the boundaries of the Nelson and Slocan (formerly Slocan City) mining divisions. It is accessible from the Nelson-Balfour highway by a private road 9 miles long up Sitkum Creek valley.

Initial development of the vein was done in 1896 and 1897, but there is no record of further activity until 1927 except for a small shipment of ore in 1915. In 1936, the property was acquired by the Alpine Syndicate which, after construction of a 50-ton flotation mill and aerial tramway in 1940, continued production until 1942. Subsequent shipments were made from 1946 to 1948 by the present owners.

From 1915 to 1948 a total of 17,099 tons of ore was mined and this yielded 11,413 ounces gold, 108,571 pounds lead, 7,087 ounces silver, and 37,667 pounds zinc. The property was examined by the writer in 1948.

The claims are underlain by coarse-grained, porphyritic Nelson granite. This is cut by a few dykes of aplite and several of lamprophyre, the latter being later than the vein. Some normal faults having displacements up to 20 feet were observed in the workings, and these faults offset all dykes and veins.

The workings consist of two adits, No. 7 and No. 10, at elevations of 7,150 and 6,925 feet respectively. They follow the vein which strikes S75°W and dips 15° to 30°N. The lower adit is 1,131 feet long. The upper adit, whose exact length was not measured, is driven through the upper part of the peak to the cliff overlooking the basin of Alpine Creek to the northwest. The two levels are joined by gently dipping stopes that also extend above the upper level and below the lower.

The vein has been traced on the surface by open-cuts and underground for a length of more than 1,200 feet. It ranges in width from 2 feet to nearly 7 feet, the average width being about 3½ feet. The gangue in the vein is quartz which in a few localities is brecciated and cemented by calcite that also forms short veinlets in the walls. The ore minerals are auriferous pyrite and lesser amounts of galena and sphalerite.

Morning Star (143)

References: Minister of Mines, B.C., Ann. Repts.: 1901, p. 1027; 1935, pp. A27, E33; 1936, p. E50; 1937, pp. A38, E50; 1940, p. 81; 1942, p. 73; 1947, p. 172; 1949, p. 192.

The Morning Star claim, held by record, is owned by W. Clements of Slocan City. It is situated on the north side of Springer Creek opposite Dayton Creek, a few hundred feet above their junction. The claim was staked about the turn of the century and nearly all the workings were driven in 1901. There is however no record of production at that time. Four tons of ore was shipped in 1935 by Mr. Clements and small shipments were made in 1936 and 1937 by lessees. G. A. MacMillan of Toronto optioned the property in 1946, 1947, and 1949 and shipped 2 tons of ore. It has remained idle since that time.

During the period 1935 to 1949, production totalled 25 tons of ore containing 42 ounces gold, 114 ounces silver, 1,121 pounds lead, and 913 pounds zinc. The property was examined in June 1950 by A. B. Irwin of the Geological Survey.

The rock underlying the property is mainly medium-grained biotite-hornblende diorite intersected by a few small felsite dykes. Near the veins the diorite is bleached and silicified.

The workings consist of two adits; the lower and more extensive is 410 feet above the mouth of Dayton Creek and N20°E from it. The portal of the upper adit is north of and 100 feet above the lower portal.

The main vein has been traced continuously for 380 feet in the lower working and a branch vein near the south end has been followed for 120 feet (*see* Figure 16). The north part of the main vein strikes N10°W and the south part N30° to 40°W. The branch vein has the same trend as the north part of the main vein. The dip of the vein varies along its length from 55° to 65°W. In the lower level the width of both veins ranges from 1 inch to 3 inches. In the upper level, where it has been stoped, the vein is 1 foot to 2 feet wide for a length of 30 feet, but on either side of the stopes it is 3 inches wide or less. It is terminated at the south end against a fault that strikes N20°E and dips 50°W. What may be the continuation of the main vein is exposed in the back of the lower working from the fault to the portal. There a vein 2 to 6 inches wide and 40 feet long occurs in

71994-8—12

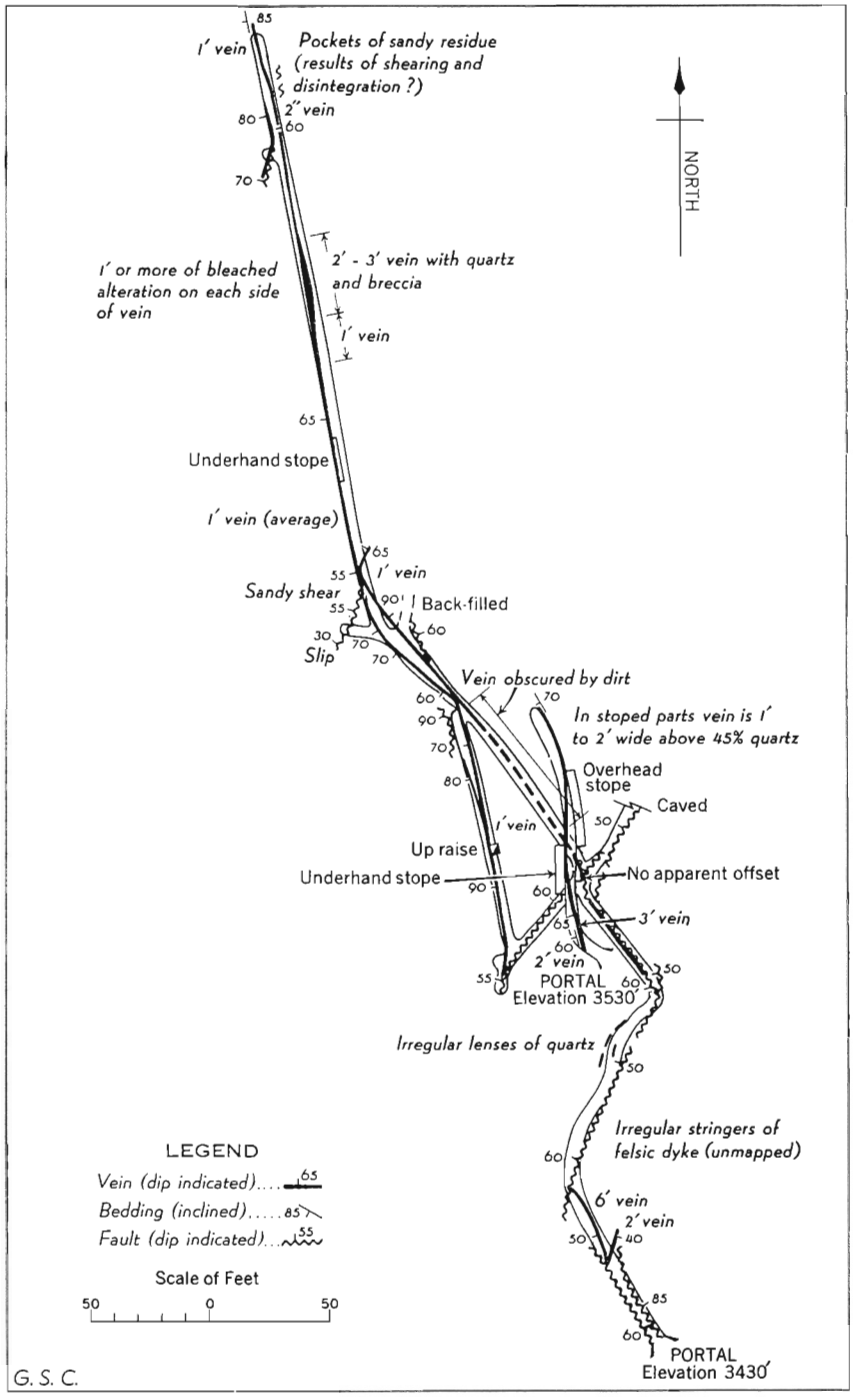


Figure 16. *Plan of workings of Morning Star mine (geology by A. B. Irwin, 1950).*

a broad zone of bleached and silicified diorite. This vein strikes N30°W and dips 50°SW. Near the portal it feathers out into a zone of branching veinlets and shears.

Metallic minerals in the vein consist of fine steel galena, sphalerite, cubes of pyrite, and a little tetrahedrite(?). The gangue is mainly of quartz with siderite or ankerite and a little calcite.

Goldstream (175)

References: Minister of Mines, B.C., Ann. Repts.: 1932, p. 179; 1938, pp. A37, E8. B.C. Dept. of Mines, Bull. 1, 1932, p. 116.

The Goldstream claim, held on location in 1938, is on the north side of Chapleau Creek about half a mile northeast of the Kilo mine, from which it is accessible by road. Initial exploratory work was carried out in 1931 and 1932 by G. Stoll, G. Soucey, and associates and it consisted of entirely trenching and stripping the vein. The property was leased in 1938 by C. Ritchie and one or two partners who drove a drift westward 50 feet from the bank of a creek. The only ore produced was stoped at this time and amounted to 40 tons, containing 22 ounces gold and 23 ounces silver.

The property was examined in July 1950 by A. B. Irwin of the Geological Survey.

Country rock on the claim consists of porphyritic Nelson granite. The vein, which strikes N75°E and dips 20°N, ranges in width from 6 to 16 inches and has been followed underground for 50 feet and intermittently on the surface for 200 feet. In many places the vein splits into two or three branches. The vein is composed of white quartz with tight walls and contains pyrite in cubes and clusters, the cubes being up to half an inch across. A little galena is also present, mainly encased in the larger pyrite cubes but also as isolated crystals.

Kilo (176)

References: Minister of Mines, B.C., Ann. Repts.: 1897, p. 535; 1899, p. 689; 1904, p. 168; 1912, p. 150; 1932, p. 179; 1933, p. 207; 1938, pp. E5-E8; 1939, p. 79. Bureau of Mines, 1936a.

The Kilo group, comprising the Kilo, Kilo No. 2, Violet, Wedge, and Pansy Crown-granted claims and fractions, is north of Chapleau Creek and west of the second small tributary east of Cameronian Creek. It is accessible by a road about 8 miles long from the Slocan highway near the Lemon Creek bridge. It is owned by Mrs. N. F. McNaught of Silverton.

The property has been operated intermittently since 1897, but the amount and content of ore shipped prior to 1900 is not recorded. From 1900 to 1939 inclusive, a total of 2,357 tons of ore was produced, and this yielded 953 ounces gold, 870 ounces silver, 106 pounds lead, and 46 pounds zinc.

The first shipments of ore were made direct to smelters or to custom mills. In 1912 a mill was reported to be in operation but appears to have been largely devoted to hand-sorting. Since then the mine was operated by lessees in 1932 to 1934, 1938, and 1939. It was examined in July 1950 by A. B. Irwin of the Geological Survey.

71994-8—12½

The property is underlain by coarse-grained, porphyritic Nelson granite cut by small dykes of pegmatite. The underground workings consist of five levels and one sublevel, of which all but the highest and lowest levels are connected by raises; the highest level is connected to the surface by a raise. In 1950 only the second level (No. 1) was accessible; its portal is just above the road at an elevation of about 4,800 feet.

The vein strikes N25° to 45°W and dips 30° to 40°NE. Where observed, it is 3 inches to 2 feet wide. According to earlier reports the vein has been drifted on for more than 300 feet but ends against a narrow fault near the face in No. 3 level. The vein is of quartz with pyrite, now much oxidized, and a little galena and sphalerite. In many places it is brecciated and is bounded by gouge. Adjacent to the vein the granite wall-rock is much decomposed.

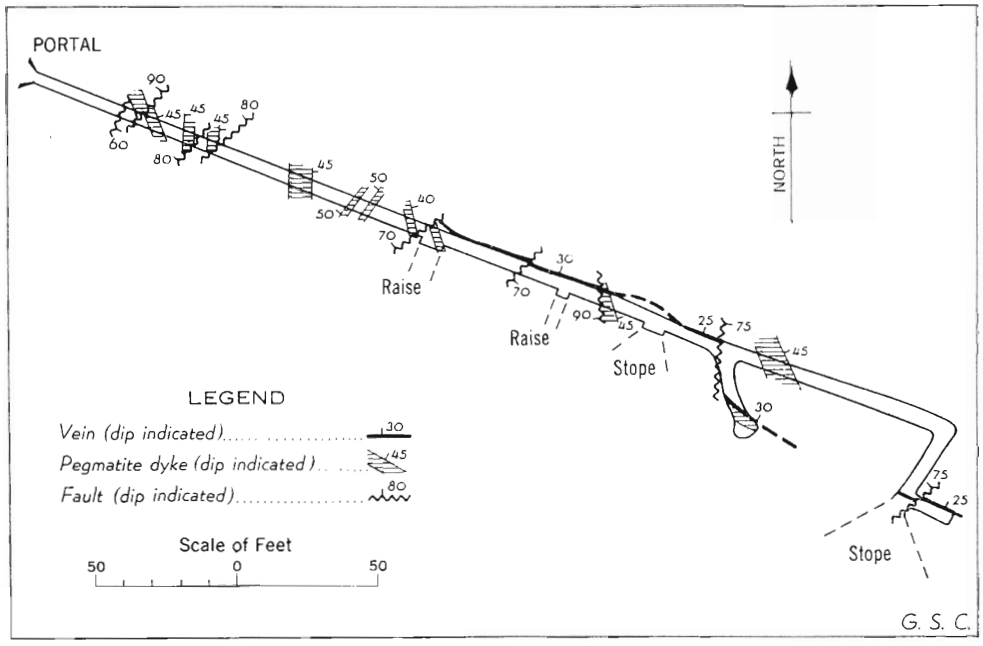


Figure 17. *Plan of workings of Chapleau mine (geology by A. B. Irwin, 1950).*

Chapleau (178)

References: Minister of Mines, B.C., Ann. Repts.: 1896, p. 48; 1899, p. 689; 1900, p. 830; 1904, p. 169; 1938, p. E5; 1941, p. 62; 1946, p. 168. Bureau of Mines, 1936b.

The Chapleau property, comprising the Chapleau and Chapleau Consolidated fraction Crown-granted claims, together with several other claims acquired by purchase and location, is owned by M. L. Craig and associates of Nelson. The underground workings, consisting of a single level, two raises, and stopes, are at an elevation of about 5,380 feet on the north side of Chapleau Creek, west of the Kilo mine. The Chapleau mine may be reached by a road about a mile long

that leads close to the mine workings from the road up Chapleau Creek. The road junction is about 8 miles from the Slocan highway and near the Kilo mine.

The Chapleau was one of the first properties on Lemon Creek and its tributaries to receive attention, and was early regarded as promising. In 1896 an initial shipment of 4 tons of ore yielded 3.6 ounces gold and 94.7 ounces silver a ton. Subsequent development was rapid and by 1900 an aerial tramway and a 10-stamp mill had been erected under the management of the Chaplau Mining Company. In 1904 however, as a result of decreasing values of the ore and difficulties encountered by faulting of the vein, the mine was closed. It was leased in 1905 but no further activity is reported until 1932 and 1933 when trial shipments of ore were made by lessees. In 1935, 50 tons of ore was shipped from the property by Atlas Gold Mines, Limited, of Slocan City. Subsequent shipments of ore were made by lessees in 1936, 1939, 1940, and 1941. In 1946 and 1947 the present owners rehabilitated the workings and constructed the road to the property but no shipments of ore were made.

Total production during the period 1900 to 1941 inclusive, is 326 tons of ore which contained 947 ounces gold and 13,105 ounces silver. The property was examined in July 1950 by A. B. Irwin of the Geological Survey.

The country rock is porphyritic granite that is bounded a short distance to the north and northwest by a large pendant and other inclusions of argillaceous quartzite. The granite is cut by small dykes of fine-grained granite, pegmatite, and aplite. The phenocrysts of orthoclase and microcline in the porphyritic granite are commonly not more than half an inch long except near the pegmatite dykes, where they form zones of larger phenocrysts up to 3 inches long that are parallel with the dykes. Some of the pegmatites contain small crystals of garnet and magnetite but no mica or ferromagnesian minerals.

The vein is exposed intermittently in the tunnel for more than 200 feet (*see* Figure 17). It is encountered first 155 feet from the portal, and followed for 110 feet. At that point it is displaced 20 feet to the right by a fault that strikes N10°E and dips 75°E. Beyond the fault the vein is revealed in two short crosscuts, the more easterly providing access to the largest stope.

The vein strikes N70°W and dips 25° to 30°NE. Its width ranges from 3 inches to 2 feet and widths up to 4 feet have been reported in earlier publications. The gangue is quartz that in places forms drusy cavities lined with small crystals of quartz. Pyrite is the most abundant metallic mineral. Sphalerite and galena are also present in specimens collected by Dr. Irwin. Ore submitted for milling tests to the ore-dressing laboratory of the Bureau of Mines, Ottawa in 1936 was reported to contain also a little chalcopyrite, free gold, and possibly ruby silver.

Venango (187)

References: Minister of Mines, B.C., Ann. Repts.: 1938, p. E37; 1942, p. 61; 1943, p. 64; 1945, pp. 96, 98; 1949, p. 163. Stevenson, 1943, p. 155. Mulligan, 1952, pp. 26, 27.

The Venango property, which adjoins the Granite-Poorman mine on the west, is owned by Venango Gold Mines, Limited. Although the Venango claim was

Crown-granted in 1900, little development work was done on the claim until 1938. From 1939 to 1950 inclusive, shipments of ore totalled 829 tons, containing 366 ounces gold and 414 ounces silver. The property was examined in 1949 by R. Mulligan, whose report follows.

At the Venango, two veins opened up are described (Minister of Mines, B.C., Ann. Rept., 1945, p. 98) as similar to those of the Granite-Poorman, and part of the same system of fracturing.

