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Maps in E Kootenay Atlas TLUC

MINERAL DEPOSITS OF THE EAST KOOTENAY REGION

MINERAL DEPOSITS, EAST KOOTENAY REGION

Introduction

This report is to accompany maps showing mineral deposits and mineral potential, and maps showing groups of current mineral claims, coal licences and petroleum and natural gas licences and leases. The claim, licence and lease data are dated September 1970.

The map of mineral deposits and mineral potential is based on published and unpublished information, personal knowledge of staff geologists and consultation with Cominco geologists in the Vancouver exploration office. The conclusions represented are of a general nature compiled on a scale of 1:250,000 to give a regional picture of the mineral resources and to show the places where deposits have been mined and tested. The areas shown as having moderate potential for metallic mineral deposits are the areas which on the basis of present knowledge are most likely to contain significant orebodies. Orebodies may be discovered, however, outside these areas by continued search and because of the recognition of new valuable commodities. The maps can be used for only the most general considerations of land use.

The following tables show total production of metals, coal, industrial minerals and structural materials from within the area.

TABLE 1a

GROSS METAL PRODUCTION - GOLDEN MINING DIVISION

Property or Mine	Years	Mined tons	Gold oz.	Silver oz.	Copper lb.	Lead lb.	Zinc lb.	Cadmium lb.
B.C. and Tilbury	1905-8, 1927	87	--	6,394	--	91,306	942	--
Black Diamond	1906-7	47	--	1,930	--	58,801	--	--
Bunyon	1904	15	--	105	2,795	--	--	--
Charlemont	1907	13	--	861	--	12,247	--	--
Comstock	1907	21	--	690	--	24,668	--	--
Copper Butte	1916-17	34	--	1,700	3,400	--	--	--
Crown Point	1909, 1929	6	--	264	--	8,396	--	--
Delphine	1899-1905	187	--	19,751	6,670	103,353	--	--
Giant	1908, 1916, 1930, 1947-57	927,111	4	622,421	485,752	64,874,328	7,120,750	17,199
Helldiver	1920	35	--	874	--	19,343	--	--
Hidden Treasure	1898, 1916	17	--	350	11,600	--	--	--
Hot Punch, Silver Spray, Star	1908-9, 1919, 1926	80	2	3,491	--	60,115	1,992	--
Isaac	1916-24	476	--	13,123	--	334,667	--	--
Key or Silver Key	1936, 1939-40	4	--	1,420	--	120	42	--
Lancaster	1890	30	--	--	33,000	--	--	--
Lead Queen	1916-19, 1926-29	429	1	14,120	--	321,582	2,630	--
Lucky Jim	1961	5	--	223	--	5,130	160	--
Mabel R	1918	17	--	133	--	19,904	--	--
Mineral King	1954-68	2,313,068	--	1,844,189	1,459,477	82,215,885	198,834,972	32,540

Property or Mine	Years	Mined tons	Gold oz.	Silver oz.	Copper lb.	Lead lb.	Zinc lb.	Cadmium lb.
Mt. Fraction	1901-3	36	--	8,187	3,649	87	--	--
Nip and Tuck	1916, 1923	98	1	6,818	--	94,447	--	--
Paradise	1901-6, 1916-29, 1949-52	71,247	32	737,189	--	15,979,124	7,988,687	8,914
Pretty Girl	1904, 1917, 1928	9	--	457	3,677	--	--	--
Ptarmigan	1900-3, 1906, 1920, 1957-59	725	114	89,027	8,407	7,758	1,871	--
Ruth Vermont	1965	17	1	1,056	--	10,335	6,425	--
Silver Belt	1901, 1916-18	108	--	4,782	--	39,574	--	--
Silver King	1915, 1925	29	--	832	--	18,201	--	--
Sitting Bull	1919	13	--	1,044	--	8,468	--	--
Steele	1923	221	--	5,127	--	140,543	--	--
Tecumseh	1904-7	79	--	7,991	--	87,026	--	--
Tennessee	1917	1	--	--	180	--	--	--
Trojan	1919	44	--	7	9,239	--	--	--
Vermont and Ruth	1892, 1927, 1930, 1951	62	5	5,821	--	61,898	8,200	--
White Cat	1924-28	167	--	4,980	--	177,791	--	--
TOTALS		3,314,538	160	3,405,357	2,027,846	164,775,097	213,966,671	58,653

TABLE 1b

GROSS METAL PRODUCTION - FORT STEELE MINING DIVISION

Property or Mine	Years	Mined tons	Gold oz.	Silver oz.	Copper lb.	Lead lb.	Zinc lb.	Cadmium lb.
Anderson Group	1937-40	420	102	167	--	442	--	--
Aurora	1910-11, 1926-27	2,458	--	9,686	--	403,500	688,834	--
Birdie L	1937	25	1	484	--	7,611	--	--
Burton	1916-18	228	--	4	17,101	--	--	--
Comet	1925-26	24	--	38	11,721	--	--	--
Copper King	1924, 1928	14	1	105	906	--	--	--
Dibble	1895, 1934	32	1	1,205	240	--	--	--
Estella	1951-54, 1963, 1966-67	120,724	66	205,538	2,641	11,422,255	21,661,020	22,581
Grundon	1919, 1923, 1927	31	--	107	--	7,303	7,702	--
Humbolt	1963-64	9	--	216	--	5,804	2,399	--
Judylu	1951	25	--	59	--	5,333	246	--
Kootenay King	1952-53	14,617	23	28,367	--	1,567,199	1,943,129	2,171
Magnet	1968	10	--	22	--	1,773	--	--
Midway	1933, 1937-40, 1959, 1962	1,288	292	2,750	238	5,618	3,750	--
Minnie	1917	1	--	60	--	370	--	--
North Sea	1898-1910, 1918-21, 1929	67,531	--	1,338,431	--	47,938,812	13,899	--
Park	1916-17, 1923	144	--	729	--	23,437	--	--
Payroll	1907	18	6	23	--	--	--	--

Property or Mine	Years	Mined tons	Gold oz.	Silver oz.	Copper lb.	Lead lb.	Zinc lb.	Cadmium lb.
Quantrell	1916-17	75	--	1,446	--	67,160	--	--
Red Eagle	1927	1	--	8	133	--	32	--
St. Eugene	1899-1929	1,626,210	2,535	5,873,731	--	249,199,671	31,929,526	--
Society Girl	1900-01, 1910-13, 1948-52	3,289	--	13,891	--	1,101,558	52,721	--
Stemwinder	1926	28,241	42	62,862	--	2,084,079	8,798,474	--
Sullivan	1900-69	101,793,555	4,708	229,462,024	7,645,500	13,576,746,022	11,735,056,502	2,782,96[illegible]
Victor	1921	7	1	172	--	5,327	--	--
TOTALS		103,658,977	7,778	237,002,125	7,678,480	13,890,593,274	11,800,158,234	2,807,71[illegible]

APPROXIMATE QUANTITY AND VALUE OF

MINERAL PRODUCTION FORT STEELE AND

GOLDEN MINING DIVISIONS

Commodity	1969 Quantity	Value in dollars	Total value to date in dollars
Silver	3 million ounces	6 million	161 million
Lead	186 million lbs.	30 million	1060 million
Zinc	155 million lbs.	24 million	846 million
Cadmium	329 thousand lbs.	1.2 million	7 million
Iron concentrates	182 thousand tons	1.9 million	10.7 million
Placer gold			470 thousand
Tin	288 thousand lbs.	470 thousand	15 million
Barite	27 thousand tons	190 thousand	3.5 million
Gypsum	281 thousand tons	764 thousand	7 million
Structural Materials		417 thousand	4.5 million
Coal	842 thousand tons	6.7 million	281 million
Totals		71.2 million	2,397 million

METALS

The area contains important deposits of silver, lead and zinc and significant amounts of iron, copper, gold, tin, tungsten and radio-active metals. It is an area of complex geology which, though completely mapped on scales of 2 and 4 miles to the inch is incompletely explored.

The area contains the Sullivan orebody which is unique in terms of size and geological characteristics. Currently stated reserves are 60 million tons and the company has production plans to the year 2000. The Sullivan orebody is the largest reserve of silver, lead and zinc in the province, upon which directly depends a significant part of the economy of southeastern British Columbia. Several hundred thousand dollars are spent each year by Cominco Ltd. and by other exploration companies in the search for another similar deposit. It is possible to set only very general limits on the area in which such a deposit may be found and exploration should not be discouraged by regulations which restrict the area of search.

Two areas of moderate potential for silver, lead and zinc occur in the northern Purcell Mountains. These two areas together have had one or two producing mines of moderate size for the last 20 years. The most recent past producer, the Mineral King, closed in 1968; the Ruth Vermont began production in July 1970. The most significant deposits are the Silver Giant and Mineral King which are considered to be mined out, but which will probably produce more ore from the same or closely related nearby zones. The Ruth Vermont is reported to contain a silver, lead, zinc orebody estimated to be worth $25 million at current prices which will be mined out in approximately 5 years. In my opinion other deposits of similar size can be expected to be found in these two areas in the foreseable future.

An area containing a number of copper, silver, lead, and zinc showings and small mines lies along the eastern side of the Rocky Mountain Trench south from Windermere Lake to the International Boundary. Currently a small copper-silver orebody is being prepared for production near Bull River by Placid Oil. It is called the Bull River Mine and the known orebodies are expected to be mined during the next 5 years. A mill with a capacity of 750 tons per day is under construction and mining initially is by open pit.

Traditionally the Rocky Mountains have been considered barren of metallic minerals. Recent work and wider ranging exploration have found interesting lead, zinc, copper and tungsten mineralization with significant potential. Two areas of moderate potential are shown, one in the Clark Range, in the Flathead and another east of the upper Kootenay River.

Placer gold has been taken from several streams in the area and there will continue to be minor exploration and placer gold mining. Placers containing radioactive minerals have been tested recently in upper Vowell, Malloy, Bugaboo and Forster Creeks.

COAL

The approximate outline of the area containing coal-bearing strata is shown on the map. Three parts, the Elk River coalfield, the Fernie basin and the Flathead area are recognized.

The Elk River coalfield has an estimated total potential of recoverable coal amounting to approximately one billion tons. Three companies have proved up substantial reserves. The northernmost property is that of Emkay Scurry Limited along Big Weary Ridge and Little Weary Ridge north of Aldridge Creek. Considerable testing has been done and an operating company (Emkay - Scurry Limited) was formed in December 1969. Reserves of recoverable raw coal estimated in July 1969 amount to 139 million tons.

