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DEPARTMENT OF MINES
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR

MEMOIR 148

No. 129, GEOLOGICAL SERIES

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

BY
J. F. Walker

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1926

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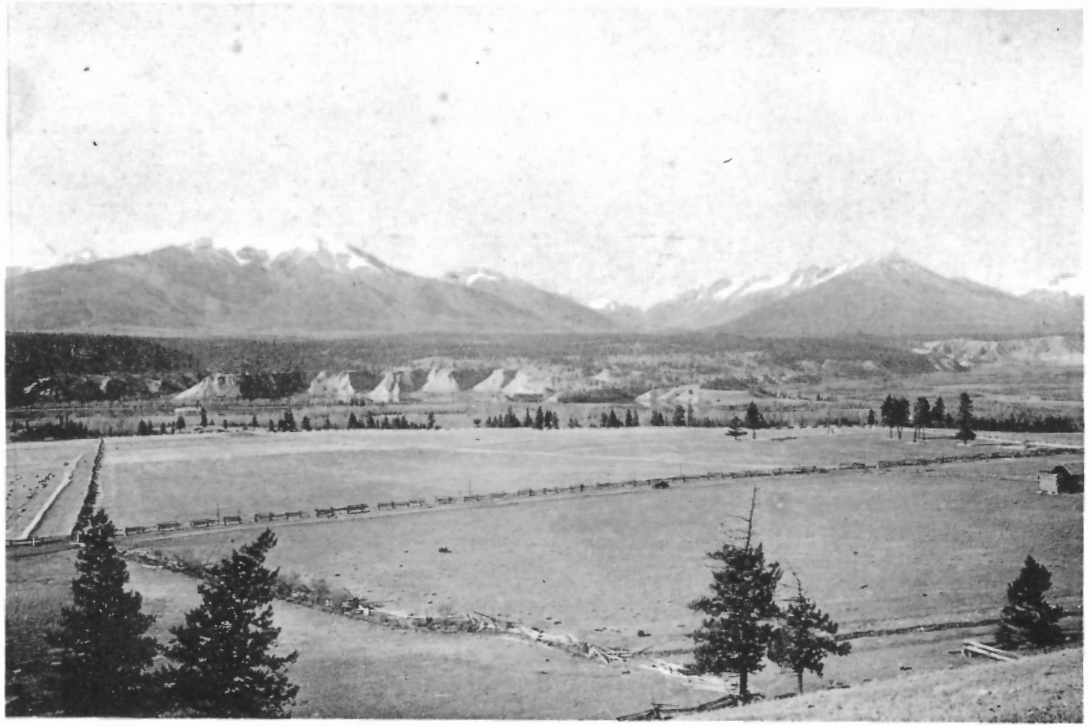

View of Rocky Mountains trench, looking west across terraces toward Purcell range. The hanging-valley is that of Horsethief creek. (Page 3.)

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Geology and Mineral Deposits of Windermere Map-Area, British Columbia

CHAPTER I

INTRODUCTION

Windermere map-area forms a part of Windermere mining division, Kootenay district, southeastern British Columbia. It lies in the neighbourhood of lake Windermere, on the Canadian Pacific railway, midway between Golden, on the main line of the Canadian Pacific railway, and Cranbrook, on the Crow's Nest branch of the same railway, and represents an area 22 miles north and south by 35 miles east and west. It includes parts of the westernmost range of the Rocky Mountains system, and of the Columbia valley which here lies within the Rocky Mountains trench and, in the southwest corner, reaches to the summit of the Purcell range at about 25 miles from the trench.

The Scenic International Parks highway passes through the map-area along the east side of the trench and a second road parallels it on the west side of the valley. A good road runs from Wilmer for 18 miles up Horsethief valley; beyond this point the road is passable to the head of McDonald creek. The roads from Wilmer and Invermere up Toby creek, to where they join at the stream crossing, are in good condition and their continuation to the Paradise mine is also in good condition, but the extension of the same road up Toby creek from Pinehurst, though reopened in 1924 to the old bridge at Jumbo creek, is little more than passable. Numerous trails, though many of them have not been kept open, afford ready access to all parts of the district.

FIELD WORK AND ACKNOWLEDGMENTS

The area was topographically surveyed during the seasons of 1911, 1912, and 1913 by S. C. McLean, A. G. Haultain, and K. G. Chipman, Topographical Division, Geological Survey.

The geological field work upon which this report is based was commenced in the season of 1921 by S. J. Schofield, work being confined chiefly to the region south of the map-area. Work within the map-area was begun in the season of 1922 by the present writer, continued in 1923 under the direction and with the assistance of M. F. Bancroft, and completed in 1924 by the writer. About ten months were spent in the map-area and seven weeks in the district to the south, exclusive of the season spent by Dr. Schofield in that region.

Efficient assistance in the field was rendered by P. N. Whitley in 1922, by G. W. H. Norman and R. B. McConnell in 1923, and by G. W. H. Norman and H. S. Bostock in 1924.

Field work was facilitated through the courtesies of many residents of the district. The writer takes this opportunity of thanking the members of the Department of Geology at Princeton University for kind assistance and criticism during the preparation of this report. Thanks are also due to Dr. C. D. Walcott, Dr. Rudolf Ruedemann, and Dr. Edwin Kirk for palæontological determinations.

PREVIOUS WORK AND LITERATURE

Previous work of a reconnaissance nature was done in the general area by G. M. Dawson. The annual reports of the British Columbia Minister of Mines, for the years 1896 to the present, make mention of numerous properties in the district. The report for 1915 gives a full account of mining activities up to that time. Dr. C. D. Walcott, during the season of 1923, investigated the stratigraphy of the Beaverfoot-Brisco-Stanford range. Dr. F. P. Shepard made observations on the stratigraphy and structure along the Rocky Mountains trench during the seasons of 1920 and 1921 and again during the season of 1924.

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CHAPTER II

GENERAL CHARACTER OF DISTRICT

PHYSICAL FEATURES

The western and greater part of Windermere map-area lies within the eastern side of the Purcell range whose summit is included in the southwest corner of the map-area. East of Purcell mountains is the Rocky Mountains trench which traverses the eastern part of the map-area in a north-northwesterly direction. East of the trench lies the Stanford range whose western slopes are included in the map-area. This range is the southern extension of a single range which for no apparent reason has been divided into the Beaverfoot, Brisco, and Stanford ranges. Topographically, these three ranges are a unit and should be so designated. They are a western member of the Rocky mountains, are bounded on the west by the Rocky Mountains trench and on the east by Kicking Horse, Beaverfoot, and Kootenay rivers, which occupy a trough more or less paralleling the Rocky Mountains trench.

The Rocky Mountains trench in this district is a valley 3 to 6 miles wide. The north-flowing Columbia river, its sloughs, and Windermere lake, occupy a median depression about three-quarters of a mile wide. The level of the lake is 2,566 feet above sea-level and this is about the average elevation of the central depression, which is rimmed by steep, silt banks broken by numerous dry gullies. Dissected terraces flank this depression at elevations of roughly 2,700, 2,800, and 3,000 feet above sea-level (*See* Plate I). The rainfall in the trench is small and the terraces have a semi-arid appearance, with the trees set well apart, little or no underbrush, and sparse grass. The streams from the Stanford range on the east are small, and occupy small gullies cut through the terraces, whereas the streams from the Purcell range on the west, such as Toby and Horsethief creeks, have cut deep, picturesque canyons across the terraces (*See* Plate VI). Looking west from the trench the western wall is seen to rise abruptly in the northern part of the map-area to 5,000 feet above the upper terraces. Southward the western wall rises more gently and is much lower. Two great gaps—the hanging valleys of Toby and Horsethief creeks—appear in the wall. The eastern wall of the trench rises abruptly from the upper terraces to 5,500 feet above sea-level (*See* Plate II B).

The most comprehensive view of the area is from the mountain summits bordering the trench on the west in the neighbourhood of Toby and Horsethief creeks. These summits are just above timber-line, which throughout the district is at about 8,000 feet above sea-level. To the north, east, and southeast lie the Rocky mountains. Many of the well-known peaks along the summit of the main range are easily discernible. Closer at hand are the lower summits of the western ranges, many of which lie below the level of the observer. Between the observer and the western ranges of the Rockies lies the great trough of the Rocky Mountains trench, its floor 4,000 to 5,000 feet below the point of observation.

Turning to the west, a different view meets the eye. Great peaks, rivalling those of the Rockies seen a moment before at distances of 40 to

80 miles, rise only 10 to 15 miles away. Many glaciers clothe the sides of these summits and they and the cirques formed by glaciers that have vanished give a rugged grandeur to the scenery. Four thousand feet below the observer may be seen the deep valleys of Horsethief or Toby creeks extending for many miles back into the Purcell range, to terminate abruptly in a sudden rise near the summit of the range (*See* Plate III A). These creeks occupy splendid examples of slightly modified glaciated valleys. The larger tributaries to Toby and Horsethief creeks occupy beautiful hanging valleys with gentle gradients, and drop suddenly 400 to 500 feet into the main valley (*See* Plate VII A).

CLIMATE AND AGRICULTURE

Windermere map-area is in what may well be called a dry belt. The average annual precipitation in Columbia valley over a period of ten years is 12 inches.[1] Precipitation is naturally greater in the higher altitudes. The climate is bracing and enjoyable and, coupled with the magnificent scenery, makes it an ideal outing resort as well as a healthy and agreeable place of residence.

Irrigation is necessary for agricultural pursuits. Vegetables, small fruits, and some grains do remarkably well. The short growing season and late frosts make the growing of large fruits a precarious business. Potato growing and dairying show promise of a good future.

TIMBER

The whole district is fairly well wooded, though forest fires and logging operations have cut large swathes in certain localities. The trees in the trench are set well apart and give the country a park-like appearance. Fairly plentiful, but coarse, grass is found in the thick timber along the higher terraces close to the foot of the mountains and makes good range for cattle. The cutting or destruction of the trees, however, soon results in a barren range, for the growth of grass is largely due to the moisture retained in the shelter of the wooded areas.

The slopes of the mountains along the trench are well wooded, as are the sides of the tributary valleys. Some good stands of spruce occur in the larger creek bottoms. The principal trees are pine, fir, spruce, hemlock, larch, birch, poplar, and alder.

GAME

Blue and willow grouse are plentiful, and also ducks during their period of migration. A few ptarmigan may be seen in any of the high basins. Goat are found in the higher and more inaccessible parts of the district, but are very scarce in the front ranges. The white-tail or valley deer, as well as the black-tail or mountain deer, are still to be found in fair numbers. Black bear are numerous in some seasons, and a few grizzly are still in the district. A few coyotes are to be found along the creeks and borders of the trench. Beaver, working along the water supply used for irrigation purposes at Wilmer, cause some annoyance. Certain of the small fur-bearing animals are trapped along the creeks. A wolverine was seen by the party in 1923 at Earl Grey pass.

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[1] Dom. Exp. Station, Invermere, B.C., Rept. of Supt., 1923.

CHAPTER III

GENERAL GEOLOGY

Windermere map-area, as already stated, is situated partly in the Purcell range, partly in the Rocky Mountains trench, and partly in the Stanford range of the Rocky Mountains system.

In the Purcell range are found a great thickness and variety of unfossiliferous, metamorphosed sedimentary rocks of Precambrian age. They are divisible into two series by a marked unconformity. The lower series is correlated with the Purcell series of Schofield.[1] For the upper series the name Windermere series is now proposed. Intrusive into the Precambrian sediments are numerous, schistose, greenstone dykes and sills of undetermined age. Because of their intense alteration and their similarity to the more altered phases of the Purcell intrusives of Cranbrook area, which are in part at least of pre-Gateway age, these intrusives, in the absence of evidence to the contrary, are considered to be Precambrian. Cutting these greenstone dykes and sills and the Precambrian sediments are two types of highly altered silicic dykes also considered to be Precambrian. Overlying the Windermere series with slight angular unconformity and occupying a small area in the Purcell range is a succession of Palæozoic sediments representing the Upper Cambrian, Lower Ordovician, Richmond, and Devonian. A granite stock on Horsethief creek and another west of Farnham creek, have the general appearance of the granite phase of the Nelson batholith. There is a similar stock south of Earl Grey pass, and a little farther south is the Fry Creek granite area also believed to be related to the Nelson batholith.[2] The intrusion of the stocks was later than the folding of the sediments during mountain-building, believed to have taken place in the Jurassic[3], and, therefore, the granite stocks are considered to be of late Jurassic age.

In the Rocky Mountains trench, along the western side, are numerous outcrops of the Precambrian sedimentary formations. On the east side are outcrops of the Windermere series and also of the Palæozoic formations. The principal exposures in the trench are of glacial silts and gravels.

In the eastern part of the area, in the Stanford range, are found three divisions of the Palæozoic. The Cambrian is represented by the Upper Cambrian Ottertail formation and the lower part of the Goodsir formation; the Ordovician by the upper and greater part of the Goodsir formation, by the Glenogle shales of Lower Ordovician age, and by the Wonah quartzite and Beaverfoot formations of Richmond age. The Silurian is represented by the Brisco formation. No intrusive rocks have been found in this part of the area.

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[1] Schofield, S. J., "Geology of Cranbrook Map-area"; Geol. Surv., Canada, Mem. 76, 1915, p. 23.
[2] Bancroft, M. F., Geol. Surv., Canada, Sum. Rept., 1920, pt. A, pp. 99 A–101 A.
[3] Schofield, S. J., "Geology of Cranbrook Map-area"; Geol. Surv., Canada, Mem. 76, 1915, p. 95.

—	—	Purcell range	Rocky mountains
Era	Period	Formation	Formation
Quaternary	Recent	Alluvium (chiefly in Rocky Mountains trench)	
	Pleistocene	Glacial silts, gravels, and till (chiefly in Rocky Mountains trench)	
Unconformity			
Mesozoic	Jurassic (?)	Granite stocks and apophyses	—
Intrusive			
Palæozoic	Upper Devonian	Starbird formation	
	Middle or Lower Devonian (?)	Mount Forster formation	
	Disconformity		
	Silurian		Brisco formation
	Richmond	Beaverfoot formation	Beaverfoot formation
	Richmond (?)		Wonah quartzite
	Disconformity		
	Lower Ordovician	Goodsir formation	Glenogle shales Goodsir formation
	Upper Cambrian	Ottertail formation	Ottertail formation
Unconformity			
Late Precambrian	—	Greenstone dykes and sills	—
	Intrusive		
	Windermere series	Horsethief formation	Horsethief formation
		Toby conglomerate	—
	Unconformity		
	Purcell series	Mount Nelson formation	
		Dutch Creek formation	

PRECAMBRIAN ROCKS

PURCELL SERIES

The Purcell series in the neighbourhood of the International Boundary has been described by Daly[1] and in the Cranbrook map-area by Schofield.[2] Daly[3] and Schofield[4] have correlated the Galton series of the Rocky

[1] Daly, R. A., Geol. Surv., Canada, Mem. 38, pt. 1, p. 119.
[2] Schofield, S. J., "Geology of Cranbrook Map-area"; Geol. Surv., Canada, Mem. 76, p. 23.
[3] Daly, R. A., Loc. cit., p. 178, table VII.
[4] Schofield, S. J., Loc. cit., p. 50.

mountains and the Purcell series of the Purcell range. The Purcell series has also been correlated with the Belt terrain of Idaho and Montana.[1] Schofield[2] has conclusively shown the Purcell series to be Precambrian in age and Sampson,[3] of the United States Geological Survey, is satisfied that the Purcell series is the equivalent of the Belt terrain of Idaho and Montana.

The various members of the Purcell series from the Aldridge to the Roosville have been recognized as far north as the vicinity of Ram creek on the east side of the Rocky Mountains trench 25 miles south of Windermere map-area.[4] On the west side of the trench, opposite the above locality, the Purcell strata from the Kitchener to the Roosville are exposed in a section along Skookumchuck creek and in the low hills north of the creek. About 8 miles north of Skookumchuck, on the trail from Torrent to the bend of Skookumchuck creek, a hitherto undescribed formation with distinctive lithologic characters appears above typical Roosville beds. This new formation continues into Windermere area, maintains its distinctive characters throughout, and has a thickness of about 3,000 feet. For this formation, the name Mount Nelson is now proposed. The Mount Nelson, the Roosville, and the underlying Phillips, formations, although they do not occur to the south in the type area of the Purcell series, are a part of this series, for they conformably succeed its lower members and form a part of one great succession of sediments.

Northwards from Skookumchuck, the Roosville, Phillips, and upper part of the underlying Gateway, formations gradually lose their identities and in Windermere area cannot be separately distinguished, and, therefore, the three formations have been treated as a unit under the name of Dutch Creek formation. The Purcell lavas at the base of the Gateway have not been found north of Skookumchuck creek and, so far as known, the Dutch Creek and overlying Mount Nelson formations are the only members of the Purcell series that occur in Windermere map-area. These two formations, and their equivalent strata, it is now proposed to designate the Upper Purcell series whose base is defined as being the horizon of the uppermost Purcell lava at the boundary between the Gateway (lowest horizon of the Dutch Creek formation) and the underlying Siyeh.

Dutch Creek Formation

The name of this formation, which is the northern extension of the Roosville, Phillips, and upper part of the Gateway, is derived from Dutch creek, on the northern side of which the measures are clearly exposed. The formation is confined to the southern and western part of the map-area where it is broadly developed.

The Dutch Creek is the oldest formation exposed in the Windermere area. It is made up of a succession of strata varying in nature from slate and quartzite to magnesian limestone.[5] The slates form the greater part

[1] Walcott, C. D., Bull. Geol. Soc., Am., vol. 17, 1906, p. 19.
Daly, R. A., Loc. cit., p. 178, table VIII.
Schofield, S. J., Loc. cit., p. 51.
[2] Schofield, S. J., Geol. Surv., Canada, Mus. Bull. 35.
[3] Personal communication.
[4] Schofield, S. J., Geol. Surv., Canada, Mus. Bull. 35, p. 15.
[5] The term magnesian limestone is used throughout this report to designate limestones including dolomites which contain sufficient magnesium to prevent reaction with cold dilute hydrochloric acid.

of the formation exposed, are grey to almost black or green on both fresh fractures and weathered surfaces. They are fine grained and laminated. In some, the presence of much quartz tends to coarsen the grain, and in such rocks the beds may be as much as 2 to 4 inches thick, but phases found to be 60 per cent quartz grains with a maximum grain of 0·1 mm. may be thinly laminated and fine grained. Pyrite cubes are common in the dark grey to black slate at the top of the formation, but are rarely found in the other slate horizons. The quartzites are thin bedded and fine grained, with a faint greenish colour. Impure quartzites lying in zones of intense folding have been changed to quartz schists. The limestones are crystalline, magnesian, and thin bedded; in colour grey, weathering cream to buff. The limestones and quartzites grade from west to east into slates and argillaceous quartzites.

The Dutch Creek formation is overlain conformably by the Mount Nelson formation.

Typical sections of the Dutch Creek formation are as follows:

(1) End of Farnham ridge between Horsethief and McDonald creeks (*See* section No. 4, Figure 1).

		Feet
Mount Nelson:	Lower quartzite	
Dutch Creek:	Dark grey to black slate	1,600
	Platy limestone grading downward into platy quartzite	1,000
	Limestone and limy slate	200
	Quartzite	50
	Dark grey to black slate	150
	Vari-coloured slate	450
		3,450
	Base unexposed	

(2) Ridge on north side of Jumbo creek near west edge of map-area (*See* section No. 2, Figure 1).