In September 1949, a new vein, described as the faulted extension of the vein originally discovered, was being drifted on by the Norcross brothers from a point about 210 feet at north 60 degrees west from the old shaft. At a point reported as 30 feet short of the projected fault extension, the drift swung left to crosscut a mica lamprophyre dyke, and picked up the vein striking about north 20 degrees west and dipping 40 degrees northeast. The vein matter here consisted of quartz with pyrite, coarse galena, red to black zinc blende, and a little chalcopyrite. Free gold was reported. Scheelite (Stevenson, 1943, p. 155) has been found in significant amounts but has not as yet been recovered.

The country rock is 'normal' medium-grained pseudodiorite, not particularly mafic. A thin section of drill core from the Venango, like the sections from the Granite-Poorman area, showed conspicuous replacement of plagioclase by soda-potassic feldspar, and of ferromagnesian mineral by biotite.

Hummingbird (198)

References: Minister of Mines, B.C., Ann. Repts.: 1921, p. 144; 1930, p. 267; 1932, p. 185; 1933, p. 221; 1946, p. 140. McAllister, 1951, pp. 55-57.

The Hummingbird group of claims was examined in 1948 by A. L. McAllister whose report is quoted below.

The Hummingbird property lies on the divide between Apex and Five Mile Creeks, at an elevation of 5,450 to 6,300 feet. It is readily accessible by means of an excellent pack-trail from Apex.

The prospect consists of seven claims staked by E. McDanniels, Leslie Hall, and Harry Wassick and two bonded claims belonging to the estate of Robert Qua, the original owner.

Between 1934 and 1946, some development was carried out by McDanniels, Hall, and Wassick, who optioned the property in 1946. During 1948, Mr. McDanniels spent the summer on the property preparing for a program of underground exploration during the next winter.

The only production of ore is recorded for 1933 and 1934. This totalled 84 tons, containing 63 ounces gold, 11,361 pounds zinc, 2,943 pounds lead, and 151 ounces silver.

McAllister continues:

Of the workings on the property (*see* Figure 18, in pocket) two adits are now accessible, the others are completely caved. The lower of the accessible adits follows a mineralized quartz vein that strikes north 80 degrees east and dips 45 to 50 degrees south. The upper adit, at an elevation of 5,775 feet, consists of a 70-foot crosscut and a 130-foot drift. The drift runs north 55 degrees east, presumably on the same vein as the lower adit. Numerous open-cuts and areas uncovered by sluicing are now completely sloughed; other open-cuts reveal barren and mineralized quartz veins.

The veins on the Hummingbird property cut members of the Ymir group, but granitic rocks underlie much of the area. Members of the Ymir group are mostly grey-black argillaceous quartzite, which has been silicified along the contact zone. A few

small bands of fine chloritic schist are interbedded with the quartzite, and one 20-foot band of white, calcareous quartzite is found in the canyon walls south of the lower workings.

Granitic rocks lie north, south, and east of the workings on the property. The most common facies is a medium-grained gneissic granite or granodiorite. Foliation, due to the alinement of biotite, is concordant with the bedding in the nearby sedimentary rocks. Numerous granitic sills, averaging 2 feet in thickness, cut the sedimentary rocks.

The best showings on the property are found in bedded fissure veins, and these have been responsible for the aggregate small production. The lower adit and the main adit drift follow two such veins or, what is more probable, the same vein. In the main adit, the drift follows a single persistent quartz vein between well-defined walls. This vein reaches a maximum width of 1½ feet, but averages less than 6 inches. An ore shoot containing abundant sphalerite and galena, found at the northeastern end of the drift, has been stoped to the surface along 18 feet of the vein. The shoot rakes steeply to the northeast and has been further developed by a 50-foot inclined shaft. In this part of the vein, the galena and sphalerite are confined to the white quartz and do not replace the wall-rock. Pyrite occurs as fine-grained stringers through the vein and is highly oxidized. A little pyrrhotite was seen.

In the lower adit, the mineral deposit lies roughly parallel with the bedding, and comprises several discontinuous veins. At a point 115 feet from the portal one such vein attains a thickness of a foot. Much of the zone here consists also of brecciated wall-rock, which has been heavily mineralized with sphalerite and pyrite. Small amounts of arsenopyrite and chalcopyrite were noted.

A single vein, parallel with the bedding, is exposed 80 feet to the southwest of the portal of the lower adit. It is well mineralized with galena and sphalerite, and is probably an extension of the vein followed in the lower adit.

Old reports refer to a vein 75 feet northwest of, and parallel with, the vein now exposed in the upper adit. The exploratory adit to this vein is now completely caved. Two other quartz veins, lying parallel with the bedding, but barren where exposed, are found near the lower adit.

Smaller quartz veins, either barren or sparsely mineralized, are found striking north 70 to 80 degrees west along the canyon walls near the lower workings.

About 2,000 feet northwest of the mine buildings, at an elevation of 6,300 feet, a vein striking north 30 degrees west and dipping 40 degrees northeast is contained entirely in granitic rocks. It has been traced along its strike for nearly 300 feet. Where it reaches its maximum width of 4 feet, it has been explored by a 50-foot inclined shaft. The shaft encountered a lens of massive pyrrhotite, which contained accessory quantities of sphalerite, galena, chalcopyrite, marcasite, pyrite, limonite, and hematite.

Although well mineralized with pyrrhotite, the low gold content appears to have been the reason for the lack of interest in these veins in recent years.

Several minor faults, all post-ore, were noted in the adits; they vary in strike from north 10 degrees west to north 20 degrees east and dip steeply westward. A persistent joint set on the property strikes north 70 degrees west and dips 70 degrees northeast.

Golden Eagle, T. S., and Sun Fraction (211)

References: Minister of Mines, B.C., Ann. Repts.: 1937, p. E38; 1938, p. E37; 1945, p. 99; 1946, p. 141; 1947, p. 160; 1948, p. 130; 1949, p. 164. Mulligan, 1952, p. 32.

The Golden Eagle, T. S., and Sun fraction claims, near the crest of the west ridge of Red Mountain are accessible by road from Nelson, which is about 6 miles in a straight line northeast of the group. Production of ore from 1925 to 1940 and from 1948 to 1952 totalled 107 tons, which contained 92 ounces gold, 4,409 pounds lead, 2,330 pounds zinc, and 133 ounces silver. The showings were examined in 1949 by R. Mulligan who reported:

During 1949 Mr. Wm. Rozan was developing quartz veins in fine granitic porphyry near the crest of the west ridge of Red Mountain. The showings consisted of a northerly

striking fissure vein, exposed by trenching for several hundred feet, and a flat-lying vein a short distance to the southeast. A tunnel was being driven beneath the latter. The veins contain pockets of oxidized sulphide ore reported to carry good gold values.

Golden Age (217)

References: Minister of Mines, B.C., Ann. Repts.: 1922, p. 208; 1923, p. 217; 1924, p. 192; 1928, p. 324; 1929, p. 346; 1931, p. 138; 1941, p. 64; 1942, p. 60. Cockfield, 1936, pp. 58, 59. McAllister, 1951, pp. 53-55.

The Golden Age mine was examined in 1947 by the writer and subsequently by A. L. McAllister whose account is quoted below.

The Golden Age property consists of nine claims straddling the Nelson-Ymir road about 10 miles south of Nelson, and just opposite the Euphrates mine.

The property was first prospected in 1922 in an effort to locate the source of gold-bearing quartz float found on the slopes below, and several short adits and open-cuts are reported to have been made. In 1923, the Golden Age Mining Company was formed to develop the property. Intermittent work continued until 1928. A stamp mill was erected, but little ore was available for it, and in 1929 the mill was destroyed by fire. During 1941 and 1942, Trimetals Mining Inc. of Spokane held the property. Some diamond drilling and drifting were done and a small mining plant was installed. The ore was to be treated in the Euphrates mill. Work ceased in April 1942.

Total production from the property from 1928 to 1945 inclusive, was 20 tons of ore, yielding 29 ounces gold, 185 ounces silver, 133 pounds lead, and 137 pounds zinc.

McAllister continues:

The veins cut sheared volcanic rocks of the (Rossland) formation and several, dark, unsheared dykes. Both veins and shear zones strike northwest. Values are principally in gold, which accompanies galena, sphalerite, chalcopyrite, pyrite, and nests of scheelite, all in a quartz gangue. Some gold is reported to occur in the wall-rocks. The vein walls are indefinite in most places, the quartz occurring in numerous small veinlets across widths of as much as 5 feet, but generally less than 1 foot.

Workings on the property consist of three adits and a few open-cuts. The lowest and shortest adit is 50 to 60 feet below the road. At the time of the writer's visit it was inaccessible, but Cockfield reports that it comprises a 130-foot drift running northwesterly, and a 20-foot crosscut to the southwest. Two small dykes are exposed in the adit, and a narrow band of sulphides follows one of these on its western side. Other small bunches of sulphides occur along the zone, which may or may not be continuous with the zone exposed in the upper workings.

The middle adit, at road level and 100 feet northwest of the lower adit, is 1,442 feet long. It is a drift on a shear zone that strikes north 40 degrees west. Three crosscuts, southwest from the drift, at 350, 670, and 950 feet respectively from the portal, are in sheared volcanic rocks, but show no evidence of mineralization. The veins along the drift reportedly reach a width of 5 feet, but stoping has evidently removed the wider parts, and widths now visible range from mere stringers to 3 feet. Stopes are found 249 feet from the portal, and in the vicinity of the first and third crosscuts. Beyond the last crosscut the vein is very irregular in width. At the face it is 3 feet wide and well mineralized.

The upper adit, 92 feet above the main adit, is apparently on the same zone and lies above an ore shoot exposed in the level below. At the portal, a shear zone strikes north 10 degrees west and dips westerly at 60 degrees. The vein consists of irregular lenses and stringers of quartz. About 90 feet from the portal a small stope extends upward only a few feet. Narrow veins at this point carry pyrite, chalcopyrite, and galena.

Protection (Goodenough) (224)

References: Minister of Mines, B.C., Ann. Repts.: 1897-1955. B.C. Dept. of Mines, Bull. 1 (1932), p. 102. Drysdale, 1917b, p. 95. Cockfield, 1936, pp. 3, 32, 34-37. McAllister, 1951, pp. 47-51.

The Protection property was examined in part by the writer in 1947 and in part by A. L. McAllister in 1948. The following account is quoted from his report (1951, pp. 47-51).

> The Protection mine lies about 4½ miles northeast of Ymir on the north slope of Ymir (Wildhorse) Creek Valley. The property was staked in 1897. In 1899 it was optioned to the Ymir Gold Mining Company, who sank a 60-foot shaft. No further work is reported on the property prior to 1923, at which time the owners began to explore the property in search of an extension of the vein shown on the Ymir Consolidated property, which lies northeast of the Protection. In 1926, it was optioned to Porcupine Goldfields Development and Finance Company Limited; in 1928, to the Enterprise Consolidated Mining Company Limited; and later, to the Ymir, Consolidated Gold Mining Company, which was organized to mine the Protection and Ymir properties in conjunction. Accordingly, a flotation mill, with a capacity of 125 tons daily, was constructed on the Ymir property, and ore from the Protection was trucked to it. The mill closed down after only 4 months operation.
>
> Activity at the Protection began again during the summer of 1936, when a large-scale development program was carried out. During 1938 and 1939, the mill operated continuously under the same company, and in 1940 and 1941 under lessees who operated the mill one shift daily. Since this time, intermittent shipments have been made by various lessees. Production has been mainly from stope remnants and pillars, and the hand-sorted ore has been shipped to the Trail smelter. The name was changed from 'Goodenough' to 'Protection' in 1945.

Total production of ore from the property from 1898 to 1955 inclusive was 16,086 tons, and this yielded 10,640 ounces gold, 1,515,591 pounds lead, 1,547,989 pounds zinc, 82,691 ounces silver, and 1,134 pounds cadmium.

McAllister continues:

> The rocks on the property are mostly argillite and argillaceous quartzite of the Ymir group, cut by tongues of granite and lamprophyre and aplite dykes. The bedding strikes roughly northeast.
>
> The veins strike north 60 degrees east, cutting the bedding planes at acute angles. They dip steeply northwest. The ore is valued chiefly for its gold content, but good percentages of sphalerite, galena, and some chalcopyrite are found. A little cadmium apparently accompanies the other sulphides. The gangue is milky quartz, with lesser amounts of brecciated wall-rock and some stringers of calcite. A few grains of brown tourmaline have been reported.
>
> Two shafts, sunk on a shoulder of a hill between the Protection and Ymir mines are now inaccessible. Five adits reach the mine below these shafts. No. 1 level is 225 feet below the collars of the shafts, and follows the Goodenough veins north 70 degrees east for 1,200 feet. The vein occupies an irregular fault fissure, and shows marked variations in width over short distances; the maximum width observed was 5 feet, but wider parts have probably been mined out. It consists in places of a single, well-defined vein and at other places of several veinlets along a crushed shear zone. At least six ore shoots have been mined along this level. A crosscut, 780 feet from the portal, has been driven north 20 degrees east for 75 feet. At 60 feet from the drift it intersects a small shear zone, which was followed northeast for 60 feet, but encountered no vein material.
>
> No. 2 level runs slightly north of, roughly parallel with, and 132 feet below No. 1 level. The main drift is 1,158 feet long, and seven short crosscuts have been driven from it. The rock is almost entirely argillite and quartzite, with some granite. No vein

is encountered for 100 feet beyond the portal, at which point a 6-inch quartz vein with little sulphides was followed for 20 feet before it gradually petered out into a broad shear zone. Between 300 and 570 feet beyond the portal the vein has been almost completely stoped. Sixty feet above the drift, and about 500 feet beyond the portal, lessees have uncovered a pocket rich in sulphides. At this point a sample taken across a 5-foot width assayed 0.55 ounce of gold and 3.97 ounces of silver a ton. Six hundred and forty feet from the portal a crosscut runs southeast for 100 feet and terminates in a small stope running north 25 degrees east. On this level the vein is 6 inches wide, but 30 feet below, where it was being mined at the time of examination, it reaches a width of 18 inches. Beyond this, in the main drift, at least four small shoots have been mined, one just beyond the crosscut mentioned above, one 800 feet, one 830 feet, and one 975 feet from the portal. At 975 feet from the portal two small crosscuts, each 35 to 40 feet long, leave the drift. They encounter no vein material. Beyond these crosscuts the quartz vein becomes much wider, and near the face is as wide as the drift. Values have, however, apparently not warranted stoping.

At 575 feet from the portal of No. 2 level a manway leads to No. 3 level, on which 1,500 feet of drifts and crosscuts have been run to explore parallel veins. Stoping has been more continuous on the most northerly of these and in the western part of the workings. Veins up to 4 feet wide are exposed, but are mostly stoped.

No. 4 level cuts through barren argillite and some intrusive rock for 592 feet, at which point a short crosscut runs north to join a 100-foot drift. This drift has a timbered back and several ore chutes. Whether or not the orebody extended down to this level is not known, but no evidence of mineralization was noted at either end of the drift. Across the trend of this zone is a 68-foot crosscut running northwest from the main drift at 694 feet from the portal. No vein was found in this crosscut. Between 815 and 975 feet from the portal the main drift follows a shear zone up to 4 feet wide. Although the zone contains numerous small quartz veins it carries little sulphides. At a point 565 feet from the portal an 80-foot crosscut runs southeast to join a subsidiary drift 430 feet long. This drift, parallel with the main drift, shows only narrow quartz veins and little sulphides. Ore chutes lead to stopes above, but little has been mined near this level. A narrow shear exposed in a crosscut running east from the main drift 740 feet from the portal is probably an extension of this zone.

Production from the 400-foot level has been confined almost entirely to a drift running north 80 degrees east for 513 feet beyond the point where it joins the main drift 880 feet from the portal. Along this drift an ore shoot has been mined almost continuously for 200 feet to a point 513 feet from the main drift, beyond which the workings are inaccessible. Pillars show the vein to be 1 foot to 5 feet wide in this area, and to consist of sulphides in white quartz. The white quartz has itself been fractured, and the fractures filled with drusy quartz.

No. 5 level is a drift 143 feet long following a vein that in places is 14 feet wide and carries good values in lead, zinc and copper, but little gold. At a crosscut 65 feet beyond the portal the vein splits, a part going into the foot-wall, and a part following the main drift. It gradually narrows toward the face and becomes barren. Several tons of ore have been shipped from near the portal.

No. 6 level[1] lies 100 feet below No. 5. Near the portal of this level several quartz veins occupy a shear zone 30 feet wide that pinches out almost completely 70 feet beyond the portal. At 175 feet beyond the portal a narrow, unmineralized vein enters the drift from the north wall. The main drift follows this vein for 130 feet, and from there for 50 feet farther along a branch drift running north 47 degrees east. This drift continues 63 feet beyond to where it intersects a small, barren shear zone. Beyond the junction of this drift with the main drift, the latter follows a fairly persistent quartz vein and shear zone. The vein is in places 3 feet wide, and a small part of it has been stoped. It narrows and disappears before the face is reached.

[1] This level has been driven since Cockfield's examination.

Centre Star (Wesko) (237)

References: Minister of Mines, B.C., Ann. Repts.: 1934, p. E9; 1935, p. E28; 1936, p. E46; 1937, p. E46; 1938, p. E3; 1940, p. 67; 1942, p. 63; 1944, p. 61; 1946, p. 144; 1947, p. 162; 1948, p. 133. Cockfield, 1936, pp. 3, 5, 20-24. McAllister, 1951, pp. 45-47.

