OUT OF

CANADA
DEPARTMENT OF MINES
HON. W. A. GORDON, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR

MEMOIR 173

Slocan Mining Camp, British Columbia

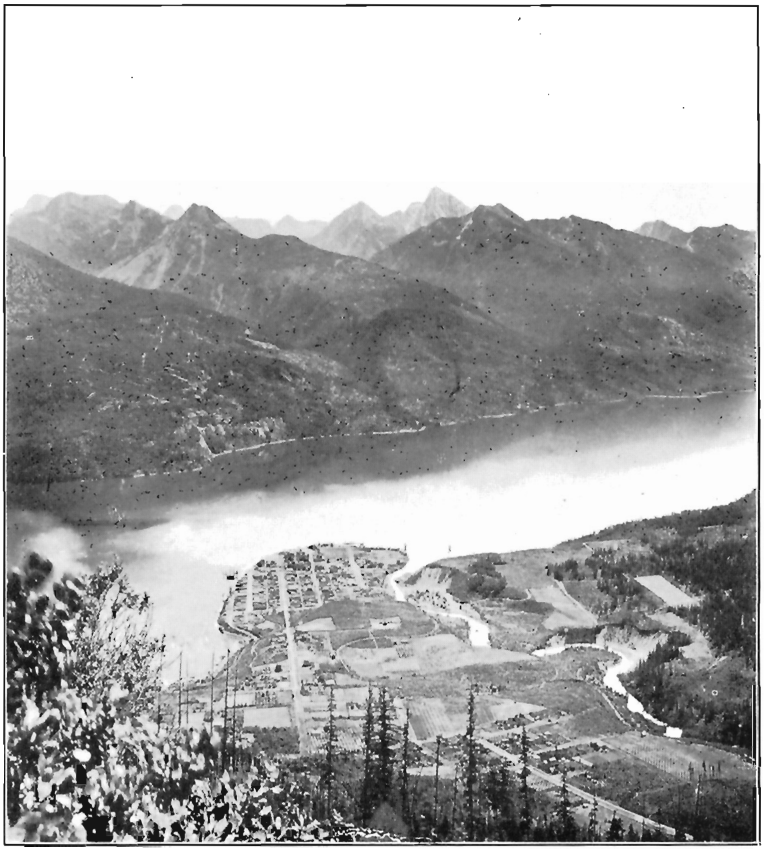
BY

C. E. Cairnes

OTTAWA
J. O. PATENAUDE
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1934

Price, 50 cents No. 2358

PLATE I



Kaslo, British Columbia. Looking southeasterly over the town of Kaslo and across Kootenay lake to mountains of the Purcell range.

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CHAPTER I

INTRODUCTION

GENERAL STATEMENT

Slocan mining camp has long been noted for the number of its silver-bearing ore-bodies and for the success that has attended their development.[1] The deposits comprise fissure-filling and replacement types and occur mainly in sediments of the Slocan series. A number of important deposits have also been found in the Nelson granite and related intrusives and a few discoveries have been made in other formations.

The ores are chiefly valuable for their silver and secondarily for their lead and zinc content. In a few instances gold is an important constituent. The silver-bearing minerals are, as a rule, associated with the lead rather than the zinc ores. In some cases the ores are mined for their silver content alone. Nearly all the larger deposits, however, contain important quantities of lead and zinc and in a few instances the returns from these have exceeded the silver values. Within the past fifteen years or more the marked improvements in milling and metallurgical practice, particularly in the treatment of the zinc content of these complex ores, and the facilities provided by the Trail smelter and customs mill, have done much to encourage mining in the Slocan.

In spite, however, of the high-grade character of the ores and the advantages provided by present milling, smelting, and refining technique, the Slocan camp can hardly be regarded as prosperous. Of the two hundred and five properties in Sandon and Slocan map-areas, which in the past have shipped ore, about sixty-five were operating in 1928 and of these less than thirty, mostly situated in Sandon map-area, were producing ore in any quantity or realizing returns in proportion to the investments incurred. Since 1929, save for a few small operations, mainly by lessees, the properties were closed with but little hope of reopening until prices for silver, lead, and zinc rose appreciably.

FIELD WORK AND ACKNOWLEDGMENTS

The present report is the result of field work by the writer in 1925, 1926, 1927, and a part of 1928, coupled with information gathered from previous work by other officers of the Geological Survey, notably the late O. E. LeRoy, the late C. W. Drysdale, and M. F. Bancroft. Much of the time during each season was devoted to examinations of mining properties.

[1]Description of individulal properties, as listed in table on pages 12 to 19 of this report, are on file with the Geological Survey, Bureau of Economic Geology, Department of Mines, Ottawa.

The writer is under deep obligation to the people of Slocan district for their cordial assistance; particularly to the mine owners, managers, and superintendents who gave freely of both their time and information in the examination of properties in which they were interested, and extended their hospitality at the mines.

Much help in the compilation of this work was received from manuscripts and published reports of members of the Geological Survey, who had previously done field work in this area, and valuable suggestions were gained by personal contact with other members of the Geological Survey, particularly J. F. Walker and H. C. Gunning, who were conducting investigations in adjoining or nearby areas in Kootenay district.

Field work was facilitated by the able and hearty co-operation of the writer's assistants, Messrs. W. E. Chantler, E. B. Gillanders, and J. G. Pearcey, in 1925; E. B. Gillanders and J. G. Pearcey in 1926; J. G. Pearcey, W. A. Jones, J. S. Stevenson, E. H. Lovitt, and R. P. Graham in 1927; and J. A. Harkness and J. S. Stevenson in 1928.

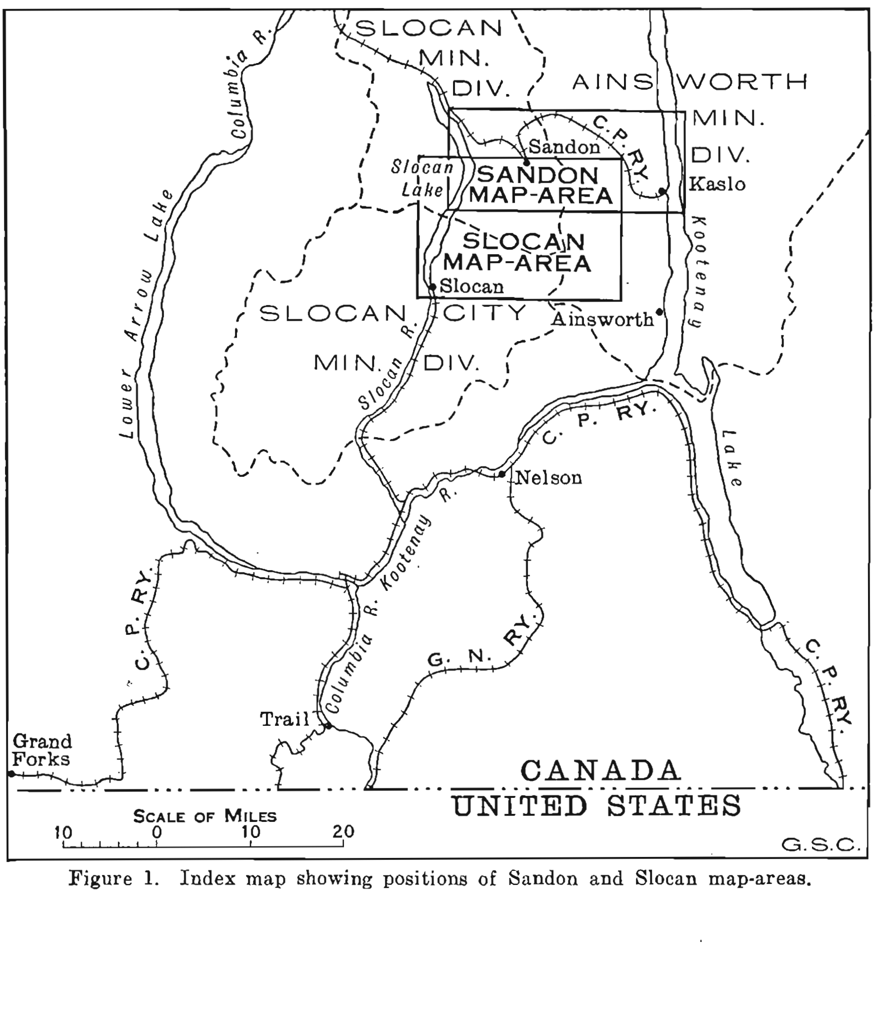

Figure 1. Index map showing positions of Sandon and Slocan map-areas.

SITUATION AND MEANS OF COMMUNICATION

Sandon map-area (*See* Figure 1) is traversed by a branch line of the Canadian Pacific railway which connects by rail and boat with Revelstoke on the main line and by boat and railway with Nelson. In 1926 a highway was completed between Kaslo and Nelson, and in the following year the motor road from Nelson to Slocan was extended along the east shore of Slocan lake to connect with Silverton and thence with New Denver, Rosebery, and Sandon. Subsequently, highways were established between Sandon and Kaslo and between Rosebery and Nakusp on Upper Arrow lake. Aside from these trunk roads, the Slocan camp is, for a mountainous country, well supplied with roads and trails so that most of the properties are readily accessible by car, wagon, or saddle horse.

HISTORY OF MINING

Slocan's mining history dates back to the discovery, in the early twenties of last century, of outcropping lead ore on the east shore of Kootenay lake at the present site of Blue Bell mine, Riondel. The discoverers, Indian and Hudson's Bay Company trappers, are reported to have made some use of the lead in this deposit for their muzzle-loading rifles.

Active exploration of the region did not begin, however, until after 1865, when the discovery of placer gold in the Big Bend country of Columbia river drew a rush of prospectors into the Kootenays. In 1868 an American prospector, Henry Doane, rediscovered and did some work on the Blue Bell mine. He later interested Senator George Hearst, of California, in his discovery and, together, they are credited with some crude attempts to smelt the Blue Bell ore on the ground—attempts which were inevitably unsatisfactory in view of the primitive equipment, low grade of the bullion, and distance from transportation. Following the collapse of this effort nothing of interest occurred in Slocan for years. The Big Bend country ceased to attract and the district lapsed into its pristine state of a complete wilderness. The Dewdney trail, built in the early sixties from Fraser river into the Kootenays, fell into complete disrepair and Kootenay lake could be approached only from the south via Senyaquateen, near the present Sandpoint.

In 1881 Robert Evan Sproule, prospector, gifted with an eye for the future, entered the Kootenays. He discovered and prospected the great "Granby" lode of the Boundary district which at that time was valueless. Continuing to the northeast he eventually reached Kootenay lake and re-located the Blue Bell in 1882. At about the same time more influential interests in the persons of John C. and George J. Ainsworth, of San Francisco, were taking cognizance of the mineral country about Kootenay lake. They were owners of the "Kootenai", the second steamer to ply between Revelstoke and the International Boundary, and had secured a franchise for a railway connecting Columbia valley with Kootenay lake over the route now followed by the line operating between Robson and Nelson. In their employ as "mining scout" was a young man, Thomas Hammil, who early in 1883 located the "Lulu" and

"Springs" claims, the first to be staked at Hot Springs, later known as Ainsworth, on the west shore of Kootenay lake nearly opposite the Blue Bell. Later in the year Hammil jumped Sproule's locations across the lake. There followed a long contested lawsuit which proved too expensive for Sproule and his supporters and was eventually decided against them. The affair culminated in June 1885 when Sproule took the law into his own hands by shooting Hammil. The neglect of the Ainsworths' attorneys led, however, to their losing the Blue Bell, which subsequently became the property of Dr. Wilbur A. Hendryx and partners, and the location took the name of Hendryx camp. In the mid-eighties a considerable settlement grew up about the site of the present town of Ainsworth and in 1887 and 1888 the Great Northern steamers "Spokane", "International", and "Alberta", as well as some privately owned boats, plied between Bonners Ferry and Hot Springs and Hendryx camps.

Most of the silver-lead ore discovered in these early years carried comparatively low values in silver. When, in the late eighties, a prospector, Jim Brennan, brought from a district farther north samples that assayed as high as 150 ounces a ton in silver, there was a rush to investigate this country. On September 9, 1891, two prospectors, Eli Carpenter and John L. (Jack) Seaton, after an unsuccessful trip into this more northern country climbed Payne mountain, to the north of the present town of Sandon, in the hopes of observing a more direct route back to Ainsworth. On the summit (Plate III A) they discovered outcroppings of the Payne vein and staked a claim on it. The story is told that on their return to Ainsworth, Carpenter deceived Seaton by showing him assay returns from an Ainsworth property instead of the rich values obtained from their Payne samples. Seaton immediately lost interest in the discovery until Chas. Olsen, the owner of an hotel at Ainsworth, happened to overhear Carpenter planning with another man, Bielenberg, to return to the Payne and stake all the surrounding ground. Olsen subsequently persuaded Seaton to guide a prospecting party to the locality. Carpenter and Bielenberg, so as not to attract attention, made their way back in a round-about way via Nelson and Slocan lake, whereas Seaton and his party travelled by the more direct Kaslo Creek route and reached their destination first. Seaton's party included, at first, W. M. Hennessy, J. G. McGuigan, and Frank Flint, but was joined near Sproule's Fifteenmile House (now Blaylock station) by J. J. Hennessy, who was accepted as a fifth member. The party thereupon went by the name of the Noble Five, and on September 28, 1891, located several claims near Sandon including the Noble Five group.

The year 1891 may be regarded as the first year of the great boom in Slocan. In the spring of that year only one house stood on the delta of Kaslo creek; in 1892 Kaslo had a population of between four and five thousand. From Kaslo the common route into the country about Sandon led up Kaslo and Montezuma creeks. On this route John Sandon, Ed. Becker, Tom McLeod, and Chas. Rossiter (or Joe Fletcher) staked the Montezuma in September, 1891. Altogether some eighty locations were made in this first year, the staking being done under the Apex law which provides a claim 1,500 feet by 600 feet with extralateral rights. This law

Sandon, British Columbia. Looking up the valley of Carpenter creek with Reco mountain in the middle background.

was repealed in 1892, the claim size being changed to 1,500 feet square with vertical side lines.

In 1892, seven hundred and fifty locations and three hundred and forty transfers and bills of sale were recorded, the aggregate value of the latter being $550,000. It has been estimated that $201,000 in cash changed hands by reason of transfers within these first two years. Many of the prospectors received but little for their discoveries. For $500 Eli Carpenter gave one-half interest in the Payne to Scott McDonald, who in turn sold it to A. W. McCune. S. S. Bailey in the meantime secured Seaton's half interest and raw-hided out some ore. McCune started a lawsuit against Bailey, eventually buying his interest for $75,000. McCune ran the mine for about five years and shipped an average of 50 tons of ore a day, which netted him about $100 a ton. Altogether he had recovered about a million dollars worth of ore when he sold the property to the Payne Consolidated Mining Company of Montreal for another million.

In 1892 sixteen properties were in operation. As transportation was by pack-horses only the richest ore could stand the heavy charges. George W. Hughes brought in the first train of pack-horses, fifty-seven in number, to freight 400 tons of ore from the Freddie Lee mine at Sandon to Nakusp on Upper Arrow lake. The charges for freight and treatment of this ore, which was smelted in Montana, amounted to $90 a ton. Ore packed from the Washington mine to Kaslo cost $45 a ton. Not only were costs very high but the financial panic of 1893 brought about a disastrous drop in the price of silver.

After the early discoveries prospectors extended their field of investigations southward and southwestward into the great area occupied by the granitic rocks of the Nelson batholith. In the vicinity of Slocan (Slocan City) the Dayton claim was staked on Dayton creek by Wm. Springer on June 10, 1893. The following years saw the location of many more claims. The success attending the early development of certain of these properties, notably the Enterprise mine, demonstrated the possibilities of this granite area and led to a very active campaign of prospecting and development. The discovery of attractive gold values on properties staked on Memphis (Twelvemile) creek and farther north accelerated prospecting, and resulted in the staking of a large part of Slocan City mining division.

The rival towns of Slocan City, Brandon, and West Slocan at the south end of Slocan lake rapidly reached their peak of prosperity and activity. A road was built from the lake shore up Enterprise (Tenmile) creek to Enterprise mine and, about 1897, a rail connexion made from Slocan to the Robson-Nelson line.

A great deal of prospecting was also being carried on with fair results about the headwaters of Kokanee (or Yuill) creek and on Keen (South fork of Kaslo) creek.

Transportation in Sandon map-area prior to 1894 was by means of a pack trial from Sandon to Nakusp and a wagon road from Kaslo to Bear lake. The road cost $20,000 and was built by private subscription. It was afterwards extended to Sandon. In 1895 the Kaslo and Slocan railway (narrow gauge) was completed between Kaslo and Cody. The Canadian Pacific railway completed a branch line between Nakusp and Three Forks in 1894 and later extended this to Sandon (Plate II).

In 1894-95 Dr. Wilbur A. Hendryx and partners, owners of the Blue Bell mine, built a 200-ton concentrator at Camp Hendryx and erected a small lead smelter at Pilot Bay, the first and only venture of this sort in or near the Slocan. The plant was erected primarily to treat Blue Bell ore, but did not prove a success and was closed down in the following year. In 1899 the Blue Bell property passed into the hands of the Bank of Montreal.

On January 14, 1896, the Hall Mines smelter was blown in at Nelson and entered the market for the gold-copper ores of Rossland as well as the silver-lead ores of Slocan.

In 1898 the Canadian Pacific railway purchased the Trail smelter, the nucleus of the present great plant of the Consolidated at Trail.

By 1901 Slocan district, represented by Ainsworth, Slocan, and Slocan City mining divisions, contained 917 Crown-granted mineral claims and 2,500 others held by location.

In 1905 the Canadian Metal Company, a French organization headed by Edward Riondel, bought the Blue Bell property on Kootenay lake. This company was primarily in the field for zinc ore and had built a zinc-retort, custom smelter at Frank, Alberta, where they had acquired coal lands. This enterprise, however, was unsuccessful and in the following year the Blue Bell mine came under the management of S. S. Fowler, who has long been identified with developments at this property.

In 1911 the Kaslo and Slocan railway was taken over by the Canadian Pacific railway and connected at Parapet Junction with a newly built road from Bear lake down the valley of Seaton creek. From Bear lake to Kaslo the road was rebuilt to standard gauge and the part of the Kaslo and Slocan railway between Bear lake and Cody dismantled.

The country has suffered materially from calamities peculiar to mountainous areas and to careless communities. Heavy freshets on Kaslo creek in 1894 and again in 1909 did great damage to the town of Kaslo. The town of Sandon was burnt on May 3, 1900. Forest fires swept through the district in 1894 and again in July, 1910, resulting in loss of life and much property as well as serious transportation difficulties. A miners' strike at Sandon lasted from June 12, 1899, to February 13, 1900.

By the mid-nineties the district, as regards the number of shipping mines and value of ore sold, ranked as the most productive mining camp in the province. In the beginning the ores were worked chiefly for their high silver values, but presently important returns were received for the lead content. Most of the early discoveries were small and were rapidly worked out or were found at depth to contain an increasing proportion of zinc ore for which smelters exacted a severe penalty in proportion to the amount present. Concentration of the silver-lead content seemed to furnish one solution of this difficulty and many a management precipitantly undertook expensive mill construction without adequate ore reserves. In the early milling practice, too, losses in silver were particularly heavy and zinc ore, where its concentration was attempted, was commonly too low grade to afford a profit. In addition, and in spite of the success which a few properties had attained in their deeper developments, the prevailing impression was that the ores of the Slocan " did not go down," and mine operators hesitated to venture the profits realized from the production of their outcropping ore-bodies on undertakings designed to prove their properties at depth.

This period of uncertainty was succeeded by that including the Great War, when the urgent demand for metals and their ensuing high market prices caused a second great mining boom in the district. The outbreak of the war brought about an unsettled state of affairs, resulting in the closing down of several shipping mines, but towards the end of September, 1914, arrangements were made whereby the Trail smelter again accepted ore shipments, and conditions gradually improved with the ever-increasing demand for lead, zinc, and silver. Mining and prospecting were carried on most energetically. Conditions encouraged deeper developments and the success attendant upon a number of ventures of this sort did much to remove scepticism as to the possibilities of the district. Production reached a peak that neither in previous nor subsequent times has been nearly equalled (*See* Figure 2).

Since the war production has dropped off greatly, as a result of the reduction in metal prices and partly because of the exhaustion of many of the larger ore-bodies which feverish developments of the war period had brought to light. New discoveries have been rare and shipments have resulted chiefly from further developments on properties that had already provided important tonnages. A miners' strike in 1921 cut down production in that year to a minimum. The following years, to and including 1929, however, witnessed a steady production and more consistent and well-advised programs of development by the larger companies. Improvements in mill design resulted in more satisfactory selective concentrations of the valuable ore minerals, and property owners lacking a mill of their own were able to take advantage of the 600-ton custom mill installed by the Consolidated Mining and Smelting Company at Trail. Encouragement was afforded the local mining industry by the removal, in 1928, of the penalty for zinc in lead ores and by a slight decrease in treatment charges for zinc ores; by the proposal of the West Kootenay Power and Light Company to construct a transmission line into the Slocan; and by the discovery, as at the Noble Five, Galena Farm, Whitewater, and Mammoth properties, of new and important ore-bodies.

The drastic fall in metal prices in 1929, and its continuation into 1930, cut short the enthusiasm of the preceding years. According to a statement issued by the Provincial Department of Mines the effect of these low metal prices has been more severely felt in No. 5 Mineral Survey district (which includes the Slocan) than anywhere else in the province.

The following table compiled from Annual Reports of the Minister of Mines for British Columbia gives the returns in silver, lead, and zinc of Slocan district (including Slocan, Slocan City, and Ainsworth mining divisions, and largely credited to Sandon map-area) as compared with the strongest competitors in these metals, viz., the Fort Steele and Portland Canal mining divisions.

Year	Mining division	Silver	Lead	Zinc
		$	$	$
1895	Fort Steele	....	....	....
	Slocan	914,246	532,255	....
1900	Fort Steele	560,303	1,639,848	....
	Slocan	1,442,949	969,743	....
1905	Fort Steele	652,342	2,045 750	....
	Slocan	666,846	271,422	....
1910	Fort Steele	254,809	954,983	....
	Slocan	608,547	358,588	192,473
1915	Fort Steele	227,154	1,108,472	20,250
	Slocan	992,199	765,676	1,053,395
1920	Fort Steele	342,933	1,927,924	2,795,847
	Slocan	963,248	730,921	252,249
	Skeena (Portland Canal chiefly), etc.	1,262,483	....	....
1925	Fort Steele	2,145,630	17,839,053	7,273,650
	Slocan	646,056	598,103	469,657
	Portland Canal	1,652,066	65,910	1,361
1930	Fort Steele	1,966,719	11,854,338	7,883,240
	Slocan	53,886	49,993	28,464
	Portland Canal	1,597,070	90,413	....

During Slocan's forty years of mining history many properties that once were productive have long since been abandoned; others are being held for possible further exploration, although little has been done on them for many years; and still others have been incorporated with nearby properties. Several of the early discoveries developed into properties that are still among the more important. Whitewater mine has a record of thirty-three producing years (up to and including 1929), Slocan Star-Silversmith, and Rambler-Cariboo mines have each shipped ore in thirty-one different years, and Ruth-Hope in thirty-two. The Standard mine, the largest producer in the district, produced continuously from 1905 to 1924, inclusive. At the peak of production in 1918 some forty-four properties made shipments having an aggregate value of about $3,500,000. In 1929, there were thirty-three shipping properties and the value of the production of the district, embracing thirty-seven properties, was estimated to be $1,358,031, of which $558,477 is attributed to silver, $322,664 to lead, $461,681 to zinc, and $5,209 to gold.

The diagram, Figure 2, shows a distinct relation between the price of metals and the tonnage of ore mined in Slocan district.

Slocan ores are mostly intimate mixtures of argentiferous galena, sphalerite, silver minerals, and pyrite in a gangue of siderite, quartz, or calcite, or a mixture of these three minerals. Recent developments in ore dressing have done much towards permitting an effective separation of the valuable from the valueless constituents, and have enabled the operator to obtain a comparatively clean separation of the zinc component from the silver-lead and high-grade silver minerals without the serious losses attendant upon earlier attempts in this direction. Modern metallurgical practice has also enabled the operator to dispose of this zinc component profitably.

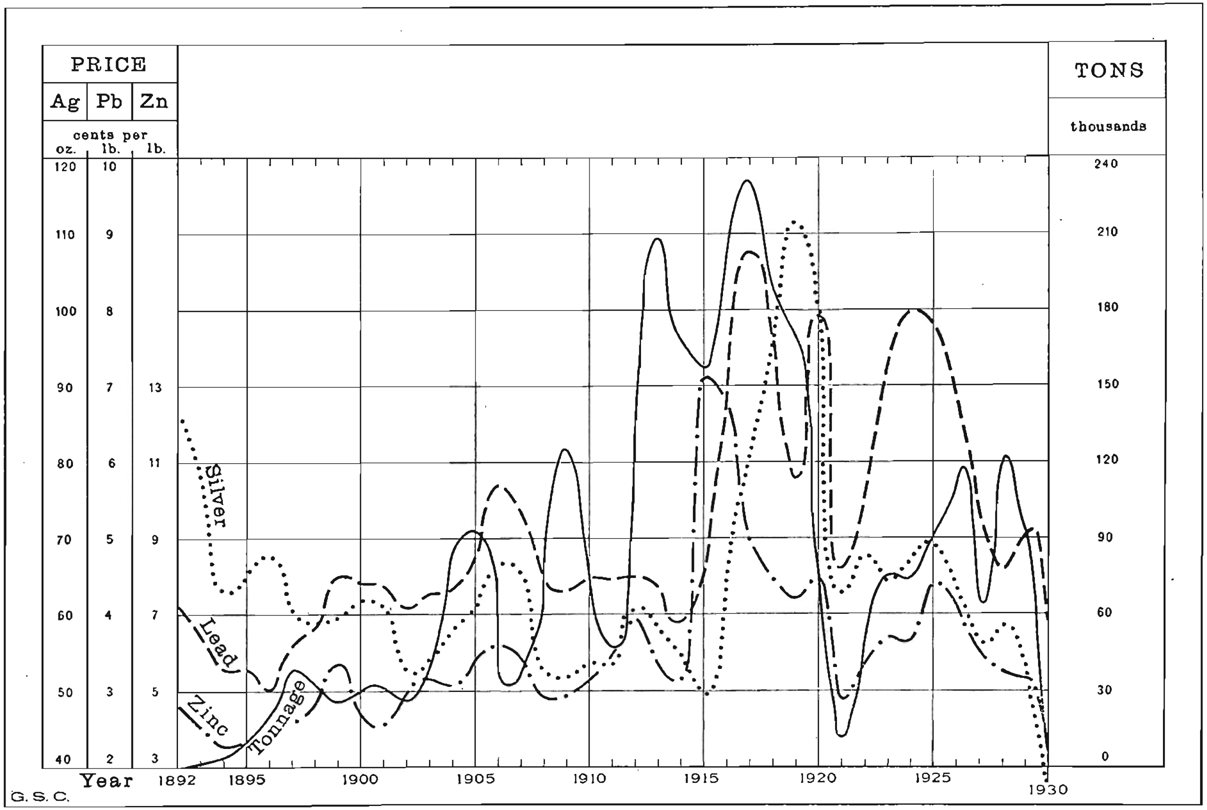

Figure 2. Graph showing prices of metals and tonnage of ore produced in Slocan district (Slocan, Slocan City, and Ainsworth mining divisions).

Commencing in 1899, early shipments of zinc ore were chiefly from the Lucky Jim mine, but by the close of 1905, 14,000 tons had been shipped from fifteen properties, of which the Slocan Star, Lucky Jim, Bosun, and Payne were the largest producers. The Kansas smelteries, to which most of the Canadian zinc ore was sent in these early years, demanded a high-grade zinc product and paid little or nothing for included lead or silver, as the treatment of zinc ore at the time for silver and lead resulted either in severe losses of these metals or in a correspondingly high cost of treatment. Only for certain properties, such as the Lucky Jim, where high-grade zinc ore could be readily hand sorted, did the shipments offer any reasonable returns. Where the ore required milling the methods of water concentration then in vogue could not eliminate an objectionable high proportion of the commonly associated siderite gangue, or of iron pyrites, thereby reducing the grade of the zinc concentrates below the profitable point.

Between 1905 and 1916, largely as a result of improvements in milling methods, some 20,000 tons of metallic zinc were contained in shipments of zinc ores from the district, a large proportion of these shipments being in the form of concentrates. It was, however, in the ten years ending about 1926 or 1927, when the price of spelter was consistently high and properties in the Slocan were able to take advantage of the electrolytic-zinc plant of the Consolidated Mining and Smelting Company at Trail, that the zinc output increased to an amount closely bordering on that of lead. In this period shipments from the Sandon area contained over 40,000 tons of metallic zinc.

The increasing importance of the zinc industry has affected mining operations in the district, because properties are now, or were until recently, valued for their zinc as well as silver and lead, whereas formerly those carrying a comparatively high zinc content were regarded as worthless. Old dumps containing discarded zinc ore have been re-treated for its extraction. In 1924, for example, a mill, with a capacity of 100 tons a day, was installed in the valley of Kaslo creek to handle the large tonnage of zinc ore discarded from the Whitewater mine in its earlier years of operation. Most of the zinc ore shipped from the district has come from some thirty properties situated mainly within Sandon map-area. These include most of the larger shippers from this area and their aggregate production, on a basis of valuation, has so far included much more important silver values and a considerably greater content of lead, than of zinc. Even if, in estimating the relative value of these three metals, we consider only the silver and lead produced in years when zinc ore also was shipped, we find the value of the silver production was much greater and that of lead somewhat greater than that of zinc.

The following table, based on returns submitted annually to the provincial government, represents the production of properties situated in Sandon and Slocan map-areas during the years 1892 to 1933 inclusive. All properties, so far as the writer is aware, are included. The figures for "tonnage" and "value" are not strictly accurate since for the first few years of mining in this district the returns are often quite incomplete and in the case of certain important properties, such as the Payne, are far below the actual value of production. The figures for "value" are subject to some adjustment too, in that they are based on the average market price for the year rather than the price prevailing at the particular time of the year at which shipments were made. On the whole, however, this table expresses at least an approximate idea of the production of this area since shipments first began. For a list of properties shipping ore from Sandon area, 1915 to 1924, inclusive, *See* Geological Survey, Canada, Summary Report 1925, part A, pages 187, 188. In calculating values the average New York prices for each year have been used as a basis and for silver 95 per cent, for lead 90 per cent, and for zinc (St. Louis) 85 per cent of such prices taken. No other deductions have been made.

List of Productive Properties in Slocan Mining Division

Location in grid[1]	Name of property	Years in which shipments are recorded																																								Tonnage	Value (Ag, Pb, Zn)	Order			Remarks
		92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33			Ag	Pb	Zn	
C-3	Adams																																											....	....	....	....	....	Probably small shipments
C-4	Ajax																																											....	....	....	....	....	Shipments, but no records
C-3	Alamo																																											....	....	....	....	....	*See* under Idaho-Alamo
C-3	Alpha (Grady)			X	X																															X								2,205	221,507	1	2	....	
C-4	American Boy					X			X		X	X	X	X	X	X	X	X															X				X							4,180	262,253	1	2	3	2 ozs. gold
D-4	Antoine				X	X		X	X		X	X	X	X	X								X							X					X		X							1,306	189,068	1	3	2	
C-2	Apex																					X	X			X								X	X									170	10,498	1	....	....	15 ozs. gold
D-4	Best	X																									X																	52	5,694	1	2	....	No returns for 1892
	Big Boulder	|X|																																								40	5,735	1	2	....	Large boulder of ore
C-3	Black Colt and Palmita																											X				X	X			X				X				566	40,846	1	2	....	
D-3	Black Grouse																							X	X	X																		23	1,508	1	....	....	1 oz. gold
C-4	Bluebird	X	X	X		X		X				X	X	X																														925	118,416	1	2	....	No returns for 1892
	Bob Fraction												X	X																														26	2,025	1	....	....	
C-2	Bosun							X	X	X	X	X	X			X													X	X	X	X	X	X	X	X	X	X	X	X			X	X	68,586	1,862,589	1	2	3	40 ozs. gold
C-3	Buffalo														X	X	X								X										X			X						113	18,749	1	2	....	
C-3	California and Clipper						X								X	X	X																											343	34,176	1	2	....	
C-4	Canadian													X	X	X	X											X		X	X		X	X	X	X	X	X	X	X				690	88,600	2	1	....	9 ozs. gold
D-2	Capello									X	X	X																	X															155	37,618	1	....	....	38 ozs. gold
C-3	Carnation-Jenny Lind-Read				X											X																	X			X		X						608	20,462	1	2	....	4 ozs. gold
C-4	Chambers					X																								X														26	2,558	1	2	....	
C-4	Chicago																																											....	....	....	....	....	Shipments included with Colonial
C-3;D-3	Cinderella													X	X								X	X										X										236	87,616	1	2	....	
C-4	Colonial-Chicago															X	X						X	X												X	X		X					331	27,305	1	2	....	2 ozs. gold
B-4	Comstock													X	X			X								X				X														342	34,271	1	2	....	1 oz. gold
C-3	Corinth and Yakima														X	X		X								X									X									154	14,117	2	1	....	
C-4	Daniel																									|X|																18	1,171	2	....	1	
D-4	Dardanelles	X	X			X		X				X																																631	101,661	1	2	....	
D-3	Eagle																																				|X|					4	193	1	....	....	
	Early Bird																|X|																									2	247	1	2	....	
C-3	Echo																										X	X	X			X						X						815	107,781	1	2	3	
C-4	Elkhorn																X	X								X							X					X		X				157	9,665	2	1	....	1 oz. gold
C-3	Emily-Edith																																											....	....	....	....	....	Shipments included with Standard

	Empire													X																															1	132	1	2		
C-3	Evening and Jennie																						X	X																					16	1,169	1	2		
B-4	Fisher Maiden			X									X	X	X			X	X	X																		X							717	40,642	1	2		
C-4	Freddie Lee	X	X																									X	X	X		X													817	104,989	1	2		3 ozs. gold
C-2	Galena Farm																									X	X	X	X	X			X	X	X	X	X	X	X	X	X				79,822	1,322,245	3	2	1	59 ozs. gold
C-4	Gem																											X	X	X		X	X	X											59	8,460	2	1		
C-4	Goodenough				X	X					X				X																														403	42,761	1	2		
D-4	Great Western																																								X				64	4,477				Records incomplete
C-5	Greenhorn																																																|*See* Home Rule
C-4	Grey Copper																											X														X		X	41	5,527	2	1		1 oz. gold
C-3	Hartney										X	X	X		X	X	X				X	X	X				X																		264	16,050	1	2		
D-4	Helenita																																																|*See* Rio
C-3	Hewitt and Lorna Doone										X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X						112,613	1,530,323	1	2	3	75 ozs. gold
C-5	Home Rule (and Greenhorn)																									X																			2	164	2	1		Other small shipments
C-4	Hope																																																|*See* Ruth-Hope
C-3	Idaho and Alamo		X	X	X								X	X	X	X	X			X	X	X	X		X	X	X	X	X	X	X						X	X	X						24,922	832,174	1	2	3	5 ozs. gold
C-4	Ivanhoe				X	X			X		X	X	X	X	X								X	X	X	X	X	X	X	X	X							X	X	X	X			19,879	475,978	1	2	3	
C-3	Jenny Lind																																																|*See* Carnation
C-4	Last Chance				X	X		X			X	X	X	X			X	X												X	X	X													4,721	498,501	1	2		Incomplete records
C-4	Leadsmith (Noonday)			X												X	X							X		X	X		X			X	X					X			X			389	29,963	2	1	3	
C-3	Lone Batchelor																																																|*See* Victor
B-4	Lou Dillon																																																|Small shipments, no returns
D-4	Lucky Jim		X		X		X							X	X		X		X	X		X	X		X	X	X	X	X	X				X	X	X	X	X	X					134,653	2,219,451	3	2	1	51 ozs. gold
C-3	Lucky Thought																							X	X	X	X	X						X	X			X	X	X				8,670	165,224	1	2		7 ozs. gold
C-4	Madison							X																																				20					No returns
C-4	Majestic and Unexpected													X	X	X	X			X		X				X																		241	22,331	2	1		
C-3	Mammoth																																				X	X	X					X	1,290	103,019				
	Margaret																							X																				4	193	1	2		
C-3	Marion								X						X				X																									52	5,588	1	2		
C-4	Mascot																						X																					1	53	1	2		
D-4	McAllister												X	X		X	X		X	X										X		X			X	X		X	X					17,595	426,212	1	2		42 ozs. gold
C-4	Mercury											X	X	X		X									X																			193	23,524	1	2		
C-2	Metallic																		X													X	X			X	X							106	5,740	1	2		1 oz. gold
C-3	Miller Creek																																																|Shipments included with Wonderful
D-4	Miner Boy		X																																									3	878	1			
C-3	Minniehaha																																				X							99	2,200				2 ozs. gold
D-2	Molly Hughes										X	X		X	X	X	X		X	X	X				X	X		X	X	X	X	X	X	X	X	X	X	X	X				X	1,960	127,634	1	2		542 ozs. gold
D-3	Monitor (and Ajax)					X			X		X	X	X	X	X				X													X	X	X	X	X	X	X	X					4,495	341,966	1	2	3	972 ozs. gold
C-3	Mountain Chief		X	X	X																											X	X	X	X	X	X	X	X					3,085	364,310	1	2		5 ozs. gold
C-5	Mountain Con								X		X	X	X	X	X	X	X	X			X		X		X							X					X							494	119,350	1	2		12 ozs. gold

[1]Numbers in this column refer to Maps 272A and 273A, in pocket.

List of Productive Properties in Slocan Mining Division—Conc.

Location in grid[1]	Name of property	Years in which shipments are recorded																																										Tonnage	Value (Ag, Pb, Zn)	Order			Remarks
		92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33			Ag	Pb	Zn	
C-3	Mowitch, Home Run, and Rosemarie											×		×																×					×									92	7,880	1			Records incomplete; 26 ozs. gold
D-4	Native Silver Bell (or Silver Bell No. 2)							×	×																																			106	17,246	1	2		
C-4	Noble Five		×	×	×						×										×	×	×							×		×				×	×	×	×	×				26,140	527,128	1	2	3	
C-2	Noonday and Curley								×																																			600	54,363	1	2		
C-4	Noonday																																																*See* Leadsmith
C-4	Number One and Twilight																				×	×				×	×	×	×			×			×									471	55,043	2	1		
D-4	Ocean																												×															3	522	1	2		
C-4	Omega													×	×														×															18	1,850	1	2		
C-4	Oro																																				×							8	196				
D-4	Payne				×						×	×	×	×	×	×	×			×						×	×	×		×		×												91,586	633,134	1	2		Records quite incomplete
C-3	Queen Bess		×					×	×	×	×	×		×												×	×	×	×	×	×	×		×	×	×	×	×	×					18,914	2,174,123	1	2		23 ozs. gold
D-4	Rambler-Cariboo				×	×					×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×		×	×				157,861	2,941,916	1	2	3	10 ozs. gold
C-3	Read																																																Shipments included with Carnation
C-4	Reco		×	×	×	×		×	×		×	×	×	×	×	×	×	×	×	×	×	×	×		×	×	×	×	×															6,716	835,413	1	2	3	
D-4	Red Fox										×	×	×	×	×	×																					×							558	78,780	1	2		
C-4, D-4	Redress																													×	×													8	2,027	1	2		
C-4	R. E. Lee				×	×						×			×	×																												247	41,719	2	1		
C-4	Richmond-Eureka					×											×	×	×	×	×	×	×	×		×		×	×	×						×								15,146	546,504	1	2		
D-4	Rio												×					×				×			×														×			×	×	163	21,529	1	2		Includes Helenita; 3 ozs. gold
B-2	Rockland							×																																									No returns
	Rosemarie																																																Shipments included with Mowitch
D-4	Ruby Silver					×										×		×																										40	6,754	1	2		
C-4	Ruth-Hope				×	×			×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×		×	54,003	1,955,271	1	2	3	223 ozs. gold
C-4	Sapphire								×																																			33	3,871	2	1		Earlier shipments of 95 tons
C-3	Silver Bell and Hustler										×			×	×	×			×																									209	19,953	1	2		

D-4	Silver Bell No. 2																																																*See* Native Silver Bell
C-3	Silverite																												X															49	6,460	1	2		
C-4	Silversmith-Slocan Star	X	X	X	X		X	X		X	X	X	X	X			X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	189,403	8,032,294	1	2	3	1,124 ozs. gold
D-4	Slocan Boy				X						X			X																														381	41,977	1	2		
C-4	Slocan King																																							X				11	1,297				
C-4	Slocan Sovereign						X			X			X		X	X	X	X								X	X	X	X	X		X	X	X		X			X	X				4,565	133,990	2	1		2 ozs. gold
C-4	Slocan Star																																																Shipments included with Silversmith
D-4	Soho (and Tom Moore)									X	X																						X						X	X				256	8,250	1	2		
C-3	Standard and Emily-Edith							X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	336,627	10,610,868	3	1	2	23 ozs. gold
D-4	St. Keverne										X			X																														16	2,244	1	2		
C-3	Sunshine and Yakima			X	X										X	X		X								X												X						116	10,457				Returns incomplete
C-4	Surprise			X							X											X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X					49,423	2,893,989				8 ozs. gold
	Tom Moore																																																*See* Soho
C-4	Trade Dollar																																																*See* Sunset-Trade Dollar-Bell (Ainsworth M.D.)
	Twilight																																																*See* Number One
C-3	Van Roi		X	X				X	X				X		X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X						264,469	2,804,188	1	2	3	39 ozs. gold
C-3	Victor														X	X	X	X		X		X		X			X						X	X	X	X	X	X	X			X	X	1,590	195,912	1	2		63 ozs. gold; including shipments from Lone Batchelor
C-4	Victoria																										X																	2	180	2	1		5 ozs. gold
C-5	Vulture								X						X																													583	62,378	2	1		
C-3	Wakefield												X	X	X	X	X								X				X										X					5,819	83,684	2	1		
D-4	Washington		X	X		X					X	X					X													X			X		X									8,470	401,045	1	2		
D-2	Wilmer										X																																	2	112	1			
C-4, C-3	Wonderful and Miller Creek					X	X	X			X	X	X		X	X							X	X	X	X	X	X	X	X		X	X		X	X	X	X						26,029	452,248	1	2	3	197 ozs. gold
C-3	Yakima (*See* Sunshine and Yakima)																																																

[1] Numbers in this column refer to Maps 272A and 273A, in pocket.

80437—2½

List of Productive Properties in Ainsworth Mining Division

Location in grid[1]	Name of property	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	Tonnage	Value (Ag, Pb, Zn)	Order Ag	Order Pb	Order Zn	Remarks
A-6	Baltimore											X		X	X	X	X																											54	6,880	1	2		1 oz. gold
D-6	Beaver																																													1	2		Small production; no records
C-5	Bell																																																*See* Sunset-Trade Dollar-Bell
B-6	Bismark									X	X	X	X	X		X	X	X	X	X																								1,063	72,853	1	2		
	Black Bear																															X												5	146	2	1		
B-5	B.N.A.																		X																									3	283	1	2		
D-4	Bon Ton																										X	X	X															13	2,756	1	2		Also a few tons in 1893
D-5	Caledonia																							X			X	X			X	X	X	X			X							68	3,957	2	1		
C-6	California-Big Ben-Marble Arch																																																*See* Silver King
D-5	Charleston											X		X	X	X		X						X	X									X		X								145	16,931	1	2	3	4 ozs. gold
C-4 C-5	Comstock-Virginia																	X																										5	478	1	2		
B-6	Cork-Province												X	X	X	X	X	X	X				X	X	X	X	X	X	X				X	X	X	X		X	X					64,731	565,146	2	1	3	10 ozs. gold
D-4 D-5	Corrigan																																																Small production; no records
D-8	Cuba																																																5 tons ready for shipment on 1926
B-5	Daybreak																																																*See* Gibson
D-5	Doherty (Iron Hand)																																																Small production; no records
C-5	Echo and Almeda												X																															14	1,516	1	2		
D-6	Emerald Hill																X																											4	724	1	2		
D-4	Empress (King and Queen)												X	X	X	X	X	X	X																									115	13,722	1			
D-5	Eureka																																																Shipments in the nineties; no records
C-5	Flint														X		X			X	X						X														X			325	12,307	2	1		
B-5	Gibson (Daybreak)				X																															X	X	X						571	19,339	2	1		2 ozs. gold
B-5 B-6	Gold Cure																		X																									20	1,748	1	2		(Approximate)
C-5	Helen																								X																			6	812	1	2		
D-5	Hillside																																																Small shipments; no returns
B-5	Index																		X												X													11	1,616	2	1		

D-5	Jackson and Northern Belle			X	X			X	X				X		X																							X						1,618	127,111	1	2		1 oz. gold
A-6	Jessie-Bluebird (Ontario No. 2)																X	X	X	X								X			X													172	31,745	1	2		
C-5	Keno																														X													3	212	2	1		
D-4	King and Queen																																																*See* Empress
C-6	Liberty								X																								X		X									5½	624	2	1		
D-5	Lincoln																											X				X												55	5,627	2	1		
D-4	London Hill		X			X						X										X																						60	6,203	1			
C-5	Lucky Boy			X																																								20					High-grade silver-lead
C-5	Martin																									X	X							X										59	5,107	2	1		
D-5	Metals Recovery																																		X	X	X	X	X					37,801	128,244	2	3	1	80 ozs. gold
C-5	Mohawk (and TenDay Man)																											X	X		X													22	5,039	1	2		
D-5	Monte Christo																X																				X							28	1,575	2	1		
C-6	Montezuma								X								X	X							X			X									X		X					4,035	75,772	2	1		Records not complete
D-5	Ohio																																																Small production; no records
A-6	Ontario No. 2																																																*See* Jessie-Bluebird
A-6	Pontiac (Tecumseh)							X	X	X	X		X		X																													1,368	18,441	1	2		
C-5	Rainbow																																	X										6	541	2	1		
A-5	Revenue																						X	X		X												X	X					181	14,703	2	1		4 ozs. gold
B-5	Silver Bear																													X			X					X	X					155	21,257	1	2		
B-5	Silver Bell							X	X										X										X	X	X													472	71,130	1	2		
D-4	Silver Glance		X								X	X			X	X		X												X														249	20,904	1	2		
	Silver King																									X																		3	436	1	2		
A-4	Smuggler																																																Small production; no returns
D-5	Sunset									X																																		52	5,818	1	2		Near Retallack
A-6	Sunset									X																																		60	5,802	1	2		Woodbury Creek
C-4	Sunset-Trade Dollar-Bell									X	X	X	X		X	X	X			X					X	X	X									X	X							3,762	404,881	1	2		
	Ten Day Man																																																Production included with Mohawk
D-5	Texas-Cowboy				X		X	X																																									Returns incomplete
C-5	U.S.																						X	X																				180	8,803	3	2	1	
C-5	Utica																		X	X	X	X	X	X	X	X	X	X	X	X	X	X												5,564	576,501	1	2	3	
A-5	Violet																														X													4	668	1	2		
D-5	Wellington	X	X	X		X						X						X	X	X					X																			666	84,418	1	2		
D-5	Whitewater and Whitewater Deep	X				X		X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				150,183	3,699,868	1	2	3	1,070 ozs. gold
D-4	Winona-Boon																																																*See* Corrigan

[1] Numbers in this column refer to Maps 272A and 273A, in pocket.