		Feet
Mount Nelson:	Lower quartzite	
Dutch Creek:	Dark grey to black slate	500
	Thin-bedded magnesian limestone	500
	Greenish quartzite	600
		1,600
	Base unexposed	

(3) End of ridge to east of Mineral, and south of Toby, creeks (*See* section No. 8, Figure 1).

		Feet
Mount Nelson:	Lower quartzite	
Dutch Creek:	Dark grey to black slate	1,000
	Chiefly argillaceous quartzite with some lime in upper part	2,000
	Black slate	?
		3,000+
	Base unexposed	

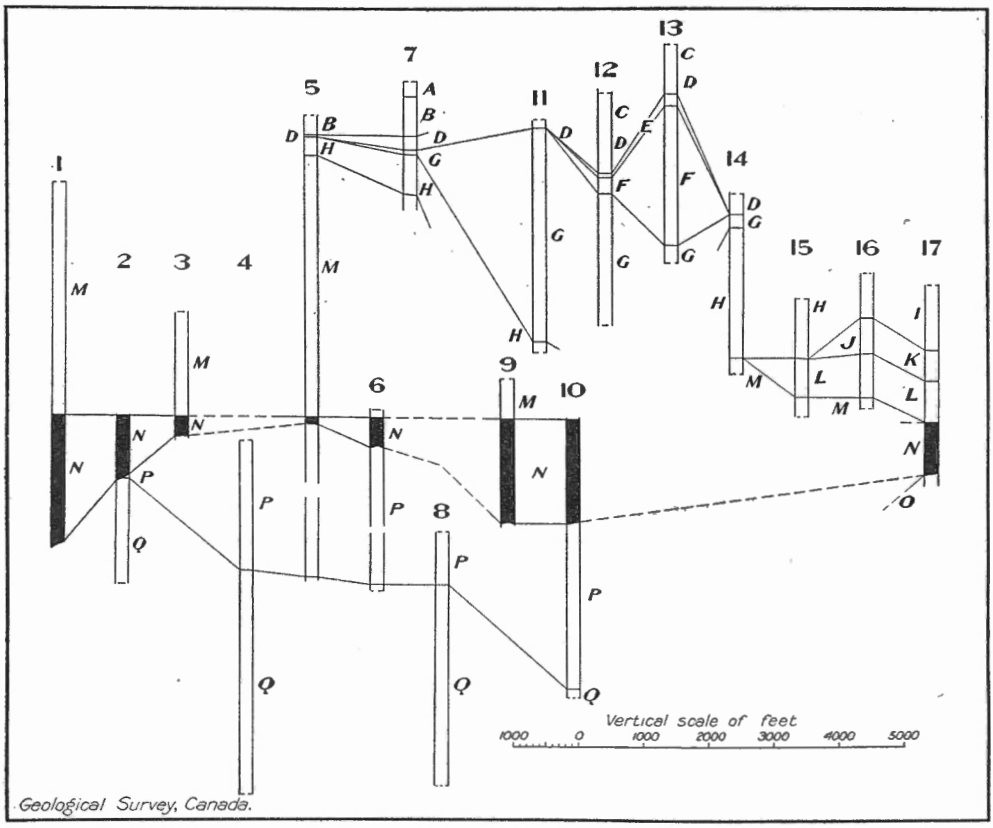

Figure 1. Geological sections, Windermere region, B.C.

Explanation of Figure 1

The individual columnar sections were measured in the following localities: No. 1, east from Earl Grey pass; No. 2, from west to east, on ridge between Jumbo mountain and Jumbo creek; No. 3, head of Delphine creek; No. 4, northeast end of Mount Farnham ridge; No. 5, east to west along ridge between Law and Horsethief creeks; No. 6, west from Paradise basin; No. 7, southwest slope of mount Forster; No. 8, nose of ridge, south of Toby creek and east of Mineral creek; No. 9, mount Brewer and northeast; No. 10, ridge between head of Brewer creek and Laundry creek; No. 11, north from Stoddard creek, along front of Stanford range; No. 12, first north branch of Windermere creek; No. 13, summit of Windermere creek, eastward; No. 14, across ridge south of Fairmont creek; No. 15, north side of Kootenay river above Canal Flats and opposite Grainger mountain; No. 16, Grainger mountain, south side of Kootenay river about 4 miles above the bridge; No. 17, ridge south of Ram creek and east of Sheep creek.

In the figure, the individual formations represented in columnar section are indicated by symbols, as follows:

Starbird	A	Mount Whyte	J
Mount Forster	B	Burton	K
Brisco	C	Cranbrook	L
Beaverfoot	D	Horsethief	M
Wonah	E	Toby	N
Glenogle	F	Roosville	O
Goodsir	G	Mount Nelson	P
Ottertail	H	Dutch Creek	Q
Elko	I		

(4) Generalized section along southern edge of map-area west of mount Able.

		Feet
	Erosional surface	
Dutch Creek:	Dark grey to black slate	500+ to 1,200+
	Buff-weathering magnesian limestone and slate	300 to 600
	Platy quartzite	600±
	Dark grey to black slate	800±
	Buff-weathering magnesian limestone	300±
	Base unexposed	
	Approximate maximum thickness	3,500

Mount Nelson Formation

This formation is named after mount Nelson whose picturesque peak is built of the massive limestone of the lower part of the formation. Mount Nelson is also the centre of an area in which the formation is well exposed. The best sections are in the ridges between Law, Slade, and Clearwater creeks and in the ridge between the head of Brewer creek and Laundry creek.

The Mount Nelson formation comprises a succession of crystalline magnesian limestones and slates and has at its base, and also near the upper erosional surface, massive white quartzites. It has an observed thickness of about 3,400 feet. It rests conformably on the Dutch Creek formation and is the youngest known member of the Purcell series. It is overlain unconformably by the Windermere series.

The lower quartzite, or basal member of the formation, is a massive, white, granular rock composed of grains about 1 mm. in diameter. The grains are cemented with silica, and to a small extent with limonite and calcite. The beds average about a foot in thickness.

The magnesian limestones are grey, blue, white, purple, and brick red on fresh fracture, and weather to grey, cream, buff, and purple. They are chiefly fine grained and crystalline, and the beds range from 2 or 3 inches to 2 feet in thickness. The slates are grey to black, green, and purplish, and weather to the same colours. In some places they approach an argillite in nature. Shallow-water features such as sun-cracks are found at a few localities in some horizons, and a few casts of salt crystals were found in a massive green slate at the 8-mile on the wagon road on the south side of Toby creek. The colour of the limestones and slates changes from point to point both along, and across, the strike of the beds. The thickness and nature of the beds vary in a similar way. The beds are decidedly lenticular.

The upper quartzite appears near the summit of the formation, as so far seen, and is very similar to the lower quartzite, but is somewhat more massive. It has a grain of about 1 mm. It may be differentiated from the lower quartzite, in all localities so far seen, by the nature of the underlying beds which, in the case of the upper quartzite, are magnesian limestones and in the case of the lower quartzite are slates. The two quartzites are the best horizon markers of the formation in the area.

The Mount Nelson formation has been mentioned as appearing above the typical Roosville near Torrent, 20 miles south of the map-area. It is traceable northward to a point on the west side of Columbia lake, about

4 miles north of Canal Flats, beyond which, until the Windermere map-area is entered, it has been removed by erosion, and the Dutch Creek beds appear at the surface.

The following are typical sections of the Mount Nelson formation.

(1) Section between the Paradise basin and mount Nelson (*See* section No. 6, Figure 1).

		Feet
Windermere series:		
Unconformity		
Mount Nelson:	Dark grey to black slate	130+
	Grey, siliceous, magnesian limestone	200
	White quartzite (upper)	240
	Grey, siliceous, magnesian limestone	100
	Purplish slate	100
	Purplish magnesian limestone	50
	Purplish slate	20
	Purplish magnesian limestone and slate	170
	Grey magnesian limestone	50
	Blue-grey magnesian limestone	100+
	Several hundred feet of highly crumpled beds	?
	Blue to grey, siliceous, magnesian limestone	150+
	Buff-weathering purplish slate	80
	Purplish slate	80
	Grey slate	50
	Blue to grey magnesian limestone	95
	Greenish slate	90
	White quartzite (lower)	160
		1,865+
Dutch Creek formation.		

(2) Ridge between head of Brewer creek and Laundry creek (*See* section No. 10, Figure 1).

		Feet
Mount Nelson:	Grey, siliceous, magnesian limestone	100+
	Purplish magnesian limestone	300
	Limy slate	25
	Grey magnesian limestone	50
	Limestone breccia	25
	Purplish magnesian limestone	200
	Purplish and green slate	80
	Bluish magnesian limestone	300
	Greenish slate	300
	Green and red slate	150
	Blue-grey magnesian limestone	420
	White quartzite (lower)	600
		2,550+
Dutch Creek formation.		

Origin of the Purcell Series

Except a slight decrease in grain of the quartzites from west to east, there is little evidence in the Windermere map-area as to whence came the Purcell sediments. Schofield[1] suggests that they came from the west.

Within the map-area they indicate deposition in standing water, but in only a few beds show signs, such as ripple-marks and sun-cracks, of having been exposed to the atmosphere. To the south of the map-area in the neighbourhood of Skookumchuck creek and in the Cranbrook map-area, the Gateway formation, which is the equivalent of the lower strata of the Dutch Creek formation, shows in the abundance of sun-cracks, ripple-marks, and casts of salt crystals, that much of the formation was at times exposed to the atmosphere and the strata are such as may form on the flood-

[1] Schofield, S. J., "Geology of Cranbrook Map-area"; Geol. Surv., Canada, Mem. 76, p. 40.

plain of a large subsiding delta. The absence of such phenomena in the equivalent strata in the Windermere area shows that subaqueous and subaerial deposition took place contemporaneously during at least one period of deposition in Purcell time.

The thickness and areal extent of the Purcell series and equivalent strata in British Columbia and the United States indicate that the basin of sedimentation was a large and subsiding one. Walcott[1] considers that it was enclosed and its water was fresh or brackish. The great thickness of limestone in the neighbourhood of the International Boundary scarcely bears out such an hypothesis, but rather indicates true marine conditions. The basis of Walcott's argument is the apparent lack of life in the Purcell and equivalent strata, and its sudden appearance in the Cambrian. This may now be explained by the greatness of the hiatus existing between the Cambrian and the Purcell series, for the gap is much greater than had previously been believed even by those who claimed unconformable relations. Evidence of the extent of the break is afforded by the Precambrian Windermere series which is definitely post-Purcell in age, and the relations as propounded on a later page are such that it is evident the Purcell sediments were subjected to at least two cycles of erosion before the laying down of the Lower Cambrian marine sediments.

The varying nature of the clastic material, and the great amount of limestone forming the Purcell series, indicate change in relief of the land mass from which they were derived.

Structure of the Purcell Land Mass

The Purcell sediments were subjected to folding in pre-Windermere time, as is indicated by the angular unconformity between the two series. The unconformity is marked, though the discordance seldom reaches 45 degrees. There is little difference between the degree of metamorphism exhibited by the two series, and this fact, coupled with the moderate angular discordance, indicates that the pre-Windermere folding was of a broad, open character. There must, however, have been considerable uplift to give a relief that would account for the formation of the great basal conglomerate of the Windermere series.

The amount of shortening in the Purcell sediments, due to pre-Windermere folding, is difficult to estimate, for continuous sections showing both series over sufficiently great distances cannot be obtained. From the data at hand it does not appear to have been very great.

Some conception of the condition of the Purcell sediments in pre-Windermere time may be obtained from a study of the boulders in the basal conglomerate of the Windermere series and a comparison of them with the beds from which they were derived. At the head of Paradise basin there is in the Purcell strata a grey, magnesian limestone, highly fractured and the cracks filled with silica. Boulders of this limestone are present in the Windermere conglomerate, fractured and sealed with silica in exactly the same manner as exhibited by the rock in place in the underlying beds. The fractures extend across the bedding, and so are very probably due to strain and not to slumping through dolomitization. Their presence thus points to

[1] Walcott, C. D., Smith. Misc. Coll., vol. 57, 1910, p. 1.

folding and fracturing of the limestone under no very great load. Many quartzite boulders in the conglomerate undoubtedly come from the underlying Purcell beds. They show but very few old cemented fractures. Many fresh fractures have been produced in these boulders where the conglomerate has been subjected to intense folding. It would appear that these boulders were in the form of quartzite before the deformation of the conglomerate. Their character is the same whether they occur in a limy, siliceous, or argillaceous matrix, so it would seem that they had assumed the quartzitic form before deposition in the conglomerate, otherwise a variation in their cement would be expected to occur in the different phases of the matrix. Thus we may assume that the quartzite was in existence as a quartzite before the formation of the conglomerate, but that it, unlike the limestone, had not been fractured. This suggests that the limestone was laid down as a crystalline limestone[1] and fractured on folding, whereas the quartzite, laid down as a sandstone, suffered deformation as such and was cemented during or after uplift of the Purcell series by percolating waters highly charged with silica, some lime, and iron. This would explain why the limestone was fractured and not the quartzite. The cementing of the cracks in the limestone was probably accomplished by these same silica-charged waters. It suggests metamorphism in pre-Windermere time by diagenetic processes. The Purcell muds, during the same interval, were apparently consolidated to shales, as some fragments of shale are present in the conglomerate. Fragments of slate occur in some phases of the conglomerate, but as the matrix is generally of a slaty nature in these phases, the cleavage is probably due to shearing after the formation of the conglomerate.

The extent of the region affected by the pre-Windermere uplift is not known. The Windermere series is correlated with the Summit series at the International Boundary 90 miles away. Presumably the uplifted area extended south of the boundary and doubtless reached northwards from Windermere map-area.

WINDERMERE SERIES

Strata of the Windermere series were observed by Schofield and Shepard, but their relations to the underlying and overlying formations were not determined.

Toby Conglomerate

The Toby conglomerate is the basal member of the Windermere series and has been named after Toby creek along which the formation is well developed in easily accessible exposures. The formation appears in northwest-trending belts which are distributed across the area, from the terraces west of Windermere lake to the west boundary of the map-area. Good but small exposures may be seen along the wagon road on the west side of Windermere lake, the best being at Brady creek. The finest exposure of the conglomerate is on mount Brewer where its full thickness is revealed above timber-line (*See* Plate IV A).

[1] Steidtmann, Edward, Jour. of Geol., vol. 19, 1911, p. 328.

Within the map-area the Toby conglomerate varies in thickness from about 50 to 2,000 feet. Its nature is extremely variable. In places the matrix is largely slate through which are scattered fragments of slate and shale and occasional boulders of limestone and quartzite. Along or across the strike the matrix may change rapidly to one of limestone holding chiefly limestone boulders, or may grade into a highly siliceous type in which the boulders are chiefly quartzite. In other places quartzite and limestone boulders are equally abundant and lie in a slaty matrix. The percentage of boulders to matrix is very variable, ranging from scattered fragments forming only 5 to 10 per cent of the rock to a compact boulder mass (*See* Plate IV B).

Within the formation are a few lenticular beds of slate and quartzite.

The materials composing the conglomerate have not travelled far and in all cases the boulders can be identified with underlying rocks of the Purcell series. Many of the boulders are rounded, but many also are subangular and angular, indicating rapid erosion and transportation with but little opportunity for wear (*See* Plate IV B). The boulders and fragments vary in size from 4 by 5 feet (the greatest seen) down to pebbles and shingle. The average size is about 4 to 10 inches.

Horsethief Formation

The Horsethief formation is named after Horsethief creek in the vicinity of which the strata and their relations to the overlying and underlying beds are well displayed. The chief exposures of the formation are along the eastern and western edges of the part of the Purcell range within the map-area. Numerous outcrops occur along the western terraces of the trench. The best exposures in the trench are between the wagon-road crossings on Forster creek and to the west of the south end of Windermere lake. The formation also outcrops at intervals along the front of the Stanford range from Windermere creek to the south boundary of the map-area.

The formation is made up in large part of grey, green, and purplish slate with several lenticular beds of coarse quartzite and pebble conglomerate and numerous thin interbeds of blue-grey, crystalline, and mostly non-magnesian limestone, which occur at different horizons but form a relatively small part of the whole formation.

The coarse quartzite and pebble beds vary in thickness from 20 up to 100 feet and more. Most of the pebbles are quartz and quartzite, but a few are limestone; all are well sorted and closely packed. In some beds a few boulders were seen. A few feldspar grains are present in the quartzite beds. The pebbles, which are apparently derived in large part from the Purcell series, differ in size in different beds and grade downward from an average maximum diameter of 1½ inches to grains such as make up the coarse quartzites. At the head of Delphine creek these quartzite and pebble beds are represented by a great thickness of quartzite and fine conglomerate, and the limestone interbeds are particularly abundant in the lower part of the formation.

Around Earl Grey pass the strata exhibit contact metamorphism due to the intrusion of a granite mass to the south. The coarse quartzites

and fine conglomerates have beeen recrystallized and the slate on approaching the contact grades into a phyllite.

The Horsethief formation—the youngest Precambrian formation in the map-area—conformably overlies the Toby conglomerate. Its thickness on the ridge to the east of mount Law, where its relations to the overlying and underlying formations are exposed, is about 4,000 feet. Near Earl Grey pass its thickness is apparently greater, and may exceed 5,000 feet. In general the grain of the strata decreases in coarseness from east to west.

Origin of the Windermere Series

Toby Conglomerate. The size and shape of the boulders, the unassorted character of the formation as a whole, and the evident derivation of the boulders from the immediately underlying Purcell series indicate that the materials were not transported any great distance (*See* Plate IV B). The surface on which the conglomerate rests is fresh and irregular of outline, thus indicating that it had been subjected to rapid erosion (*See* Plate V A). The marked variation in thickness of the conglomerate from 50 to 2,000 feet is strongly suggestive of fan structure and the rock may well be called a fanglomerate. Analogous formations being formed at the present day are the great piedmont deposits of the interior basins of Asia and western United States and such as occur along the southern slopes of the sub-Himalayas bordering the great alluvial plains of the Ganges and Brahmapootra. Such formations are built in regions of marked relief, and where conditions favour rapid erosion and the existence of streams with sufficient transporting power to move debris to the lower slopes of a basin or valley bordering an area of high relief, yet unable to transport their load beyond their point of debouchure from the area of high relief. In other words, a sudden change in grade is the ideal condition. These conditions are to be found along a great warp or fault scarp or possibly along a coast-line, where the materials, instead of accumulating as a piedmont deposit, could be attacked by waves and carried into deep water so rapidly that no marked degree of sorting could result. Lyell[1] cites a case near Nice on the Mediterranean where spring floods bring down great quantities of gravel which are rapidly carried into water reaching a depth of 2,000 feet at only a few hundred yards from the beach. Such conditions would account for a formation occupying a very narrow area, but hardly could explain the building of a formation such as the Toby which occupies an area many miles broad.

Horsethief Formation. Overlying the Toby conglomerate is the Horsethief formation whose lower member is generally a dark blue-grey, thin-bedded, crystalline limestone. At some localities scattered boulders are found in the lower part of the formation, as if the conditions that gave rise to the conglomerate were at times still effective, but in a diminished degree. Although the greater part of the Horsethief formation, as observed, is slate, many thin beds of bluish limestone and several beds of pebble conglomerate are characteristic features. No shallow-water features such as sun-cracks or ripple-marks were observed. The conglo-

[1] Lyell, Sir Charles, "Principles of Geology", 1853, p. 289.