The Centre Star mine was examined in 1948 by A. L. McAllister who describes it as follows:

> The Centre Star property, consisting of six Crown-granted claims (Redman, Twilight, Gold Island, Crowfoot, Blend Canyon, and Centre Star) and ten others held by location, lies on the western slope of Jubilee Mountain just southeast of Ymir. A 3-mile road joins the workings to the Nelson-Salmo highway at Ymir.
>
> Initial staking took place in 1900, and some work was done at that time. The first large scale development began in 1934 when the property was acquired by the Wesko Exploration and Development Company. Production was continuous during 1937 and until August 1938. The mill closed in October of that year, since when small, intermittent shipments have been made by lessees.

Total production of ore from the Centre Star from 1936 to 1950 inclusive, was 56,725 tons, which yielded 12,415 ounces gold, 2,130,562 pounds lead, 1,048,588 pounds zinc, and 95,014 ounces silver.

McAllister's description continues:

> The property lies in a broad contact zone between the Nelson batholith and rocks of the Ymir group. The zone consists of sheared and altered argillites and quartzite cut by innumerable small bodies of granite and granite-gneiss. Small bodies of aplitic intrusive rocks are found in the workings as well as lesser amounts of andesitic rock related to the Elise formation. Lamprophyre dykes cut the orebody and follow post-ore faults.
>
> Numerous faults complicate the structure. Of these the most prominent strike north 30 to 55 degrees east and dip vertically or steeply southeast. Two such faults are exposed for hundreds of feet in the 300-foot level, from the eastern and western limits of the ore shoots. The ore shoots lie in veins along fault fissures striking north 60 to 80 degrees east and dipping steeply northwest. The veins vary in width up to 25 feet. Brecciated wall-rock is common in many of them.
>
> The veins are cut by numerous faults, most of which strike between northeast and north, and dip to the east or southeast. Movement along these faults has been such as to offset the eastern side to the south. Other faults offsetting the veins strike northwest and dip northeast.
>
> The veins consist of pyrite, pyrrhotite, sphalerite, and galena in a quartz gangue. Values are mainly in gold, and considerable silver is also present. Pyrrhotite is more common on the lower levels. On the surface, the veins are oxidized and the vein matter consists of honeycombed masses of limonite, quartz, manganite, and some pyromorphite and cerussite.
>
> At present the mine workings consist of five main levels and a few subsidiary levels. Much of the vein material has been stoped. Although considerable work has been done on the property since Cockfield's examination much of his general descriptive material still holds good, and the reader is referred to his report for a fuller treatment.
>
> The best showings were found in the vicinity of the 300-foot level, where one shoot attains a width of 25 feet near one of the wide, northeasterly trending shear zones. The wide part of this shoot rakes steeply east along the junction of the vein and the fault referred to above. On this level the shoot has a length of more than 200 feet, and is cut off to the east by a north-south fault. East of the fault the vein is followed for 170 feet by a drift. This eastern part of the vein has again been offset to the south about 50 feet. The most easterly workings on this level consist of a long drift following

a second, northeast trending fault. Little evidence of mineralization was noted along this drift, and no ore shoots have been found east of it, although small veins were observed striking northeast and even west of north.

Numerous lamprophyre dykes are found on this level. They cut the ore veins and are definitely post-mineral.

The geology on other levels is similar to that on the 300-foot level, and veins striking north 60 to 80 degrees east are offset by minor faults.

Several small veins are exposed in surface cuts on the property, but these have not been correlated with underground ore shoots. Some are described by Cockfield.

The most striking feature of the veins is their localization in the fissures running north 60 to 80 degrees east, and their sharp truncation against two bounding northeasterly striking fault zones. Cockfield believes that these faults are pre-mineral; if so, the chances of finding ore beyond them are materially lessened.

Clubine-Comstock (243)

References: Minister of Mines, B.C., Ann. Repts.: 1932, p. 188; 1933, p. 228; 1934, pp. E14, E15; 1935, p. E28; 1936, pp. E4-E7; 1942, p. 63; 1946, p. 144. B.C. Dept. of Mines, Bull. 1 (1932), p. 99. Walker, 1934, pp. 77, 78.

The Clubine-Comstock property, consisting of several claims held by location, is on the west side of Salmo River valley about 3 miles north of Salmo, from where it is accessible by road. The Boulder City and adjoining claims were staked in 1925 by L. R. Clubine of Salmo on an old prospect abandoned long previously. Initial development in 1925 and 1926 was done by the Consolidated Mining and Smelting Company of Canada, Limited. The property was acquired in 1932 by Clubine-Comstock Gold Mines Limited, who operated the mine from that year until 1940. In 1941 and 1942 it was operated by lessees. In 1946 further development work was done by the owners, but no shipments of ore are recorded.

During the years 1926 to 1942 inclusive, a total of 3,986 tons of ore was shipped. This yielded 3,964 ounces gold, 7,699 ounces silver, and 1,804 pounds zinc. The property was examined by the writer in June 1948.

The country rock is porphyritic augite andesite and non-porphyritic andesite of the Rossland formation. Less than a mile to the southeast is the contact of a large stock of Nelson granite that intrudes the Rossland formation and may lie at no great depth below the property. The andesites are cut by lamprophyre dykes, the most prominent of which is exposed in the workings. These comprise at least seven levels accessible by adits, and one sublevel, and explore the vein between the 3,125-foot and 3,630-foot elevations.

The vein is irregular in width, and occurs along the hanging-wall of a lamprophyre dyke that is at least 25 feet wide. The lamprophyre is strongly sheared especially along the foot-wall where irregular pods consisting largely of biotite occur within the dyke. The vein consists of a series of lenticular masses of quartz up to a foot or more thick that are apparently elongated down the dip. Its strike varies from N10° to 20°W and it dips about 40°E. Little vein material was visible in the workings examined. It consists of quartz, mainly brecciated, containing various amounts of pyrrhotite with minor chalcopyrite, galena, and sphalerite.

Midnight (299)

References: Minister of Mines, B.C., Ann. Repts.: 1897-1956 (especially 1935, pp. E9-E11). B.C. Dept. of Mines, Bull. 1 (1932), pp. 122-123.

The Midnight claim, Crown-granted in 1897, is on the west side of Little Sheep Creek about 2 miles west of Rossland, from where it is accessible by road. It adjoins the I.X.L. claim on the east. The Midnight Consolidated Mines Limited acquired ownership of the claim in 1956.

Total production of ore from 1927 to 1952 inclusive, was 4,085 tons, which yielded 6,501 ounces gold and 3,777 ounces silver. The accessible workings were examined in June 1950 by the writer, at which time the claim was owned by Kootenay Central Mines Limited.

The claim is underlain by fine-grained, massive andesite of the Mount Roberts formation. A large body of serpentinite occurs to the south. The rocks of the Mount Roberts formation are intruded within the claim by many lamprophyre dykes, up to 10 feet wide, that strike roughly N15°W and dip 45° to 75°E. At least some of these dykes are earlier than the Midnight vein.

On the Midnight claim only the east end of the A vein of the I.X.L. and O.K. claims was observed in the accessible workings, near the west edge of the claim. To the east of this, in what Sargent (Minister of Mines, B.C., Ann. Rept. 1935) describes as the lower Midnight adit which shares a common portal with the I.X.L. No. 4 level, a sinuous vein that strikes northerly and dips 45° to 55°W is explored for a distance of 300 feet. It varies in width from 2 inches to 6 feet and two branch veins from it have been traced near its northern end.

The vein matter is quartz and some ankerite, with pyrite, a little galena, and free gold that locally is said to be visible. Chalcopyrite, though present in the veins, is not sufficiently abundant to be recoverable; the Midnight vein differs mineralogically in that respect from those on the adjoining I.X.L. and O.K. claims.

Other gold-silver deposits within the map-area, together with selected references except where these are numerous, are listed below.

L. H. (125)

Minister of Mines, B.C., Ann. Repts.: 1904, p. 173; 1915, pp. 127-129; 1917, p. 158; 1945, p. 105.
McConnell, 1897a, pp. 26, 27.
Cairnes, 1935, pp. 66-68.

Little Daisy (126)

Minister of Mines, B.C., Ann. Rept. 1935, pp. E3, E4.
B.C. Dept. of Mines, Bull. 1 (1932), p. 115.

Lakeview (142)

Minister of Mines, B.C., Ann. Rept. 1937, pp. E3-5.

Oro Fino (171)

Maconachie, 1940, pp. 12-14.

Good Hope (Ophir) (182)

Minister of Mines, B.C., Ann. Rept. 1928, p. 322.
LeRoy, 1912a, pp. 146, 151, 152.

Whitewater (183)

Minister of Mines, B.C., Ann. Repts.: 1890, p. 366; 1948, p. 131.
B.C. Dept. of Mines, Bull. 1 (1932), p. 101.

Nevada and Royal Canadian (186)

Minister of Mines, B.C., Ann. Repts.: 1890, p. 366; 1928, pp. 321, 322; 1933, pp. 218, 219.
LeRoy, 1912a, p. 151.
Cockfield, 1936, pp. 72-76.
Stevenson, 1943, p. 155.

Granite-Poorman (188)

Minister of Mines, B.C., Ann. Repts.: 1889-1956.
LeRoy, 1912a, p. 147.
Cockfield, 1936, pp. 66-69.

May and Jennie (191)

Minister of Mines, B.C., Ann. Repts.: 1900, p. 845; 1904, p. 138.
LeRoy, 1912a, p. 152.

Star and Alma N. (192)

Minister of Mines, B.C., Ann. Rept. 1930, pp. 268, 269.
Cockfield, 1936, pp. 69-71.

Venus and Juno (194)

Minister of Mines, B.C., Ann. Repts.: 1899-1946.
LeRoy, 1912a, pp. 150-152.
Cockfield, 1936, pp. 63-65.

Athabaska (196)

Minister of Mines, B.C., Ann. Repts.: 1896-1946.
B.C. Dept. of Mines, Bull. 1 (1932), pp. 95, 96.
LeRoy, 1912a, p. 148.
Cockfield, 1936, pp. 65, 66.

Catherine (199)

Minister of Mines, B.C., Ann. Rept. 1928, p. 320.
B.C. Dept. of Mines, Bull. 1 (1932), pp. 96, 97.

Perrier (200)

Minister of Mines, B.C., Ann. Repts.: 1910-1937.
B.C. Dept. of Mines, Bull. 1 (1932), p. 96.
LeRoy, 1912a, pp. 146, 151.
Cockfield, 1936, pp. 61-63.

California (201)

Minister of Mines, B.C., Ann. Repts.: 1897-1947.
LeRoy, 1912a, pp. 146, 150.

Daylight and Berlin (205)

Minister of Mines, B.C., Ann. Rept. 1937, pp. E28, E29.

Starlight (208)

Minister of Mines, B.C., Ann. Repts.: 1894, p. 742; 1896, p. 86; 1932, p. 183.

Bear (214)

Minister of Mines, B.C., Ann. Repts.: 1937, pp. E36-38; 1939, p. 80.

Fern (215)

Minister of Mines, B.C., Ann. Repts.: 1894-1946.
McConnell, 1896, p. 35A.
Drysdale, 1917b, pp. 137-146.
Cockfield, 1936, pp. 48-52.
Mulligan, 1952, p. 29.

Canadian Belle (216)

Minister of Mines, B.C., Ann. Repts.: 1937, pp. E34-36; 1947, p. 160.
Mulligan, 1952, pp. 29, 30.

Euphrates (218)

Minister of Mines, B.C., Ann. Repts.: 1912-1940.
Drysdale, 1917b, pp. 147, 148.
Cockfield, 1936, pp. 55-58.

Second Relief (219)

Minister of Mines, B.C., Ann. Repts.: 1899-1948.
Cockfield, 1936, pp. 7-12.

Harriet (220)

Minister of Mines, B.C., Ann. Rept. 1937, pp. E39, E40.

Porto Rico (221)

Minister of Mines, B.C., Ann. Rept. 1922, p. 207.
McConnell, 1899, p. 32A.
Drysdale, 1917b, pp. 128-137.
Cockfield, 1936, pp. 46, 47.

Spotted Horse (222)

B.C. Dept. of Mines, Bull. 1 (1932), pp. 98, 99.
Cockfield, 1936, pp. 47, 48.

Tamarac (223)

Minister of Mines, B.C., Ann. Repts.: 1928, pp. 334, 335; 1932, pp. 187, 188.
Drysdale, 1917b, pp. 98, 99.
Cockfield, 1936, pp. 43, 44.

Ymir (225)

Minister of Mines, B.C., Ann. Repts.: 1896-1944.
McConnell, 1899, pp. 31, 32A.
Drysdale, 1917b, pp. 100-107.
Cockfield, 1936, pp. 32-34.

Blackcock (Black Cock) (228)

Minister of Mines, B.C., Ann. Repts.: 1928, pp. 332, 333; 1932, p. 187; 1934, pp. E13, E14.
Drysdale, 1917b, pp. 67, 68.
Cockfield, 1936, pp. 39-42.

Pilot-Good Hope (233)

Minister of Mines, B.C., Ann. Repts.: 1923, pp. 216, 217; 1930, p. 271.
Drysdale, 1917b, pp. 72, 73.

Myrtle (234)

Cockfield, 1936, p. 19.

Yankee Girl (236)

Minister of Mines, B.C., Ann. Repts.: 1896-1954.
Drysdale, 1917b, pp. 112-116.
Cockfield, 1936, pp. 26-31.
Wright and Morrell, 1938.

Second Chance (244)

Minister of Mines, B.C., Ann. Rept. 1930, p. 278.

Keystone (245)

Walker, 1934, pp. 76, 77.

Gold Hill (247)

Walker, 1934, pp. 78, 79.

Arlington (248)

Minister of Mines, B.C., Ann. Repts.: 1899-1954.
Walker, 1934, pp. 75, 76.

Reno (253)

Minister of Mines, B.C., Ann. Repts.: 1914-1947.
Walker, 1934, pp. 25-28.
Mathews, 1953, pp. 21, 23, 35, 42-43, 51, 54-57.

Fawn (Golden Fawn) (254)

Walker, 1934, pp. 37, 69.

Nugget (255)

Minister of Mines, B.C., Ann. Repts.: 1907-1950.
Walker, 1934, pp. 28-30.
Mathews, 1953, pp. 43, 51, 57, 74.

Motherlode (Mother Lode) (256)

Minister of Mines, B.C., Ann. Repts.: 1906-1942.
Walker, 1934, pp. 30-32.
Mathews, 1953, pp. 41, 51, 62, 74.

Columbia (258)

Minister of Mines, B.C., Ann. Rept. 1928, p. 346.

Kootenay Belle (259)

Minister of Mines, B.C., Ann. Repts.: 1904-1950.
Walker, 1934, pp. 38-41.
Mathews, 1953, pp. 51, 54, 55, 57-59, 62, 63.

Yellowstone (260)

Minister of Mines, B.C., Ann. Repts.: 1899-1947.
Walker, 1934, p. 42.
Mathews, 1953, pp. 42-45, 51, 54, 55.

Vancouver (261)

Minister of Mines, B.C., Ann. Repts.: 1905-1934.
Walker, 1934, pp. 41, 42.

Queen (262)

Minister of Mines, B.C., Ann. Repts.: 1899-1952.
Walker, 1934, pp. 42-45.
Mathews, 1953, pp. 37, 41-43, 51, 52, 56, 69.

Ore Hill (263)

Minister of Mines, B.C., Ann. Repts.: 1917, pp. 170, 171, 195; 1936, pp. E14-16.
Walker, 1934, p. 80.
Mathews, 1953, pp. 46, 63.

Sumit (Summit) (264)

Minister of Mines, B.C., Ann. Rept. 1910, p. 111.
Walker, 1934, pp. 79, 80.
Mathews, 1953, pp. 51, 52, 63.

Lucky Strike (270)

Minister of Mines, B.C., Ann. Rept. 1938, pp. E17-21.

Davne (271)

Minister of Mines, B.C., Ann. Rept. 1938, pp. E17, E18, E21.

Bunker Hill (276)

Minister of Mines, B.C., Ann. Repts.: 1933, pp. 238, 239; 1934, pp. E24, E25; 1936, pp. E18-21.
Walker, 1934, p. 89.

Casino Red Cap (278)

Minister of Mines, B.C., Ann. Rept. 1951, p. 135.

R. E. Lee (282)

Minister of Mines, B.C., Ann. Rept. 1896, pp. 17, 30.
Drysdale, 1915, p. 169.

Richmond (292)

Minister of Mines, B.C., Ann. Rept. 1921, pp. 149, 151.
Drysdale, 1915, p. 171.

71994-8—13

Hattie (293)

Minister of Mines, B.C., Ann. Rept. 1921, pp. 149, 151.
Drysdale, 1915, pp. 170, 171.

Golden Drip (Gold Drip) (296)

Minister of Mines, B.C., Ann. Rept. 1923, pp. 231, 232.

Snowdrop (300)

Minister of Mines, B.C., Ann. Repts.: 1948, p. 129; 1955, pp. 47, 48; 1956, p. 76.
B.C. Dept. of Mines, Bull. 1 (1932), p. 123.

Jumbo (302)

Minister of Mines, B.C., Ann. Rept. 1896, p. 26.
Brock, 1906, pp. 17, 18, 20.
Drysdale, 1915, pp. 46, 70, 146-149.