Fording Coal has proved up substantial reserves on Eagle and Turnbull Mountains north of Kilmarnock Creek and in the Greenhill area to the west. Total reserves of approximately 279 million tons are reported of which substantially less coal is recoverable. The decision was made this year to put the property into production early in 1972. A 15 year contract to ship 3 million tons of coal per year to Japan was negotiated.

Crows Nest Industries Limited has tested three areas near Line Creek and coal seams on Line Creek Ridge are being prepared for production.

A large part of the coal reserves of the Fernie basin are held by Kaiser Resources Ltd. The company estimates a potential of

1.5 billion tons is present within their holdings. The company has a 15 year contract to ship approximately 5 million tons per year to Japan.

Isolated sections of the coal-bearing formations are present in the Flathead. Early estimates of coal reserves included the Flathead, but in recent estimates (G.S.C. paper 70-8) they have been eliminated. Good quality coal is present in the Flathead but recent testing of the most promising area (Cabin Creek) shows that is currently not economic.

INDUSTRIAL MINERALS

Commercial production of industrial minerals in the area has been limited to barite and gypsum and minor amounts of shale and dolomite. Exploratory work has been done on limestone, magnesite, phosphate and silica deposits and trial shipments were made from some of them.

Barite

Barite ($BaSO_4$) is used chiefly as a weighting agent in oilwell drilling muds where its value depends on its high specific gravity, softness, and chemical inertness. For most of its many other uses the mineral must be white and chemically pure.

Many occurrences of barite are known in the area but all are small and most are uneconomic to-day. Because of the negative results of a considerable amount of prospecting for barite and of the nature of the known deposits, the prospects of finding important new deposits are considered slim.

The mineral has been produced at Parson (75,000 tons), Brisco (140,000 tons), Spillimacheen (80,000 tons), Invermere (15,000 tons), and Toby Creek (24,000 tons). Present production originates at mines at Parson and Brisco and at plants recovering barite from old mill tailings ponds at the sites of the former Giant (Spillimacheen) and Mineral King (Toby Creek) mines. The Parson and Brisco mines will probably be mined out within 2 or 3 years. The tailings pond at the Giant mine is nearly depleted but several thousand tons of potential ore remain in the upper workings of the old mine. The other known deposits are very small and preliminary exploration on them has failed to reveal large quantities or cheaply mineable small quantities of ore.

Dolomite

Dolomite is used herein to refer to a rock consisting essentially of the mineral dolomite ($CaCO_3$ $MgOCO_3$). Its main uses are as a flux in the iron and steel industry, as a refractory, and as a source of magnesia and magnesian lime. Other uses are numerous. Its market value is low.

Dolomite is present as extensive beds in many of the rock formations in the area. West of Glenogle a wide belt is crossed by the railway and highway. The Jubilee Formation contains much dolomite and is well exposed along the base of Jubilee Mountain, on the east face of Steamboat Mountain, east of Athalmer, in the Stanford Range, and around Canal Flats. South and east of Fernie several formations contain dolomite.

Cominco quarried about 20,000 tons of dolomite between 1960 and 1962 from a deposit at Norkay, near the mouth of Bull River. Production ceased when it was found cheaper to buy rock from a quarry operating in Alberta near Crows Nest.

At present accessible markets for dolomite are not great enough to warrant production in British Columbia. However, the deposits in this region should be considered of potential value for the future.

Gypsum

Gypsum ($CaSO_4$ $2H_2O$) is used in large quantities in the manufacture of plasters, wallboard, cement, and for land dressing. For the first 2 uses it must be very pure and in all cases the unit value is low.

Considerable areas of the district are underlain by gypsum-bearing formations and many gypsum occurrences are known within them. Much of the gypsum is beyond the reach of economic transportation at present and much is of poor grade. It is not thought very likely that sizeable new areas of gypsum-bearing formations will be discovered in the region.

There has been production of gypsum at Mayook (110,000 tons) and east of Windermere (more than 2½ million tons). Present production is from the Windermere quarry. There does not appear to be any prospect of new quarry development in the immediate future but some of the deposits should provide gypsum at a later date when gypsum becomes scarcer.

Limestone

Limestone ($CaCO_3$) is one of the basic raw materials of the chemical and metallurgical industries. It occurs in various purities throughout the area. One deposit near Wardner was studied with a view to production but nothing developed. At present it would appear that accessible markets are too small to support a quarry. No doubt in the future there will be limestone produces.

Magnesite

Magnesite ($MgCO_3$) is used chiefly as a raw material for the manufacture of high melting point bricks and other refractory products to line furnaces and kilns. Synthetic magnesite extracted from brines now competes strongly in industry with the natural mineral.

A large deposit of high grade magnesite occurs on Mount Brussilof, 20 miles northeast of Radium, and smaller deposits are known just west of Brisco and south of Marysville. There is a good chance other deposits will be recognized in similar geological formations.

Small local demand and excessive transportation costs to larger distant markets have prevented exploitation of the magnesite. However, in the future, these deposits could prove valuable.

Phosphate

Phosphorus is essential to all life and is one of the main elements required to be provided to plants in fertilizers. The chief commercial source to-day is phosphorite—a sedimentary rock containing secondary phosphate.

Phosphate - bearing sedimentary rocks are widespread in the area and many deposits have been found. However, in these rocks, the occurrences explored to date have proved below acceptable economic grade and size. In addition, processes to up-grade the material to useable quality are apparently not available. Because of the ready availability of cheap high-grade rock from other sources, our deposits, at best, can be considered only as possible future sources.

Shale

Small amounts (less than 2,000 tons per year) of shale are quarried near Canal Flats for the production of industrial fillers. No great increase in demand for this particular material is envisaged and supplies appear adequate.

Silica

The mineral quartz is mined as the chief industrial source of silica (SiO_2). It occurs as veins, as quartzite and sandstone rocks, and as sand. The major uses are for smelter flux, in glass manufacture, in the silicon carbide and ferro-silicon industries, and in the granule trade. In all cases the value is relatively low and, except for flux, the quality must be high.

In the northern part of the area, particularly near Golden, a belt of very pure quartzite, the Mount Wilson (Wonah) Formation is fairly widespread. Two or three attempts have been made to exploit this rock at different places but, to date, none has proved economically workable. With changes in economic conditions and technology, however, this material could become a source of silica and must be considered as of future potential. Similarly, certain quartzite beds in the southeast corner may prove of value.

PETROLEUM AND NATURAL GAS

The Fernie and Flathead area has significant potential for the production of petroleum and natural gas. The area contains a thick sedimentary sequence with many possible situations for the accumulation of petroleum and natural gas. There are many oil and gas seeps. Comparable sedimentary rocks in the nearby Alberta foothills are productive.

Geological conditions make exploration expensive and slow. To date more than thirty wells have been drilled in the Flathead-Fernie area, most of them shallow in the vicinity of seeps. Recently wells drilled by major companies have been deep tests, at least three below a depth of 10,000 feet. Although much was learned geologically, no significant shows of petroleum or natural gas have yet been encountered in these deep wells. Exploration will continue (a deep test well was started in October near the head of Harvey Creek in the Flathead region) and it is expected that commercial quantities of petroleum and natural gas will eventually be found.

James T. Fyles

Mineralogical Branch
Department of Mines and
Petroleum Resources
November 5, 1970

MINERAL RESOURCES -- REVELSTOKE AREA

METALLIC MINERALS

The area outlined on the accompanying map and referred to herein as the Revelstoke area is mainly in the drainage basin of the Big Bend of the Columbia River. It includes parts of the Monashee, Selkirk, Purcell, and Rocky Mountains and is one of the most rugged parts of southeastern British Columbia. The area contains Revelstoke, Glacier, and Yoho National Parks in which there is no mineral exploration and mining, although one of the largest past producers is near Field in Yoho Park. The principal metals are lead, zinc, and silver with by-product cadmium and copper. One of these deposits contains small amounts of tin. Recently a significant deposit of molybdenum has been discovered.

There is little or no production from within the area at the present time but three companies are planning to go into production in the near future. These are:--

(1) King Resources Company, Knox molybdenum property--about 200 tons per day mill

(2) Columbia Metals Corporation Ltd., True Fissure lead-zinc-silver property--135 tons per day mill

(3) Stannex Minerals Ltd., Woolsey and Snowflake lead-zinc-silver(-tin?) property

In relation to the rest of British Columbia the area is one of high potential for lead and zinc. It contains some of the largest known deposits. Although many of the mines and prospects were discovered many years ago, significant new discoveries have been made recently, including the Ruddock Creek lead-zinc and the Knox molybdenum deposits. Development of the large lead-zinc deposits has been hampered by the rugged topography, poor recovery of zinc from some of the ores and the current low prices of lead and zinc.

Within the Revelstoke area for purposes of this evaluation, mineralized belts outlined on Figure 1 have been rated on the basis of metal content and the possibility of production from within the belts in the near future.

RECENT ACTIVITY

The most recent significant production has been from the Monarch and Giant mines which closed in 1957 and the Spider which closed in 1958. Since that time, major exploration has been done as indicated below:--

(1) Bralorne Pioneer Mines Limited with subsidiary and associated companies in 1960, 1963, and 1965 did deep diamond drilling on the King Fissure property.

(2) Cominco Ltd. between 1964 and 1967 carried on extensive prospecting and property examinations throughout the area.

(3) Columbia Metals Corporation Ltd. in 1966 to 1968 did drilling, geophysics, and stripping on the True Fissure and nearby properties.

(4) Between 1965 and 1967, Columbia River Mines Ltd., following exploration by Rio Tinto and others, developed significant reserves at the Ruth Vermont property.

(5) Falconbridge Nickel Mines Limited between 1960 and 1963 did extensive helicopter supported prospecting throughout most of the area. The It and In claims were recorded in 1960 and drilling in 1962 and 1963 proved up significant reserves of lead and zinc.

(6) In 1965, King Resources Company obtained claims covering the Knox molybdenum showings discovered by prospectors in 1964. Since then the company has drilled the

showings and discovered significant molybdenum ore and has done intensive prospecting of about 200 square miles of country immediately northwest of Revelstoke.

(7) Between 1964 and 1967 Stairs Exploration and associated companies of Ivan C. Stairs did extensive exploration in the area north of Revelstoke. They did regional mapping, underground work, and drilling on the Roseberry, A and E, Standard, and J and L properties.