List of Productive Properties in Slocan City Mining Division

Location in grid[1]	Name of property	Years in which shipments are recorded																																										Tonnage	Value (Ag, Pb, Zn)	Order			Remarks
		92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33			Ag	Pb	Zn	
A-2	Alma (Myrtle)																																																*See* Myrtle
A-2	Alice S.																								X																			16	831	1	2		
A-2	Anna																					X						X		X	X	X		X	X		X	X						135	22,990	1	2		
A-2	Arlington						X			X	X	X	X		X	X	X	X			X							X	X			X												12,795	470,411	1	2		
A-2 A-3	Black Prince and Two Friends					X	X		X	X	X		X	X	X	X						X	X	X	X	X	X	X	X		X	X						X	X					1,776	149,669	1	2		
A-2	Bondholder									X	X		X	X																														72	4,273	1	2		
	Club													X																														5	189	1			2 ozs. gold
A-1	Colorado													X	X										X																			27	2,328				
A-1	Cripple Stick (Ruby and Mabel)												X	X																														11	135	1			1 oz. gold
B-2	Daisy (Little Daisy)																																									X	X	10					5 ozs. gold
A-1	Dayton												X																									X						14	237	2	1		2 ozs. gold
A-3	Eastmont and Westmont																X	X	X	X	X	X	X	X				X	X									X	X					2,011	186,590	1	2		58 ozs. gold
A-3	Enterprise					X				X	X	X	X	X	X				X	X	X	X		X	X	X	X		X						X	X	X	X						8,556	648,833	1	2	3	
A-2	Evening Star (No. 8)					X																						X																24	7,490	1			30 ozs. gold
A-1	Exchange					X																																						5	608	1			5 ozs. gold
	Graphic and Rosebud														X	X																												6	980	1	2		
A-1	Hamilton												X										X		X																			36	2,047	1	2		3 ozs. gold
A-3	Hampton										X	X	X		X	X																X												92	28,104	1	2		
A-1	Happy Medium																																											13	1,310	1	2		4 ozs. gold
B-2	Highland Light													X		X												X																11	1,813	1			
A-2	Howard Fraction				X	X																																						19	2,643	1			17 ozs. gold
B-2	Kalispell					X	X																																					16	2,410	1			
A-2	Lily B.																						X					X				X												38	2,464	1	2		
A-2	Little Tim																											X		X	X	X	X	X	X									61	9,426	1	2		
A-2	Meteor						X						X			X				X	X	X				X	X	X	X			X	X					X				X		517	75,217	1			309 ozs. gold
A-2	Myrtle																X																											13	29,044				
A-3	Neepawa (Peg Leg)													X	X	X	X				X		X						X				X	X	X									255	34,074	1	2	3	
A-2	Ottawa												X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X								6,198	487,089	1			3 ozs. gold
B-4	Para																																																Small production; no records
A-1	Paystreak (Whitehope)						X					X																																14	743	1			20 ozs. gold
A-3	Peg Leg																																																*See* Neepawa
	Port Hope													X																														11	990	1			8 ozs. gold

A-1	Republic											×	×	×														×	×	×															164	8,273	1		76 ozs. gold
A-1	Mabel																																																*See* Cripple Stick
A-4	Slocan Chief (Snowstorm)									×																							×	×											4	465	1	2	
A-2	Speculator										×																																		11	769	2	1	
A-2	Tamarack															×	×																												117	8,424	1	2	
A-2, A-3	Two Friends (and Black Prince)																																																*See* Black Prince
A-1	V and M										×																																		12	478	1		4 ozs. gold
A-3	Westmont																																																*See* Eastmont and Westmont
A-1	Whitehope																																																*See* Paystreak

1 Numbers in this column refer to Maps 272A and 273A, in pocket.

PREVIOUS AND CORRELATIVE GEOLOGICAL WORK

The first geological work in the district was a reconnaissance survey, in 1889, by Dawson (7)[1] of the shores of Kootenay lake. This was followed, in 1894 and 1895, by a general investigation of Slocan mining camp by McConnell (18), whose geological information was incorporated in the West Kootenay sheet (19) issued in 1904.

In 1892, E. D. Ingall, Chief of the Division of Mineral Statistics and Mines, Ottawa, visited the camp and reported (14) on a number of the new discoveries.

Commencing in 1908, LeRoy (17) made frequent visits to the Slocan and together with his assistant Drysdale (9), who later assumed charge of the work, completed, in 1916, a more detailed study of the geology and mineral deposits within Sandon map-area. Bancroft made further investigations in this area in 1917 and 1919 (1).

Other work bearing on geological and economic problems of the Slocan has been done by Brock (4) within the area of the West Kootenay sheet; by Bancroft, Walker, and Gunning (2) in the neighbouring Lardeau map-area; by Schofield (21), Bancroft, and Walker (25) in Kootenay Lake district; and by Cairnes (5, 1928) in Slocan and Upper Arrow Lakes area. In addition, the annual reports of the Minister of Mines for British Columbia (20) contain a wealth of information on mining operations in Slocan and neighbouring districts.

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CHAPTER II

TOPOGRAPHY

Slocan mining camp occupies an eastern area within the Selkirk Mountain system. Two principal ranges in this system are represented, namely Lardeau mountains to the north and Slocan mountains to the south of the transverse valley between Kaslo on Kootenay lake and New Denver on Slocan lake. West of Slocan lake Slocan map-area overlaps a part of the eastern flanks of Valhalla mountains and east of Kootenay lake Sandon map-area occupies a narrow fringe along the western border of the Purcell range.

Slocan mountains extend southward to the transverse valley occupied by the west arm of Kootenay lake and Kootenay river. They occupy an area of about 780 square miles, and for the most part consist of rugged ridges of alpine character (Plate IV A) culminating, south of Slocan map-area, in the Kokanee massif, the highest peak of which reaches 9,400 feet above sea-level. From this massif radiate several large streams fed by permanent mountain glaciers.

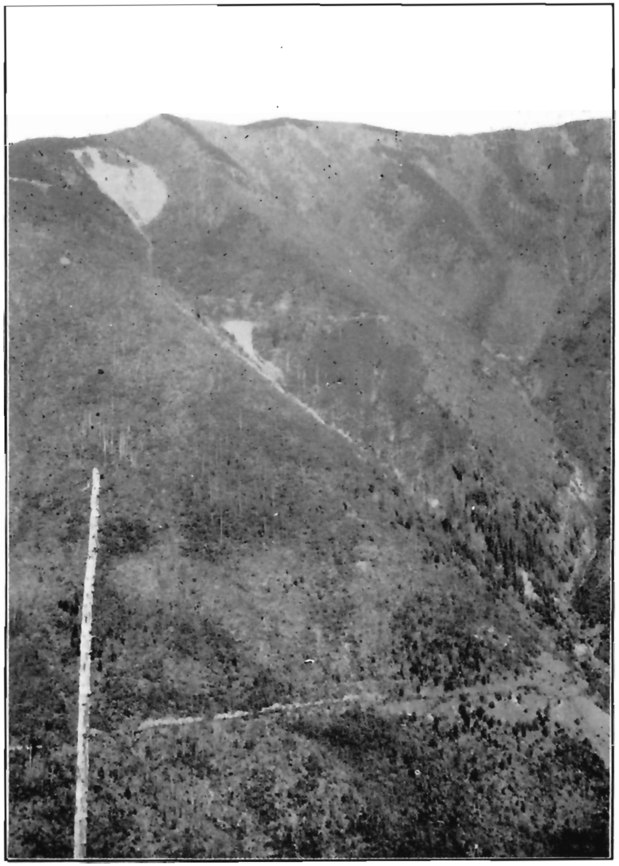
Lardeau mountains trend northwesterly to the northeast arm of Upper Arrow lake. Their eastern boundary is Kootenay lake and the valley occupied by Lardeau river and Trout lake. Westerly they extend to Slocan lake and the through valley between Slocan and Upper Arrow lakes. This is also a rugged group (Plate III B), and on the whole is more difficult of access than Slocan mountains.

The higher peaks in Sandon map-area are from several hundred to 1,000 feet or more lower than those in surrounding regions. This condition has markedly affected glaciation and the accumulation of glacial deposits and, thus, has controlled the development of various local topographic features.

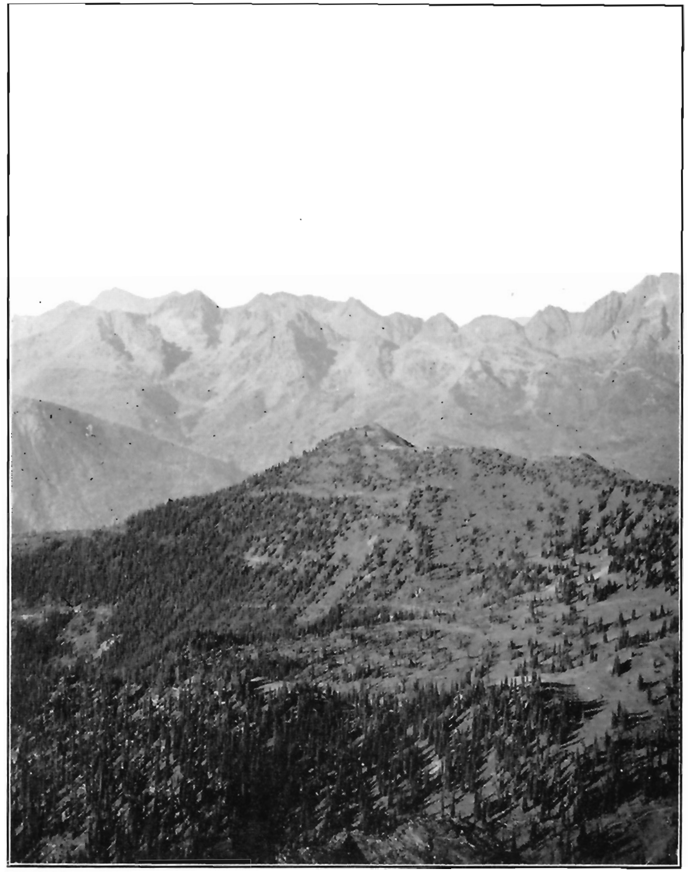
The areas under consideration show the strong relief characteristic of a mountainous topography in a late adolescent stage of erosion. There are no extensive upland flat areas; the valley walls have comparatively uniform slopes of moderate angles; and the larger tributary valleys possess, on the whole, fairly uniform gradients throughout their lengths.

Ridge tops may be either rounded or sharply serrate, depending largely on local rock structure and the character of the bedrock (*See* Plate IV A). The areas of Nelson granite and Kaslo series are normally more rugged and sharper in outline than those underlain by sediments of the Slocan series.

East of Slocan lake there is a noticeable flattening in the topography at about the 3,000-foot contour (between 1,200 and 1,300 feet above the lake), and this feature corresponds to a change of slope west of the lake at about the same elevation. A similar topographic development is noticeable along the west side of Kootenay lake below the 3,000-foot

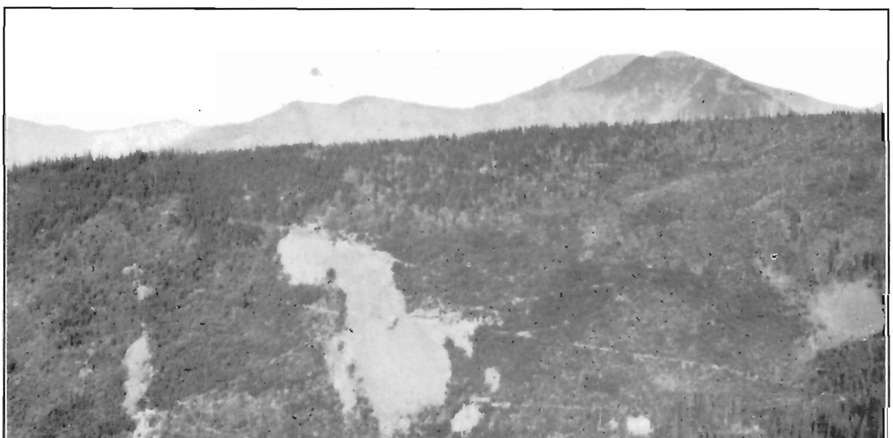


A. Part of the northeastern slope of Carpenter Creek valley below Sandon; showing dumps from workings on the Payne mine. (Neg. No. 67569.)



B. Looking north over Dardanelles basin and Dardanelles peak (foreground) across the wide valley of Kaslo creek to rugged mountains beyond the limits of Sandon map-area.

A. Looking south across the valley of Kaslo creek and up the tributary valleys of Twelve-mile and Holmes creeks to mount Carlyle (right background), mount Holmes (right-centre background), and the Kokanee massif (left extreme background).



B. Buildings and dumps at the Queen Bess mine in the valley of Howson creek. (Neg. No. 67580) contour south of Kaslo creek. These comparatively flat areas are covered by drift except in places where low, narrow ridges of more resistant strata project above the general level. They probably represent former base levels of erosion that have persisted, though modified to some extent by glaciation, since late Tertiary time.

A number of ridge tops are comparatively level over considerable distances. There is, however, no general accord between these upper levels and, consequently, no general explanation can be given. Two long, nearly flat ridges deserve special mention. One lies south of Three Forks and forms the top of the Queen Bess ridge between Carpenter and Howson creeks (Plate IV B). In a distance of about 6,000 feet this ridge only drops from 6,100 to 5,500 feet. The underlying rocks are chiefly slates of the Slocan series. The other ridge, composed of Kaslo series greenstones, lies west of Kootenay lake and south of the head of Falls creek. In a distance of over 3 miles it has a maximum vertical relief of only 500 feet, the elevation ranging from 6,000 to 6,500 feet. Neither of these comparatively flat spurs is the summit of the ridge of which it is a part; the summit stands 1,000 or more feet higher and rises rather rapidly to this higher elevation from the upper end of the flat areas. Are these two features, at widely separated points in the area, and underlain by rocks of entirely different character, remnants of an earlier peneplained surface? This suggestion finds little support elsewhere in the area. On the other hand, the spurs lie not far from either Slocan or Kootenay Lake valleys, which furnished the main outlet channels for glacial ice in the Glacial period, and erosion on the ridges adjoining or near these outlet valleys probably was more pronounced than elsewhere in the area. The smoothly rounded tops of these flat spurs; the little evidence of effective regional glaciation on higher parts of the ridges; and the abrupt truncation of the spurs by the strongly erosive action of the main tributary glaciers flowing down Kaslo and Carpenter Creeks valleys are features that imply that these flatter parts of the ridges mark the upward limit of effective glaciation in the area.

The usual features of alpine topography are well developed. Cirques with rock-rimmed lakelets, either single or in series, occur, as at the headwaters of Keen, Woodbury, Silverton, and Montezuma creeks. Those situated below the broader divides or cols are commonly walled by comparatively gentle slopes, and their broad floors are carpeted by a luxuriant growth of flowering plants and grasses. Cirques that have formed below peaks and the sharper, steeper divides or cols, are narrow; are walled by steep, in places precipitous, slopes; and are floored by talus with patches of smooth rock appearing in places.

The larger streams in both Sandon and Slocan map-areas are fed by glaciers, and most of them maintain a good volume throughout the year. The larger glaciers all lie to the south, north, or west of Sandon map-area as, for example, Kokanee glacier in Slocan mountains; glaciers at the heads of Lyle and Whitewater creeks in the southern Lardeau mountains; and New Denver glacier at the head of Sharp (Glacier) creek in Valhalla mountains (Plate V).

Cordilleran ice undoubtedly covered much or all of Sandon and Slocan map-areas in Pleistocene time. Glacial striæ are, however, scarce and poorly preserved, except towards the main valley bottoms. A huge glacial erratic of coarse-grained, massive, porphyritic granite was noted on the summit of Carpenter Mountain ridge at an elevation of 6,300 feet, and 3,600 feet northeast of the contact of the Slocan series with the Carpenter Mountain granite stock. It might have come from this stock, and indicates at least that a considerable thickness of ice must have swept over this high ridge. Another huge erratic of a similar granite, seen alongside the road from Sandon to Payne mine at an elevation of 4,250 feet, is of a different type from the nearby granitic stocks and more resembles that of the main mass of the Nelson batholith as exposed farther up Carpenter Creek valley. A large slab of massive, black argillite, discovered near the top of Bondholder mountain, at an elevation of about 7,000 feet, resembles members of the Slocan series as exposed several miles to the north. An assemblage of erratic material discovered along the course of the creek draining southeasterly from the Silver Glance property into Bear lake includes numerous greenstone boulders evidently obtained from the Kaslo series, the nearest exposures of which lie several miles to the northeast. These and other such erratic materials suggest that an ice-sheet, or sheets, advanced upon Sandon area from different directions, but that the main outlet from the district was towards the south or southwest.

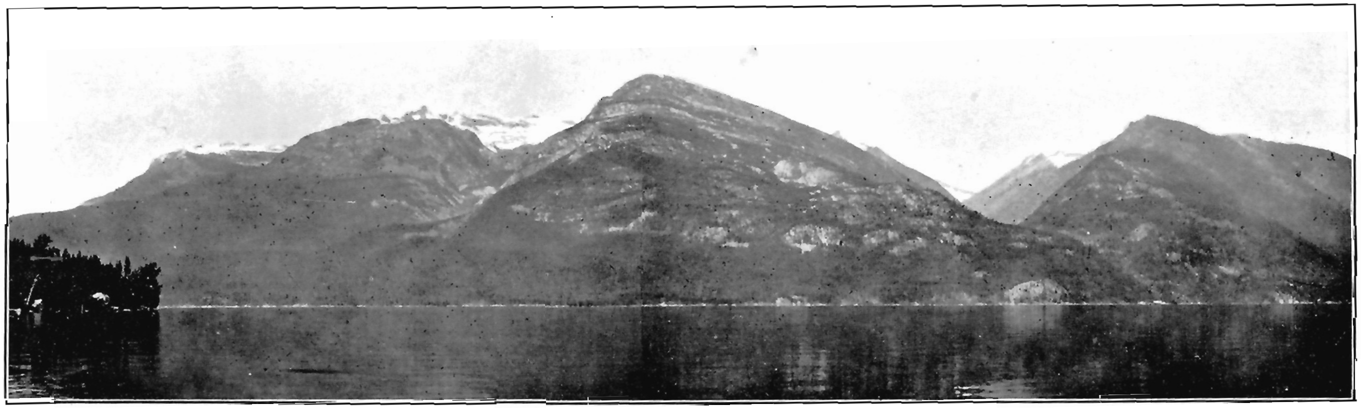
The relatively low uplands of Sandon area tended to preserve it from active erosion except in the vicinity of Slocan and Kootenay Lakes valleys, which provided the main outlets for glacial ice and, consequently, bear the contours of glacial troughs and along their shores show polished and striated rock surfaces. Otherwise the area served as a "settling pond" for glacial materials brought by the advancing ice. Movement out of the area was restricted and the accumulated ice tended to remain and to effect but little erosion of the upland surfaces. The rock debris accumulated during the period of Cordilleran ice movements was augmented by products of valley glaciation and piled up in the lower courses of the main streams. A tremendous amount of glacial materials thus accumulated in Sandon area. Much of this has since been swept away by streams, but much still remains in the form of prominent terraces and bench lands along the lake shores and lower courses of the main streams, remnants of much higher benches, and heavy deposits of unassorted drift filling old valleys and otherwise generally distributed over much of the upland slopes.

The imprint of valley glaciation is seen in the numerous cirque-like basins; the rock-rimmed lakelets on and near the higher divides; and the truncated spurs along the major valleys.

Terraces formed of unconsolidated materials are common, and in some cases conspicuous, features in both Sandon and Slocan areas. They vary in elevation from less than 100 to over 3,500 feet above Kootenay and Slocan lakes and are regarded as having been formed in late Glacial and post-Glacial times, following the accumulation of great quantities of glacial debris.

The difficulty of tracing most of these terraces for any considerable distance, and the discrepancy in the number and elevation of those observed in closely adjoining sections, are probably the result of local conditions affecting not only their formation but afterwards their partial or complete

PLATE V



Valhalla mountains west of Slocan lake and opposite Rosebery and New Denver. The principal valleys shown are those of Sawmill (on the right) and Sharp (Glacier) creeks; at the head of the latter can be seen the New Denver glacier. (Neg. No. 64548-9.)

destruction. Such conditions included the occurrence and behaviour of bodies of ice along the valley bottoms; the formation of dams along the course of a stream, particularly at the junction of tributary valleys; the bursting of such dams and their subsequent formation at points lower down the valley; irregular conditions of reassortment and deposition of glacial materials, resulting at times in regularly bedded sands and silts along quiet stretches of water, and at others in the accumulation of coarse, or irregularly sorted and bedded material formed when sudden freshets, bursting of dams, and the accumulations of slide debris interrupted the even course of deposition. These conditions involved successive formation and destruction of partly sorted materials, and developed a series of terraces at irregular, vertical intervals in the valleys occupied by the tributary streams. The main valleys, including those occupied by Kootenay and Slocan lakes, provided similar conditions on a greater and more regular scale, so that the terraces along them are larger and more persistent.

Along the east shore of Slocan lake, between Rosebery and New Denver, one well-marked terrace stands at about 320 feet and another at about 250 feet above the lake. Between New Denver and Silverton the southern extension of the lower terrace forms the Harris Ranch flats at the elevation of No. 4 tunnel of the Bosun mine, nearly 250 feet above the lake. Up Wilson creek prominent terraces were observed at elevations of 250, 330, and 420 feet above Slocan lake. Up Carpenter creek and north of Denver canyon two terraces were observed at about 535 and 720 feet above lake level. The lower of these is the more prominent. In the valley of Silverton (Fourmile) creek terraces were noted at 640, 750, and 1,250 feet above the level of Slocan lake.

On the west side of Kootenay lake, well-defined terraces are represented by old and recent delta levels at and near the mouth of Kaslo creek (Plate I). The older levels occur about 250 and 650 feet above lake level. The upper terrace is well marked and continues, broken only by the erosion of side streams, to and above Zwicky. Farther up the valley other well-defined terraces were observed in the vicinity of Robb (Spring), Rossiter, Twelvemile, Lyle, and Whitewater creeks at elevations ranging from 1,240 to 1,900 feet above Kootenay lake, the principal intermediate terraces occurring at intervals of 1,375, 1,410, 1,490, 1,560 feet.

Towards the mouths of the valleys of the more important streams such as Kaslo, Carpenter, Wilson, and Silverton, the terraces are remnants of old delta deposits, cut into by the streams and the derived materials, incorporated in the deltas now being built out into the lakes. The towns of Kaslo, New Denver, Rosebery, and Silverton occupy recent deltas whose surfaces lie only a few feet above lake level.

ORIGIN OF SLOCAN AND KOOTENAY LAKES VALLEYS

Slocan lake and Kootenay lake occupy valleys for the origin of which different theories have been advanced. Soundings (18, 1895, page 23; 17, 1913, page 97) in Slocan lake indicate that, in general, it deepens from north to south, from 765 feet opposite Rosebery to 830 feet between Rosebery and New Denver, to 925 feet near the south end. Soundings by the writer, in 1927, indicated that opposite New Denver the lake is 765 feet deep near the centre, 690 feet deep three-fourths of the distance across, and 320 feet deep 200 yards from the west shore opposite a steep rock bluff.

Kootenay lake is not nearly as deep as Slocan lake although covering a much greater area and only a few feet lower in elevation. Prior to 1926 the only authoritative soundings were, one of 380 feet in the middle of the south end of the lake opposite Sanca and another of 450 feet opposite Ainsworth north of the West Arm (19). In 1926 a great number of soundings were made between Kaslo and Schroeder creek. These indicated an almost flat bottom at between 380 and 395 feet down the middle of the lake and to within a short distance of either shore, from where the sides rise steeply. Kootenay lake, therefore, possesses more regular bottom contours than Slocan lake, but this may be due as much to a more even flooring of unconsolidated deposits (in the form of Glacial debris and post-Glacial alluvium) as to any inherited greater regularity in the rock bottom of Kootenay lake.

The deep, prominent valley occupied by Kootenay lake, called the Purcell trench, partly follows and partly cuts across the geological formations on either side.

Different views have been advanced to account for the occurrence of this prominent topographic feature and for the positions of adjacent formations (9, page 56; also map—*See* structure sections; 27, 1914, page 41, and 1920, pages 60-65; 6, page 600). Of these views it appears that Schofield's interpretation of the origin of the Purcell trench as a valley formed by an antecedent river is more likely correct, though it is less certain as to when and under what physiographic conditions the initial stream had its beginning.

A similar interpretation probably holds for the valley occupied by Slocan lake. This valley is not as wide as that of Kootenay lake and, in detail, is more sharply irregular. The two valleys parallel each other in a rather remarkable way in spite of the fact that they intersect quite different assemblages of rocks. Slocan Lake valley, from New Denver northward, is in line with and is continued by the northwesterly trending valley connecting with Upper Arrow lake at Nakusp. The direction is that of the general Cordilleran trend of formations, a direction along which folding, faulting, and the physical characteristics of the rocks have influenced the course of stream erosion. In the vicinity of, and south of, Rosebery (5, 1928, map), the Slocan series is broadly developed east of the lake, but on the west are highly metamorphosed Precambrian rocks whose attitudes are entirely unlike those of the Slocan series. This condition is highly suggestive of faulting along the lake bottom. Northwest of the head of Slocan lake, along the valley leading to Upper Arrow lake, no direct evidence of material displacement of the rock formations on either side of the valley could be obtained, and at Summit lake a tongue from the Kuskanax batholith crosses without any apparent offset, indicating that if important faulting exists along the course of the valley it developed in pre-Kuskanax time. Elsewhere the valley bottom is mostly obscured by drift and faults might be present without being detected. The principal rocks along the northeasterly side of the valley are granitic rocks of the Kuskanax batholith, whereas the formations on the opposite side are chiefly sediments of the Slocan series. It is probable that the course of the valley has been guided to some extent by this flank of the batholith bordered by softer and more easily eroded rocks. The southern half of Slocan lake trends about 20 degrees west of south, coincident with the foliation of the crushed, granitic rocks on either side, a condition that again suggests that rock structures have played a part in influencing the course of this valley.

CHAPTER III

GENERAL GEOLOGY

INTRODUCTION

Selkirk mountains, within which the Sandon and Slocan map-areas lie, are composed of formations ranging in age from Late Precambrian to (?) Tertiary, but Precambrian measures and post-Triassic intrusives occupy the major part of this great territory. Palæozoic and Mesozoic sediments and volcanic rocks occur as scattered patches or narrow belts resting on a basement of the Precambrian rocks or caught up as inclusions within the post-Triassic intrusives.

Late Precambrian strata of the Windermere series (25, pages 120-126; map) extend across the prominent valley occupied in part by Kootenay lake and in part by Duncan and Beaver rivers. The youngest member, the Lardeau series, occupies most of Lardeau map-area, and farther south occupies the eastern part of Sandon map-area. West of Slocan lake are more limited areas of Precambrian rocks of probably earlier Windermere age.

West of the summit of the Purcell range no pre-Carboniferous Palæozoic members have been definitely identified and Carboniferous formations are limited in extent. Minor areas of sediments in Lardeau and Slocan districts are probably Carboniferous.

West and southwest of Kootenay lake are considerable areas of volcanic rocks, associated in places with late Palæozoic and Mesozoic strata. An area of such rocks is that underlain by the Kaslo series of Sandon map-area described in the present report. This series is believed to be Triassic, and has been traced northwesterly into Lardeau map-area.

Mesozoic sediments in Selkirk mountains are difficult to separate, lithologically or structurally, from the late Palæozoic strata, and in the case of the Milford group of Lardeau and Slocan areas show no evidence of any interruption in sedimentation from Upper Carboniferous to Triassic time. Fossil remains here, as elsewhere, furnish the chief basis for separation. On this basis the Slocan series is now referred to the Triassic and forms the largest single known area of Mesozoic sediments in Selkirk mountains (6).

Intrusive rocks are most extensively developed in the southwestern part of Selkirk mountains, to the south of a line running west from Kaslo. Much of this great area is occupied by a complex of batholithic rocks referable chiefly to one great period of intrusion and correlated with the Nelson (West Kootenay) batholith. Associated with, but cutting this batholith, are minor areas of intrusives that are so distinctive in composition and structure as to suggest that they are probably younger. Such later intrusives include the Rossland alkali granite and syenite (19), the monzonite stocks of Franklin mining camp (9, 1915), and the Kuskanax batholith east of Upper Arrow lake (5, 1928, map). Elsewhere in Selkirk and Purcell mountains are a number of large, stock-shaped bodies of granitic rocks, some of batholithic proportions, which for the most part much resemble members of the Nelson batholith but may include later intrusives. Much granitic material appears as banded, or gneissic and pegmatitic, granitic rocks closely associated with and partly replacing Precambrian and later strata. Within the areas covered by the present report, and farther northwest in the vicinity of Upper Arrow lake, these intrusives are correlated with the Nelson batholith. Elsewhere in Selkirk mountains, as along the shores of Kootenay and Upper Arrow lakes (5, 1928, map; 2, map) and northward in the Big Bend country (11, map), similar gneissic and pegmatitic granites have been encountered and referred to the same general period of intrusion. The batholiths and larger stocks are attended by a host of minor stocks, dykes, and sills. The rocks of these bodies vary greatly in appearance, and though dominantly of acid or intermediate composition they include many basic types occurring chiefly as narrow dykes.

No precise time can be allotted to the period or periods of intrusion of the batholithic and attendant intrusives. Their contacts with the Triassic sedimentary and volcanic formations are invariably intrusive, so that they are certainly of post-Triassic age. Relations with Tertiary volcanics and sediments west of Lower Arrow lake indicate that some of the intrusives there are of Tertiary age, though such rocks appear to occupy relatively small areas as compared with the bulk of the post-Triassic irruptives.

Table of Formations

Era	Period	Formation	Lithology
Quaternary	Recent		Stream alluvium and delta deposits; glacial debris; slide debris; spring deposits; soil
	Pleistocene		Fluvioglacial terrace deposits; morainal deposits
Mesozoic and (?) Tertiary	Post-Triassic		Mafic dykes: lamprophyres; minettes; carbonate mariposite dyke rocks
			Salic stocks, dykes, and sills: granite, syenite, granodiorite, quartz diorite, diorite; porphyritic and felsitic equivalents
		Nelson pegmatite-gneiss complex	A complex of coarse (pegmatitic) granite, fine to medium gneissic granite, and inclusions of Precambrian rocks
		Gradational contact	
		Nelson non-porphyritic granite and granodiorite	Medium-grained, equigranular, biotite-hornblende granite, and granodiorite
		Gradational and intrusive contacts	
		Nelson granite: Nelson porphyritic granite	Chiefly coarse-grained hornblende or hornblende-biotite granite carrying abundant and conspicuous phenocrysts of potash feldspar
		Gradational contact	
		Nelson granite: Nelson granite-gneiss	Chiefly coarse-grained, crushed, and partly foliated, porphyritic granite carrying conspicuous phenocrysts of potash feldspar, mostly microline
		Gradational contact	
		Nelson granite: Nelson gneiss	Crushed, partly foliated, and commonly banded granite-gneiss carrying abundant inclusions of older rocks
Intrusive contact			
Mesozoic	Triassic	Slocan series	Slate, argillite, quartzite, limestone (in part fossiliferous), conglomerate, and tuffaceous sediments
		Disconformity	
		Kaslo series	Andesitic volcanic rocks and related basic intrusives (greenstones); serpentine and talcose rocks; intercalated, probably tuffaceous, sediments

Table of Formations—Concluded

Era	Period	Formation	Lithology
		Unconformity	
Mesozoic and Palæozoic	Triassic and Carboniferous	Milford group	Chiefly chert, massive and banded
			Slate, fissile argillite, cherty greenstone, limestone (mostly flaggy and fossiliferous); andesite; and porphyrite
		Unconformity	
Late Precambrian	Windermere	Lardeau series	Crystalline schists, greenstone and green schists, crystalline limestone, paragneiss
		Undivided	Crystalline schists, crystalline limestone, paragneiss
		Relations not known	
Mesozoic and (?) Pre-Mesozoic	Triassic and (?) older	Undifferentiated; probably chiefly Slocan series	Schists, quartzite, argillite, limestone, and volcanic rocks

DESCRIPTION OF FORMATIONS

UNDIVIDED WINDERMERE

Under the heading, Undivided Windermere, are included rocks that outcrop in areas west of Slocan lake and that lithologically and structurally closely resemble members of the Lardeau series exposed in Sandon map-area on both sides of Kootenay lake. No direct correlation, however, can be made as the nearest Lardeau strata lie many miles east of Slocan lake; and the Undivided Windermere also bears a close lithological resemblance to the Precambrian rocks of other areas, such as along either shore of Upper Arrow lake, which have been included with the Hamill series (2, map) that underlies the Lardeau series but is also of Windermere age. The only other rocks in the two map-areas with which the "Undivided Windermere" strata might be confused are certain bodies of highly metamorphosed rocks occurring farther south on Slocan lake and thought to be Triassic or possibly Palæozoic.

The Windermere rocks occur in several scattered areas west of Slocan lake. In each they are intimately associated with the Nelson pegmatite-gneiss complex into which, as a result of injection, recrystallization, granitization, and replacement, they so grade that it is most difficult to decide whether to map some of them as Precambrian or to include them with the intrusives. This is especially true of the numerous bodies lying within the area of pegmatite-gneiss. It is less true of the larger bodies, whose boundaries can be approximately outlined.

The bulk of these Windermere strata consist either of crystalline, light grey to whitish limestone or quartz-biotite schist. The limestone forms beds up to 100 feet or more thick, is commonly granular, and contains varying amounts of quartz, graphite, and garnet and other lime-silicates. The schists are equigranular, medium to fine grained, and carry about equal proportions of dark and light minerals, giving them a characteristic "salt and pepper" appearance. The constituent minerals are quartz, plagioclase, and biotite and, more rarely, amphibole. These schists are finely banded and pass into rocks that are indistinguishable from the gneissic, granitic member of the Nelson pegmatite-gneiss complex. Other rock types include lustrous mica schists, garnetiferous mica schists, and quartz-sericite schists derived in part from argillaceous and in part from quartzitic sediments.

The intense alteration to which these Windermere rocks have been subjected is essentially a regional, contact metamorphism connected with the associated batholithic intrusives, and is analogous to that described in detail for members of the Lardeau series.

LARDEAU SERIES

As defined by Walker (25, page 126) the Lardeau series comprises the youngest known formations of Windermere time. Its upper limit in Sandon area is marked by the unconformity separating the Precambrian measures from the overlying late Palæozoic and Mesozoic sediments of the Milford group. In its southerly extension from Lardeau map-area, the series, except where cut off by granitic intrusives, forms a belt of varying width along either side of Kootenay lake as far south as Crawford bay (25, map). Its base lies east of Kootenay lake beyond the limits of Sandon map-area.

Within Sandon map-area, the Lardeau strata strike north to northwest and, for the most part, dip westerly. North of Schroeder creek they lie in one or more open folds. South of this creek no major folds were noted and the absence, except locally and on a small scale, of any recognizable repetition of beds has indicated that in this direction the open folds of the north have passed rather rapidly into a monocline. On the east shore of Kootenay lake the structure appears to be continuous with that on the west side, but is interrupted by large masses of plutonic rocks and is obscured by a host of dyke-like intrusions which traverse the Lardeau rocks in every direction.

The Lardeau series is a thick assemblage of, mainly, altered sediments. These are so abundantly associated with granitic intrusives and, as a result of metamorphism, show so many insensible gradations to rocks lithologically resembling the intrusives that it proved impossible in most places to map the intrusives separately. Where recognizable, the sediments consist of schists, crystalline limestone, and quartzite. A section exposed along the west shore of Kootenay lake from the north edge of Sandon map-area to Kaslo and from Kaslo west to the Milford group contact on Buchanan mountain is, in ascending order, as follows:

(I) From north edge of map-area to mouth of Schroeder creek, average strike north 21 degrees west; average dip 39 degrees southwest.
Banded and massive quartzites; crystalline limestone (a few feet); quartzite and schist (some garnetiferous); crystalline limestone (a few feet); quartz-biotite schists and gneiss. Total thickness, 2,075 feet.

(II) From mouth of Schroeder creek to mouth of Milford creek; average strike north 26 degrees west; average dip 39 degrees southwest.
Crystalline limestone (50 to 100 feet; quarry); quartzite and quartzitic schists; micaceous schists; greenish, micaceous schists; greenish, chloritic schists; granitic intrusives and paragneisses; schist (wide belt); schists and intercalated quartzites; granitic intrusives; quartz-sericite schists and quartzites. Total thickness, 1,667 feet.

(III) From the mouth of Milford creek to about ½ mile north of Kaslo; average strike north 9 degrees west; average dip 36 degrees west.
Granitic intrusives (including 100-foot sill) and paragneisses; quartz-sericite schists; highly micaceous schists; quartz-mica schists; schists and gneisses; quartz veins; schists and granitic intrusives; limestone schist and intrusives; granitic sill (75 feet); limestone (10 feet); schist (20 feet); limestone (25 feet); schist; limestone (100 feet; quarry); quartz-mica schist and banded quartzite; micaceous schists; limestone (50 feet); intrusives and injection gneisses; micaceous schists; quartz-biotite schists. Total thickness, 2,200 feet.

(IV) From about ½ mile north of Kaslo west to Milford group contact; average strike north 6 degrees west; average dip 40 degrees west.
Granitic intrusives; quartzitic schists; crystalline limestone. Total thickness, 775 feet.
Limy schists, granitic intrusives, and paragneisses; crystalline limestone. Total thickness, 1,175 feet.
Granitic intrusives; lustrous mica schists; quartzitic and garnetiferous schists; crystalline limestone. Total thickness, 1,560 feet.
Quartz-sericite schists; granitic intrusives; greenish, chloritic schists; crystalline limestone. Total thickness, 1,075 feet.
Granitic intrusives; soft, micaceous schists; crystalline limestone. Total thickness, 1,075 feet.
Rusty, sericitic and garnetiferous schists; green and grey, chloritic and sericitic schists. Total thickness, 1,950 feet.
Brown to white, crystalline limestone; sericite schists. Total thickness, 390 feet.

This section has a total thickness of 13,942 feet but includes abundant granitic rocks, which though in places readily distinguishable are mostly too intimately associated with sediments to be separable. No deduction has been made for minor folds, and although the duplication due to any one would amount to only a few feet many such plications might materially increase the apparent thickness of the series. The true thickness of the part of the Lardeau series present may not exceed 10,000 feet.

Quartzites. Beds of quartzite from a few feet to more than 100 feet thick occur at intervals through the Lardeau series. They are abundant at the base of the section and are prominent again about 4,000 feet above the base where, however, they are, in general, more schistose and less pure. The purer quartzites are massive, grey rocks commonly showing bedding by fine banding in shades of grey. They vary from such as are composed almost entirely of quartz grains to others in which argillaceous or calcareous matter or secondary, metamorphic minerals are important constituents. The more massive types grade into others that are notably schistose and that, in general, carry abundant colourless mica, probably sericite; biotite may also be present.

Limestones. Limestone bands from a few feet to 200 or 300 feet thick occur at several horizons in the series. Three wide bands outcrop along the west shore of the lake, two within about 2 miles north of Kaslo and a third south of the mouth of Schroeder creek. The northern extension of the third band contains the ore deposits at the Cuba mining property; its southern extension angles across the lake and may form the large limestone exposures opposite Kaslo, at the old marble quarry. Several other bands of limestone were noted on the eastern slope of the southern end of Blue ridge. Most of the limestone is light grey to white, massive, and coarsely crystalline, and contains impurities that form narrow dark bands or disseminated crystals. Small, scattered flakes of graphite are common; garnet and tremolite are locally abundant. One outcrop, about ½ mile up Falls creek, carries abundant flakes of biotite with scattered crystals of quartz and feldspar. Lenticular quartz veins are common and mostly conform with bedding structures. Some of the less pure limestone is quite schistose and has, in places, been transformed to dark green amphibolite. Analyses of the Schroeder Creek limestone by H. A. Leverin, of the Mines Branch, gave:

—	Dark grey	Light grey
Insol	2·91	0·52
Fe_2O_3; Al_2O_3	0·48	0·56
$CaCO_3$	89·28	96·07
$MgCO_3$	6·81	2·50

Schists. The abundant, highly schistose strata of the Lardeau series are mainly sedimentary, but certain, intercalated, greenish bands are more likely of igneous origin. Two such prominent bands are exposed in the valley of Schroeder creek, one within a few hundred feet of the base of the Milford group and the other about 4,000 feet below this base (Figure 4). They are not fully exposed but appear to be each at least several hundred feet thick. The same bands were noted in the basin of Falls creek and, presumably, are continuous with other exposures observed towards the south end of Blue ridge. In the basin of Schroeder creek these rocks are in part schistose and in part fairly massive. They are dark to light green, highly altered, and fine grained. Farther south they occur as chlorite and actinolite schists. A specimen from an outcrop on the road between Kaslo and Zwicky was examined microscopically and found to contain abundant needle-like crystals of amphibole, innumerable grains of epidote, and considerable magnetite, lying in a chloritic, partly opaque groundmass. These rocks may be correlated with greenstones of igneous origin associated with the Lardeau series in Lardeau map-area where they are regarded as intrusive equivalents of the Kaslo series (2, page 14).

Metamorphism

The Lardeau series in Sandon map-area, as elsewhere along the shores of Kootenay lake, is distinguished by its highly metamorphic character. This is so pronounced as to have led early investigators to include these rocks with the Shuswap series, a series then thought to form a basement

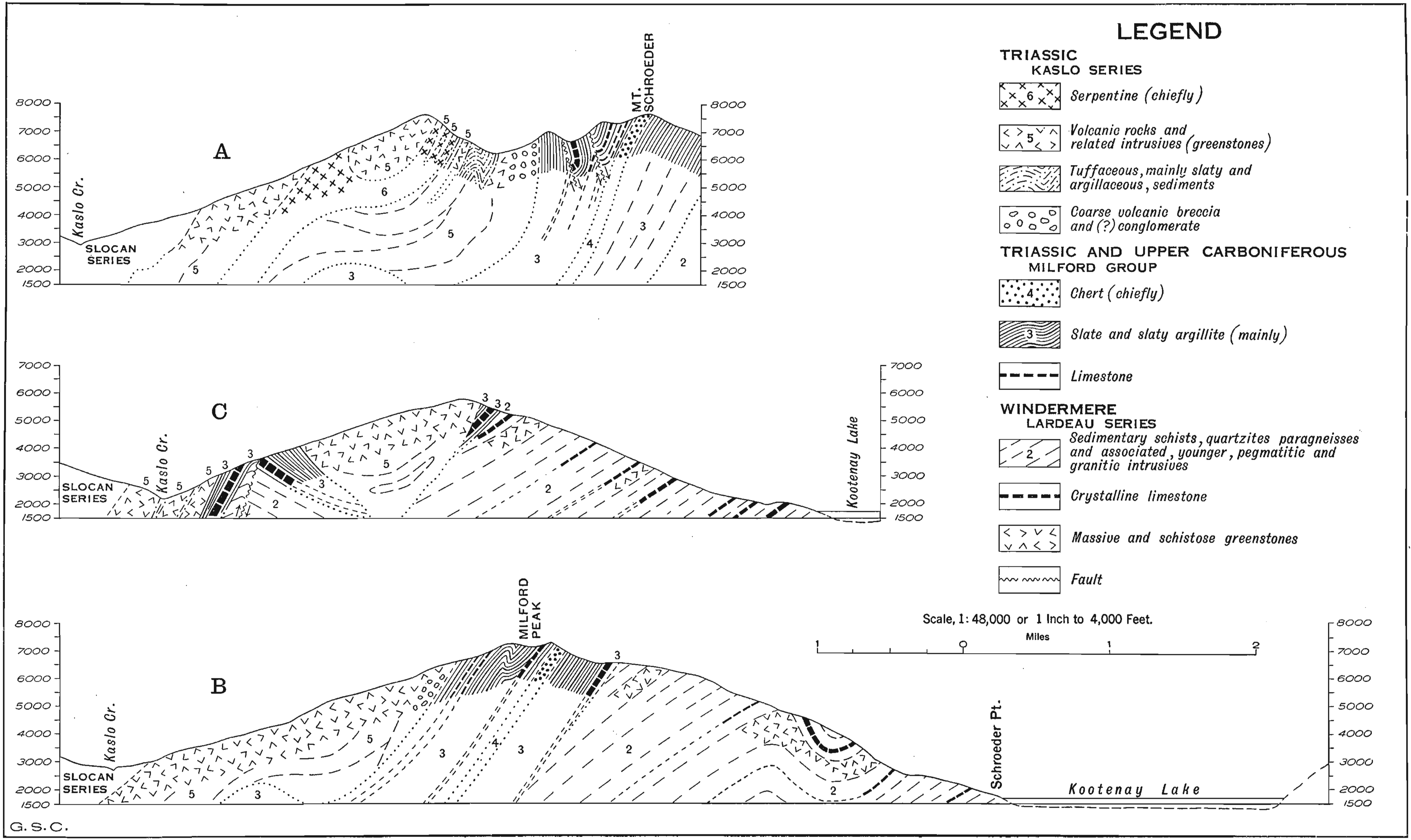


Figure 4. Structure sections of the Kaslo series, the Milford group, and the Lardeau series, Sandon map-area. Sections "A", "B", and "C" continue northeasterly from sections IJ, OP, and ST, respectively (*See* Map 273A and Figure 3, in pocket).

complex of the oldest rocks in the province. Traced into the Lardeau country to the northwest of the head of Kootenay lake, the Lardeau series passes out of this zone of intense metamorphism and resolves itself into rock types whose original characters are, in general, more readily determinable. The greater metamorphism in the south is believed to have resulted from the abundant pegmatitic, granitic intrusives in the vicinity of Kootenay lake. Such intrusives point to a release of magmatic vapours and mineralizing agents such as might be expected to exert marked effects. In Sandon map-area the metamorphic zone connected with the intrusives almost coincides with the Lardeau series, though towards the south, as in the vicinity of Kaslo creek, lower members of the Milford group are more altered than they are farther north, and still farther south, in Ainsworth area, metamorphism of only slightly less intensity than that displayed in the Lardeau series extends into formations correlated with both the Milford group and the Slocan series.