Columbia-Kootenay (325)

Minister of Mines, B.C., Ann. Repts.: 1896, pp. 28, 29; 1898, p. 1093; 1904, p. 207.
Drysdale, 1915, pp. 128, 129.

Copper-silver-gold Deposits

Only seven copper-silver-gold deposits occur within the map-area. However, two of them, the Queen Victoria and Eureka, are of some economic importance and another, the Silver King, was the first major discovery made. The only exception to the above order of value of the metals is the Lily May where silver exceeds copper in value. The Silver King and Lily May produced also a little lead and zinc. The Lord Roberts ore yielded only copper and silver.

The copper-silver-gold deposits occur in only two minor belts. The first lies within and northwest of the northwest end of the major gold-silver belt, and is to a degree also associated with a few gold-copper-silver deposits. The other belt, which contains only two minor producers north of Rossland camp and one south of it, is vaguely peripheral to the gold-copper-silver deposits of the camp.

Three of the copper-silver-gold deposits are contact metamorphic types. These are the Monarch and Queen Victoria west of Nelson, which occur in skarn, and the Lord Roberts, in augite porphyry and limestone of the Mount Roberts (?) formation. The other four deposits are fissure-filled veins, although in the Eureka there is much replacement of rock adjacent to the vein. The country rocks are pseudodiorite with abundant xenoliths of crystalline limestone on the Eureka, sericite and chlorite schist of the Rossland formation on the Silver King, and slate and argillaceous quartzite of the Mount Roberts formation on the Lily May and View properties respectively.

The Monarch and Queen Victoria deposits consist of pyrite, chalcopyrite, magnetite, and minor pyrrhotite in a gangue of garnet, pyroxene, amphibole, epidote, and calcite. The Eureka ore comprises chalcopyrite, azurite, malachite,

chrysocolla, minor galena, and native silver in a gangue of quartz and calcite. The Silver King veins are of quartz, carbonate, and manganite(?), and contain pyrite, chalcopyrite, bornite, tetrahedrite, malachite, azurite, galena, and stromeyerite. The View and Lily May veins are quartz with pyrrhotite, pyrite, chalcopyrite, and in the Lily May, also a little galena, sphalerite, and stibnite or possibly boulangerite. The Lord Roberts deposit comprises magnetite, pyrrhotite, pyrite, chalcopyrite, and bismuthinite (?) in a gangue of quartz, hornblende, and feldspar.

Queen Victoria (181)

References: Minister of Mines, B.C., Ann. Repts.: 1896, p. 560; 1906, p. 149; 1908-1928. LeRoy, 1912a, p. 154. Mulligan, 1952, pp. 35, 36.

The Queen Victoria mine is about a mile north of Beasley, some 8 miles west of Nelson. It is accessible by road from the Nelson-Trail highway. Ore production began in 1907 and continued intermittently until 1927, and totalled 45,218 tons containing 1,433,713 pounds copper, 20,923 ounces silver, and 195 ounces gold. The property was examined in 1949 by Mulligan (1952, pp. 35, 36) who described it as follows:

> This orebody is a contact metamorphic or skarn type of deposit. The workings are mainly open glory holes, and as such, still accessible. The lower workings are in a fine green to red rock, in places composed largely of garnet and epidote, with very abundant calcite in coarsely recrystallized stringers. Some epidote is also coarsely crystalline, and resembles tourmaline. Black amphibolite bands are common in the upper western workings. At the extreme west end the only bit of unrecrystallized limestone recognized was found pinching out between quartzite strata. Hard greenish quartzite immediately underlies the ore zone, and presumably overlies it in great thickness. Pseudodiorite lies not far below, and the general horizon seems to be about the same as that of numerous occurrences of pyroxenite and pyroxene-biotite rock farther east.
>
> A thin section of typical fine green skarn rock consists largely of epidote, with diopsidic pyroxene, bluish green amphibole, and fresh anorthoclase and soda-microcline. Sphene and apatite are also present, but calcite is very scarce. The rocks and orebody are disrupted by small faults, and cut by fine grey feldspar-porphyry dykes. A thin section of one dyke has much potassic and soda-potassic feldspar with some broken and altered plagioclase phenocrysts, in a fine, sutured, feldspathic groundmass with green biotite, epidote, some quartz, and accessory sphene and apatite. These dykes are unlike any common rocks of the map-area.
>
> The metallic minerals are pyrite, chalcopyrite, and minor pyrrhotite and magnetite. The ore is low grade and the property has been idle for a number of years.

Silver King (206)

References: Minister of Mines, B.C., Ann. Repts.: 1887-1956. Dawson, 1890, pp. 57B-60B. LeRoy, 1912a, pp. 139, 146, 156. Mulligan, 1952, pp. 32-34.

The Silver King group is on the northeast side of Toad Mountain, about 3 miles by road southwest of Nelson. The original claims were staked by the Hall brothers in 1886, and production of ore which began in 1889 continued intermittently until 1948. In this period 222,246 tons of ore was shipped, and this contained 14,946,235 pounds copper, 4,441,051 ounces silver, 280 ounces gold, 30,798 pounds lead, and 7,397 pounds zinc. The few accessible workings were examined in 1949 by Mulligan (1952, pp.32-34) whose report follows:

> The claims of this group are situated along the axes of the 'schist zone' of undifferentiated Rossland formation, and constitute what was known in the early days

as the 'Silver-copper belt'. The most important claims definitely belonging to this group are the Silver King, Kootenay Bonanza, Dandy, Grizzly Bear, Ollie, and Iroquois. The Victoria, Jessie, Daylight, Berlin, etc., farther east within the schist zone apparently have values chiefly in gold.

The schists along this axis, although all in shades of green, appear to be in part clastic in origin, unlike those closer to Toad Mountain, whose origin as augite porphyry can still be recognized. 'Sericite schist' is undoubtedly sheared Silver King porphyry, remnants of which are to be seen in unmined parts of the lode at the surface. Perhaps a tongue of this rock, more brittle than the volcanic-clastic rocks, proved favourable for development of the cross-fissures that have been repeatedly mentioned as the loci of deposition within the lode. 'Compact magnesian limestone', mentioned in early reports of the B.C. Department of Mines, is not in evidence, but limestone blocks or lenses several feet in length were seen in volcanic schist on the ridge south of the mine. In the late summer of 1949 the lower adits, which were not caved, were still plugged with ice and snow, and little information is to be had from the surface workings.

Ore minerals seen in specimens collected are pyrite, chalcopyrite, bornite, tetrahedrite, malachite, azurite, and galena. They occur in fine stringers in country rock. Prominent in the sparse quartz-carbonate wall-rock gangue are large lamellar aggregates of a black, submetallic, rather hard mineral, probably manganite.

W. R. Baragar (personal communication) who has studied the mineralography of a suite of Silver King ores, finds that stromeyerite, a copper-silver sulphide, is the only important argentiferous mineral, and that it and galena were deposited later than chalcopyrite, bornite, and tetrahedrite; furthermore, that stromeyerite is associated chiefly with bornite. His classification of this orebody as a zeno-epithermal deposit is certainly in keeping with both the mineralogical contrast with the 'gold-belt' properties, and with its proportionately greater distance, laterally and vertically, from probable deep-seated igneous sources.

Other copper-silver-gold deposits with principal references are listed below.

Monarch (180)

Minister of Mines, B.C., Ann. Repts.: 1922, p. 207; 1928, p. 319.

Eureka (193)

Minister of Mines, B.C., Ann. Repts.: 1913, p. 128; 1915, pp. 146, 147; 1953, p. 113; 1956, p. 78.
LeRoy, 1912a, pp. 153, 154.
Mulligan, 1952, pp. 34, 35.

Lily May (294)

Minister of Mines, B.C., Ann. Repts.: 1896, pp. 17, 31; 1921, p. 151; 1949, pp. 157, 158.
Drysdale, 1915, pp. 170, 171.

View (314)

Drysdale, 1915, p. 135.

Lord Roberts (326)

Minister of Mines, B.C., Ann. Rept. 1920, p. 137.
Brock, 1907, p. 62.
Drysdale, 1915, pp. 158, 159.

Gold-copper-silver Deposits

Ore deposits containing gold, copper, and silver in approximate decreasing order of value are not numerous within the map-area, but perhaps represent the most productive of all types, due almost entirely to the four central properties of

the Rossland camp. The Central, Victoria and Jessie, Northern Light, White Bear, St. Elmo, and Cliff and Consolidated St. Elmo mines differ from the normal type as the value of copper exceeds that of gold, and in the Homestake, O.K., and I.X.L. properties, the value of silver exceeds that of copper, although the production of copper on these properties is relatively important. On the other hand, the Giant-California and Nickel Plate mines have yielded little silver. Only the Velvet mine in this group has produced lead and zinc, and these in minor amount.

Gold-copper-silver deposits form two belts: a minor one including only four properties of secondary importance occurring with silver-copper deposits in the core of the northwest part of the major gold-silver belt; and a major one comprising the economically important core of the Rossland camp. The Velvet mine, however, occupies an isolated position southwest of the Rossland camp.

The gold-copper-silver deposits are of three types. The first of these comprises sulphide replacements along fissures or intrusive contacts, with little or no quartz or carbonates. Examples of this type are the Le Roi, Centre Star, Nickel Plate, Josie (Le Roi No. 2), War Eagle, Phoenix, White Bear (at depth), Monte Christo, Nest Egg, Sunset No. 2, and Crown Point properties, the last named being a replacement along contacts of diorite porphyry intrusive into augite porphyry. In this type of deposit, the host rocks are sheared augite porphyry, monzonite, and greenstone. The second type comprises fissure-filled lodes containing gangue minerals, mainly quartz and perhaps some carbonates, with little or no disseminated sulphides in the adjacent wall-rock. Examples are the Gold Hill, Northern Light, Gold King, O.K., I.X.L., upper levels of the White Bear, and Evening Star properties, where the host rocks are massive andesite and augite porphyry or brittle argillaceous quartzite. The third type is intermediate to the other two, and comprises disseminated sulphides in shear zones containing veins or stockworks of veinlets. Examples are the Central, Victoria-Jessie, California (near Rossland), Velvet, and Spitzee, the last named, however, differing from the others in that the "veinlets, stringers, and impregnations" occur in monzonite along the contact with intrusive pulaskite (Drysdale, 1915, p. 140). The host rocks in this type vary widely, being granodiorite, greenstone, fine-grained monzonite, argillaceous quartzite, and serpentine.

The importance of the host rock was recognized early when the operators of the White Bear property sunk a deep shaft in argillaceous quartzite to reach the underlying augite porphyry, and were rewarded by finding larger and richer orebodies in the latter. Similarly the St. Elmo-Monte Christo fissure yields more and better ore in the east end where the country rock is fine-grained monzonite than in the west end where it is argillaceous quartzite.

The gangue in the gold-copper-silver deposits is altered country rock with little or no quartz and carbonate, or else it is quartz with minor carbonates. Ankerite is present in the O.K. and I.X.L. veins, and calcite occurs in the Le Roi, Josie, St. Elmo, Cliff and Consolidated St. Elmo, and Velvet ores. A little scheelite occurs also in the last three mentioned.

Ore minerals of the 'Rossland type' are auriferous pyrrhotite, chalcopyrite, some pyrite, and, according to Gilbert (1948), "other sulphides". Ores of this

71994-8- -14

type occur on the Crown Point, Nest Egg, Sunset No. 2, Le Roi, Centre Star, Nickel Plate, Josie (Le Roi No. 2), War Eagle, and Monte Christo properties. On the Monte Christo, erythrite is also present. In others, such as the Central, Victoria-Jessie, Gold King, Homestake, and Spitzee deposits, pyrite is more abundant than pyrrhotite. This is true also in the California where arsenopyrite is present, and in the Evening Star, where danaite (cobaltous arsenopyrite) has been identified. Arsenopyrite is present in White Bear ore, which otherwise is of the 'Rossland type.' The Giant vein differs from others in that it contains arsenopyrite, pyrrhotite, pyrite, molybdenite, bismuthinite, minor chalcopyrite, and native gold, so that this may be more properly classed as a gold-silver deposit. A little molybdenite is reported in the Evening Star and in the Velvet, St. Elmo, and Cliff and Consolidated St. Elmo, where a little galena and sphalerite also are present. Bornite and chrysocolla occur only in the Gold Hill ore, associated with pyrite, arsenopyrite, chalcopyrite, and free gold.

O.K. and I.X.L. (297 and 298)

References: Minister of Mines, B.C., Ann. Repts.: 1892-1956, (especially 1935, pp. E4-E9). Drysdale, 1915, pp. 46, 69, 73, 151, 152. B.C. Dept. of Mines, Bull. 1 (1932), pp. 122-123.

The adjoining I.X.L. and O. K. Crown-granted claims are on the west side of Little Sheep Creek about 2 miles by road west of Rossland, and are aligned in a westward direction in the order named. They were staked in 1891 and 1892 and were developed and operated intermittently, individually and in different combinations since that time by various owners and lessees. The present owner of the group is Midnight Consolidated Mines Limited who acquired the property together with the Midnight in 1956.

The I.X.L. and O.K. claims have produced a total of 6,049 tons of ore in the years 1899 to 1953 inclusive. This contained 26,281 ounces gold, 9,248 ounces silver, and 19,839 pounds copper; approximately 97 per cent of the value of these metals was from the I.X.L. The accessible workings were examined by the writer in June 1950 when the I.X.L. claim was owned by Kootenay Central Mines Limited.

Many of the workings that were examined by Sargent (Minister of Mines, B.C., Ann. Rept. 1935, pp. E4-E9) as well as some that were driven subsequently were inaccessible at the time of the writer's visit. Much of the information here is therefore taken from Sargent's report.

The claims are underlain mainly by fine-grained, massive andesite, with minor interbeds of tuffaceous slate and limestone all of the Mount Roberts formation. From one of the limestone beds on the O. K. claim Brock (Daly, 1912, p. 321; Drysdale, 1915, p. 199) collected fossils of Pennsylvanian age. These rocks are overlain to the west by volcanic rocks of the Rossland formation, and to the south are bounded by a large body of serpentinite that is also exposed in the lower workings of the O. K. claim. The rocks of the Mount Roberts forma-

tion are intruded by a small body of biotite monzonite and several lamprophyre dykes, some of which are up to 10 feet wide. Sargent states that some of these cut the veins.

Three veins are known, the A, B, and C. The C vein is the probable extension of the Baker vein exposed in the upper workings of the O.K. These veins are 60 to 80 feet apart and are roughly parallel. In general they strike N50° to 80°E, dip 35° to 65°SE, and occupy faults in which up to 6 inches of gouge occurs. The veins range in width from a fraction of an inch to 2 feet. They are traversed by two sets of faults. One set strikes N30° to 60°E, dips 50° to 80°SE, and displaces the veins very little. The other strikes about N30°W, and the most prominent fault, which traverses the centre of the I.X.L. claim, appears to offset the B vein about 50 feet. To the east of this fault the veins strike roughly east and dip 45° to 60°S.

The gangue minerals of the veins are quartz, with some ankerite, and contain pyrite, chalcopyrite, a little galena, and free gold that in places is said to be visible to the naked eye. The ore is found in rich pockets that are erratically distributed in the veins. An example of such ore is reported in the 1953 shipment which consisted of 120 pounds that contained 28 ounces gold and 6 ounces silver.

Velvet (330)

References: Minister of Mines, B.C., Ann. Repts.: 1897-1956. Drysdale, 1915, pp. 78, 90, 154-158. Stevenson, 1943, p. 154.

The Velvet property, comprising the Velvet and Portland Crown-granted claims and several others held by location, is on the east side of Big Sheep Creek about a mile north of the International Boundary. It is accessible by road; the southern trans-provincial highway (No. 3) crosses it. The property is owned by Mid-West Copper and Uranium Mines Limited.

The Velvet and Portland claims were located in 1896 and were developed separately until their amalgamation in 1904. The property has been operated successively by several companies, and was acquired by the present owners in 1955. Total ore produced from 1901 to 1956 inclusive, was 61,317 tons, which yielded 17,561 ounces gold, 1,710,706 pounds copper, 15,425 ounces silver, 36 pounds zinc, and 22 pounds lead. The property was examined by the writer in June 1950, when it was inactive.

The ore deposit is developed by a vertical shaft serving six levels, of which two, No. 4 and No. 6 are accessible from the surface by long adits. At the time of the writer's visit, No. 1 level, the adit to No. 4 level, and the entire No. 6 level were inaccessible owing to caving.

The property is underlain mainly by serpentinite which forms a huge roof pendant surrounded by Coryell syenite. Within the serpentinite are large xenoliths of Rossland volcanic rock, particularly on the Portland claim. The rocks within the pendant are cut by dykes up to 20 feet wide of commonly porphyritic syenite and pulaskite (?), and medium-grained granodiorite. These dykes are probably

71994-8- -14½

related to the Coryell and Nelson plutonic rocks respectively, and in general are parallel with the main shears. A few small dykes of lamprophyre are also present.

The serpentinite is traversed by a main shear zone and three or more subparallel shears. The main shear zone contains the largest ore shoots and strikes N10°E to N15°W in the levels examined and dips 50°E to 50°W, but most commonly steeply west. The shear zones contain fissure veins of quartz and calcite with specularite, chalcopyrite, and pyrite, and a little galena and sphalerite, and these minerals have in part replaced the wall-rock adjacent to the veins. Ore shoots have been formed most commonly at the intersection of the shear zones with dykes or with small subsidiary shears. In the upper levels, the sulphides have been largely altered to limonite and malachite. A lens of molybdenite 3 inches by 2 feet was noted by Drysdale (1915, p. 78). Scheelite is sparsely disseminated in the ore (Stevenson, 1943, p. 154).