(8) Stannex Minerals since 1967 has done underground work and local exploration of the Snowflake, Regal Silver, and Woolsey properties northeast of Revelstoke.

These companies probably have spent a total of at least 4 million dollars on exploration for metallic mineral deposits in the Revelstoke area since the beginning of 1960.

LEAD-ZINC-SILVER DEPOSITS

The area contains about 60 properties which have produced 1 ton or more of lead-zinc ore as indicated in Table I. Many have produced less than 1,000 tons of ore, most of it before 1930. Only 13 mines have produced more than 1,000 tons and only 3 more than 100,000 tons. All of the ore has been mined by underground methods and from most properties it was shipped as crude ore, mainly to the smelter at Trail. At 8 mines the ore was concentrated in mills near the mines and the concentrates shipped, partly to the Trail smelter and partly to smelters in the United States.

TABLE 1.--PRODUCTION

			GROSS CONTENTS						
		Tonnage	Gold Ounces	Silver Ounces	Copper Pounds	Lead Pounds	Zinc Pounds	Cadmium Pounds
Ajax	1912-1914	13		18,901		552,696		
American	1903	14		892		18,154		
Badshot	1904	28		3,859		24,200		
Beatrice	1900-1917	585	6	45,410		359,384		
ιack Prince	1904	30		4,643		8,532		
Broadview	1900-1906	238	19	8,668		1,145		
Copper Chief	1905, 1917	14		1,936		2,672		
Cromwell	1900-1901, 1953	15	64	223		13	19	
Dunvegan	1900, 1925	155		4,816		77,280	1,120	
Ethel	1899, 1918	76		9,251		12,664		
Eva	1903-1908	31,656	7,561	989				
Fidelity	1912-1918	44	28	2,867		24,185		
Foggy Day	1917	9	39	125				
Francis & Noel	1911	6		2,897		5,070		
Giant	1947-1957	927,111	8	622,421	485,756	64,874,328	7,120,750	17,299
Gillman	1933	1	2	2		48	51	
Gladstone	1900	3		100		1,902		
Goldfinch	1903-1904	1,450	671	180				
Good Luck	1905	26			6,891			
Great Northern	1896-1904	26	55					
Hidden Treasure	1898, 1916	17		350	11,600			

		Tonnage	Gold Ounces	Silver Ounces	Copper Pounds	Lead Pounds	Zinc Pounds	Cadmium Pounds
High Grade	1911-1915	5	959			1,658		
Horseshoe	1902-1903	46		10,585	4,294	30,196		
IXL & OK	1905	7	8	390	3,777			
Lanark	1914-1922	883	7	33,385	645,476			
Lancaster	1890	30			33,000			
Lucky Boy	1903-1912	421	1	86,882	217,285			
Lucky Jack	1904-1908	509	75	12				
Mammoth	1905-1907	83	8	15,550	51,075	4,304		
Mastodon	1926, 1952, 1960	31,940	8	6,113		180,334	5,911,619	24,716
Meridian	1935-1941	56,086	8,313	3,732				
Metropolitan	1901	6	1	1,216		1,976		
Mohican	1903	9	1	495		4,894		
Monarch, etc.	1888-1957	911,627		807,760		101,959,004	157,223,377	19,876
Mohawk	1963	9		434		2,993	3,746	
Nettie L	1899-1922	12,820	781	459,253		1,309,868	28,239	
Noble Five	1905, 1923	11	3	794		3,858	546	
Ophir Lade	1932	13	13					
Oyster-Criterion	1904	10,102	1,613	600				
Porphyry & Ironhill	1901	6		10	1,450			
Regal	1930, 1949-1953	2,828	2	9,930	242	207,945	52,174	
Ruffled Grouse	1901, 1902	9		1,446		1,685		
St. Elmo	1899	6	1	624		2,420		
Silver Bell	1941	4		171		2,932	500	

		Tonnage	Gold Ounces	Silver Ounces	Copper Pounds	Lead Pounds	Zinc Pounds	Cadmium Pounds
Silver Belt	1899	1		133		1,537		
Silver Cup	1895-1941	22,544	4,978	1,419,339		5,684,204	110,447	
Silver Pass	1947	7		317		3,039	2,224	
Silver Queen	1917	26		1,300		20,800		
Snowflake	1927-1929, 1967	144	1	5,558	1,023	133,275	17,063	
Spider	1911-1917, 1926-1929, 1937-1958	141,169	11,913	1,719,474	188,161	23,908,704	25,396,069	133,093
Sunday	1901	7		123	301	6,987		
Teddy Glacier	1929	6	4	74		1,884	2,978	
Tennessee	1917	1			180			
Towser	1917	25	5	1,400		20,117		
Triune	1900-1905, 1916-1918	653	335	144,928		494,867	9,749	
True Fissure	1908-1944	5,076	198	42,148		533,019	286,570	
Vermont & Ruth	1892, 1927, 1951, 1965	79	5	5,822	1,056	72,233	14,625	
Western Cross		1		5		212	216	
'innipeg	1918	21		1,050		28,582		
Winslow	1934-1941	1,788	596	312		477	28	
Woolsey	1927	5		189		3,620	196	
Totals		2,160,530	38,282	5,510,084	1,651,567	200,530,232	196,188,731	194,984

The lead-zinc-silver deposits are of three types:--

Type (a)--Replacements in carbonate rocks

Type (b)--Layers of sulphides interbedded with the formations in metamorphosed sedimentary rocks

Type (c)--Veins and lodes

Type (a)

Replacements in carbonate rocks are disseminated or massive deposits of galena, sphalerite, and pyrite in dolomite and limestone. They are low to moderate grade in lead and zinc and usually contain less than 1 ounce per ton in silver. The only significant production in the Revelstoke area has been from this type of deposit and amounts to 1,870,678 tons. Details of the production and average grade based on the production figures are shown in Table II.

TABLE II.--PRODUCTION AND AVERAGE GRADE
LEAD-ZINC REPLACEMENT DEPOSITS

	Tonnage	Silver Oz./Ton	Lead Per Cent	Zinc Per Cent
Giant	927,111	0.67	3.5	0.38
Mastodon	31,940	0.19	0.29	9.3
Monarch	911,627	0.88	5.6	8.6

The Giant, Mastodon, and Monarch mines were closed largely because the known reserves were exhausted and exploration on and near the orebodies had failed to find significant new ore. No doubt more mineralization of the sort that has been mined exists at or near these properties. Recent exploration at the Ruth Vermont property has outlined a replacement orebody with reserves estimated at 750,000 tons having an average grade of silver, 6 ounces per ton; lead, 3 per cent; and zinc, 4 per cent.

Type (b)

Lead-zinc deposits of Type (b) constitute the largest potential in the area, but none of them has yet been mined. Estimated reserves for three of the properties based on published and unpublished data and personal knowledge are shown in Table III. These estimates are of tonnages and grades of material that, under present economic and technological conditions, is marginal to submarginal ore.

TABLE III. -- RESERVES
TYPE (a) and TYPE (b) LEAD-ZINC DEPOSITS

	Tonnage	Silver Oz./Ton	Lead Per Cent	Zinc Per Cent
It, In (Ruddock Cr.)	5,000,000	1	5	5
King Fissure (Jordan River)	4,000,000	1	5	5
Ruth Vermont	750,000	6	3	4
Wigwam	300,000	1	1.5	4.5
Total	10,050,000			

Deposits of Type (a) and Type (b) contain potential ore the quantity of which can only be guessed at. The King Fissure deposit is of limited size and probably contains a total of 5 million to 10 million tons. Limits to the Ruddock Creek deposit cannot be set and an estimate of ultimate potential is not possible. The Ruth Vermont orebody appears to be fully outlined but mining will permit access to favourable ground to the south.

The potential of properties such as the Wigwam and Cottonbelt cannot be judged on the basis of present knowledge even though they have been known and explored sporadically over a period of years. Other Type (a) and Type (b) deposits on which little or no work has been done include the Kinbasket on Kinbasket Lake, the Bend on the Cummins River, showings near Downie Lake, and showings in the Monashee Mountains northwest of Revelstoke. The potential of a number of small showings of this type near Shuswap Lake is uncertain.

Type (c)

The vein deposits of Type (c) in contrast to Types (a) and (b) are relatively small and high-grade. They constitute a low potential but small quantities of ore will be produced from them from time to time. The main producers are in the Lardeau district southeast of Revelstoke, the Spider mine at Camborne has had the greatest production and has been the only significant producer in recent years (1952-1958).

It is very difficult to estimate the potential lead-zinc content of the vein deposits in the area. There are many veins and very few reliable estimates of reserves. The True Fissure near Ferguson is reported to have reserves of 60,000 tons of ore grading: Gold, 0.044 ounce per ton; silver, 6.9 ounces per ton; lead, 6.0 per cent; and zinc, 6.7 per cent (Columbia Metals Corporation report, March, 1969). Stannex Minerals Limited claims ore reserves of 340,000 tons of unspecified grade at the Snowflake, Woolsey, and Regal silver properties northeast of Revelstoke (George Cross Newsletter, April 12, 1969). No other property is known to have a measurable tonnage of reserves.

It seems reasonable to conclude that in the forseeable future the vein deposits will produce at least as much ore as they have in the past, which amounts to about 290,000 tons.

MOLYBDENUM DEPOSITS

A molybdenite deposit discovered in 1964, 12 miles northwest of Revelstoke, now known as the Knox property, is associated with syenite gneiss and is a type of occurrence not found elsewhere in British Columbia. Although ore reserves have not been published, the orebody currently being developed for production by King Resources Company probably contains a few hundred thousand tons of ore grading 2 to 3 per cent molybdenite. This is a relatively small high-grade deposit in contrast to the large low-grade deposits being mined elsewhere in the Province. The deposit is currently being prepared for mining.

Prospecting for molybdenite associated with syenite in metamorphic rocks northwest of Revelstoke is continuing and it is not possible to predict the outcome. Bodies of syenite and associated molybdenite were found west of the Perry River in 1968. Syenite probably is more extensive than indicated on recent geological maps and little prospecting for molybdenite has been done around bodies of syenite near Kinbasket Lake.

SUMMARY AND CONCLUSIONS

(1) In comparison with British Columbia in general, the Revelstoke area has a medium to high potential for metallic mineral production.

(2) Most of the potential is for lead, zinc, and silver with associated minor amounts of

copper, cadmium, gold, and tin. Small but significant bodies of molybdenite have recently been found.