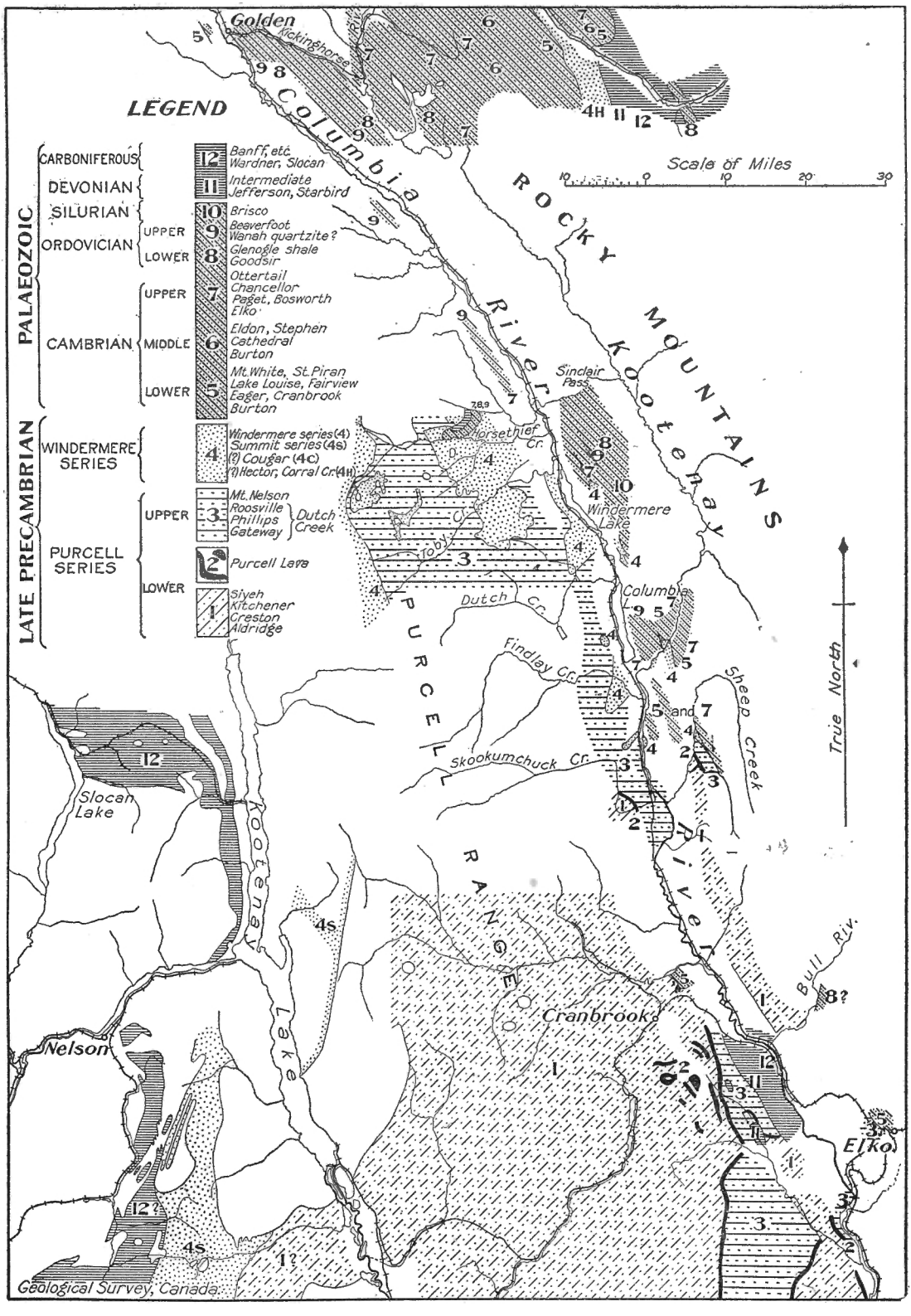

Figure 2. Index map of southeast British Columbia, showing distribution of known Precambrian and Palæozoic formations.

TABLE I

General Correlation Table

—	Windermere map-area 1	Field map-area 2	Beaverfoot-Brisco Stanford range 3	Grainger mt. Canal Flats 4	Ram Creek section 5	Findlay Creek-Skookumchuck area 6	Cranbrook section 7	Purcell trench to Pend D'Oreille river 8
Devonian	Starbird Mount Forster							
Silurian	Brisco		Brisco					
Ordovician (Richmond)	Beaverfoot Wonah quartzite (?)	Halysites beds	Beaverfoot Wonah quartzite					
Lower Ordovician	Glenogle Goodsir Ottertail	Graptolite shales Goodsir	Sinclair Mons (Ozarkian) Lyell (?)					
Upper Cambrian		Ottertail Chancellor Sherbrooke Paget Bosworth		Ottertail	Ottertail=Elko			
Middle Cambrian		Eldon Stephen Cathedral			Burton			
Lower Cambrian		Mt. Whyte St. Piran Lake Louise Fairview		Mt. Whyte Cranbrook	Burton Cranbrook		Eager Cranbrook	
	Unconformity	Conformable in places		Disconformity	Unconformity		Unconformity	
Late Precambrian	Windermere series: Horsethief Toby conglomerate	Hector and Corral Creek		Horsethief	Toby conglomerate	Horsethief Toby conglomerate		Summit series: Wolf, etc. (?) Monk Irene volcanics Irene conglomerate
	Unconformity				Unconformity	Unconformity		Unconformity
	Purcell Series, Upper: Mount Nelson Dutch Creek				Roosville Phillips Gateway	Mount Nelson Roosville Phillips Gateway	Gateway	
	Purcell Series, Lower				Purcell lava Siyeh Kitchener Creston	Purcell lava Siyeh Kitchener	Purcell lava Siyeh Kitchener Creston Aldridge	Priest River terrain

1. Walker, J. F., This report. 2. Allan, J. A., "Geology of Field Map-area"; Geol. Surv., Canada, Mem. 55. 3. Walcott, C. D., Smith. Misc. Coll., vol. 75, No. 1. *Note:* Walcott considers the Richmond to be Silurian. 4. Walker, J. F., This report. 5. Walker, J. F., This report. The original section by Schofield starts 2½ miles farther south (*See* Schofield, S. J., Geol. Surv., Canada, Mus. Bull. 35). 6. Walker, J. F., This report. 7. Schofield, S. J., Geol. Surv., Canada, Mus. Bull. 35 (Modified). 8. Daly, R. A., Geol. Surv., Canada, Mem. 38 (Revised).

merate beds, and traces of crossbedding in the coarse quartzite beds, are the only suggestions of shallow-water conditions. The thickness, as already stated, is 4,000 to 5,000 feet. The Horsethief formation was deposited in standing water in a subsiding basin or valley bordering the area of high relief along the margin of which the Toby conglomerate was deposited. The level of the basin apparently fluctuated, and permitted the advances of the water over the conglomerate, resulting in the formation of the slate and quartzite interbeds. Undoubtedly sedimentation took place at times in the basin contemporaneously with the formation of the conglomerate and it is probable that the conglomerate was reworked to some extent.

Age and Correlation of the Windermere Series

Near Torrent the Windermere series rests unconformably on the lower part of the Mount Nelson formation of the Purcell series. Due east from this point, on the eastern wall of the trench, in the Ram Creek section,[1] a remnant of the Toby conglomerate rests unconformably on the Roosville formation of the Purcell series. This conglomerate remnant was included by Schofield in the conglomerate member (Cranbrook conglomerate) of the overlying Lower Cambrian. The succession at Ram creek is restated below in column 1.[2] Two and a half miles to the north, the 40 feet of shale and conglomerate represented in Toby conglomerate increases to a thickness of 800 feet as indicated in a measured[3] section represented in column 2 below. At Grainger mountain,[4] 10 miles farther north, the Lower Cambrian quartzites rest on the Horsethief formation as expressed in section 3[5] of the following table.

1		2		3	
	Feet		Feet		Feet
Elko	1,000+	Ottertail	1,000+	Ottertail	?
Burton	475	Burton	475±	Burton or Mount Whyte	730
Cranbrook: Quartzite	300	Cranbrook	600	Cranbrook: Quartzite	300
Cranbrook: Sandstone (fossils)	20			Cranbrook: Sandstone (fossils)	50
Cranbrook: Quartzite	300			Cranbrook: Quartzite	325
Disconformity		*Unconformity*		*Disconformity*	
				Horsethief	200+
Toby: Shale	20	Toby: Shale	5		
Toby: Shale containing large boulders	20	Toby: Conglomerate	800		
Unconformity		*Unconformity*			
Roosville		Roosville			

[1] Schofield, S. J., Geol. Surv., Canada, Mus. Bull. 35, p. 15.
[2] Section as taken from Schofield's notes and roughly checked and modified to show position of Toby conglomerate.
[3] The Burton and Ottertail estimated as approximately same thickness as in section 1.
[4] Walcott, C. D., Smith. Misc. Coll., 1924, vol. 75, No. 1, p. 30, gives a hurriedly examined section on Grainger mountain.
[5] The partial section on Grainger mountain as given in Schofield's notes was carefully checked and completed by the writer.

The base of the Cranbrook quartzite is clearly defined in all three sections and at all other points observed. It is noticeable that fossiliferous beds occur at essentially the same horizon in the quartzites at Ram creek and Grainger mountain. Fossils as determined by Walcott show these beds to contain at Ram creek[1], water-worn, minute fragments of trilobites, a species of *Salterella, Olenellus* fragments, *Wanneria* sp. Several good trilobite heads occur on slabs of sandstone, and at Grainger mountain, *Obolus* sp. and *Olenellus* sp. The fauna is Lower Cambrian and resembles that of the Mount Whyte horizon.

Farther northward, the Cranbrook quartzites are exposed east of Sabine mountain, where they are 600 feet thick and rest unconformably on the Horsethief beds of which a thickness of 600 feet is exposed. Ten miles farther north, within Windermere map-area, the Ottertail formation rests on the Horsethief, and at other points the same relation exists, the Cranbrook quartzites being absent everywhere.

The evidence of the Precambrian age of the Windermere series is shown above in that the base of the Lower Cambrian is clearly defined and that the Lower Cambrian rests in different places on different horizons of the Windermere, thus indicating an interval of erosion between the times of deposition of the two series.

M. F. Bancroft[2] has correlated the Toby conglomerate with Daly's Irene conglomerate at the International Boundary. This correlation is based on work by Bancroft in Windermere map-area and on the east side of Kootenay lake, midway between Windermere map-area and the International Boundary.

The Toby conglomerate borders the western side of Windermere map-area with a general strike of south to slightly east of south. At Earl Grey pass the strike swings to about south 15 degrees west and a projection of this strike to the south would pass through an area of a similar formation at a distance of 30 miles from where Bancroft traced the conglomerate south for 28 miles to Kootenay lake. The same regional strike of about south 15 degrees west prevailed throughout this distance. He remarks on the variation in thickness of the conglomerate throughout this distance and points to the more irregular eastern boundary as indicating the base of the formation. He postulates a profound unconformity at the base of the conglomerate and sedimentation from east to west. A projection of the same regional strike for 20 miles, from Bancroft's southern exposure of the conglomerate, would meet the northern exposure of Daly's[3] Irene conglomerate (*See* Figure 2, index map of part of southeastern British Columbia). Bancroft notes the similar nature of the conglomerate throughout the distance from Windermere area south to Kootenay lake. He notes, also, the marked similarity between the Horsethief formation of the Windermere series and the part of the Summit series above the Irene volcanics. The volcanics have not been seen in Windermere area.

Daly[4] considered the Irene conglomerate to be a basal member of the Purcell group. Drysdale[5] tentatively suggested that the Irene conglomerate (at the base of the Summit series) as developed along the Inter-

[1] Schofield, S. J., Geol. Surv., Canada, Mus. Bull. 35, p. 13.
[2] Personal communication.
[3] Daly, R. A., Geol. Surv., Canada, Mem. 38, pt. III, sheet 6.
[4] Daly, R. A., Geol. Surv., Canada, Mem. 38, pt. I, pp. 161–167.
[5] Drysdale, C. W., Geol. Surv., Canada, Sum. Rept., 1916, p. 61.

national Boundary, is the basal member of a series younger than the Purcell series, but thought it probable that the Summit series was of Lower Cambrian age and was the equivalent of the Siyeh and overlying members of the Purcell group. This correlation, as stated by Drysdale, was based on an assumption that the Irene volcanics were the equivalents of the Purcell lava.

The correlation of the Summit series with the Windermere series, as proposed by Bancroft, is accepted by the present writer. The Windermere series, as stated on preceding pages, is now known to be post-Purcell and pre-Lower Cambrian.

The Hector and Corral Creek formations, as indicated in Table I, page 16, are considered to be equivalent of the Horsethief formation. The reason for suggesting the correlation of these formations with the Windermere series rather than, as proposed by Walcott[1], with the Camp Creek and Kintla-Sheppard, the latter of Upper Purcell age,[2] may be summed up as follows.

The general structure of the Purcell series in the Purcell range and western edge of the Rocky mountains, is a great northward-pitching arch. The Purcell series in its northward extension is confined more and more to a narrow belt on the eastern side of the Purcell range, and in Windermere area only the upper members are exposed. The Windermere series, which comes in between the Purcell series and the Palæozoic at Ram creek, thickens rapidly to the north. It outcrops along the eastern side of the trench from Ram creek to Windermere area. Much float of the Horsethief formation is found within the Rocky mountains 20 miles up Kootenay river from Canal Flats. Thus, the broad structural relations indicate the probability that the Precambrian strata immediately underlying the Lower Cambrian in Bow valley to the northeast, are representatives of the Windermere series rather than of the Purcell series, and it is significant that the Hector and Corral Creek formations are lithologically more like the Horsethief formation than the members of the Purcell series. The available evidence is not conclusive, but at least it does not contradict the suggested correlation.

Structure of the Windermere Land Mass

The Windermere series was laid down on an eroded surface of folded Purcell strata in an area that was apparently uplifted after the close of Windermere time. Evidence of this uplift, of the existence of a land mass, is furnished by the distribution and character of the Palæozoic strata. The Lower and Middle Palæozoic formations of the Rocky Mountains region that extend across the Rocky Mountains trench rapidly decrease in thickness in a westerly direction, as if approaching a region of non-deposition, presumably a land area. The Carboniferous is the oldest Palæozoic formation known to occur on the west side of the Purcell range and in the Selkirks. The Ottertail formation, at the summit of the Upper Cambrian, overlaps the complete Cambrian section as developed in the Rocky mountains, and in Windermere area rests on the Horsethief formation, and within the map-area the Richmond overlaps the Glenogle and Goodsir

[1] Walcott, C. D., Smith. Misc. Coll., vol. 53, No. 7, p. 431.
[2] Schofield, S. J., "Geology of Cranbrook Map-area"; Geol. Surv., Canada, Mem. 76, table opp. p. 52.

formations and lies on the Ottertail formation. Shallow-water features are pronounced in the Ordovician Goodsir and Wonah formations. Along the Rocky Mountains trench the Lower Cambrian rests in different places on different members of the Windermere and Purcell series. The same is true of the Ottertail in the case of the Windermere series. There is a slight angular unconformity at the base of the Cambrian in some places.

It appears that a land mass existed in the region of the Purcell range in early Palæozoic time. A western part of this land mass must have been high in order that it might supply the sediments of the Palæozoic formations. It does not seem possible, as has been suggested,[1] that the clastic materials came from a land lying west of the present shore of British Columbia. The near shore features of certain of the Palæozoic formations and the way in which the formations overlap one another and thin to the west negative such a conception.

PRECAMBRIAN IGNEOUS ROCKS

Under this heading are grouped descriptions of a number of highly altered dyke and sill rocks, almost all of which are made up of secondary minerals. The original constituents show as altered remnants in only a few cases. These rocks may be grouped in classes as follows:

(1) *Greenstone Dykes and Sills.* Hand specimens of these rocks are dark grey to dark green and they are frequently schistose. Under the microscope they are found to consist chiefly of chlorite, calcite, and quartz. Some biotite and a little altered plagioclase feldspar were noted in some specimens. Magnetite is generally present and also a little pyrite.

(2) *Brownstone Dykes and Sills.* In the hand specimen these rocks have a rusty, speckled appearance. Under the microscope they appear to be chiefly quartz and calcite or quartz and sericite. The rusty colour is due to disseminated limonite. Biotite and chlorite are sometimes present in small amounts. A little microcline and plagioclase feldspar was observed in a few specimens. Pyrite is sometimes present.

(3) *A Dark Grey Dyke or Sill Rock* which has the appearance of being amygdaloidal. The apparent amygdules are white calcite. The groundmass effervesces with cold, dilute hydrochloric acid and is essentially calcite. Under the microscope the rock is seen to consist of calcite. The calcite shows traces of spherulitic structure probably derived from the mineral which it has replaced. What appeared to be amygdules in the hand specimen are areas of coarsely crystalline calcite.

(4) *A Coarse Crystalline Dyke Rock,* composed chiefly of quartz some of which is opalescent. Under the microscope this rock is found to consist of quartz and sericite with a little altered plagioclase feldspar, chlorite, and titanite (?). A few pyrite cubes are scattered through the rock.

(5) *A Sill or Flow Rock,* purplish red and apparently amygdaloidal. Under the microscope this rock shows a groundmass of lath-shaped feldspar, quartz, and calcite. A little sericite was observed. Iron oxide as hematite and limonite is disseminated through the rock and gives it the purplish

[1] Schofield, S. J., Trans. Roy. Soc., Can., vol. XVII, p. 95, 1923.

red colour noted. The amygdules are composed of calcite, quartz, biotite, and chlorite, with small concentric structures of jasper and quartz on their edges.

(6) *A Dyke Rock* which may belong to class (1), but may be of a different age. Under the microscope it is seen to consist of augite, biotite, chlorite, and quartz. A little calcite, magnetite, and plagioclase feldspar were observed. Though altered, this rock is much fresher than any of those noted above.

The rocks of groups (1) and (2) are by far the most common and cut the Precambrian sediments throughout the western part of the area. Types (2) and (4) are younger than type (1). The dykes have not been found cutting the Palæozoic formations, nor have they been found terminating at the base of the Palæozoic formations. The dykes and sills have been folded and faulted with the sediments. The apophyses of the granite stocks have not been deformed and are comparatively fresh. The age of these rocks has not been definitely determined; they are younger than the Windermere series and older than the period of folding and faulting which is believed to be Jurassic.

The greenstones resemble the more highly altered phase of the Purcell intrusives and are found in the area between the Windermere and Cranbrook map-areas; it would seem, therefore, that the Purcell intrusives of the latter area may not all be of pre-Gateway age as has been supposed[1], but that they may be in part younger.

Mineralization appears to have no relation to these dykes and sills except that in one or two instances the fracture along which the intrusive found its way has also been the path followed by the younger mineralizing solutions which thus gave rise to a vein along the side of the dyke.

These dykes and sills have not been shown on the map. They follow the trend of the folding, namely northwest and southeast throughout the area between Paradise mine and the summit of the Purcell range.

PALÆOZOIC ROCKS

OTTERTAIL FORMATION (UPPER CAMBRIAN)

The Ottertail formation is well exposed along the western face of the Stanford range and also on the slopes of Forster mountain in the Purcell range. The formation is made up of thick and thin-bedded magnesian, crystalline, or semi-crystalline, limestone. It is generally grey, and weathers grey to white. Some horizons are quite siliceous, the silica standing out on the weathered surface in irregular ridges. Schofield[2] speaks of this feature in the Elko formation as coral-like markings, which well describes it. The Ottertail is a distinct lithologic unit throughout the Stanford range. It is a cliff-forming formation. The thickness varies within the area from about 2,000 feet, south of Fairmont Springs, to 270 feet, on the east end of Law ridge.