In general the purer beds of limestone and quartzite seem to have resisted metamorphism best, though the limestones have been recrystallized. Many quartzite bands are massive, though adjoining rocks are highly schistose and otherwise altered beyond recognition. The quartzitic rocks vary from phases in which crushing of the component grains is recognizable only under the microscope to others that are highly schistose, and in which quartz, though still the most abundant constituent, is associated with a large proportion of chiefly lamellar minerals of which a light-coloured mica (probably sericite) is generally most conspicuous. The rocks listed in the section of the Lardeau series as quartzitic schists, quartz-sericite schists, and quartz-biotite schists are derivatives of quartzites or quartzitic strata.

Argillaceous sediments and impure quartzitic and calcareous strata have been most completely altered. Recognizable beds of argillite or slate were not observed along the shores of Kootenay lake nor anywhere west of the lake in the southern half of the map-area. North of Milford creek the Lardeau strata are, on the whole, less metamorphosed and, in this direction, a few outcrops of dark grey to black, distinctly argillaceous strata were seen. Most of such rocks were greatly sheared and crumpled, with lustrous schistose surfaces and, in places, were heavily charged with pyrite. Still farther northwest, and extending into Lardeau map-area, argillaceous beds are abundant, but in Sandon map-area they are mostly altered to crystalline schists containing abundant mica in conspicuous scales that give a high lustre to the cleavage planes of the rocks. The mica, in different bands, may be either a colourless or coloured variety. The parting planes of these schists are commonly lumpy from the development of silicates, of which red garnet is the most common and in many places very abundant; other such minerals are staurolite and varieties of amphibole. Quartz is generally conspicuous and plagioclase feldspars were noted under the microscope.

Injection Gneisses and Gneisses

Gneissic members of the Lardeau series represent extremes of alteration and in general afford little clue to their original character. Both in texture and composition they show all gradations from rocks of sedimentary to those of granitic origin. An early stage in such a metamorphosis is exemplified in some outcrops by the presence of aplitic material injected along parting planes in schistose members of the Lardeau series. The intrusive matter forms discontinuous bands a small fraction of an inch wide, and sharply defined against the, in general, much darker sedimentary material. Later stages show a larger proportion of injected material and more extensive metamorphism of the intervening bands of older rock, partly by replacement and partly as a result of recrystallization, until the entire mass becomes granitic in texture though maintaining a distinctly banded appearance (*See* Plate VI). In still later stages, because of continued supply of granitic material, these rocks pass into light-coloured, finely banded, acid granite still retaining structures of the original sediments. The banding is by thin lines of oriented crystals of dark minerals formed, probably, from constituents of the transformed sediments.

The granitic intrusives to which is attributed the intense metamorphism of the Lardeau series of Sandon area, and adjoining parts of Kootenay Lake valley, are presumably connected with the period of intrusion of the Nelson batholith. This assumption is based on the following considerations. (1) The intrusives are similar in appearance and composition to those intimately associated with highly metamorphosed Precambrian rocks of Slocan and Arrow Lakes area (5, 1928, pages 95-97) where the intrusives occupy large areas and grade into members of the Nelson granite. (2) They are not of Precambrian age since they intersect members of the Milford group and possibly, also, later formations.

Relations to Other Formations

Except for the pegmatite dykes, which crosscut the Lardeau series in every direction and with but little apparent regard to its structure, the granitic intrusives tend to conform with the enclosing formations and to occur in their more schistose members. In part, these intrusives advanced by injection into and replacement of the older rocks. They are, regardless of size, medium to fine-grained, sill-like masses, mostly showing a finely banded or gneissic structure. The boundaries of such masses may, in detail, be somewhat irregular, partly as a result of inequalities in the rate of replacement and partly owing to complete fusion and movement of the molten mass. In the latter case all traces of bedding or schistose structures are lost; textures may be less uniform and, in places, coarser, and contacts are more sharply defined and less regular than in the case of the gneissic granitic bodies.

The contact of the Lardeau series with the Milford group (*See* Figure 4) is best exposed in the northern half of Sandon map-area. Where it crosses Schroeder creek dark grey, slaty sediments of the Milford group overlie a heavy band of grey to brownish grey, mashed quartzite or quartzite schist of the Lardeau series. The Milford beds dip from 60 degrees to the southwest to almost vertical, and though the attitude of the underlying quartzite was less readily determinable it appears to be conformable or nearly so. The slaty Milford sediments are succeeded, about 250 feet above their base, by a heavy, dark grey, sparingly fossiliferous limestone. South of Schroeder creek the Lardeau-Milford contact was located on the north, south, and west shoulders of Milford peak. At each of these localities the same, or a similar, quartzite bed of the Lardeau series was observed, and on the west shoulder of the mountain, at an elevation of

Specimen of banded gneiss from area of the Lardeau series east of Kootenay lake and a little south of Kaslo: the lighter bands are fine-grained, acid granite which appears to have been injected between bands of older, dark rock partly replacing them. (Neg. No. 72209.)

about 6,200 feet, this quartzite underlies slaty Milford sediments overlain by a limestone bed about as thick as that on Schroeder creek. On the north and south shoulders of Milford peak the same quartzite and limestone were seen, but at these localities the intervening Milford slate is absent or thinned to a few feet. At each locality the quartzite of the Lardeau series appears to be conformable with the limestone of the Milford group, and to be dipping about 45 degrees to the west or southwest. South of Milford and Falls creeks the contact for several miles follows the upper eastern slope of Blue ridge, but is poorly exposed. Portions of the Milford limestone were, however, observed at intervals for over 2 miles south of Falls creek. In these outcrops the dip of the limestone bed lessens greatly, averaging about 20 degrees to the west. At the head of a creek lying a little south of west from Verandah point on Kootenay lake the Milford limestone is exposed. The immediately underlying strata are hidden, but a short distance down hill some greenish schists appear at a stratigraphic position several hundred feet nearer the limestone than similar looking schists in the vicinity of either Milford peak or Schroeder creek.

At the southern end of Blue ridge the Milford group is missing for a mile or so, in which distance highly metamorphosed members of, apparently, the Lardeau series are in contact with intrusive rocks of the Kaslo series. No quartzite was observed near this contact, the Lardeau rocks including various types of schists and a few feet of buff-weathering limestone or marble.

Farther west the contact is poorly exposed, though at different places fissile, slaty rocks of the Milford group and schistose, partly crystalline, members of the Lardeau series were observed within a few hundred feet of it. Along the road up Kaslo Creek valley, north of the railway, the contact is fairly well exposed. Here the Milford group is represented by a few hundred feet of mostly fissile, slaty rocks overlain by a thick limestone member; and the underlying Lardeau rocks are composed of greenish schists intruded by one or more narrow granite sills. The limestone band is 300 to 400 feet thick and carries a few poorly preserved fossils, but is more metamorphosed than in the more northerly exposures. Its thickness, fossiliferous character, and the fact that it is underlain by slaty sediments similar in character and amounts to those occupying an analogous position on Schroeder creek and east of Milford peak, are substantial evidence that the same limestone bed occurs at each of these widely separate places. Further, the fact that in Kaslo Creek valley the Milford group is underlain by greenish schists, not unlike those occurring at greater stratigraphic intervals below this group as the contact is traced northward to the vicinity of Milford peak, is evidence that there is an erosional unconformity between the Milford group and the Lardeau series.

The Lardeau-Milford contact has been followed in Lardeau map-area over a distance of 32 miles, commencing 6 miles north of Sandon map-area (2, pages 12-14). In this distance no angular discordance has been reported, but it is recorded that in places the basal member of the Milford is a conglomerate that "varies in thickness and nature and is composed of fragments derived from the underlying Windermere (Lardeau series) rocks". Elsewhere in Lardeau map-area small bodies of sedimentary rocks correlated on a basis of lithology and fossil content with the Milford group are stated to rest on widely separated horizons of the Lardeau series.

The intervening 6 miles between Lardeau and Sandon map-areas have been sufficiently explored to indicate the continuity of the Milford-Lardeau contact between the areas. Little doubt, therefore, exists as to the correlation of the strata of the two areas. In Lardeau map-area the available evidence seems unmistakably to indicate that the interval separating the period of deposition of the Lardeau series from that of the Milford group was a long one. In Sandon map-area no conglomerate was observed at the base of the Milford, but as already stated there is some evidence that the Lardeau series had been subjected to erosion prior to the deposition of the Milford group.

In Lardeau area it is reported that " a band of fossiliferous limestone occurs a few feet above the conglomerate" (2, page 13). This limestone probably is the same as that observed near the base of the Milford group in Sandon map-area. South of this map-area the same limestone was located by the present writer with some certainty at a number of places. It may correspond to the limestone band in Ainsworth area referred to by Schofield (21, 1920, page 15) as the Star limestone and placed by him at the base of the Slocan series, but more probably it is equivalent to the limestone band crossing the north fork of Woodbury creek a few hundred feet east of the Star limestone, and hence lying within the pre-Slocan, Josephine formation.

MILFORD GROUP

The Milford group overlies the Lardeau series and underlies or is cut by members of the Kaslo series. Detailed structural and stratigraphic studies across the belt occupied by these rocks have failed to supply evidence of synclinal structure as postulated by LeRoy and Drysdale and have sustained the earlier interpretation by McConnell that these rocks, in general, dip westerly to southwesterly and exhibit successively younger beds in that direction. Additional collections of fossils substantiate Bancroft's conclusions that both Carboniferous and Mesozoic horizons are present, and that no structural or lithological differences distinguish the Palæozoic from the Mesozoic strata. Consequently, the whole assemblage has been grouped and Bancroft's term " Milford ", originally chosen for the Mesozoic members only, has been applied to the entire group. The idea previously advanced that this group, in whole or in part, consists of Slocan strata is, so far as Sandon map-area is concerned, now abandoned, since in this area the Milford group is regarded as stratigraphically below the Kaslo series which in turn underlies and, consequently, antedates the Slocan series.

The following section of the Milford group approximately represents the maximum thickness and character of the several rock types exposed from west to east across the Blue ridge within Sandon map-area (*See* Figure 4).

	Approximate thickness Feet
Slate, platy argillite, limestone, quartzite	2,550
Chert, cherty greenstone, andesite, porphyrite	470
Argillite, slate, limestone, cherty greenstone	1,155
Limestone	310
Slate	100
Total	4,585

North from Milford peak more than 1,100 feet of argillaceous sediments and cherty greenstones lie between the prominent limestone band situated towards the base of the Milford group and the main chert band. Within a distance of 2 miles south of Milford peak the thickness of the sediments intervening between the limestone and chert decreases by about one-half. This lessened thickness is maintained, so far as could be determined, for several miles southward to where the strata are cut off by Kaslo intrusives. The decreased thickness in the south seems largely due to the almost complete disappearance of the cherty greenstones, which are thought to be of volcanic origin and, consequently, liable to marked variations in thickness in comparatively short distances.

Platy Argillite and Slate. The upper half or more of the Milford group, as exposed in the northern half of Sandon map-area, is composed largely of argillaceous rocks. Similar rocks also occur in the lower part of the series, but are associated with a much larger proportion of other rock types. The argillaceous rocks are mostly dark grey to black and carry varying proportions of calcareous and, less commonly, sandy material. They are interbedded with limestone and impure limestone beds from 1 foot to 300 feet thick, and in one particular zone are interbedded with 100 feet or more of quartzite and quartzitic strata. The purely argillaceous beds grade insensibly into the calcareous strata. They are characterized by strongly developed, platy, slaty, or schistose partings brought about in part by deformation and in part by the original bedding in which alternate laminæ, a small fraction of an inch wide, vary slightly in composition. The parting planes very nearly coincide with the bedding. In general appearance and structure the argillaceous rocks much resemble the slaty members of the Slocan series as developed in their eastern outcrops, but are more generally calcareous and are interbedded with rocks quite different from those constituting the Slocan series.

Quartzite. Sandy beds are associated in small amount with the argillaceous members of the Milford group. They are mostly only a few inches thick and grade into the argillaceous rocks.

On the summit of Blue ridge, about a mile northwest of Milford peak, a quartzite band, 100 feet or more thick and about 1,000 feet stratigraphically above the middle of the chert belt, crosses an east-west jog in the ridge in a northwesterly direction and dips about 40 degrees to the southwest. The rock is massive, grey to brownish grey, medium grained, somewhat calcareous, and holds much feldspar.

Quartzite was also noted on the east slope of the valley of Kaslo creek on the Harp and Manganese properties. Here the quartzite is a grey rock forming bands a few inches thick, alternating with bands of more argillaceous material of about the same thickness. Outcrops of the quartzite weather brown to black as a result of the decomposition of contained iron and manganese minerals. Examined under the microscope the quartzite was seen to carry varying proportions of black and reddish oxides and, locally, abundant grains of a manganiferous garnet (spessartite?) commonly surrounded by rims of black manganese oxide. Most specimens also show abundant, tiny, diamond-shaped crystals of another manganese mineral, probably braunite. Aside from these manganese minerals the rock is composed chiefly of quartz grains.

Chert and Associated Volcanics. Probably the most interesting member of the Milford group is a narrow but continuous band composed principally of chert, averaging about 400 feet in width, and extending from the northern edge of Sandon map-area, at the summit of mount Schroeder (Plate II), to the head of Falls creek, a distance of about 7 miles. Farther south, along the upper eastern slope of Blue ridge, it is obscured by drift. Two miles south of Falls creek it and overlying members of the Milford group are cut out by porphyrite intrusions of the Kaslo series. The only other occurrence of chert that might correspond with this belt is on the summit and near the south end of Blue ridge, within an area of Kaslo intrusives where small inclusions of chert lie at a stratigraphic horizon corresponding roughly with that of the chert band farther north. North of Sandon map-area the chert belt has been observed on the high summits at the head of Davis and Cooper creeks.

The chert is a dense, hard rock, colour banded in pale tints of red, purple, and green to creamy white, but light green to white predominant. The bands vary from less than an inch to several feet wide and mostly follow the bedding, which is marked by fine, closely spaced lines and is not everywhere readily detected.

Under the microscope the chert is seen to be extremely fine grained, to be composed largely of minute particles of silica lacking regular boundaries, and to contain wisps of chloritic and sericitic material, a little epidote, and grains of magnetite some of which are partly oxidized. Bedding is indicated by parallel thin bands of slightly varying coarseness. An approximate analysis by W. A. Jones, University of Toronto Laboratory, of a typical specimen of this chert, gave:

	Per cent
SiO_2	92·04
Al_2O_3	2·21
FeO	1·08
Fe_2O_3	0·85
CaO	0·75
MgO	1·02
K_2O	0·64
Na_2O	0·40
H_2O	0·53
Total	99·52

The bedding structures are those of a sediment, but owing to its dense texture and abnormally high silica content it is uncertain whether the chert is an extremely fine siliceous silt or, more probably, a chemical precipitate. If a precipitate, its origin could be ascribed to volcanic emanations accompanying the andesite and certain tuffaceous beds associated with the chert belt.

A lens-shaped body of massive, dark green, fine-grained andesite a few feet wide occurs within and towards the southwest side of the chert belt on mount Schroeder. It carries a great deal of epidote, in part disseminated through the massive rock and in part forming clusters or crystalline aggregates filling irregular cavities. As exposed the rock is uniformly fine grained and seems to be conformable with beds of greenish grey, rather cherty, well-bedded rocks which, in turn, are conformable with beds of chert. The andesite was seen only at this one place.

PLATE VII

Looking northwest to mountains at the headwaters of Schroeder creek: mount Jardine on the left and mount Schroeder on the right. (Neg. No. 67552-3.)

Associated with, and apparently related to, both the andesite and the chert are beds of fine-grained, greenish grey, thinly bedded, rather siliceous tuff or tuffaceous sediments. These rocks are so altered that their original composition is a matter of doubt. Although not as hard as the chert they have a cherty appearance and carry varying proportions of finely disseminated silicia which, as in the case of the chert, was probably deposited chemically. Beds of this character, intercalated here and there with narrow bands of typical chert, are abundant to the east of the main chert belt west and south of Milford peak. They are quite distinct in appearance from the argillaceous sediments with which they are interbedded to the east of the chert belt and are thought to be chiefly volcanic ash.

Porphyrite. A sill 90 to 100 feet thick, of a medium-grained diorite porphyrite, occurs near the middle of the main chert belt. It was noted and traced by Bancroft (1, 1919, page 45), and regarded as a dyke related, in origin, to the Kaslo series. This interpretation has been sustained by more recent work. In appearance and mineral composition it is quite like the intrusive members of the Kaslo series. As exposed on Mount Schroeder the porphyrite is a massive, medium-grained, greenish grey rock carrying about equal proportions of light and dark green minerals. Studied microscopically it is seen to be composed chiefly of feldspar and a uralitic hornblende, the latter occurring in large and small crystals and blades. Granular aggregates and isolated small crystals of pyroxene are also present. The feldspars include some orthoclase but more plagioclase, about oligoclase in composition. Accessory minerals include a little quartz, magnetite, ilmenite altered to leucoxene, and chloritic alteration products. The texture is equigranular, both feldspar and hornblende occurring in well-developed crystals.

Other dyke-like bodies of very similar appearance were noted on the east slope of Blue ridge south of Milford peak, but were not traced far.

Limestones. Every limestone bed of appreciable size observed by the writer was found to be fossiliferous. The fossils are commonly closely crowded and are mostly fragments of crinoid columns. The limestones are typically fine grained, mostly dark coloured, and commonly flaggy, though in some cases quite massive. They grade either across or along their strike into limy argillites. The heavy, apparently continuous, limestone band near the base of the Milford group changes in appearance from north to south along its strike as a result of increasing metamorphism. Where it crosses Schroeder creek it is a dark grey, flaggy rock of uniform texture. Near Milford peak it is distinctly lighter in colour, more massive, and in part finely crystalline. Where it crosses Kaslo creek it is compact, mostly finely crystalline, carries a conspicuous amount of graphite in small bunches and streaks, and is, in part, strikingly banded dark grey and white, the white bands being quite siliceous.

Structure (See Figure 4)

On Mount Schroeder ridge (Plate VII) the Milford strata are vertical or nearly so, and for a short distance may be overturned. Farther south, in the vicinity of Milford peak, the strata dip west at 40 to 60 degrees. Still farther south, as along the upper east slope of Blue ridge, they dip west at about 20 degrees and, except where cut off by Kaslo intrusives, dip under the Kaslo volcanics to reappear on the west side of Blue ridge in a sharp, anticlinal fold.

The structure of the group is everywhere complicated by faulting, much of which has taken place about in line with the strike of the formations. A cross-fault running northeasterly along the southern shoulder of Milford peak, about 500 feet below the summit, has displaced the formations on the southeast of the fault 100 to 200 feet to the southwest. A strong shear zone crosses the lower valley of Kaslo creek to the east of where the lower limestone member of the group crosses the railroad and road above it. This zone is several yards wide and composed of sheared, slickensided, slaty rocks. It occurs on the axis of an anticlinal fold, but owing to paucity of exposures farther north and south could not be accurately interpreted.

Relations to Other Formations

Along the southeastern flank of Blue ridge the western edge of the area of Milford strata is defined in part by intrusives of the Kaslo series, but is not well exposed. From the headwaters of Falls creek to the north edge of the map-area exposures are relatively abundant and the west contact of the Milford group was observed at many places. From Falls creek to a point directly west of Milford peak the thickness of the part of the Milford group overlying the chert belt changes from about 700 feet to over 2,500 feet. This thickness is maintained for the next 4 miles to Mount Schroeder ridge. Near Milford peak, and for about 1 mile northwest along the contact, the adjoining Kaslo rocks resemble a lava in which fragments of crust have been incorporated. Farther northwest they are mostly coarsely fragmental, resembling rudely bedded volcanic breccias. Such rocks are well exposed along the east and southeast slopes of Iron mountain and on the north slope of the valley of Schroeder creek. A similar rock type adjoins the Milford group on Mount Schroeder ridge. Elsewhere along the contact finer textured Kaslo rocks, in part roughly bedded and in part massive greenstones similar to those occurring farther south, were observed. The nature of this assortment of rocks of the Kaslo series definitely precludes the idea of intrusion along this part of the contact, but does suggest that the Kaslo rocks were laid down on a land surface or on a surface that was only locally covered with water and subject to erosion. The underlying members of the Milford group wherever examined were platy, argillaceous and calcareous types, no more deformed near the contact than at a distance from it. At each observed point, too, the attitude of the sediments appeared to coincide with the line of the contact. In places it was noted that the upper few feet of the Milford rocks were more decomposed than those farther from the contact, a condition suggesting that the Milford beds had been weathered and eroded prior to deposition of the Kaslo series. If so, the marked decrease in thickness of the upper part of the Milford group south of Milford peak may have been due to pre-Kaslo erosion. However, the upper part of the Milford strata is of rocks that, with the exception of limestone beds, are difficult to trace and are so alike that it is impossible to be certain whether or not different beds are in contact with the Kaslo series at different places.

Age

Though there is nothing in the appearance or structure of the Milford group to indicate that its members are other than of one geological period, palæontological evidence indicates that the group includes both Palæozoic and Mesozoic members. A number of fossil collections made by the writer, and chiefly from that portion of the group that overlies the chert belt, have been reported on by F. H. McLearn of the Geological Survey as follows:

536F.C. (8431). From limestone float, probably not far out of place; about ½ mile south of Schroeder peak and 400 feet below the summit of Schroeder ridge:
Belemnites? sp.
Immature keeled ammonite
Age: Mesozoic; Triassic?

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

310F.C. Fossiliferous limestones, south slope of Schroeder peak:
Crinoid stem
Age: Mesozoic

311F.C. Fossiliferous limestone float from the south slope and near the summit of the divide between Jardine and Schroeder peaks, probably nearly in place:
Crinoid stems
Belemnites? or Atracites?
A coral
A small Ammonite with ceratitic suture line
Age: Mesozoic; may be Triassic

Collections from strata below the chert belt within Sandon map-area contain numerous crinoid stems but no determinable fossils. A few miles north of the area, along the continuation of the same belt of Milford strata, a collection (5564) made in 1917 by M. F. Bancroft from the ridge east of Cooper mountain and obtained from near the base of the group was reported by E. M. Kindle (1, 1917, page 37) as including "*Athyris* sp. undt. and *Spirifer* cf. *marionensis*. The presence of a *Spirifer* which is either identical or closely related to *Sp. cameratus* seems to place this horizon in the Pennsylvanian."

The above determinations indicate that somewhere at or below the chert belt either there are beds ranging in age from Palæozoic to Mesozoic or that at some horizon a disconformity marks an hiatus between Upper Carboniferous and Triassic sedimentation. No lithological or structural change being anywhere apparent, the entire assemblage has been mapped under the one name and referred to as the Milford group.

KASLO SERIES

The Kaslo series occupies a single area of about 27 square miles in the eastern half of Sandon map-area and lies between the Milford group on the east and the Slocan series on the west. The area narrows southeastwards from about 3 miles to less than 1 mile, and terminates about 3 miles southeast of the map-area. This series has been variously referred to as the "Kaslo volcanics" (owing to the abundance of its volcanic members), the "Kaslo schists" (by reason of the marked schistose character of large portions of it), and the "greenstone belt" (because of the predominant colour of its constituent rocks). None of these terms is entirely correct as the rocks vary in origin, structure, and colour. The series shows no regular stratigraphic succession but is made up of overlapping lenses of volcanic flows, pyroclastic deposits, and tuffaceous sediments associated with sheets, dykes, plugs, and laccolithic masses of related intrusives. Vertical or steep jointing is well marked in places and is about at right angles to the general trend of the series; this feature in conjunction with the high dip of the planes of schistosity has resulted in a very rugged topography, with peaks bounded by steeply inclined or vertical walls (Plate III B). The more abundant members are volcanic, but these, particularly in the more southern exposures, are intimately associated with a large proportion of related intrusive types, and the whole is intercalated with minor sedimentary beds whose colours range from green to black. The volcanic members are represented both by pyroclastic rocks and flows.

Pyroclastic Rocks. Pyroclasts range from fine-grained tuffs to breccias carrying fragments, chiefly lapilli, several inches in length. The rocks are mostly greenish, though not uncommonly the coarser members in particular are somewhat mottled in shades of green and greenish grey to grey. Both matrix and fragments are fine grained and so altered that their original composition is uncertain. The fragments commonly stand out because they are, in general, less altered than the matrix. They vary from light grey to dark green, the greenish ones being difficult to distinguish from the matrix, even under the microscope, the composition and texture of matrix and fragment being nearly alike and alteration having further obscured the boundary lines. Recognizable essential minerals include crystals of green amphibole, partly altered grains or crystals of pyroxene, and altered oligoclase-andesine, and place the composition of the green matrix and green fragments as andesitic. The lighter coloured fragments are commonly more siliceous and some are quite cherty, whereas other darker grey, fine-grained ones seem to be argillaceous. They resemble members of the underlying Milford group and are less numerous than the greenish, andesitic fragments. The coarser fragmental beds grade into the finer, which may be referred to as tuffs. The finer grained tuffs, unless seen in association with coarser fragmental types, are difficult to distinguish from some of the lavas. Bedding is, in general, poorly defined and where best shown, as in the coarser members, is indicated by an alinement of the fragments within a comparatively structureless groundmass.

The fragments, large or small, are mostly angular but some are well rounded and resemble pebbles of a conglomerate. All commonly are flattened, possibly by the deformative movements that produced the pronounced schistosity exhibited, here and there, by the different members of the Kaslo series. The rounded, greenish, andesitic fragments are lapilli which probably would tend to develop rounded rather than angular contours as they solidified. The rounded outlines of the cherty or argillaceous fragments appear to be due to water abrasion.

The volcanic breccias and tuffs occur most conspicuously towards the base of the Kaslo series. They are well exposed near the summit of

Blue ridge between the headwaters of Enterprise creek and the northern boundary of the map-area. In this section they have a stratigraphic range of at least 1,000 feet, but are mingled with flows and intrusive bodies in proportions that vary from place to place. The coarser breccias were not observed southeast of Enterprise creek, and in this direction the tuffaceous members give way to flows, flow-breccias, and intrusives. The variation in character and thickness of the several rock types of the Kaslo series immediately overlying the Milford group is a noteworthy feature and one that characterizes this series as a whole.

Flows. Much of the Kaslo series is composed of fine-grained, massive to schistose, green rocks that are believed to be chiefly lavas associated with varying proportions of flow breccias. The flow breccias contain small, angular fragments of lava crust that are difficult to distinguish from the lava matrix except on wet, slightly weathered surfaces.

Examination under the microscope indicates that most of the lavas and flow-breccias are andesites, though more acid and possibly more basic types also occur. The principal minerals are plagioclase and green amphibole. The former ranges from albite or albite oligoclase to andesine. The amphibole is chiefly hornblende. In some specimens it seems to be primary, whereas in others it resembles an alteration product of pyroxene. Actinolite is a common secondary mineral in the more schistose members. Augite is generally abundant in the less altered, more massive rocks and occurs mostly in small crystals or grains. Orthoclase is common but not abundant.

Inconspicuous flow structures occur in these lavas. They are generally best shown in the flow breccias, and are indicated by a rude orientation of the fragments parallel to narrow discontinuous bands or streaks of a shade of green slightly different from that of the main rock body. No pillow structures were observed, and only a few doubtful bubble cavities were noted.

Intrusives. The intrusive members of the Kaslo series are similar to the lavas in composition and in places grade texturally into them. In general, however, though the two types may be most intimately associated, their boundaries are readily distinguished by the coarser texture of the intrusive. The intrusives are most abundant in the southern part of Kaslo area along the eastern and southern slopes of Blue ridge where they form an apparently continuous sheet in the Milford strata. Elsewhere they form less regular bodies, as in the vicinity of the headwaters of Enterprise creek and on the divide between Lyle and Rossiter creeks.

They are medium to rather coarse-grained, equigranular rocks containing a large proportion of dark minerals and little or no visible quartz. They may be massive or exhibit any degree of deformation. Their prevailing colour is green, more pronounced in the more altered types but also varying with the proportion of original mafic minerals present. Plagioclase and amphibole are the abundant minerals, the former having about the composition of andesine and the latter most resembling hornblende and occurring in part as distinct, well-developed, twinned crystals and in part as a uralitic alteration product of original augite. The latter may, in the less altered rocks, be preserved in amounts sufficient to constitute an essential mineral. Other primary but less abundant constituents are othoclase, quartz, biotite, magnetite, and ilmenite. Secondary minerals include abundant chloritic products, epidote, carbonate, serpentine, talc, leucoxene, and iron oxides.

The following analysis by W. A. Jones, University of Toronto Laboratory, is of a comparatively fresh, massive specimen obtained from an outcrop above the highway northeast of Zwicky, where rock of this sort forms a large laccolithic mass of granitic texture and composed of pale green amphibole, plagioclase (about andesine), and chlorite, epidote, and other alteration products.

	Per cent
SiO_2	45·92
Al_2O_3	16·34
FeO	2·34
Fe_2O_3	1·92
CaO	19·00
MgO	12·46
Na_2O	0·85
K_2O	0·30
CO_2	0·41
TiO_2	0·14
MnO	0·01
P_2O_5	0·03
H_2O	1·03
	100·75

The significant features of this analysis are the low silica and high lime and magnesia content as compared with alumina, which is about that of an average diorite. In the transformation of the primary constituents, particularly the amphibole, to chlorite and epidote, lime and magnesia may have been added and silica carried away. Some carbonate, probably chiefly calcite, is evidently present in the altered rock.

Serpentine. In places the igneous members of the Kaslo series are almost completely changed to secondary minerals, as for example, the serpentine member. This occupies most of two distinct belts in the northern part of the map-area, northwest of the heads of Emerald and Schroeder creeks (*See* Map 273A, in pocket). The more westerly belt is much the larger and is mostly composed of serpentine, whereas the other belt is largely altered to a carbonate-talc rock and contains intercalated greenish schists.

The serpentine is a dark, olive-green rock of uniform texture and weathers to a dirty or dull white. Fibres of serpentine wool have developed along shear planes. Under the microscope the rock appears as a fibrous, almost colourless mass of serpentine blades with grains of magnetite, chromite (?), and some carbonate. The purity of the serpentine; its occurrence, particularly in the more westerly belt, as a distinct lithological unit; and its sharp contacts with adjoining greenstone rocks indicate a distinctive original composition. The form of this main serpentine belt, over most of its length, is that of a sill or a flow. Its southern end, however, is, in plan, somewhat knob-shaped and crosscuts the adjoining rocks of the series, which are chiefly fine-grained greenstones of the lava type. From such features it is believed that this serpentine body is an altered basic intrusive of the Kaslo series injected as a sill-like body fed from its cupola-shaped southern end.

The smaller, easterly belt of serpentine has a more complex composition than the other. It contains a large proportion of serpentine, and of talc-carbonate rock derived from the serpentine, intercalated with bands, up to 100 feet wide, of, chiefly, schistose greenstone of extrusive origin. The serpentine and derived rocks are probably connected at depth with the main serpentine belt to the west, their more extensive alteration being due to their occurrence in a zone of deformation along which subsequent alteration has occurred.

Towards the base of the Kaslo series, particularly on the east slope of Jardine mountain, the rocks over a width of several hundred feet carry abundant calcite- and magnesian-bearing carbonates. The surfaces of these rocks have a peculiar, pebbly appearance much resembling that of conglomerates. These rocks farther southeast are apparently breccias and, therefore, those in the vicinity of Jardine mountain are also probably breccias that have been attacked by circulating, probably, meteoric, carbonated waters. The matrix has suffered most decomposition and replacement and has, in consequence, tended to weather away, leaving the less altered fragments projecting like pebbles of a conglomerate.

Sediments. Sediments form only a small part of the Kaslo series. They form narrow, discontinuous lenses aggregating only a few hundred feet in thickness. The largest observed exposures are on the ridge extending from Jardine mountain to Beaver mountain, and others occur in highway and railway cuts in the valley of Kaslo creek below Zwicky. The sediments are dark grey to greenish grey, mostly fine to medium grained, in part massive and in part slaty or schistose. A thin section of a dark grey specimen from the summit of Jardine mountain was found to carry little or no recognizable quartz. Scattered through the fine-grained, indeterminate groundmass were numerous microlites of feldspar and a number of well-formed crystals of plagioclase. The composition of these sediments and their association with igneous rocks indicate a tuffaceous origin.

Structure and Contact Relations (*See* Figure 4)

The Kaslo rocks form an almost structureless mass. Contacts with the underlying Milford group and the overlying Slocan series afford the principal clues to their structure and, consequently, to their thickness. The Milford group, except where cut off by intrusive members of the Kaslo series, forms a syncline under the Kaslo rocks of the south end of Blue ridge and, farther west, resumes its more general southwesterly dip. This double fold is believed to occur also in the overlying Kaslo series in this southern part of the area. Farther north, the general structure of the Kaslo series is less readily interpreted, but on the Beaver-Jardine-Schroeder Mountain ridge the succession and dips of fragmental volcanic and sedimentary members imply another double fold, a syncline followed by an anticline. If this structure has been correctly inferred and, as seems likely, persists through the intervening length of the outcrop area, a fairly satisfactory estimation of the thickness of the series becomes possible. On this conception (*See* Figure 4) the maximum thickness, between Jardine mountain and a point a little south of the mouth of

Beaver creek, is about 6,200 feet, and the minimum thickness, in the vicinity of Kaslo creek, is less than 3,000 feet.

The basal members of the Slocan series contain erosion materials from the uppermost members of the Kaslo series. There is, however, little apparent discordance between the two series along their contact. At the few places where an appearance of angular unconformity exists, it may be attributed to slumping of the Slocan slates, to slaty cleavage resembling bedding, or to local deformation and faulting of the Slocan slates against the more massive Kaslo greenstones. Nowhere were Kaslo rocks found to invade the Slocan strata, although the contact is well exposed and was carefully studied. This condition is unlike the Kaslo-Milford contact where Kaslo intrusives invade the underlying Milford strata. Intrusives are most abundant in the lower part of the Kaslo series, but, particularly in the southern part of the map-area, do occur to some extent near, if not actually at, the top. The absence of intrusion into the Slocan series favours the view that the Kaslo intrusives are of the same age as the effusive and pyroclastic rocks. The abrupt cessation of both volcanic and intrusive rocks at the Slocan series contact indicates at least a time interval during which volcanic activity died away.

Mode of Formation

So far as the sedimentary members of the Kaslo series are concerned there is little to indicate whether or not it is marine. However, the Kaslo series is underlain and overlain by marine formations which bear considerable lithological resemblance to some of its sedimentary members. This is particularly true of certain platy, argillaceous sediments occurring within a few hundred feet of the base of the Kaslo series in the valley of Kaslo creek less than a mile southeast of Zwicky. No sediments, however, occur in the upper part of of the Kaslo series and, so far at least as Sandon map-area is concerned, sedimentation was not continuous from Kaslo into Slocan time. Except for the sedimentary beds there is little to indicate that the lavas and pyroclastic rocks were extruded or laid down under water. The pyroclasts are mostly so poorly sorted as to suggest that they were deposited on land.

Alteration

Alteration of the more massive members to greenstones commenced soon after or even during formation of these rocks and involved the development of chlorite, serpentine, uralite, saussurite, and albite by accompanying volcanic gases and heated aqueous solutions. The large body of serpentine and other smaller bodies of the same rock probably formed at this early date. On the other hand much alteration undoubtedly occurred long after the deposition and intrusion of the Kaslo series. Much of this later alteration may be related to the period of the intrusion of the Nelson batholith when orogenic disturbances caused much of the deformation of the Kaslo series, and zones of weakness generated by such deformation facilitated subsequent alteration by juvenile and meteoric waters. Solutions accompanying vein formation appear to have resulted in extensive carbonatization and the development of conspicuous amounts of talc and, more locally, of the bright green mica, mariposite. In the vicinity of the quartz veins on the Phoenix gold property the big serpentine body is largely altered to talc and a brownish weathering, calcium-magnesium-iron carbonate. On the Voyageur claim carbonate and mariposite are abundantly developed. Similar alterations were observed elsewhere in the area of Kaslo series both within and without (5, 1926, page 48; 2, pages 118-124) the map-area.

Another type of alteration has resulted from the circulation of carbonated meteoric waters which, in the vicinity of the east slope of Jardine mountain, have partly replaced a belt of rocks, composed principally of volcanic breccias, by abundant, calcium and magnesium-bearing carbonate.

Mineralization

The Kaslo series carries a greater variety of mineral occurrences than any other formation in the area, but few of economic importance. Early explorations in the Slocan mainly centred on a number of discoveries in the "greenstone" belt, but were subsequently diverted to more lucrative showings in the Slocan series and the adjoining Nelson granite.

The principal metals of the mineral deposits in the Kaslo series are gold, silver, lead, antimony, and copper. Placer gold is reported to have been discovered in the beds of streams draining the flanks of Blue ridge, and in particular in the valley of Enterprise creek. Gold also occurs in quartz veins associated with chalcopyrite and pyrite. Silver-lead veins carrying high silver values have received most development to date. An important occurrence of antimony sulphide (stibnite) is in quartz veins on the Alps Alturas property to the north of the area (5, 1926). Copper discoveries have as yet been of little commercial interest, but chalcopyrite is a not uncommon constituent of quartz veins.

Age

The Kaslo series is underlain and overlain by sediments in which fossils of Mesozoic, probably Triassic, age have been discovered. On this basis the age of the series may be referred with some confidence to the Triassic.

UNDIFFERENTIATED MESOZOIC AND(?) PRE-MESOZOIC

At many places, mostly south of Sandon map-area, there are bodies of sedimentary, and in some cases volcanic, rocks isolated in the Nelson granite. Though they are presumed to be mostly parts of the Slocan series some may be older. They are intruded by the Nelson granite and by minor bodies of mainly acid irruptives. These rocks are widely distributed within Slocan map-area. For the most part they are clustered in areas the limits of which have been approximately outlined on the accompanying maps. Within these areas most of the inclusions are too small to be mapped. Elsewhere individual inclusions are as much as several square miles in extent.

These rocks, especially those of the smaller inclusions, have been metamorphosed by the Nelson intrusives, though the effects have depended on their composition and a variety of other factors. As a whole, and particularly in the eastern part of Slocan map-area, metamorphism has not been as intense as might be expected. Small inclusions, 100 feet or less in length and width and, apparently, only a few feet or yards deep, have in many places been changed to fine-grained, crystalline schists whose original composition is unknown, but larger bodies have, except possibly along their edges, preserved their original textures and structures so well that it is rarely difficult to identify the several members of which they are composed. These resemble members of the neighbouring Slocan series and include a variety of argillaceous, quartzitic, and limy sediments. The argillites have passed partly to a hornfels in which andalusite is a characteristic and abundant constituent and is associated with small flakes and shreds of biotite which under the microscope are reddish brown. Sericite is also a common alteration product in argillaceous and quartzitic rocks. The quartzites and quartzitic sediments have their structures well preserved, and in most places bleaching is about the only sign of change; close to the batholithic contact, a notable amount of sericite may be present, and impure varieties may contain a little garnet, biotite, and amphibole or other minerals developed from aluminous or calcareous impurities. Some limestone beds are partly to completely recrystallized. They are abundant in the more easterly areas, as on either side of, but mostly east of, Keen creek. Associated with them are other limy strata which are commonly more altered than the purer limestone beds.

The more westerly inclusions are, in part, more strongly metamorphosed, particularly the large one in and about the basin of Aylwin (Eightmile) creek a few miles south of Silverton. This body shows many variations in degree and kind of metamorphism. Locally, as on the L.H. group of claims, it has been so greatly changed that it is difficult to distinguish inclusion from phases of the Nelson granite. Elsewhere the inclusion has been invaded by many irregularly shaped and, in places, wide bodies of a medium-grained, evenly granular to porphyritic granite carrying abundant quartz and a conspicuous amount of pyrite, and, in places, chalcopyrite. These intrusives are believed to be more directly connected with the ore mineralization in their vicinity than most of the minor acid intrusives of Sandon or Slocan map-areas. Members of the inclusion contain, in addition to the normal sedimentary types encountered farther east, a large proportion of greyish green to greenish rocks; apparently of volcanic origin. They are dense to finely crystalline rocks, some of which contain abundant phenocrysts of green, uralitized pyroxene which under the microscope show thick prismatic sections commonly 5 or 6 millimetres long. The matrix of the porphyritic rocks is in some cases a distinctly igneous intergrowth of crystals and shreds of green, pleochroic amphibole, numerous small crystals of some pyroxene, plagioclase feldspar, and, generally, abundant quartz; in others it is more granular and may be largely obscured by alteration products. Particularly conspicuous in the vicinity of Highland Light peak, near the batholithic contacts, is another dark, granular rock in which occur light-coloured bodies up to an inch or more in diameter that resemble fine-grained granite or felsite and give the rock the appearance of a breccia or agglomerate. Under the microscope the fragmental appearance is less noticeable and the light-coloured, granitic bodies grade into the darker matrix, which is composed of the same materials but in different proportions. Both have a recrystallized appearance and are composed of abundant quartz grains associated with biotite, amphibole, and quite a little feldspar of uncertain composition, but probably sodic plagioclase. As a rule the matrix contains more small flakes and shreds of reddish brown biotite. Much amphibole, probably actinolite, and some magnetite and iron sulphide are also present. This curious rock may have been a volcanic breccia or, possibly, a conglomerate. Most of the other members of this large inclusion are distinctly granular and recrystallized. Some, because of the large percentage of quartz grains and paucity of feldspar, appear to have been sandstones; others carrying much feldspar and mafic minerals, chiefly amphibole and biotite, may have been tuffaceous rocks; and still others are almost certainly volcanic. The less altered varieties are chiefly quartzitic rocks, some very pure, others limy or argillaceous.

This large inclusion was mapped on the West Kootenay sheet as Lower Selkirk, thereby correlating the rocks with the Kaslo series. It appears to the writer, however, that the several members bear, on the whole, a stronger lithologic resemblance to the Slocan series. The less metamorphosed, normal sedimentary types find exact counterparts among the more massive members of the Slocan series as exposed in the westerly parts of their outcrop area. The other members, including those resembling volcanic rocks and particularly those in which large phenocrysts of pyroxene are so abundant, are very similar to volcanic members of the Slocan series exposed to the northwest of Sandon map-area on both sides of the valley of Bonanza creek (5, 1928, pages 98-99; also map).

Many small inclusions in the Nelson batholithic rocks occur along both shores of Slocan lake and are mostly too small to map. They lie in the Nelson gneiss and in the crushed porphyritic member of the Nelson granite, and show all gradations from rocks that undoubtedly are foreign to the batholithic intrusives, to others that have been completely granitized and have in consequence much the same composition as the intrusives. Such rocks closely resemble some of the undivided Windermere rocks seen farther north along the west side of Slocan lake, and possibly should be included with them. They have been separated partly because they are associated with different members of the Nelson batholithic complex and partly because those occurring along the east shore of the lake are, in places, not far from larger bodies of rocks that seem to be isolated remnants of the Slocan series.