(3) Total production from the area has amounted to 2,160,530 tons of ore: Gross contents--Gold, 38,282 ounces; silver, 5,510,084 ounces; copper, 1,651,567 pounds; lead, 200,530,232 pounds; zinc, 196,188,731 pounds; cadmium, 194,984 pounds. There is no production in the area at present although three properties are expected to come into production in the near future.

(4) It is estimated that 3 million to 5 million dollars has been spent on exploration in the area since 1960.

(5) The greatest production and potential for lead and zinc is in replacement deposits in carbonate rocks (Type a) and in layers of sulphides in metamorphic rocks (Type b). None of these deposits is being mined at present.

(6) The known reserves of lead, zinc, and silver are estimated to have a total value of 400 million dollars at 1968 prices. The potential for additional discoveries is high, but it is not likely that the large low-grade deposits will be mined in the near future.

(7) The Knox molybdenite deposit probably has a gross value of more than 5 million dollars estimated at 1968 prices.

(8) The potential for molybdenum is unknown but probably low in comparison to the rest of British Columbia.

NON-METALLIC MINERALS

In any area the production and use of most non-metallic minerals depends on the population and industrial development of the area. With the small population of British Columbia in general, and of the Revelstoke area in particular, these materials are not used to nearly the same extent as in more populous regions. However, as our population increases, the demand for more quantities and varieties of non-metallics will rise. For this reason, some materials, for which there is no present demand, will be mentioned because of the possibility of future markets for them. On the whole, however, the non-metallic possibilities for the Revelstoke region must be rated low.

At the present time the only operating non-metallic properties in the area are local gravel pits and two small barite producers at Parson and Spillimacheen. In the past, small trial shipments of silica were made from deposits at Quartzite Point on Shuswap Lake and Moberly Peak near Golden, a few hundred tons of agricultural lime was produced from a tufa deposit at Solsqua, a small shipment of marble chips was made from Sidmouth, and more than 1 1/4 million tons of gypsum was quarried at Falkland.

Adequate supplies of gravel for forseeable requirements appear assured.

Mountain Minerals Limited mines high-grade white barite from 2 veins on a property 6 miles southwest of Parson. Since the mine opened in 1941, about 74,000 tons has been produced. Reserves are small, probably less than 10,000 tons being recoverable.

Baroid of Canada separates barite from the old tailings pond of the former Silver Giant lead-zinc mine 7 miles northwest of Spillimacheen. Since production began in 1959, about 65,000 tons of barite has been recovered. Some lenses of barite still remain in the veins of the old mine. Total reserves in the tailings and veins may be between 50 and 100 thousand tons, depending on the grade required.

The gypsum quarry at Falkland closed down because of the exhaustion of ore suitable for building products. Considerable quantities of low-grade gypsum and anhydrite remain in the deposit should there develop any demand for these for agricultural use or as a source of sulphur.

On Mount Moberly, Mountain Minerals Limited has opened a quarry and removed trial shipments of silica from a large deposit of friable quartzite that averages 98.5 per cent SiO_2. Although not workable now it is a potential source of silica.

A large band of glassy white quartzite suitable for granules and flux outcrops on the shore of Shuswap Lake and up the hillside at Quartzite Point. This, though not economic now, has potential value.

Clay suitable for common brick and tile occurs on the Pillar Lake road 10 miles north of Falkland. This might be used in the future.

Kyanite used in ceramics, occurs in many places in the rocks north of Revelstoke. Known occurrences are too low-grade to be mined now but changing conditions and new discoveries might allow future development.

Similarly, deposits of nepheline syenite, another ceramic raw material, are known on Mount Copeland, Trident Mountain, and near Sullivan River. These might be used in the future.

A relatively small, low-grade asbestos deposit near Sidmouth might sometime be developed to produce asbestos cement fibre.

May/69 J. T. Fyles & J. W. McCammon

FIGURE I

Map of the Revelstoke area showing: Metallic mineral potential (based on metal content and anticipated production).

✖ Significant past producers.
✕ Significant potential non-producers.

Title Mineral Industry of the Central Kootenay Region

Author James T. Fyles

Date and Typist November 10, 1969 bl

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CENTRAL KOOTENAY REGION

MINERAL INDUSTRY

BY JAMES T. FYLES

Present Situation

Jersey Mine

Reeves MacDonald Mine

H.B. Mine

Bluebell Mine

Potential

Lead, Zinc and Silver

Tungsten

Molybdenum

Gold

Copper

Conclusion

Structural Materials and Industrial Minerals

Economic Impact

Concluding Comments

CENTRAL KOOTENAY REGION

MINERAL INDUSTRY

BY JAMES T. FYLES

Present Situation

The Central Kootenay Region, numerically, has the highest concentration of mines of any area of the Province, and has had a glorious mining history. Economically, exploration and mining provided the impetus for original settlement, and for many years, almost the entire economic base.

Mineral production remained at a fairly consistent level during the early 1960's but with the closing of the H.B. mine in 1966, a drop in production was recorded. The following table outlines lode metal production in the Region for the 1960's.

LODE METAL PRODUCTION

Year	Ore Shipped or Treated: Large Mines*	Others (tons)	Total	Value $	% of Provincial Lode Metal Total Value
1968	1,067,028	27,479	1,094,507	19,476,533	4.8
1967	1,153,347	16,054	1,169,401	16,213,210	6.2
1966	1,448,563	33,700	1,482,263	25,780,920	12.3
1965	1,458,250	57,424	1,515,674	28,652,024	16.3
1964	1,540,002	31,768	1,571,770	26,029,778	14.4
1963	1,245,032	10,927	1,255,959	20,495,807	11.3
1962	1,509,063	20,038	1,529,101	20,644,201	13.0
1961	1,520,092	19,662	1,539,754	22,552,602	17.6

* 1967 and 1968 Bluebell, Jersey, Reeves MacDonald, 1961 - 66 includes H.B.

Source: Department of Mines and Petroleum Resources.

By value of production, zinc was the leading metal mined in the Region in 1968, accounting for approximately 57 per cent of the total. Lead comprised about 29 per cent, with the remainder made up of cadmium, silver, and lode gold. Appendix Number 6 shows quantities and values of each metal produced in the Central Kootenays during the last several years and shows the producing mines in 1968. The accompanying map shows the location of the largest mines and the principal mining camps in the Region.

A total of 22 mines operated during 1968 with the three larger ones accounting for 97 per cent of ore shipped or treated. Each of these mines and the H.B. will be considered in turn.

Jersey Mine (Canadian Exploration Ltd.)

The lead-zinc orebodies at the Jersey mine are low grade disseminated deposits in limestone. They consist of 8 to 10 coalescing lenses of sulphides with a low dip and a low plunge that are mined by trackless equipment in roadways and open stopes. Total production to 1968 has amounted to 7,258,700 tons with an average grade of 0.09 ounces per ton silver, 1.75 per cent lead, 3.75 per cent zinc, and 0.28 per cent cadmium.

In spite of extensive exploration from time to time in the mine area and the nearby district, reserves have declined and no new large orebodies have been found. Current production is from pillars, remnants and relatively small extensions of the known orebodies. During 1968 and 1969 the average grade has declined and production of ore has been increased to maintain the amount of concentrates, which are shipped to the Bunker Hill Smelter at Kellogg, Idaho. The closing of the Jersey mine can be expected in the next few years unless new orebodies are discovered.

Reeves MacDonald Mine (Reeves MacDonald Mines Limited)

Orebodies of the Reeves MacDonald mine form a steeply plunging trough-shaped lens of sulphides in limestone. The main or Reeves orebody has been mined by a system of levels, shafts and open stopes from the surface at an elevation of 2,700 feet almost to sea level. Faulted repetitions of the upper part of the orebody have been mined as separate zones. A total of 6,112,552 tons of ore has been produced up to 1968 with an average grade of 0.095 ounces per ton silver, 0.97 per cent lead, 3.43 per cent zinc, and 0.20 per cent cadmium. The ore also contains minor amounts of copper.

The upper levels are now virtually mined out and recent production has been from the lowest parts of the Reeves orebody. Recently more selective mining has been used to increase the grade. Several mineralized zones are known which have not been mined. In 1966 exploration on the south side of the Pend d'Oreille River across from the Reeves MacDonald mine was accelerated and an orebody has been developed, the mining of which is expected to begin late in 1969. This mine, known as the Annex, will probably replace the Reeves MacDonald.

The operation of the mine is controlled by companies in the United States directly or indirectly associated with the Bunker Hill Smelter at Kellogg, Idaho, which receives the concentrates.

H.B. Mine (Cominco Ltd.)

Orebodies at the H.B., like those at the Jersey and Reeves MacDonald are large lenses of disseminated sulphides in limestone. Most of the lenses have a steep dip and a low plunge. Ore was mined underground by a series of levels, raises and open stopes. Long hole vertical ring drilling of the largest orebody resulted in low cost mining. Production has totalled 5,246,712 tons of ore with an average grade of 0.15 ounce per ton silver, 0.86 per cent lead, 4.33 per cent zinc and 0.36 per cent cadmium.

The mine was closed in 1966 because of company policy and will be reopened. Significant reserves are developed for mining and recent exploration in the mine area has discovered interesting new mineralized zones.

Bluebell Mine (Cominco Ltd.)

Orebodies at the Bluebell mine in contrast to those in the Salmo district are relatively massive sulphides in limestone. They occur as large pods, extending laterally from a set of fractures which transect the limestone almost at right angles. Total production to 1968 has amounted to 4,582,451 tons with an average grade of 1.36 ounces per ton silver, 4.85 per cent lead, 5.17 per cent zinc, and 0.24 per cent cadmium. In addition, the ore contains minor amounts of copper.

The mine is on Riondel Peninsula on the east shore of Kootenay Lake. The mineralized limestone dips 35 degrees to the west and consequently, in depth to the west as well as to the north and south, it passes beneath the lake. This situation has set practical limits for mining and reserves of available ore are diminishing.

Potential

In spite of extensive mining in the past 90 years, the Central Kootenay Region contains large quantities of lead, zinc and silver, and smaller quantities of tungsten, gold, molybdenum and copper. The main centers of production include the Slocan, extending from near Retallack to Slocan City, the Bluebell-Ainsworth camp, the Nelson-Ymir gold camp, the Sheep Creek gold camp and the Salmo lead-zinc belt. The south Lardeau from which there has been little production, has significant potential. Some of these districts with characteristic mineralization overlap into others and a few important occurrences are away from the main centers of mineralization.