According to Drysdale, there is a considerable fluctuation in the metal content of the ores; in some localities the ore is "high in gold and low in copper and in others the reverse is true."

Other gold-copper-silver properties, together with selected references except where these are numerous, are listed below.

Central (189)

Minister of Mines, B.C., Ann. Repts.: 1910, p. 105; 1924, p. 192.

Victoria and Jessie (207)

Minister of Mines, B.C., Ann. Rept. 1932, pp. 182, 183.

Gold Hill (209)

Minister of Mines, B.C., Ann. Repts.: 1902, pp. 157, 158; 1927, pp. 316, 317.

Northern Light (210)

Minister of Mines, B.C., Ann. Rept. 1928, p. 323.

Gold King (213)

Minister of Mines, B.C., Ann. Repts.: 1915, pp. 148, 149; 1932, pp. 185, 186.
B.C. Dept. of Mines, Bull. 1 (1932), p. 97.
Drysdale, 1917b, p. 146.
Cockfield, 1936, pp. 53-55.

Crown Point (280)

Minister of Mines, B.C., Ann. Rept. 1896, p. 29.
Drysdale, 1915, pp. 161-163.

Homestake (287)

Minister of Mines, B.C., Ann. Rept. 1896, pp. 17, 30, 31.
Brock, 1907, pp. 20-21.
Drysdale, 1915, pp. 166, 167.

Nest Egg (288)

Minister of Mines, B.C., Ann. Repts.: 1896, p. 31; 1949, p. 158.

Sunset No. 2 (289)

Minister of Mines, B.C., Ann. Rept. 1949, p. 158.

Giant-California (303, 304)

Minister of Mines, B.C., Ann. Rept. 1923, p. 230.
Brock, 1903, p. 84; 1906, p. 17.
Drysdale, 1915, pp. 73, 141-143.

White Bear (305)

Drysdale, 1915, pp. 136-140.

Phoenix (306)

Minister of Mines, B.C., Ann. Repts.: 1896, p. 31; 1949, p. 158.
Drysdale, 1915, p. 170.

Spitzee (307)

Drysdale, 1915, pp. 90, 140, 141.

Le Roi (308)

Minister of Mines, B.C., Ann. Repts.: 1890-1942.
McConnell, 1896, p. 36A.
Brock, 1906, p. 20; 1907, pp. 57-62.
Drysdale, 1915, pp. 56, 110-116.
Gilbert, 1948.

CENTRE STAR GROUP

Centre Star (309), Mabel (317), Virginia (318), Iron Horse (319), Iron Colt (320)

Minister of Mines, B.C., Ann. Repts.: 1892-1942.
Brock, 1906, pp. 18, 24; 1907, pp. 57-61.
Drysdale, 1915, pp. 45, 46, 52, 59, 78, 83, 94-108.
Gilbert, 1948.

Nickel Plate (310)

Minister of Mines, B.C., Ann. Repts.: 1893, p. 1042; 1896, pp. 24, 25.
Drysdale, 1915, pp. 125, 126.

Josie (Le Roi No. 2) (311)

Minister of Mines, B.C., Ann. Repts.: 1890-1942.
Drysdale, 1915, pp. 116-124.
Gilbert, 1948.

War Eagle (312)

Minister of Mines, B.C., Ann. Repts.: 1893-1942.
McConnell, 1896, pp. 36, 37A.
Brock, 1906, pp. 18, 24; 1907, pp. 57, 58.
Drysdale, 1915, pp. 45, 61, 63, 75, 78, 82, 96-108.
Gilbert, 1948, pp. 189-195.

St. Elmo (313)

Minister of Mines, B.C., Ann. Rept. 1896, pp. 25, 26.
Brock, 1906, pp. 18, 26.
Drysdale, 1915, pp. 78, 134, 135.
Stevenson, 1943, p. 154.

Cliff and Consolidated St. Elmo (316, 315)

Minister of Mines, B.C., Ann. Rept. 1896, pp. 25, 26.
Brock, 1906, p. 18.
Drysdale, 1915, pp. 132-134.
Stevenson, 1943, p. 154.

Monte Christo (321)

Minister of Mines, B.C., Ann. Repts.: 1897, pp. 538, 543, 544; 1914, p. 332.
Brock, 1906, pp. 18, 26.
Drysdale, 1915, pp. 108, 109.

Evening Star (323)

Drysdale, 1915, pp. 80, 145, 146.

Zinc-lead-silver Deposits

Twenty properties within the map-area have produced zinc, lead, and silver in decreasing order of value, and several of these properties, the Standard, Mammoth, Galena Farm, Cork-Province, H. B., Jersey, and Reeves-Macdonald are of major importance. In the Cliff property, included in this group, the value of silver exceeds that of lead. Cadmium is a by-product in the Standard, Mammoth, Cork-Province, Jersey, and Reeves-Macdonald mines, and it even exceeds the value of silver in the last two but is of minor importance in the Standard. Zinc only has been produced at the U.S., and the Daniel has yielded no lead. Ores of the Standard, Galena Farm, A. U., Mammoth, Cork-Province, Black Fox, H. B., and Michaely mines have yielded a little gold, but in those from the Dundee and Dewey mines, the value of gold is greater than that of silver.

The zinc-lead-silver deposits form two belts within the map-area. The first is poorly defined and appears to be a scattering of this type of deposit among the silver-lead and lead-silver-zinc deposits of the Slocan camp. All these deposits are fissure-filled lodes with perhaps some sulphides disseminated in the adjacent wall-rock, particularly in the Cork-Province mine. The country rocks of all but the Galena Farm and part of the Daniel veins are argillaceous, quartzitic, and calcareous rocks of the Slocan group. The Daniel vein is partly in quartz porphyry. The Galena Farm veins, however, are mainly in granitic rocks of the Nelson batholith, but are partly in large, highly metamorphosed inclusions of argillite and quartzite.

The gangue in the veins of this belt of zinc-lead-silver deposits is mainly quartz with calcite and siderite, except in the Mammoth and Cork-Province where carbonates predominate and in the U.S. vein where the gangue consists of crushed rock and gouge. Fragments of wall-rock occur in many of the veins, especially the Cork-Province and Black Fox. Fluorite is locally abundant in the Galena Farm veins. Ore minerals in these deposits are mainly sphalerite, galena, and pyrite, with: in the Standard, tetrahedrite and some chalcopyrite and ruby silver; in the Mammoth, grey copper and other silver minerals; in the A.U., grey copper; and in the Cork-Province a little chalcopyrite.

The other belt of zinc-lead-silver deposits lies within the 'lime belt' of the Salmo map-area, which extends from Porcupine Creek southward to Lost Creek, except where interrupted by granite in Hidden Creek valley, and thence southwestward across Pend-d'Oreille River. The zinc-lead-silver deposits in this belt are for the most part large and of comparatively low grade. No production has yet been attained from the more northerly of these properties—the Oxide (McAllister, 1951, pp. 42-45) and the Jack Pot (Minister of Mines, B.C., Ann. Repts., 1948, pp. 132, 133; 1949, pp. 165, 166), both owned by New Jersey Zinc Explorations Limited. As mentioned previously, the Aspen property should probably be included in this group. The productive part of this zone extends from the H. B. to the Reeves-Macdonald mine. Southwest of Pend-d'Oreille River other showings occur in the Red Bird group (Walker, 1934, pp. 61, 62) and geochemical prospecting by the Consolidated Mining and Smelting Company of Canada, Limited has revealed anomalous zinc values on the Bar group to the west (Minister of Mines, B.C., Ann. Rept., 1951, p. 143).

The deposits in this belt, with the exception of the Oxide, are replacement bodies of sulphides in dolomitized limestone of the lower Laib formation. The gangue is dolomite with some calcite, and the ore minerals are sphalerite, galena, and pyrite. Some pyrrhotite occurs in the Jersey and Reeves-Macdonald ores.

The remaining six zinc-lead-silver deposits do not appear to be associated with others of the same type, and except for the Dundee are of minor importance. The Piedmont is the only contact-metamorphic deposit of this type in the map-area. It consists of pyrrhotite, sphalerite, and galena in skarn adjacent to porphyritic Nelson granite. The Dundee and Dewey are quartz-filled fissures with, in the former, brecciated wall-rock and some later calcite. The veins occur in argillite and argillaceous quartzite of the Ymir group, and traverse tongues of granodiorite. The ore minerals are pyrite, sphalerite, and galena. The Silver Dollar vein lies in argillite of the Rossland (?) formation and consists of sphalerite, galena, some pyrite and a little chalcopyrite in a gangue of calcite and ankerite(?). No geological information has been published on the Shamrock property. Some confusion exists about the Monday deposit. Drysdale (1915, p. 169) describes it as of the "Rossland type" in fine-grained monzonite, but White (Minister of Mines, B.C., Ann. Rept., 1949, p. 158) states that it is a "transitional type" occurring in slates. Elsewhere (*idem,* 1937, p. A39) the ore is said to be gold-silver.

Standard (13)

References: Minister of Mines, B.C., Ann. Repts.: 1896-1956. Cairnes, 1934, pp. 94, 104; 1935, pp. 136-141. Starr, 1948. Hedley, 1952, pp. 11, 55, 56, 86, 122.

The Standard property, one of the largest producers in the Slocan mining camp, consists of a number of Crown-granted claims grouped about a nucleus of six such claims that follow the outcrop of the main lode. These claims are the Emily Edith, Shunieau, Standard, Surprise, Alpha, and Echo.

The lode was first discovered on the Alpha and Emily Edith claims, located in 1892, and was not found on the Standard claim until 1909. In 1913 the property

was acquired by the Standard Silver Lead Company who operated it until 1921, when it was closed by a strike. A small production was continued by lessees until 1928 when Western Exploration Company Limited purchased the property and that company has operated it intermittently since that time.

Total production of the Standard property in the period 1894 to 1953 inclusive, was 778,366 tons. This includes early production from the Emily Edith and Alpha claims and from the Mammoth mine since 1937 inclusive. From this ore, 103,892,242 pounds zinc, 83,862,573 pounds lead, 8,475,383 ounces silver, 101,099 pounds cadmium and 521 ounces gold were obtained.

The property is a short distance east of Silverton and extends eastward up the lower slopes of Idaho Peak to an elevation of about 3,000 feet above Slocan Lake. It was examined briefly in June 1950 by A. B. Irwin of the Geological Survey.

Bedrock is mainly impure argillites, quartzites, and minor limestone of the Slocan group. These sedimentary rocks are intruded by a small stock of granodiorite in Emily Creek, and are traversed by numerous dykes ranging in composition from quartz porphyry to basic types. According to Hedley, the strata are folded into a recumbent syncline with beds facing southwest, the axial plane being roughly horizontal. Within this syncline the folding is intricate. It takes the form of a sort of crumpling along the uptilted trough of the syncline, forming what Hedley refers to as 'Z-folds'. The structure is further complicated by faults which are mostly parallel with the attitude of the beds and which strike in general northwest.

In addition to the main Standard lode there are several branch veins, most of them short, but one, the I vein, is much longer than the others. A second vein, known as the Robin lode, is several hundred feet southeast of the main lode. The main lode is sinuous. On the Emily Edith claim, where it lies within a shear zone 50 feet wide, it strikes east and dips 50° to 60°S. To the east it curves northward, and from the east part of the adjoining Shunieau claim to its termination on the Echo, it strikes roughly N65°E with an average dip of 40°SE. The main lode has been traced intermittently for a distance of nearly 6,000 feet. Near the north edge of the Standard claim the main lode splits; the hanging-wall split is called the I vein, and has been explored for more than 500 feet. Along the junction of the I vein and main lode was a high-grade body of galena up to 12 feet wide, 400 feet long, and extending over 400 feet vertically. This ore was rich in silver. Ore extracted in recent years has been relatively low in silver and high in zinc. In 1950 most mining was done on No. 5 level but No. 7 level was being extended in anticipation of intersecting an orebody that plunges eastward from No. 6 level.

Although the principal production has come from the main lode, the I vein has produced a considerable tonnage of ore that is relatively high in silver. Other splits from the main lode are much narrower and shorter, but yield ore that is higher grade than average.

The main lode varies from 20 to nearly 200 feet in width, and within it are several oreshoots. These lie along or near the foot-wall gouge and consist of a breccia of argillite and quartzite cemented by quartz, calcite, and siderite. Ore

occurs mainly where the vein crosses the bedding planes; where the vein is parallel with the bedding ore is much less common. The wall-rocks adjacent to the vein were bleached and silicified before the ore minerals were deposited. In the branch veins, including the I vein, carbonates are less abundant in the gangue. Metallic minerals include sphalerite, galena, which in many places is gneissic, tetrahedrite, pyrite, and some chalcopyrite. Starr reports also a little ruby silver.

The Robin lode strikes about N60°E and dips 65°SE more steeply than the main lode. Cairnes speculated that the Robin lode might be the continuation of the I vein, but Starr states that it has not been identified in the Standard workings.

Galena Farm (19)

References: Minister of Mines, B.C., Ann Repts.: 1895-1956. Rept. of Zinc Commission, 1906, pp. 271-272. Cairnes, 1934, p. 85; 1935, pp. 43-48.

The Galena Farm property, comprising the Currie, Grover, Peerless Revised, and Kate Crown-granted claims is owned by Galena Farm Consolidated Mines, Limited, c/o Geoffrey Clarke, 4049 South Perry Street, Spokane, Washington. The property is about 2 miles by road south of Silverton and several hundred feet in elevation above Slocan Lake.

Cairnes states that the name "Galena Farm" was derived from the widely distributed galena float that led to the discovery of the vein. It was first exploited by Galena Mines, Limited, of London, England, and in 1915 was acquired by Patrick Clarke of Spokane, who died shortly afterward. It was operated profitably for many years by the Clarke estate, and the operating company was known successively as Northland Mines, Limited, and Galena Mines Company. From 1925 to 1929 it was operated by several groups of lessees, then it passed into the hands of the present owners. The property has been active intermittently since that time, principally by lessees, and mainly since 1947 by Frank S. Mills of Silverton.

Production of ore began in 1900, and to the end of 1953 totalled 87,412 tons, from which 9,556,399 pounds zinc, 6,133,773 pounds lead, 580,578 ounces silver, and 62 ounces gold were obtained.

An examination of the property was made by A. B. Irwin of the Geological Survey in June 1950.

The veins are chiefly in granitic rocks of the Nelson batholith near its northern contact, but small to large inclusions of metamorphosed argillite and quartzite of the Slocan group are widely distributed within the granitic rocks. One such belt of metamorphic rocks some 80 feet thick forms the hanging-wall of the Noonday vein. Metamorphic rocks form part of the hanging-wall along the outcrop of the main vein, where exposed, but in the shaft these are on the foot-wall side.

Two veins have been discovered on the property, the Main lode and the Noonday lode. Cairnes has pointed out that the two veins may be parts of the same vein separated by a fault, but as he believed the fault is reverse rather than normal, he favoured the view that the veins are different.

The more southerly, or Main, lode is by far the more productive. Early development was done east of the main crosscut; but in 1948 Mr. Mills and his

associates found new ore west of the main crosscut and in 1950 most of the mining was done in this part. Four levels, the 25-, 75-, 100-, and 125-foot levels, and two raises were driven there.

The Main lode strikes N70°W and dips in general 25° to 35°N but flattens for a short distance about 50 feet from the bottom, where it terminates against a fault. The vein is from a few feet to 20 feet wide and extends more than 500 feet west from the east end, where it is cut off by a fault that strikes N20°W and dips 75°E. A continuation of the vein east of the fault has not been found. The Main lode is offset by a number of faults of small displacement. One of these, observed by Irwin, is about 150 feet west of the main shaft. There the vein is about 5 feet wide and is offset 7 or 8 feet by a normal fault containing 18 inches of breccia. Four or five feet of breccia overlies the vein south of the fault, but none occurs to the north.

The vein matter is largely quartz, with lesser siderite, calcite, and, locally, fluorite. Cairnes observed that the last-named mineral is abundant in places. Sphalerite and galena form lenses and streaks up to 5 feet thick within the vein, and in some places are distributed across the full width of the vein. Some pyrite was also noted. Sphalerite is more abundant than galena, and this appears to be particularly so in the western workings.

The Noonday lode, so named because it was early regarded as the continuation of the vein on the Noonday property to the east, is parallel with the Main lode. When Cairnes visited the property in 1928 it had been explored underground for a length of 400 feet. Little further development has been done on it since that time, but some ore has been removed from the old stopes, particularly in 1949.

Cork-Province (103)

References: Minister of Mines, B.C., Ann. Repts.: 1900-1954. Rept. of Zinc Commission, 1906, pp. 169-173. Cairnes, 1935, pp. 206-210.

The Cork-Province property is owned by Base Metals Mining Corporation Limited, 62 Richmond Street West, Toronto, Ontario. It comprises thirteen claims, some Crown-granted. The mine is on the south side of Keen Creek and may be reached by a road about 9 miles long from Kaslo.

The Cork group of claims was staked about 1900 and ore production began in that year. The Province group was staked in 1901. The two properties were developed separately until 1914 when they were amalgamated under the ownership of Cork-Province Mines Limited. The mill that was on the Cork property was expanded to a 120-ton capacity in 1917, and in 1918 a flotation unit was installed. The mine was operated until 1930 when it was closed and in 1931 the mill machinery was sold. In 1937, 1940, and 1948 the mine was leased, and in 1949 it was acquired by the present owners who operated it until 1953. Until the erection of a new mill in 1951 the ore was custom-milled.