The strata of the inclusions in the post-Triassic intrusives, except those associated with the Nelson gneiss on the shores of Slocan lake, dip at moderate to high angles, and there is a noticeable tendency for both strike and dip to conform with the contact with the surrounding intrusives. This feature is most marked in the larger, belt-shaped bodies of the older rocks, such as occur in the eastern half of Slocan map-area, and is least characteristic of smaller bodies that have no marked elongation. Within those areas of the Nelson granite in which inclusions are numerous (*See* Map 272A, in pocket) the tendency towards structural conformity is again very noticeable, since the longer axes of the inclusions are commonly about parallel with the bedding and with one another. This conformity of bedding structures with batholithic contacts is well exhibited along the contacts of the main areas of the Slocan series with the batholithic rocks, and is particularly noticeable in two belt-like areas flanked by batholithic intrusives, one of which lies southwest of the Comstock-Virginia mine in Sandon map-area, and the other northeasterly from the valley of Keen creek near the Index property in Slocan map-area. Although these two belts strike almost at right angles to each other, and the Keen Creek belt strikes at right angles to the general trend of the Slocan series, their component strata form synclinal structures the axes of which strike about parallel to the directions of the belts. The same holds true of the large belt-like inclusion of undifferentiated rocks lying east of the Revenue property, on the east slope of the valley of Keen creek. This belt has a general north trend, corresponding to the strike of its constituent members, which form a compressed syncline. Towards its south end the belt is broken through by the batholithic intrusives and swings to the east as a host of inclusions, most of which are too small to be mapped. Each inclusion examined was found to occupy a relatively narrow, roughly elliptical area pointing eastward with the strike of individual beds within it.

SLOCAN SERIES

The Slocan series is widely exposed in Sandon and Slocan areas and contains most of the important silver-lead and zinc deposits. It continues to the northwest, but southwards is cut off by batholithic intrusives. The series comprises a variety of sediments which, for convenience in description, are classed as slates, argillites, limestones, quartzites, conglomerates, and tuffaceous beds. All gradations in textures and composition from one variety to another may be found. In structure they range from massive, blocky rocks to others notably fissile and slaty. The series has been subjected to varying degrees of local and regional, dynamic and thermal metamorphism.

Slates. The term is here applied to all platy or fissile rocks of distinctly argillaceous composition. Such rocks predominate in the eastern half of the outcrop area. Another prominent belt of slate, occupying a high stratigraphic position, occurs as a broad syncline along the eastern slopes of Carpenter Creek valley southeast and northwest of Parapet (*See* structure sections CD and EF, Figure 3, in pocket). This belt is repeated on the summit of the flat-topped ridge between Carpenter and Howson creeks; at the top of Idaho peak; on the summit of the ridge extending easterly from Carpenter mountain; and across the valley of Carpenter creek near New Denver. Slaty rocks occur elsewhere in the series, but are subordinate to other rock types.

The slates are typically fine-grained rocks varying through shades of grey and green to black. They include, towards the middle and top of the series, several hundred feet of thinly banded rocks in which alternate bands are light grey, dense, and quartzitic and the others are darker grey and argillaceous. Bedding is commonly indicated by narrow bands of alternating shades corresponding to slight differences in composition, or by occasional interbedded strata of quite distinct characters. Most of the slates cleave at a small angle or parallel to the bedding.

In composition the slates vary from purely argillaceous rocks to argillaceous quartzites on the one hand and to argillaceous limestones on the other. A sample of andalusite schist, collected by C. W. Drysdale from Keen creek, was analysed by M. F. Connor, Mines Branch, with the following result.

	Per cent
SiO_2	61·32
Al_2O_3	21·40
Fe_2O_3	1·28
FeO	5·00
MgO	2·20
CaO	0·80
Na_2O	1·35
K_2O	2·62
TiO_2	0·44
MnO	0·14
H_2O-	0·12
H_2O+	2·63
FeS_2	....
Carbonaceous matter estimated	0·30
BaO	....
S	0·02
CO_2	....
P_2O_5	....
	99·62

The slates are commonly quite carbonaceous. A specimen of typical carbonaceous slate, on analysis by H. A. Leverin, Mines Branch, was found to contain 2·22 per cent carbon. A nodule of crushed, slickensided, carbonaceous slate was determined by the same analyst to carry 7·21 per cent carbon. A specimen of unsheared argillite from the Silversmith mine was found by Leverin to carry 0·75 per cent carbon, whereas the sheared equivalent held 2·09 per cent carbon. These highly carbonaceous sediments with glistening polished surfaces are popularly known as "graphitic slates," though none of the carbon is in the form of graphite. Wide zones of such rock have been encountered in many mining operations. It is very unstable and is known as "running ground."

Pyrite is common in the slates, generally in cubes up to more than one-eighth inch in size. The force exerted by the growing crystals is shown by a bulging of the slate about the cubes. In some cases the cubes are surrounded by narrow, irregular rims of fibrous quartz.

Argillites. The argillites of the Slocan series differ from the so-called slates chiefly in that they are massive rather than platy or fissile. No sharp line can be drawn and some geologists do not separate them. Alternating layers of different composition may vary from a small fraction of an inch to several feet in thickness. Weathered surfaces commonly show the bedding more distinctly than fresh surfaces. All gradations from limy argillites to quartzitic argillites were noted. The rocks are very fine grained; even under the microscope they reveal only abundant argillaceous and carbonaceous material through which are disseminated small quartz grains, more or less calcite in small grains and patches, often abundant, small sericite scales, and, in some cases, numerous small flakes of reddish brown biotite. This biotite is most prominent near intrusive bodies.

Pyrite is also common, and in places abundant, as disseminated grains, cubes, or, more rarely, lath-shaped crystals, and as nodular masses up to an inch or more in diameter. Surfaces of such pyritiferous argillites are commonly stained with iron rust.

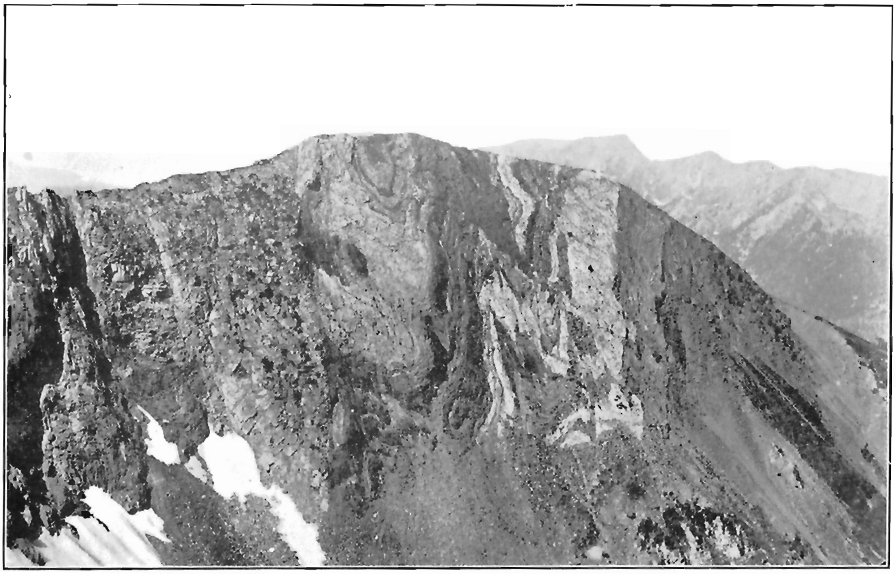
Argillites constitute an important proportion of the Slocan series in the western half or more of its exposed area. Their massive members are in general those in which the numerous fissure veins are best developed.

Limestones. Limestones form a small part of the Slocan series. In the western half of the area of this series, outcropping limestone beds are mostly confined to three zones occurring at stratigraphic intervals of from 1,200 to 1,500 feet (*See* structure sections, Figure 3). Farther east limestone beds are much more conspicuous, individual bands being several hundred feet in width. True average thicknesses of particular beds are difficult to determine because of original variations in thickness and subsequent orogenic deformation (Plate VIII A). The beds pinch and swell along their course and may show every gradation from nearly pure limestone to calcareous quartzites and argillites. The more westerly exposures are in general less pure than the easterly ones. Of the following analyses by H. A. Leverin, Mines Branch, Ottawa, the first two are typical of much of the larger limestone exposures in the more easterly parts of the outcrop area, whereas the third analysis represents less pure, western types.

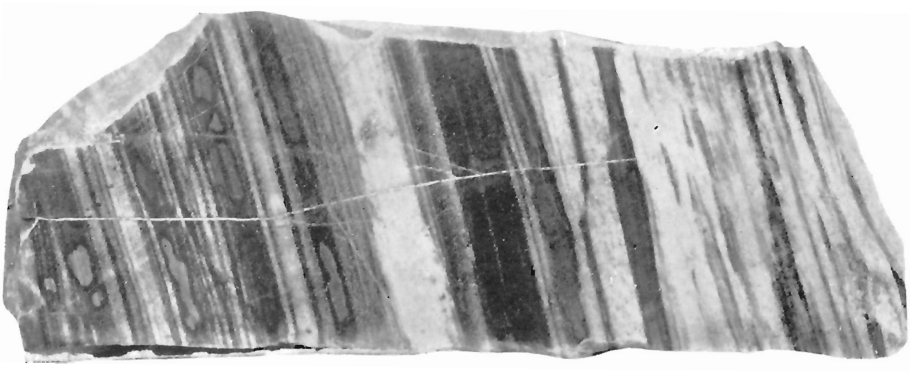
—	(1)	(2)	(3)
CaO	53·40	54·71	18·34
MgO	1·46	0·60	3·41
Fe_2O_3	0·15 }	0·30	5·22
Al_2O_3	0·15 }		
SO_3	0·25		
P_2O_5	0·07		
Insol	0·64	0·24	54·00
Loss on ignition	43·00		
	99·12		

(1). White, dense marble from a wide limestone belt near the mouth of Keen (Mansfield) creek.
(2). Light grey to white limestone at the Lucky Jim mine.
(3). Brownish grey, siliceous limestone at the Last Chance mine.

These limestones vary from light grey and brownish grey to almost black, depending on the character and amount of the impurities. The chief impurities noted under the microscope in the more granular limestones are quartz and in the denser types argillaceous matter. Towards the top of Payne Mountain ridge and in Payne mine workings a limy argillite zone carries in places numerous small fragments of granite. The limestones are mostly massive, fine-grained rocks, but near the larger intrusive bodies they are, locally, coarsely crystalline and, in places, contain bunches and disseminated grains of brown garnet, e.g., at the head of Montezuma basin and at the batholithic contact on the ridge running up to the



A. Highly contorted, interbedded limestones (light coloured) and andalusite schists (dark) as seen from the head of the first creek west of Holmes creek, looking west across the divide east of the head of the east fork of Twelvemile creek. (Neg. No. 9937.)



B. Interbedded quartzite (light) and argillaceous quartzite (dark) of the Slocan series, Van Roi mine. (Neg. No. 72214.)

Mountain Con mine. On the southerly slope of Texas peak, above the Utica mine, argillaceous limestone holds abundant, shining, black crystals of a scapolite, probably meionite.

The limestones are of particular stratigraphic importance in that they have furnished the chief horizons for delimiting the structure of the Slocan series and have supplied almost all the fossils collected from this series. Some beds contain large ore-bodies, such as those at Lucky Jim and Whitewater Deep mines, deposited by replacement from solutions.

Quartzites. The quartzitic members of the Slocan series vary from white through shades of light grey, brown, and dark grey to black. They are generally massive, compact, fine to medium-grained rocks. The purer varieties have a vitreous lustre. They range from nearly pure quartzite, composed of closely packed quartz grains cemented by silica or a small proportion of argillaceous or carbonaceous matter, to less pure varieties carrying varying proportions of argillaceous, calcareous, and feldspathic materials. Grains of feldspar are generally present, and in some cases form so much of the rock that the term feldspathic sandstone is preferable to quartzite. Feldspathic material is also abundant in other bedded types regarded as tuffaceous in origin.

Quartzite and argillite are commonly interbedded (*See* Plate VIII B) in zones ranging from one to several hundred feet in thickness, and composed of alternating layers from less than an inch to several inches thick. Elsewhere quartzite forms thick beds with little trace of bedding. Heavy beds of almost white to cream-coloured quartzite outcrop along the southern slopes of Silverton Creek valley in the vicinity of Van Roi and Hewitt mines. Their bleached appearance is probably due to thermal metamorphism by adjacent intrusives of the Nelson batholith. Light grey quartzite beds about 20 feet thick occur at intervals through the predominantly slaty belt of the Slocan series in the eastern half of its exposed area. These quartzite beds are commonly traversed by a network of irregular veins or lenses of white quartz, and locally are regarded as having exerted some structural control in the formation of vein-bearing fissures. Grey quartzites occur elsewhere in the Slocan series but are associated with dark grey to almost black quartzitic beds, the darker colours being attributed to argillaceous and carbonaceous impurities. Pyrite is common to abundant in the quartzite beds and its oxidation products stain their weathered surfaces.

Conglomerates(?). Three rock types to which the term conglomerate might be applied were noted. One of these forms a band of a few feet wide just above the Kaslo series. It consists of fragments of the underlying greenstones in a slaty matrix like the overlying slaty members of the series. The fragments are of light to dark green andesitic rocks up to several inches in length, and have been flattened by pressure. No similar rock was observed elsewhere. A second type is represented by beds at two or more horizons in the Slocan series. The lowermost of these, associated with beds of the second limestone zone, is a narrow, limy bed, about a foot thick, that carries abundant small fragments of granite and isolated crystals of quartz and orthoclase. This narrow but persistent bed was observed at a number of points, including Lucky Jim mine, Reco mountain, the K and S grade between Three Forks, and McGuigan creek. Small granitic fragments were also noted in thicker, more argillaceous limestone beds associated with the third limestone zone on Payne Mountain ridge near Payne mine and again on the Sunset-Trade Dollar ridge. A third type is represented by a fragmental rock forming massive beds along the east shore of Slocan lake north of Silverton. This rock carries rather angular fragments up to an inch in diameter, some apparently of sedimentary and others of porphyritic, probably volcanic, rocks. With them, and scattered through a fine-grained, indeterminate groundmass, are feldspar and amphibole crystals, much biotite, and little, if any, quartz. This rock is repeated at the same horizon on the divide south of Rio property. In composition and association it is more like volcanic breccia than a conglomerate.

Pseudo-conglomerate. As a result of deformation certain Slocan strata might be mistaken for conglomerate. The most widespread type has resulted from the shearing of interbedded quartzite and slate. The quartzitic beds have broken and the slate has flowed around the disjointed fragments of quartzite. All stages may be observed from undeformed rocks to those in which the quartzite beds are represented entirely by fragments lying at all angles and appearing like angular pebbles in a conglomerate. Beds of this character are abundant at various horizons in the Slocan series. They were observed particularly on the slopes of London Hill and Carpenter Mountain ridges.

Pseudo-conglomerate has also developed by shearing of limestone bands in which alternate layers were hard and soft, or in which limestone is interbedded with minor widths of argillaceous, quartzitic, or intrusive material. The more resistant members break up and form inclusions within the purer and more plastic limestone. In the big limestone belt at Lucky Jim mine this structure is well developed (Plate IX A).

Tuffaceous Sediments. Interbedded with other members of the Slocan series, particularly with the more massive types, and rarely distinguishable from them in the outcrop or hand specimen, are beds that when examined microscopically seem to be composed of volcanic ejectamenta. These are light to dark grey and yellowish brown, massive rocks which in the outcrop or hand specimen might readily be classed as quartzitic or calcareous argillites. Microscopically, they consist of large and small fragments of feldspar crystals; or feldspar crystals and rock fragments. Some of the rock fragments are fine grained, dense, and of indeterminate origin, but others are porphyritic and distinctly resemble volcanic rocks. Flakes and shreds of reddish brown biotite are generally abundant. Quartz is subordinate and thereby contrasts with the feldspathic sediments. The groundmass forms a large percentage of these tuffaceous rocks, and is of indeterminate composition and more or less opaque, like volcanic ash. The angular outlines and fresh appearance of the feldspar fragments is plainly indicative of no normal processes of erosion and deposition. North of Sandon map-area exactly similar rocks have been found interbedded with undoubted volcanic breccias and one lava flow, all parts of the Slocan series. On the whole there appears little doubt but that these members of the Slocan series are of tuffaceous origin.

A. Outcrop of limestone "conglomerate" at Lucky Jim mine.

B. Specimen of augen-gneiss from the Nelson granite: large phenocrysts are of microcline feldspar. (Neg. No. 72213.)

These tuffaceous rocks are too much like the more normal sedimentary types with which they are intimately associated to be mapped separately. They were identified only in the western half of the area of the Slocan series, but finer grained equivalents may occur farther east among the more slaty members. They are exposed along the east shore of Slocan lake north of Bosun mine. Here they are dense, dark grey to almost black rocks whose weathered surfaces commonly have a rather pitted appearance. The "conglomeratic" rock, previously referred to as outcropping along the lake shore north of Silverton, may be included with these tuffaceous sediments. Rocks closely resembling the fine-grained tuffs occur in Idaho basin and near Leadsmith mine. A yellowish brown, irregularly bedded rock exposed along the western slopes of Kane creek near the Black Grouse property is probably also tuffaceous. Its colour appears to be due to extensive oxidation and hydration of iron sulphides, which are commonly abundant in the tuffaceous rocks. Most of these tuffaceous rocks occur well up in the Slocan series, chiefly above but possibly also not far below, the third limestone zone (*See* cross-sections, Figure 3, in pocket). Their aggregate thickness could not be determined and probably varies greatly both along and across the strike of the rocks.

Structure

The accompanying cross-sections (*See* Figure 3) attempt to interpret the complex structure of the Slocan series and to correlate various horizons across the entire breadth of the area of the series. They are approximations and express only the broader structural features. The innumerable minor folds and faults everywhere present cannot be expressed on the scale adopted.

The Slocan series is the most deformed of all the formations, probably because it consists of alternating bands and layers of quite different structural competence. It is notable that bodies of this series, and possibly of earlier formations, caught up in the Nelson batholith, show less deformation than the main mass of the series.

The Nelson granite, partly at least, reached its final position by raising, tilting, and forcing aside the superincumbent rocks, and as the principal contact of the Nelson granite with the Slocan series has a general east strike, a series of flexures in this general direction have been imposed upon the Slocan strata and are particularly pronounced near the contact. In addition, the Slocan series has, as a result of regional deformation, been strongly folded along axes striking nearly northwest in line with the general Cordilleran trend.

Broadly viewed, the Slocan strata lie in numerous dome-shaped and basin-shaped folds, but in detail the structure is complicated by numerous faults, zones of shearing and slipping, overturned folds, and locally, by intensely contorted strata. In the Sandon-Slocan map-area, it is practically impossible to decipher the structures, for over large parts of the area outcrops are few and the series lacks key horizons and also differs in the character of sedimentation from west to east.

The limestone beds might be expected to furnish the best horizon markers, but they are not easily distinguished and towards the west they thin rapidly and carry more and more siliceous and argillaceous impurities. Also, they seem to have varied in their original thickness and to have had this variation increased by folding. Because of such conditions and because of the lack of exposures at critical localities it was impossible to trace individual limestone beds far or to correlate them with certainty. Much of the limestone of the Slocan series seems, however, to lie in three horizons, as indicated on the accompanying cross-sections which show the thicknesses approximately (*See* Figure 3). A fourth but thinner horizon lies about midway between the lowermost and base of the series. It is exposed only in the east. Numerous other smaller, less continuous, less clearly defined beds of limestone or notably limy rocks were observed which are hardly worth depicting in the structure sections.

Estimated on the structures shown in the cross-sections, the maximum thickness of the Slocan series is about 6,800 feet. The composition of the series varies so greatly from east to west that no single section is representative of the whole. Eastern sections comprise chiefly slate and thinly interbanded slate and quartzite, with which are included a maximum combined thickness of about 1,800 feet of limestone. Farther west the strata become, on the whole, more massive, are composed largely of quartzite, argillite, and massive tuffaceous beds, and contain much less limestone than the more easterly sections.

Contact Relations

The Slocan series rests disconformably on the Kaslo series. Within Sandon map-area the contact trends north to northwesterly and dips southwesterly to westerly, from 45 degrees to nearly vertical and averaging about 65 degrees. It conforms with the attitude of the overlying members of the Slocan series, occasional appearances of discordance being misleading. However, these structural relations do not represent actual continuity between the two series, for volcanic and intrusive members of the Kaslo series cease abruptly at this contact and a curious conglomeratic rock already described forms the basal member of the Slocan series. This conglomerate is interpreted as signifying an interval of erosion during which detritus from the Kaslo series was incorporated in the basal member of the Slocan series.

The Slocan series is the youngest assemblage of consolidated sediments and volcanic rocks in Sandon and Slocan map-areas. It is intruded by the Nelson granite, by a great number of stocks presumably related to this granite, and by a host of dykes thought to be related to the same period of batholithic and stock intrusion. The contact of the Slocan series with the Nelson granite lies largely within Sandon map-area. The northern edge of the batholith is convex to the south with, on the east and west, apophyses and outlying stocks extending northerly into the Slocan series, as in the vicinity of Silverton and the basin of Twelvemile creek. The granite contact dips northerly beneath the Slocan series at about 35 degrees, judging from the course followed by the contact and the position of batholithic apophyses and stocks. The tendency of the adjacent Slocan strata to strike and dip parallel with the contact plane of the batholith is particularly pronounced along almost any section of the contact that preserves a fairly regular course for a mile or more. It is less characteristic, or the contact may be distinctly crosscutting, where its course is irregular. The tendency holds even for the stock-like apophyses of the granite. Presumably, deformation of the Slocan series was partly caused by the invasion of the granite batholith. Most of the other numerous stocks within the area of the Slocan series cut sharply across the bedding structures and are comparatively steep walled. The great majority of the dyke-shaped intrusives, including mostly the more salic types, strike very nearly with the trend of the enclosing formations, though they may cut strongly across these formations at depth.

Metamorphism

The metamorphism of the Slocan series has resulted from a combination of dynamic and thermal agencies, related, it is thought, chiefly to one great period of folding and batholithic intrusion. Deformation has produced sheared and slaty structures and pseudo-conglomerates. Thermal metamorphism on the other hand has tended rather to preserve the original structures by induration and recrystallization, and is best exemplified close to intrusive bodies, especially to the main batholithic contact. (A more complete discussion of phenomena at this contact will be given in the subsequent section of this report on post-Triassic Intrusives.)

Mineralization

Most of the important silver-lead and silver-lead-zinc deposits occur within the area underlain by the Slocan series. Mineralization has chiefly taken the form of fissure vein deposits, the fissures in most instances having a northeasterly strike and southeasterly dip. Replacement of the wall-rock is a common feature, its degree depending on the character of the enclosing rocks. Where, for example, the rock is limestone, replacement may be the chief mode of formation of the ore deposits. The mineralization is attributed to the Nelson batholith and is regarded as having followed the period of intrusion of this batholith.

Mode of Formation

The Slocan series as developed in Sandon and Slocan map-areas is essentially sedimentary, and judging by its fossil content was mostly laid down in marine waters. Some of the beds, however, are tuffaceous sediments and appear to occupy about the same horizons as certain definitely pyroclastic beds observed farther north in sections about the head of Slocan lake and farther northwest. The materials probably came from the west and were laid down in comparatively shallow waters, for from east to west the beds tend to become more massive and coarser textured. Cross-bedding is a notable feature of nearly all members of the series, and is particularly common in the more arenaceous and shaly beds. Ripple-marks have also been noted. Plant remains have been found on Reco mountain. Except for these plants all collections of fossils were of marine animal organisms obtained from limestone beds or notably limy strata occurring in the eastern half of the area of the Slocan series. The apparent paucity or lack of fossils in central and western exposures corresponds with the change in the character of sedimentation in this direction and may indicate shallower waters in the west. The tuffaceous members are well-bedded rocks and are thought to represent pyroclastic materials laid down chiefly on land areas and thence transported by erosional processes into the sea.

Age

Prior to the discovery of fossils in the Slocan series it had been provisionally designated as Palæozoic and probably Carboniferous (7, page 32). The earlier fossil collections were of poor material and did little more than appear to confirm this age designation. In 1919, however, a collection obtained by Bancroft from the Milford group included fragments of a species of *Belemnites* implying a Mesozoic age for the containing beds.

In 1925 and 1926 the writer collected fossils from twenty-seven localities. Three lots proved to be indeterminate; nine were of fragments of crinoid columns, many of them star-shaped; one contained a "probably Mesozoic" coral; another consisted of crinoid columns and corals; and six lots were doubtfully referred to as containing ammonites. The remaining seven lots were reported upon by F. H. McLearn as follows.

Lot 218 F.C. Whitewater road; *Atracites?* sp., crinoid stems, *Gervillia* sp., *Arcestes?* sp. May be Triassic.

Lot 569 F.C. (8441), from limestone bed at elevation of 7,300 feet on ridge extending east from Texas peak; *Ptychites?* sp. and other poor ammonite specimens, *Belemnites?* sp. Probably Triassic.

Lot 556 F.C. (8437), from limestone float along south slope of Texas peak within 600 feet of summit; *Belemnites* sp., indeterminate ammonites. Probably Mesozoic.

Lot 197 F.C. (8427), Mount Holmes ridge about 1 mile southeast of mount Holmes; *Belemnites* sp., poor ammonites. Mesozoic, Triassic?

Lot 456 F.C. (8430), from limestone float on trail to Montezuma mine about ½ mile below the Montezuma camp; star-shaped crinoid column, corals, small distorted *Belemnites?*.

Lot 554 F.C. (8435), from limestone bed 400 feet below and east of summit of Texas peak; *Belemnites* sp., crinoid columns.

Lot 632 F.C. (8449), above Whitewater Deep mine workings; a smooth ammonite?, a costate ammonite?, indeterminate ammonites; if an ammonite, Triassic?

These collections leave little doubt of the Mesozoic and probably Triassic age of the Slocan series. On the other hand collections from the headwaters of the middle fork of Kemp creek and from near Helen prospect, near Blaylock, made by Bancroft in 1919, are reported by E. M. Kindle (1, 1919, page 42) as follows:

"Kemp creek. The fossils from this lot include crinoid stems *Pugnax* sp. undet., *Seminula?* undet., and *Gastrioceras?* cf. *G. kingii*. This fauna cannot be older than upper Devonian nor younger than Triassic. I believe it to be of Carboniferous age probably Pennsylvanian.

"Helen prospect. This includes a single fossil, a goniatite, which appears to belong to the genus *Gastrioceras* and comparable with *G. kingii*. This is a Carboniferous genus and the lot is accordingly referred to the Carboniferous."

These two collections have been re-examined by F. H. McLearn, who states that "the best preserved specimen is an ammonoid. The state of preservation, however, does not warrant a definite identification. Late Palæozoic or Triassic is the best dating that can be offered for this specimen."

The Slocan series overlies the Kaslo series which in turn overlies the Milford group, the upper members of which carry Mesozoic, probably Triassic, fossils. Consequently, the Slocan series must be Triassic or younger, and probably Triassic since there is little or no evidence to suggest that a Jurassic or later fauna is present.

The intercalation of sediments with distinctly volcanic members is a feature characteristic of the Triassic elsewhere in British Columbia.

NELSON BATHOLITH

The Nelson batholith occupies much of the western part of Kootenay district. As represented in Sandon and Slocan map-areas it is a complex of intrusive types differing chiefly in structure and texture, but varying also in composition and in age. The batholith may, on these bases, be subdivided into three main components, namely Nelson gneiss, Nelson granite, and Nelson pegmatite-gneiss. Of these components the Nelson granite has been further subdivided into three members—one a crushed, porphyritic granite, another a massive, porphyritic phase of the same granite, and the third a more equigranular rock varying from granite to granodiorite. Contacts between adjoining components and members are gradational, so that the batholith is regarded as representing one great period of intrusion.

Nelson Gneiss

The Nelson gneiss occupies about 8 square miles in Sandon map-area and is distinguished by banded structures resulting from granitic invasion into older bedded formations. It is gradational into the adjoining, crushed member of the Nelson granite and the passage zone, a few hundred yards wide, contains, here and there, isolated inclusions of metamorphosed rocks.

The gneiss is typically a grey, granitic rock in which dark bands, from a fraction of an inch to several inches wide, of partly or completely replaced and crystallized older rocks alternate with mostly wider bands of a light-coloured, aplitic granite. The bands of older rock are dark grey to dark greenish grey, finely crystalline, and may be either sharply defined against or grade into intervening bands of granite. Their metamorphic origin is indicated by their less altered facies and by inclusions of still less altered sediments in the adjoining Nelson granite. The associated granite is medium grained, and is composed mainly of quartz and alkali feldspar. Dark minerals, where present in noticeable amounts, form thin, discontinuous lines parallel to the broader banding of the gneiss.

Approaching the contacts of the Nelson gneiss metamorphism is less pronounced, and the aplitic granite gives place to the crushed and foliated member of the Nelson granite. Even within areas of the Nelson gneiss granitic material gradational in texture and passing into typical foliated granite occurs.

The Nelson gneiss strikes from nearly north to about northeast, and dips uniformly to the east at about 25 degrees. This attitude persists in the northerly half of the belt, where inclusions are less continuous and where larger intervals of foliated granite occur.

Nelson Granite

The crushed granite member of the Nelson granite is, in the main, a distinctly foliated rock whose structure has been produced by deformation and is best shown where deformation is most pronounced, though to some extent it is also dependent on the abundance of dark materials. The rock is light grey to, more commonly, distinctly pinkish, and of medium to coarse grain, in which phenocrysts of alkali feldspar up to an inch or more in length are in most places abundant. It is composed chiefly of feldspar and quartz with a small proportion of hornblende and biotite and accessory magnetite and titanite. Microcline and orthoclase are abundant constituents and quartz is generally conspicuous. Plagioclase is subordinate and has about the composition of albite-oligoclase. Those phenocrysts of alkali feldspar examined microscopically proved to be microcline. The hornblende and biotite are mostly altered to chlorite and magnetite. Most of the magnetite is, however, a primary constituent and in places was observed to be the most abundant dark mineral. The quartz has been severely granulated and the feldspar phenocrysts are squeezed into a rude alinement with other salic constituents between thin foliæ of hornblende and biotite, the whole constituting in places a typical augen gneiss (*See* Plate IX B).

Within a width of, perhaps, several hundred feet this foliated granite passes into the massive, porphyritic granite member of the Nelson granite. West of Slocan lake it is adjoined by, principally, the Nelson pegmatite-gneiss complex, the boundary being drawn arbitrarily where gneissic granitic rocks associated with inclusions of presumably Precambrian formations begin and intrusions of coarsely crystalline, irregular textured, pegmatitic granite first appear. The relations between these several rock types are exhibited in a transition zone as much as half a mile wide and probably averaging at least a quarter of a mile. The change begins by gradation into a less crushed, less porphyritic, and somewhat finer textured granite, carrying a little more quartz and tending to light grey. Essentially the same minerals are present on both rocks, but the proportions change and a little muscovite enters. The transition is marked also by the appearance of irregular masses of pegmatitic granite, increasing numbers of partly to completely granitized inclusions of older rocks, and a development of finely banded structures.

The foliation of the crushed granite strikes very nearly with the gneissic structures of the Nelson gneiss. This parallelism is probably due to the fact that the foliated granite was deformed before it was completely solid, and as a result the direction of foliation has conformed more or less closely with the boundaries of the more resistant inclusion of the Nelson gneiss. Deformation was caused by orogenic forces associated either with the intrusion of the Nelson batholith or with succeeding, Tertiary irruptives, and was concentrated along certain zones in the partly consolidated Nelson intrusives.

The porphyritic granite member of the Nelson granite is, in general, readily distinguished by abundant simple crystals and Carlsbad twins of potash feldspar up to 2 inches long. Exposed surfaces are mostly light grey, but may have a pinkish cast from weathering of the potash feldspar. The rock contains 5 to 10 per cent of hornblende and biotite, the former being generally the more abundant. Locally, as near the batholithic contacts, there may be as much as 50 per cent or more of hornblende. Studies with the microscope indicate that the rock is a granite verging on granodiorite. Orthoclase is generally more abundant than microcline and forms the large phenocrysts except where the rock has been deformed when microcline takes its place. The quartz shows strain effects even in the more massive rocks, and may be fractured into a mosaic of angular fragments lying between the larger feldspar and other crystals. Plagioclase is subordinate to potash feldspar except towards the borders of the batholith, where the rock grades into granodiorite and quartz-diorite. The plagioclase is mostly about albite-oligoclase, though varying from albite to oligoclase-andesine. Some of its crystals are zoned, especially in the border facies and apophyses of the batholith. Micropegmatitic and microperthitic intergrowths are common, but do not constitute an important percentage of the mineral constituents. Dark green hornblende and brown biotite are the characteristic mafic constituents and may be partly altered to chlorite. Accessory minerals include grains of titanite, magnetite, and apatite, small needles of rutile, and occasional sulphide minerals.

The following table includes three chemical analyses of the porphyritic granite and, for comparison, two average analyses of granitic rocks of somewhat similar composition.

—	1	2	3	4	5
SiO_2	65·50	66·46	60·09	69·73	66·64
Al_2O_3	17·23	15·34	17·20	14·98	15·57
Fe_2O_3	1·50	1·68	6·73	1·62	1·91
FeO	1·40	1·83	....	1·66	1·94
MgO	1·00	1·11	0·47	1·08	1·41
CaO	3·04	3·43	8·24	2·20	3·50
Na_2O	5·35	4·86	2·45	3·28	3·41
K_2O	3·40	4·58	6·23	3·95	3·72
TiO_2	0·20	0·27	....	0·34	0·50
MnO	0·12	....	....	0·11	0·06
H_2O-	0·06	−0·29	....	0·78	1·15
H_2O	0·74				
S	0·04	....	....	....	....
P_2O_5	—	0·08	....	0·27	0·19
	99·58	99·93	101·41	100·00	100·00

Analysis 1, by M. F. Connor, Mines Branch, Ottawa, is of a specimen obtained by C. W. Drysdale from the head of the north fork of Montezuma creek, a light grey to almost white, massive rock with phenocrysts of potash feldspar from ¼ inch to 1 inch wide and up to 2 inches long. It consists of microcline, orthoclase oligoclase (Ab 80-An 20), quartz, biotite, hornblende, and titanite.

Analysis 2, by Dr. F. Dittrich, Heidelberg, is of a specimen collected by R. W. Brock from near the Molly Gibson mine, Kokanee mountains, a short distance south of Slocan area. No description of this specimen is available, but the rocks in this vicinity are typical of the porphyritic granite phase of Nelson batholith.

Analysis 3 is of a specimen obtained near Springer creek not far from Slocan City. "It was found," writes Gwillim (12, 1897), "to be a crushed biotite-granite containing a good deal of plagioclase. The quartz and feldspar show marked indications of great pressure. Much biotite, partly altered to chlorite, is present and is associated with epidote. The specimen was considerably decomposed being from near a vein and also near the surface."

Column 4 represents the average of 184 analyses of granites younger than Precambrian (Osann and Clarke); in it 0·06 per cent BaO and 0·02 per cent SiO are combined with the CaO content. Column 5 is an average of 20 analyses of quartz monzonite (Clarke).

Analyses 1 and 2 are very much alike and probably close to the average composition of the typical porphyritic granite. When compared with average compositions 4 and 5, it will be seen that they are of a granite in some respects closely resembling granodiorite. (The term granodiorite is used in this report to include granitic rocks including quartz-monzonites, whose compositions range between granite and quartz diorite.) The silica content is rather low for typical granite, but is offset by the high percentage of alkalis. The predominance of soda over potash probably indicates soda in the orthoclase. In a crystal of orthoclase from the Nelson porphyritic granite Gwillim found 5·76 per cent soda and 12·39 per cent potash as compared with the 16·9 per cent potash present in the theoretically pure mineral. As there is little sign of perthitic intergrowths of plagioclase in the orthoclase the soda content may be best regarded as a chemical component of the orthoclase.

The porphyritic granite member grades into the crushed granite and into the pegmatite-gneiss component described later. The single body of non-porphyritic granite and granodiorite is considered to be slightly younger than the porphyritic granite and to have been intruded into the latter when it was only partly consolidated. The porphyritic member holds many inclusions of Mesozoic and possible pre-Mesozoic rocks and intrudes the Slocan series.

Some mineralogical and textural changes occur near the contact of the porphyritic granite with pre-batholithic formations, particularly the Slocan series. Along the main contact of the granite and its stock-like apophyses with the Slocan series, and for 1,000 to 2,000 feet or more from this contact, the Slocan strata are distinctly more metamorphosed than farther away. Elsewhere, except in narrow belts around minor intrusive bodies, the Slocan series exhibit but little thermal metamorphism. Within the 1,000-2,000-foot contact zone (the actual width at any place depending largely on the dip of the granite beneath the pre-batholithic cover), and within 100 to 200 feet of the granite body, the Slocan sediments are partly to completely recrystallized and many secondary, metamorphic minerals have developed. The limestones are coarsely crystalline and hold crystals and masses of garnet and such minerals as tremolite, wollastonite and scapolite, and graphite. The slates and argillites are hard, compacted hornfels carrying garnet, crystals of andalusite up to an inch or more in length, and abundant biotite. The quartzitic rocks, too, are bleached and partly recrystallized. Rarely, however, is it difficult to identify the original characters of the affected rocks. Beyond this more intensely altered zone the Slocan strata grade into less altered types until at about 2,000 feet, or in some cases half a mile or so, the effects of thermal metamorphism are barely noticeable, if at all.

The porphyritic granite, too, varies in appearance and composition near its contacts with pre-batholithic rocks. At half a mile or less from the contact with the Slocan series its phenocrysts become smaller and fewer. Its composition also changes. Quartz decreases. Plagioclase increases and tends to develop zoned structures and to be more calcic. Hornblende may become relatively abundant and within a few hundred feet or so of the contact may compose as much as 50 per cent of the rock; individual crystals may reach an inch or more in length and where such crystals are plentiful the rock takes on an ophitic texture. Not uncommonly the granite is somewhat foliated within the zone of contact influence, a feature attributed to flowage rather than to deformation since the rocks are not more crushed or strained than elsewhere. Both within and without the contact zone basic patches of irregular size and shape and uncertain origin were noted. They are composed largely of dark minerals, principally hornblende, though biotite may be abundant. Like changes in texture and lithology occur in the granite in areas where inclusions are abundant.

The (non-porphyritic) *granite* and *granodiorite* member of the Nelson granite is, on the whole, finer grained and of more uniform texture than the porphyritic member, but carries the same suite of minerals in much the same proportions. It varies from granite to acid granodiorite. It is a light grey rock composed essentially of quartz, orthoclase, plagioclase, microcline, biotite, and hornblende in about this order of decreasing abundance. Accessory and secondary minerals include apatite, magnetite, titanite, and chlorite. The quartz is partly fractured and strained. Plagioclase is generally well twinned and varies in composition from albite-oligoclase to oligoclase-andesine. It may be more abundant than orthoclase. Microcline is scarce compared with orthoclase, and biotite more abundant than hornblende. One specimen obtained from near the head of Granite creek contained small crystals of pyroxene, probably diopside. Micropegmatitic intergrowths of quartz in orthoclase are generally to be observed, but in very small amounts.

This non-porphyritic member forms an irregular-shaped mass of 5·5 square miles about the headwaters of Silverton, Fennell, and Granite creeks. From this mass numerous apophyses extend into the surrounding porphyritic granite. In places there appears to be every gradation from one member to the other, but elsewhere the contacts are sharp and at such places the non-porphyritic phase intrudes the porphyritic. Dykes of the former were also observed cutting the porphyritic granite at different places near the main area of the more equigranular rock. Both rock types have been derived from the same parent magma, but the non-porphyritic member is slightly younger and was intruded into the partly consolidated porphyritic granite.

Nelson Pegmatite-Gneiss

The pegmatite-gneiss component of the Nelson batholith is broadly developed west of Slocan lake in Valhalla mountains (5, 1928, pages 101-104). Its members are also associated with the Lardeau series, but too intimately for the most part to be mapped separately.

The pegmatitic member is characteristically a light grey, very coarse-grained rock of irregular texture. Quartz, plagioclase, orthoclase, and muscovite are the essential minerals, and occur mostly in about this order of abundance. Quartz is commonly rather smoky. The feldspars are white to creamy yellow and vary from microscopic size to more than 2 inches in length. Muscovite occurs in small flakes and in thick books up to one-half inch or more in diameter. Biotite may also be present, but generally in minor proportions to muscovite. Ruby-red garnets were noted in many places and occur mostly in clusters of well-formed crystals from 1 to 2 millimetres in diameter. In thin section plagioclase was observed to be more abundant than orthoclase and was finely twinned with, in some cases, the lamellæ disappearing before reaching the edges of the crystals. Pegmatitic intergrowths are common. The quartz is but little strained, and occurs in part as rounded grains within larger feldspar crystals.

These pegmatitic rocks in part intrude and in part grade into the gneissic member and in either case are lithologically alike. They occur in very different amounts in different parts of the pegmatite-gneiss complex. North of Sharp (Glacier) creek, pegmatitic rock is very abundant, forming a large part of the ridge above the 4,000-foot contour. It is also quite abundant on the ridge south of Hoben (Falls) creek, but is comparatively scarce on the ridge between these creeks. Elsewhere it occurs as more or less isolated bodies of irregular dimensions, mostly not over a few feet wide or 100 feet long, and was nowhere observed to intrude adjoining batholithic components.

The gneissic member is a medium-grained, grey rock of uniform texture and possesses, in general, a banded structure represented by thin, dark, parallel lines spaced, on an average, from 1 to 2 millimetres apart. In places this structure is barely recognizable, if present at all. Every gradation exists between the more massive and the distinctly gneissic types. Both are characterized by the presence locally of red garnets occurring either as single individuals or in streaks or clusters, and both types show, here and there, small cavities containing amethyst quartz, calcite crystals, limonite pseudomorphs after pyrite, and clusters of black tourmaline crystals. Under the microscope the gneiss has a granular appearance, suggesting recrystallization and a derivation, at least in part, from pre-existing rocks. Quartz is abundant and is only slightly strained. Plagioclase is generally more abundant than orthoclase, and microcline is rare or absent. Both biotite and muscovite are commonly present and sericite occurs as a secondary mineral. A little hornblende was noted in one slide. Micropegmatitic intergrowths are common, but perthite is comparatively rare. Accessory minerals include sphene, magnetite, iron oxides, chlorite, kaolinite, red garnet, and sulphides. The composition of these gneissic rocks ranges from that of binary granite to quartz monzonite.

The gneiss is the more abundant member of the complex. In the area west of Slocan lake it holds numerous inclusions of Precambrian rocks more or less completely granitized, as in the Lardeau series, the end product being a thinly banded granite-gneiss whose structure is believed to represent original bedding or schistosity. In certain cases the gradation seemed unmistakable and takes place both along the strike of the inclusions and across their structures. The gneissic phase, as already stated, grades into a massive granite which seems to be a final stage in the metamorphic cycle, and in which local melting or a more continuous local supply of granitic material has destroyed all traces of original structures. The bodies of massive granite are of irregular size. One, over half a mile in maximum diameter, occurs at the head of Sharp (Glacier) creek to the south of the New Denver glacier.

No ore deposits have been discovered in the pegmatite-gneiss component within the map-area. At a couple of places a little prospecting has been done in the gneissic granite near bodies of partly granitized inclusions and has revealed small, lens-like masses, a few inches in diameter, of pyrrhotite and pyrite, apparently replacing the gneiss and included rocks. In places within the massive granite body east of New Denver glacier small miarolitic cavities carry clusters of partly oxidized pyrite cubes.

Origin. The pegmatite-gneiss forms part of the Nelson batholith, since west of Slocan lake it grades into other components of the batholith. Areas of it contain numerous inclusions of presumably Precambrian rocks. These rocks are not as steeply tilted nor as closely folded as later pre-batholithic formations in Sandon and Slocan areas and, on the whole, preserve from one inclusion to another a uniform attitude, indicating that at one time they were continuous over the area now occupied by the pegmatite-gneiss. They are highly metamorphosed and in certain instances appear to pass along their strike into rocks equivalent to the gneissic members of the pegmatite-gneiss complex. The gneissic member of the complex is characteristically a rock of fresh, recrystallized appearance and in places grades into a massive phase of like texture and composition. The pegmatitic phase of the complex has much the same composition as the gneissic phase, and in places the two rocks grade into each other but in other places the pegmatitic granite cuts the gneiss. Mineralization is poorly developed in the pegmatite-gneiss, whereas it is abundantly developed and of commercial importance in the Nelson granite.

The comparatively undisturbed attitudes of the pre-batholithic rocks forming the inclusions seem to indicate that intrusion was accompanied by little if any disturbance of the overlying rocks. The granitic material seems rather to have soaked slowly into the overlying rocks and completely granitized them over large areas. The composition of the intrusive material was doubtless modified, but probably not greatly since the final product, the granite-gneiss, has everywhere much the same appearance and, so far as microscopic studies have gone, much the same mineral composition regardless of the composition of the nearby, less-altered, older rocks and whether it forms broad bodies or narrow bands in recognizable older rocks. That the invading material was not much changed in composition is also suggested by the fact that the granite-gneiss has essentially the same mineral composition as the associated pegmatitic rocks and in places grades into them. All the pegmatite rocks are similar. The fact that some of them definitely intrude the gneiss does not necessarily mean that such bodies are much younger than those that grade into the gneiss. It probably means that the period of formation of the pegmatities extended over a considerable time. It seems, in short, probable that the granitic material that produced the granite-gneiss was like that which produced the pegmatites, in other words that the invading granitic magma was essentially a pegmatitic differentiate of the Nelson batholith carrying abundant volatile constituents, and able to gradually saturate and transform the once overlying rocks.

As the metamorphosed rocks are of Precambrian age, and were overlain by many thousands of feet of later pre-batholithic formations, metamorphism must have been comparatively deep-seated and these older, underlying rocks would be the first to be attacked by the rising pegmatitic magma and also the last to recover from the effects of such an intrusion. It has already been pointed out that in Kootenay Lake area the zone of intense metamorphism associated with pegmatitic and gneissic granitic rocks was mainly confined to the Lardeau series, but also extended upwards for a varying but relatively short distance into overlying measures. Gneissic rocks, presumably of Mesozoic age, occur with the Nelson gneiss in the valley of Slocan lake and, although no associated pegmatitic granite was there observed, the gneisses bear a close lithological resemblance to members of the pegmatite-gneiss component and may well be the result of related phenomena. It consequently appears that metamorphism of the type being discussed in places affected strata well above the Precambrian measures, though in Sandon and Slocan areas it was chiefly the deeper-seated formations that were most generally and completely affected. The poor mineralization of the pegmatite-gneiss component of the Nelson batholith may also mean that this component formed far below the surface, where temperatures were too high to favour the formation of mineral deposits.