The Central Kootenay Region, which contains hundreds of occurrences of valuable metallic minerals, has been actively explored for almost a century. Prospecting, surface and underground work, and diamond drilling have been done on most of the showings, and ore has been shipped from many of them. The regional geology is well known and the detailed geology of several camps has been studied by the Provincial and Federal geological surveys and by companies, notably by Cominco Ltd. Geophysics and geochemistry are being used more widely in exploration, and more sophisticated studies of this sort will become important in the future.

As a result of exploration several important mineralized zones are known within the Region and others are continually being found. The discovery of large new orebodies in the old camps requires an understanding of the old work, the application of advanced scientific knowledge and the expenditure of large sums of money on projects in which the outcome can rarely be anticipated with certainty. On the other hand, small orebodies will continue to be mined as they are discovered, largely by the guidance and ingenuity of local people.

Future trends in mining in the Central Kootenay Region are difficult to predict because of the large numbers of mineralized zones in the area, and because of the general uncertainty of economic factors. The following analysis, based on personal knowledge, emphasizes geological potential, which is a measure of the amount of material available. It must be viewed in the light of changing economics, technology, and changing policies of companies and governments.

Lead, Zinc and Silver

These metals are the most important within the Region. Significant reserves are known and considerable ground is favourable for exploration. Deposits like the Reeves, H.B., and Jersey, known as the Salmo type which are of low grade in lead and zinc and contain very little silver, constitute the largest reserves and geological potential. Newly discovered orebodies at the Reeves MacDonald are being mined and it is expected that comparable orebodies will be discovered nearby.

Orebodies at the H.B. contain significant reserves which may be increased by exploratory drilling. At the Jack Pot property, 7 miles north of the H.B. and owned by New Jersey Zinc Exploration Company (Canada) Ltd., 1 million to 2 million tons of sub economic zinc ore with small amounts of lead has been outlined by extensive drilling and underground work. In the South Lardeau a Salmo type of deposit at the Duncan mine on Duncan Lake, owned by Cominco Ltd., contains several million tons of zinc-lead ore with grades comparable to those at the H.B. Twenty miles northwest of Duncan Lake, on the Bannockburn prospect is a large mineralized zone of low grade lead and zinc, somewhat similar to the Salmo type which has not been extensively explored and is too inaccessible for mining at present. Between these properties, particularly between the Bannockburn and the northern end of Kootenay Lake and between the Jack Pot and the entrance to the west arm of Kootenay Lake, are many showings indicating geologically favourable ground for prospecting for the Salmo type of deposit.

The Region also contains in its northwesternmost corner a very large low grade zinc-lead deposit known as the Big Ledge owned by Cominco Ltd. Several million tons of sub economic mineralization has been delimited by extensive drilling.

Exploration for the Bluebell type of relatively high grade replacement deposit has not been successful. In the Ainsworth camp on the west side of Kootenay Lake, Cominco Ltd. carried out extensive exploration between 1953 and 1957 on the Lakeshore property and nearby area. Widespread mineralization of the

Bluebell type was discovered but the mineralized zones were not economic. On the eastern side of the lake exploration around the Bluebell mine has not been encouraging and surveys by the company show that the lake itself is too deep for practical exploration or mining beneath it.

The Slocan camp characteristically contains many veins and fissure lodes with relatively small lead-zinc orebodies rich in silver. They have been mined intermittently by individuals and small companies. This type of production is continuing and is stimulated by the currently high price of silver, and it is possible that orebodies capable of supporting a more continuous sort of operation will be discovered as a result of this work. An extensive exploration programme by Silmonac Mines Limited near Sandon, begun in 1964, has recently had some success, but it is too soon to predict what size orebody has been found.

Tungsten

The Emerald and associated tungsten mines near the Jersey, south of Salmo, produced 13,739,939 pounds of tungsten (WO_3) concentrates between 1944 and 1958 from about 1 million tons of ore. They were closed by Canadian Exploration, Ltd. when contracts for the sale of the concentrates to the United States were terminated. Tungsten mineralization continues as direct extensions of the mined orebodies, both to the south and to the north. The northern extension on the Invincible claim is reported to have reserves of 300,000 tons grading 0.7 per cent tungstic oxide. Other tungsten deposits are present nearby on the Canadian Exploration property, and similar deposits occur a few miles to the northeast. Tungsten mineralization of various types has been found at a number of other localities in the area.

Molybdenum

Many showings of molybdenite are known throughout the Region but none has been of economic value. The known potential is not great, but the area is geologically favourable for exploration.

Gold

The Sheep Creek camp has produced 1,763,000 tons of ore, gross contents 739,000 ounces of gold and 372,000 ounces of silver, but very little mining has been done since 1951. The Nelson-Ymir area has produced 1,783,000 tons of ore, gross contents 529,000 ounces gold, 6,540,000 ounces silver, and recent production has been very small. In addition, small amounts of lead, zinc and copper have been produced from these gold camps. Little or no systematic exploration for gold has been carried on for 20 to 30 years and the potential is unknown.

Copper

The largest amounts of copper produced in the Region include about 15 million pounds from the Silver King mine near Nelson, 1.5 million pounds from the Queen Victoria south of Nelson, and 5 million pounds as a byproduct of lead-zinc production at the Bluebell. Production from the Queen Victoria and Silver King was of direct shipping ore, mainly during and prior to World War I. The mines are thought to be exhausted, but the Silver King mine area may have significant potential. Production figures for the Silver King indicate an average grade of 3.36 per cent copper and almost 20 ounces per ton silver. The general copper potential of the Region, however, is probably small in relati‹˙ to production from other parts of the Province.

Conclusion

Experience in the Kootenays has shown that exploration and production are very sensitive to changes in metal prices. Operations at the H.B. and Reeves MacDonald, because these are relatively high cost operations, were suspended from 1953 to 1955 when the price and demand for lead and zinc was relatively low. High prices for silver in the last few years have stimulated exploration and mining in the Slocan. A rise in the price of lead or zinc, tungsten, or gold would significantly change the present pattern of exploration and production.

Structural Materials and Industrial Minerals

The value of production of structural materials and industrial minerals in the Central Kootenay Region over the last few years is shown in the following table.

Title Mineral Industry

Author James T. Fyles

Date and Typist November 12, 1969 bl 11

PRODUCTION OF STRUCTURAL MATERIALS AND INDUSTRIAL MINERALS IN THE REGION

Year	Industrial Minerals $	Structural Materials $
1968	197,831	748,465
1967	nil	511,681
1966	118,368	513,155
1965	127,459	139,395
1964	76,956	384,377
1963	81,438	275,707
1962	17,512	310,201
1961	nil	245,650

Production has not been large because the demand for these products has never been great in the Region.

Quarries are situated at Crawford Bay and Sirdar, on Kootenay Lake, and at Sheep Creek, near Salmo. The main products are dolomite chips, limestone grit, quartzite and granite. Local markets demand some of the production and one company is selling in Alberta. Several sand and gravel pits are located in the Region and produce to meet local demand.

Quartz deposits on Mount Nelson, 3 miles northwest of Nelson, and on the west side of the north fork of Winlaw Creek, 4 miles east of Winlaw, have been examined as possible sources of silica. Production from these has not proved economically feasible under present conditions. Large quantities of limestone of variable purities are known in the areas around the north arm of Kootenay Lake and around Salmo. Some marble was quarried in the former Region, but at present no limestone of any type is produced.

ECONOMIC IMPACT

The economic impact of the mineral industry in the Central Kootenay Region is probably best indicated by employment and earnings. Currently, the Region's three large mines employ, in total, about 572 persons, with per employee weekly wages and salaries in the industry averaging approximately $196.00. The number of persons employed in smaller operations is estimated to be about 100, but much of this work is highly seasonal or part-time; wage rates, however, are estimated to be similar. Probably about 25 to 30 persons were employed in the production of industrial minerals and structural materials. In addition, there are an estimated 200 persons who are employed at Cominco's operations at Trail but reside within the Region, and therefore, should be included when attempting to measure total economic impact. The following table outlines the direct employment at mines in the Region for the last several years.

EMPLOYMENT OF REPORTING MINES

Year	Number of Mines Reporting	Total	Mine	Mill	Office, Administration and Others
1968	3	572	406	41	125
1967	3	604	438	47	119
1966	6	803	588	66	149
1965	6	815	599	70	146
1964	4	846	616	62	168
1963	4	688	512	52	124
1962	5	758	567	57	134
1961	4	826	616	64	146

Source: Department of Mines and Petroleum Resources.

Exploration consisting of bulldozer work, diamond drilling, underground work and technical surveys employs a number of men each year, mainly between March and November. This work has a small but significant impact on the economy of the Region, which it is not possible to assess quantitatively.

In 1968, it is estimated that wages and salaries paid to residents of the Central Kootenay Region, whether or not they were employed within the Region, were in the neighbourhood of $5.5 million. This figure is roughly half that of renumeration paid for employment by the forest industry.

Riondel, Remac and the Jersey Townsite are communities which rely entirely upon mining for their existence. Salmo depends on it to a large degree and the closing of the H.B. mine was severely felt there. The Slocan area depends to a small extent on mining activity. The city of Nelson, and to a smaller degree, Trail, rely upon the region's mining income to sustain commerce. Many Cominco Smelter employees reside in the Castlegar-Kinnaird area and this source of income is most important to these centres.

The closing of the H.B. mine in 1966 reduced the mineral production of the Region and restricted the economic well-being of the Salmo district. Over 100 persons had been employed at the mine and the cessation of activity reduced total annual mining payroll by more than $850,000. Resulting repercussions included the cancellation of plans for a new shopping centre in Salmo and a reduction in trade enjoyed by local retail and service establishments. The city of Nelson also felt the loss of part of this payroll.

The portion of the economic base attributible to activity in the mineral industry has been somewhat reduced during the last several years but mining is, and will continue to be, a critical sector of the Region's economy.

CONCLUDING COMMENTS

The Central Kootenay Region has been one of the most important areas of the Province for the production of silver, lead, zinc, tungsten and gold. Although reserves of lead-zinc ore at the three largest mines in the area are low, the Region has a high potential and significant reserves have been more or less well defined. Silver is being produced from small mines in the Slocan and exploration stimulated by the current silver prices may lead to the discovery of new orebodies. The area contains deposits of tungsten, molybdenum, gold, and copper, most of which are not being mined but which have some potential. In the last decade, the area has lost some of its importance in relation to the rest of the Province, partly because of the declining interest in lead and zinc, but mainly because of the development of the copper, molybdenum, and iron resources in other parts of the Province. The mineral industry in the Central Kootenay Region, however, will continue to be of major economic importance.