Within the map-area the Ottertail formation rests on the Horsethief formation of the Windermere series, in some places with unconformable relations and in others with seeming conformity. It is overlain with apparent

[1] Schofield, S. J., "Geology of Cranbrook Map-area"; Geol. Surv., Canada, Mem. 76, p. 68.
[2] Schofield, S. J., "Geology of Cranbrook Map-area"; Geol. Surv., Canada, Mem. 76, p. 47.

conformity by the shales and limestones of the Goodsir formation. No fossils have been found in the formation either in Windermere map-area or to the south, but this formation is the stratigraphic and, in general, the lithologic equivalent of the Ottertail formation of Upper Cambrian age of Field map-area[1], 40 miles distant along the strike of the strata. Walcott[2] has used the name Lyell (?) in describing this formation in the Stanford range. The correlation with the Lyell is made over a gap of 100 to 132 miles and across the summit of the Rocky mountains.

South from Windermere map-area the formation is traceable for 25 miles to Ram creek. It is the Elko formation of Schofield's Ram Creek section[3] and of the described sections on Grainger and Sabine mountains[4]. In its southward extension from the Windermere map-area the Ottertail rests successively on the Cranbrook quartzites, east of Sabine mountain, and the Burton or Mount Whyte formation on Grainger mountain and at Ram creek.

GOODSIR FORMATION (UPPER CAMBRIAN AND LOWER ORDOVICIAN)

Within the map-area this formation is found throughout the Stanford range and also in the small Palæozoic area on the north side of Horsethief creek in the Purcell range. The formation is variable in character and also in its thickness within the area. In the thicker sections the lower part is generally a succession of calcareous shales and thin-bedded argillaceous limestones grading upward into thin-bedded, blue-grey limestone. In the thinner sections it is chiefly shale with thin limestone interbeds and some thin beds of fine conglomerate. Intraformational conglomerates are found at many horizons throughout the formation. They are such as may have been formed by the disturbance and burial of layers of sun-cracked calcareous mud. They are similar to the edgewise conglomerates near Bellefonte, Pa., as described by Ulrich.

The rapid variation in thickness is probably to be accounted for both by non-deposition and by erosion. The thickest section in the area is immediately north of Stoddart creek above the terraces of the trench. The exposures in this section are, however, not very good. Walcott[5] describes this section as including the Mons formation from near its upper limit down to the Briscoia zone at the base. As later explained the name Mons is considered to be a synonym of Goodsir. On the first north fork of Windermere creek some 800 feet of the upper part of the formation is exposed. A small collection of fossils obtained from an horizon 30 feet below the top of the formation was submitted to Dr. Walcott, who comments as follows: "You will also note that Loc. 7848, which is 30 feet below the graptolite shales, contains an Asaphoid tail, indicating the Ordovician or Sarback of the Canadian". The Sarback formation has been described by Walcott as being typically developed in the eastern Rocky mountains north of the main line of the Canadian Pacific railway. At 525 feet below the top of the formation Dr. Walcott reports an *Obolus* and *Xenostegium* of his upper Mons, and at 600 feet from the top (*See*

[1] Allan, J. A., "Geology of Field Map-area", Geol. Surv., Canada, Mem. 55, p. 73.
[2] Walcott, C. D., Smith. Misc. Coll., vol. 75, No. 1, p. 39.
[3] Schofield, S. J., Geol. Surv., Canada, Mus. Bull. 35.
[4] Walcott, C. D., Smith. Misc. Coll., vol. 75, No. 1, pp. 25–29.
Schofield, S. J., "Geology of Cranbrook Map-area"; Geol. Surv., Canada, Mem. 76, p. 47.
[5] Walcott, C. D., Smith. Misc. Coll., vol. 75, No. 1, p. 21.

Plate III B) he reports an *Obolus* and *Eoorthis*, also of his upper Mons. Near the head of Windermere creek and just east of the map-area two small collections of fossils were made, one at the top of the formation and the other 30 feet below the top. From the first collection Dr. Walcott reports a Cephalopod and *Bellefontia* or *Leiostegium* tail and from the second *Lingulella*, Cephalopods, and an Asaphoid tail. He notes that these horizons are above his Mons. About a mile north of this locality, and within a few feet of the top of the formation, occurs a small fauna which has been worked up by Dr. Ulrich and reported upon by Dr. Walcott, in part: "He (Dr. Ulrich) found four species of *Megalaspis*, three closely allied to *M. limbata* and one to *M. planilimbata* of Sweden. A small *Schumardia* has also turned up. This fauna indicates the presence of a Canadian horizon beneath the graptolite shale which is above the upper Mons, as found in the Stoddart-Dry Creek section (Walcott, C.D., Smith. Misc. Coll., vol. 75, No. 1, p. 22). Dr. Ulrich considers that the *Ceratopyge* zone is represented by this fauna." It will be noted from the preceding that a new faunal horizon has been found in the formation and that it is higher than any hitherto reported by Walcott from the Mons. Raymond[1] describes the *Ceratopyge* fauna from collections made by Shepard[2] along the Rocky Mountains trench apparently from a corresponding horizon at other localities to the north. At present it seems that the Goodsir formation within the map-area is divisible into five faunal zones. The four lower zones are those characterizing Walcott's Mons formation and it is possible that the uppermost may be the equivalent of that of his Sarback formation. As pointed out by Walcott[3], the faunal zones of his Mons formation are provisional and subject to change with more detailed study. In what follows these zones will be referred to by numbers, the lowest zone being termed the first and the highest the fifth. The fifth zone is missing from the section at the head of Stoddart creek, and from Swansea mountain[4].

Dr. Walcott reports fragments of *Briscoia-Symphysurina* (?) as being in a collection of fossils obtained from near the base of the formation on the lower slopes of Swansea mountain. This species apparently indicates the presence of an horizon at about the boundary of the first and second zones. It is not known whether the third zone is present on Swansea mountain where the formation is much thinner than to the north and east, suggesting either non-deposition or erosion of the highest zones. Farther south, on the ridge southeast of Fairmont Springs, the four upper zones are missing. On the map the Beaverfoot-Brisco strata are shown overlapping the Goodsir and resting on the Ottertail. This may be in part because of minor faulting, but higher up on the ridge the section is unbroken and the Goodsir has a thickness of only 100 to 200 feet. The formation at this point is chiefly shale with thin beds of fine pebble conglomerate and calcareous sandstone and some of limestone. The upper surface of the formation is slightly irregular and it is overlain by the Beaverfoot-Brisco formations. The upper horizons possibly were never present at this

[1] Raymond, P. E., Am. Jour. Sci., Fifth series, vol. 3, 1922, p. 204.
[2] Shepard, F. P., Jour. of Geol., vol. 30, 1922, pp. 361–376.
[3] Walcott, C. D., Smith. Misc. Coll., vol. 75, No. 1, p. 37.
[4] Swansea mountain is the 5,600-foot knob standing out close to the trench, to the northeast of the town of Windermere.

locality or they may have been destroyed by erosion contemporaneously with deposition farther to the east and north, or by erosion of a later date.

The 70 feet of the Goodsir on mount Forster in the Purcell range cannot be assigned to any definite horizon on the fossil evidence so far obtained.

Age and Correlation. This formation is considered to be the lithologic and stratigraphic equivalent of the Goodsir formation of the Field map-area.[1] The correlation is made over a gap of 40 miles along the strike of the formations. The Sabine formation of Schofield[2] represents the first zone of the Goodsir as developed in Windermere area. The Mons formation of Walcott[3] is the equivalent of the first four zones of the Goodsir of Windermere area. The name Goodsir, given by Allan in 1911, has precedence over Mons[4] or Sabine and is, therefore, used in this report.

The lowest zone of the Goodsir in the Windermere map-area may possibly be somewhat older than the faunal zone near the base of the Goodsir in the Field map-area, which, according to the practice of the Geological Survey, is considered to belong to the Ordovician. To the north of Windermere area, fossils have been collected from what is apparently an extension of the Goodsir beds and these fossils have been stated to be of Upper Cambrian age, though now they are referred by Walcott to the Ozarkian. It is possible that these "Upper Cambrian" forms are from beds belonging to the first zone of the Goodsir. Since this may be the case, the Goodsir, as developed in Windermere map-area, is considered as possibly including both Upper Cambrian and early Ordovician horizons.

The Goodsir formation rests with apparent conformity on the Ottertail formation, though the lithologic change is quite marked. It is a change from a resistant limestone formation to a less resistant, easily eroded shale and thin-bedded limestone formation. The Goodsir is overlain in places, in the eastern part of the area, by the Glenogle shales. Near the head of Windermere creek the lithologic change is gradational; the faunal change, however, is abrupt. Slightly west, on the first north fork of Windermere creek, the lithologic change is very marked. At other places in the area the Goodsir formation is overlain with apparent conformity by the Wonah quartzite and in other places by the Beaverfoot-Brisco formations. The lithologic change is in each case very marked. The Glenogle shale, Wonah quartzite, and Beaverfoot-Brisco formations rest successively on the Goodsir formation from east to west. The only discordance in strike or dip between the Goodsir and overlying formations was found to the south of the map-area, on the north end of Sabine mountain, where there is a slight angular discordance between the Beaverfoot-Brisco formations and the Goodsir.

GLENOGLE SHALE (LOWER ORDOVICIAN)

This formation is found in the easternmost part of the map-area, to the north and south of Windermere creek. The lower part of the formation is chiefly black shale with interbeds of a hard, mud rock and bluish limestone. The upper part grades from a sandy shale to a thin-bedded, argillaceous sandstone. This sandy shale is missing in the more westerly exposures.

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[1] Allan, J. A., "Geology of Field Map-area"; Geol. Surv., Canada, Mem. 55, p. 94.
[2] Schofield, S. J., Trans. Roy. Soc., Can., sec. IV, 1920, p. 76.
[3] Walcott, C. D., Smith. Misc. Coll., vol. 75, No. 1.
[4] Walcott, C. D., Smith. Misc. Coll., vol. 72, No. 1, 1920, p. 15.

Age and Correlation. This formation is considered to be the stratigraphic and lithologic equivalent of the graptolite shales of Field map-area[1]. Burling[2] gave the name Glenogle to these shales in 1922. An unbroken section has not been found, as yet, at or near Glenogle.

A complete section of the Glenogle shales was found near the head of Windermere creek, just east of the map-area (*See* Plate II A). The section is exposed in a steep gully at the head of a small draw about one mile north of the summit of the pass and on the west side of the summit of the range. The strata occur in the underlying limb of a large fold overturned to the west. This fold has a north pitch and continues north to Sinclair mountain where Walcott[3] measured a section across the upper limb. The succession at the head of Windermere creek is unbroken from the upper part of the Goodsir through the Glenogle shale and Wonah quartzite into the Beaverfoot-Brisco formations as follows:

	Feet
Beaverfoot-Brisco formations	759
Wonah quartzite	167
Glenogle shale, upper part	535
lower part	1,627
Goodsir formation (fifth zone)	?

Collections of fossils from various horizons in the lower 1,627 feet of the Glenogle shale were submitted to Dr. Rudolf Ruedemann, whose determinations are shown in Table II, pages 26 and 27. Dr. Ruedemann writes as follows: "The most remarkable feature of this great section is that in spite of its great thickness, only the three Deep Kill zones (Beekmantown) are represented.

[1] McConnell, R. G., Geol. Surv., Canada, Ann. Rept., 1886, pt. D., p. 22 D.
Allan, J. A., "Geology of Field Map-area"; Geol. Surv., Canada, Mem. 55, p. 100.
[2] Burling, L. D., Geol. Mag., vol. LIX, 1922, p. 456.
[3] Walcott, C. D., Smith. Misc. Coll., vol. 75, No. 1, p. 9.

TABLE II

Chart Showing Distribution of Graptolites in Glenogle Shales, Windermere Creek

Determinations by Dr. Rudolf Ruedemann

—	10	30	82	92	97	112	125	275	414	530	634	734	780	784	800	854	916	946	956	966	1069	1084	1120	1141	1154	1230	1238	1246	1271	1283	1348	1358	1403	1433	1471	1490	1580	1597	1600	1627
Caryocaris curvilatus Gurley													c	cc				x		x															x					
Caryocaris cf. *oblongus* Gurley									x																																
Caryocaris sp. nov. *(putillus)*	x																																								
Caryocaris sp. nov. (long, narrow form)																						x																			
Caryocaris sp. (long form)																					x																				
Caryocaris sp				x		x		x					x		x	x							x			x															
Climacograptus pungens Rued																					x	x														cc		x		x
Climacograptus sp. (nov?)																				x																					
Cryptograptus antennaris (Hall)														x							x	x						x		x	x				x	x	x				
Cryptograptus cf. *antennaris* (Hall)?																																x									
Cryptograptus sp																											x														
Dawsonia cf. *campanulata* Nicholson									x																																
Dawsonia sp																																		x							
Dichograptus octobrachiatus (Hall)							cc																																		
Dichograptus cf. *separatus* Elles															x																										
Didymograptus caduceus nanus Rued																					x																				
Didymograptus cf. *euodes* Lapworth													x	x																											
Didymograptus extensus (Hall)		x		x	x				x																																
Didymograptus cf. *extensus* (Hall)										x																															
Didymograptus filiformis Tullberg																						x				c															
Didymograptus cf. *filiformis* Tullberg																												x													
Didymograptus gibberulus Nicholson (=*D. caduceus* Salter)														x	x					x	x																				
Didymograptus nicholsoni Lapworth var. *planus* Elles and Wood												cc	x	cc																											
Didymograptus nitidus (Hall)														x																											
Didymograptus walcottorum sp. nov												x	cc	cc	x	x		x																							
Didymograptus walkeri sp. nov														x																											
Didymograptus sp. nov								x	x	x																															
Didymograptus sp																		x						x											x	x					
Diplograptus (Glyptogr.) dentatus Hall																					x							x	x	x		x		x							
Diplograptus (Glyptogr.) cf. *dentatus* Hall																																				x					
Diplograptus dentatus Brongniart																					x		x		x								x								
Diplograptus inutilis Hall																																			x						
Glossograptus echinatus Rued																							x	x											x	x		x			
Glossograptus cf. *echinatus* Rued																																	x								
Glossograptus sp														x											x																
cf. *Goniograptus perflexilis* Rued		x																																							
Goniograptus thureaui McCoy var. *postremus* Rued															x																										
cf. *Goniograptus thureaui* McCoy *postremus* Rued																																								x	
Goniograptus sp. (young)													rr																											
Loganograptus logani Hall var. *pertenuis* Rued																					x																				
Phyllograptus angustifolius Hall											cc		c	x																											

| | | |

Determination of other fossils from the Glenogle shales, by Miss A. E. Wilson.

1,348 feet from the base
- *Lingula* sp.
- *Rhynchotremo*-like brachiopod
- Gastropod

956 feet from base
- *Lingula* sp.
- *Obolus* sp.
- *Protorthis* sp.
- *Asaphus* sp.
- Ostracoda (2 species)

946 feet from base
- *Obolus* sp.

275 feet from base
- Endosiphon of a peculiar form

Stations 164, 165 (the two lowest horizons) may represent the lowest, *Clonograptus* zone of the Point Levis section. The graptolites are, however, not sufficiently complete or well-enough preserved to be conclusive.

The stations representing the rocks from 87-734 feet (above the base) clearly belong to the *Tetragraptus* zone. The fauna is essentially that of the east of America, or of Europe.

The stations from 780-946 feet (above the base) represent a zone that has some elements in common with our *Didymogratus bifidus* zone, to which this zone would correspond by its position; but it has in the prevailing *Didymograptus walcottorum*, in *D. gibberulus*, and in a new genus, elements that are entirely foreign to the east of America, and that probably point to the Pacific.

The rest of the section, from 956-1,627 feet (above the base) is again entirely similar to the corresponding New York and Quebec zones in composition; it contains all the characteristic forms of our last Deep Kill zone."

Northwest from this locality, on the first north fork of Windermere creek, the Glenogle shales are only 200 feet thick. (This locality is shown as a fossil locality on the map).

A collection of fossils from this section is reported on by Dr. Ruedemann as follows:

Horizon: 125 feet above the base
- *Caryocaris* (small form)
- *Didymograptus hirundo* Salter (cf. *potulus*) fragment
- *Trophograptus* sp.
- *Retiograptus* cf. *tentaculatus* (Hall)
- Crustacean (cf. *Emmelezoe*)
- *Medusina* sp. nov.?

Horizon: 100 feet above the base
- *Caryocaris* sp. (long form)
- *Didymograptus hirundo* Salter
- *Didymograptus* sp. nov.
- *Tetragraptus quadribrachiatus* Hall
- *Phyllograptus anna* Hall
- *Climacograptus pungens* Rued.
- *Glossograptus echinatus* Rued.
- *Liospira* sp. (?) (internal cast)

Horizon: 80 feet above the base
- *Caryocaris* sp.
- *Didymograptus walcottorum* sp. nov.

The Glenogle shales, at this locality, rest on the upper or fifth zone of the Goodsir formation and are overlain by the Wonah quartzite. The upper surface of the shale is slightly irregular and depressions in it are filled with sand grains. The overlying beds of the quartzite are apparently conformable in dip and strike with the shales, though there is evidence of erosion of the shales. The fauna seems to indicate an horizon about at the boundary between the *Didymograptus walcottorum* and third Deep Kill zones. The lower zone, of the main section to the southeast, unless it is represented in the lower 80 feet from which no fossils were obtained, is apparently missing. The formation, which is only 200 feet thick and unbroken, at this point, is thinning toward the west, apparently by non-deposition of the lower part and by erosion of the upper part. It is possible that some of the thinning may be accounted for by the possible lenticular nature of individual beds.

Another section of the formation, east of Tegart mountain, was examined. This section of the Glenogle shale is about 450 feet thick. The lower part, about 200 feet thick, is a yellowish-weathering, thin-bedded, magnesian limestone. It is overlain by 50 feet of thin-bedded, light grey limestone, and this by 200 feet of black shale. The formation rests on the Goodsir and is overlain by the Wonah quartzite, which at this locality is a crossbedded sandstone.

Dr. Ruedemann examined fossil collections made from this section and reports as follows:

5-10 feet below top of shale
- *Caryocaris* (long form)
- *Didymograptus filiformis* Tullberg
- *D. nicholsoni planus* Elles and Wood
- *Climacograptus pungens* Rued.
- *Glossograptus echinatus* Rued. var. *major*
- *Diplograptus (Glyptograptus)* cf. *dentatus* Brgt.