Mineralization as Related to the Nelson Batholith

Most of the Nelson batholith is composed of massive, fresh rocks which have escaped serious deformation. Joint fractures are generally well developed and mostly consist of two or more steeply inclined and another more nearly horizontal. The directions of the steeply inclined joint planes vary from place to place but, most commonly, range from north to northeast for one set and east to southeast for the other set. Deformative stresses have found relief locally in fissuring and shearing along directions that appear to have been largely controlled by the joint fractures. Shearing may be marked by widths of as much as several feet of crushed and broken rock and fault gouge, and where movement has been pronounced its direction may be indicated by marked striations along the walls of the shear zones.

Since mineral deposits occur in some of these fractures regardless of their direction, it is evident that some of the fracturing antedated mineralization. But some deformation occurred in post-mineral times, for mineral veins are faulted and sheared. These post-mineral movements, however, rarely appear to have been as strong as those that provided the channels for ore deposition. Disseminated ore minerals other than iron sulphides were seen only in the immediate vicinity of mineralized fissures or shear zones. The inference is that mineralization did not occur until after the consolidation of the batholithic rocks and after an early period of deformation.

Judging from the distribution of known ore deposits in the Nelson batholith all members have not proved equally favourable to mineralization. The least favourable are those of the pegmatite-gneiss component. The Nelson gneiss of Slocan Lake valley is also less favourable. The other members, collectively referred to as the Nelson granite, are all favourable, but in Sandon and Slocan map-areas the porphyritic granite member is the most prolific of mineral deposits, and the formations intruded by it have provided the most numerous and most important deposits. Wherever, too, the Nelson granite has been found in Kootenay and adjoining districts of British Columbia mineralization of varying importance has been discovered in both the intrusive and the intruded rocks regardless of the character of the latter. It is inferred, therefore, that the relation of mineralization to this granite is a more than casual one; that in all probability both granite and ore minerals originated from the same magma, but that mineralization took place after a period of shearing and fracturing of an upper consolidated part of the granite.

The period of deformation during which fissuring and fracturing occurred is most readily correlated with the Laramide or Rocky Mountain orogeny, which is interpreted as having occurred at the close of Cretaceous or in Early Tertiary time. This matter is discussed more fully in later pages of this chapter. Assuming such a correlation it is concluded that mineralization of the batholith probably occurred in Early Tertiary time.

STOCKS

The Slocan series is cut by many stock-shaped bodies of granitic rocks from a small fraction of a mile to several square miles in area. A few seem from their position and appearance to be almost certainly projections of the batholith, e.g. the large, roughly circular area chiefly of granite and occupying much of Carpenter mountain; the smaller bodies at Apex mine on Carpenter creek, and near the junction of Emily Edith and Silverton creeks; and the larger area of granite about Helen mine southeast of Blaylock. Such bodies are stock-shaped in plan, but in section they dip beneath the surface at a relatively low angle like the main batholithic contacts and unlike stocks in general. These bodies like the batholith tend to conform with the structures of the overlying formations, probably as a result of deformation set up by the advancing magma.

Most of the stock-shaped bodies, however, differ in appearance from the batholithic rocks. Few of them have that coarse porphyritic texture so peculiar to the Nelson granite. The larger ones are generally medium-grained, more or less equigranular rocks and the smaller bodies may be quite fine grained and may or may not be porphyritic. Some characteristic " bird's eye " porphyry types were observed along the lower valley of Carpenter creek. The Silversmith mine " plug " is also of this character. In composition the stocks range from quite siliceous granite to diorites, the common types being granite or granodiorite. Tendencies to develop more basic border phases are not marked, the rock composing a stock being, in general, remarkably uniform. Much the same suite of minerals is present in each of the several stocks, but the proportions vary. Quartz, except in the diorites, is essential and generally abundant. Orthoclase is the predominant potash feldspar, but some microcline was observed. Plagioclase varies from albite and albite-oligoclase to andesine. Zonal structures are common, especially in feldspar phenocrysts of the bird's eye porphyry type mentioned above. Muscovite was observed in some of the more acid stocks. Hornblende and biotite are comparatively abundant and both are commonly present. No pyroxene was noted. Accessory minerals include magnetite, apatite, sphene, and sulphides. Chlorite, sericite, calcite, and epidote are common secondary products.

The following analysis, by W. A. Jones of University of Toronto Laboratories, is of medium-grained, holocrystalline, quartz-biotite granodiorite obtained from a small stock or irregular-shaped body outcropping on Carbonet No. 2 claim in the upper valley of Robb creek. The rock is very similar to many of the smaller stocks or large dykes intruding the Slocan series at widely separate localities. It shows a rather marked similarity to analyses given elsewhere of the Nelson granite:

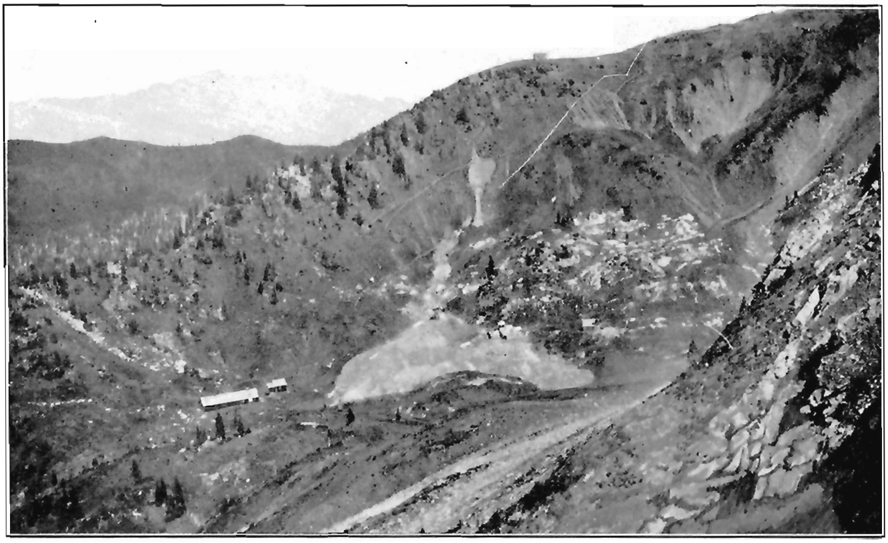
	Per cent
SiO_2	67·70
Al_2O_3	16·30
Fe_2O_3	0·58
FeO	1·74
CaO	3·74
MgO	0·96
K_2O	2·19
Na_2O	4·26
$H_2O\pm$	1·13
TiO_2	0·43
CO_2	0·65
	99·68

Silica is slightly higher than in the Nelson granite, but the alumina is an almost exact average of the first two given for this granite. The total alkali is too low for granite, but is a fair average for granodiorite. The excess of soda over potash is characteristic of the Nelson granite. In the present analysis, however, this feature is accentuated and is probably largely attributable to excess of plagioclase over orthoclase, though, as in the Nelson granite, it may be partly due to soda in the potash feldspar.

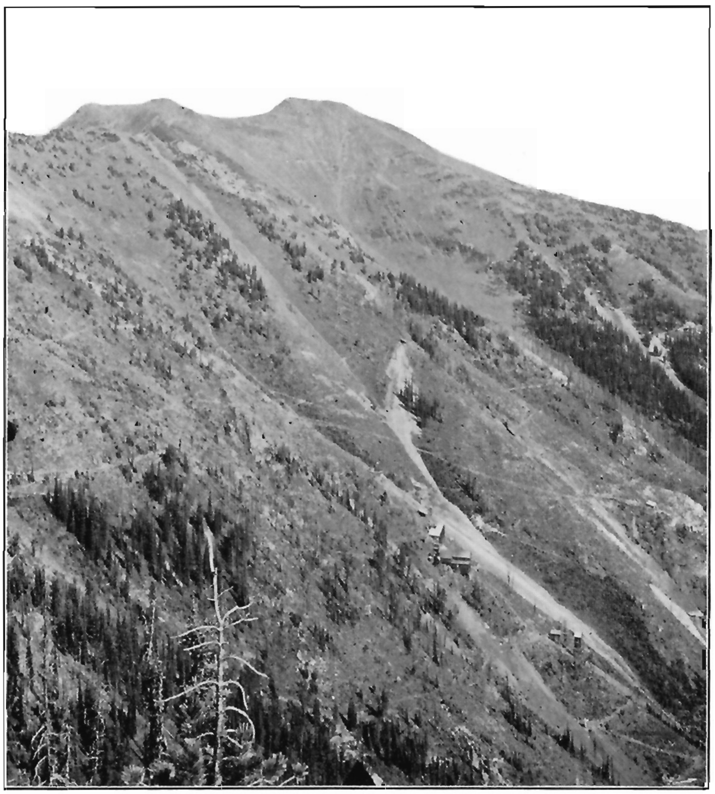
The great majority of the stocks cut the pre-batholithic formations at steep angles. They have not been observed in contact with the batholith or with the batholithic stock, so their relative ages cannot be directly inferred. Most of them occur at a distance from the batholith contact, but near Paddy peak and the Utica mine three small stocks lie within a mile of the main contact of the Nelson granite with the Slocan series. These three stocks cut steeply through the Slocan strata, which were strongly cross-folded. The cross-folds developed before intrusion of the stocks and as a result of the intrusion of the Nelson batholith. It follows that stock intrusion succeeded that of the Nelson granite, but it is not likely that the interval was long. The stocks have been somewhat deformed, are definitely pre-mineral, and in several instances contain important ore deposits.

MINOR INTRUSIVES

A vast number of minor intrusives outcrop in Sandon and Slocan map-areas. A large proportion cut the Slocan series, but many intersect other formations. Light-coloured intrusives are much the more abundant and are locally called "porphyries." The term is sometimes applied to more basic varieties, but usually these are given other names depending on their colour, texture, and mineral composition. For purposes of further discussion the minor intrusives will be classified as "salic" or "mafic,"



A. Antoine basin at the head of McGuigan creek: showing Antoine buildings in the basin and dumps from Antoine and Red Fox workings: the light-coloured rocks are chiefly porphyritic intrusives invading Slocan sediments. (Neg. No. 67575.)



B. The southern slope of Reco mountain north of Cody; buildings and dumps of a number of properties may be seen, including the American Boy, Last Chance, Noble Five, and Reco mines.

comprising, respectively, those in which quartz (and or) feldspars predominate and those in which such minerals are subordinate to ferromagnesian constituents.

Salic Dykes and Sills. Great numbers of salic intrusives intersect the Slocan series, commonly in the vicinity of metalliferous deposits. They are abundant within a wide zone striking northwesterly about midway of the area of the Slocan series. They are mostly dyke-shaped and with sharp contacts. Some of the larger bodies, as on the slopes of Reco and Payne mountains, reach a width of from 100 to 1,000 feet and are readily traceable for a mile or more. In slaty or other fissile rocks they tend to split and follow planes of lamination or schistosity, but show less of this tendency in more massive formations. Most of the salic intrusives tend to follow the strike of the enclosing sediments, but generally stand at steeper angles.

The salic intrusives vary from acid pegmatitic and aplitic types to others allied with quartz monzonites and quartz diorites, but intermediate types of the composition of granite, quartz syenite, and acid granodiorite are the most abundant. Their mineral components are similar to those of the stocks. The larger bodies are coarser or, if porphyritic, contain more and larger phenocrysts than the smaller bodies. The colour varies mainly from white, creamy, or slightly pinkish white to light grey; biotite, and less commonly hornblende, are rarely plentiful enough to give a darker tone. These light-coloured, salic intrusives are readily distinguishable even at a distance from the darker Slocan series (Plate X A).

Mafic Dykes. Mafic intrusives are less abundant than the salic types. They weather more readily than the rocks they intrude and, therefore, do not afford conspicuous outcrops. In many cases the weathering, particularly of olivine, has produced a pseudo-amygdaloidal texture.

The most abundant type is a dark green, medium-grained lamprophyre composed essentially of olivine, pyroxene, and biotite in different proportions. In most cases the olivine is entirely altered to serpentine, talc, or carbonate. The pyroxene is generally fresh and in most of the specimens examined was either augite or diallage, though bronzite was identified in a basic dyke at the Mountain Con mine. There are abundant shreds and flakes of biotite which under the microscope is commonly brownish red. Magnetite, limonite, and pyrrhotite are accessory. A little quartz is generally present and may be partly or entirely secondary. Feldspar when present is in subordinate amount, and is calcic plagioclase. Amphibole occurs in some specimens, but is scarce and may be partly altered to chlorite.

These intrusives form dykes, rarely more than a few feet wide, though in some places, as at Slocan Sovereign mine, they reach a width of about 50 feet. They are more abundant in the Slocan series and more commonly tend to follow or parallel the course of the metalliferous veins than that of the enclosing rocks. In consequence, they strike nearly at right angles to the salic dykes and in most observed cases, at least, cut across them. Similar mafic dykes occur in the Nelson granite.

A second type of lamprophyre, observed in the granitic areas at Fisher Maiden and Comstock mines, carries no olivine, but abundant amphibole, chiefly hornblende. In these dykes, biotite, calcic plagioclase, and accessory quartz, magnetite, and ilmenite are present and epidote is a common secondary mineral.

A third type of lamprophyre is composed almost entirely of secondary minerals, is light to dark grey, and commonly shows numerous bright green streaks and brownish spots. These rocks under the microscope are seen to be composed largely of ferruginous, magnesian carbonate with which is associated a colourless mica, a little quartz, more or less serpentine, chlorite, sulphides, and, commonly, calcite. The mica appears to be a chrome-bearing variety akin to mariposite, and is the green mineral seen in hand specimens. The brownish areas are due to oxidation of iron sulphides and ferruginous carbonate. The original composition of these rocks is uncertain, but some outcrops appeared to indicate a gradation into the dark green lamprophyre type already described. Examples of these completely altered dykes are best seen in the vicinity of Whitewater and Jackson mines, though they appear elsewhere in the Slocan series.

Another type of mafic dyke, referred to in general as "minette", is common in the Slocan series. These dykes are mostly only a few inches wide, are dark coloured, carry a large proportion of black mica, and much resemble one another in the hand specimen. Under the microscope, however, they are seen to vary considerably in composition. Biotite is always abundant and some specimens show much orthoclase. Others carry greenish amphibole with interstitial quartz and feldspar. In most cases these rocks are so altered that the original composition is a matter of doubt. Many such were observed near Sandon.

Basic intrusives are associated with the Kaslo series and intrude the Milford group. These have about the composition of hornblende diorite and are thought to be related to the period of vulcanism that gave rise to the Kaslo series. The hornblende appears to be mostly secondary after pyroxene. Other minerals present include important percentages of feldspar, mostly soda-lime plagioclase, some pyroxene (augite), much epidote, a little quartz, and more or less chlorite and serpentine.

Age. The salic and most of the mafic dykes are of pre-mineral age, for they are cut by the fissures that provided entry for the mineral-bearing solutions. The mafic dykes seem on the whole, since they cut the salic dykes, to be the younger. Most of the salic dykes and sills strike northwesterly, whereas the mafic dykes have a predominant northeasterly trend. Salic dykes, such as occur so abundantly in the Slocan series, are scarce in the granite areas, whereas mafic dykes are about equally prominent in both formations. The salic minor intrusives are considered to represent a late stage in the intrusion of the Nelson batholith, for many of them bear a lithological resemblance to the non-porphyritic granite and granodiorite member of the Nelson granite which is somewhat younger than the main body of this granite.

The minor intrusives are much less deformed than the pre-batholithic formations they intrude, undoubtedly because the latter were deformed before intrusion of the Nelson batholith. Developments underground have, however, shown that minor intrusives were, in places, involved in shearing that affected older formations. In a number of instances both in the Slocan series and the Nelson granite mafic dykes have been observed to be followed by fissures and shear zones providing access for mineralizing solutions. This feature has, in fact, appeared so significant in mining operations as to suggest some connexion between these dykes and mineralization. It appears unlikely that the mafic dykes are the source of ore mineralization, for they are free of ore minerals except where they have been fractured. They were, however, probably intruded during a period of deformation just before and possibly extending into the period of mineralization; in some cases, where their intrusion did not completely heal the original planes of weakness or where they themselves were less competent than the rocks they intruded, further fracturing or shearing occurred along them and provided channels for ore-bearing solutions. A few, small, mafic dykes of definitely post-mineral age were observed cutting across the ore-bearing fissures or shear zones as, for example, at the Enterprise and Anna mines. At the V and M property a similar dyke is intruded along a fault which displaces a vein.

Age of the Nelson Batholith and Associated Intrusives

The Nelson batholith and associated intrusives cut the Slocan series of Triassic age. No younger consolidated formations occur in the map-areas, so any attempt to fix more definitely the date of intrusion must be based on indirect evidence.

The various members of the Nelson batholith grade into one another as if they represent nearly, if not quite, continuous irruption, which doubtless occupied a considerable interval of time. The so-called batholithic stocks are projecting parts of the batholith. The other smaller intrusive bodies, stocks and dykes, are indicated to be younger by such contacts as have been observed. But these stocks and the many smaller salic intrusive bodies so resemble phases of the Nelson granite that it can scarcely be doubted that all are closely related. The mafic dykes may be complementary to the salic bodies and if so would belong to the same general period of intrusion. Thus, excluding the intrusives related to the Kaslo series and certain dykes younger than the mineralized veins, the available evidence indicates that all the intrusive bodies are related in origin, though differing somewhat in age; all are younger than the Slocan series and older than the period of mineralization. The sequence commenced with batholithic intrusion, was followed by the invasion of stocks and the salic minor intrusives, and concluded with the injection of the mafic dykes.

The main folding of the Slocan series was completed before the end of the batholithic period, as is indicated by the relations exhibited by the stock-like bodies, and by the fact that the deformation of the Nelson granite is rarely pronounced except in the case of the crushed granite bordering Slocan lake, and even this deformation seems to have been produced prior to complete consolidation of the intrusive. The orogenic forces may have persisted in some degree until after the close of the batholithic period and have caused the local fracturing, brecciation, etc., exhibited by the batholithic rocks, but it seems much more probable that such deformation was produced in a later period of orogenic disturbance. But mineralization took place after most, at least, of this fracturing occurred, and since mineralization and the Nelson granite are evidently closely related in origin, it follows that batholithic intrusion did not long precede the orogenic disturbance that affected the batholithic rocks. If the date of this orogenic disturbance could be determined, the batholithic period could be rather closely fixed. If, as already suggested, the orogenic period was that of the Laramide revolution, and if it be assumed that this orogeny occurred at about the same time in the Selkirk as in the Rocky mountains, then the invasion of the Nelson batholith must be assigned to late Cretaceous time.

Outside Sandon and Slocan map-areas, members of the Nelson batholith are in contact with younger intrusive bodies that may be Tertiary, e.g., the Kuskanax batholith (5, 1928, pages 104-105) lying between Slocan and Upper Arrow lakes and the Rossland Alkali Granite and Syenite (19) on either side of Lower Arrow lake. These intrusives have been called Tertiary because they are fresh and intrude the Nelson batholith; also because they occur near Tertiary sediments and volcanics which are dyked by very similar rocks, and because they contain no ore minerals or mineral deposits quite unlike those seemingly related to the Nelson granite.

The Nelson batholith and other granitic rocks of southern British Columbia are so distributed (22, Figure 1, face page 14) with respect to the great body of batholithic rocks of the west border of the province as to suggest that all are related. The Nelson batholith and associated intrusives are, however, on the whole, more diversified and more acid than the bulk of the Coast intrusives. It is a granite and is associated with intrusive bodies considered to be Tertiary and in part of decidedly alkaline composition, whereas the main body of the Coast Range intrusives ranges from granodiorite to quartz diorite. If it is a rule that the younger intrusives are more acidic than the older, the Nelson batholith might be considered a somewhat later phase of batholithic invasion than the main belt of Coast Range intrusives.

General opinion favours the view that the period of intrusion of the Coast Range intrusives was long. Because these intrusives cut Jurassic rocks in widely separate areas in southern British Columbia, the Coast Range "batholith" is there believed to be not older than Jurassic, and, as some of the intruded rocks yield fossils of Middle and even lower Upper Jurassic age, it very likely did not antedate Upper Jurassic time. In other areas members of this great belt of batholithic rocks intrude sediments of Lower Cretaceous age that, however, include conglomerates which, in places, are largely composed of cobbles of granitic rocks very similar to the intrusives. From such observations it seems fairly evident that the main belt of Coast Range intrusives is a complex of intrusions that commenced in Upper Jurassic time and continued at least well into the Cretaceous period. No intrusive contacts of the Coast Range batholithic complex with Upper Cretaceous strata have been found, and in many places the intrusives have been found lying unconformably below Tertiary sedimentary and volcanic rocks. If the Nelson batholith is related to, but is somewhat younger than, the main mass of the Coast Range intrusives in southern British Columbia its age is almost certainly Cretaceous and may well be late Cretaceous.

PLEISTOCENE AND RECENT

Pleistocene and Recent deposits cover large parts of both Sandon and Slocan map-areas, and in many places have greatly hindered prospecting and surface explorations. For convenience in description these deposits may be referred to two classes, unassorted and sorted.

The unassorted deposits are chiefly of glacial origin and, therefore, mostly Pleistocene. They occupy much of the higher valleys and the upland slopes, where they extend to and even for some distance above timber line. They are, in the main, glacial drift that has escaped transportation downhill. Though most of this drift accumulated during the Pleistocene period, some is even now forming in the vicinity of glaciers on the higher peaks and divides. The unassorted deposits are of varying thickness and irregular distribution. The materials composing them range from erratics up to several feet in diameter and scattered loosely over the upland surfaces, to heavy deposits of ill-assorted debris occupying the gentler valley slopes and varying from a few feet to more than 100 feet in thickness. Deposits of the latter sort are notable along the main valleys in Sandon map-area which lie in an area that is lower than surrounding areas and, in consequence, has received much glacier debris. These deposits of the main valleys consist of compacted sand and clay carrying rock fragments, mostly of local formation.

Slide debris is abundant. Wooded areas are being reduced by lumbering operations and recurring disastrous forest fires leaving much of the map-area comparatively open (Plate X B). These open areas are largely steep mountain slopes and are subject to snow slides, particularly in the late winter and early spring months. Such slides are a constant menace to mining operations and necessitate special care in selecting sites for buildings (Plate X A), adit entrances, and tramways. The slide materials include snow, surface vegetation, and, commonly, thousands of tons of underlying soil and rock. They accumulate in the valley bottoms, forming deposits 100 feet or more in thickness and covering many acres, especially at the mouths of steep tributary valleys or gulches. Wide swaths denuded by heavier vegetation and extending down the more lightly forested slopes are common and are conducive to further slides. Such avalanches or rock slides occur chiefly on the more precipitous slopes, but at the base of all cliffs or other steep, rocky slopes talus is constantly accumulating and may cover large areas in the valleys below.

The sorted deposits mostly occur in the lower valleys and are divisible into terrace deposits, delta deposits, and stream alluvium. The terrace deposits are chiefly of late Pleistocene age; the others are Recent. The terrace deposits are widespread and occur at elevations ranging from about 250 feet to 3,500 feet above Slocan and Kootenay lakes. The more prominent and persistent terraces occur along the shores of the lakes, and the materials composing them are commonly well bedded but show great variations in character within short distances. The materials are chiefly sands and gravels, but include minor bands of silt or very fine sand. The beds are commonly sharply defined but individually quite variable in thickness, pinching and swelling to a marked degree. Locally, as a result of floods or the accumulation of slide debris, much ill-sorted material may be mixed with the better stratified sands and gravels. For the most part the beds are nearly horizontal or dip slightly towards the centre of the valley that they border, or dip down the valley at smaller angles than the valley floor. The terrace tops vary in width from less than a few yards to several hundred yards, the wider benches, as along the shores of the lakes, affording considerable acreages of arable lands.

The delta deposits are more local in extent and are still forming. They are conspicuous features at the mouths of the larger streams where they jut for half a mile or more into the lakes. The larger deltas have provided ideal locations for townsites, combining the most favourable climatic conditions, fertility of soil, and convenience to transportation with unusually picturesque surroundings (Plate I). The towns of Rosebery, New Denver, and Silverton on Slocan lake and Kaslo on Kootenay lake are situated on such deltas, the latter town occupying in part an older terrace 250 feet above the level of the present delta of Kaslo creek.

Aside from the delta deposits stream alluvium is uncommon. The valley bottoms are generally narrow and the streams have mostly cut down to, or near, rock bottom and have developed canyons in their lower courses.

Interesting spring deposits occur in these areas and in places are in process of formation. These include numerous deposits of calcareous tufa (travertine), one conspicuous deposit of bog manganese, and several minor deposits of bog iron. Calcareous tufa has formed where waters carrying excess carbonic acid gas have dissolved limestone beds and on reaching the surface have deposited their load of calcium carbonate. Much the same process is responsible for the formation of the bog manganese and bog iron deposits, and is discussed more fully on subsequent pages of this report.

Special areas of mineral springs occur, one between Tenmile creek and Zwicky near the new motor road, and another along the railway track opposite Kemp creek. At the latter place the spring waters are depositing quantities of bog iron. There is also a well-known mineral spring at Kaslo near the old concentrating plant north of the Canadian Pacific Railway wharf. Another iron-bearing spring was noted in the main adit at Galena Farm mine.

CHAPTER IV

ECONOMIC GEOLOGY

GENERAL STATEMENT

Sandon and Slocan map-areas embrace an area of 527 square miles within which 205 or more properties have at one time or another made ore shipments, and many others have been extensively prospected.[1] The mineral reference map published by the Department of Lands, Victoria, B.C. (8) shows the extraordinary number and localized concentrations of claims. If this claim map be compared with the geological maps accompanying this report it will be seen that the situation and congestion of properties are related to their geological environment. Most of the claims are within areas of the Slocan series or of members of the Nelson granite, so it may be assumed that these formations were most favourable for ore deposition. Their relative importance in this respect is not, however, in proportion to the number of claims staked in each. Within Sandon and Slocan quadrangles the claim map shows about 850 patented and surveyed claims in the Slocan series as against about 425 such claims in the batholithic intrusives, but the total value of ore produced from the Slocan series is about thirteen times as much as that from the Nelson batholith. The deposits in the intrusive rocks are smaller on the average than those in the Slocan series, but on the other hand most are richer, carrying high silver and sometimes gold values but relatively small percentages of lead and zinc. The average value of ore mined from the granitic rocks has been a little over $38 a ton, whereas ore from the Slocan series has averaged about $29 a ton. It is interesting also to note how tenaciously claims within the area of the Slocan series are being held in contrast with those in areas of other formations. Most of the 740 or so claims in Slocan mining division are located in rocks of the Slocan series. About 8 per cent of these, according to the list published by the provincial government in May, 1929, have reverted to the Crown. In Slocan City mining division, on the other hand, most of the 200 or so claims are in areas of the Nelson granite and about 24 per cent of them have reverted to the Crown. Similarly, about 22 per cent of the 370 or so claims shown in that part of Ainsworth mining division included in Sandon and Slocan map-areas have reverted to the Crown, and most of these abandoned claims lie either within areas of the Nelson granite or within areas underlain by formations other than the Slocan series.

The numerous properties of any one congested area occur at altitudes differing by as much as 5,000 feet. Throughout this vertical range the characters of the deposits near the surface are commonly remarkably

[1] Descriptions of individual properties have been prepared by the author and are on file with the Geological Survey, Bureau of Economic Geology, Department of Mines, Ottawa.

alike. This feature is apt to give rise to the belief that individual deposits should maintain a fairly constant composition throughout, and that perhaps some of the larger ore-bodies should persist from the summit of a divide to depths corresponding to at least the lowest elevations at which outcrops of similar ore have been discovered. Unfortunately such a desirable condition has not been demonstrated to exist. Several of the more important lodes have been productive over a vertical range of from 1,000 feet to over 3,000 feet, but in each such case the maximum ranges represent the combined vertical range of two or more distinct deposits along one vein-bearing lode. Mining indicates that any ore-body, irrespective of the altitude of its outcrop, probably does not continue to any great depth. The individual deposits, too, have been found to change in mineral composition with depth.

Silver is the metal of chief value in Slocan ores, but lead and, in the last decade and a half, zinc are also of primary importance. In many properties silver, and in a few silver and gold are the only metals of economic significance. Ores from such properties are composed mainly of quartz with negligible, or minor, lead or zinc content, and are referred to as "dry ores" (*See* Plate XI A). In most of the larger properties, however, silver, lead, and, generally, zinc have all been important constituents, and ores from these properties constitute the "wet ores" of the Slocan camp. The principal valuable ore minerals are argentiferous galena, argentiferous grey copper (silver-bearing tetrahedrite and freibergite), and sphalerite (zinc blende). Values in different ore-bodies or even within the same ore-body vary widely, ranging from a few dollars to, perhaps, several hundred dollars to the ton. This variation depends on the concentration of the valuable ore minerals, on their relative proportions, and on variations in the silver content of the galena and grey copper. As a rule, however, the silver content of any one ore-body bears a nearly constant ratio to the lead content, and for all the silver-lead deposits would average about $1\frac{1}{2}$ ounces of silver to each per cent of lead.

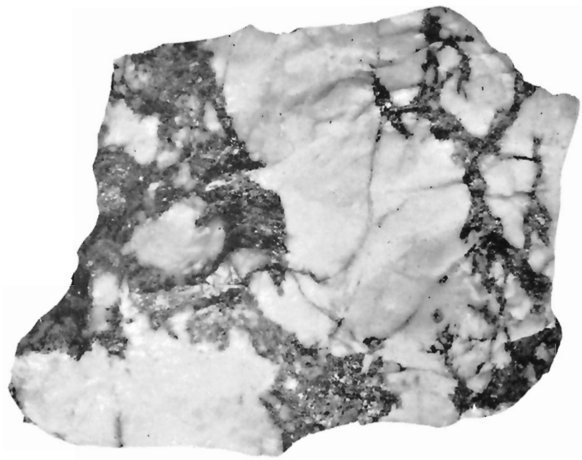
CLASSIFICATION OF ORE DEPOSITS

Slocan ore deposits can best be classified according to their mode of formation as vein deposits, replacement deposits, spring deposits, and detrital deposits.

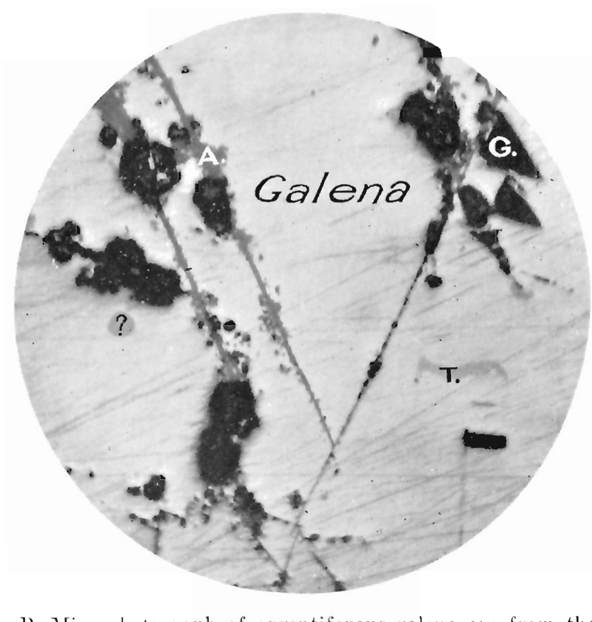
Fissuring, fissure-filling, and replacement were the main processes involved. The first two are of principal importance, and in many cases the only important ones. In most occurrences, however, the wall-rocks have been partly replaced by the metalliferous solutions. The channels followed by the solutions included open fissures, joint fractures, and broad zones of more or less intensely sheared and brecciated ground. Shearing, faulting, and brecciation preceded, accompanied, and followed the invasion of the ore-bearing solutions, and as a result the earlier formed minerals of some deposits were fractured and subsequently recemented by later minerals.

VEIN DEPOSITS

Vein deposits are the chief source of Slocan ores. Since various terms employed in describing vein deposits have been used with such different



A. A Specimen of typical "dry ore" from the McAllister mine: quartz (light) and grey copper (dark). Natural size.



B. Microphotograph of argentiferous galena ore from the Payne mine: A, anglesite; G, gangue; ?, unknown mineral; T, grey copper. (Neg. No. 70849.)

meanings, it seems necessary to define these terms as they are used in this report. By *vein* will be meant a continuous body of minerals developed along a fracture or a set of connecting fractures. A vein forms by filling a fracture space, or by replacing the rock walls along a fracture or by both these processes. By *single vein* will be meant a vein following a single fracture. By *composite vein* will be meant a vein that branches to follow more than one fracture whether the several branches formed simultaneously or not. By *lode* and *vein-lode* will be meant any single body of fractured ground in which an ore-bearing vein or veins occur or may be expected to occur. The term "vein" has commonly been confused with "lode" and both have been called "veins," although much of a lode may contain little or no vein minerals. In the area under present consideration most of the more profitable vein deposits occupy relatively small parts of the lodes in which they occur. By *fissure* will be meant a fracture of considerable length and depth. Veins that have formed in or along fissures and whose dimensions are largely controlled by the fissures are referred to as *fissure-veins,* but if replacement has been the principal factor the resultant mineral body will be termed a *replacement lode deposit.* The great majority of the mineral deposits are either single or composite veins. The two vein types possess many features in common and are identified in a general way with, respectively, the smaller and larger mineral deposits.

Single Veins

Numerous fissures afford no evidence of faulting of one wall with respect to the other. Veins formed in them are mostly small and rarely of economic value, though they may have directed attention to nearby, important mineral deposits. They occur as gash veins within massive strata flanked by less competent rocks; along joints in granitic bodies; along joint and tortional fractures in the more massive sediments; and in the vicinity of major ruptures, where they tend to be numerous and may join larger veins. Veins of this sort range from a few feet to, perhaps, 100 feet or more in length and from a mere film to several inches wide. Less is known of their depth. They are generally simple in structure and composition. In the Slocan and Kaslo series some are composed of nearly solid, coarsely cubical galena. Generally a little pyrite is present and as a consequence outcrops may be marked by a rusty streak. Elsewhere, as within the "dry-ore" areas in the Slocan series, or within the Nelson granite, the most abundant type of simple, single vein is composed largely of quartz containing a sparse dissemination of one or more sulphide minerals, of which pyrite is most common, galena and zinc blende locally most abundant, and high-grade silver minerals (principally argentiferous grey copper) most valuable. Where wall-rock is easily replaceable, as in the case of limestone, replacement processes extending outwards from a single fracture may give rise to the formation of important ore-bodies as they do, in part, at the Lucky Jim and Whitewater Deep mines.

The more important single veins follow fault-fissures and constitute profitable vein deposits, but not the largest. They are best defined where the fissures intersect the more massive parts of the Slocan series or intrusives rocks. In most cases the positions of the fault-fissures appear to have been controlled by lines of previously developed weakness. For example, the fault-fissures tend, on the whole, to stand at high angles, a condition which, particularly in the Slocan series, is attributed to their control by a northeasterly system of steep joints. For the same reason they are generally fairly straight, though liable, especially in the Slocan series, to be offset at intervals for distances varying from a few inches to 50 feet or more. Such offsets are generally in line with the bedding or schistosity and tend to occur within the less competent rocks. Where the rock structure is uniform and the fissures dip in one direction, all or nearly all the offsets are in one direction, a feature that once recognized expedites mining operations.

The single fault-fissure veins occupy varying proportions of the fault-fissure lodes in which they occur. Veins of the dry-ore type are more persistent than silver-lead or silver-lead-zinc veins and may continue along the entire investigated length and depth of the lode. Such veins pinch and swell, may split here and there to form two or more veins, and may even, for short distances, seem to be discontinuous though the apparent gaps may be bridged. They may have a seam of gouge along one or both walls of the lode; or, in places, include abundant fragments of the wall-rocks. The ore minerals are scattered or in streaks in the quartz and tend to be concentrated towards one wall, generally the hanging-wall. Most single, fault-fissure veins of the wet-ore type are separated by intervals, in some cases long ones, in which vein minerals are scanty or absent. Such veins, too, are, as a rule, more nearly equivalent in their dimensions to ore deposits than are dry-ore veins because they contain less gangue. Considerable parts of the lodes containing these wet-ore veins may be composed mainly of gouge and fragments of country rock, and even in the better mineralized parts there is apt to be more rock debris than in lodes containing dry-ore deposits.

Examples of single, fault-fissure veins of the dry-ore type occur on the Capello, Little Tim, Para, and Snowstorm properties. On the Capello group the principal quartz vein follows a fault-fissure for 200 feet, in which distance it averages 5 or 6 inches thick. The vein carries a little calcite and is mineralized with argentite, grey copper, and pyrite. The ore minerals are in part disseminated through the quartz, but tend to be concentrated near or along the hanging-wall side of the vein. The quartz veins on the other properties mentioned carry, in addition to high-grade silver minerals, argentiferous galena and blende. The abundant vein mineral is quartz varying from less than an inch to a foot or more thick. At the face of the main drift of the Little Tim mine the vein disappears, though the fissure is still well marked by a narrow seam of crushed rock and gouge. The ore minerals, where present, are in part disseminated through the gangue, but, particularly in the cases of galena and blende, tend to be concentrated in solid bands or narrow, lens-shaped masses along one or other wall of the vein, principally the hanging-wall.

Single, fault-fissure veins of the wet-ore type embrace a variety of mineral combinations. The chief gangue material is quartz, siderite, or calcite, or more than one of these minerals, though, in general, any single vein is composed mainly of one. The abundant ore minerals are galena and (or) zinc blende, but argentiferous grey copper is generally present in important amounts. Veins illustrative of this type are the Hartney, Payne (in part), U.S., and Reco (in part), in the Slocan series; the Revenue in the Nelson batholith; and the Beaver and Eureka in the Kaslo series.

The Hartney vein was followed at the surface over a vertical range of 510 feet, but the vein matter, as mined, did not extend far below the surface as the fissure tightened in this direction on encountering harder rocks. The vein varied from an inch or so to 2 feet thick and was widest near the surface. It was composed of an intimate mixture of galena and blende in a gangue of quartz, with lesser amounts of calcite and siderite and with fragments of wall-rock.

The Payne vein was the most profitable of this type discovered in the district. It extended across a narrow, high divide and dipped about 60 degrees southeast. At about No. 3 level (350 feet or so below the summit of the ridge) the vein matter formed a composite vein in a wide lode, but above No. 3 level, and extending most of the way from one side of the ridge to the other, the main vein was simple in structure, remarkably uniform in composition, and of high value. This part of the vein was sharply defined against the wall-rocks; it averaged probably a foot or more wide and over an average width of about 4 inches was composed of nearly solid, coarsely cubical galena. The remaining vein matter, chiefly quartz, tended to lie beneath the " paystreak " of galena. On No. 3 level the vein was continuous for over 1,200 feet from its outcrop on the southwestern flank of the ridge to where, towards the northeast flank, the vein fissure encountered a minor slate band along which it swung to the northwest for a short distance to where it ended against a strong fault or crush zone. The galena (Plate XI B) carried grey copper and other high-grade silver minerals and averaged nearly 2 ounces in silver to the per cent of lead.

The U.S. vein in Jackson basin was simple in structure but of somewhat unusual character for it was worked for its zinc content only, some 180 tons carrying an average of 52 per cent zinc having been shipped during the only productive years, 1913 and 1914. The course of the fissure coincides with that of the enclosing sediments. The vein occupied only a part of the investigated length of the lode, and is stated to have been formed of nearly solid zinc blende. Elsewhere the lode is composed chiefly of crushed fragments of the wall-rock and of gouge, in which are disseminations and narrow streaks or stringers of blende, pyrite, and quartz.

The No. 3 vein on the Reco property, otherwise known as the "Little" or "Reco-Goodenough" vein, was an excellent example of a single, fault-fissure vein, and was of particular interest because of the quantity of unusually high-grade silver-lead ore produced from it. This vein was traced underground for more than 1,000 feet and over a vertical range of more than 500 feet. To the southwest the fissure in which it occurred appears to be continuous with, or to form part of, a zone of fissuring including the No. 4 vein of the Reco group and, if so, would have a total length of about 4,000 feet. No. 3 vein, as developed, averaged only 6 or 8 inches wide with a maximum thickness of about 30 inches. Nearly 4,000 tons of ore averaging 226 ounces in silver a ton and 43 per cent lead was produced from it. The vein had a steep southeasterly dip, and cut across argillaceous and quartzitic beds of the Slocan series and many light-coloured, acid dyke rocks. The chief ore minerals were argentiferous galena and grey copper associated with blende, ruby silver, argentite, and native silver. A little pyrite was also present. The ore minerals formed a paystreak averaging 3 inches thick, the remainder of the vein being mostly mixed quartz and calcite gangue. Not all the vein was equally productive, but most of it down to No. 4 level (200 feet below the surface) was stoped out. Below this level the "pay-ground" pitched at about 30 degrees southwest or out of the hill. In the opposite direction the fissure was intercepted by a series of faults which appeared to be in part pre-mineral and in part of post-mineral age. Mineralization was scanty in this section and the vein discontinuous, the lode matter being chiefly gouge and crushed wall-rock with irregular streaks, lenses, and disseminations of vein matter through it. The fissure, however, appeared to continue strongly to near the extreme northeasterly face of Nos. 4 and 6 adits where it is said to have feathered out in a soft, green, basic dyke about 7 feet wide.

The main vein on the Revenue property occurs in a well-defined fault-fissure lode cutting the Nelson granite. The lode averages about 3 feet wide and is occupied in part by broken and crushed wall-rock and in part by a quartz vein. The ore minerals are principally galena and blende, partly disseminated through the quartz and partly concentrated in a paystreak of solid or nearly solid ore up to several inches thick. The higher grade ore has been largely stoped out of the upper levels where it appeared to rake to the northeast, into the hill, at an angle of about 30 degrees.

The veins on the Beaver and Eureka properties occur in rocks of the Kaslo series. So far as could be seen the veins are discontinuous and lie in narrow, straight, fault-fissure lodes in which the vein matter, principally clean galena, formed paystreaks varying from an inch or less to several inches thick and from a few feet to, perhaps, 50 or more feet long. In places the vein matter included considerable quartz gangue.

Composite Veins and Lodes

A composite vein may occupy two or more roughly parallel fissures that locally merge or are connected by a network of mineralized cross fissures. Such a composite vein is termed a *linked-vein* and the lode in which it occurs a *linked-vein lode.* The lode matter between the component parts of such a vein may be much wider than the fissures and, typically, is composed of comparatively massive and unmineralized country rock. Where, however, this country rock has been brecciated and the brecciated mass cemented and (or) partly replaced by vein minerals the resultant, aggregate mineral deposit is called a *breccia-vein* and the lode of which it forms part is called a *breccia-vein lode.* Where a composite vein occurs in an intensely sheared zone in which vein matter is as a rule narrow, though in places expanding across much of the zone, the whole vein deposit is termed a *shear-vein* and the lode it occupies a *shear-vein lode.*

The three types of composite veins and lodes show all gradations from one to another and one lode may include all three types. Linked-veins are characteristic of lodes that cross formations presenting abrupt changes in physical properties. Breccia-veins occur characteristically in the more resistant rocks which, under stress, tend to fracture rather than shear. They are common in the Nelson granite and occur in the more massive members of the Slocan series, particularly where the lodes cut across the strata. They form substantial ore-bodies within limestone beds or other limy and, consequently, easily replaceable rocks. On the other hand, lodes that follow the trend of fissile or slaty rocks or that intersect soft, relatively incompetent strata are more apt to develop as a broad zone or zones of intensely sheared ground within which vein mineralization tends to occupy only relatively narrow widths close to the walls of the shear zones. Post-mineral movements may break such vein deposits into discontinuous veins and irregular masses.

Brecciated vein matter recemented by later vein material is characteristic of composite veins and indicates that mineralization took place at intervals in such composite vein-lodes. It resulted mostly from minor deformative movements occurring during the stage of mineralization to which the deposit is related, and may have quite a different representation on an adjoining or nearby deposit of the same stage.

Composite vein-lodes are from a foot or so to 150 feet or more wide. They may be miles long and, in some cases at least, 4,000 feet deep. These figures do not apply to the veins but to zones of broken ground along which veins, generally of a composite character, have been found.

The width of a composite vein at any particular point is defined as the aggregate width of vein matter within the lode whether it occupies one or more than one part of the cross-section of the lode. Rarely are the wider parts of a composite vein-lode entirely formed of vein minerals, though narrowed parts commonly are. The composite vein of the Hewitt mine (*See* Figure 5) is characteristic of the linked-vein type. It formed in a lode which has a maximum width of over 100 feet and within which as many as four well-defined, mineralized fissures occur whose aggregate widths of vein matter did not exceed 15 feet. The intervals between the fissures are occupied chiefly by comparatively unmineralized country rock. At the Arlington mine a vein more typical of the breccia-vein type lay in a lode of 60 to 70 feet maximum width, containing three or four nearly parallel mineralized fissures a foot or so wide in brecciated granitic rock impregnated with minor amounts of ore and gangue minerals. The Silversmith lode which, particularly in the lower levels, is of the shear-vein type, reached in its better mineralized area a width of about 80 feet, but nearly all the vein matter was confined to two sections, together less than 20 feet thick following the foot- and hanging-walls. The Standard lode, which is mainly representative of the shear-vein type, had a maximum width near the main ore-body of about 150 feet. It included two pronounced ore-bearing channels, one near the hanging- and the other near the foot-wall, with a combined maximum width of about 45 feet. The main, or foot-wall section, attained a width of 40 feet, about half of it solid or nearly solid galena and the remainder ore of milling grade. Between the foot- and hanging-wall sections the lode was composed of more or less sheared, and in part sparsely mineral, country rock. Several other composite veins occur in lodes 20 to 50 feet wide, but such dimensions are far above the average.