APPENDIX NUMBER 6

MINERAL INDUSTRY STATISTICS
Metal Production in the Central Kootenay Region

	Zinc		Lead		Cadmium		Silver		Lode Gold	
	Quantity lb.	Value $	Quantity lb.	Value $	Quantity lb.	Value $	Quantity oz.	Value $	Quantity oz.	Value $
1968	76,313,185	11,100,516	39,409,921	5,577,686	409,900	1,168,215	673,860	1,556,956	1,940	73,160
1967	61,711,829	9,215,428	34,996,997	5,285,247	309,324	866,107	474,511	792,960	1,416	53,468
1966	103,735,430	16,205,548	44,558,161	7,255,406	547,025	1,411,324	620,402	864,220	1,178	44,422
1965	113,134,424	17,689,699	47,801,471	8,244,320	599,160	1,665,665	726,325	1,012,308	1,061	40,032
1964	110,710,429	16,346,587	45,937,101	6,735,297	606,706	1,965,727	675,933	942,643	1,047	39,524
1963	98,967,104	13,036,936	44,528,503	5,348,764	541,003	1,298,407	554,655	765,230	1,231	46,470
1962	107,685,842	13,376,736	52,497,110	5,407,728	613,476	1,128,796	596,982	692,674	1,023	38,267
1961	119,300,447	13,952,187	62,681,701	6,901,882	672,818	1,076,509	636,066	595,968	698	24,751

Source: Department of Mines and Petroleum Resources.

Producing Mines in 1968

Property or Mine	Location	Ore Shipped or Treated	Product Shipped
Howard	Ymir	32 tons	Crude ore
Jersey Mine	Salmo, Iron Mtn.	506,220 tons	Lead concentrates, 8,407 tons; zinc concentrates, 31,910 tons
New Arlington	Salmo, Erie Creek	5,722 tons	Crude ore
Reeves MacDonald Mine	Nelway	309,311 tons	Lead concentrates, 5,130 tons; zinc concentrates, 19,127 tons
Silver Dollar	Salmo, Erie Creek	4,093 tons	Crude ore
Antoine	McGuigan Creek	6,670 tons	Lead concentrates, 241 tons; zinc concentrates 359 tons
Arlington	Springer Creek	836 tons	Crude ore
Bluebell Mine	Riondell	251,497 tons	Lead concentrates, 14,983 tons; zinc concentrates, 26,839 tons
Crown	Ainsworth	30 tons	Crude ore
Enterprise	Slocan	60 tons	Crude ore
Freddy	Silverton	63 tons	Crude ore
Homestake	Slocan	45 tons	Crude ore
Joyce	Silverton	76 tons	Siliceous ore
Little Tim	Slocan	21 tons	Crude ore

Moonshine	Lardeau	169 tons	Crude ore
Ottawa Mine	Springer Creek	4,415 tons	Crude ore
Silver Hoard	Ainsworth	99 tons	Crude ore
Slocan Sovereign	Sandon	30 tons	Crude ore
Standard	Silverton	4,905 tons	Lead concentrates, 80 tons; zinc concentrates, 203 tons
Victor	Sandon	38 tons	Crude ore
Washington	New Denver	171 tons	Lead concentrates, 17 tons; zinc concentrates, 40 tons; crude ore, 8 tons
Westmont	Slocan	24 tons	Crude ore

STRATIGRAPHIC AND STRUCTURAL SETTING OF STRATABOUND
LEAD-ZINC DEPOSITS IN SOUTHEASTERN B.C.

Trygve Höy

B.C. Ministry of Energy, Mines and Petroleum Resources
Victoria, British Columbia V8V 1X4

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The Shuswap Metamorphic Complex forms the core of the Columbian orogen and comprises a belt of high-grade metamorphic rocks that lie immediately west of the Kootenay Arc. Its eastern boundary is marked by a series of gneiss "domes" spaced approximately 80 km apart that expose crystalline Aphebian basement in their cores. A number of syn- and post-tectonic batholiths intrude the metasediments of the Shuswap Complex.

Stratabound base metal deposits in southeastern B.C. are hosted by rocks that range in age from Proterozoic to Devonian. Proterozoic deposits include the clastic-hosted Sullivan deposit, in siltstone and turbidite wacke beds of the Helekian Purcell Supergroup in the Purcell anticlinorium, and carbonate-replacement deposits in overlying platform carbonates of the Purcell Supergroup. An extensive Lower Cambrian platformal carbonate, the Badshot Formation, hosts a number of intensely deformed lead-zinc deposits in the Kootenay Arc. They are interpreted to be analagous to Mississippi Valley type deposits, formed in a stratigraphic trap near the western edge of the Lower Cambrian platform. Middle Cambrian deposits are in stratigraphic traps in shoal carbonate complexes adjacent to shale basins. Deposits in Devonian rocks are uncommon, probably because Devonian exposures generally represent platformal carbonates well removed from the platform edge. Middle Cambrian deposits occur in the eastern edge of the Purcell anticlinorium and in the Rocky Mountain fold and thrust belt, and Devonian occurrences are restricted to the Rocky Mountains.

This paper is a summary of the type and distribution of stratabound deposits in southeastern B.C. It reviews a number of examples of each type and attempts to outline their local stratigraphic and structural settings. It is evident that regional paleogeography played an important role in controlling the distribution of most deposits in southeastern B.C. Hence, an interpretation of the paleogeography and depositional environment of host sediments as well as their relationship to paleotectonic elements, is emphasized in the paper.

This paper is essentially an un-edited, first draft of a paper that will be prepared for submission to CIM Bulletin. References are not complete; only the most recent references are generally used.

PROTEROZOIC PURCELL SUPERGROUP

A number of important stratabound lead-zinc deposits occur in the Proterozoic Purcell Supergroup. These include the clastic-hosted Sullivan mine, and the Kootenay King, North Star, Stemwinder and Vulcan "deposits" (Figure 2). Replacement deposits in Purcell platformal carbonates include the Mineral King and Paradise deposits.

STRATIGRAPHIC AND STRUCTURAL SETTING

Purcell rocks are exposed in three tectonically distinct areas in southeastern British Columbia and southwestern Alberta. From east to west, these are the Clark Range within the Lewis thrust sheet, the Hughes, Lizard and Galton Ranges on the east side of the Rocky Mountain Trench, and the Purcell Mountains within the Purcell anticlinorium

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INTRODUCTION

Southeastern British Columbia comprises a number of discrete and generally separate tectonic belts, each with a unique structural style and a distinctive stratigraphic succession.

The Purcell Anticlinorium (Figure 1) is a broad north-plunging structure in Helikian and Hadrynian age rocks between the Foreland Thrust and Fold Belt to the east and the Kootenay Arc to the west. It is transected by a number of steep longitudinal and transverse faults. The transverse faults appear to have been active intermittently since at least Hadrynian time and played an important role in controlling the type, distribution and thickness of late Proterozoic to early Paleozoic sediments (Lis and Price, 1976).

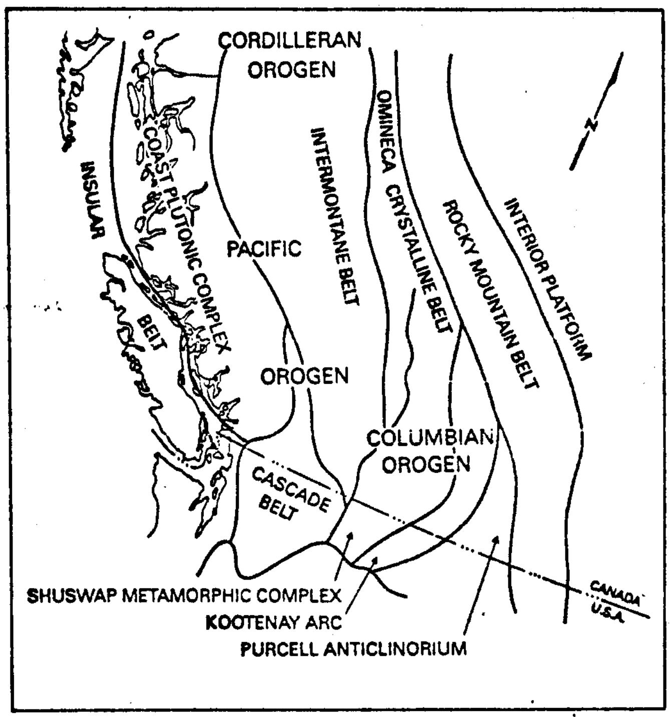


Figure 1: Regional tectonic map.

The Kootenay Arc, a generally north-trending arcuate structural zone developed in a succession of rocks ranging in age from Hadrynian to early Mesozoic, is west of and merges with the Purcell Anticlinorium. In general, the earliest recognized structures in the Arc are tight to isoclinal, north-trending recumbent folds. In the northern Kootenay Arc, the Lardeau area, there is some evidence that these structures may have developed during the Devono-Mississippian Caribooan orogeny (Read, 1976, 1976).