Third Deep Kill zone

10-15 feet below top of shale
- *Tetragraptus quadribrachiatus* (Hall) var.
- *Retiograptus tentaculatus* (Hall)
- *Trigonograptus ensiformis* (Hall)
- *Diplograptus (Glyptograptus) dentatus* Hall

Third Deep Kill zone

40-50 feet below top of shale
- *Didymograptus filiformis* Tullberg
- *D. gibberulus* Nicholson
- *D.* c.f. *extensus* (Hall) fragment
- *Climacograptus pungens* Rued.
- *Glossograptus echinatus* Rued.
- *Caryocaris* sp. (fragment)

Third Deep Kill zone, low

Base of shale
- *Caryocaris* sp. (long form)
- *Tetragraptus (bigsbyi) similis* (Hall)
- *Didymograptus gibberulus* Nicholson
- *D. walcottorum* sp. nov.
- *Didymograptus* cf. *extensus* (Hall)
- *Phyllograptus* cf. *ilicifolius* (Hall)
- *Caryocaris* sp. nov. (long form)

Second Glenogle zone (of *Didymograptus walcottorum*) 70 feet below the shale in the yellowish-weathering magnesian limestone.
- *Didymographus walcottorum* sp. nov. (young)
- *Phyllograptus angustifolius* Hall

Second Glenogle zone

The first collection of fossils from the Glenogle was made by McConnell from a locality on Kicking Horse river on the main line of the Canadian Pacific railway and was reported on by Lapworth[1] as being of Utica or Trenton-Utica age and as possibly somewhat older than the typical Normanskill. This inference was confirmed by Ruedemann[2] after examining fossils collected by Burling from the Kicking Horse River section. Ruedemann described Burling's collection as indicating an horizon between the Deep Kill and Normanskill shales. In 1923 Kindle collected fossils from the shales at a point 1¼ miles west of Glenogle station. These were submitted to Ruedemann who determined the fauna as being from an horizon of lower Deep Kill age[3]. Walcott[4] collected fossils from a locality 2¼ miles west of where Kindle obtained fossils. Ruedemann reported the fauna of this collection as belonging to the *Didymograptus bifidus* horizon of the Deep Kill, but as also containing some older elements. Walcott[5] considers this horizon to be part of his Sinclair formation and states that the upper part of the Sinclair as originally defined may yet prove to be the equivalent of the Glenogle shales which apparently he would restrict so as to include only the higher zones in the strata in the general vicinity of Glenogle.

The *Tetragraptus* and *Didymograptus walcottorum* zones of the Windermere Creek section are known to be present near Glenogle, and at Glenogle is found a higher faunal zone than any known in the Windermere section. It seems likely, therefore, that the upper faunal zone (Third Deep Kill zone) of the Windermere Creek section is also present in the strata near Glenogle. All these zones are grouped as one formation, for—lithologically—the formation is a unit, and it is seldom possible to get sufficient faunal evidence to make an accurate subdivision. Burling[6] for this reason defined the Glenogle shales to include the horizons of Chazyan and Canadian age, that is, to include all the shaly strata in the vicinity of Glenogle. Following the precedent set by Burling the term Glenogle shales is used in this report to include what may be the *Clonograptus* zone, and the three Deep Kill zones of the Windermere Creek section and the zone between the Deep Kill and Normanskill (Chazyan of Burling) as yet discovered only near Glenogle.

The type locality of the Sinclair formation as defined by Walcott[7] is on Sinclair pass, just north of Windermere map-area. At this place Walcott measured a section of 1,655 feet of strata which he assigned to this formation. These beds, as already stated, extend south to where a section of the same beds was measured on Windermere creek by the present writer. The upper arenaceous part of the Sinclair section corresponds to the upper arenaceous part of the Windermere Creek section; the fauna of the upper 517 feet of the Sinclair section corresponds to the fauna of the upper zone (Third Deep Kill zone) of the Windermere Creek section; the lower part of the Sinclair section, from which no fossils were obtained by Walcott, may corespond to the *Didymograptus walcottorum* zone and part of the

[1] McConnell, R. G., Geol. Surv., Canada, Ann. Rept., 1886, pt. D, p. 23 D.
[2] Walcott, C. D., Smith. Misc. Coll., vol. 75, No. 1, p. 33.
[3] Personal communication from E. M. Kindle.
[4] Walcott, C. D., Smith. Misc. Coll., vol. 75, No. 1, p. 34.
[5] Walcott, C. D., Loc. cit.
[6] Burling, L. D., Geol. Mag., vol. LIX, 1922, p. 458.
[7] Walcott, C. D., Smith. Misc. Coll., vol. 75, No. 1, p. 34.

Tetragraptus zone of the Windermere Creek section. It is evident that the beds on mount Sinclair, and on Windermere creek, belong to the same formation.

Near Glenogle, Walcott[1] assigned to the Sinclair formation strata containing the fauna of the *Didymograptus walcottorum* zone and perhaps part of the *Tetragraptus* zone of the Windermere Creek section. The Sinclair formation, as known from fossil evidence, thus represents only two zones, and possibly part of a third zone of the Windermere Creek section.

WONAH QUARTZITE (ORDOVICIAN)

Within the map-area this formation occurs in a few places along the eastern part of the Stanford range, from east of Tegart mountain to the northern boundary of the area.

In the section exposed near the head of Windermere creek the quartzite has a thickness of 167 feet made up of, in descending order:

	Feet
White quartzite	92
Sandstone	25
White quartzite	50

The formation thins toward the west to a thickness of 60 feet on the first north fork of Windermere creek and a short distance west is still thinner. East of Tegart mountain it is a coarse-bedded sandstone 40 feet thick.

The formation is the stratigraphic equivalent of the quartzites at the base of the *Halysites* beds of McConnell[2] and Allan[3]. The name, Wonah quartzite, was given by Walcott[4] to the formation as exposed in Wonah ridge south of Sinclair creek and just north of Windermere map-area. Definite evidence of the age of the formation is lacking. It may be early Richmond as postulated by Walcott.[5] The Wonah quartzite rests on what appears to be an erosion surface of the Glenogle shales and at two localities rests on the Goodsir formation. Within the map-area there is no discordance in dip and strike between the Wonah and underlying formations, but it is evident that they are separated by a considerable time interval. The Wonah is overlain conformably by the Beaverfoot-Brisco formations, the lower of which is Richmond in age. The Wonah, therefore, may be of early Richmond age and can hardly be as old as Chazy.

BEAVERFOOT-BRISCO FORMATIONS (RICHMOND AND SILURIAN)

These two formations are found throughout the Stanford range within the map-area, and what is apparently the Richmond occurs also in two localities on, respectively, the north and south sides of Horsethief creek in the Purcell range.

The formations consist of thick to moderately thin-bedded, crystalline and semi-crystalline limestones. The Richmond (Beaverfoot) or lower beds, are on the whole more massive, more magnesian, and darker weathering than the Silurian (Brisco), or upper beds, which are on the

[1] Walcott, C. D., Smith. Misc. Coll., vol. 75, No. 1, p. 34.
[2] McConnell, R. G., Geol. Surv., Canada, Ann. Rept., 1886, pt. D, p. 21 D.
[3] Allan, J. A., "Geology of Field Map-area"; Geol. Surv., Canada, Mem. 55, p. 101.
[4] Walcott, C. D., Smith. Misc. Coll., vol. 75, No. 1, p. 49.
[5] Walcott, C. D., Smith. Misc. Coll., vol. 75, No. 1, p. 43.

whole lighter weathering, thinner-bedded, and less magnesian. The change, however, is transitional and no accurate lithologic division can be made. These limestones, like the Ottertail beds, are cliff-forming. They may be distinguished from the Ottertail strata by their contained faunas, by the darker weathering colour of the lower beds, and by the lower silica content of the lighter-weathering upper beds.

The beds are the stratigraphic equivalent of the limestone part of the *Halysites* beds of McConnell[1] and Allan.[2] Burling[3] first referred to these beds as being of Richmond age and in 1922 gave the name Beaverfoot[4] to them. Walcott[5] has given the name Brisco to the Silurian beds, but in the Sinclair Canyon section, as reported by Walcott, and in the Windermere map-area the Richmond is transitional into the Silurian. It is impossible to make an accurate division, either on lithologic or faunal evidence between the Richmond (Beaverfoot) beds and the Silurian (Brisco) beds. For these reasons the strata have not been subdivided and are here included under the name Beaverfoot-Brisco formations.

The best section of the Beaverfoot-Brisco strata was found near the head of Windermere creek in the same section with the Glenogle shales previously mentioned. Several hundred feet of the uppermost beds exposed and lying near the axis of the overturned fold are not included in the section. The section is as follows. All determinations of fossils and remarks thereon are by Alice E. Wilson.

	Feet
Beaverfoot-Brisco formations:	
Several hundred feet of light grey limestone disturbed and poorly exposed.	
1. Light grey limestone weathering light grey. A 4-foot bed weathering dark grey at 16 feet from top. Fauna from top beds. *Virgiana* sp. (Silurian)	64
2. Grey limestone weathering a dark slate grey	10
3. Light grey limestone weathering light grey. Stringers and nodules of black chert at 97 feet from top	127
4. Grey limestone weathering a dark slate grey	55
5. Chiefly grey limestone weathering a dark slate grey with light weathering bands in upper part. White chert nodules in a dark grey horizon 50 feet from top. Crinoid stems observed beneath chert horizon	65
6. Light grey limestone weathering light grey. Crinoid stems observed 25 feet from top.	70
7. Limestone weathering light and dark grey. Crinoid stems, corals, and brachiopod fragments observed at top.	
A collection from an horizon 100 feet from top contains:	
Halysites n. sp. (a)	
Diphyphyllum n. sp.	
Favosites sp.	
Streptelasma sp.	
Rhynchotrema n. sp. nr. *R. capax*	
Rhynchotrema sp.	
Brachiopod undt.	
Actinoceras sp.	
"This fauna shows the beginning of those forms which give a Silurian aspect to beds which still retain an undoubted Richmond fauna"	130
8. Dark grey limestone weathering dark slate grey with a few light weathering beds.	
Fauna: from the top	
Rhynchotrema increbescens n. var.	
75 feet from top	
Streptelasma n. sp.	
Halysites n. sp.	
Coral indt.	
Crinoid stems	
Rhynchotrema increbescens n. var.	
143 feet from top, lots A (upper) and B (lower) separated by about 2 feet	

[1] McConnell, R. G., Geol. Surv., Canada, Ann. Rept., 1886, pt. D, p. 21 D.
[2] Allan, J. A., "Geology of Field Map-area"; Geol. Surv., Canada, Mem. 55, p. 101.
[3] Burling, L. D., Geol. Soc., Am., vol. XXVII, 1916, p. 158.
[4] Burling, L. D., Geol. Mag., vol. LIX, 1922, p. 459.
[5] Walcott, C. D., Smith. Misc. Coll., vol. 75, No. 1, p. 47.

Lot A. *Dinorthis* sp.
Rhynchotrema sp. (a) nr. *R. capax*
Byssonychia radiata var.

Lot B. a *Stromatoporoid*
Cyrtodonta ? sp.
Spyroceras sp.
Actinoceras ? siphuncle
Trilobite fragments

"These two lots, though but a couple of feet apart, have an entirely different matrix as well as a different fauna. Lot A is a typical Upper Ordovician Beaverfoot fauna. Lot B represents a Richmond horizon, but both matrix and fauna differ from any other Richmond section submitted."

188 feet from top
Halysites n. sp. (a)
Streptelasma n. sp.
Rhynchotrema n. sp. (a) nr. *R. capax*
Plectambonites cf. *saxens* (Sardeson)
Protokionoceras ? n. sp. 213

9. Calcareous sandstone, Crinoid stems observed at top 25

Part of section measured 759

The calcareous sandstone at the base rests on the Wonah quartzite with apparent conformity. This section, which includes both the Richmond and Silurian, clearly shows the difficulty of making a division between the two.

A lens of graptolite shale occurs in the upper or Silurian part of the stratigraphic group, on the summit of Tegart mountain. The following section includes this horizon and the limestone immediately above and below it.

Feet

1. Blue-grey limestone weathering buff, fucoid markings on weathered surface 25

2. Alternate beds of fine-grained, blue-grey limestone, weathering buff, and shale. Fauna from top beds, determinations by Dr. Rudolf Ruedemann.
Favosites sp. (between *favosus* and *niagarensis*)
Cheirurus (Ceraurus) cf. *niagarensis* Hall
Dalmanites sp. nov.
Calymene sp. cf. *niagarensis* Hall (pygidia) 25

3. Chiefly shale with a few limestone interbeds of 2 to 6 inches
Fauna, determinations by Dr. Rudolf Ruedemann
Top beds. *Monograptus* sp. ? (poorly preserved)
20 feet from top
Graptolites (no report)
28 feet from top
Monograptus sp. cf. *runcinatus* Lapworth
38 feet from top
Monograptus sp. ? (not identifiable) 53

A collection from the same horizon about 300 yards to the north yielded a few poorly preserved specimens regarding which Dr. Ruedemann writes: "They are species of *Monograptus* (one of *priodon* type), *Retiolite (Gladiograptus) geinitzianus* Barrande, and *Rastrites* (fragment). They are hence of Upper Silurian age (about Gala-Tarannon or Clinton) and seem to fall in with collections I received from Drs. Walcott and Kirk from the Banff and Windermere motor road."
Another lot from this locality contains, according to Dr. Ruedemann:
Monograptus cf. *marri* Perner cc

4. Limestone immediately below the graptolite shales
Fauna, determination by Dr. Ruedemann
Lot A. *Liospira* sp. (small)
Tentaculites sp.
Orthoceras sp.
Zygospira ? sp.
(All fossils small, Silurian or Ordovician)

Lot B. *Cheiurus* cf. *niagarensis* Hall (vranidium) (Silurian)

The bluffs by Fairmont Springs yielded a Richmond fauna from an horizon near the base of the Beaverfoot-Brisco strata. Collection by Mr. E. M. Kindle, determination by Miss A. E. Wilson.

Halysites n. sp. a (Ordovician type)
Syringopora sp.
Streptelasma n. sp. c
Streptelasma n. sp. a
Rhynchotrema? cf. *anticostiense* (Billings)
Dinorthis n. sp. a

A small collection of fossils was obtained from an horizon about 500 feet above the base of the formations in the area exposed to the northeast of Columbia lake. The fossils, determined by Miss A. E. Wilson, are as follows:

Halysites n. sp. (b)
Rhynchotrema n. sp. (b)
Brachiopod undt.
"Probably near the base of the Silurian of the upper part of the Richmond."

Strata of the Beaverfoot-Brisco assemblage are found in the Purcell range on the north and south sides of Horsethief creek. The strata are 200 feet thick on the north side and 25 feet thick on the south side. No fossils of any diagnostic value were obtained from these localities. The beds are massive, and weather a dark slate-grey, like the lower beds of the Richmond; the light-weathering beds more pronounced in the upper, Silurian, part are missing in these sections. On the north side of Horsethief the strata rest on the Goodsir, on the south side of the creek on the Ottertail. The surface of the Ottertail formation is slightly irregular, otherwise there is no evidence of an unconformity except as is expressed by the lithologic change and the difference in age of the formations. In these localities the strata are overlain by the Mount Forster shales of presumably Devonian age. The contact is apparently conformable, but the lithologic change is very marked.

MOUNT FORSTER FORMATION (DEVONIAN?)

The Mount Forster formation, named after mount Forster, on the north side of Horsethief creek in the Purcell range, occurs in two small areas in the Purcell range on, respectively, the north and south sides of Horsethief creek.

The maximum thickness of the formation, as displayed on the slopes of mount Forster, is about 600 feet. The strata are chiefly shale, some of which has a slaty cleavage, varying in colour from light grey to greenish and pink. The colours are not restricted to definite beds, but vary in the same beds in short distances. Thin limestone interbeds distributed through the formation occur at intervals roughly 25 feet apart. The limestone is semi-crystalline to crystalline and generally fine grained.

The Mount Forster formation rests conformably on the Beaverfoot-Brisco strata. The lithologic change is very marked and may indicate a considerable time interval. The formation grades upward into an Upper Devonian limestone. No fossils have as yet been found in the formation. It is quite unlike the Beaverfoot-Brisco strata as seen anywhere in the district and since it merges upwards into the overlying Upper Devonian it has been provisionally classed as Devonian.

STARBIRD FORMATION (UPPER DEVONIAN)

The Starbird formation has been named after Starbird ridge on whose southeast slopes the strata are exposed. The locality is on the north side of Horsethief creek opposite the old Starbird ranch, in the Purcell range.

The formation is essentially calcareous, though a considerable amount of arenaceous and argillaceous material accompanies the lime. The rocks grade from limestone at the top through arenaceous limestone to limestone and shale at the base.

The Starbird formation rests conformably on the Mount Forster formation and grades into it. The dividing plane is an arbitrary one, placed where the lower essentially shale beds change to those essentially of lime. The upper part of the Starbird formation carries an Upper Devonian fauna. The following section was measured on the west slope of the summit of mount Forster, on the east end of the Starbird ridge. The fossils as listed were determined by E. M. Kindle.

	Feet
1. Grey limestone in beds up to 2 feet thick	
Fauna from top beds:	
Productella cf. *coloradoensis*	
Schizophoria striatula	
Atrypa reticularis	
From an horizon approximately 5 feet lower	
Cladopora sp.	
In the lower part of this section many crinoid stems were seen	30
2. Greyish limestone and calcareous sandstone. A crossbedded, calcareous sandstone occurs near the top	100
3. Limestone in beds up to 1 foot thick with brownish shale which increases in amount downward through the section	100
Conformable contact with Mount Forster shale	

A collection of fossils was made from 25 feet of strata occurring on the end of a ridge southwest of mount Forster and belonging to essentially the same stratigraphic horizon as division No. 1 of the above section. The fossils have been determined by Mr. Kindle who reports, subject to revision, as follows:

Productella? sp.
Schizophoria striatula
Atrypa reticularis
Spirifer cf. *raymondi*
Spirifer cf. *argentarius*
Actinopteria? sp. (represented by fragment)

"The age of this fauna is unmistakably Devonian. Its Middle or Upper Devonian age is equally apparent. The fauna, however, is notable for the absence of species which are commonly regarded as decisive index fossils of either Upper or Middle Devonian time. The abundance of *Schizophoria striatula* not distinguishable from the Upper Devonian Iowan form of this species, and other collateral evidence, lead me to place this fauna in the Upper Devonian."

"The regional affinities of this fauna, so far as suggested by this list, are not very striking, but appear to point towards a relationship with certain facies of the Upper Devonian of the northern Rocky Mountains states. The fauna is decidedly unlike any fauna known to me in the eastern ranges of the Canadian Rockies."

MESOZOIC ROCKS

GRANITE STOCKS, SILLS, AND DYKES (JURASSIC ?)

To the Jurassic (?) have been assigned the granite stocks and their apophyses, on Horsethief creek and to the west of Farnham creek, in the Purcell range. A similar granitic mass lies just south of Earl Grey pass and is not far distant from the Fry Creek granite area which is considered part of the Nelson batholith[1] which is presumably of Jurassic age.[2]

The Horsethief Creek stock extends westerly from the mouth of McDonald creek to the western boundary of the map-area north of Stockdale creek. It lies largely on the north side of Horsethief and Stockdale creeks, but crosses both creeks and outcrops for some distance up the south sides of their respective valleys. The dimensions of the stock within the map-area are roughly 7½ miles east and west by 3 miles north and south. The stock extends 2 to 3 miles north of the map-area.

The mineralogical composition of the Horsethief stock is that of a granite. The rock consists essentially of microcline, microperthite, sodic plagioclase, and quartz. The ferromagnesian minerals are represented by a little biotite. The rock is light coloured, medium to coarse in grain, and in general porphyritic. In the porphyritic phase the phenocrysts are microcline, of a pale pinkish grey colour, and in many instances are well zoned. The phenocrysts measure up to 1½ inches in the coarser phases.

The rock mass is homogeneous, the composition of the marginal phases being essentially that of the main mass. The grain, however, is somewhat finer near the margin.

The granite is heavily jointed. The joint-planes have no definite relation to the form of the stock and are variable in direction.