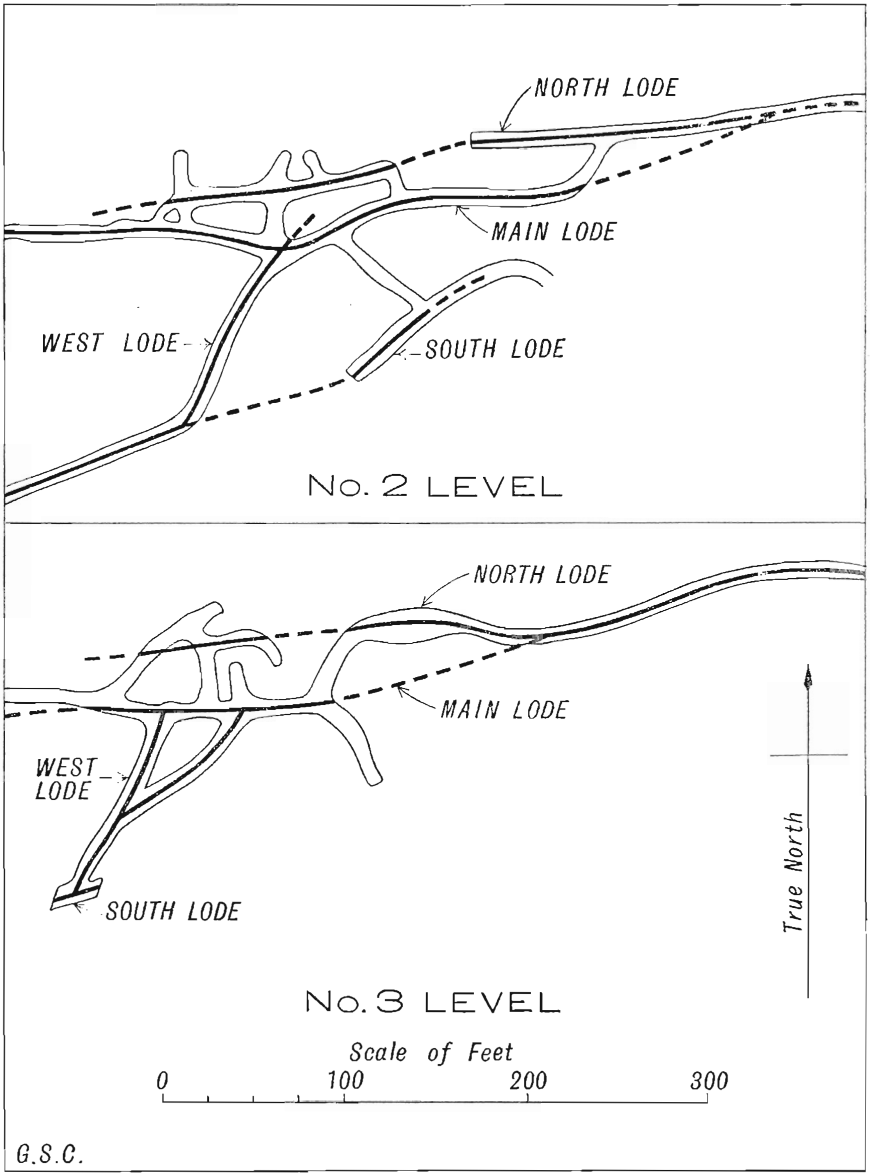


Figure 5. Plan of parts of Nos. 2 and 3 levels, Hewitt mine, showing positions of lodes.

For practical purposes the length of a composite vein-lode may be defined as the distance to which the lode has been followed in mining operations. Composite vein-lodes are rarely less than 100 feet long, and may contain several apparently distinct veins with longer intervals of barren or only slightly mineralized lode matter between. Lodes that hold veins in which quartz is the abundant gangue are apt to carry more continuous vein matter than those holding typical silver-lead and silver-lead-zinc veins. The Silversmith-Slocan Star lode has an observed length of 5,400 feet and contains, from east to west, the Silversmith, Slocan-Star, and Richmond-Eureka veins, which are about 1,000, 700, and 700 feet long, respectively; small amounts of vein matter evidently never continuous with these main veins are scattered along the intervals from one to the next. On the other hand, the Hewitt and Van Roi lodes are each about 3,000 feet long and carry almost continuous vein matter. On most properties, however, the vein or veins in a lode are short compared with the lode; the Idaho lode is more than 2,500 feet long, but the main vein is only about 500 feet long; the Ivanhoe lode is 3,000 feet long, but its main vein is 700 feet; the Queen Bess lode is 1,700 feet long, its main vein 500 feet; the Rambler-Cariboo lode is 2,000 feet long, its principal vein 900 feet; the Standard (including Emily Edith, Alpha, and Echo) lode has been followed for 6,000 feet, but the main Standard vein was continuous for only 1,000 feet.

Where a lode appears to be continuous with another lode, though continuity has not been actually established, the term *correlated length* will be used to designate the total of the observed lode lengths and the assumed connecting intervals of the lode system. For example, the Silversmith-Slocan Star lode has been followed for 5,400 feet underground and by closely spaced surface workings and seams continuous with the Hope lode which has an observed length of about 1,800 feet. The *correlated* length of this Hope-Silversmith lode system is about 9,000 feet. Other examples are: the American Boy-Last Chance-Surprise lode system over a mile long; the Slocan Sovereign-Texas-Reco No. 2 lode, 4,500 feet long; the Number One-Reco No. 3 lode system, 4,000 feet long; the Emily Edith-Standard-Idaho-Queen Bess lode system, over 4 miles long; the Van Roi-Hewitt over 8,000 feet long, and which if it includes the Galena Farm workings would be over twice as long; the Whitewater lode, about 4,800 feet long; the Arlington-Specular lode system, about a mile long, or if correlated with the Neepawa and Westmont lodes, nearly 4 miles; and, finally, a wide lode system extending from the valley of Keen creek (developed in that vicinity by the Index, Silver Bear, and Silver Bell mines) northwesterly across Kyawats and Klawala creeks to link up with developments on the Gibson, Gold Cure, and Bismark properties, and having thereby a correlated length of nearly 4 miles.

Less is known about the depths reached by composite vein-lodes and composite veins than about their widths or lengths because lodes and veins have rarely been bottomed. Many lodes have shown distinct indications of "tightening" or narrowing in the deeper workings. Depth of a lode is defined as the vertical distance between its highest outcrop and its lowest known position. The high relief of the Slocan district exposes most lodes to much greater depths than do the deepest underground workings on their veins. For example the Standard lode from the uppermost Echo to lowest Emily-Edith workings is about 2,200 feet deep, whereas the deepest underground working on the Standard vein is only about 1,000 feet. Other examples illustrating the depths of the more prominent composite veins and vein-lodes are given in the following table:

—	Depth of main lode	Depth of main vein disclosed by mining
Alamo	750	350
American Boy-Last Chance	1,600	500
Bosun	650	650
Hewitt	1,300+	1,300+
Idaho	800	400
Monitor	500	350
Queen Bess	700	400
Rambler-Cariboo	1,300	1,300
Ruth	600	500
Silversmith-Slocan Star-Richmond-Eureka	1,700+	700
Sunset-Trade Dollar	1,000	500
Van Roi	1,350	1,350
Whitewater	1,500	1,100

These figures show that several composite veins have observed depths of 500 to 1,300 feet and that a few have persisted throughout the investigated depth of the lode. In these as in most other instances the veins have not been actually bottomed, though in many cases they narrowed to unprofitable widths or changed in mineral composition to an unprofitable type.

If the various correlations of the composite vein-lodes, mentioned on a previous page, are correct, the maximum range of lode depths will be materially increased, but there will be no corresponding increase in the range of the depths of veins in these lodes.

Composite veins carry the same suite of ore and gangue minerals as do single veins. They are usually larger than single veins, but this difference is not directly proportional to the size of the respective lodes in which they occur. Single vein lodes not uncommonly are almost entirely composed of vein minerals, whereas very considerable parts of composite vein-lodes may be fragments and masses of wall-rocks. Ore shoots in composite vein-lodes are, however, by virtue of the size of the lode, commonly much larger than shoots in single vein-lodes.

Examples of the *linked-vein* type of composite veins are afforded at the Hewitt mine (dry-ore type) and at the American Boy and adjoining Last Chance mines (wet-ore type). The lode system at Hewitt mine strikes nearly east and west and dips northerly at an average angle of 70 degrees. It angles slightly across mainly massive strata of the Slocan series near their contact with Nelson granite, tongues of which appear in the upper workings. As developed at the several mine levels the lode has shown from one to four distinct vein-bearing fissures (*See* Figure 5) linked together in the one lode system, with intervals of unmineralized and relatively barren ground between. The lode matter in the separate fissures consists largely of country rock crushed to gouge or brecciated and cemented by quartz carrying a varying but mostly small, proportion of ore minerals. Locally these minerals are important constituents and their concentration has provided several important ore shoots on the property. Records of production are incomplete, but such as are available indicate that over 93,000 tons of ore has been mined from this property and that this ore has contained an average of nearly 14 ounces in silver to the ton, over 1 per cent lead, and about 2 per cent zinc.

At the American Boy and Last Chance mines the main vein-lode follows a strongly fissured zone which cuts across Slocan strata and numerous porphyritic intrusives on a strike that varies from about north 45 degrees east on the American Boy to about north 60 degrees east on the Last Chance property. It dips southeast at 60 to 65 degrees. The lode includes two and in some places more than two, well-defined fault-fissures, each marked by from one to several inches of gouge and by a variable width of crushed rock. The fissures meet and separate at irregular intervals, forming a braided structure from a few inches to over 20 feet wide. The main lode is joined in places by vein-bearing fissures entering from the hanging-wall side and striking a few degrees east of north. Good ore has formed at the junction of some such fissures with the main lode as well as at other places along it. Vein matter as mined has consisted mainly of argentiferous galena, and zinc blende with quartz and siderite associated with variable amounts of crushed rock. Production records are incomplete, but indicate an average content of about 65 ounces silver to the ton and 35 per cent lead for American Boy ore; that from the Last Chance mine has carried 124 ounces silver to the ton and 48 per cent lead.

Breccia-veins, as previously noted, are particularly characteristic of lodes in the Nelson granite and occur at such properties as the Arlington, Speculator, Neepawa, Westmont, Ottawa, and Fairmont. Unfortunately access to the workings was so limited that only partial details were obtained. The vein matter on each is chiefly of the "dry-ore" type, the principal gangue being quartz. The Arlington lode has a maximum width of between 60 and 70 feet and has been explored to a vertical depth of 647 feet. The principal mineralization occurs in a series of nearly parallel fissures striking about in line with the lode. The fissures are up to a foot or more wide and are relatively short. They were occupied by quartz with bands and less regular masses of mixed galena, blende, stephanite, grey copper, and native silver. Where sufficiently concentrated these metallic constituents formed ore-bodies from which nearly 13,000 tons of ore, averaging nearly 60 ounces in silver a ton and about 5 per cent lead, has been produced. Towards the northeast, on the adjoining Speculator group, the lode is said to have a maximum width of 150 feet, but has produced very little ore to date. The same lode is believed to be continuous northeasterly across the divide between Springer and Enterprise creeks and to connect in this direction with the lode on the Mabou and Ohio, Neepawa, and Westmont properties. The Enterprise vein may also form a part of this lode system, though it is a single, well-defined, fault-fissure vein.

In the lower workings of the Neepawa property are two strongly sheared and brecciated zones, each several feet wide, separated by about 80 feet of fairly massive granite. The two zones are impregnated with, and the crushed fragments partly replaced by, vein minerals which also form veinlets and minor impregnations in the intervening granite body. The principal vein mineral is quartz. It cements the brecciated wall-rocks and forms veins and lenses of irregular dimensions. Associated with this quartz is some spathic iron and, generally, a slight, visible impregnation of sulphide minerals, chiefly pyrite and a rosiny zinc blende with, more locally, a little disseminated galena. In No. 4 adit a few inches of banded blende and quartz associated with lesser galena was noted over distances amounting to only a few feet.

The lower workings of the Westmont have been chiefly concerned with a strongly sheared and brecciated lode averaging about 4 feet wide. It is composed of broken and crushed wall-rock partly cemented and replaced by vein quartz and carrying disseminations, pockets, and streaks of ore minerals. The quartz also forms ribs and lenses up to 2 feet or more thick. It is partly banded and shows some comb structure. The ore minerals include an intimate but variable association of galena, blende, pyrite, grey copper, ruby silver, and native silver.

The Ottawa mine workings develop a wide lode including two principal, mineralized components, each averaging several feet wide with an interval of 30 feet or more of comparatively massive granite between. Most of the work has hitherto been done on the easterly component (Ottawa vein) which varies from 2 to 20 feet in width; it is composed of gouge, brecciated granite, quartz, barite, and ore minerals, the latter of which were sufficiently concentrated locally to provide stoping ground up to 8 feet wide. Quartz forms vein-like or lens-like masses up to several feet wide and also occurs as a cement to fragments of the wall-rock. The ore minerals are mostly associated with a large proportion of gangue, but also form pockets or small shoots of cleaner material. They include argentite, native silver, grey copper (?), and more or less galena, pyrite, and a rather rosiny zinc blende. In places barite is said to have been the predominant gangue and to have been invariably associated with high-grade, silver-bearing minerals.

The Fairmont lode of the Fairmont property as displayed in an open-cut has a width of 12 feet and comprises about 6 feet of gouge and crushed wall-rock, several stringers of quartz, and, on the foot-wall, a 4-foot quartz vein carrying streaks and disseminations of ore minerals including zinc blende, galena, pyrite, and some argentite. The lode is stated to have been traced for 1½ miles on the surface. Underground it has been followed continuously, by one drift adit, for 1,200 feet and is remarkably straight. Near the face of the adit a 2-foot vein of quartz carries pyrite and a little galena and blende.

Very similar conditions to those obtaining on the lodes referred to above occur on other properties in the granite areas as, for example, the Fisher Maiden, Ontario No. 2, and Pontiac-Tecumseh.

Breccia-vein lodes are not, however, confined to batholithic intrusives. Most of the composite vein-lodes in the Slocan series show here and there resemblances to breccia-veins, though in general they may be more fittingly included with other types. Examples of breccia-vein lodes are found on the Alamo, Bluebird, and Hope properties. The Alamo lode, which is fairly typical, has been mined over a length of 1,500 feet and a vertical depth of about 750 feet. It occupies a strongly fissured and brecciated zone from a few inches to over 9 feet wide and composed of ore minerals (chiefly galena), of gangue (mainly quartz), and of crushed wall-rock. The ore minerals occur partly solid and partly mixed with gangue and other vein filling. Between 8 and 9 feet of solid galena was discovered at one point in the main ore shoot. Zinc blende becomes more abundant in the deeper workings, where the chief vein mineral is quartz associated with a little calcite and siderite. Other ore minerals include grey copper, ruby silver, pyrite, and, locally, conspicuous amounts of chalcopyrite.

Where most readily observed the "Big vein" lode at the Bluebird mine is a zone of brecciation, about 8 feet wide, cemented mainly by quartz and carrying disseminated sulphides and pockets of silver-lead ore.

The Hope lode has been mined for a length of 1,800 feet and to a vertical depth of about 550 feet. It varies from less than 1 foot to about 40 feet wide, and has been formed by a combination of fracturing, shearing, and fissuring, the prominence of each process varying according to the nature of the rocks traversed and the angle at which the lode encounters them. The lode is composed of crushed wall-rock, gangue, and ore minerals in about this average order of abundance. The abundant gangue mineral is coarsely crystalline calcite which in places occupies most of the lode and within the main ore shoot occurred principally as conspicuous bands or long, lens-shaped masses, up to 3½ feet thick, lying next or near the hanging-wall and underlain in turn by masses of ore minerals which partly replaced and were subsequently moulded in the calcite gangue. Siderite and quartz are the other gangue constituents. The chief ore minerals are galena, sphalerite, and grey copper. In the productive area they formed masses of nearly pure sulphides. Mixtures of ore and gangue were less common. The sulphide masses were roughly lens-shaped, varying in thickness up to 2½ feet and averaging, probably, 100 feet long. They were either strung out in line or occurred overlapping each other or arranged *en échelon*. In general they favoured the hanging-wall, but also occurred near the foot-wall as well as within the body of the lode. These masses were surrounded by gangue or by masses of crushed and cemented fragments of the wall-rocks.

The third type of composite vein, the *shear-vein*, has features in common with those already discussed. Veins of this type occur in more intensely and completely sheared ground than is typical of the linked-veins or breccia-veins and they are apt to be small in proportion to the lodes they occupy. These lodes are zones of relatively unstable ground along which any strain in the enclosing formations is readily taken up. Vein matter deposited in them is generally deformed, is not apt to be continuous, and, except under the more favourable structural conditions, is not likely to be of economic importance. Such shear-vein lodes are most typically formed along belts of slaty, fissile rocks such as compose a large part of the Slocan series. These belts of rock have a general northwesterly strike and many prominent shear zones trend in this direction, though few have been mineralized to any notable extent. Shear zones in comparatively strong rocks or in a continuous vein-lode have proved in several cases to be well mineralized. The same suite of ore and gangue minerals occurs in these lodes as in other types of composite veins, but vein deposits in them are likely to be much brecciated, distorted, and even considerably displaced.

Features of this sort are well illustrated in the Silversmith-Slocan Star lode system on the Silversmith, Ruth-Hope, Slocan King, and Richmond Eureka properties. From west to east this correlated lode trends southeasterly from Ruth-Hope to near Silversmith ground where it curves east and then northeast, maintaining the last direction for about 1,000 feet, in which stretch lay the great Silversmith ore shoot. Farther along its course the lode swings abruptly to the southeast for several hundred feet until it reaches the Slocan Star claim. In the next several hundred feet, including that section of the lode once occupied by the Slocan Star ore-bodies, the lode gradually turns east and then northeast and in the latter direction enters Slocan King and Richmond-Eureka ground. For most of its developed length of over a mile this lode intersects chiefly argillaceous sediments of the Slocan series. West of the Slocan Star mine workings, however, it swings from northwest to southwest around a plug-like body of feldspar porphyry, which forms its hanging-wall in the Silversmith mine. The average dip of the lode is about 47 degrees southerly. The irregular course of the lode is due partly to the structure of the enclosing sediments and partly to the plug-like intrusive. The lode formed by a combination of strong fissuring and shearing, the latter being particularly pronounced where the lode follows or swings to follow the rock structures, especially where these structures involve slaty or soft, argillaceous rocks. In intermediate stretches, where the lode cuts more directly across the stronger sediments, it is narrower, straighter, and formed more by fissuring than by shearing. Wide, sheared sections are principally developed where the lode is curved or has been guided by rock structures. The curved parts formed favourable sites for mineral deposition as instanced by the Slocan Star ore-bodies, and to some extent by the Silversmith ore shoot. In the Slocan Star workings ore was extracted almost continuously for maximum dimensions of 500 feet length, 850 feet vertical depth, and about 20 feet thickness. This ore was a mixture of ore and gangue minerals (principally galena and siderite) and was associated with varying, and in places large, proportions of sheared and slickensided wall-rocks. Northwest of these ore-bodies the lode carried very little vein matter, but is strongly defined by a wide zone of sheared rocks. At intervals small pockets of, chiefly, galena were discovered and showed evidence of deformation and, in part, probably displacement. East of the Slocan Star ore-bodies the lode intersects harder ground, is narrower, and has yielded stringers and lenses up to 1 foot thick and 50 feet or more long of quartz, quartz and siderite, or siderite carrying some sphalerite, galena, and pyrite. However, for much of the section of about 1,500 feet between Slocan Star and Richmond-Eureka ore-bodies, the lode is essentially barren. Along the northeasterly course from Slocan Star ground, which corresponds with the average strike of the fissure veins in the district, the Richmond-Eureka ore-bodies occur.

The swing westerly from Silversmith to Ruth-Hope ground marks an intensely sheared zone. In the lower workings on these properties the shearing is confined principally to foot- and hanging-wall sections of the lode. Each section consists of sheared, slickensided ground from several to over 50 feet wide, and is separated from the other by a wedge of comparatively massive rock which increases in width downwards, and in the lowest workings is over 100 feet thick. Mineralization is mainly confined to the two sheared sections and was greatest at their junction near the heart of the main Silversmith ore shoot. On either side of this shoot mineralization varies in continuity and character. To the northeast it consists in the lower workings of only occasional streaks and scattered small lenses of gangue minerals, chiefly quartz, and a little pyrite and blende and, more rarely, galena, but one small body of lead-zinc ore was stoped from the upper levels several hundred feet from the Silversmith shoot. In the opposite direction (on the Ruth-Hope property) ore had been (1927) followed almost continuously along the foot-wall section of the lode for 300 to 400 feet, but the hanging-wall section proved less attractive in the shorter distance explored. The foot-wall vein minerals formed a succession of partly overlapping, lens-like bodies conforming in contours with minor undulations in the enclosing rocks and composed of clean galena, clean blende, and mixtures of the two associated with varying proportions of spathic iron and quartz gangue. The common succession from the outside to the central parts of the lenses began with quartz and passed gradually through spathic iron and zinc blende to a galena ore. The galena was mostly gneissic (banded), indicating that it had been sheared, a suggestion well supported by the associated, highly sheared lode filling.

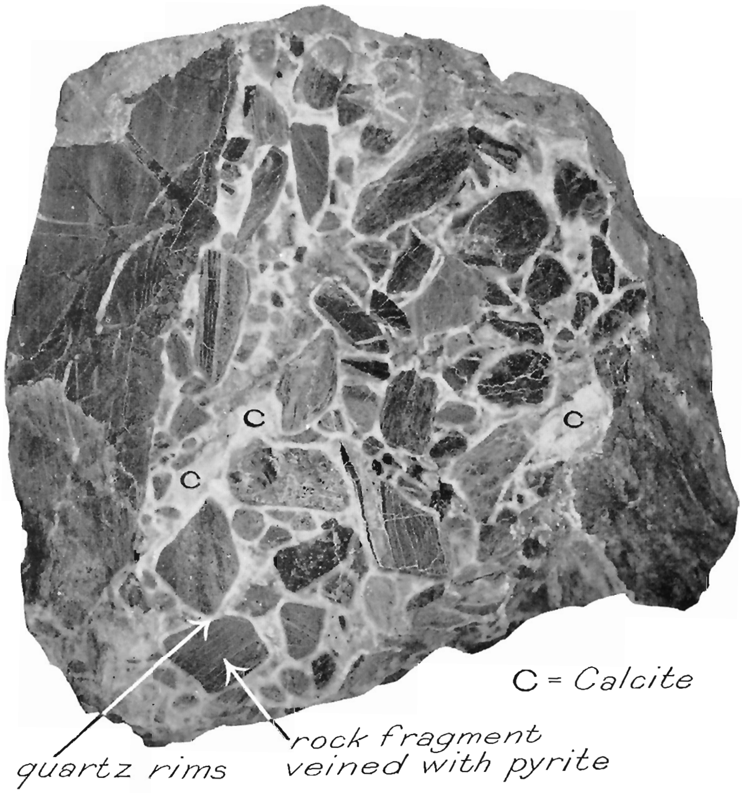
Among the many other shear-vein lodes in the Slocan camp might be mentioned those on the Whitewater, Wellington, Ivanhoe, Lucky Thought, Mammoth, Mohawk, Silver Bear, and Black Grouse properties. Most of the larger vein-lodes in the district are sheared to an important degree, though in other respects they are better classified with the other two types of composite vein-lodes.

Composite veins differ from single veins not only in form but in having been repeatedly fractured, consequently there has been repeated deposition of vein minerals and a vein once formed mainly of worthless gangue may have become valuable by fracturing and introduction of ore minerals. This lends encouragement to the complete exploration of composite veins that otherwise might not be expected to contain worthwhile mineralization. Single veins, on the other hand, are regarded as having formed from a single incursion of vein-forming solutions, and once bottomed or the profitable vein matter extracted they present no further attraction. However, single and composite veins are not always readily distinguishable. Though single veins were mineralized in a fairly uniform sequence of ore and gangue minerals, this sequence is readily disturbed by changes in conditions. Only part of the sequence may be present (as in some of the dry-ore deposits), or the same mineral or minerals may be repeated (as in simple, banded deposits), or the sequence may appear to be in part reversed, as in certain deformed deposits. Irregularities of this sort may be difficult to differentiate from the effects of composite mineralization.

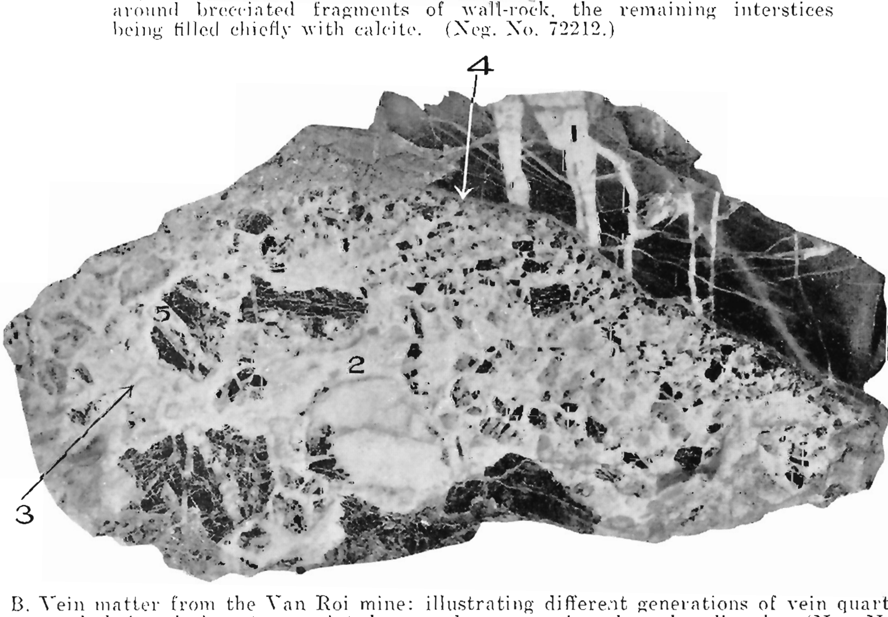
The best criteria of composite mineralization are: (1) brecciation of vein minerals and their cementation by the same or different minerals; (2) the presence of mineral-filled fractures angling across vein deposits, or occurring as band-like parts with sharp boundaries and composed of distinctive mineral assemblages; and (3) reversals in the normal order of mineral deposition.

(1) Brecciation and cementation are well shown in many composite veins, principally as fragments of vein matter or wall-rock surrounded or partly surrounded by a different mineral or mineral aggregate (Plate XII A). Brecciation is also indicated in a mass of vein matter, by fragments of wall-rock carrying minerals distinct from those in the vein matter or intersected by veinlets abruptly terminated at the boundaries of the fragments. In the main vein-lode of the Wonderful mine fragments of wall-rock are heavily mineralized with pyrite and pyrrhotite, and are surrounded and partly replaced by later vein matter consisting chiefly of galena and sphalerite. A somewhat similar relation was observed in the Whitewater Deep workings, where fragments of limy rocks mineralized with pyrite are partly replaced by later sphalerite. In the Silversmith-Slocan Star lode east of the main Slocan Star workings, narrow bands of spathic iron with a little quartz and no ore minerals are separated by about equal widths of wall-rock carrying much disseminated pyrite and narrow veinlets of quartz. The quartz veinlets do not extend into the spathic iron bands, but represent a generation of quartz earlier than that associated with the siderite. Two stages of mineralization are, therefore, present, the first was characterized by the introduction of pyrite and quartz and the second by the formation of spathic iron and quartz.

Excellent illustrations of this type of composite mineralization were seen in the Van Roi-Hewitt composite vein-lode. Plate XII B pictures a specimen from the Van Roi mine in which at least two and probably three stages of vein quartz deposition may be recognized. The first generation (marked 1) intersects part of the wall-rock of the vein-lode; a second (2) surrounds, replaces, and cements fragments of wall-rock and ore minerals (galena and sphalerite). This second generation also cements numerous quartz fragments, each of which is surrounded by a thin, brownish film of spathic iron. The same thin film lies along the wall of the vein (as at point 4), and around the fragments or along fractures in the ore minerals. It can be vaguely seen in the picture surrounding a piece of quartz (at point 5) which in turn veins a fragment of blende. A much larger fragment of quartz lies below point 2 in the picture. The sequence of events is, in part, fracturing followed by the incursion of quartz and associated galena and sphalerite, then a second period of fracturing followed by the incursion of quartz and ferruginous carbonate.



A. Ledge matter from Van Roi mine; showing narrow, even rims of quartz around brecciated fragments of wall-rock, the remaining interstices being filled chiefly with calcite. (Neg. No. 72212.)



B. Vein matter from the Van Roi mine: illustrating different generations of vein quartz and their relations to associated ore and gangue minerals and wall-rock. (Neg. No. 72211.)

A specimen of vein matter from the Corinth mine contained a small rock fragment intersected by tiny veinlets of quartz and completely surrounded by sphalerite except for a narrow rim of spathic iron which partly surrounds the rock fragment and cuts off the quartz veinlets. The sphalerite body is, in turn, completely surrounded by coarsely crystalline calcite. Apparently vein quartz was introduced, brecciation took place, then vein matter carrying siderite and sphalerite was introduced from which the siderite was first deposited, and some time after deposition of the sphalerite the vein matter was further disrupted and recemented by calcite. In this, as in the majority of cases, however, it is difficult to decide on the relative age of calcite as, under deformative conditions, it may mould itself around fragments of rock and vein minerals, giving the impression of being the last mineral to form when in reality it may have been one of the earlier minerals.

Where fragments of a single mineral, such as quartz, occur in a matrix of the same mineral the evidence for two periods of mineralization may not be convincing unless other supporting proof is obtained or unless the quartz matrix and the fragments have distinctive appearances. Otherwise such a relationship might merely indicate brecciation of a quartz vein without subsequent introduction of more vein quartz. In other, numerous instances where small bodies of one or more minerals are scattered through another mineral, this relationship is not always evidence of brecciation and cementation. The small bodies may have replaced the enclosing mineral much in the same fashion as ore and gangue minerals have replaced wallrocks; or the small bodies and the enclosing mineral may have consolidated together, as so commonly seems to be true of chalcopyrite in sphalerite, or, if consolidation was not contemporaneous the two classes of minerals may have been introduced together, as in the case of grey copper in galena; or, the enclosing medium, particularly if it is calcite or galena, may have been given the appearance of holding the included smaller bodies as a result of deformation, though all the minerals may have been deposited at about the same time.

(2) All gradations exist between brecciation and cementation, as described above, and a condition wherein mineral-filled fractures cross older vein matter. In places these fractures are so numerous and large that they exceed in bulk the vein matter they intersect. The same effect may also be produced with relatively few fractures where important replacement has extended outward from the walls of the fractures. Commonly the fractures crossing a lode form a nearly parallel system extending from wall to wall. The material added generally consists in part of ore minerals, and, therefore, except where important replacement of ore minerals has taken place, increases the total metal content of low-grade lode matter and, in most cases at least, does not decrease the metal content of high-grade deposits.

The Big or West lode of the Utica mine varies in width from 3 to 20 feet; is mainly composed of crushed and sheared rock fragments; and possesses well-defined walls marked by heavy seams of carbonaceous, slickensided gouge. In the productive section, which had a length of about 400 feet on the main level, the principal values were found in a succession of ore shoots crossing the lode from wall to wall, with comparatively barren intervals between. The location of these shoots was influenced by cross-fractures. Much the same condition governed the deposition of a large part of the rich silver-lead ore in the main shoot at the Standard mine, which consisted of a series of bands or lenses of ore angling across foot- and hanging-wall sections of the vein-lode with intervals of crushed, carbonaceous ground. This structure was probably in part the result of deformation that continued into post-mineral time. It led to the deposition of galena in a vein deposit which, at an earlier stage, carried zinc blende as the chief ore mineral. Likewise in the Silversmith-Slocan Star lode cross-fractures striking diagonally across the lode and intersecting wide bands of chiefly siderite and crushed wall-rock were mineralized with clean galena or with galena mixed with blende and gangue minerals. In all the cases mentioned, the later added minerals not only filled the new fractures provided but replaced the lode matter on either side.

Very similar processes seem also to have enriched deposits of dry ore. The West vein at the Anna mine lies in a sparsely mineralized, partly silicified, breccia-vein lode about 15 feet wide in the Nelson granite. The lode has well-defined walls marked by several inches of gouge and is traversed by a series of cross-fissures and parallel fissures in which ore minerals are concentrated to form shoots averaging about 50 feet long and up to 2 feet wide. The shoots are composed principally of stephanite and grey copper with a little galena, zinc blende, and, in places, considerable chalcopyrite. Quartz is the abundant gangue mineral and was introduced in part before, and in part at about the same time as, the sulphides. The last generation of quartz is associated with a little barite. In the productive section of the McAllister mine the chief values were found in small, rich shoots occurring at intervals along the vein-lode and composed chiefly of high-grade, silver-bearing minerals, principally grey copper. The main vein itself is composed chiefly of quartz and varies in width from 3 to 9 feet. The positions of the shoots were governed, at least to some extent, by cross-fissures intersecting the vein at a small angle, and this feature suggests that the bulk of the ore minerals were introduced after a fracturing of the quartz vein.

An indication of more than one generation of mineralization is also afforded by bands, mainly composed of a single mineral, that follow, for the most part, the course of a composite vein and are sharply defined against vein matter or wall-rock. The presence of such bands suggests the occupation of fractures formed by re-opening of a vein or vein-lode during the period of mineralization. Where one or other or both walls of a lode are sharply defined, as by a seam of gouge or a smoothly slickensided rock surface, any reopening would be apt to occur along such walls and, in consequence, subsequent mineral deposits would likely form there. Such later deposits differ in the nature of their contacts with adjoining vein matter from those that form in this position as a result of simple fissure filling. The contacts are not gradational, but are characteristically sharply defined and the bands may, at intervals, angle across the vein to run along the opposite wall. They rarely occur along opposing faces of both walls. At the Flint mine a band or "paystreak" composed mainly of galena, and varying from an inch to over 3 feet thick, lay chiefly along the hanging-wall of the Flint vein-lode which varies in width from a few inches to over 11 feet. In places the paystreak crossed to the foot-wall of the lode. It evidently formed subsequent to the remainder of the lode, which is composed of crushed granite, quartz, siderite, zinc blende, pyrite, and galena. The Wakefield vein affords a further illustration. There the lode was first occupied by a vein of calcite lying between sharply defined walls and in places several feet wide. Reopening of the vein along, principally, the hanging-wall permitted the incursion of solutions depositing calcite and ore minerals across an average width of about a foot. Subsequent shearing resulted in the formation of a breccia with fragments of ore minerals (galena and blende) scattered through a matrix of calcite which had moulded itself around the sulphide fragments. Later movements reopened the vein along the walls, principally the hanging-wall, and resulted in the deposition of a narrow paystreak of galena interbanded with zinc blende and associated with a variable amount of quartz. The boundaries of the paystreak with the vein breccia are commonly marked by thin, film-like seams of crushed, carbonaceous rock. Very similar relations occur in the Hope vein-lode, though the structure of this lode is, on the whole, more complex, in that reopenings were not confined to the walls as the later mineralization formed to an important extent along fractures diagonally crossing the lode.

(3) In a subsequent section of this report on paragenesis the normal sequence of deposition in a silver-lead-zinc deposit will be shown to begin with quartz and to be followed in order by siderite, sphalerite, and galena. A vein containing a complete suite of the essential vein mineral might be expected to have quartz along both walls followed within by successive bands of siderite and blende, and with galena mainly in the middle. The bands would grade into one another and the proportion of the chief mineral in each would vary, depending upon the composition of the mineralizing solutions. Otherwise, however, any abnormal sequence of mineralization would indicate that mineralization had taken place during more than one distinct stage. The Flint and Wakefield veins, for example, composed mainly of spathic iron (or calcite) and sphalerite, but containing a paystreak of galena along one or both walls, suggest two stages of mineralization of which the later is represented by the galena formed as a result of the reopening of the zinc-bearing vein. At the portal of No. 5 adit, Jackson mine, a 2-foot dyke within the vein-lode is overlain by 1½ feet, mainly of galena, and underlain by nearly 4 feet of brecciated vein matter consisting of a mixture of quartz, siderite, blende, and crushed argillite. The distinctive types of vein mineralization on the two sides of this dyke are indicative of composite mineralization. Very similar relations existed along the main sections of the Idaho and Richmond-Eureka veins where paystreaks of clean galena occurred along the hanging-wall of the veins and were underlain by vein matter, largely of gangue.

Attitudes of Lodes and Veins

A relation seems to hold between the degree of productiveness and the directions followed by the lodes and veins. On Figure 6 are plotted the courses of all the productive lodes concerning which reliable information could be obtained. Although the lodes strike in almost every direction, those striking between north and east are much the more numerous and include nearly all the veins that have individually furnished ore worth more

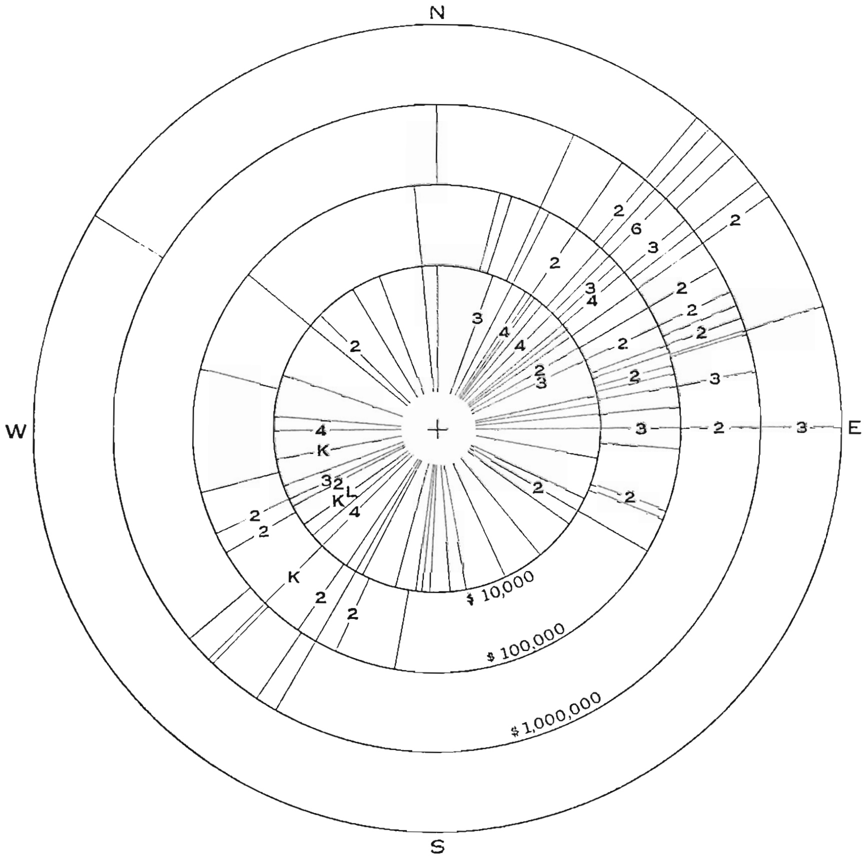


Figure 6. Strikes of productive lodes in Sandon and Slocan map-area.

Explanation of Figure 6. Lines in the NE. and SE. quadrants represent strikes of lodes intersecting the Slocan series. Lines in the NW. and SW. quadrants represent strikes of lodes intersecting granitic rocks, the Kaslo series (K), and the Lardeau series (L). Lines not bearing a number or two letters represent single lodes; other lines bear numbers indicating the number of lodes represented by them. Lines extending from the centre of the figure to the innermost circle represent the strikes of lodes each of which has produced ore valued at less than $10,000; lines extending from the inner circle to the next represent lodes credited with productions valued at more than $10,000 but less than $100,000; lines extending between the next two circles represent lodes credited with productions valued at more than $100,000 and less than $1,000,000; lines extending between the two outer circles represent lodes credited with productions valued at more than $1,000,000.

than $10,000. The figure further indicates that productive lodes in the Slocan series greatly outnumber all those in other formations, and that of the latter only those in the Nelson granite are important. It is obvious, too, that the proportion of important producing properties in the granitic rocks is much smaller than among those in the Slocan series, comparatively few being credited with a production worth more than $100,000 and only one, as against eleven in the Slocan series, exceeding the million dollar mark. All the productive lodes in the Slocan series that have produced ore to the value of $100,000 or more have strikes lying in the northeast quadrant and nearly 60 per cent of these strike between north 30 degrees east and north 60 degrees east. In the granitic rocks, six of the seven lodes that have yielded more than $100,000 worth of ore strike between north 30 degrees east and north 50 degrees east, but the seventh and largest producer strikes north 57 degrees west.

Most of the productive lodes dip southeasterly. Of the lodes in the Slocan series that strike northeasterly, 90 per cent dip to the southeast, and of those dipping in the opposite direction only four have supplied any considerable amount of ore. It is noteworthy that these four are situated close to the main granite contact. In the granite areas, on the other hand, only about 60 per cent of the northeasterly striking lodes dip southeast.

The dominant northeasterly trend of the lodes in the Slocan series is also the trend of a master system of jointing, and it is reasonable to suppose that fissures would develop more readily along such joint fractures than across them. The northeasterly trending fissures cut sharply across the strata and, therefore, would afford more permanent channels for ore deposition than those more nearly parallel to the bedding planes, along which the more pronounced shearing has occurred and where fissures, in consequence, would be more easily destroyed. The importance of the northeasterly strike and southeasterly dip of the fissures in the Slocan series may also be partly due to the fact that as this strike is very nearly parallel to the main batholithic contact and the southeasterly dip is toward it, these fissures were more readily entered by mineralizing solutions from the batholithic granitic source than those that strike or dip in a contrary direction. This last explanation is supported by the fact that lodes with a northeasterly trend and southeasterly dip are of less relative importance in the batholithic intrusives than in Slocan strata. Moreover, lodes of more than average economic value in the Slocan series that dip other than to the south or southeast are so close to the batholithic contact as to render the direction of dip of less probable importance.

Structures of Veins and Lodes in Relation to Rocks Traversed

Where lodes pass from massive to slaty or otherwise less competent rocks single veins may split into composite veins. A single vein following the bedding or schistose structures of the enclosing rocks is apt to split into two or more major, and perhaps a number of minor, veins, each tending to follow different structural planes. Where a single vein changes from a steep dip to a lower angle it may become composite. Though composite veins are more common in soft than in hard rocks they occur in the latter where these have been sheared and brecciated. Breccia-veins are, for example, conspicuous in the batholithic rocks and are probably more characteristic of them than of sedimentary formations, where shearing, mashing, and slipping of competent against less competent members are more noticeable features.

The attitudes of veins and lodes intersecting rocks of uniform character, such as the batholithic rocks or the more massive members of the Slocan series, may exhibit considerable regularity, but much variation, particularly in dip, may be expected in a complex assemblage of strata such as characterizes part of the Slocan series. In crossing from soft, more or less fissile beds to harder or more massive strata the lode dip is commonly steepened. Generally, too, both lodes and their contained veins narrow in the harder rocks, though maintaining a more regular width than they do in softer formations where they may pinch and swell irregularly or even fray out into a number of small, discontinuous, vein-bearing fissures. It has been a common experience to discover that where lodes cross dykes or sills in softer, less competent sedimentary rocks, their dip steepens and the lodes narrow.

In general, slaty or otherwise fissile or thinly laminated rocks, such as form wide belts of the Slocan series, do not carry veins, except where they have been supported by adjacent, more massive beds or by igneous ribs. The Whitewater lode, for example, lies within and strikes almost parallel with a wide belt of slates which in the vicinity of the lode are supported by strong ribs of quartzite and by a number of crossing dykes. In most cases, however, fissures, and, therefore, veins, on encountering slaty ground tend to split and end. An apparent contradiction to the rule is afforded by such important deposits as the Slocan Star, Silversmith, and Standard, where the bordering rocks are notably soft and sheared. In these cases, however, the deposits occur in exceptionally wide and pronounced zones of shearing and fissuring that are enclosed by quite massive and competent members of the Slocan series.

The relations existing between the numerous dykes and the veins and lodes are important. Most of the acid dykes or "porphyries" have a general northwesterly trend closely alined with that of the Slocan series with which they are chiefly associated. As the dykes are on the whole more competent rocks than the sediments shearing has commonly taken place along their contacts and the sediments have in most cases suffered the greater deformation. Fissure veins or vein-lodes that cut across the Slocan series and encounter dykes with their attendant borders of sheared rock are likely to appear to have been cut by faults that follow the courses of the dykes. Analogous conditions may also obtain in relation to any comparatively resistant bed or group of beds of the Slocan series.

The mafic dykes, as contrasted with the more acid types, are much less regular in trend and dimensions, and in many cases both within the Slocan series and the Nelson batholith they and veins follow the same lodes. In a few instances small basic dykes cut across veins, but most of the basic dykes have been involved in the shearing that developed the fissures occupied by the veins and have themselves been subjected to a certain amount of mineralization. This close association of veins and basic dykes seems to mean that fissuring was in progress for a considerable time; that the dykes were intruded during an early stage; and that the mineral solutions rose during a later stage. Presumably, the basic dykes and mineralizing solutions are closely related in origin.

Dykes have also influenced disposition of vein mineralization by deflecting mineral solutions into certain channels or sections of channels, by forming walls against which ore and gangue minerals tended to concentrate, by deflecting fissures, and by concentrating in their vicinity the effects of fissuring.