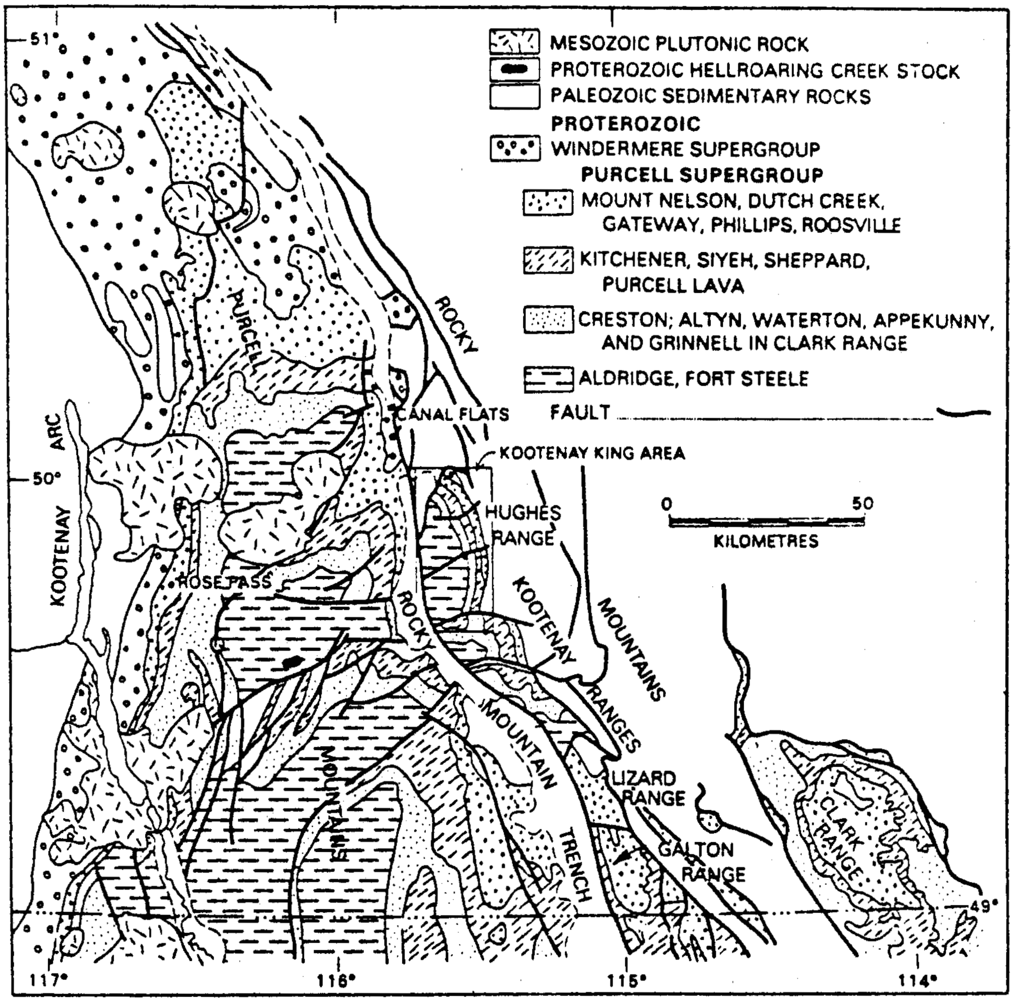


Figure 3: Geology map showing distribution of Purcell Supergroup.

McMechan (1979) and Hoy (1979a). The Kootenay King deposit is a laminated stratiform Pb-Zn deposit in siltstone correlative with Middle Aldridge turbidites to the south and west. The Aldridge is underlain by coarse fluvial sands of the Fort Steele Formation and includes, in its central part, a succession of turbidite wacke beds. It is overlain by dominantly shallow-water tidal flat, flood plain and deltaic deposits of the Creston Formation and a carbonate plaformal succession, the Kitchener-Siyeh Formation (Figure 4). Andesitic volcanic rocks overlie the Kitchener-Siyeh east of the trench and along the southeast margin of the Purcell anticlinorium. They in turn are overlain by shallow-water clastic shelf deposits of the Gateway, Phillips and Roosville Formations.

The oldest Purcell rocks, exposed in the Purcell anticlinorium to the west, are rusty-weathering siltstone and quarzite of the Lower Aldridge Formation (Figure 4). They are overlain by about 3000 metres of arenaceous quartzite turbidite beds and interbedded siltstone of the

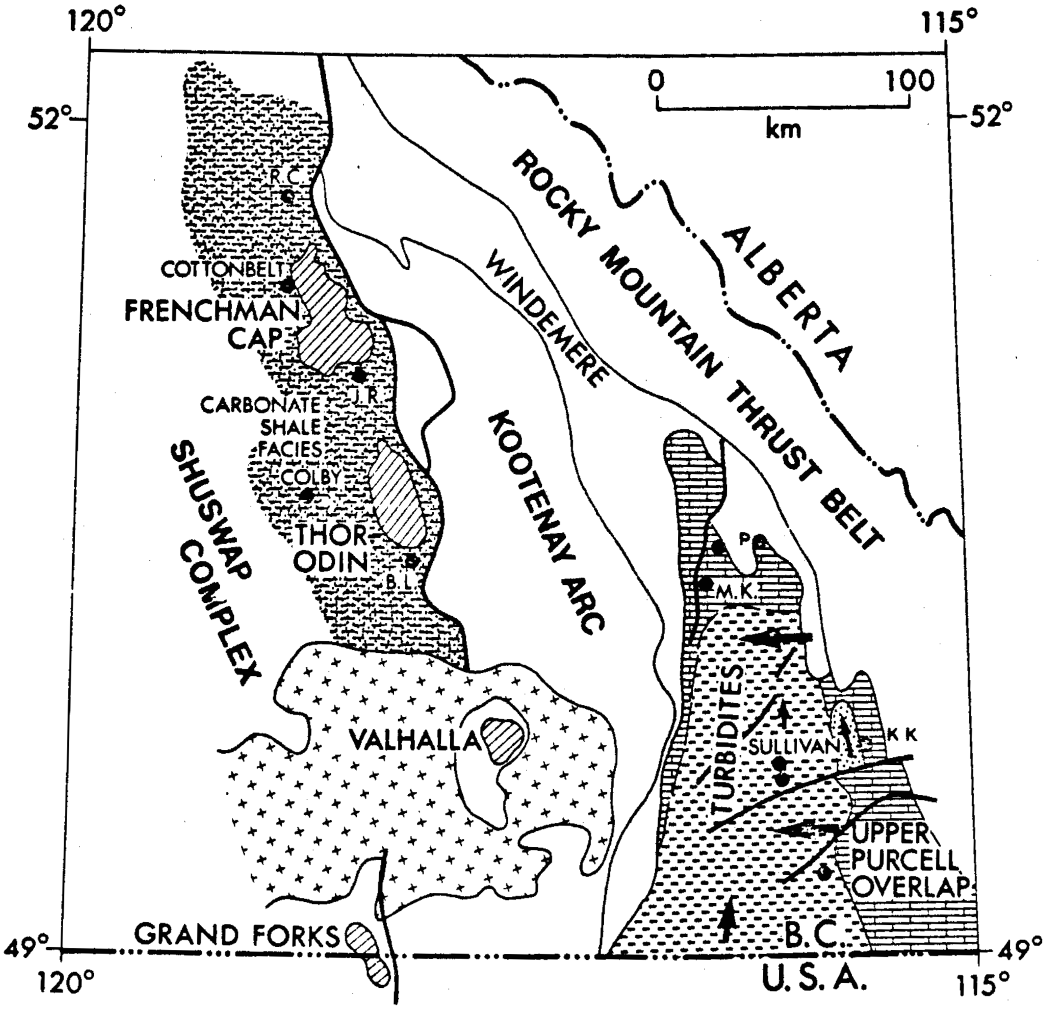


Figure 2: Distribution of Purcell Supergroup and Shuswap Metamorphic Complex and location of mineral deposits. R.C. - Ruddock Creek, J.R. - River Jordan, B.L. - Big Ledge, M.K. - Mineral King, K.K. - Kootenay King, P. - Paradise; large arrows indicate onlap of upper Purcell platformal carbonates and clastics; small northerly-directed arrows indicate sediment transport direction.

(Figure 3). In the Clark Range, arenaceous and carbonate facies are relatively more important and formations are thinner and lithologically diverse (Price, 1964). Coarse-grained fluvial and shallow-water sediments host a number of widespread, low-grade stratabound copper occurrences in the Clark Range. These are described by Morton et al. (1973) and Collins and Smith (1977) and will not be discussed further in this paper. In the Purcell Mountains, formations are thicker and rocks somewhat more argillaceous, whereas rocks just east of the trench are transitional between the area to the west and the Clark Range to the southeast. Purcell rocks east of the Rocky Mountain Trench have been described by Rice (1937), Leech (1958 and 1960), Price (1962 and 1964),

PURCELL MOUNTAINS	HUGHES–LIZARD–GALTON RANGES	CLARK RANGE
PURCELL SUPERGROUP Mount Nelson		
Dutch Creek	Roosville Phillips Gateway	Roosville Phillips Gateway Sheppard
Kitchener-Siyeh	Purcell lava Kitchener-Siyeh	Purcell lava Siyeh
Creston	Creston	Grinnell Appekunny
Aldridge	Aldridge Fort Steele	Altyn Waterton (Lewis thrust)
(base not exposed)	(base not exposed)	

Figure 4: Correlation of Purcell Supergroup (after Leech, 1960; Price, 1964; and Edmunds, personal communication, 1976).

Middle Aldridge, and 300-400 metres of thin-bedded rusty-weathering argillite and siltstone of the Upper Aldridge Formation. The overlying Creston Formation consists generally of shallow-water argillaceous quartzite, siltstone and argillite and is overlain by carbonate of the Kitchener-Siyeh "Formation". Argillite, dolomite and quartzite of the overlying Dutch Creek Formation (Figure 4), gives way upwards to dolomite and dolomitic limestone of the Mount Nelson Formation, host of the Mineral King and Paradise deposits.

In summary, Fort Steele fluvial sandstones in the Kootenay King area are supplanted to the west by deep-water siltstone and occasional turbidite beds of the Lower Aldridge in the Purcell Mountains. Middle Aldridge time is marked by the introduction of extensive and thick accumulations of turbidite deposits. Locally, intraformational conglomerate, boron alteration zones, and sulphide accumulations developed. The basin of turbidite deposition expanded and, during Middle Aldridge time, overlapped inner fan deposits in the Kootenay King area. Post Aldridge rocks record deposition in an extensive, generally shallow-water marine, platform environment.

CLASTIC-HOSTED DEPOSITS

Clastic-hosted stratabound Pb-Zn deposits are restricted to Lower and Middle Aldridge sediments. The Sullivan deposit and the Vulcan occurrence, a thin stratiform pyrrhotite laminated zone containing minor lead and zinc (Gifford, 1971), occur at the Lower-Middle Aldridge boundary. North Star and Stemwinder deposits, just south of Sullivan, are in Lower Aldridge siltstone, and the Kootenay King deposit is in Middle Aldridge siltstone.

Sullivan

The Sullivan, described recently by Ransom (1977) and Hamilton et al. (in press), is one of the largest base metal deposits in the world. It has produced in excess of 100 million tonnes of ore and has reserves of approximately 50 million tons grading 4.5% Pb, 5.9% Zn and 37 g/tonne silver.

The orebody is approximately 2000 metres in width and 100 metres in thickness. Its western part (see section, Figure 5) comprises "massive pyrrhotite containing occasional wispy layers of galena" overlain by layered pyrrhotite, sphalerite, galena, and pyrite, all intercalated with clastic beds. Its eastern part, separated from the more massive western part by an irregular transition zone, includes five distinct conformable layers of generally well-laminated sulphides separated by clastic rocks. The sulphide layers thin to the east away from the transition zone and are replaced at the limits of the ore deposit by iron sulphide bands.