The walls of the stock are nearly vertical. Contact metamorphism is not marked. The intruded sediments are chiefly slates and quartzites of the Dutch Creek formation. These have been changed at the contact to quartz-mica schists in which the mica is chiefly biotite with less sericite. Chlorite and a little hornblende have been developed in some of the schists. Schistosity gives place to a banded quartz-mica rock with slight cleavage which in turn gives place to the unmetamorphosed rock. The change is gradual and it is difficult to determine accurately the distance to which metamorphism has taken place.

Numerous tongues, from a few inches up to 100 feet in thickness, penetrate the sediments about the contact of the granite. They are fine to medium in grain and are in part porphyritic. The finer-grained phases are practically free from ferromagnesian minerals and may be called alaskites. The mineralogical composition is essentially that of the main stock. A few of the smaller dykes and sills are pegmatitic in structure and contain a noticeable amount of white mica and some black tourmaline.

In numerous veinlets close to the contact are found actinolite, diopside, epidote, common garnet, vesuvianite, and rosettes of talc (?). These are practically the only contact minerals developed in the slates. Wollastonite and tremolite are developed along the bedding planes in limestone near the mouth of McDonald creek.

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[1] Bancroft, M. F., Geol. Surv., Canada, Sum. Rept., 1920, pt. A, p. 101 A.
[2] Drysdale, C. W., "Geology of Franklin Mining Camps"; Geol. Surv., Canada, Mem. 56, pp. 61 and 62.

The granite was apparently intruded as the last phase of mountain-building. It cuts the folded and faulted sediments and the apophyses do not show deformation. The stock cuts the large thrust fault, on the north side of Horsethief creek, which cuts the folded sedimentary structures and is hence a late feature in the deformation of the sediments.

The coarseness of the grain, the homogeneity of the mass, and very low ferromagnesian mineral content suggest that the stock is a differentiate from a larger body. The coarseness of grain and slight contact phenomena suggest that it was intruded probably as a partly crystalline mesh and at a comparatively low temperature.

To the west of Farnham creek, on the western border of the map-area, is a small stock about three-quarters of a mile long by one-quarter to one-half mile in width. This stock was only hastily examined. It is intruded into the Windermere series. Mineralogically, it apparently grades from an alaskite to about a granodiorite. It is medium to fine-grained and does not show the marked porphyritic character of the stock on Horsethief creek. The slates at the contact have been changed to a spotted schist. The spots are segregations of biotite. The contact zone is very narrow and the walls of the stock quite steep.

This stock may be examined at the lake of the Hanging Glaciers which lies just west of the map-area.

LAMPROPHYRE DYKES

On the east and west ends of the ridge lying to the northeast of mount Brewer are two small lamprophyre dykes about 10 inches in width.

Mineralogically, they are chiefly biotite and augite with minor quartz and what is apparently glassy feldspar and minute particles of magnetite. They are porphyritic and schistose. The phenocrysts are biotite. The rock is rotten in appearance, but under the microscope it appears comparatively fresh. The schistosity appears to be a primary feature due probably to differential pressure at the time of injection and not to subsequent pressure after the complete crystallization of the dykes.

QUATERNARY DEPOSITS

During the Glacial period the district was largely covered by ice. To what height continental glaciation affected the district is not known, for rapid disintegration has altered the whole area above timber-line. Continental glaciation, however, reached an elevation of at least 7,500 feet, as indicated by erratics to be seen to that height. Some of the higher peaks may have reached above the ice, but it is probable that they had small glaciers on their slopes. Pleistocene and Recent deposits are represented chiefly by the glacial silts and gravels and recent alluvium along the trench. Dawson has described the silts along the trench and similar deposits at other points in the interior of British Columbia and they are now generally known as "Dawson's White silts". The silts in Windermere area are light in colour, vary in grain from exceedingly fine to coarse, and are interbedded with gravels. Till in places overlies the silts, but has generally been removed by erosion. A fine exposure of till with well-developed hoodoos may be seen at the road crossing on Brewer creek. The till at

this point, though it may be due to valley glaciers, overlies the extension of the silts back into the creek and points to an advance of the glaciers after the deposition of the silts. The manner in which the bedding of the silts dips away from the mouths of the creeks into the trench suggests that a large part of the valley silts came from the adjacent mountains while ice was active as an erosive agent. That the ice did not occupy the trench when the silts were deposited may be seen in the gentle dip of the silts toward the centre of the valley and their truncation by recent erosion. It seems very evident that the slits once extended across the trench. Dawson[1] in referring to these silts as developed on Tobacco plains in the trench near the International Boundary, makes the following statements. "The bottom of the valley is here composed of gravelly hills which appear to represent moraine ridges in a more or less degraded state. These become lower on approaching the river, and are surrounded by wide gravelly terraces, which in sections on the Tobacco and Kootanie are seen to consist of white silt, with interbedded coarse, gravelly layers, and are probably due to the closing epoch of the glacial period, when the valley was filled by an extensive body of water, into which turbid glacial streams from the neighbouring mountains discharged."

Calkins,[2] in describing the region around Bonner's Ferry, Idaho, states that: "In the vicinity of Bonner's Ferry there were seen exposures of a very extensive deposit of fine-grained, light-coloured sands and silts, which form a high and broad terrace. These could hardly have been precipitated from suspension except in still water or a very sluggishly moving current. It seems probable, therefore, that they were accumulated in a lake formed in the Purcell trench during the recession of the ice, held in at the south by the terminal moraine and on the north by the glacier front."

Stream action, probably controlled by the breaching of the dam, has cut down through the silts. This action has been intermittent, the stream losing the downward-cutting power at intervals and cutting laterally, then cutting downward again. This has resulted in the formation of terraces which flank the present central depression along the trench. The central depression was probably cut to a greater depth than now appears, and it forms the depressions occupied by Windermere and Columbia lakes. Downward erosion has apparently slackened and the streams during periods of freshets have deposited silt in the channels, thus raising the floor of the valley. Thus the depositing of silt at the mouths of Dutch and Toby creeks, with the absence of streams of any size between, accounts for the natural dams which gave rise to the two lakes mentioned. The overflowing of Kootenay river at high water would build the natural dam which exists between it and Columbia lake at Canal Flats. Silting up of the lower end of Columbia lake by Dutch creek is still progressing rapidly.

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[1] Dawson, G. M., Geol. Surv., Canada, Ann. Rept., vol. 1, 1885, p. 148 B.
[2] Calkins, F. C., U.S. Geol. Surv., Bull. 384, p. 32.

CHAPTER IV

STRUCTURAL GEOLOGY

The structure of the Purcell range within the map-area may be called a geanticline, made up of several major folds or anticlinoria. The formations on the east side of the range plunge toward the northeast under the floor of the Rocky Mountains trench. On the summit of the range along the western boundary of the map-area, and for some distance west, the formations dip away toward the southwest. The whole structure pitches north to northwest. The general trend of the axes of folding is northwest and southeast with minor transverse folds giving northwesterly and southeasterly pitches to the major folds. An anticlinal axis passes through Jumbo mountain. The folding along it has been intense, and has produced closed folds which tend to be overturned toward the northeast. To the east a synclinal axis runs along Farnham creek and farther eastward is an anticlinal axis through Monument peak; then a synclinal axis, and finally another anticlinal axis situated just west of mount Nelson. The strata of the eastern limb of the last-mentioned anticline dip steeply to the northeast, but flatten out along the east end of Law and Slade ridges. A sharp overturn to the northeast occurs along the wall of the trench west of lake Windermere.

The correlation map of southeast British Columbia shows that the Summit-Windermere series borders the western side of the Purcell range and gradually extends inwards to the summit of the range in the Windermere map-area. The Windermere series in places borders the east side of the range, as far south as Torrent. Only the Upper Purcell formations show beneath the Windermere series in Windermere area. The Upper Purcell formations lie along the eastern side of the range from Windermere area south to the International Boundary. The Lower Purcell formations show throughout the greater part of the range near the International Boundary. At Skookumchuck creek the Lower Purcell formations begin to pass under the Upper Purcell formations and in a short distance north are completely buried. In other words the southern part of the Purcell range in British Columbia is a great north-pitching arch or geanticline with the older formations exposed in the heart of the range in the south and successively younger formations occupying this position to the north.

Uplift with open folding occurred at the close of Purcell time and uplift probably occurred again at the close of Windermere time. It is impossible to deduce, from available evidence, when the more intense folding occurred which produced the present structures. Schofield[1] dates the building of the Purcell range as late Jurassic and Drysdale[2] gives the granite mass along the Selkirks a Jurassic age. Within Windermere area it is clearly evident that folding and faulting had been mainly accomplished before the intrusion of the granite stocks, but the apparent primary schistosity of the lamprophyre dykes near mount Brewer indicates a con-

[1] Schofield, S. J., "Geology of Cranbrook Map-area"; Geol. Surv., Canada, Mem. 76, pp. 95, 97, and 102.
[2] Drysdale, C. W., "Geology of Franklin Mining Camp"; Geol. Surv., Canada, Mem. 56, pp. 61 and 62.

dition of differential stress as existing at the time of the injection of the dykes. As lamprophyres are considered to be a late phase of igneous intrusion it is apparent that compressive stresses still existed after the time of intrusion of the granite bodies, although these masses were not deformed. Mineralization is considered to be a last phase of igneous intrusion, and in this map-area is associated with minor closed and fractured anticlinal folds. These deposits do not show deformation except in a few cases where mineralization has been closely associated with faults along which later movements, as indicated by the sheared condition of the veins, have taken place. The later movements along the faults may have been a continuation of the Jurassic deformation or may have been associated with the Laramide revolution which undoubtedly must have affected the Purcell range, but apparently caused uplift without folding.

In Windermere map-area the Precambrian formations on the west side of the trench are overturned, and plunge to the northeast. The Horsethief formation is exposed at several places on the east side of the trench, and is folded and faulted with the Palæozoic formations. The strata in the Stanford range are highly folded and faulted. The Palæozoic formations in the neighbourhood of the trench are thinning very rapidly to the west. It would appear that the intense folding and faulting in the Stanford range were due in large part to the folding of the rapidly thinning Palæozoic formations against the resistant Purcell mass to the west. The trench at this point appears to have been eroded along the western margin of this area of intense folding and faulting where the shattering of the formations was probably greatest. There are no true border faults along the trench within the map-area. From Windermere area to south of Skookumchuck creek, the Precambrian formations on the west side of the trench plunge beneath the floor of the valley and at several places outcrop on the east side of the trench. There is no border faulting of any note along the west side of the trench in this section. The structures on the east side of the trench from Canal Flats to Sheep creek are more simple than those to the north. The Palæozoic formations and the Windermere series form a series of folds with gently dipping eastern limbs and steeply dipping, slightly broken western limbs. The first border fault of any note is one which lies along Sheep creek and which probably connects to the south with the great fault extending between Wildhorse creek and Bull river. From Sheep creek to Wildhorse creek the displacement along the fault may be small, for there is room for the formations on the east side of the trench to turn over so as to conform to the structure on the west side of the trench without any great displacement. At Bull river the border fault on the east side of the trench is clearly evident, as noted by Dawson[1] and Schofield.[2] This fault has the greatest displacement of any known to occur along the trench.

The Palæozoic formations and the Precambrian Horsethief formation of the western front of the Stanford range, are, as already stated, highly folded and faulted with a general northwest and southeast trend. The strata are closely folded and frequently are overturned toward the west.

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[1] Dawson, G. M., Geol. Surv., Canada, Ann. Rept., 1885, p. 190 B.
[2] Schofield, S. J., Trans. Roy. Soc., Can., sec. IV, 1920, pp. 75 and 76.

Fine examples of overturning may be seen at the heads of Stoddart and Windermere creeks and also above Fairmont Springs. Due to the prevalence of faulting the folds in most cases are broken. The Rocky mountains were built at the close of the Palæogene and the tilted strata of the Stanford range probably represent the western margin of the then folded area. The Purcell range may have been deeply eroded in Mesozoic time and, if so, was probably re-elevated at the time of formation of the Rocky mountains. Mansfield[1] has postulated two major periods of movement for the formation of the Rocky mountains in Idaho: the Laramide in early Tertiary and a probable Pliocene period during which the Salt Lake formation, tentatively placed in the Pliocene, was deformed. The Pliocene (?) movement was one of uplift with open folding. There is no record of the late Tertiary events in the Rocky mountains of Canada, but it is quite possible that both the Rocky mountains and the Purcell range have undergone elevation since the Laramide revolution.

No faulting of pre-Windermere age has been detected in the map-area. In post-Windermere time faulting may have accompanied the intrusion of dykes represented by greenstone and other altered dykes of the western part of the area. More recent faulting has cut these dykes, but evidently occurred before the intrusion of the granite stocks, as is indicated by the manner in which the granite stock on Horsethief creek cuts the most pronounced fault in the area. This fault was a thrust from northwest to southeast of considerable displacement whereby the Precambrian was thrust over the Palæozoic on Horsethief creek and the Dutch Creek formation was thrust over the Windermere series near the head of Farnham creek. The displacement along the southern part of the fault, near Jumbo creek, was slight and the fault apparently dies out in this neighbourhood. This fault cuts across the trend of the folding and is later than the folding, since the structure below the fault is the same on both sides of Horsethief creek. The faulting apparently took place at the culmination of the folding. Deformation since occurred, for the plane of the fault is deformed on Farnham creek. The deformation is, however, slight and consists only of a small uplift of the fault-plane on the west side of Farnham creek. This uplift may have been associated with the intrusion of the stocks as a late phase of mountain-building and igneous intrusion.

The majority of the faults in the Purcell range are associated with the folding, and hence are considered to be Jurassic, but, as already stated, movement has taken place along a few faults since mineralization and may have been produced during the closing phases of the Jurassic disturbance or possibly was associated with the Laramide revolution which must have affected the Purcell range.

The faulting in the Stanford range was undoubtedly associated with the elevation of the Rocky mountains and hence is post-Fort Union[2] or post-Palæogene. How recently faulting and movement along old fault-planes may have taken place, there is no means of determining. The existence of numerous hot and cold springs does not help in determining the age of the faulting, other than that it may be anywhere from Tertiary to Recent. The hot springs are apparently waning, for the large deposits

[1] Mansfield, Geo. Rogers, Jour. of Geol., vol. 29, 1921, p. 465.
[2] MacKenzie, J. D., Trans. Roy. Soc., Can., vol. XVI, 1922, sec. IV, pp. 87–132.

of tufa-cemented gravels on Windermere creek and at places outside the map-area indicate greater activity in the past, or else denote a long period of activity. Boulders of the tufa-cemented gravels have been observed in the Pleistocene formation. There is no definite system of upthrow or downthrow to the faulting of the Stanford range within the map-area.

Leaching along the faults was apparently very active and resulted in the formation of the so-called red breccias which are not breccias in the true sense of the word. The brittle limestones, apparently, were folded under a light load, and were broken with the development of much jointing near the fractures. Solution has, seemingly, taken place along the fractures and the lime has been leached along bedding and joint-planes, thus forming fragments which in shape simulate boulders. The fragments have been re-cemented, probably contemporaneously with the leaching, by the introduction of a considerable amount of iron which gives the vivid colours to these zones. The effect of the leaching can be seen to decrease gradually outwards from the centre of the zones, so that the " breccias " pass laterally into solid rock. The zones of these so-called red breccias cut the formations in the Stanford range, nearly parallel to the strike of the range, and by reason of their brilliant colours are plainly visible from the trench.

CHAPTER V

ECONOMIC GEOLOGY

Interest in mining in Kootenay district, of which Windermere map-area is a part, was first aroused in the early sixties by the discovery of gold on Wildhorse creek. Some of the early prospectors searching for gold, then the only mineral with a ready market in the district, explored Kootenay and Columbia valleys and tributary creeks. Finding, as may still be found, a little gold on Dutch and Toby creeks, they evidently tried to discover the source of the gold on the mountain sides, for the remains of an old camp and workings were found some years ago on mount Taynton, high above the creek. Their efforts failed and there is no record of any subsequent discovery of gold ore within the map-area.

With the location of the main line of the Canadian Pacific railway settlers and prospectors came into the district, but as gold was still the only mineral with a market, the district, so far as mining was concerned, lay dormant. In the nineties, the silver-lead properties of Cranbrook area to the south attracted attention and stimulated prospecting throughout the district. Many claims on silver-lead deposits were staked in Windermere area, work was done on some, and a few properties made small shipments in 1901 and 1903. As in many other mining camps, undue optimism caused the expenditure of considerable money on properties which did not warrant it. The disastrous results gave the district a bad name and except for a small boom a few years ago, mining activities have been very limited, with only one property that is producing at all steadily and one or two that produced irregularly.

The metallic mineral deposits occurring in the map-area are lead-silver and lead-silver-zinc. Copper and gold deposits of economic value have not yet been found. Deposits of barite and impure gypsum or gypsite occur, but have no present economic value.

LEAD-SILVER AND LEAD-SILVER-ZINC DEPOSITS

The lead-silver and lead-silver-zinc deposits are essentially of the fissure and bed-vein type and are generally associated with minor anticlinal folds or wrinkles on the limbs of the larger folds. The general strike of the veins is that of the folding, namely about north 30 degrees west. The greater number of the deposits occur in the Purcell series, largely due to the greater areal extent of that series, and in part probably to the massive character of the Mount Nelson formation and its resultant tendency to fracture when folded.

Quartz is the chief gangue mineral; calcite, barite, and siderite are present in subordinate amounts. The quartz is of two generations, the earlier being in part vitreous and in part milky, suggesting a change from high temperature to moderate temperature conditions. The later quartz is milky, typical of moderate temperature conditions. The barite on the Bunion property is dense and massive, whereas on the Mineral King it is crystalline and white to pale green. The calcite is white to pale cream, the colouring being due to iron, probably in the form of carbonate. Siderite is chiefly an alteration product of pyrite.

The sulphides are chiefly galena, sphalerite, pyrite, and a little chalcopyrite. Freibergite or argentiferous tetrahedrite is the principal silver-bearing mineral. It shows marked variations in its micro-chemical reactions apparently due to the varying silver content.

The chief oxidized mineral is cerussite or lead carbonate and it occurs as sand carbonate, the earthy variety. It forms an important ore mineral in the Paradise mine.

The evidence regarding the order of deposition of the minerals of a single deposit or of a number of deposits of similar nature, as obtained by the study of polished surfaces, is often contradictory, but the study of numerous specimens from several prospects indicates the order of deposition to be about as follows: gangue, pyrite, sphalerite, tetrahedrite, galena. This order does not always hold good, but does so in the majority of specimens examined. Conditions during the deposition of the minerals undoubtedly were changeable.

An examination of sulphide specimens from the Paradise mine under the metallographic microscope showed some pyrite to be earlier than the galena and sphalerite and some to be later, cutting the other minerals as a veinlet. The galena generally replaces the sphalerite, which is present only in minor quantities and is speckled with minute particles of chalcopyrite. The galena is of medium grain and contains blebs of freibergite and polybasite. A little covellite shows on the edges of some of the freibergite blebs and is clearly secondary. Veinlets of carbonate cut the sulphide and are evidently secondary.

A few specimens from sacked ore from the Bald Eagle property were examined under the microscope. These showed pyrite to have been the first mineral to form. It was followed by galena and sphalerite which seem to have been alternately precipitated with a suggestion that the galena, on the whole, was slightly later than the sphalerite. Some of the sphalerite is thickly peppered with minute specks of chalcopyrite. The galena has penetrated the calcite of the wall-rock, opening it up along cleavage planes and completely separating clean-cut rhombs of the calcite (*See* Plate VIII A and B).