Total production of ore from the property from 1900 to 1953 was 169,433 tons, containing 14,986,081 pounds zinc, 11,278,513 pounds lead, 456,973 ounces

silver, 105,791 pounds cadmium, and 56 ounces gold. An examination of the mine was made in July 1950 by A. B. Irwin of the Geological Survey.

The rocks underlying the property are argillite, limestone, and quartzite of the Slocan group. These rocks are highly metamorphosed by the adjacent Nelson batholith, the contact of which is a short distance north of the mine. The limestone is recrystallized and much of the argillite is altered to andalusite schist. The strata in general strike N70°E and dip 80°SE.

The orebodies are developed on five levels. The upper three levels are adits, but only the lowest of these, No. 3, which is the main haulage level, was open at the time of examination. No. 4 and No. 5 levels are served by an inclined shaft sunk 250 feet from No. 3. There are also a number of raises and winzes. No. 3 adit, which is at an elevation of 3,326 feet, is driven nearly 1,800 feet in a direction S29°E and intersects several beds of limestone. Two of these beds form sharp folds whose axes plunge 60° to 65°E and indicate that the more southerly beds have moved downward and westward relative to those to the north. About 920 feet from the portal the crosscut intersects a shear zone that strikes N50°E and dips 70°SE. Two main ore shoots were encountered in the drift to the east. These occur at the intersection of limestone beds with the fault, and rake steeply east. Two other small orebodies were also intersected in the drift and diamond-drill holes cut others along a shear zone parallel with the main shear and about 60 feet southeast of it on the No. 5 level. One of the latter ore shoots was seen in the 506 crosscut.

The gangue in the orebodies consists of various proportions of siderite, calcite, quartz, present only locally, and fragments of wall-rock. The metallic minerals are sphalerite, galena, pyrite, which is locally abundant, and a little chalcopyrite. The ore shoot in 506 crosscut only was described by Irwin. This ore shoot is 4 to 7 feet wide but only 22 feet of its length was explored. It appears to be conformable with the bedding of the limestone; it strikes N70°E and, in contrast to the other orebodies, dips north. The ore consists of sphalerite, galena, and pyrite in a gangue of calcite and fragments of limestone.

Piedmont (Hope No. 2) (179)

References: Minister of Mines, B.C., Ann. Repts.: 1898, p. 1078; 1899, p. 844; 1901, p. 1028; 1922, p. 204; 1927, p. 277; 1928, p. 295; 1929, p. 318; 1946, p. 168; 1948, p. 149; 1951, p. 43.

The Piedmont property, consisting of the Hope No. 2 Crown-granted claim, is on the upper slopes of Chapleau Creek valley east of Cameronian Creek. It may be reached from the Slocan highway by a road about 4 miles long from the Lemon Creek bridge, and thence by about a mile of good, well-graded trail from a point a short distance above the Cameronian Creek bridge.

The property was not productive during the period of early development, from 1898 to 1901. In 1927 it was acquired by Piedmont Mines, Limited, who extended the underground workings in an effort to delineate the deposits and they installed an aerial tramway and mill. In 1928 and the early part of 1929

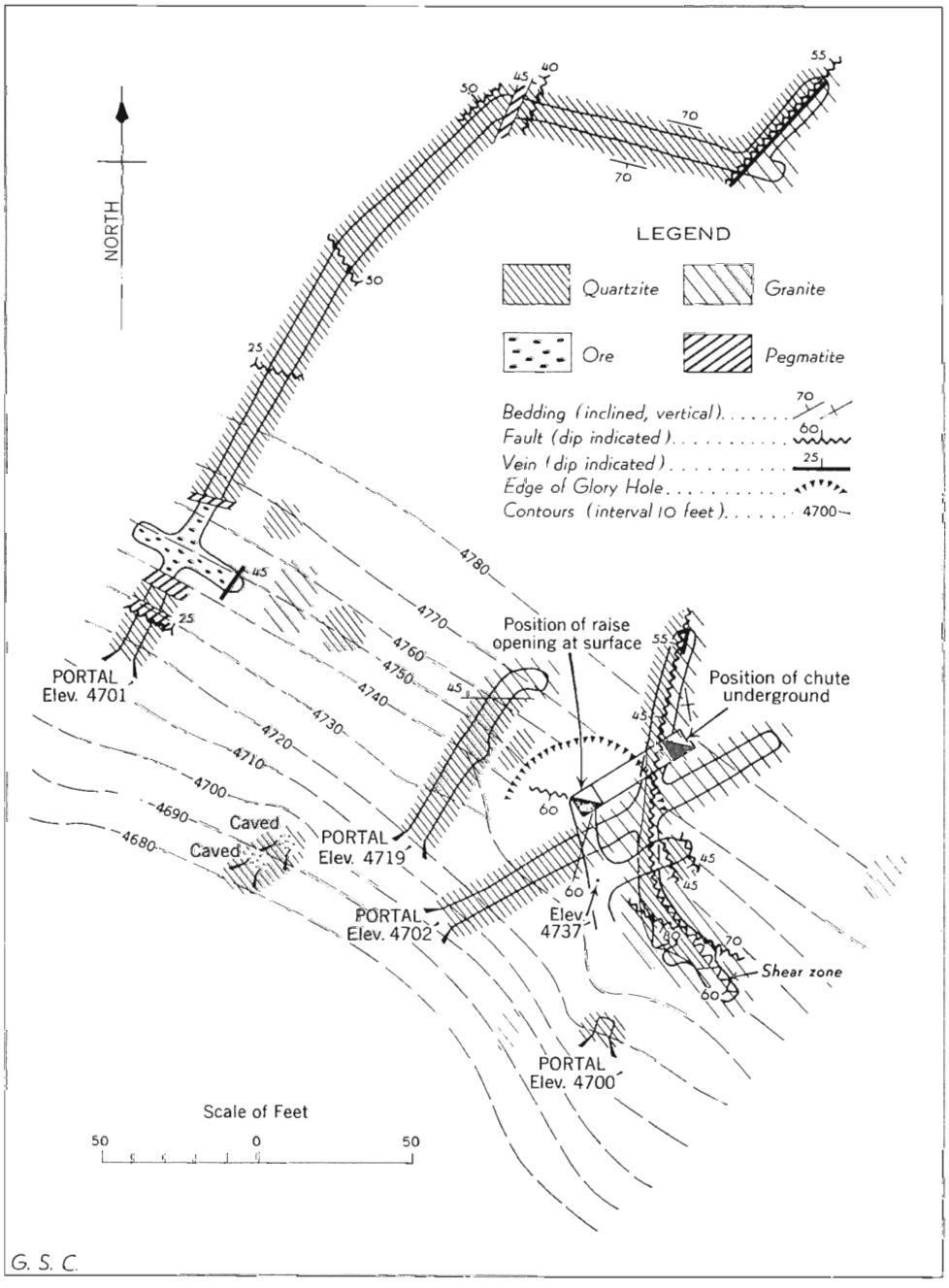


Figure 19. *Plan of Piedmont mine, Lemon Creek (Hope No. 2 claim) (geology by A. B. Irwin, 1950).*

nearly 500 tons of ore was mined and treated before the mine and mill were shut down. In 1948 and 1951, 25 and 12 tons of ore respectively were shipped by lessees.

In the period 1928 to 1951 inclusive, 525 tons of ore was produced, yielding 156,477 pounds zinc, 50,216 pounds lead, and 1,984 ounces silver. The property was examined in July 1950, by A. B. Irwin of the Geological Survey.

The rock underlying the claim is mainly porphyritic Nelson granite enclosing a large pendant of black, argillaceous quartzite and minor limestone, now largely altered to skarn. The eastern contact of the pendant with granite is marked by a sinuous fault that strikes generally north and dips 45° to 70°W. The pendant rocks are cut by small, irregular bodies of granitic rocks and pegmatite.

The workings are at an elevation of about 4,700 feet and consist of a glory hole about 40 feet in diameter and three adits, only one of which intersects ore (*see* Figure 19). The ore occurs in skarn that consists of various proportions of garnet, calcite, and diopside, and forms a flat-lying lenticular mass at least 60 feet in diameter and 10 feet thick. Most of the ore consists of pyrrhotite, sphalerite, and galena, forming bands and disseminations, but some vein-like protuberances of the mass appear to intersect the quartzite near the skarn.

About 40 feet from the portal of the longest, or western, adit a smaller zone of more sparsely mineralized sulphides is explored by two short drifts, but the size and shape of this zone are indeterminate.

Other zinc-lead-silver deposits within the map-area, with principal references except where these are numerous, are listed below.

A.U. (Lucky Thought) (21)

Minister of Mines, B.C., Ann. Repts.: 1916, p. 197; 1956, p. 98.
Cairnes, 1935, pp. 73, 74.

Mammoth (32)

Minister of Mines, B.C., Ann. Repts.: 1922-1956.
Cairnes, 1935, pp. 75-78.
Hedley, 1952, pp. 86-90.

Altoona (52)

Minister of Mines, B.C., Ann. Repts.: 1928, pp. 288, 289; 1929, pp. 309, 310; 1951, pp. 170, 171.
Cairnes, 1935, pp. 4, 5.
Hedley, 1952, pp. 67, 68.

Daniel (57)

Minister of Mines, B.C., Ann. Rept. 1922, p. 199.
Cairnes, 1935, p. 35.

U. S. (89)

Cairnes, 1935, pp. 251, 252.

Black Fox (104)

Minister of Mines, B.C., Ann. Repts.: 1899, pp. 704, 705; 1951, p. 165.
Rept. of Zinc Commission, 1906, pp. 267, 268.
Cairnes, 1935, pp. 196, 197.

Dundee (235)

Minister of Mines, B.C., Ann. Repts.: 1904, p. 125; 1915, pp. 151, 152; 1934, pp. E7, E8; 1953, p. 115; 1954, p. 125.
McConnell, 1899, p. 32A.
Drysdale, 1917b, pp. 109-111.
Cockfield, 1936, pp. 25, 26.
McAllister, 1951.

Dewey (238)

Minister of Mines, B.C., Ann. Repts.: 1926, p. 276; 1927, p. 303.
Cockfield, 1936, pp. 17-19.

Silver Dollar (250)

Walker, 1934, p. 84.

H. B. (252)

Minister of Mines, B.C., Ann. Repts.: 1914, p. 327; 1915, pp. 160-162; 1950, pp. 124-126; 1956, pp. 83, 84.
Walker, 1934, pp. 47-52.
Green, 1954, pp. 20-23.

Jersey (266)

Minister of Mines, B.C., Ann. Repts.: 1906-1956.
Walker, 1934, pp. 54-57.
Green, 1954, pp. 17, 18.
Whishaw, 1954.

Michaely (Red Rock) (274)

Minister of Mines, B.C., Ann. Repts.: 1933, pp. 237, 238; 1936, pp. E28-30.
Walker, 1934, p. 64.

Reeves-Macdonald (275)

Minister of Mines, B.C., Ann. Repts.: 1928-1956.
Walker, 1934, pp. 57-61.
Green, 1954, pp. 12-14.

Monday (290)

Minister of Mines, B.C., Ann. Repts.: 1937, p. A39; 1949, p. 158.
Drysdale, 1915, p. 169.

Tungsten Deposits

The only productive tungsten deposits within the map-area are the Emerald, Feeney, and Dodger ore zones, owned by Canadian Exploration, Limited. Only the Emerald was developed at the time of the writer's examination of this property, and it is described in some detail in Tungsten Deposits of Canada (Little, 1959), together with other tungsten occurrences within the map-area. Other reports, based on more recent observations of the Emerald, Feeney, and Dodger ore zones are referred to below.

Emerald (265)

Minister of Mines, B.C., Ann. Repts.: 1941-1956.
Stevenson, 1943, pp. 135-146.
Ball, 1954.

Molybdenum Deposits

Although many properties in the Nelson area contain molybdenite in their ores, only from the Molly, which is south of Lost Creek, has any production been recorded.

Molly (267)

Minister of Mines, B.C., Ann. Rept. 1915, pp. 165-167.
Walker, 1934, pp. 84, 85.
Stevenson, 1943, pp. 146-148.

Iron-oxide Deposits

Only one property in Nelson map-area (west half) has produced iron oxides in appreciable quantity. It is the International (Lomond) which is described below.

International (Lomond) (273)

References: Minister of Mines, B.C., Ann. Repts.: 1915, p. 167; 1929, p. 355; 1946, p. 148; 1947, p. 165; 1948, p. 136; 1949, p. 174; 1950, p. 128; 1951, p. 143; 1952, p. 150. Walker, 1934, pp. 62, 63.

The International group of fifteen Crown-granted claims, known for a time as the Lomond property, lies along Lomond Creek, east of Pend-d'Oreille River and immediately north of the International Boundary. It is accessible by a short branch road from the Nelway-Waneta road. The group is owned by International Lead and Zinc Mines Limited.

Prior to 1915 little work was done on the ground covered by the present claims. Further exploration was carried out intermittently until 1929. In 1946 and 1947 an option on the property was taken by Sheep Creek Gold Mines Limited, but after some exploratory drilling the option was dropped. Lessees worked the deposit in 1948 and the first half of 1949 and shipped some 3,800 tons of iron oxides to the Lehigh Cement Works, Metaline Falls, Washington, for use in certain types of cement. At the same time the owner, G. Shallenberger, shipped about 20 tons of sorted galena ore to the smelter at Trail but as this contained iron oxides, a penalty was imposed by the smelter. In the latter half of 1949, and 1950, shipments of iron oxides were continued. In 1951 the property was purchased by the present owners but no further production is recorded.

Total shipments of ore from 1948 to 1950 amounted to 19½ tons of hand-sorted galena ore that contained 9,702 pounds lead, 962 pounds zinc, and 38 ounces silver. To mid-1949, shipments of iron oxides totalled 3,792 tons, and perhaps 5,000 or 6,000 tons were shipped from then until the end of 1950. The workings along Lomond Creek were examined by the writer in July 1949.

The rocks exposed along Lomond Creek are black, mottled cream and black, and banded cream dolomites that probably represent the lower strata of the middle division of the Nelway formation. These strata vary in strike from N70°E to S40°E, but in general trend about east. They dip 15° to 50°S, the average being

nearer the lower figure. Only one dyke, of aplite, about a foot wide, was observed cutting the dolomite. A single reverse fault of small displacement, striking N60°E and dipping 75°NW, was also noted.

The workings along Lomond Creek comprise six adits, all comparatively short and some branching, and a number of open-cuts and pits. These are aligned roughly along Lomond Creek and explore a series of irregularly shaped bodies containing abundant hard goethite and soft earthy limonite. Within the earthy material are nodules of galena with thin coatings of anglesite and transparent to translucent crystals of cerussite mostly encrusted on the goethite.

The orebodies probably represent oxidized remnants of replacement bodies of pyrite or perhaps pyrrhotite and galena. These bodies occur within a stratigraphic range of less than 50 feet, and appear to favour the cream or mottled dolomite, although some are encased in black dolomite. They are closely spaced for a distance of nearly 1,000 feet along strike. The orebodies range in size from a few feet in diameter to one that is at least 20 by 50 feet and up to 16 feet thick.

The adit on Pend-d'Oreille River, described by Walker, was not examined. There a bedded deposit of limonite 1 foot to 7 feet thick was seen by him. Neither this nor the open-cuts, now caved, on the more easterly claims were examined by the writer.

The production zone along Lomond Creek dips southward toward the International Boundary which is only a few hundred feet distant. Thus, at no great depth the ore would be in United States territory. At such depth, however, the mineral deposit might consist of primary pyrite or pyrrhotite and some galena.

REFERENCES

Alcock, F. J.
1930: Zinc and Lead Deposits of Canada; *Geol. Surv., Canada,* Econ. Geol. Ser. 8.

Allan, J. A.
1914: Geology of Field Map-Area, B.C. and Alberta; *Geol. Surv., Canada,* Mem. 55.

Allan, J. A., and Rutherford, R. L.
1924: Geology along the Blackstone, Brazeau and Pembina Rivers in the Foothills Belt, Alberta; *Alta. Sci. and Indust. Res. Council,* Rept. No. 9.

Ball, C. W.
1954: The Emerald, Feeney and Dodger Tungsten Ore-Bodies, Salmo, British Columbia, Canada; *Econ. Geol.,* vol. 49, No. 5, pp. 625-638.

Bancroft, H.
1914: The Ore Deposits of Northeastern Washington; *U.S. Geol. Surv.,* Bull. 550.

Bancroft, M. F.
1918: Southern Lardeau, Slocan District, B.C.; *Geol. Surv., Canada,* Sum. Rept. 1917, pt. B., pp. 35-41.
1920: Slocan Map-Area, B.C., *Geol. Surv., Canada,* Sum. Rept. 1919, pt. B., pp. 39-48.

Bauerman, H.
1885: Forty-ninth Parallel of North Latitude West of the Rocky Mountains; *Geol. Surv., Canada,* Rept. Prog. 1882-83-84, pt. B., pp. 1-42.

B.C. Department of Mines
1932: Lode-Gold Deposits of British Columbia; Bull. 1.
1955: Index No. 3 to Publications of the B.C. Dept. of Mines (with suppl. tables).

Bell, W. A.
1956: Lower Cretaceous Floras of Western Canada; *Geol. Surv., Canada,* Mem. 285.