Faulting of Veins and Lodes

A system of pronounced shear zones in the Slocan series strikes northwesterly with the general trend of the strata and at right angles to so many of the vein-lodes. Crushing, shearing, slipping, and brecciation of the rocks are most pronounced where the ruptures conform closely with the bedding, and in many such cases involve widths of from 50 to 100 feet or more. Much of this deformation took place before mineralization, but in part after the development of the northeasterly striking fissures and zones of fissuring that subsequently were mineralized. Hence, what appear to be the faulted parts of a single vein may be two distinct veins formed in separate parts of a fissure that had been faulted in pre-mineral times. Veins in the same lode separated by a seemingly inconsequential fault may have formed at different times and under different conditions; they may be quite unlike in mineral composition. A fissure may carry an important ore deposit on one side of a fault and be barren on the other side. Banking up of vein against gouge in a fault that cuts off the mineral-bearing fissure is good evidence that faulting commenced before and not after mineralization. It has been rather common practice in the Slocan to claim that a vein on one property is the continuation of a vein on adjacent or nearby properties and if the two veins are not in line to assume faulting somewhere between. In most cases, however, the correlation of the veins is based on the correlation of the containing lodes and involves the unwarranted assumption that vein matter everywhere within such a lode was deposited at the same time and is of the same sort.

In the batholithic intrusives there is no such pronounced direction of shearing nor predilection for mineralization to occur only in fractures striking northeasterly (*See* Figure 6), and more of the faults affecting mineralized fractures seem to be post-mineral. The Enterprise fissure-vein, the most productive of any yet discovered in Slocan City mining division, strikes north 50 degrees east and dips about 70 degrees southeast. One major and several minor faults cut it at about right angles. A displacement of about 60 feet has taken place along the main fault and on either side of it the vein matter forms shoots of ore. Similar relations hold in the case of the smaller faults. On the Howard Fraction group a silver- and gold-bearing quartz vein, striking east and dipping at a low angle to the north, is at intervals faulted from 3 to 8 feet. The faults are post-mineral. Similar relations were observed in veins occurring in stocks and stock-shaped apophyses of the batholith, as at the Molly Hughes mine. The general conclusion is that, though in the larger mineralized shear zones and mineral lodes in the Nelson batholith some movement occurred during the period of mineralization, yet the principal faults affecting the lodes are post-mineral and, consequently, such lodes may be expected to carry the same type of mineralization on either side of the faults.

REPLACEMENT DEPOSITS

Beds of limestone or other notably limy strata have been locally extensively replaced by vein minerals. The widths of the fissure or fissures providing access for mineralizing solutions are insignificant as compared with the widths of replaced limestone on either or both sides. At the Lucky Jim a limestone belt from a few feet to over 100 feet thick is intersected, nearly at right angles, by a series of straight, persistent, and nearly parallel fractures striking north 50 to 55 degrees east and dipping steeply to the southeast. These fractures correspond with a well-defined system of jointing in the limestone and adjoining rocks. They

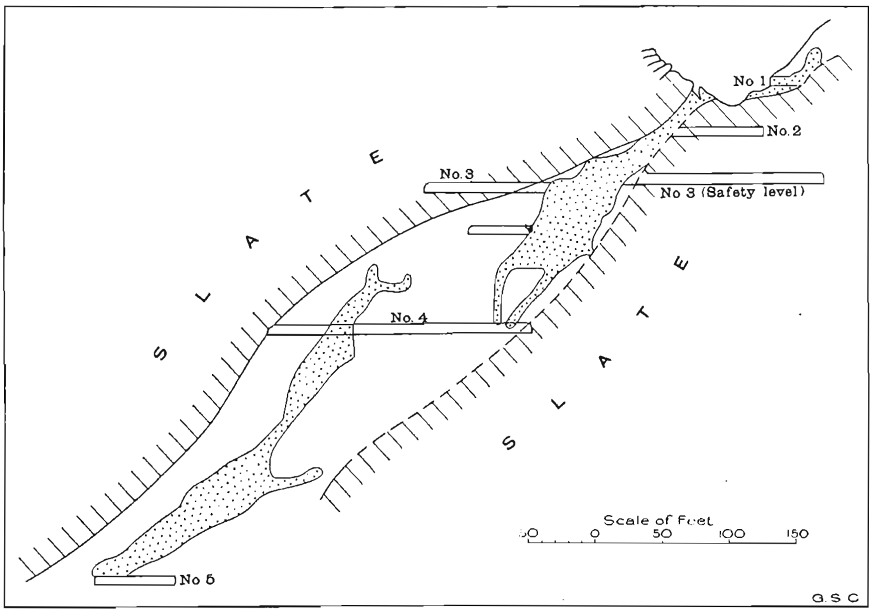


Figure 7. Vertical section, in part diagrammatic, Lucky Jim mine, showing two of the principal ore shoots (represented by pattern of dots) and boundaries of the limestone belt (indicated by pattern of sloped ruling).

vary in width from mere cracks, along which a little or no mineralization is evident, to others that were probably open fissures but whose widths have been obscured by extensive mineral replacement of the wall-rocks. Some movement along a few of these fissures is indicated by offsets in the limestone contacts and by grooves along the walls. Replacement outward from groups of these fissures formed a succession of chimney-shaped ore-bodies varying from about 10 feet to 50 feet in diameter and extending vertically for from 150 to 250 feet (*See* Figure 7). Where the fissures were closely spaced or the direction of replacement was controlled by a narrow, comparatively impervious dyke or dykes within the limestone belt, replacement of the limestone either extended from fissure to fissure or was deflected laterally beneath the dyke rocks and formed, in both cases, mineralized zones up to several hundred feet long. The ore in some of the shoots was nearly solid zinc blende. In others it was a mixture of blende, with a little galena, pyrite, calcite, and, more rarely, quartz, and varying proportions of unreplaced limestone. Galena was most abundant at the higher elevations and pyrite became in general most plentiful in the lower workings, where it was intimately associated with blende.

In the Whitewater Deep workings small fissures running out from the hanging-wall of the main Whitewater vein passed through a heavy limestone formation, which was extensively replaced to form large ore-bodies. At the Cork-Province mine the principal mineralization formed where the main vein angles across a series of limestone beds. At such intersections the limestone is replaced chiefly on the hanging-wall side. Replacements of a similar character occurred at the Caledonia property near Blaylock, at the Montezuma and Lincoln mines, and on properties southeast of Keen creek in the vicinity of and including the Bismark and Gibson.

Replacement of other than limestone or notably limy strata has been important in many properties, but not to the same degree. The notable ore-body discovered on the Surprise occurred mainly between the walls of a wide porphyry dyke (or closely spaced succession of dykes), and developed in large part as the result of replacement of the dyke rocks. This ore-body was somewhat ellipsoidal. The central part was composed chiefly of high-grade silver-lead ore; the outer part contained mainly zinc blende which decreased in amount inwardly. Breccia-veins in the granitic rocks, such as those occurring at Neepawa and Westmont mines, show abundant evidence of replacement of rock fragments, principally by quartz.

Replacement deposits commonly preserve the original structures and textures of the rocks replaced. This feature is particularly well shown in limestone replacements, where the ore is in places beautifully banded, corresponding to the original bedding structures. The bands may be only a small fraction of an inch wide but each is composed of different proportions of ore and gangue minerals. Under the microscope original grains of calcite are seen to be represented by pseudomorphs of galena. In some cases the galena is crowded with impurities and the individual grains may be bordered by small grains of pyrite following the boundaries of the original calcite crystals (Figure 8).

The most important ore mineral of the limestone replacement deposits is sphalerite. It is commonly associated with some galena and locally galena may be more abundant. Pyrite may also be conspicuous, as in the lower workings on the main ore-bodies at the Lucky Jim mine. Other sulphides, such as pyrrhotite, arsenopyrite (rare), and high-grade, silver-bearing minerals may also be present, though replacement bodies as a whole carry low silver values. Gangue minerals may or may not be important constituents. Generally, siderite is most abundant. At the Lucky Jim there is very little gangue of any sort, but at the Whitewater Deep and Cork-Province siderite is abundant. Some quartz and calcite are generally present, but are subordinate to the iron carbonate.

Replacement deposits in other than limestone rocks contain the same minerals as the associated vein deposit and in much the same proportions.

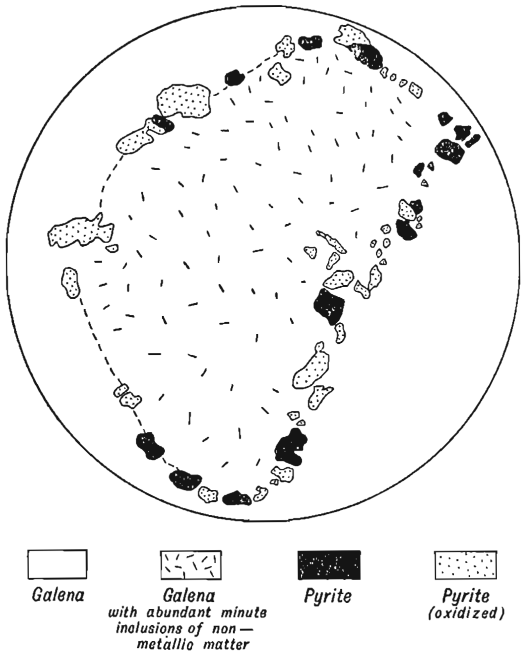


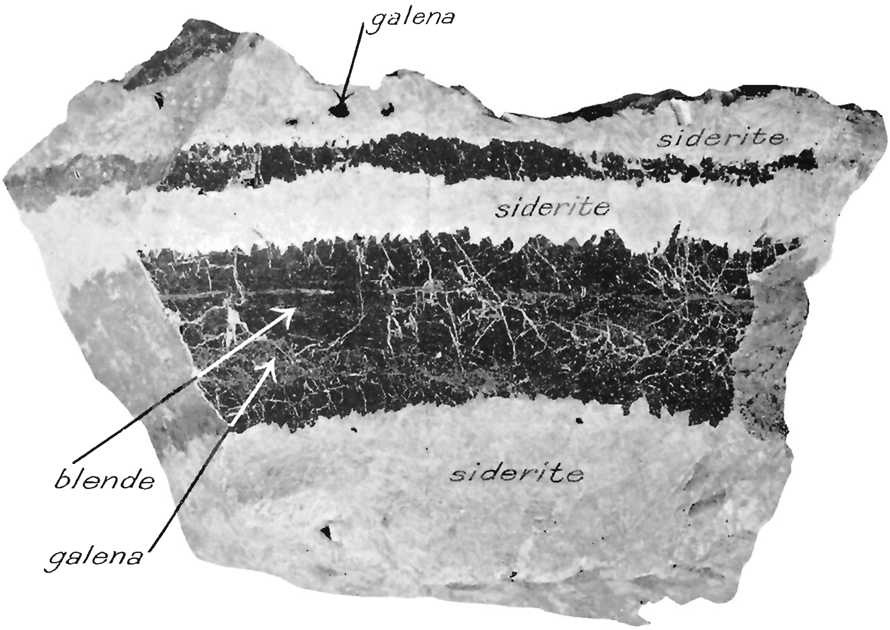
Figure 8. Camera-lucida sketch of Lucky Jim ore (188). Magnification: 40X.

ORE SHOOTS

Most of the ore shoots are parts of vein deposits, but a few are largely replacements. The ore shoots in veins are the parts that may be profitably mined. Such parts may include most of a vein deposit or only a small part of it. The silver-lead and silver-lead-zinc veins, particularly single veins, are more apt to contain relatively extensive shoots and to consist of solid or nearly solid ore than veins mined primarily for silver or silver and gold.

The ore shoots in veins are lens-shaped or tabular. In general they are thin, but in special circumstances, as for example where masses of ore have been dragged from their original positions in the lode by post-mineral movements, they may form comparatively thick ellipsoidal masses, but of no considerable bulk. Bodies of this sort have been found in the Silversmith-Ruth Hope and Standard vein-lodes. In other instances ore shoots may be more or less cylindrical or cigar-shaped, as at the Bosun mine, or chimney-shaped, as at the Montezuma and Bismark.

Some ore shoots are composed almost exclusively of ore minerals; others hold various proportions of ore and gangue minerals. Some ore



A specimen of banded zinc ore from No. 8 level, Payne mine, composed chiefly of sphalerite and siderite. (Neg. No. 72208.)

shoots, especially in single veins, are essentially uniform. Others consist of several closely adjacent bodies of ore each sharply defined, or one or more may grade into adjacent low-grade vein or lode matter.

The silver-lead ore shoots in single veins may consist almost entirely of galena, and though possibly only a few inches wide yet by reason of their purity and high silver content may be mined at a profit. Such shoots have the form of veins and may occupy the entire, or almost the entire, width of the lode in which they occur. Gangue minerals when present tend to form bands along one or both walls of the shoot. Along its strike the ore shoot either ends by pinching of the lode to unprofitable widths or by becoming lean. With depth the silver-lead deposits tend, typically, to carry more and more sphalerite and siderite, the latter at the expense of the ore minerals, the vein matter tending to be mainly siderite and sphalerite, commonly interbanded (Plate XIII), with only occasional pockets or disseminations of galena. At still greater depth quartz may appear, at the expense of the sphalerite and farther down of the siderite, until the deposit becomes barren or nearly barren of ore mineral and the shoot may be said to have been bottomed.

Shoots in single veins and mined primarily for silver or silver and gold are composed mainly of quartz. They are of two general types, namely, those holding little or no galena and sphalerite (Plate XI A) and those in which these minerals are important because of associated silver values rather than for their lead or zinc content. The ore minerals in either type are disseminated through the vein quartz or are partly segregated in streaks or narrow vein-like bodies. Such streaks may occur at intervals across the width of vein quartz, but tend to form most abundantly near one or other wall of the vein. The boundaries of the shoots are defined by the grade of the vein matter.

The ore shoots of the larger silver-lead and silver-lead-zinc deposits are composed in part of nearly solid sulphides and in part of sulphides, gangue minerals, and, in many cases, abundant fragments of wall-rock. The high-grade material may form bands or streaks either grading into or rather sharply defined against adjoining lower grade vein matter. Commonly there are two such bands (" paystreaks "), one close to the hanging-wall and the other near or adjoining the foot-wall. Together they, in most instances, represent only a small part of the width of the shoot and the interval between them is of varying mixtures of ore, gangue minerals, and fragments of partly mineralized wall-rock. Such intervening mixtures may carry sufficient values to pay for mining but, whether mined or not, the intervening low-grade materials and the two paystreaks are regarded as one ore shoot. At the Silversmith mine the hanging- and foot-wall parts of the main ore shoot spread so far apart below the eighth level that they were extracted separately in these lower workings. Much the same condition was encountered at the Bosun and Silver Bear mines. The ore shoots may exhibit more complex structures than these. In all or parts of some shoots the high-grade materials form masses of varying size and shape that are irregularly spaced in the deposit and are surrounded by gangue or by mixed gangue and sulphides.

Ore shoots vary in size from such as have provided only a few tons to others that have provided tens of thousands of tons. They vary in length from less than 100 to several thousand feet; in thickness from a few inches to 50 feet; and in depth from less than 50 feet to several hundred feet. Commonly high-grade ore forms a large proportion of the small and particularly the narrower shoots, but only a minor part of the larger shoots. The largest and most valuable shoot was in the Standard mine and extended from about No. 4 to below No. 6 level, a vertical depth of about 400 feet, had a maximum length of about 400 feet and a maximum thickness of about 50 feet, including on No. 5 level as much as 20 feet of clean galena ore. The ore was mostly extracted from 1908 to 1916 and had a gross value of between $6,000,000 and $7,000,000. Second in importance was the Silversmith ore-body at Silversmith mine. This shoot extended from near No. 4 to No. 11 levels, a vertical distance of over 600 feet. It was mined over a maximum length of about 500 feet and a maximum width of 30 feet, and yielded about 300,000 tons of clean and concentrating ore, having a gross value of nearly $4,000,000.

The factors that produced the ore shoots were many and their actions complex. In the simplest cases vein-forming solutions rising in fractures would, other factors being equal, deposit more vein matter in more open parts of a fissure than elsewhere, so these parts would be more likely to produce ore shoots than more restricted parts. The shape and attitude of such shoots would be controlled by the fissure system. Deformative movements during the period of mineralization were of great significance in the production of ore shoots, because the ascending mineralizing solutions would be forced to follow more restricted channels and would tend to deposit higher grade materials.

Where replacement gave rise to ore shoots the controlling factor was that the vein-lode crossed easily replacement strata, particularly limestone. The forms of the resultant ore-bodies were regulated largely by the thickness of the strata and their position with respect to the plane of intersection of the lode.

It has been pointed out by Irving (16) that "the intervention of impervious rocks in the path of mineral waters, or any other cause which may operate to impound them, seems to stimulate their chemical activity and increase the extent of area mineralized." This feature, Irving states, seems particularly true of replacement deposits in limestone. Impounding structures may be either such as abruptly stop the mineralizing solutions or merely restrict their flow. A narrow dyke, or possibly dykes, in the limestone beds at the Lucky Jim deflected the course of mineralizing agents and caused much larger deposits than elsewhere in the limestone body where such obstructions were not encountered. In the vein deposits it is not uncommon to find ore banked up against gouge in a fault that had crossed the vein-bearing fissure in pre-mineral time.

If one wall of a fracture with curving inequalities be displaced along the fracture plane open spaces would result at opposed concavities which would be good sites for ore deposition, especially if the walls were lined with impervious gouge. A number of the larger ore deposits in the district lie along curved parts of vein-lodes and it is believed that the channels in which they formed were developed in this manner. Important among such deposits are the main Queen Bess ore shoot, the Slocan Star ore-bodies, and probably also the main Silversmith shoot.

In many instances mineral concentration has taken place at the junction or at the intersection of fissures. The first type, commonly called "feeder veins," joins a main fissure or vein-lode. When such fissures were mineralized at the same time as the main fissure or vein-lode it is common to find conspicuous development of vein matter, in some cases ore-bodies, at their junctures. For example, at the Last Chance mine the Blizzard vein joins the Last Chance vein on the hanging-wall side and at their junction occurred the main ore-body at the Last Chance mine. According to the old mine plans, it provided almost continuous stoping ground over a maximum length of 1,000 feet and a maximum vertical depth of 400 feet. Probably the outstanding example was the great ore shoot of the Standard property. It was the largest yet discovered in the district and occurred at the junction of the main Standard and the I veins. The intersecting type of fissure that has influenced the formation of ore shoots includes those fissures which may either cross a lode diagonally or follow a course parallel with and within the lode. In neither case do they extend beyond the walls of the lode. Such fissures have formed either prior to or during the period of mineralization. In the first case they were important in that they furnished a readier access for mineralizing solutions to those parts of the lode in which they occur; in the second case they were significant features in the development of composite ore shoots formed at intervals during the period of mineralization.

It is becoming increasingly evident in the Slocan that the ore deposits favour certain beds or assemblages of beds and are poorly represented in adjoining strata. Consequently, exploratory work in such localities may be limited to the favourable rocks where fissures cross them. The favourable rocks form what is here referred to as "potential ground." It may consist of one bed, e.g. the limestone member at the Lucky Jim property, or several, very similar in composition and structure as at the Van Roi, Queen Bess, and Payne mines; or may include much wider belts of sediments, as on the northern slope of Carpenter Creek valley above Sandon, or that block of ground embracing the Whitewater and Charleston properties. Operators should pay particular attention to the rocks close to their main ore shoots. Instead of spending so much time and money following a vein-lode into unfavourable country rock, they should first search for other parallel or nearly parallel lodes in rocks similar to those in which the already discovered main ore shoot occurs.

Mining work in the Slocan has shown that ore-bodies play out in depth, partly as a result of decrease in size and partly because of a change in composition to lower grade or barren vein matter. In most cases the veins and the lodes in which they occur tend to narrow with depth, e.g. the Galena Farm, McAllister, Rambler-Cariboo, Sunset-Trade Dollar, Wakefield, and Alamo mines. In extreme cases the bottom of an ore shoot may be a series of discontinuous small lenses or stringers of ore and gangue minerals tightly frozen to the wall-rocks. Such a condition is well illustrated at the Bosun and Noble Five mines. Rarely the vein-lodes show no diminution, but rather an increase in width below the main ore shoots. Thus the Silversmith lode persisted for some distance below the main shoot as a wide body of siderite containing bands of wall-rock and a minor proportion of sphalerite.

Ore-bodies in which silver values predominate, but in which lead and zinc are also important constituents, have been classed with the dry-ores in which the abundant vein matter is quartz. Such deposits show all gradations into typical silver-lead and silver-lead-zinc deposits, in which quartz is the essential gangue. They are particularly common in the Nelson granite. Not many have been worked to the same extent as the more typical wet-ore deposits, so it is difficult to generalize; however, the tendency seems to be for the vein material as a whole to become progressively poorer in ore minerals with depth and to end much in the same fashion as the silver-lead and silver-lead-zinc deposits.

Shoots of typical dry-ore (those in which galena and sphalerite are negligible or missing) appear, in the few instances where any considerable depth has been attained in mining operations, to carry most of the little galena present at depth. Such changes in composition are, however, not economically important, and the silver-bearing ore shoots are bottomed not so much as a result of narrowing of the vein or decrease in quantity of vein minerals as by a loss in silver values.

Quartz veins lacking silver values and mineralized with gold-bearing sulphides occur on a few widely separated properties, of which the Phoenix and L.H. are examples. The relation of these deposits to the other dry ores of the district is uncertain, nor has sufficient work been done on them to indicate how they change with depth.

Ore-bodies may be composed almost entirely of galena, blende, or other single ore mineral, or of various ore minerals associated with quartz, siderite, and calcite and (or) other less common minerals, all in variable proportions. Considerable quantities of rock are also particularly characteristic of composite vein deposits and replacement deposits. "Clean" as applied to particular ore minerals is a relative term. Nearly all galena contains a little sphalerite and the converse is generally true of the sphalerite. Nearly all parts of any ore deposit contain disseminated pyrite, though generally not much, and there is a distinct tendency for its concentration in the deeper, less valuable parts of an ore shoot. In many of the larger shoots of the district, such as the Payne, Standard, Idaho, Silversmith, and Queen Bess mines, the principal ore was nearly solid galena, carrying, in some cases, as in the Silversmith shoot, abundant small but easily visible specks and lumps of grey copper. The ore of the old workings of the Sunset-Trade Dollar mine was mostly clean galena. Much of the ore obtained in the early years from the Lucky Jim and the Bell and U.S. properties in Jackson basin was, on the other hand, remarkable for the content of almost pure zinc blende. Ore from the Colorado (Charleston), Ohio, and Reco-Goodenough veins included much grey copper associated in the first mentioned vein with, chiefly, sphalerite; in the second, with chalcopyrite; and in the third, the most productive of these veins, with galena. Freibergite is the chief ore mineral in most of the silver-bearing veins, and occurs partly in solid masses of appreciable size but mainly disseminated in a quartz gangue. It is also a principal silver-bearing mineral in the wet ores, though rarely forming any considerable percentage of these deposits. Pyrargyrite is fairly common, but rarely abundant in either wet or dry ores. Other high-grade, silver minerals locally important and occurring mostly in dry ore deposits are argentite, stephanite, and native silver. On several properties one or more of these minerals has been present in excess of, or even to the exclusion of, grey copper.

A curious variety of lead ore, locally referred to as "black ore", was found in considerable quantities in the old workings of the Whitewater mine and has also been noted on other properties such as the Wellington, Charleston, and Utica mines. A complete analysis by the Mines Branch, Ottawa, of a specimen from Wellington mine, gave the following results:

	Per cent
Lead	50·45
Zinc	15·56
Iron	2·82
Copper	0·72
Al_2O_3	3·87
CaO	0·65
MgO	0·91
H_2O	1·21
SiO_2	6·17
Sulphur	17·46
P_2O_5	0·03
C	0·16
Au— 0·04 ounce troy/ton of 2,000 lbs.	100·01
Ag—121·20 ounces " "	

Under the microscope a polished surface of this ore was seen to be composed chiefly of dull galena, forming a matrix to other ore and gangue minerals, that occurred mostly as comparatively small fragments and dust-like particles. Chief among these was zinc blende, which appeared to be greatly brecciated. Other minerals included minor proportions of pyrite and chalcopyrite and possibly minute masses of silver-bearing minerals. Assuming that the lead, zinc, and copper in the above analysis were combined to form galena, sphalerite, and chalcopyrite, the percentages of these minerals in the ore are 58·25 per cent, 23·16 per cent, and 2·07 per cent, respectively. The amount of sulphur and iron remaining after affecting these combinations is almost in the exact proportion required to form FeS and not pyrite and, therefore, it seems likely that a fair percentage of this iron was combined with zinc in the zinc blende, and that the amount of zinc blende present is consequently somewhat higher than the percentage as calculated from zinc alone. Pyrite is probably about equal in amount to chalcopyrite and the remaining iron (less than 1 per cent) is probably present in the gangue minerals. The carbon is thought to be mostly free and to be represented by innumerable microscopic specks through the galena.

Other specimens of this "black" ore were observed to contain considerable grey copper scattered through the galena, but no other silver-bearing minerals were recognized.

Most of the important ore shoots are mixtures of ore and gangue minerals. This material, as extracted, is classified as shipping or high-grade ore and milling ore. Some ore shoots are almost entirely of milling ore, but mostly they contain an important proportion of high-grade or shipping ore, without which the associated "mill feed" would scarcely pay to mine.

OXIDATION OF VEIN AND REPLACEMENT DEPOSITS

The high resistance of galena and quartz to oxidation as compared with the other ore and gangue minerals no doubt partly accounts for the relatively numerous outcrops of such vein matter. Outcropping bodies of nearly pure galena appear, on the whole, to have suffered little oxidation. On the other hand, at least one body of sphalerite, the discovery ore-body at the Lucky Jim mine, was almost completely oxidized to a depth of about 50 feet, the materials in the oxidized zone being a reddish aggregate of iron oxides with a little zinc silicate, considerable calcite (or aragonite), and fragments of partly replaced wall-rock and of sphalerite.

The greater oxidation on some properties than others is very largely due to larger proportions of pyrite, the oxidation of which has furnished a strong solvent acid. Pyrite, pyrrhotite, and siderite oxidize rapidly, others such as grey copper, chalcopyrite, and sphalerite less rapidly, but more readily than galena or quartz. Oxidation has reached in many ore-bodies to depths of 100 to 200 feet and deeper in a few cases. It began before the Glacial period in the Blue Bell ore deposits on Kootenay lake (25, page 133) where, in spite of comparatively severe glaciation, it is prominent in the lowest workings to about 400 feet beneath Kootenay lake. It is also certain that oxidation has operated since glaciation. Within much of Sandon map-area, where glacial erosion has been less marked than glacial deposition, much oxidation has taken place in deposits that were protected from erosion by morainic matter.

Oxidized deposits are distinguished by abundant reddish iron oxide. This oxide may occupy cavities in dominantly quartzose or galena-rich masses, or a soft, reddish, porous mass, stained in places by copper carbonates and containing partly decomposed fragments of sphalerite, nodular masses of galena, pieces of wall-rock, etc., may form the bulk of the vein matter. Associated with such material is a varying but generally small percentage of secondary minerals such as lead and zinc carbonates and sulphates, manganese oxides, and native silver or other high-grade, secondary, silver-bearing minerals. Instances of this sort occur at the Queen Bess, Noble Five, Ruth-Hope, Rambler-Cariboo, Reco, and Whitewater mines. As a rule the most completely oxidized vein matter, or "carbonate ore", occurs near the surface and most of it has long since been mined. Oxidized ores are, however, still being mined in small quantities from the upper levels of some properties, such as on the Ruth No. 2 vein of the Ruth-Hope property, the Queen Bess mine, the Mountain Con, Galena Farm, etc. On such properties the iron sulphides, of which pyrite is the most plentiful, have been oxidized to hydrous iron oxides and the siderite to mixtures of hydrous iron and manganese oxides. Pseudomorphs of limonite after siderite and pyrite are common. The sphalerite has been transformed to iron oxide, zinc carbonate, and zinc silicate. Copper carbonates are nowhere abundant. Anglesite (lead sulphide) has developed along fractures and cleavage lines in the galena. At the Wellington clusters of white or pale yellow prisms of anglesite are associated with cerussite (lead carbonate). Cerussite was noted on some other properties. Grey copper has altered to secondary copper carbonates and sulphates and silver minerals, chiefly native silver. Oxidation of argentiferous zinc blende and galena also produces secondary, relatively stable silver minerals, and carbonate ores so derived generally carry good silver values. Much or all of the ruby silver and native silver in the oxidized zone is probably secondary. In most cases the resulting carbonate ore occupies much the same space as the original ore and the percentage of silver per unit of volume is much the same as in the primary deposits. In such cases there may be little if any concentration of silver, but merely a loss of lead and zinc. In other instances, as at the Hewitt mine, where ruby silver and native silver were particularly prominent in the upper parts of the ore deposits, their concentration appears to have resulted from enichment processes connected, in part at least, with oxidation and the circulation of meteoric waters.

SPRING DEPOSITS

Spring deposits of manganese ore of Recent age occur in the lower valley of Kaslo creek 7 miles from Kaslo (13, pages 107-114). The manganese, in the form chiefly of hydrous manganese oxides, is associated with bog iron deposits and calcareous tufa, substances of related origin. Calcareous tufa is abundant in other localities, but so far as is known no use has been made of it. In places it is largely a mass of replaced moss, leaves, and twigs whose forms are retained in the greatest detail. Heavy deposits 20 feet or more thick occur along the railway and motor road between Kaslo and Zwicky, up Wilson creek, and along the railway between Rosebery and the head of Slocan lake.

DETRITAL DEPOSITS

Erosion and transportation have locally concentrated ore minerals, in some cases into workable bodies. A little placer gold has been found in stream beds draining the area occupied by the Kaslo series, the valley of Enterprise creek being probably the most important in this respect though hitherto providing no economic deposits. At a number of properties near Sandon concentrations of boulders of galena have provided tonnages of high-grade silver-lead ore. One such property, the Gem, situated on Carpenter creek just above the Cody, has been worked in a small way for years, the source of the galena being referred to outcroppings of ore higher up the hill on the Chambers group or still higher properties. The boulders of galena ore rolled down the hill slopes and much of the associated lighter soil and rock materials were carried away by stream action. At other properties, such as the Wonderful, Idaho, Minnesota, and Monte Cristo, concentration has been chiefly by gravitation. The origin of the galena float at Galena Farm mine is less certain and may be related to glaciation.

In 1892 what is known as the "Big Boulder" was discovered on Sandon creek below the Slocan Star workings. It was principally galena and yielded 40 tons of ore carrying 70 per cent lead and 130 ounces silver to the ton, and it was thought (1893) that sorting would give 25 tons more of the same grade.

DISTRIBUTION OF SILVER-LEAD-ZINC MINERAL DEPOSITS

A single vein-lode may persist from top to bottom of the side of a deep valley, but on investigation will be found to comprise more than one vein. The zone of mineralization within the lode may possess a very definite rake, but within the zone individual veins and shoots may rake quite independently. For example, the zone of mineralization that includes the Echo, Alpha, Standard, and Emily-Edith vein deposits rakes roughly with the present surface over a vertical range of about 2,200 feet. The ore on the Echo property, however, had a pronounced pitch into the hill; the Alpha shoot lay practically along and at the surface; the rake of the main Standard shoot was controlled largely by the line of junction of the main and I-vein lodes and other shoots at higher levels pitched into the hill towards the main shoot; and the Emily-Edith deposits seemed to follow the dip of the lode in which they occurred. The mineralized zone at the Queen Bess mine pitched into the hill at an average angle of about 25 or 30 degrees and contained a succession of ore-bodies with individual rakes at increasing distances from the surface.

A rapid change in mineral composition with depth is commonly exhibited by the vein deposits and suggests a steep, thermal gradient as a controlling factor in mineral deposition. On the other hand, vein deposits of the same type occur at any elevation and in this respect show no relation to present land forms. This condition might be supposed to indicate that deposits similar to those at higher elevations might occur vertically below them to depths at least as great as those of the lowest outcropping deposits of the same kind. This supposition has been tested by driving long adits and deep drifts to intercept or follow lodes that higher up carried important mineral deposits, and the results have proved more disappointing than encouraging. In some instances important tonnages of ore were blocked out, but with rare exceptions the values and the quantity of vein matter were found to have decreased and often to have little value. Whether deposits are high on the mountain slopes or low in the valleys, experience goes to prove that the individual deposits are relatively shallow, change in composition vertically, and are not underlain by other similar deposits.

In these respects, and in the rough parallelism so often existing between the slope of the surface and the zone of mineralization on a property, lies the support for a belief that mineralization at least of the silver-lead and silver-lead-zinc deposits formed in an undulating zone which over considerable areas accidentally parallels the present surface.

All available information indicates that this zone is 1,000 to 2,000 feet thick and that within it a steep thermal gradient existed at the time of mineralization. The position of this thermal zone was controlled by the position and intensity of the source of heat, the Nelson batholith, and by the surface of the ground. As it is known that the surface of the Nelson batholith was highly irregular, the position of the zone would tend to vary from place to place. The configuration of the land surface at that time is unknown. If it had been essentially level the zone would more nearly parallel the surface of the batholith; if the relief of land surface was also great, the zone would parallel neither surface. So any appearance of parallelism with the present surface must be accidental. Mineralization may have been confined to such a zone and mineral deposits may occur within restricted parts of seemingly favourable formations because the barren areas are either eroded parts of the zone or have not been eroded deeply enough to expose it.

Mineralization in the upper half or so of such a zone should be characterized by silver-lead ore-bodies and its lower parts by ore carrying principally zinc. The basal parts of zinc-ore deposits have commonly much more pyrite than higher parts, so pyritiferous zinc is fair evidence that the mineral zone is nearly bottomed and that exploration should be transferred to higher elevations. Conversely, a body of galena is fair evidence that operations are being conducted in a higher section of the zone and that, especially where there is strong fissuring and evidence of composite mineralization, ore may be expected downward for several hundred to a thousand or more feet. In following a lode up the slope of a mountain, the discovery of a series of deposits of similar type within this lode would indicate that approximately the same horizon in the mineral zone was being followed; if the deposits changed from those mainly characterized by zinc to others carrying more lead the inference would be that the mountain slope afforded a section through the mineral zone, that the top of the zone might be reached, and that no further deposits would be discovered higher up in the lode.

RELATIONSHIPS OF SLOCAN MINERAL DEPOSITS

The combined evidence of field and laboratory study indicates that Slocan mineral deposits formed during one, probably fairly long, period of mineralization. The evidence also indicates that the deposits are related in origin to the Nelson granite. That the many deposits did not all form contemporaneously is shown by the repeated injections of vein matter into many, and particularly the larger, lodes. With these indications as a basis it is hereby proposed to show that the various types of Slocan deposits formed at three or four stages; that the deposits of each succeeding stage show a mineralogic relationship to those of the preceding stage, though otherwise represented by a distinctive mineralization; that, however, the mineralogical relationships are closer between types of a certain stage than as between types of different stages; and that the mineral relationships are exhibited in such a way as to establish the belief that the successive stages of deposits formed under conditions of decreasing temperatures.

The deposits may be classified and discussed according to the five principal types represented.

(1) Deposits of the first type consist of barren or nearly barren quartz veins occurring in all formations; these may carry sparsely disseminated pyrite and, more rarely, pyrrhotite, and the wall-rocks may be conspicuously impregnated with pyrite. The veins are mostly mere stringers cutting across the formations in any direction. Less commonly they reach widths of several feet, may be traced for at least several hundred feet, and, as such, occur in the more slaty, schistose, or thinly bedded rocks where they follow the less competent structures. The quartz is massive, whitish, and vitreous, and is popularly referred to as "bull-quartz". The facts that the veins may be individually very irregular

on strike, that collectively they appear to follow no system of fractures such as characterize the economic vein deposits of the district, and that it is common to find fragments of wall-rocks carrying veinlets of such barren quartz and disseminated iron sulphides in the metalliferous vein deposits point to the conclusion that these barren quartz veins represent an early stage of mineralization in the district. Further, their dyke-like form, massive, vitreous character, and slight mineralization by only iron sulphides suggest that they formed at higher temperatures and under somewhat different physical conditions from the succeeding, more extensively mineralized types of deposits.

(2) A second type is represented by a few, widely scattered mineral deposits containing values in gold and consisting of bodies of quartz and silicified wall-rocks carrying two or more of such minerals as pyrite, pyrrhotite, chalcopyrite, arsenopyrite, and gold. All these minerals occur in the L.H. deposits (1, 1917, pages 33-38) whose gold values are associated mainly with arsenopyrite. At the Phoenix property (1, 1917, page 33) the quartz carries pyrite, chalcopyrite, and gold, values in gold being chiefly in the chalcopyrite. At the Rockland there is relatively little quartz. Pyrite and chalcopyrite are disseminated in a shear zone in quartzitic sediments, and where most concentrated carry appreciable gold values. The L.H. and Rockland deposits occur within a body of metamorphosed, in part granitized, sediments and volcanic rocks, probably chiefly Slocan series, whereas the Phoenix deposit is in Kaslo greenstones. The three deposits are alike in that they carry pyrite and chalcopyrite, are auriferous, and contain no silver, lead, or zinc values. Presumably, they were derived from separate solutions that had a common origin related to the Nelson granite. Sufficient work has not been done on them to indicate how their mineral composition may change with depth, nor was their structural relationship to veins of the barren quartz type determined. They may and probably do pass at depth into barren quartz deposits, but this, if so, would not infer that the eroded, upper parts of the barren quartz veins of the district were auriferous. The two types of deposits may have formed in quite distinct stages or from different solutions at about the same stage. Their relationship is indicated by their quartz gangue, the presence of iron sulphides as principal ore minerals, and the absence of silver, lead, and zinc minerals such as characterize the more abundant and important mineral deposits of the district. The one possible exception lies in the occurrence of narrow stringers of calcite cutting across an ore-body in the L.H. workings. These calcite stringers are reported to carry small nodules of native arsenic containing high values in silver. The veinlets evidently formed at a later stage than the main body of the deposit; also the calcite and arsenic indicate lower temperature conditions and the presence of contained silver values affords one possible link with the silver-bearing deposits of the district. The auriferous quartz deposits, too, are less dyke-like and less massive than the barren quartz veins. They also show considerable replacement and, together with their greater variety of metallic minerals, indicate that they formed under different conditions from veins of the first type. A principal difference in conditions may well have been one of temperature,

the auriferous deposits forming at somewhat lower temperatures than the others.

(3) Mineral deposits of the third type are the most important in the district. They are the typical silver-lead-zinc " wet ore " deposits and occur characteristically in the Slocan series. In these deposits values are in silver and lead or in silver, lead, and zinc, and all three metals may be about equally important, though those of silver generally predominate; one or more of a variety of gangue minerals may be present and the proportion of ore minerals may equal or even exceed that of the gangue minerals. Galena and sphalerite are here abundant and silver-bearing minerals are mainly associated with them and are less conspicuous than in the succeeding types of " dry ores." These " wet " ores may be classified into sub-types according to the relative abundance of the associated gangue minerals. In many deposits quartz is almost the only gangue mineral; in other deposits or parts of deposits calcite is relatively most abundant; in still others, siderite is the chief gangue mineral; and one property, the Galena Farm mine, contains considerable fluorite. Quartz is generally conspicuous in the upper parts of the deposits, but at depth is commonly replaced by siderite and at still greater depth quartz again dominates. The lower quartz zone is generally low grade or barren of ore minerals as contrasted with the high-grade material in the upper zone. The upper quartz gangue is apt to be more cellular and vuggy than the quartz at depth. In the majority of " wet " ore deposits calcite is not conspicuous, but it is abundant at most of the properties lying within a roughly triangular-shaped area with Emily-Edith, Idaho, and Leadsmith properties at the three corners (*See* Map 273A). In each case it is the prominent gangue mineral in the uppermost parts of the deposits and may persist to the deepest workings.

The normal order of succession, from top to bottom, of the gangue minerals in deposits holding abundant quartz and siderite is, as already stated, quartz, siderite, quartz. This order is well shown in many of the larger deposits, such as those at the Slocan Star, Richmond-Eureka, Payne, Whitewater, and Enterprise mines, etc. In the same deposits the ore minerals show a transition from galena and high-grade silver minerals in the upper quartz horizon down through galena deposits associated with increasing sphalerite to mostly sphalerite in the siderite zone, with very little ore or no mineralization in the lower quartz zone. Where, as in several of the larger, composite ore-bodies, the mineralization has formed as the result of repeated injections of mineral-bearing solutions, the normal succession with depth of gangue and ore minerals may be less evident owing to overlap of the materials deposited during the successive stages.

A significant feature connected with deposits of the third type and, to a less noticeable extent with deposits of the succeeding type, is that at depth, as in vicinity of and below the more zincy zone, iron-bearing sulphides, particularly pyrite, are commonly much more conspicuously developed than at higher horizons. Chalcopyrite may also be a fairly conspicuous mineral and, more rarely, pyrrhotite. Also, as in the case of the Monitor mine, these sulphides may contain appreciable gold values. Such features are reminiscent of the auriferous quartz deposits of the second type and lend some support to the view that the latter formed at a somewhat earlier stage and at somewhat higher temperatures than deposits, as a whole, of the third type.

(4) Deposits of the fourth type are dry ores in which silver is the metal of chief importance, but in which there are also values in lead or zinc or in both of these base metals; in which quartz is the abundant gangue mineral; and in which the gangue is greatly in excess of metalliferous constituents. Deposits of this type are mostly confined to the Nelson granite and are particularly characteristic of the mineral deposits in this granite. Examples occur at the Fisher Maiden, Jessie-Bluebird, Alice S, Arlington, Black Prince, Lily B, Little Tim, and Ottawa properties. A few have been found in the Slocan series, the most productive being those of the Hewitt mine, situated along the granite contact. The distinction between this and the third type is partly one of relative ore mineral and gangue mineral proportions and partly one of higher silver values in proportion to lead and zinc content in ores of the fourth type as compared with those of the third. These distinctions are, however, not sharp and some deposits are difficult to classify as belonging definitely to either type. Few of the deposits of the fourth type have been developed to the extent, or have produced a tonnage comparable with that, of many of the larger productive properties carrying ores of the third type. Little information could be obtained to indicate how, if at all, these deposits changed within the relatively shallow vertical depths to which they have been explored. In general, deposits of the fourth type as a whole more closely resembled the upper, more argentiferous parts of deposits of the third type than the lower, more zincy, lower grade parts of the same deposits. The resemblance was not only one of mineral composition but of character of the constituent quartzose gangue, which tended to be more vuggy (in places even chalcedonic and exhibiting crustification) as compared with the massive, less well mineralized quartz from the lower parts of the third type of deposits as described above. These resemblances are, in fact, such as to suggest that the solutions responsible for both types of deposits and the physical conditions under which the deposits formed were much alike. In general, too, it appeared that where a change was noticeable at depth it was towards a type of deposit more like the third type. An illustration is afforded by the Hewitt and Van Roi deposits, which occur within the same lode system. The two deposits or, rather, groups of deposits occur on opposite sides of a deep gulch marked by strong shearing and faulting about at right angles to the course of the lodes. The Hewitt workings are partly in Nelson granite, those of the Van Roi are entirely in the Slocan series. At the Hewitt mine the ore extracted has been essentially "dry," averaging about 13 ounces of silver to the ton for each per cent of lead, whereas Van Roi ore is considered a "wet" ore and has averaged about 3 ounces of silver to the per cent of lead. But, with increasing depth, the deeper ores at the Hewitt mine have lost their silver values at a greater rate than those of lead and zinc, and in this respect take on with depth more of the characters of wet ores at the Van Roi mine. The difference between the mineral deposits of the two properties thus does not seem to be due to differences in their positions relative to the Nelson granite, for if such were the case the Van Roi deposit would be expected to grade downward, as it approaches the batholith, into a deposit resembling that of the Hewitt, instead of which the Hewitt deposit appears to grade downwards into one that is taking on the characters of a deeper part of the Van Roi deposits.

Deposits of the third and fourth types have been found, at many places, in lodes intersecting narrow quartz veins of the first type and containing inclusions of pyritized wall-rocks such as have been found associated with these "barren quartz" veins. There is, however, but little structural evidence to indicate the relationships of deposits of the auriferous type to those of the silver-lead-zinc types unless, perhaps, the argentiferous calcite-arsenic veinlets at the L.H. mine may be accepted as a suggestion that the silver-bearing deposits of the district formed at a later stage or stages than deposits of the first or second types. Deposits of the second type are mineralogically and structurally more like deposits of the first type than those of the third and fourth, or, where they most resemble the latter, that resemblance is, as noted above, confined to the deeper, least argentiferous parts of the silver-lead-zinc deposits. The resemblance is, however, not one of identity, and is merely such as to suggest that, as the deeper parts of the silver-lead-zinc deposits may be assumed to have formed under somewhat higher temperature conditions than the upper parts, the auriferous deposits of the second type formed as a whole at higher temperatures and probably at an earlier stage in the period of mineralization than deposits of the third and fourth types.

In so far as deposits of the silver-lead-zinc types are concerned there is little reason, either structural or mineralogical, to assume that they formed at other than essentially the one stage. Both types occupy the same well-developed fissure system; both carry a similar suite of ore and gangue minerals; both may occur in the same lode system, nor is there evidence of deposits typical of one type occurring in lodes intersecting lodes of the other type; and, finally, there are indications that with developments at depth both types tend to become more alike in their mineral proportions and compositions. If we may assume from the available evidence, that deposits of the second or "auriferous" type formed at a later stage than those of the first or "barren quartz" type it seems equally safe to assume that the silver-lead-zinc deposits of the third and fourth types formed at a third stage in the period of mineralization related to the Nelson granite.