The most interesting feature seen in polished specimens from the Silver Spray prospect is, that where galena and tetrahedrite are in association and where the minerals have been leached it is the galena which has been removed. The boundaries of the tetrahedrite remain clean and sharp, but the galena has been penetrated along the cleavage and presents a feathery edge. The galena has been replaced by copper carbonate and covellite; the covellite has formed against the galena and the carbonate against the tetrahedrite. It would appear that conditions were such at the time of leaching that the usually stable galena was more readily attacked than the tetrahedrite.

Specimens from the Mineral King prospect examined under the microscope showed in spots sulphides cutting country rock and replacing quartz and in other spots veinlets of quartz cutting country rock and veinlets of sulphides. Thus it appears that the quartz was of two generations. Pyrite is replaced by galena and sphalerite. Some specimens showed rounded boundaries between the sphalerite and galena and others the galena cutting the sphalerite; apparently the sphalerite and galena were in part contem-

poraneous and in part the galena later than the sphalerite. In some specimens no silver-bearing minerals could be detected. Others showed minute particles of freibergite in the galena and one specimen exhibited a small veinlet of galena, tetrahedrite, and freibergite replacing sphalerite and cutting pyrite, quartz, and calcite. Rounded boundaries prevail between the galena, tetrahedrite, and freibergite and suggest contemporaneous deposition. Cutting the sulphides are secondary carbonate gangue minerals. Some chalcopyrite is associated with the freibergite and a little covellite or covellite-rich chalcocite is found around the edges of the freibergite and chalcopyrite and is clearly secondary. The silver-bearing freibergite seems to be sporadically distributed and probably precipitated with the galena in its later stages.

A fine-grained specimen having the appearance of steel galena and with blebs of quartz and fine grains of pyrite scattered through it, showed on polishing to be an intimate mixture of galena and sphalerite (*See* Plate VII B). The sphalerite, with the exception of a few blebs, is not easily detected in the hand specimen, yet the polished specimen shows about equal amounts of galena and sphalerite.

Polished specimens from Larrabee's prospect showed an association of quartz, sphalerite, and galena and also pyrite and galena. The pyrite is fractured and veined by the galena. Other specimens showed much cleaner galena.

Observations throughout the Cordillera show that in general the zinc content of silver-lead-zinc deposits increases with depth. Within Windermere map-area work has not been carried deep enough to establish whether this general rule is applicable, but it is notable that the properties situated at the higher elevations are on the whole essentially lead-silver-bearing and practically free from zinc, whereas the properties located at lower altitudes carry considerably more zinc, and it is in these properties that the replacement of zinc blende by galena is noticeable. One or two apparent exceptions to this general rule are known. The White Cat ore, for example, contains only a very small percentage of zinc, whereas a property at a slightly higher elevation, to the east of it, has a marked zinc content. This anomaly is readily explained, however, by the presence of a fault of considerable throw immediately to the east of the White Cat and between it and the second property. The White Cat is on the downthrow side of the fault, and the fact that displacement has occurred along this fault since mineralization is indicated by the ore of the White Cat, which is sheared, the galena having a decidedly gneissic structure and showing distinct shearing. Bands of granulated tetrahedrite parallel the gneissic structure which, in turn, parallels the walls of the fissure.

There is no evidence of mineralization being concentrated in the neighbourhood of the granite bodies, nor are there any known contact deposits. The granite masses have steep walls and contact phenomena are not marked. The suggestion has already been made that the granite is a differentiate from a large parent body such as postulated by Schofield[1] to be co-extensive with the Purcell range, and it would seem that this parent body was the source of mineralization. The date of mineralization can be

[1] Schofield, S. J., "Geology of Cranbrook Map-area"; Geol. Surv., Canada, Mem. 76, p. 112.

inferred only from the fact that, with the exception of a few deposits closely related to faults, the deposits have not been deformed, and they, therefore, appear to have been produced at a late stage in the process of Jurassic mountain-building and igneous intrusion. Glaciation has in most cases removed the oxidized zone, laying bare the sulphide ore.

DESCRIPTION OF PROPERTIES

Paradise Mine

(*See* Figure 3)

The mine is at an elevation of 8,000 feet on the side of the basin at the head of Spring creek, a tributary of Toby creek, which it enters from the north at about 11 miles from Invermere by road (*See* Plate V B). The mine may be reached by automobile from Invermere and Wilmer and is 18 miles distant from either town. The Paradise is the only steady producer in the area; it yields about 1,000 tons of smelting ore a year.

The ore-body occurs in a grey, siliceous, magnesian, crystalline limestone beneath the upper white quartzite of the Mount Nelson formation. The limestone is shattered and lies in a small, closed anticlinal fold on the eastern limb of a major fold. The strike of the axis of the anticline is about northwest. The minor fold is broken on the west side by a fault with a downthrow to the west. East of the basin of Spring creek the limb of the major fold has been thrust slightly eastward along a fault-plane which appears to dip westward and to pass beneath the Paradise mine at a considerable depth.

The ore is highly oxidized and consists mainly of lead carbonate; in places, however, it contains residual fragments of galena. Some sphalerite and pyrite are associated with the galena in places. The ore occurs, as isolated pockets or lenses, in bedded veins and fissures which seem to occupy a comparatively narrow zone in the shattered limestone. It is thus impossible to lay out any elaborate system of development work and mining must be carried on by searching for the ore pockets with the least amount of work.

The property is developed by two adits and a blind intermediate level. The upper level, No. 2, has been driven 1,200 feet along the mineralized zone in a general northwest direction. Two hundred feet of drifting and over 3,000 feet of stoping have been done on this level. Nine hundred feet of stoping has been done on No. 4 level, which is 1,700 feet in length and 240 feet below No. 2. Some work is being done on this level at present. No. 3 level is blind, is 80 feet above No. 4, and connected both with it and No. 2. This level is very irregular, comprising about 805 feet of new workings, 250 feet of old workings, and 1,400 feet of 4-foot by 6-foot stoping. The bulk of the ore mined at present is recovered from this level. The ore is dropped to No. 4 level, hauled by hand to the surface, and dropped 250 feet to the bunkers by gravity tram. A 3-ton truck is used for summer haulage to the railway at Invermere. Winter haulage is by sleigh. Hand drilling is used throughout the mine. The ore shipped runs about 95 per cent carbonates and 5 per cent sulphides, and averages 40 to 45 per cent lead and 45 ounces silver. Total smelter shipments to date have been between 22,000 and 24,000 tons.

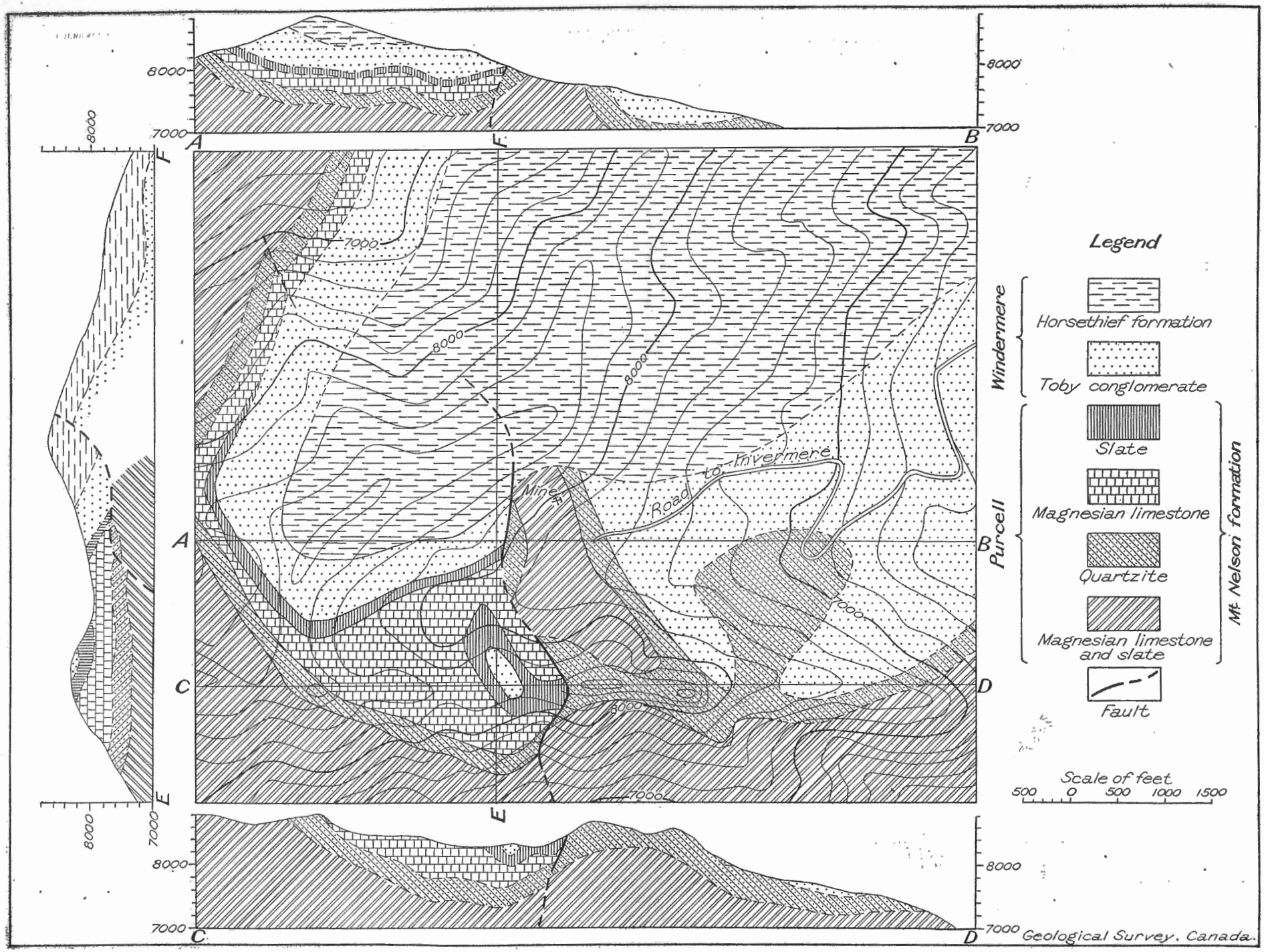


Figure 3. Paradise basin and vicinity, Windermere area, B.C., showing structures exhibited by the late Precambrian strata. Contour interval 200 feet. Vertical and horizontal scales are equal. Patterns do not represent bedding.

Bald Eagle

The Bald Eagle is situated on a small ridge on the south side of Slade creek at an elevation of 7,400 feet. It lies beyond the summit northwest of the Paradise mine and is reached either by trail from the end of the Paradise mine road or by trail from Slade creek.

Development work consists of three adits driven in the magnesian limestone overlying the upper white quartzite of the Mount Nelson formation. The upper adit was full of ice and could not be examined at the time of the writer's visit. This adit is located on a small fault with a displacement of about 75 feet. The lower adits have been driven west of the fault, evidently with intention of locating the ore at lower depths. The intermediate adit is 100 feet in length and shows a little pyrite and quartz near the portal. The lower adit is 225 feet in length and barren throughout. Some mineral has been taken from the upper working.

White Cat Group

This group of claims is situated on the south side of Slade creek at an elevation of 7,250 feet. They lie west of the fault passing west of mount Nelson. The property is traversed by a fissure vein in limy slate and slaty limestone of the Mount Nelson formation. The vein strikes from 35 degrees to 40 degrees east of north (astronomic) and dips from 65 degrees to 80 degrees to the northwest. The strike of the country rock is north, to 10 degrees west of north, and the dip is variable to the east. The vein outcrops for a distance of 250 feet and runs up the hillside from the fault mentioned above. The width of the vein varies from 20 inches to 8 feet. The ore occurs in lenses along the vein in a gangue of chiefly slaty gouge and quartz. The best showing of ore occurs in an open-cut where a lens of clean ore near the hanging-wall shows a width of 20 inches and another near the foot-wall a width of 4 inches. The length of these lenses is about 10 feet on the surface. At other points along the vein the ore pinches to practically nothing and swells to several inches in width. The fissure along the strike up the hillside either swings more to the south or pinches out. An old adit on the lower part of the vein shows some ore in the first 40 feet. The 50 feet beyond this to the face is barren, but the vein shows well-defined walls and possibly other lenses of ore may occur farther along the vein.

The property is being worked in the summer by a few men. The ore is dropped about 200 feet by a gravity tram and then taken on a go-devil to the valley bottom from whence it is hauled by wagon to the railway, a distance of about 26 miles.

A small shipment in 1924 gave the following smelter returns: gross weight, 60,825 pounds; dry weight, 60,390 pounds; lead, 74.75 per cent; silver, 32·3 ounces per ton; zinc, 1·4 per cent; SiO_2, 3·9 per cent; S, 12·4 per cent; Fe, 1·6 per cent; Ca, 0·6 per cent. Another shipment of about 5 tons gave 75·6 per cent lead and 44·6 ounces silver to the ton.

Two other showings have been uncovered on this property, but their extent is not yet known.

Delphine Group

The Delphine group is situated at an elevation of 6,350 feet, on the nose of the ridge between Delphine (north fork of Toby) creek and the largest creek entering it from the north. The property is reached by trail from the Delphine Creek road, which is now in poor condition.

On this property is a fissure vein in a buff-weathering magnesian limestone of the Mount Nelson formation. The fissure and the limestone strike north 38 degrees west. The limestone dips 32 degrees to the northeast and the fissure dips at a high angle to the northeast.

A shaft, 30 feet deep, has been sunk on the vein and is still open. From this shaft a drift runs 146 feet south and 70 feet north. The north drift has caved; a winze from it is said to lead to workings now inaccessible. The vein has been stoped from the main drift to the surface. The surface showing pinches to the south. A short adit, 52 feet long, was driven at an elevation of 6,000 feet towards the north end of the upper working. This adit was not completed. It is reported that ore still showed in the lower part of the upper working.

Kootenay Queen

This prospect is situated in a small basin, at an elevation of 6,300 feet, on the south side of Delphine creek 2½ miles from its mouth. The prospect is 1,500 feet above Delphine creek and is reached by trail from the road.

A small vein striking 7 degrees east of north and with high dip can be traced from a short distance on the surface, but shows little or no sulphides. The prospect has not been worked for several years and the old adit is caved. Some specimens from the dump show galena to be the chief sulphide, with minor amounts of sphalerite and tetrahedrite and a little secondary covellite and copper carbonate.

Hot Punch Group

This property is located at an elevation of 5,600 to 6,200 feet, near the head of Delphine creek, on a shoulder of the mountain on the southwest side of the creek. The property is reached by wagon road and trail from the Toby road. On this property a fissure traverses sheared limestone of the Mount Nelson formation. An adit, at elevation of 6,025 feet, has been driven for 75 feet and the vein stoped to the surface. At the adit face about 6 to 8 inches of ore is visible. The ore is chiefly galena with pyrite and siderite. Some of the siderite is pseudomorphic after pyrite. The vein, in this adit, has a high dip to the west. In the stope the vein is banded and is about 18 inches wide. Another adit, 25 feet lower and to the north, is caved. There is considerable pyrite and siderite on the dump. A third, still lower adit, at elevation 5,880 feet and to the north, has been driven for 35 feet south 41 degrees west, then 60 feet south 18 degrees west. From 4 to 5 inches of gangue with a little sulphide, chiefly sphalerite, is exposed in this adit. A fourth and lowest adit, at 5,620 feet, is caved and there are no sulphides on the dump.

The vein is exposed at the surface south of the upper adit and on over the shoulder of the hill as far as the creek draining the glacier under

Monument peak. The vein can be seen running up the cliff south of the creek and is lost to view in morainal material above the cliff. The general strike of the vein is north 18 degrees east, the dip on top of the shoulder of the hill is 28 degrees to the west, but steepens at the creek to 40 degrees to the west. The outcrop shows masses of galena up to 15 inches in width and a few feet in length, at intervals, in siderite, calcite, and quartz.

The most valuable part of the deposit appears to be along the outcrop. It does not appear to extend to any considerable depth from what can be seen in the workings. The ore is rather high in zinc.

Fifteen tons shipped in 1908 and 1909, gave returns of 40 per cent lead and 40 to 50 ounces silver to the ton and 200 tons recovered in 1914 had an average gross value of $80 per ton.[1]

Dominion

This prospect is situated in a basin, at an elevation of 7,300 feet, on the south side of Toby creek just west of the end of the wagon road. On it is a small fissure vein in a belt of limestone of the Dutch Creek formation. The dip of the vein is high to the northeast in the lower adit, which was driven 110 feet with a strike of 25 degrees west of north. An upper working, 20 feet higher and extending 8 feet into the hillside, shows the vein at this point to have a strike of 28 degrees west of north with a dip of 25 degrees to the northeast. The width of the vein varies up to one foot, but so far as may be seen mineralization is confined to a width of about 2 inches. The vein appears to pinch out south of the upper working. It is a quartz-tetrahedrite-galena vein.

Silver Spray

This property is situated at an elevation of 7,500 feet, on the west side of Coppercrown creek, at the end of the trail. The property is about 1,800 feet above the creek.

The mineralization consists of bedded veins in limestone of the Dutch Creek formation thrown into a small anticlinal fold. The Dominion and Lucky Boy properties are located on the same belt of limestone on the Toby slope of the mountain. The mineralization follows the bedding and can be traced up the vertical limb of the fold and over onto the crest where there appear to be several small bedded deposits. The mineralization consists of galena with less tetrahedrite and small amounts of sphalerite and copper carbonates. Development consists of recent stripping and an old caved adit.

Mineral King

This property is situated at 5,700 feet elevation on the Toby slope of the ridge between Toby and Jumbo creeks. The prospect is reached by trail from the end of the Toby road.

The deposit consists of a lenticular mass of quartz about 30 feet by 40 feet, with stringers of barite and sulphide and small bodies of sulphide, in one of the lower limestones of the Mount Nelson formation. Immediately below the showing the limestone rests with faulted relations on slate of the

[1]Ann. Repts., Minister of Mines, B.C., 1909, p. 100; 1915, p. 236; 1916, p. 93.

Dutch Creek formation. A little work has been done on the surface and some 30 or 40 tons of ore have been taken out and sacked. Thirty feet below the surface work an adit has been driven for a distance of 85 feet north 50 degrees west to where one branch runs for 50 feet north and a second for 35 feet west. Small stringers of quartz show in the faces and, at the junction of the two branches, a little quartz with some pyrite, galena, and sphalerite is visible. Unsuccessful attempts have been made to locate the extension of this showing on the Jumbo Creek slope of the ridge. The zinc content is quite high.

Larrabee's Prospect

This property is situated on the north side of Horsethief creek, at creek level, and opposite the 15 mile-post.

The deposit is in a shatter zone in the Ottertail, Goodsir, and Brisco-Beaverfoot formations. Several caves have formed in this shattered zone. Small masses of galena and pyrite are found in the caves in the shattered limestone. The pyrite is crumbly and is rapidly breaking down. Surface work along the zone shows, at intervals, small stringers of galena. The mineral distribution is irregular and is not likely to show much uniformity in this type of deposit.

Nip and Tuck

This property is situated in the basin at the head of McDonald creek at an elevation of 9,000 feet. The deposit is located on a fault, the northern extension of which runs to the west of the Ptarmigan fault. The workings at the time of the writer's visit were full of ice and inaccessible. Another prospect is located on the same fault on the north side of the basin.

Ptarmigan Mine

The Ptarmigan mine is situated on Ptarmigan creek, a tributary of McDonald creek, at an elevation of 8,400 feet. The property is reached by road to the old tram terminal at 6,600 feet elevation, then by trail to the workings. Equipment has been removed and the mine abandoned for some years.