Bennett, W. A. G.
1941: Preliminary Report on Magnesite Deposits of Stevens County, Washington; *Wash. Bur. Cons. and Devel.,* Rept. Invest., No. 5.
1944: Dolomite Resources of Washington; *Wash. Bur. Cons. and Devel.,* Rept. Invest., No. 13.

Beveridge, A. J., and Folinsbee, R. E.
1956: Dating Cordilleran Orogenies; *Trans., Roy. Soc. Can.,* vol 50, ser. 3, sec. 4, pp. 19-43.

Bowman, E. C.
1950: The Stratigraphy and Structure of Orient Area, Washington; *Harvard University,* Cambridge, Mass., unpubl. Ph.D. Thesis.

Boyle, R. W.
1953: On the Colour of Black and Grey Quartz from Yellowknife, N.W.T., Canada; *Am. Mineralogist,* vol. 38, Nos. 5 and 6, pp. 528-535.

Brock, R. W.
1899: Report on Field Work in West Kootenay Area, British Columbia; *Geol. Surv., Canada,* Ann. Rept. 1898, vol. 11, pp. 63A-71A.
1900: Report on Field Work in West Kootenay Area, B.C.; *Geol. Surv., Canada,* Ann. Rept. 1899, vol. 12, pp. 75A-96A.
1902: West Kootenay Sheet, Economic Minerals and Glacial Striae; *Geol. Surv., Canada,* Map 791.
1903: Kootenay District; *Geol. Surv., Canada,* Ann. Rept. 1900, vol. 13, pp. 62A-84A.
1906: Preliminary Report on the Rossland, B.C., Mining District; *Geol. Surv., Canada,* Rept. No. 939.
1907: On Operations in the Rossland, B.C., Mining District; *Geol. Surv., Canada,* Sum. Rept. 1906, pp. 56-65.

Bruce, E. L.
1917: Geology and Ore-Deposits of Rossland; *Minister of Mines, B.C.*, Ann. Rept. 1916, pp. 214-244.

Bureau of Mines
1936a: Ore from the Kilo Mine, near Slocan City, B.C.; *Bur. Mines,* No. 748, Invest. No. 594, pp. 95-105.
1936b: Gold-silver Ore from the Chapleau Mine of the Reward Mining Co., Limited, Slocan City Mining Division, B.C.; *Bur. Mines,* No. 763, Invest. No. 620, pp. 97-102.

Cairnes, C. E.
1926: Preliminary Report on Slocan Mining Area; B.C.; *Geol. Surv., Canada,* Sum. Rept. 1925, pt. A., pp. 182-221.
1927: Alps-Alturas Group, Slocan Mining Division, B.C., *Geol. Surv., Canada,* Sum. Rept. 1926, pt. A., pp. 45-51.
1929: Geological Reconnaissance in Slocan and Upper Arrow Lakes Area, Kootenay District, B.C.; *Geol. Surv., Canada,* Sum. Rept. 1928, pt. A., pp. 94-108.
1934: Slocan Mining Camp, British Columbia; *Geol. Surv., Canada,* Mem. 173.
1935: Descriptions of Properties, Slocan Mining Camp, British Columbia; *Geol. Surv., Canada,* Mem. 184.
1939: The Shuswap Rocks of Southern British Columbia; *Proc. Sixth Pacific Sci. Congr.*, vol. 1, pp. 259-272.
1948: Slocan Mining Camp; *in* Structural Geology of Canadian Ore Deposits; *Can. Inst. Mining Met.*, Jubilee Vol., pp. 200-205.

Calkins, F. C., and MacDonald, D. F.
1909: A Geological Reconnaissance in Northern Idaho and Northwestern Montana; *U.S. Geol. Surv.*, Bull. 384.

Campbell, C. D.
1947: Cambrian Rocks of Northeastern Stevens County, Washington; *Bull. Geol. Soc. Amer.*, vol. 58, No. 7, pp. 597-612.

Cockfield, W. E.
1936: Lode Gold Deposits of Ymir-Nelson Area, British Columbia; *Geol. Surv., Canada,* Mem. 191.

Daly, R. A.
1904: Geology of the International Boundary; *Geol. Surv., Canada,* Sum. Rept. 1903, pp. 91-100.
1912: North American Cordillera, Forty-ninth Parallel; *Geol. Surv., Canada,* Mem. 38, pts. 1, 2, and 3.

Daly, R. A., and LeRoy, O. E.
1909: Sketch Map of Sheep Creek Mining Camp, West Kootenay, B.C.; *Geol. Surv., Canada,* Map 1068.

Daniels, F., and Saunders, D. F.
1953: Final Report on the Thermoluminescene of Crystals; *U.S. Atomic Energy Comm.*, Contract No. AT (11-1)-27.

Dawson, G. M.
1889: The Mineral Wealth of British Columbia; *Geol. Surv., Canada;* Ann Rept. 1887-88, vol. 3, pt. 2, pp. 1R-163R.
1890: On a Portion of the West Kootenay District, British Columbia; *Geol. Surv., Canada,* Ann. Rept. 1888-89, vol. 4, pp. 7A-12A, 5B-66B.

Drysdale, C. W.
1915: Geology and Ore Deposits of Rossland, British Columbia; *Geol. Surv., Canada,* Mem. 77.
1917a: Slocan Area, Ainsworth and Slocan Mining Divisions; *Geol. Surv., Canada,* Sum. Rept. 1916, pp. 56, 57.
1917b: Ymir Mining Camp, British Columbia; *Geol. Surv., Canada,* Mem. 94.

Enbysk, Betty J.
1956: Additions to the Devonian and Carboniferous Faunas of Northeastern Washington; *Bull. Geol. Soc. Amer.*, vol. 67, No. 12, pt. 2, p. 1766. (Abstract.)

Evans, C. S.
1932: Brisco-Dogtooth Map-Area, British Columbia; *Geol. Surv., Canada,* Sum. Rept. 1932, pt. AII, pp. 106-175.

Frebold, H.
1953: Correlation of the Jurassic Formations of Canada; *Bull. Geol. Soc. Amer.,* vol. 64, pp. 1229-1246.
1954: Stratigraphic and Palæogeographic Studies in the Jurassic Fernie Group; *Bull. Alta. Soc. Petrol. Geol.,* vol. 2, No. 11, pp. 1, 2.
1957: The Jurassic Fernie Group in the Canadian Rocky Mountains and Foothills; *Geol. Surv., Canada,* Mem. 287.
1959: The Marine Jurassic Rocks in Nelson and Salmo Areas, Southern British Columbia; *Geol. Surv., Canada,* Bull. 51.

Gibson, R.
1948: Geology and Ore Deposits of the Libby Quadrangle, Montana; *U.S. Geol. Surv.,* Bull. 956.

Gilbert, G.
1948: Rossland Camp; *in* Structural Geology of Canadian Ore Deposits; *Can. Inst. Mining Met.,* Jubilee Vol., pp. 189-196.

Green, L. H.
1954: Wall-rock Alteration at Certain Lead-Zinc Replacement Deposits in Limestone, Salmo Map-Area, British Columbia; *Geol. Surv., Canada,* Bull. 29.

Hazlitt, W. C.
1858: British Columbia and Vancouver Island; London and New York, Routledge and Co.

Hedley, M. S.
1945: Geology of the Whitewater and Lucky Jim Mine Areas, Slocan District, British Columbia; *B.C. Dept. Mines,* Bull. 22.
1952: Geology and Ore Deposits of the Sandon Area, Slocan Mining Camp, British Columbia; *B.C. Dept. Mines,* Bull. 29.
1955: Lead-Zinc Deposits of the Kootenay Arc; *Western Miner,* vol. 28, No. 7, pp. 31-35.

Holland, S. S.
1950: Placer Gold Production of British Columbia; *B.C. Dept. Mines,* Bull. 28.

Howell, B. F.
1945: Fauna of Cambrian Metaline Formation of Washington; *Bull. Geol. Soc. Amer.,* vol. 56, No. 12, pt. 2, p. 1169. (Abstract.)

Howell, B. F., *et al.*
1944: Correlation of the Cambrian Formations of North America; *Bull. Geol. Soc. Amer.,* vol. 55, pp. 993-1003.

Irwin, A. B.
1951: Mapping Complex Folds in the Slocan Series, British Columbia; *Trans. Can. Inst. Mining Met.,* vol. 54, pp. 494-501.
1952: Discussion on Mapping Complex Folds in the Slocan Series, British Columbia; *Trans. Can. Inst. Mining Met.,* vol. 55, pp. 242-244.

Larsen, E. S., Jr., *et al.*
1954: Age of the Southern California, Sierra Nevada, and Idaho Batholiths; *Bull. Geol. Soc. Amer.,* vol. 65, No. 12, pt. 2, p. 1277. (Abstract.)

LeRoy, O. E.
1909: Phoenix Camp and Slocan District; *Geol. Surv., Canada,* Sum. Rept. 1908, pp. 65-68.
1910: Slocan District, British Columbia; *Geol. Surv., Canada,* Sum. Rept. 1909, pp. 131-133.
1911: Slocan District, British Columbia; *Geol. Surv., Canada,* Sum. Rept. 1910, pp. 123-128.
1912a: Geology of Nelson Map-area, B.C.; *Geol. Surv., Canada,* Sum. Rept. 1911, pp. 139-157.
1912b: Proctor to Midway; *Internat. Geol. Congr.,* Guide Book No. 9, pp. 61-82.
1916: Slocan Map-Area, B.C.; *Geol. Surv., Canada,* Sum. Rept. 1915, p. 93.

Little, H. W.
1949: Preliminary Map, Nelson (West Half), British Columbia; *Geol. Surv., Canada,* Paper 49-22.
1950: Salmo Map-area, British Columbia; *Geol. Surv., Canada,* Paper 50-19.
1951: The Stratigraphy and Structure of Salmo Map-area, B.C.; *Trans. Can. Inst. Mining Met.,* vol. 54, pp. 133-136.
1957a: Nelson, West Half, B.C.; *Geol. Surv., Canada,* Map 3-1956.
1957b: Kettle River, East Half, B.C.; *Geol. Surv., Canada,* Map 6-1957.
1959: Tungsten Deposits of Canada; *Geol. Surv., Canada,* Econ. Geol. Ser. 17.

Maconachie, R. J.
1940: Lode Gold Deposits, Upper Lemon Creek Area; *B.C. Dept. Mines,* Bull. 7.

Mathews, W. H.
1953: Geology of the Sheep Creek Camp; *B.C. Dept. Mines,* Bull. 31.

McAllister, A. L.
1950: The Geology of the Ymir Map-Area, British Columbia; *McGill University,* Montreal, unpubl. Ph.D. Thesis.
1951: Ymir Map-Area, British Columbia; *Geol. Surv., Canada,* Paper 51-4.

McConnell, R. G.
1896: Report on Field Work in British Columbia; *Geol. Surv., Canada,* Ann. Rept. 1894, vol. 7, pp. 30A-38A.
1897a: Report on Field Work in West Kootenay Area, British Columbia; *Geol. Surv., Canada,* Ann. Rept. 1895, vol. 8, pp. 23A-37A.
1897b: Part of Trail Creek Mining Division, British Columbia; *Geol. Surv., Canada,* Map 620.
1898: Report on Field Work in West Kootenay Area, British Columbia; *Geol. Surv., Canada,* Ann. Rept. 1896, vol. 9, pp. 19A-30A.
1899: Report on Field Work in West Kootenay District, British Columbia; *Geol. Surv., Canada,* Ann. Rept. 1897, vol. 10, pp. 27A-34A.

McConnell, R. G., and Brock, R. W.
1904: West Kootenay Sheet, British Columbia; *Geol. Surv., Canada,* Map 792.

McGuire, R. A.
1942: Sheep Creek Gold Mining Camp; *Trans. Can. Inst. Mining Met.,* vol. 45, pp. 169-190.

McLaughlin, K. P., and Enbysk, Betty J.
1950: Middle Cambrian Trilobites from Pend d'Oreille County, Washington; *J. Pal.,* vol. 24, No. 4, pp. 466-471.

McLearn, F. H.
1953: Correlation of the Triassic Formations of Canada; *Bull. Geol. Soc. Amer.,* vol. 64, pp. 1205-1228.

Mines Branch
1906: Report of Zinc Commission on the Investigation of the Zinc Resources of British Columbia.

Minister of Mines, British Columbia
Ann. Repts., 1887-1956.

Muller, S. W., and Ferguson, H. G.
1939: Mesozoic Stratigraphy of the Hawthorne and Tonopah Quadrangles, Nevada; *Bull. Geol. Soc. Amer.,* vol. 50, pp. 1573-1624.

Mulligan, R.
1951: The Geology of the Nelson (Bonnington) and adjoining part of Salmo Map-Areas, British Columbia; *McGill University,* Montreal, unpubl. Ph.D. Thesis.
1952: Bonnington Map-Area, British Columbia; *Geol. Surv., Canada,* Paper 52-13.

Newmarch, C. B.
1953: Geology of the Crowsnest Coal Basin; *B.C. Dept. Mines,* Bull. 33.

Okulitch, V. J.
1947: Report on the Stratigraphy of the Pend d'Oreille River Area of Southeastern B.C.; *Geol. Surv., Canada,* unpubl. rept.
1948: Lower Cambrian Pleospongia from the Purcell Range of British Columbia, Canada; *J. Pal.,* vol. 22, No. 3, pp. 340-349.
1949: Geology of Part of the Selkirk Mountains in the Vicinity of the Main Line of the Canadian Pacific Railway, British Columbia; *Geol. Surv., Canada,* Bull. 14.
1950: Notes on the Stratigraphy and Palæontology of the Salmo and Adjacent Areas; *Geol. Surv., Canada,* unpubl. rept.
1951: A Lower Cambrian Fossil Locality near Addy, Washington; *J. Pal.,* vol. 25, No. 3, pp. 405-407.

Park, C. F. Jr., and Cannon, R. S. Jr.
1943: Geology and Ore Deposits of the Metaline Quadrangle, Washington, *U.S. Geol. Surv.,* Prof. Paper 202.

Primak, W., Fuchs, L. H., and Day, L.
1953: Radiation Damage in Insulation; *Phys. Rev.,* vol. 92, pp. 1064, 1065.

Read, H. H.
1951: Metamorphism and Granitization; *Geol. Soc. S. Africa,* Annexure to vol. 54.

Reesor, J. E.
1954: Preliminary Map, Dewar Creek Area, British Columbia; *Geol. Surv., Canada,* Paper 53-25.
1957: Lardeau (East Half), British Columbia; *Geol. Surv., Canada,* Map 12-1957.

Rice, H. M. A.
1941: Nelson Map-Area, East Half, British Columbia; *Geol. Surv., Canada,* Mem. 228.
1944: Geology and Mineral Deposits at Ainsworth, British Columbia; *Geol. Surv., Canada,* Paper 44-13.
1947: Geology and Mineral Deposits of the Princeton Map-Area, British Columbia; *Geol. Surv., Canada,* Mem. 243.

Rigg, G. B., and Gould, H. R.
1957: Age of Glacier Peak Eruption and Chronology of Post-glacial Peat Deposits in Washington and Surrounding Areas; *Am. J. Sci.,* vol. 255, pp. 341-363.

Ruedemann, R.
1947: Graptolites of North America; *Geol. Soc. Amer.,* Mem. 19.

Sanderson, J. O. G.
1939: Geology of Brazeau Area; *Trans. Can. Inst. Mining Met.,* vol. 42, pp. 429-442.

Sampson, E.
1928: Geology and Silver Ore Deposits of the Pend Oreille District, Idaho; *Idaho Bur. Mines and Geol.,* Pamph. 31.

Schofield, S. J.
1915: Geology of Cranbrook Map-Area, British Columbia; *Geol. Surv., Canada,* Mem. 76.
1920: Geology and Ore Deposits of Ainsworth Mining Camp, British Columbia; *Geol. Surv., Canada,* Mem. 117.
1922: Relationship of the Precambrian (Beltian) Terrain to the Lower Cambrian Strata of Southeastern British Columbia; *Geol. Surv., Canada,* Mus. Bull. 35.
1946: The Origin of Kootenay Lake; *Trans. Roy Soc. Can.,* vol. 40, sec. 4, pp. 93-98.

Smith, W. S.
1916: Stratigraphy of the Skykomish Basin, Washington; *J. Geol.,* vol. 24, pp. 559-582.

Starr, C. C.
1948: Geology of the Standard Mine; *Western Miner,* vol. 21, No. 7, pp. 64-67.

Stevenson, J. S.
1943: Tungsten Deposits of British Columbia; *B.C. Dept. Mines,* Bull. 10 (revised).

Tyrrell, J. B.
1887: Report on a Part of Northern Alberta; *Geol. Surv., Canada,* Ann. Rept. 1886, vol. 2, pp. 1E-152E.

Umpleby, J. B.
1911: Geology and Ore Deposits of the Myers Creek Mining District; *Wash. Geol. Surv.*, Bull. 5.

Walker, J. F.
1926: Geology and Mineral Deposits of Windermere Map-Area, British Columbia; *Geol. Surv., Canada,* Mem. 148.
1930: Mineral Developments in Salmo Map-Area, B.C.; *Geol. Surv., Canada,* Sum. Rept. 1929, pt. A., pp. 253-273.
1934: Geology and Mineral Deposits of Salmo Map-Area, British Columbia; *Geol. Surv., Canada,* Mem. 172.

Walker, J. F., Bancroft, M. F., and Gunning, H. C.
1929: Lardeau Map-Area, British Columbia; *Geol. Surv., Canada,* Mem. 161.