An important variation from the typical silver-lead-zinc fissure vein deposits of the district is shown by those deposits that have formed in limestone members of the Slocan series, and are of considerable consequence in the eastern parts of the map-areas where the greater widths of limestone occur. In these deposits values in either lead or zinc or in both combined commonly exceed the values in silver, and the deposits are, in general, low grade. Mineralogically, they are most like deposits of the third type and, presumably, were deposited under about the same temperature conditions and from the same or similar solutions. This relation is well exhibited at Whitewater Deep mine where fissures running off from the hanging-wall of the main Whitewater lode have intersected a heavy limestone bed. Replacement of this limestone has produced a similar type of ore to that formed at the same depth within the main Whitewater lode.

(5) Deposits of the fifth type are dry ores in which silver and, in a few instances, silver and gold are the only metals of economic importance; in which quartz is the abundant and only significant gangue

mineral; and in which ore minerals constitute a relatively insignificant proportion of the deposits as compared with the quartz gangue. Deposits of this type occur in a belt a mile or so wide extending from Slocan lake, in the vicinity of the Molly Hughes mine, east-northeasterly across Kane Creek valley to the northern edge of Sandon map-area on London ridge. The more important properties in this belt are the Molly Hughes, McAllister (Plate XI A), Silver Glance, and Capello. Within the belt the deposits occur in Slocan sediments, Nelson granite, and minor intrusive bodies. Farther south and southeast, within the broad area of the Slocan series, occasional, mostly small deposits of similar type have been found as at the Apex, Mowitch, and Eagle properties, as well as several vein deposits in the vicinity of the Best, Dardanelles(?), Rio, and Rambler-Cariboo mines. Most of such deposits occur either in or near one or other of the numerous granitic stocks cutting the Slocan series. Still farther south, within the main area of the Nelson granite, are a number of widely scattered deposits of this type, a few of which, as the Anna, Hampton, and Meteor, have been productive.

Deposits of the fifth type are composed mainly of white vein quartz, which is commonly vuggy. The quartz is less massive and vitreous than that of the first two types of deposits or of the quartz of the lower quartz zone of the third type. It is more like the quartz of the fourth type of deposit or the quartz occurring in the upper, more argentiferous parts of the deposits of the third type. The metallic constituents are high-grade silver-bearing minerals, of which grey copper is most important. Others are argentite, stephanite, ruby silver, and native silver. Stibnite may be abundant; pyrite and chalcopyrite may occur anywhere in the deposits and galena may be present in small amounts, particularly at depth. No pyrrhotite, sphalerite, or arsenopyrite was observed. Mineralogically, the deposits most nearly resemble those of the fourth type though, in general, there is little difficulty in distinguishing them. Perhaps the most interesting feature connected with the two types is the fact that in a few instances, as at the Best, Dardanelles(?), Hewitt, and Rio properties, deposits which at or near the surface closely resemble those of the fifth type were found on exploration to change downwards into deposits typical of the fourth type. In no instance was a reverse order observed and, in consequence, the suggestion is provided that, if temperature gradients have had anything to do with mineral changes in Slocan deposits, then not only might it be permissible to assume that the upper parts of such complex deposits formed at somewhat lower temperatures than the lower parts of the same deposits but also that the typical dry ores of the fourth type, as a whole, may have formed at relatively lower temperatures than those of the third. The parts of the complex deposits presumably formed at the same time, but where one type occurs in one lode and the other type in an adjacent or nearby lode it may be they formed at the same or different times. They might form at the same time if the temperatures at the two places were different. They would form at different times if the temperatures at the two places were the same but were rising or falling.

Summarizing some of the important features connected with mineral deposits of the various types, it may be stated: (1) That the deposits formed from solutions of various compositions. (2) That all these solutions are related in origin. (3) That certain deposits may resemble one type in their upper parts and pass at depth into ores more like another type. (4) That this passage is invariably in the one direction, viz. from deposits resembling the fifth type downward to deposits like the fourth; and from those of the fourth type downwards to those similar to the third, and so on; and that where, as in certain composite deposits of the third type formed as a result of successive injection of mineral-bearing solutions, this order seems reversed, the later formed parts of the deposits resemble sub-types that in the earlier formed parts of the same deposits occur higher in these deposits, never lower.

This downward gradation from deposits resembling one type into those like another, and the fact that the gradations are everywhere in the same direction indicate temperature control over the mineral composition of the deposits. The general conditions also suggest that although the nearby occurrence of deposits of unlike types may be attributable, in part, to differences in the compositions of the mineralizing solutions responsible for the deposits, it is also due to temperature conditions, one type as a whole having formed at higher temperatures than the other. Since, however, it is unlikely that marked differences of temperature would exist at any one time at the sites of nearby deposits, or that compositions of mineralizing solutions entering neighbouring fractures at the same time would be unlike, the presumption is that nearby deposits of unlike types formed at different stages during the period of mineralization as the general temperature fell. This being so, if a deposit of the fifth type occurs in a lode close to another lode containing a deposit of the fourth type there is the distinct possibility that the latter is the older of the two.

In conclusion, it would appear that in spite of the number of types of mineral deposits in these areas; in spite of the evidence that these deposits formed from different solutions and at different stages during the one period of mineralization, there are certain features, chiefly mineralogic, which serve not only to correlate the various types and stages of deposits and indicate their common origin but also to suggest that successive stages of mineralization, in addition to possessing certain distinctive mineral characters, have tended also to reproduce, at depth and on a relatively small scale, the mineralogic features of preceding stages. These reproductions of earlier stages are controlled principally by temperature conditions and the extent to which the successive stages are represented in a deposit is dependent on the mineral composition of the particular solutions responsible for that deposit. The practical value of such an evolutionary hypothesis lies chiefly in the ability to determine whether a particular deposit, as exposed, represents a certain stage of mineralization or whether it is merely an evolutionary phase of a later stage. In the first case explorations of the deposit at greater depth are not likely to encounter important mineral deposition characteristic of earlier stages; in the second case such discoveries are possible. A principal, practical guide in determining whether or not a deposit has such possibilities would be the experience gained in the exploration and development of nearby deposits which presumably lay at about the same horizon. On the assumption, too, that the relative ages of the various types of deposits have been correctly inferred, and that the successive stages of mineral deposition occurred during a period of decreasing temperatures, it seems reasonable to suppose that areas that heretofore have provided deposits mainly or entirely typical of any one stage are areas where any further discoveries are, *ipso facto,* likely to be typical of that same stage or, in other words, that such areas are not those most favourable to explore for deposits typical of any other stage; also, that where the borders of such areas can be roughly defined, the mineral possibilities of adjoining areas may be gauged by the characters of bordering deposits and, to some extent, by the characters of the exceptional type or types of deposit within the defined area itself. For example, the dry-ore area on either side of Kane creek would be an area where wet-ores are not likely to be found within minable depths below the present surface, and the presence of such an area of dry-ore is suggested by the occurrence of occasional deposits of the dry-ore type within bordering areas where deposits are predominantly of the wet-ore type.

PARAGENESIS

Ores from a great many properties have been studied to determine in what order their constituent minerals were formed. Care had to be taken to recognize misleading features; many deposits had formed from separate incursions of vein matter; galena, calcite, and, to a less extent, siderite tended to flow under pressure and recrystallize about broken fragments of more resistant minerals, such as sphalerite and quartz; and chemical reactions between mineralizing solutions and minerals deposited from them resulted in apparent abnormal sequences.

About forty ore and fourteen gangue minerals have been recognized in the deposits. Thirteen of the former and five of the latter are definitely supergene, formed chiefly in the zone of oxidation and by descending waters. These comprise anglesite, azurite, cerargyrite, cerussite, chalcocite, chalcanthite, covellite, limonite, linarite, malachite, marcasite, smithsonite, wad, aragonite, kaolin (and kaolinite), mirabilite, selenite, and sulphate of alumina and sodium (mendozite?). Other, silver-rich minerals such as pyrargyrite, polybasite, brongniardite (?), and stephanite, and native silver may be in part primary and in part supergene, but are mostly regarded as late-hypogene, formed by upward secondary enrichment. The remaining minerals are primary, hypogene minerals. Over half of them are comparatively rare and their paragenetic relations with the commoner minerals could not be safely evolved. They include arsenic, boulangerite, bournonite, gersdorffite, gold, magnetite, molybdenite, rhodonite, scheelite, stibnite, stannite (?), fluorite, dolomite, and tourmaline. Most of the other hypogene minerals are fairly common to abundant. They comprise argentite, arsenopyrite, chalcopyrite, galena, grey copper, jamesonite, pyrite, pyrrhotite, and sphalerite (ore minerals), and barite, calcite, quartz, and siderite (gangue minerals).

Of these minerals the most generally important economically are argentite, galena, grey copper, pyrargyrite, pyrite, silver, and sphalerite (ore minerals), and calcite, quartz, and siderite (gangue minerals). Most of the ore-bodies in the district include more or less of each of these more common minerals and many individual specimens have been obtained in which most of them are present, so their paragenetic relations have been well observed. Except where abnormal conditions have intervened the order in which these minerals commenced to form was essentially the same during any continuous period of mineralization and is as follows, commencing with the earliest mineral: quartz, pyrite, calcite, siderite, sphalerite, grey copper, galena and argentite, pyrargyrite, silver.

There may be considerable overlap of the times of formation of the minerals, particularly of quartz, which may continue to form throughout most of the sequence. Pyrite and calcite, too, have relatively long ranges, and it is uncertain in some instances whether some of the pyrite may not have preceded the quartz. The range of siderite, sphalerite, and galena is limited. Grey copper is for the most part almost contemporaneous with galena, but in several instances it definitely commenced precipitation in company with sphalerite, and in other less certain instances it has apparently continued to form after the period of galena deposition. Argentite is also essentially contemporaneous with galena, but may be somewhat later. Pyrargyrite is mostly hypogene though probably mostly formed by enrichment processes. In certain instances, however, small bodies have been observed in galena under conditions that could hardly be interpreted as other than primary. Except in one or two none too convincing cases silver is unquestionably secondary and probably mainly supergene.

In the barren quartz veins, apparently all minerals were essentially contemporaneous. In, however, one small vein west of Slocan lake, in the upper basin of Sharp creek, small, lens-like masses of pyrrhotite contained crystals of pyrite and inclusions of quartz, suggesting that pyrrhotite was the latest of the three minerals. In these auriferous deposits quartz has a complete range from earliest to latest. In part the sulphides, pyrite and chalcopyrite, occur disseminated through the quartz, as at the Phoenix, and are evidently about contemporaneous. At the L.H., where masses of sulphides occur, pyrite is the earliest sulphide, and is succeeded in order by arsenopyrite, pyrrhotite, and chalcopyrite. Chalcopyrite has an extended range but is, for the most part, definitely later than the other iron-bearing sulphides.

In the dry-ore deposits of the Slocan, quartz and pyrite are early minerals followed in order by, if present, pyrrhotite, chalcopyrite, sphalerite and grey copper, galena, argenite, complex sulpho-salts (principally jamesonite), stibnite, ruby silver, and silver. In a specimen of McAllister ore galena and a pale grey mineral (bournonite (?)) replace grey copper and are veined by ruby silver. At the Exchange and Silver Plate the order of deposition seems to have been quartz, pyrite, argentite (?), quartz, and native silver, and this succession was repeated several times. The silver may be a product of reduction of the argentite. Specimens of Hewitt ore show stibnite veined by pyrargyrite. At the Anna and Tamarack properties, stephanite is an important silver-bearing mineral, and of probably late hypogene origin. It replaces inclusions of freibergite in galena and is surrounded by narrow rims of secondary chalcopyrite. A polished surface of ore from the Comstock-Virginia mine shows six ore minerals, of which pyrargyrite is most abundant and replaces the others which are sphalerite, lesser amounts of chalcopyrite, small masses of galena, a mineral resembling grey copper, and one minute body of a light brownish grey, soft mineral, possibly boulangerite. A well-developed quartz crystal is partly replaced by sphalerite. A specimen from the Hewitt mine shows vugs in vein quartz. The vugs are lined with quartz crystals, coated with minute rhombs of dolomite, and carry crystals of pyrargyrite. The relation of barite to the other vein minerals was not satisfactorily determined. It appears to have formed after at least much of the quartz and probably overlaps the blende-galena range.

In the wet ores, quartz, pyrite, and calcite have a long range, though they are chiefly important as early minerals and commence to form in the order given. At the Whitewater and Silversmith, for example, veins of pyrite intersect masses of siderite and at the Van Roi fractures in the ore are lined with drusy quartz and otherwise filled with calcite rhombs which, in one specimen, are coated with a thin, iridescent film composed of minute pyrite cubes. On those properties where calcite is abundant it was mostly introduced in advance of the ore minerals. At the Wakefield mine the first incursions of mineral-bearing solutions deposited abundant, clean calcite and later incursions deposited first an interbanded mixture of calcite and ore minerals (principally sphalerite) and, later, chiefly interbanded galena and sphalerite associated, in places, with a variable amount of vein quartz. The history and order of deposition of the ore and gangue may be briefly summarized as follows: (1) development of the original channel by shearing along a plane conforming closely with the bedding structures; (2) introduction of large quantities of almost pure calcite; (3) further shearing and fissuring along, principally, the walls of the calcite-bearing lode; (4) introduction of solutions depositing a mixture of calcite, sphalerite, and lesser galena, forming interbands of ore and gangue minerals; (5) further shearing and fissuring, resulting in developing fresh channels along, principally, the walls of the lode, and also in brecciation of the interbanded calcite and ore minerals and incorporation of the latter as fragments in the former; (6) incursions of further mineral-bearing solutions and deposition of galena and sphalerite, mostly as interbands associated in places with some vein quartz.

In some deposits siderite and sphalerite are essentially contemporaneous. Plate XIII shows banded ore from No. 8 level, Payne mine. The specimen is composed largely of sphalerite (dark) and siderite (light) with a little galena. The banding is attributed to the filling of a fissure by deposition of first one and then the other mineral from a slowly rising solution of essentially constant composition. The same process was beautifully illustrated by some of the zinc ore in the lower parts of the Silversmith shoot. Banded siderite-sphalerite ore in the Whitewater Deep has formed by replacement of successive layers of wall-rocks, chiefly limestone, first by one and then by the other mineral. In most cases, however, the succession from wall to centre or from bottom to top of a deposit is quartz, siderite, sphalerite, galena. This succession is partly illustrated by a large specimen of zinc ore from Alamo mine in which rock fragments, each surrounded by a narrow rim of spathic iron, are enclosed in a mass of sphalerite.

Chalcopyrite is a common associate of sphalerite in which it forms numerous microscopic masses, in some cases irregularly scattered and in others more regularly distributed along cleavage or other structural lines. In both cases the chalcopyrite is regarded as being essentially contemporaneous with the sphalerite. In a specimen of lead-zinc ore from the Bosun mine, galena replaces sphalerite, and chalcopyrite occurs along irregular minute fractures in the sphalerite and outwards along one such fracture into the galena, thus proving it later than either of these minerals. More chalcopyrite veins do not extend into the galena probably because fractures form more readily in the sphalerite than in the galena, and because the copper sulphide is thought to come from an earlier generation of this mineral forming minute bodies scattered through the zinc blende but not in the galena. The chalcopyrite forming the veinlets is, consequently, regarded as secondary, though hypogene.

Freibergite is mostly associated with galena and in most cases its deposition commenced in advance of the lead sulphide, but was mainly

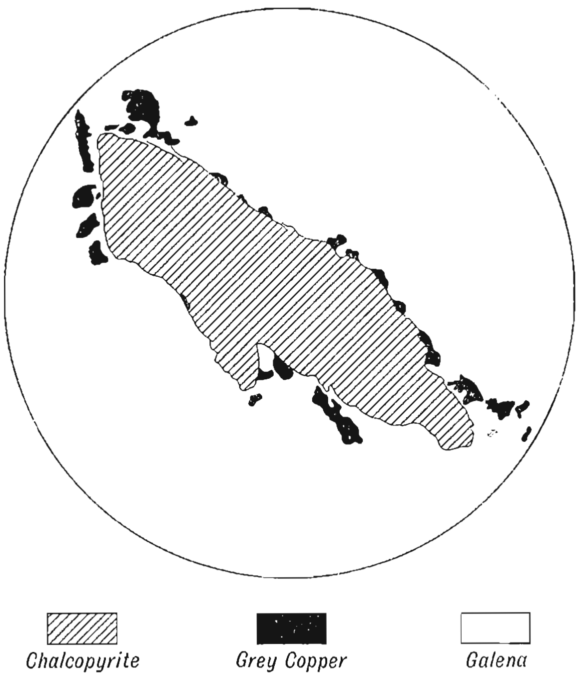


Figure 9. Camera-lucida sketch of Van Roi ore (182P). Magnification: 100X.

contemporaneous with it. In rare instances it replaces galena. It is mostly later than sphalerite and zinc ores are, consequently, less apt to carry as high silver values as galena. Where they do, as at the Bosun, Enterprise, and Utica properties, the values are in freibergite which evidently commenced precipitation within the sphalerite range. A specimen of ore from the Van Roi mine studied microscopically (*See* Figure 9) revealed galena replacing grey copper and the formation thereby of a nearly continuous series of minute chalcopyrite bodies in the galena around and near the grey copper contact.

The silver-rich minerals, freibergite, pyrargyrite, brongniardite(?), polybasite, argentite, and (?) native silver (in about this order of decreasing importance), may occur as minute bodies scattered through galena and essentially contemporaneous with it (Plate XI B).

The following table is presented to indicate, as closely as observations warrant, the relative importance of various minerals in the different types of deposits. The line, dash, and dot symbols indicate the place within the several types of deposits where each mineral is, respectively, best, moderately, or relatively poorly developed. Minerals bracketed are those concerning which little information was obtained. The hypogene minerals and a few that in part may be supergene are listed in their paragenetic order.

Relative Importance of Minerals in the Various Types of Slocan Ore Deposits

Minerals	Types of deposits				
	Barren	Auriferous	Zinc-lead "Wet" ores	Silver "Dry" ores	Silver "Dry" ores
Hypogene					
Quartz	———	———	- - - - - ———	———	———
Pyrite	- - - - - - —	———	— - - - - - -	- - - - - - -	- - - - · · · ·
Arsenopyrite	- - - - - - - -	- ———	——— · ·		
Pyrrhotite	· · · · - - - - -	- - ——— - -	- - - - - - - -	- - - · ·	
Chalcopyrite	· ·	- - ———	——— - - - - -	- - - - - - - -	- - - · ·
(Gold)		- - - - ———	——— - - - - -	- - - - - - -	- - - - - - · · ·
Calcite	? - - - -	- - - - - - - -	——— - - - - -	- - - - - - - -	- - - - - - - -
Siderite		· · ·	——— - - - -	- - - - ·	
(Barite)		?	· · - - - - - -	——— - - - -	·
Sphalerite		· · ·	——— - - - -	- - - - - - - -	- ·
Grey copper			· · · · - - - - ———	———	——— - - - - ·
Galena			- - ———	——— - - -	- - - - · ·
Argentite			- - —	——— - - -	- - - - - - - - · ·
(Bournonite)			· - - -	- - - - ———	——— - - - - - - ·
(Boulangerite)			· ·	- - - - ———	——— - - - - - - ·
Jamesonite				- - - ———	——— - - - - · ·
Stibnite				- - - —	——— -
Hypogene and (?) supergene					
Pyrargyrite			· ——— —	———	———
Stephanite			· · · ———	———	———
(Polybasite)			- - —	———	———
(Brongniardite)			- - -	———	——— ?
Supergene					
Anglesite			- - ———	——— - - -	- - - - · ·
Aragonite		- ———	——— - - - -	- - - · · · · · ·	· · · · · · ·
Azurite		· · - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - ·
Cerussite			- ———	——— - - - -	- - ·
(Chalcocite)		- - - - - -	- - - - - - - -	- - ———	——— - - ·
(Covellite)		· · - - - -	- - - - - - - -	- - - - - - - -	- - - - ·
Limonite	- - - - - - - -	- - - - - - - -	- ——— - - - -	- - - - - - - -	- - - - - · ·
Malachite		- - - ———	———	———	——— ·
Silver			- - - - - - -	- - - - - - - -	- - - - - - - -
Smithsonite			- - - ———	- - - - - - - - · ·	
Wad			- - - - - - - - -	· · · · ·	

MINERALOGY

ORE MINERALS

Anglesite. Anglesite is found sparingly in the zone of oxidation of lead ores at a number of properties such as the Mammoth, Mohawk, Rainbow, Payne, Queen Bess, Hope, Reco, and Beaver. It forms mostly in microscopic amounts along cleavage or fracture lines in galena. At Wellington mine it has been observed as clusters of white or very pale yellow prisms associated with cerussite in small cavities in the lead sulphide.

Argentite. Argentite occurs both as a primary and as a secondary mineral. As a primary constituent it is associated with some argentiferous galena, in which it forms microscopic specks which appear as minute, bright white spots when a polished surface of the galena is etched with nitric acid. The mineral also occurs sparingly in megascopic amounts in some of the vein deposits carrying mostly dry ore such as the deposits at Capello, Wilmer, Black Grouse, Silver Glance, Boomerang, Howard Fraction, and Meteor properties. As a secondary and, in part at least, supergene mineral it is found in considerable masses replacing galena at Hewitt mine, and as films associated with native silver coating joint fractures in some ore deposits as, for example, the Molly Hughes, Comstock-Virginia, and Republic properties.

Arsenic. Native arsenic is reported to have been found at L.H. mine as narrow stringers associated with calcite.

Arsenopyrite. Arsenopyrite is not common. It is important only at the L.H. mine where it occurs in granular form associated with pyrite and pyrrhotite. It occurs as minute prisms in siderite at Antoine mine and at the Last Chance mine, was also noted at Lucky Jim and Bosun mines, and is fairly conspicuous in Liberty and Flint ores in quartz veins associated with such minerals as tourmaline, pyrite, and sphalerite.

Azurite. (*See* Copper carbonates).

Boulangerite. This mineral is rarely present in amounts sufficient for positive identification. At the Soho mine it forms small masses in galena, with which it is regarded as essentially contemporaneous. At Hewitt mine a mineral resembling boulangerite is intimately associated with stibnite and galena. Boulangerite is probably also present in the ores of McAllister mine.

Bournonite. This mineral forms minute masses in galena ore from Surprise mine where it is associated with larger amounts of grey copper. It may also be present in the complex ores of McAllister mine.

Brongniardite(?) See reference to "Unknown minerals".

Cerargyrite. Found in plates and rod-like forms in sphalerite from the Utica mine.

Cerussite. Cerussite is not uncommon in the soft, granular, or powdery masses mixed with iron oxides, lime carbonates, and other impurities in the zone of oxidation of lead ores and has been noted on the

Beaver, Ruth-Hope, Black Colt, Rainbow, Reco, and Wellington properties. In the Stewart workings of the Ruth-Hope mine and at the Rainbow and Black Colt it forms clear crystals in cavities in galena. Its presence is usually detected by analysis rather than observations.

Chalcocite. Chalcocite was observed only at the Hewitt mine, where it surrounds small bodies of chalcopyrite and is probably supergene.

Chalcopyrite. Chalcopyrite occurs in most of the ores, but rarely in sufficient amount to be of value. In 1906 shipments from Idaho-Alamo mines are recorded as having included 2,861 pounds of copper; and in 1903 a shipment of 8 tons of silver ore from Rio mine contained 181 pounds of copper. Again, in 1918, 17 tons of silver ore from the Anna mine contained 242 pounds of copper. The only property that has shipped ore carrying any appreciable copper content is the True Blue, situated a few miles to the southwest of Kaslo and a little south of Sandon map-area. This property is credited with a production in 1902 of 64 tons of ore carrying an average of 1·7 ounces in silver and 7·4 per cent copper to the ton. The copper content from each of the properties cited was chiefly, at least, in the form of chalcopyrite. Chalcopyrite occurs most commonly as microscopic specks in zinc blende, but may also form as veins in blende or other ore and gangue minerals. It is noteworthy that silver-lead ores are generally lower in silver when chalcopyrite is present. On the other hand, chalcopyrite is commonly closely associated with grey copper in the dry ores and serves as an indication of the presence of high-grade silver ore, as at the Arlington mine. Chalcopyrite was observed in more than average amounts in a number of properties in the granite areas such as the Flint, Anna, Enterprise, and Lily B. It is also a notable constituent at a number of properties in the Kaslo series, and is the chief ore mineral on the Copper Prince claim at the head of Enterprise creek.

Copper Carbonates: Azurite; Malachite. Neither of these minerals is of economic importance, but their characteristic colours sometimes direct attention to mineralization that might otherwise be overlooked. They occur as thin coatings and small, crystalline and amorphous masses in the oxidized parts of ore-bodies in which grey copper or chalcopyrite is present.

Chalcanthite. This mineral is commonly found coating the walls of tunnels in which ground waters are leaching copper minerals.

Covellite. Reported by Bateman (3, page 563) as occurring "in minute microscopic amounts in ores that are partly oxidized and in which galena is altering to cerussite. It occurs as small secondary veinlets that follow the cleavage planes of galena . . . it is unquestionably secondary."

Freibergite. (*See* Grey copper.)

Galena. Galena commonly occurs in large and small cubes, but may be very fine grained (steel galena). Where sheared it has a banded or gneissic (24) structure in which the cleavage faces are distorted or curved and show marked parallelism within bands that may vary from paper thickness to an inch or more wide. The finer banded material has much the appearance of steel galena and is commonly observed along slickensided walls of a fissure, grading outward into coarser banded or massive types. When sheared the galena may present highly polished faces. The mineral forms bands, lenses, and nodules, or is intimately associated with other ore and gangue minerals. In most cases it carries grey copper (Plate XI B) generally in particles of microscopic size but in some deposits, such as the Silversmith ore shoot, the grey copper forms lumps varying up to more than half an inch in diameter. An analysis of galena from the Slocan Star mine (13, page 238) gave 1·69 per cent copper; assuming that this copper is contained only in grey copper (which, on separate analysis was computed to contain 14·57 per cent of the metal) the amount of grey copper in the galena ore would be approximately 11·6 per cent. A specimen of galena from the Silversmith shoot carrying abundant, visible grey copper was found on assay to contain 1·20 per cent copper and, therefore, on the same basis, about 8·4 per cent grey copper. In this case, however, some at least of the copper present is attributable to chalcopyrite, which occurs in microscopic masses through the grey copper.

The galena invariably carries silver exclusive of any contained in grey copper. Cube galena ore from the Bluebird mine assayed 143·70 ounces and steel galena from the Last Chance mine gave 164·22 ounces in silver, although both ores showed only a trace of copper. Other silver-bearing minerals than grey copper, such as argentite (pyrargyrite), native silver, and stephanite, were observed in megascopic amounts in or associated with galena from a number of properties.

Gersdorffite. W. Thomlinson (23) has reported this mineral on Silverton creek, where it is associated with quartz and pyrite.

Gold. Free gold is extremely rare. Where gold values are important the metal usually occurs in combination with sulphide minerals and is invisible. At the L.H. mine and the Phoenix group gold is the only metallic constituent of importance at present and occurs in part in the free state. At the Phoenix property the gold is associated chiefly with chalcopyrite and pyrite in a quartz gangue. A polished specimen of this ore showed one microscopic speck of free gold. At the L.H. mine the gold is considered to be associated chiefly with arsenopyrite; at the Monitor mine with pyrite; at the Molly Hughes with chalcopyrite and pyrite; and in the Slocan City properties with one or both of these sulphides. Occasionally fair gold values are associated with galena in certain bodies of silver-lead ore, but are not common to these deposits as a whole. A selected specimen of galena from the portal of No. 5 adit, Jackson mine, gave 0·55 ounce gold. A sample of the coarse jig lead concentrate from ore from No. 9 level, Van Roi mine, assayed 0·15 ounce in gold.

A little placer gold is reported to have been found in beds of streams draining areas underlain by the Kaslo series.

Grey Copper: Tetrahedrite; Argentiferous Tetrahedrite; Freibergite. Grey copper occurs in varying proportions in most of the ores. It is generally steel grey, massive, and presents a rough or hackly surface. It occurs in masses and stringers varying from more than an inch in thickness to microscopic proportions. As a rule it carries an important percentage of silver, but on some properties the silver content is comparatively low. It is reported, for example, that specimens of grey copper from above No. 4

level of the Standard mine assayed about 70 ounces in silver, whereas others from below this level carried up to 2,000 ounces silver to the ton. No distinction between the highly argentiferous and lower grade grey copper can be made with the unaided eye, but under the microscope the former appears slightly darker and when treated microchemically reacts faintly with cold, dilute, nitric acid.

The grey copper on analysis is found commonly to carry lead, zinc, iron, or excessive copper, as it is often difficult or even impossible to select a specimen free from minerals such as galena, zinc blende, chalcopyrite, ruby silver, and pyrite.

The manner in which grey copper may occur in galena ore has already been described. The apparent predilection of these minerals for each other is a noteworthy feature. Grey copper may, however, occur quite abundantly in, or even favour, the associated zinc blende of silver-lead-zinc ores, as, for example at the Bosun, Ruth (in part), Utica, and Enterprise mines.

Grey copper is the principal mineral in most of the dry ores where it commonly occurs as veinlets, reticulating stringers, or small, irregular masses associated with abundant vein quartz. A characteristic deposit occurs at McAllister mine where grey copper is in places almost the only metallic mineral.

Jamesonite. This mineral occurs on a few properties and forms massive, compact to fibrous lumps in vein quartz. It may also be eventually identified with one of several complex sulpho-salt minerals which occur in microscopic amounts in many silver-lead ore-bodies. Jamesonite was noted prior to 1896 in a vein on the Best claim, where it was associated with grey copper. Thomlinson also claims to have observed this mineral in ore from Reco mine.

Limonite. Limonite occurs generally as a yellow and rusty brown stain in zones traversed by oxygen-bearing waters. Pseudomorphs of limonite after spathic iron are not uncommon in the zone of oxidation and are well represented at the Beaver and Contact (Black Prince) properties.

Linarite. Linarite was found on a claim of the Beaver group. It occurs in prismatic and tabular crystals, associated with anglesite, lining cavities in ore which consists of coarse cube galena and chalcopyrite. The crystals have a vitreous lustre and are deep azure blue in colour. The mineral was investigated crystallographically by Prof. V. Goldschmidt (10), Heidelberg, Germany.

Magnetite. Magnetite is relatively rare. It occurs in dense masses closely associated with fine-grained pyrrhotite at the Whitewater Deep mine and is probably associated with pyrrhotite in other properties.

Malachite. (*See* Copper carbonates.)

Marcasite. Marcasite has not been positively identified. Characteristic crystalline forms were not observed, but certain minute veinlets and incrustations of pale yellow, fine-grained iron sulphide observed at a number of places were thought to be marcasite rather than pyrite.

Molybdenite. Molybdenite occurs in high temperature quartz veins and associated pegmatitic granitic rocks in the vicinity of Rosebery (5, 1928, page 107) and in the lower valley of Enterprise creek.

Polybasite. This mineral has generally proved difficult to identify. It does not appear to be either widespread or locally abundant, but occurs in minute proportions, associated chiefly with galena, in some of the high-grade silver-lead deposits. It was identified with considerable certainty in ore from the Bosun mine and is believed to be present in several other properties where, however, its identification was not satisfactorily established.

Pyrargyrite. (*See* Ruby silver.)

Pyrite. Pyrite is the most common and widespread of all the metallic minerals and in a few properties is the most abundant ore mineral. It occurs most characteristically as the oldest of the ore minerals, but appears also as veins in, or replaces, the other principal ore and gangue minerals. At the Van Roi mine it coats crystals of calcite. Pyrite generally increases in quantity with depth. With galena and blende it occurs in small masses, disseminated grains, streaks, or bands either coarsely or finely crystalline. It increases in quantity with decrease of galena and with increase of quartz. In the Rambler-Cariboo, Richmond-Eureka, and Hewitt mines the pyrite in part carries much silver, due possibly to a fine admixture of grey copper. Pyrite is also widely disseminated through certain argillaceous members of the Slocan series in which it occurs either as well-defined cubes (less commonly pyritohedrons, and, in some cases, in long, lath-shaped crystals) or as rounded concretionary masses up to more than an inch in diameter. It is also disseminated through rocks of the Kaslo series, and in the more or less altered granitic and porphyritic intrusives. Its ready oxidation has probably been an important factor in the formation of many of the so-called " carbonate ores " which were extensively mined in the early days of the district.

Pyrrhotite. Pyrrhotite is a much less common mineral than pyrite and except at the L.H. mine is rarely conspicuous. At the L.H. property it occurs as solid masses, stringers, and disseminated grains associated with lesser amounts of arsenopyrite, pyrite, and chalcopyrite. At Whitewater Deep mine massive, fine-grained pyrrhotite is closely associated with magnetite on No. 12 level west. Elsewhere, pyrrhotite occurs mostly in small to minute amounts in the ores. It forms veinlets in spathic iron in Slocan Star workings and occurs in a vein on Mascot claim where it is massive and in small quantities. It is stated to be invariably present in zinc concentrates from this district (15, page 237). An assay by H. A. Leverin, Mines Branch, Ottawa, of a piece of pyrrhotite from Mascot mine showed that it contained no gold and only a trace of silver.

Rhodonite. Rhodonite occurs in massive, deep pink bunches or lens-like masses in calcareous foot-wall rocks of a vein on the Harp group near Zwicky. This vein is of vitreous smoky quartz carrying pyrite, pyrrhotite, and chalcopyrite. Rhodonite is believed to have formed in this neighbourhood by metamorphism of rhodochrosite in crystalline limestone (13, pages 111-112, " Harp group ").

Ruby Silver. This is a term commonly employed to designate one or other of a group of high-grade silver minerals of which pyrargyrite seems by all odds the most important. These are dark red, semi-translucent, soft minerals giving a characteristic ruby-red streak or powder. Ruby silver commonly occurs veining or replacing galena and grey copper and, in some instances, sphalerite or other minerals. It is well developed at the Hewitt mine where it occurs in part as clusters and aggregates of beautiful crystals, associated chiefly with calcite, on the walls of small vugs in the ore shoots. These crystals are ruby red with a high lustre. Ruby silver is a conspicuous mineral on several other properties, including the Van Roi, Bosun, Comstock-Virginia, Para, Emily-Edith, and Utica.

In most cases where ruby silver is present in important amounts it appears to be a secondary though doubtfully supergene mineral. On a number of properties, however, it has been observed to occur as microscopic masses with smooth outlines, sparsely disseminated through galena, apparently quite unrelated to cleavage or other structure lines in that mineral, and otherwise suggesting contemporaneous deposition with the lead sulphide.

The ruby silver in these areas is mostly pyrargyrite. The arsenical species, proustite ($3\ Ag_2S.As_2S_3$) is rare, but is reported to have been identified on certain properties in the area of Nelson granite.

Scheelite. This mineral was found at the Meteor mine, in Slocan City mining division, where it formed a mass of about 500 pounds on No. 2 level and a smaller, kidney-shaped body, of about 25 pounds, on No. 4 level. At both levels the scheelite formed part of the vein matter.

Silver. Native silver has been observed both megascopically and microscopically on a great number of properties in the Slocan. It is rarely abundant and on the few properties where it has provided exceptionally high-grade ore its occurrence in appreciable amounts is limited to small pockets or shoots in the upper parts of the ore-bodies and generally within 200 feet or so of the surface. In most cases the silver is secondary and is found associated with such minerals as ruby silver, argentite, and calcite, or occurs as scales and dendritic forms along fracture or cleavage lines in grey copper, galena, and blende. Rich specimens of native silver-bearing ore have been obtained from the Hewitt, Utica, Black Grouse, Capello, Reco-Goodenough, Lily B, Anna, Meteor, Boomerang, and other properties. Most of these occurrences are in "dry" ores, and on properties situated in areas of granitic rocks. Under the microscope a specimen of galena from Bosun mine revealed innumerable minute bright specks of a mineral much resembling native silver.

Smithsonite. This mineral is not conspicuous, but forms part of much of the so-called "carbonate" ores occurring within oxidized parts of the ore-bodies. The mineral substance referred to as "zinc-white" and which forms a white coating, with or without a pale green cast, on the walls of old workings where water is draining from the stopes is probably in part either the sulphate or carbonate of zinc. Smithsonite is reported at Alamo mine in a brecciated lead-zinc ore carrying calcite and quartz.

Sphalerite. This mineral is present in important amounts in most of the ore deposits. Most commonly it is a massive, rich brown, lustrous mineral with well-developed cleavage. As such it formed large bodies of nearly pure ore at Lucky Jim mine, and has provided large tonnages from other important zinc properties. Less commonly it is closely compact, of pale liver-brown colour, and forms narrow bands or small lenses interstratified either with the more abundant type or with other minerals, principally pyrite and galena, as at places in the Charleston, Whitewater, and Jackson mines. In rarer cases it forms clusters of beautiful crystals. At the Lucky Jim such crystalline aggregates occur in vuggy parts of the massive ore and in nests in the associated limestone rock. They are simple octahedra and more complex forms. Other occurrences of crystals were noted at the Mountain Chief property. Not uncommonly the sphalerite varies from dark brown to almost black. In many other deposits, and particularly in those occurring in areas of the Kaslo series or of the Nelson batholith, the zinc blende is lighter coloured and resinous.

Sphalerite very commonly contains chalcopyrite as minute scattered masses. Where earlier ore or gangue materials are replaced by the sphalerite the associated chalcopyrite may cluster around the foreign body in more concentrated form than elsewhere in the sphalerite.

Massive sphalerite contains a varying silver content which is generally small and in most cases probably due to a fine intermixture of galena or grey copper or both. In exceptional cases the apparently pure sphalerite may be very rich in silver, as on the Hope, Bosun, and Enterprise mines and in the Reco No. 2 vein of the Reco mine. An assay of sphalerite from the Hope mine by H. A. Leverin, of the Mines Branch, gave 318·38 ounces of silver and 0·07 per cent copper. A specimen from Lucky Jim mine assayed—silver 1·32 ounces; zinc 61·47 per cent; and iron 3·39 per cent. Available analyses of the sphalerite indicate that the silver content mostly appears to be associated with an appreciable content of lead rather than of copper; that there is a very little cadmium present; and that manganese is almost lacking. The presence of tin, probably in the form of stannite, in one analysis, suggests that it may be present in small quantities in other properties.

Stannite. Stannite has not been identified, but is suspected to be present in the Payne mine from which sphalerite on analysis was found to carry a small percentage of tin.

Stephanite. This mineral is a conspicuous constituent of the ore at Anna mine, Slocan City mining division, where it is associated with galena in vein matter also carrying pyrite, chalcopyrite, sphalerite, and native silver in a gangue of quartz and carbonate. Stephanite also occurs in very minor proportions in the richer ores of certain other properties, including the Arlington and Tamarack mines. It is reported to have been found associated with argentite in old workings on the Silver Glance property north of Bear lake and may be present in microscopic masses in the ores of other properties.

Stibnite. Stibnite occurs at the Hewitt mine, associated with ruby silver, as clusters of small acicular crystals. It also forms massive ore in quartz veins on the Alps Alturas property (5, 1926) at the head of Kane creek to the north of Sandon map-area.

Sylvanite. Sylvanite is reported by Gwillim (12, 1894, page 496) to have been found in one mine near Slocan lake.

Tetrahedrite. See Grey copper.

Unknown Minerals: It is common to find in the galena ores microscopic specks of other minerals which because of their minute sizes cannot be identified. One such mineral has been recognized in the galena ores from a number of properties including the Payne, Winona-Boon, Hewitt, Silversmith, Mowitch, Mountain Chief, Comstock-Virginia, Sunset, Idaho, and (?) Meteor mines. In each case the mineral occurs only in microscopic masses. It is sectile, dark grey or dark bluish grey, and as hard or a little harder than galena. Microchemical reactions are rather unsatisfactory owing to the minuteness of the mineral masses, but so far as could be determined are as follows: HNO_3, tarnishes brown to black but can be rubbed clean; HCl, little or no reaction; KCN, darkens, rubs clean; $FeCl_3$, appears to roughen, but little other effect; $HgCl_2$, instantly tarnishes and turns black, persistent; KOH, sometimes tarnishes brown—other times almost negative.

Wad. Wad occurs in innumerable instances as coatings and dendritic markings on vein minerals and rocks.

GANGUE MINERALS

Actinolite. A fibrous mineral, too highly altered to determine accurately, but believed to be actinolite, was found in the ledge-matter of Leadsmith vein-lode in the long crosscut from the portal of No. 4 adit.

Aragonite. Aragonite in large clusters of colourless, radiating groups of acicular crystals was found in cavities in the wall-rock of the lower, main adit at Wonderful mine. Aragonite was also found in a vug over No. 3 level, Standard mine. On the Slocan Boy aragonite partly fills open fissures along the course of the vein; it is whitish, shading in part to bands of light green, and forms compact masses with botryoidal surfaces and internal radiating structure. This variety of aragonite was identified by Poitevin, of the Geological Survey, as *mossottite,* a rare species hitherto identified in the Lias of Gerfalco, in Tuscany, where it contained nearly 7 per cent of strontium carbonate and a trace of copper.

Barite. Barite is a fairly common gangue mineral in Slocan City mining division, in vein deposits in the Nelson batholith. In places it forms solid vein matter, but is commonly associated with calcite and a much greater proportion of quartz. Properties on which it is found include the Speculator, Anna, Little Tim, Calumet and Hecla, and Alma. Barite is also reported by Thomlinson to occur closely associated with lead ore on the Robin claim near the Standard mine. The mineral generally forms coarsely crystalline masses which are white to cream coloured and, in some cases, possess a distinctly pearly lustre.

Calcite. Calcite is a widespread gangue mineral. It is generally present in small amounts, but on a number of properties lying principally in a belt extending from Slocan lake in the vicinity of Silverton to Sandon, it forms large, coarsely crystalline masses up to several feet in thickness. Similar calcite occurs at Leadsmith mine and between this property and Sandon. On the Colonial, Cristein, and Freddie Lee properties it occurs in concretionary and botryoidal forms lining walls of the veins. Such forms are banded in white and colourless layers and possess a cross-fibre structure. Small vugs or cavities in the vein matter of many properties contain beautiful crystals (cubic, dog-tooth, and nail-head types) of calcite.

Dolomite. This is a comparatively rare gangue mineral. It has been recognized at the Hewitt and Van Roi mines, where it occurs in clusters of minute, light brown, rhombohedral crystals lining cavities in the veins. A massive, light brown type occurs at the Silver Bell and Idaho mines cementing fragments of rock and ore minerals.

Fluorite. Fluorite has been noted on the Mountain Chief property, and is particularly abundant at the Galena Farm mine where it coats large surfaces of ledge matter along fault planes and forms irregular masses as much as several inches thick enclosing fragments of ore and gangue minerals. It occurs in crystalline and massive to somewhat botryoidal and vuggy forms; varies from nearly white to pinkish blue; and appears to be distinctly later than the other primary vein minerals.

Heulandite. This zeolite is reported by Thomlinson to have been noted at the Fisher Maiden mine.

Kaolin. Kaolin associated with calcite was found in the Rambler-Cariboo vein. It also occurs as a decomposition of potash feldspar in veins in granitic rocks associated, in places, with chalcedonic quartz.

Mirabilite. A heavy coating of the salt was observed on the walls of a crosscut on No. 10 level, Silversmith mine. It forms a loosely compacted mass of clear crystals associated with a powdery, whitish variety formed from the crystalline type through loss of water on exposure to the air.

Quartz. Quartz is an abundant gangue mineral. As a rule it increases in amount with depth. In the dry ore veins it is the predominant gangue mineral. The quartz is mostly milky white and massive, but in parts of veins occurs as crystals projecting into cavities. Clear quartz crystals are not common. The Ohio vein contains long, slender prisms lying in massive siderite and associated with crystals of siderite. Crystals of clear quartz were observed in the oxidized parts of Lucky Jim orebodies. A banded chalcedonic type was noted in the batholithic rocks on a few properties, including the Smuggler and Slocan Chief.

Selenite. Colourless to white crystals of selenite encrust cavities in the wall-rocks on the long crosscut (No. 15) level of Payne mine.

Siderite. Siderite is the most common of the gangue minerals on the larger silver-lead-zinc properties, and is present on most of the other properties. It occurs mostly in coarsely crystalline bands and lenses. It may be intimately mixed with or interbanded with the ore minerals, and is more abundantly associated with sphalerite than silver-lead ore. At depth it is replaced by quartz. It varies from light honey-yellow through various shades of pinkish and reddish brown to dark grey and almost black. The common colour is light pinkish brown. On weathering it becomes dark reddish brown through formation of iron and manganese oxides. At depth and with impoverishment of the associated zinc blende the siderite generally assumes a honey-yellow colour. In Whitewater Deep workings one lens of dark grey to almost black, coarsely crystallized siderite was observed on No. 13 level. The mineral rarely shows good crystal forms, though cavities in the massive siderite may be lined with small rhombohedra and nailhead crystals. The siderite generally carries an important percentage of manganese.

A specimen of honey-yellow, spathic iron from Slocan King mine, analysed by H. A. Leverin, Mines Branch, Ottawa, was found to contain:

	Per cent
Iron	32·24
Manganese	18·75
Sulphur	0·345
Phosphorus	Trace
Insoluble	2·23
$FeCO_3$	66·78
$MnCO_3$	20·45

A sample of spathic iron from the Contact (Black Prince) claim near Blaylock (13, page 114) was reported by A. Sadler, Mines Branch, Ottawa, to contain:

	Per cent
Iron carbonate	63·20
Manganese carbonate	20·98
Lime carbonate	7·49
Manganese carbonate	5·47

Sulphate of Alumina and Sodium. A thick, white, soft precipitate coating the walls of the upper main tunnel of the R. E. Lee mine, about 400 feet from the portal, was found on analysis to be a sulphate of alumina and sodium.

Tourmaline. Tourmaline rarely occurs in the mineral deposits. At the Flint mine, however, abundant small needles of black tourmaline were observed in vein quartz associated chiefly with pyrite.

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