The workings were filled with ice at the time of the writer's visit and could not be examined. The main adit is driven along a fault. The lower quartzite of the Mount Nelson formation shows on the east of the fault and a limestone, higher in the formation, on the west side.

The strata of the ridge on the east side of McDonald creek, on which this property is located, is much folded and faulted.

Phoenix Group

This prospect is situated between the upper branches of Farnham creek. It is reached by trail from the end of the Horsethief wagon road.

The principal showing in this area is a small fissure vein in the Toby conglomerate, at an elevation of 6,700 feet, near the west branch of the creek. A shaft, about 40 feet deep, was put down some years ago and a little mineral taken out. This shaft could not be examined. Surface work shows the extension of the vein for a short distance. An adit was being

driven, at the time of the writer's visit, from the slope to the creek, on the west side of the vein, to intersect the vein at depth. This work was discontinued late in the summer. A small pile of mineral by the shaft is chiefly galena and tetrahedrite.

The other showings in this area are situated at an elevation of about 8,000 feet, on a ridge between the southeasterly branches of the creek. These showings are small quartz veins in a limestone of the Mount Nelson formation. A little tetrahedrite is present in some of these small veins, which are brightly stained with copper carbonates. The largest surface showing was a siliceous replacement of the limestone in the form of a lens about 4 feet by 20 feet and which conforms to the bedding of the limestone. Tetrahedrite is scattered through the mass. At the time the property was visited an adit was being driven, at an elevation of 7,500 feet, in an easterly direction, through the slates of the Horsethief formation toward the fault east of which lies the limestone of the Mount Nelson formation in which the small quartz veins are to be seen. The faulted area in which the "showings" occur, is well exposed on the north and west sides of the hill and also on the top.

NON-METALLIC DEPOSITS

BARITE

The Bunion property, situated on the north side of Goldie creek, at an elevation of 3,800 feet, and about 5 miles by road from Invermere, has a small showing of barite. The property has been prospected as a silver deposit, but has shown but small values. The barite appears to be in the form of a lens in a magnesian limestone of the Mount Nelson formation.

GYPSUM

Two small showing of impure gypsum, or gypsite, occur in sinks on Windermere creek about 2½ miles above the back road. These deposits have been formed by solution of the underlying limestone with redeposition in tufa-cemented gravels as gypsite. Solution is still going on as waters rising in an adjacent pond are highly charged with lime and the waters of Windermere creek are depositing lime where the creek enters the valley terraces. The gypsite appears to have been deposited in cavities, formed by slumping of the gravels. This slumping is still going on and fresh sinks forming. On the south side of the creek about 4 miles above the back road is a much larger deposit. It appears to be of the same nature as the others. Its relations are masked by timber, but the same tufa-cemented gravels apparently surround it.

FUTURE OF THE DISTRICT

The foregoing descriptions of some of the properties examined indicate the characters of the deposits occurring in the map-area. The deposits are essentially small lead-silver and lead-silver-zinc veins, many of which are too small to be of any value, but some of which may be profitably worked in a small way by using the most simple mining methods.

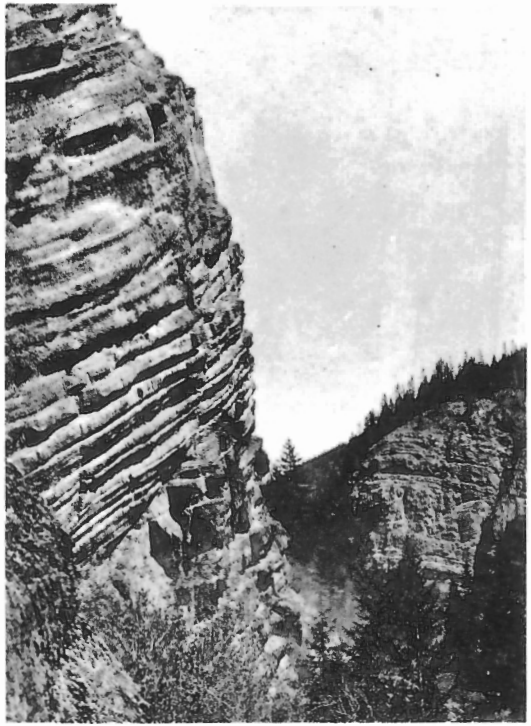
The cleaner lead-silver deposits are those located at the higher altitudes. Most of these are near timber-line or above it and the surface extent of these deposits as seen in two and three dimensions, gives a very fair estimate as to what may be expected beneath the surface. The average content of these may be taken as from 40 per cent to 70 per cent lead and about 50 ounces silver to the ton. The Paradise mine is an exceptional property, since in it the oxidized zone has not been completely removed by glaciation.

The most favourable areas for prospecting are the exposures of the Mount Nelson formation. The question of transportation must be considered in future prospecting and mining. For the type of deposit so far seen, the limit of transportation may be taken as not west of McDonald creek and the lower reaches of Jumbo creek.

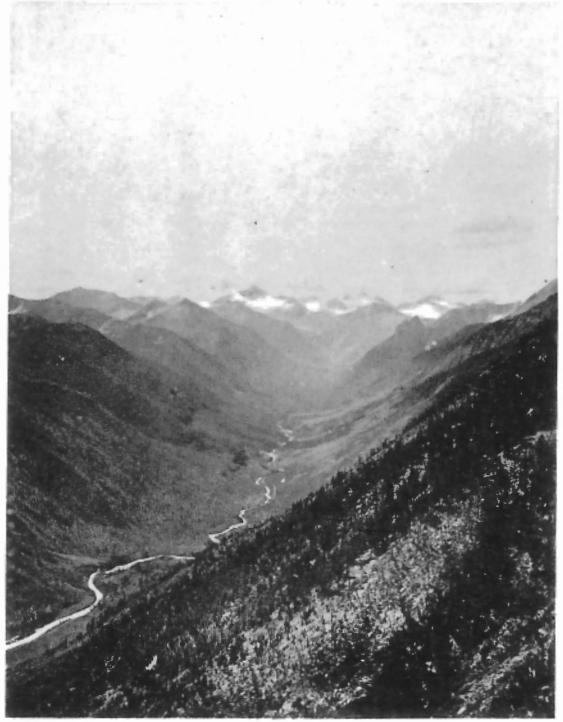
PLATE II

A. Stanford range, looking up Windermere creek, showing graptolite localities. (Page 25.)

B. View of Rocky Mountains trench and Stanford range, looking east across mouth of Dutch creek. Note wall-like character of east side of trench. (Page 3.)

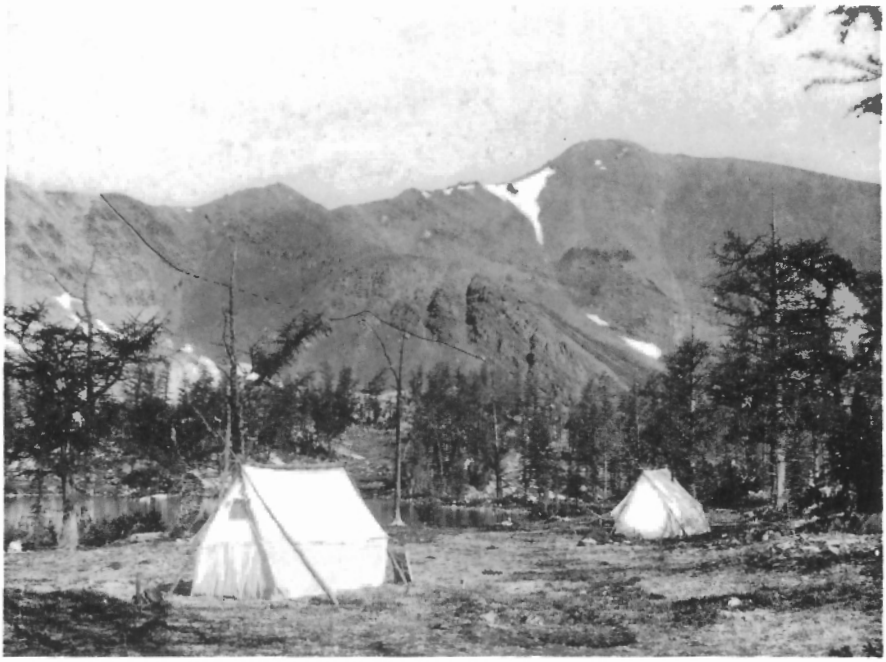


B. Differential weathering in Goodsir formation, first north fork of Windermere creek. (Page 23.)



A. View up Toby creek, from Jumbo creek to headwaters. (Page 4.)

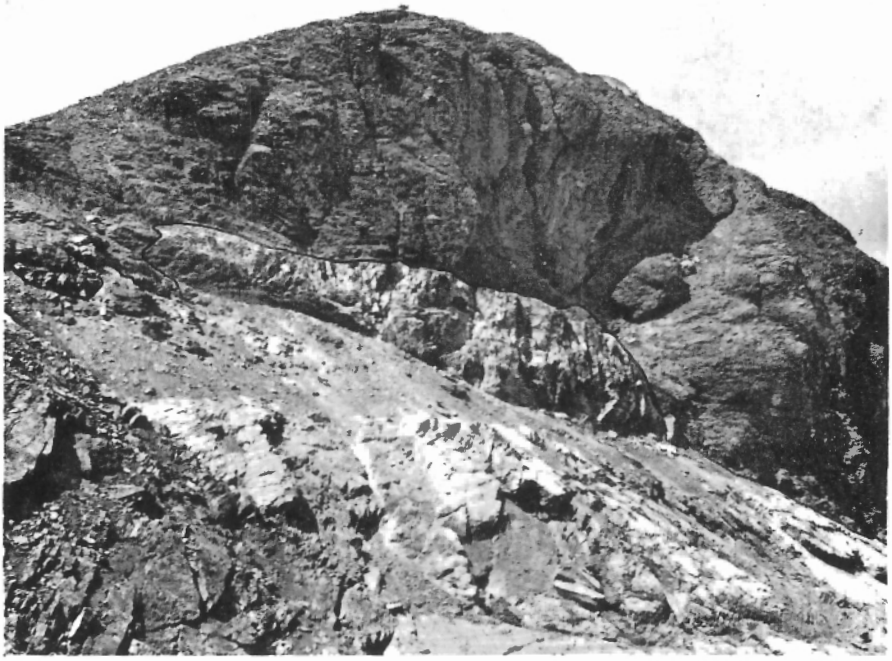
PLATE IV



A. Toby conglomerate and contact with Mount Nelson formation in mount Brewer. Sixteen hundred feet of conglomerate to right of contact (lined in); camp elevation 7,800 feet. (Page 13.)

B. Typical phase of Toby conglomerate as exposed on Jumbo creek, west edge of map-area. Hammer handle 30 inches. (Pages 14, 15.)

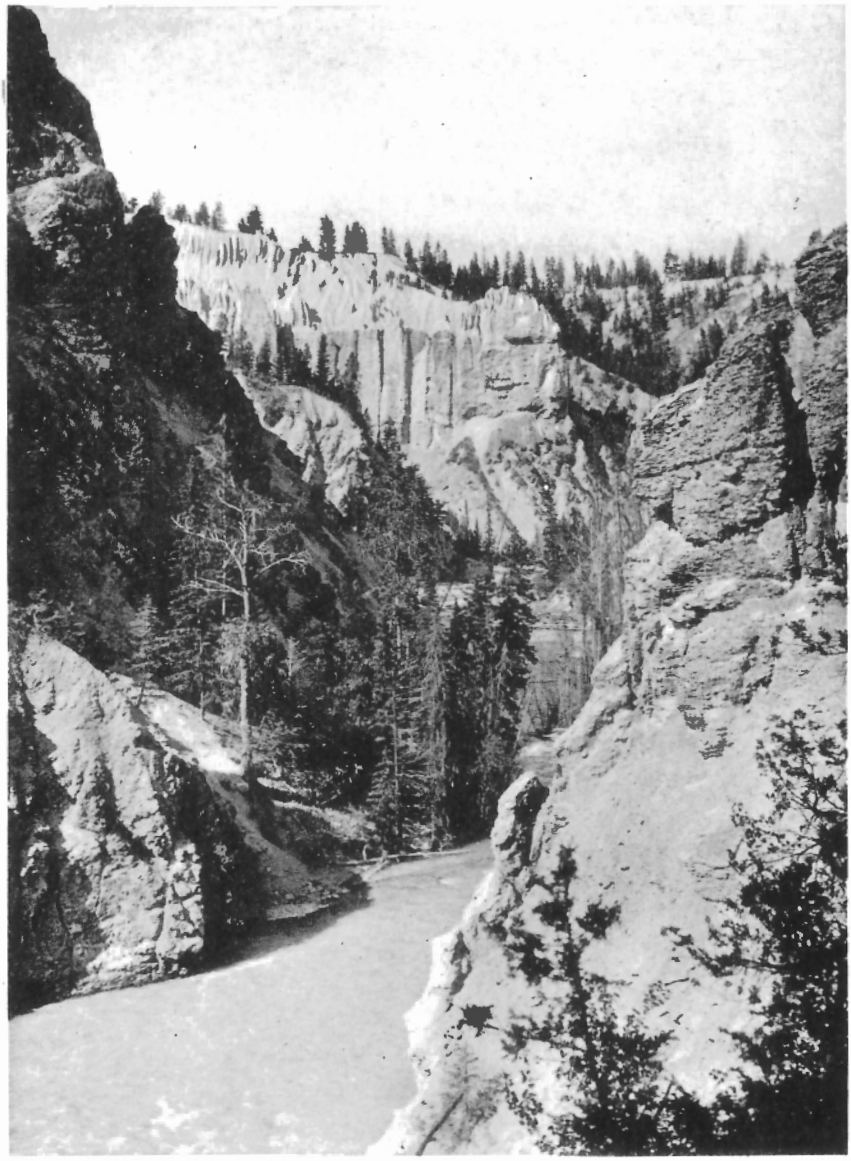
PLATE V



A. Unconformity at base of Toby conglomerate, head of Laundry creek (contact lined in). (Page 15.)

B. Paradise mine, looking north. Horsethief formation exposed in rounded ridges in foreground; Mount Nelson formation exposed in mount Slade, extreme west. (Page 46.)

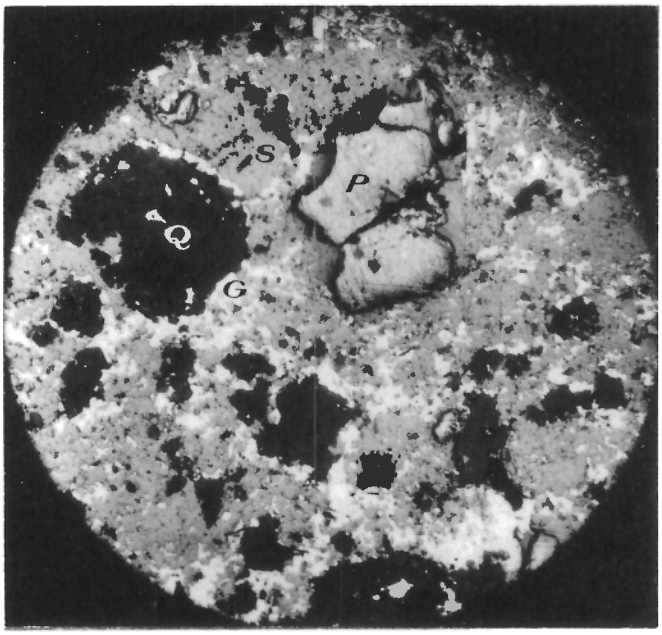
PLATE VI



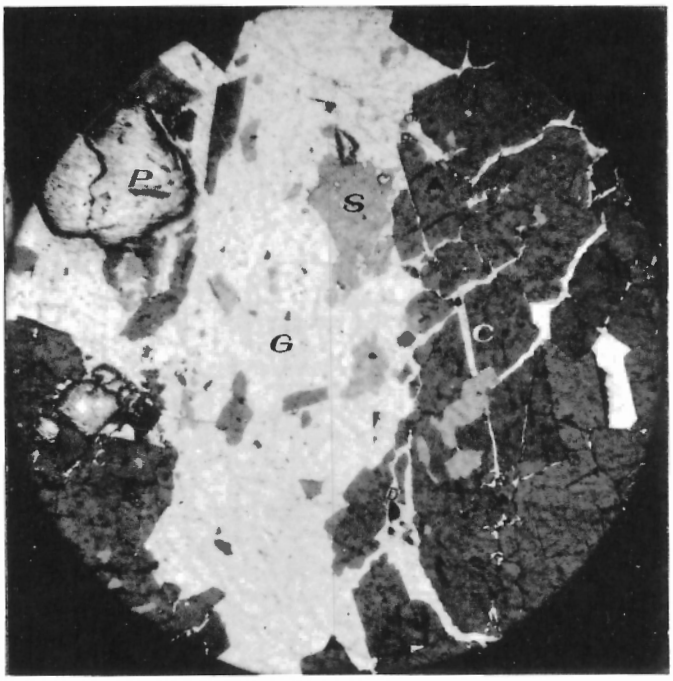
Toby Creek canyon cut through glacial silts and old rock rim of the trench. (Page 3.)

PLATE VII

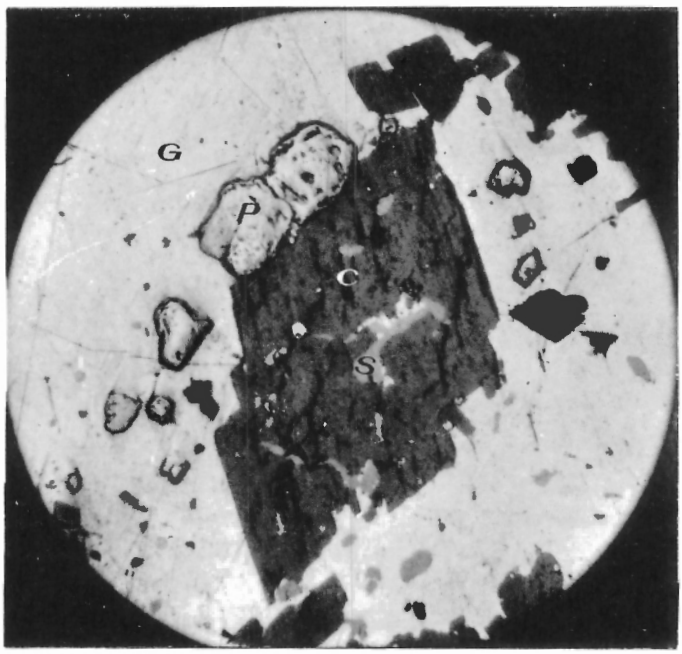
A. Farnham creek, looking north, showing lip of hanging-valley above Horsethief creek. (Page 4.)



B. Mineral King prospect. Microphotograph showing intimate mixture of sphalerite and galena. Other parts of specimen show more galena and veining of the sphalerite by galena. G=galena; S=sphalerite; P=pyrite; Q=quartz. (Page 45.)



A. Bald Eagle prospect. Microphotograph showing galena working along cleavage planes of calcite wall-rock. G=galena; S=sphalerite; P=pyrite; C=calcite. Magnification: × 60. (Page 44.)



B. Bald Eagle prospect. Isolated rhomb of calcite from same specimen as A. Note sharp edges of calcite. G=galena; S=sphalerite; P=pyrite; C=calcite. Magnification: × 57. (Page 44.)

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