Warren, P. S.
1945: Triassic Faunas of the Canadian Rockies; *Am. J. Sci.*, vol. 243, pp. 480-491.

Waters, A. C., and Krauskopf, K.
1941: Protoclastic Border of the Colville Batholith; *Bull. Geol. Soc. Amer.*, vol. 52, No. 8, pp. 1355-1418.

Weaver, C. E.
1920: The Mineral Resources of Stevens County; *Wash. Geol. Surv.*, Bull. 20.

Whishaw, Q. G.
1954: The Jersey Lead-Zinc Deposit, Salmo, B.C.; *Econ. Geol.*, vol. 49, No. 5, pp. 521-529.

Williams, M. Y.
1932: Land Movements and Sedimentation; *Bull. Geol. Soc. Amer.*, vol. 43, pp. 993-1002.

Wright, L. B., and Morrell, L. G.
1938: Ymir Yankee Girl Gold Mines Ltd.; *Trans. Am. Inst. Mining Met. Engrs.*, vol. 141, p. 13.

INDEX

PAGE

Active formation 39-41
age and correlation 41
Ajax property 119, 129
Alamo property—*See also* Idaho-Alamo property 133
Alice S. property 133, 149
Alpha property 126
Alpine property 155, 156, 158
Altoona property 191
American Boy property 129
Anglesite 194
Anna property 133, 148
Antimony 133
Apex property 133, 146
Argentite 141, 150, 152, 153
Arizona property 155
Arlington property (Erie Creek) 111, 156, 174
Arlington (Slocan-Arlington) property (Springer Creek) 111, 133, 149
Aspen property 134, 149, 185
Athabaska property 155, 156, 157, 172
A.U. (Lucky Thought) property 184, 191
Azurite 176, 177, 178

Baldy anticline 105
Baldy fault 102
Baltimore property 133, 148
Bancroft, M. F. 4
Bar group 185
Barite 133, 141, 142, 150
Bauerman, H. 3
Bear property 156, 157, 173
Beaver Mountain formation 63, 64
Bell, W. A. 50, 62, 74
Bell lode 119
Bell, Sunset, and Trade Dollar property 130
Benthin, H. 5
Birdseye property 150, 151, 154
Bismark property 133, 147
Bismuthinite 158, 177, 180
Bismuth telluride 158
Black Bear property 131
Blackcock (Black Cock) property 155, 156, 157, 174
Black Colt property 118, 128
Black Fox property 184, 191
Bland, R. C. 5
B.N.A. property 133, 139
Blue Bird property (near Rossland) .. 149
Blue Bird (Bluebird) property (near Sandon) 130

PAGE

Boadicea property 130
Bondholder property 133, 148
Bonnington complex 80
Bonnington Range 8
Bornite 177, 178, 180
Boss Fraction 127
Bosun property 134
Boulangerite 134, 146, 177
Brock, R. W. 3
Bruce, E. L. 4
Buffalo property 146
Buller, A. E. 5
Bunker Hill property 158, 175
Buster property 133

Cadmium 118, 132, 145, 155, 167, 184
Cairnes, C. E. 4
California property (near Nelson) ..155, 172
California property (near Rossland) 179, 180
California and Clipper property 126
Cambrian system, base of 23-24
Canadian and Adams property 126
Canadian Belle property 155, 156, 157, 173
Carnation property 120
Casino Red Cap property 155, 158, 175
Catherine property 155, 156, 157, 172
Central property 179, 180, 182
Centre Star group (properties) 183
Centre Star (Wesko) property (near Ymir) 155, 157, 169
Centre Star property (Rossland camp) 179, 180, 182
Cerussite 120, 169, 194
Chalcedony 133
Chalcocite 156
Chambers property 119, 130
Chapleau property 156, 162
Chicago property 129
Chrysocolla 177, 180
Cinderella property 127
Cliff property 184
Cliff and Consolidated St. Elmo property 179, 180, 184
Clubine-Comstock property 156, 157, 170
Cockfield, W. E. 4
Colonial property 129
Colorado property 150, 154
Columbia property 174
Columbia-Kootenay property 155, 157, 158, 176
Commodore property 150, 151, 154
Comstock property 119, 126
Comstock-Virginia property 119, 130

PAGE

Copper-silver-gold deposits 176
Corinth property 127
Cork-Province property 111, 184, 188
Coryell plutonic rocks 90
age 93
origin 93
Crown Point property 179, 180, 182
Crusader property 150, 154
Cub property 148
Curlew property 150, 151, 155

Daly, R. A. 4
Danaite 180
Daniel property 184, 191
Davies, J. C. 5
Davne property 158, 175
Dawson, G. M. 3
Daylight and Berlin property 156, 157, 173
Dayton property 133, 148
Dewey property 184, 185, 192
Dodger property 111, 192
Douglas property 120, 125
Dow, W. H. 5
'Dry ores' 119, 133, 150, 151, 155
Drysdale, C. W. 3
Dumac property 148
Dundee property 184, 185, 192

Early Mesozoic paragneisses 71, 72
age and correlation 72
Echo and Almeda property 130
Echo and Graphic property 119, 126
Elise formation 63, 64
Elise property 150, 151, 154
Elkhorn property 118, 128
Emerald property 111, 192
Enterprise property 133, 142
Erythrite 180
Euphrates property 156, 157, 173
Eureka property 176, 178
Evening and Jennie property 133
Evening Star property (Springer Creek) 154
Evening Star property (near Rossland) 179, 180, 184
Exchange property 154

Farrell, P. J. 5
Faults 101
Fawn (Golden Fawn) property 155, 174
Feeney property 111, 192
Fern property 156, 157, 173
Fisher Maiden property 119, 126
Flint property 119, 131
Fluorite 184, 188
Folds 104
Fourth of July and Texas property ..119, 122
Frebold, H. 5, 57, 61, 62, 67, 70
Freddie Lee property 119, 129
Fry, W. L. 51
Fyles, J. T. 4, 5

PAGE

Galena Farm property 111, 184, 187
Giant-California property 179, 182
Gibson (Daybreak) property 118, 131
Gilbert, G. 5
Goethite 194
Gold-copper-silver deposits 178
Gold Cure property 131
Gold Hill property (Erie Creek) 156, 157, 174
Gold Hill property (Fortynine Creek) 179, 180, 182
Gold Hill property (near Rossland) 150, 151, 155
Gold King property 179, 180, 182
Gold Range 10
Gold-silver deposits 155
Goldstream property 156, 161
Gold Viking property 155
Golden property 155
Golden Age property 156, 157, 166
Golden Drip (Gold Drip) property 155, 157, 158, 176
Golden Eagle property—*See also* Golden Eagle, T.S., and Sun Fraction property 155, 156, 157
Golden Eagle, T.S., and Sun Fraction property 165
Goodenough property 147
Good Hope (Ophir) property 156, 172
Granite-Poorman property 155, 156, 157, 172
Green, L. H. 5
Grey copper 133, 137, 140, 143, 150, 184
Grey Copper property 133, 147
Gunning, H. C. 5
Hall formation 63, 67–70
age and correlation 70–71
Hamilton property 133, 148
Hampton property 149
Happy Medium property 133, 148
Harker, P. 48–50
Harriet property 155, 156, 157, 173
Hartney property 126
Hattie property 157, 158, 176
Hattie Brown property 134, 149
H.B. property 111, 184, 192
Hedley, M. S. 4
Hewitt property 133, 146
Hewlett, C. G. 4, 5
Highland Light property 150, 151, 153
Hinkley property 127
Historical geology 107
Home Rule property 119, 130
Homestake property 179, 180, 182
Hope property—*See also* Ruth-Hope property 119
Howard (Durango) property 120, 132
Howard Fraction 154
Hughes, P. G. 5
Hummingbird property 155, 157, 164
Hunter V and Double Standard property 150, 151, 154

PAGE

Idaho-Alamo property 146
Index property 131
International (Lomond) property 120, 124, 193
Irene Volcanic formation 16-18
age and correlation 18
Iron Cap (Revell) property 120, 132
Iron Colt property 183
Iron Horse property 183
Iron-oxide deposits 193
Irwin, A. B. 5
Ivanhoe and Elgin property 126
I X L mine—*See also* O.K. and I.X.L. property 111

Jack Pot property 185
Jeletzky, J. A. 53, 56
Jennie Lind property 133, 146
Jersey property 111, 184, 185, 192
Joan (Duplex) property 152
Josie (Le Roi No. 2) property 179, 180, 183
Jumbo property 155, 157, 158, 176

Kalispell property 150, 153
Kaslo group 52-53
age and correlation 53
Keno property 130
Keystone property 156, 174
Kilo property 156, 161
Kootenay Belle property 175

Laib formation 30-34
age and correlation 34
Laib Creek fault 102
Laib Creek syncline 105
Lakes, H. 5
Lakeview property 156, 171
Last Chance property 119, 129
Lead-silver deposits 118
Leadsmith (Noonday) property 129
Le Roi property 179, 180, 183
LeRoy, O. E. 3
L.H. property 155, 156, 171
Liberty property 131
Lily B. property 133, 149
Lily May property 176, 177, 178
Little Daisy property 155, 156, 171
Little Tim property 133, 141
Lode deposits 118
Lone Bachelor property 127
Lone Silver (Hope) property 150, 151, 155
Lord Roberts property 176, 177, 178
Lucky Strike property 158, 175

Mabel property 183
Mable (Cripple Stick) property 154
Mabou and Ohio property 148
McAllister, A. L. 4
Maconachie, R. J. 4
McConnell, R. G. 3
McGregor intrusions 94
McLearn, F. H. 56, 61, 70

PAGE

MacLennan, D. B. 5
Madison property 133, 146
Majestic and Unexpected property 128
Malachite 176, 177, 178, 182
Mammoth property 111, 184, 191
Manganite 169, 177, 178
Maple Leaf (Porcupine) property 134, 145
Marion property 126
Marjanen, L. E. 5
Martin property 119, 131
Mathews, W. H. 4
May and Jennie property 156, 157, 172
Mayflower property 134, 145
Mercury and Silver Bell property 133, 146
Metallic (Midnight) property 135
Metalliferous deposits 111
Meteor property 150, 154
Michaely (Red Rock) property 184, 192
Midnight property 157, 158, 171
Milford group 45
Mining, history of 111
Mitchell, J. A. 5, 57
Mohawk (Ten Day Man) property 119, 130
Molly property 193
Molly Gibson property 111, 148
Molybdenite 157, 158, 180, 182
Molybdenum deposits 193
Monarch property 176, 178
Monashee Mountains 6, 9
Monday property 185, 192
Monk formation 18-20
age and correlation 20
Monte Christo property 179, 180, 184
Montezuma property 131
Morning Star property 156, 159
Motherlode (Mother Lode) property 174
Mount Roberts formation 45-48
age and correlation 48
Mountain Chief property 125
Mountain Con property 133, 147
Mowitch property 150, 151, 153
Mulligan, R. 4, 5
Myrtle property 156, 157, 174
Myrtle (Alma) property 139

Nature Boy property 134, 149
Neepawa (Peg Leg) property 148
Nelson batholith—
origin of 98
structure of 97
Nelson plutonic rocks 81
age 85
Nelson Range 8
Nelway formation 35-37
age and correlation 37
Nest Egg property 179, 180, 182
Nevada property 120, 132
Nevada and Royal Canadian property 156, 157, 172
New Springfield property 119, 128
Nickel Plate property 179, 180, 183

PAGE

Noble Five property 118, 119. 129
Noonday and Curley property 126
Norns Range 9
Northern Light property 179, 182
Norway property 150, 151, 155
Nugget property 174
Number One property 119, 129

O.K. and I.X.L. property 179, 180
Okulitch, V. J. 5, 34, 38
Olsen property 148
Omega property 129
Ontario No. 2 (Jessie-Bluebird) property 133, 147
Ore Hill property 155, 156, 157, 175
Oro property 147
Oro Fino property 156, 171
Ottawa property 133, 140
Oxide fault 103
Oxide property 185

Palmita property 127
Panasiuk, W. 5
Peck, J. W. 5
Pend-d'Oreille fault 104
Perrier property 155, 156, 157, 172
Phoenix property 179, 182
Piedmont (Hope No. 2) property 185, 189, 190
Pilot-Good Hope property 156, 174
Placer deposits 114
Pleistocene and Recent 75-76
Plutonic rocks 76
Pollock, W. O. 5
Porcupine fault 103
Port Hope property 154
Porto Rico property 155, 156, 157, 173
Properties, description of 113
Protection (Goodenough) property 155, 157, 167
Pyromorphite 169

Queen property 175
Queen Bess property 127
Queen Victoria property 176, 177
Quartzite Range formation 24-27
age and correlation 27

Rainbow property 130
Read and Tenderfoot property 127
Reco property 133, 147
Red Bird property 185
Red Eagle property 134, 149
Redress property 133, 146
Reeves-Macdonald property 111, 184, 185, 192
Referendum property 155
R. E. Lee property (Slocan camp) 129
R. E. Lee property (Rossland camp) 155, 157, 158, 175
Reno formation 27-30
age and correlation 30
Reno property 174

PAGE

Republic No. 2 property 150, 151
Revenue property 133, 147
Richmond property 157, 158, 175
Richmond-Eureka property 147
Ripple Creek fault 101
Riverside property 149
Rossland camp 111
Rossland formation 62-67
age and correlation 67
folds in 106
Rossland 'monzonite' 77
Rossland Range 10
Ruby silver 133, 136, 137, 143, 150, 156, 163, 184, 187
Ruth property—*see also* Ruth-Hope property 118, 119
Ruth-Hope property 128

St. Elmo property 179, 180, 183
Sapphire property 119, 128
Scheelite 150, 157, 164, 166, 179, 182
Scranton property 118, 123
Second Chance property 156, 174
Second Relief property 111, 155, 156, 157, 173
Seeman Creek fault 103
Selkirk Mountains 6, 7-8
Senator (Batchelor) property 150, 154
Shady Fraction (Gem) property 119, 130
Shamrock property 185
Sheep Creek anticline 105
Sheep Creek camp 111
Shenan, P. J. 5
Sheppard intrusions 94
Silver, native 133, 137, 139, 140, 141, 150, 152, 177
Silver Bear property 147
Silver Bell property 119, 131
Silver Bell and Hustler property 119, 126
Silver Cup property 119, 131
Silver Dollar property 185, 192
Silver-gold deposits 150
Silverite property 128
Silver King property 111, 176, 177
Silver-lead-zinc deposits 132
Silver Leaf property 119, 131
Silver Nugget property 150, 153
Silver Reef (Rover) property 120, 132
Silver Ridge property 128
Silversmith-Slocan Star property 118, 119, 128
Sinemurian beds 60-61
age and correlation 61
Skylark and Ranger property 150, 154
Slocan camp 111
Slocan fold 104
Slocan group 53-56
age and correlation 56
Slocan King property 128
Slocan Prince (Black Prince, Two Friends) property 133, 149
Slocan Range 8

PAGE

Slocan Sovereign property 129
Snowdrop property 157, 158, 176
Snowstorm (Slocan Chief) property 149
Sophie Mountain formation 73-74
age and correlation 74
Souther, J. G. 5
Specularite 182
Speculator property 119, 132
Spitzee property 179, 180, 182
Spotted Horse property 156, 157, 173
Stagleap Creek, faults in 102
Standard property 111, 184, 185
Star and Alma N. property 155, 156, 157, 172
Starlight property 156, 157, 173
Stephanite 133, 150
Stibnite 177
Stromeyerite 177, 178
Structural geology 97
Sumit (Summit) property ..155, 156, 157, 175
Sunset property 120, 132
Sunset No. 2 property 179, 180, 183
Sunshine and Yakima property 127
Surprise property 133, 147
Sylvanite 158

Tamarac property (near Rossland) 155
Tamarac property (Springer Creek) ..133, 148
Tamarac property (near Ymir) 156, 157, 173
Tetrahedrite 136, 141, 142, 143, 156, 158, 161, 177, 178, 184, 187
Three Sisters formation 20-23
age and correlation 23
Tin 145
Toby formation 14-16
age and correlation 16
Tozer, E. T. 53, 56
Tungsten deposits 192

Ultrabasic intrusions 76
Undivided Palæozoic rocks 42-44
age and correlation 44
Union property 120, 132
United Verde property 120
U.S. property 184, 191
Utica property 133, 137

PAGE

Valhalla plutonic rocks 87
age 90
Valhalla Range 9
Valkyr Range 9
Vancouver property 175
V and M property 150, 154
Van Roi property 111, 136
V Day and Victory V (Graphic-Rosebud) property 148
Velvet property 179, 180, 181
Venango property 156, 157, 163
Venus and Juno property 156, 172
Victor property 127
Victoria property 118, 128
Victoria and Jessie property 179, 180, 182
View property 176, 177, 178
Violet property 133, 147
Virginia property 183
Vulture property 130

Wakefield property 119, 127
Walker, J. F. 4
War Eagle property 179, 180, 183
Weasel Creek fault 102
Western anticline 105
Westmont and Eastmont property 149
White Bear property 179, 180, 182
White Hope (Paystreak) property 119, 131
Whitewater property 156, 172
Willcock (Ymir-Willcock) property 120, 132
Wilson, E. M. 5
Windermere series 14
Wolframite 157
Wonderful property 119, 128

Yankee Girl property 111, 155, 157, 174
Yellowstone property 175
Ymir group 57-59
age and correlation 59
Ymir property 111, 155, 157, 173
Young, G. A. 3
Zinc-lead-silver deposits 184