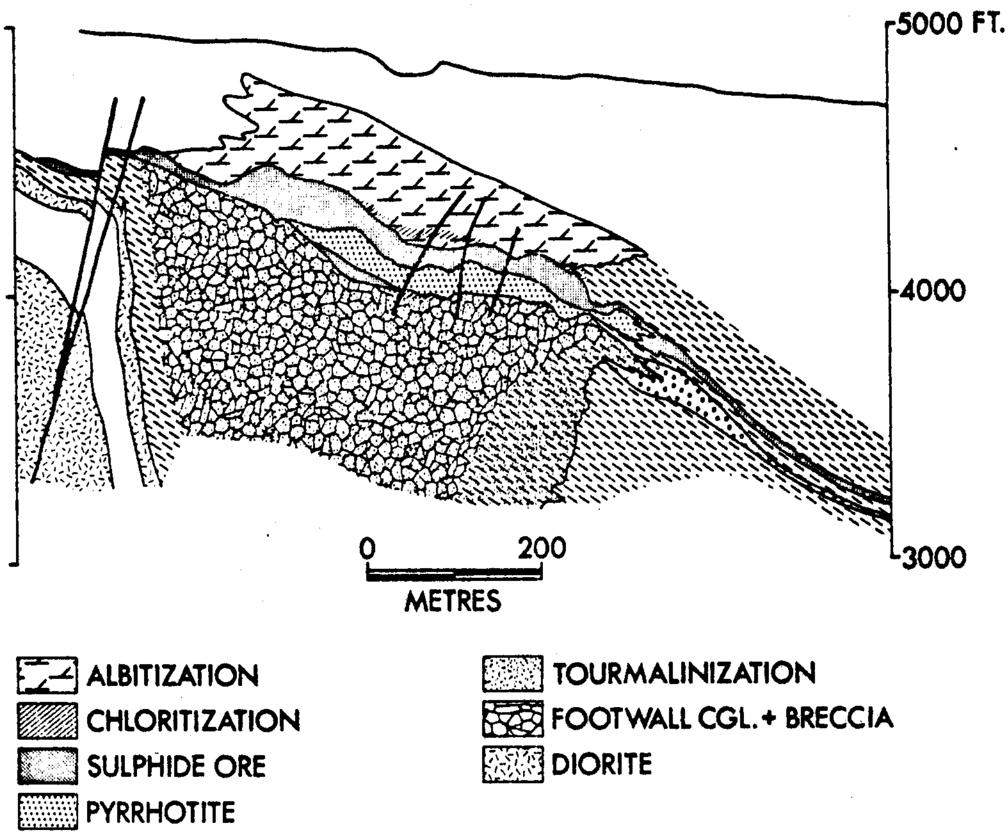


Figure 5: Cross-section of the Sullivan deposit (simplified from Ransom, 1977; Hamilton et al., in press).

An extensive brecciated and altered zone underlies the massive western part of the orebody. Linear, north-trending breccia zones, disseminated and vein sulphides, and extensive alteration to a dark, dense chert-like tourmaline-rich rock are conspicuous features of the altered footwall. Albite-chlorite-pyrite alteration is also restricted to the western part of the orebody, occurring in cross-cutting zones in the footwall tourmalinite, in the orebody itself, and up to 100 metres above the orebody in the hanging wall (Hamilton et al., in press).

The deposit is zoned with Pb/Zn and silver values decreasing towards the margin in the eastern part. Tin is concentrated in the western part. In general, metal distribution patterns are directly related to proximity to chaotic breccia. Higher absolute values and higher Pb/Zn and Ag/Pb ratios overlie the breccia zones (Ransom, 1977; Hamilton et al., in press).

The deposit is interpreted by Cominco staff to be a hydrothermal synsedimentary deposit that formed in a small sub-marine basin. Its western part lies directly above its conduit zone, the brecciated and altered footwall of the deposit.

Kootenay King

Kootenay King, a small (less than 100,000 tonne) stratiform lead-zinc deposit in Middle Aldridge clastic sedimentary rocks, occurs east of the Sullivan deposit on the east side of the Rocky Mountain Trench. The geology of the deposit was described by Ney (1957a) and the regional geology by Hoy (1979a).

Mineralization occurs near the hinge of a large anticlinal fold that is thrust eastward on to younger Paleozoic strata. It consists of a layer of finely laminated sphalerite, galena and pyrite intercalated with dolomitic to argillaceous siltstone in a grey quartzite unit called the Kootenay King quartzite. The Kootenay King quartzite is within a succession of dolomitic siltstone. Near its base, the quartzite contains coarse angular lithic clasts that are megascopically similar to both overlying and underlying siltstone. It has been interpreted (Hoy, 1979a) to be a channel sandstone deposit. To the north, in the direction of current transport and deeper-water environment, the quartzite and surrounding strata thin and become finer-grained suggesting deposition in a small fault-bounded structural depression. To the south correlative rocks comprise a thick succession of Middle Aldridge turbidites (McMechan, 1979). This suggests that the Kootenay King area is the southern faulted marginal edge of a relatively shallow-water platformal environment. Figure 6 schematically illustrates evolution of the marginal zone of the basin in Middle Aldridge time.

STRUCTURAL AND STRATIGRAPHIC CONTROL OF CLASTIC-HOSTED PROTEROZOIC DEPOSITS

The Purcell Mountains exhibit a pronounced northeast trending structural grain that is delineated by late transverse faults with attendant localization of granitic intrusions. This grain is inherited from older, fundamental faults that were active during sedimentation in late Proterozoic Windermere time and lower Paleozoic time (Leech, 1958; Price and Lis, 1975; Lis and Price, 1976). It has been suggested

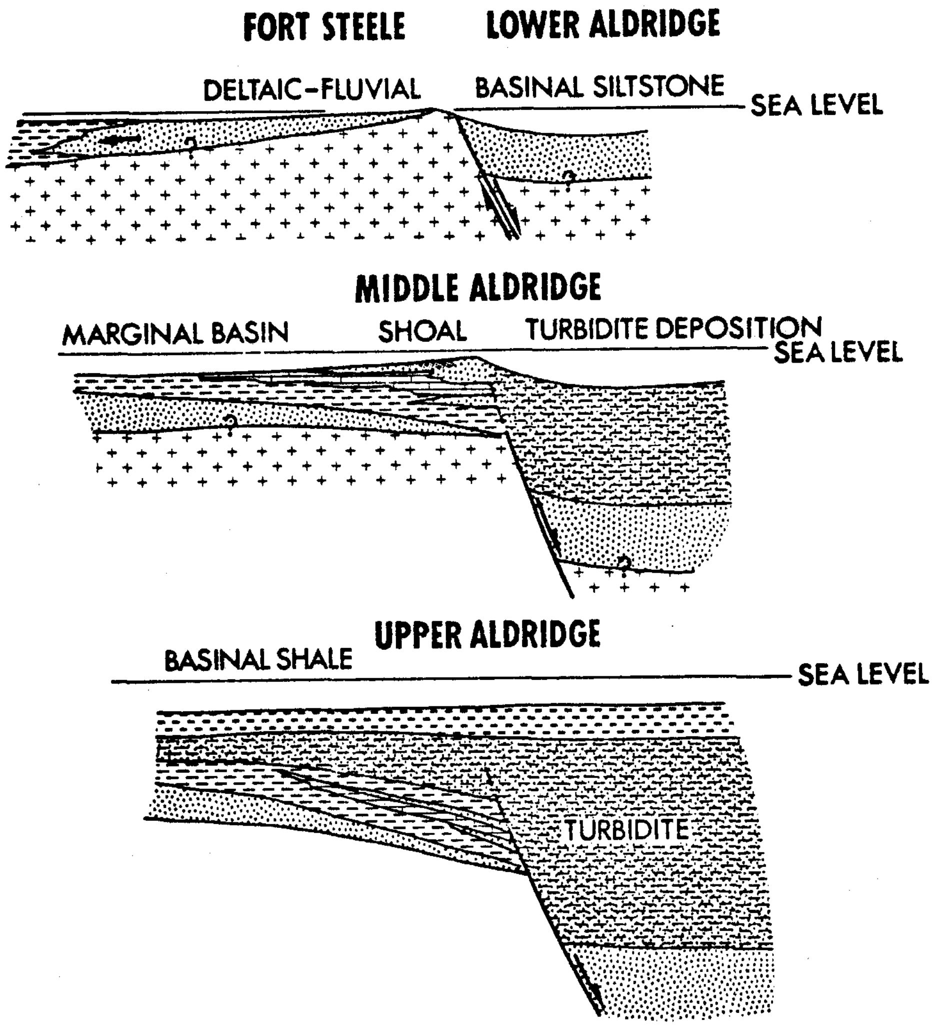


Figure 6: Postulated stages in the evolution of the fault-bounded Kootenay King basin.

(Hoy, 1979a; and, in press) that these faults locally modified the depositional pattern of older Purcell rocks. Rapid lateral facies changes, dramatic local variations in sediment thicknesses, and intraformational conglomerate are the most obvious record of these syndepositional faults (Hoy, in press). A pronounced Bouger gravity low and a magnetic lineation trend southwesterly south of Kimberley in the vicinity of the St. Mary-Boulder Creek fault and the Moyie-Dibble Creek fault. This, combined with an anomalous thickness of Middle Aldridge turbidite beds east of the trench suggested to Kanasewich et al. (1969) that a southwest trending Precambrian rift projected under flat lying Paleozoic and Mesozoic sediments in Alberta continues into southeastern British Columbia.

Areas of tourmalinization (boron concentration) that Ethier and Campbell (1977) suggest are concentrated near basin fracture zones, and intraformational conglomerate that Hoy (in press) relates to synsedimentary faults appear to be concentrated in the vicinity of the transverse structural zone south of Kimberley, and in a zone coincident with the Hall Lake fault to the north. A number of stratiform lead-zinc deposits and occurrences are also preferentially located in the vicinity of these transverse zones (Figure 7). Both the Sullivan and the Kootenay King deposits occur in somewhat thickened sections and they and a number of other showings are associated with intraformational conglomerate and tourmalinization, suggesting that basin fractures and mineral deposits are genetically linked. Local north-trending breccia zones at Sullivan (Ransom, 1977; Hamilton et al., in press) suggest that second order basins cross-cutting a regional northeast-trending rift structure were the local control of mineralization.

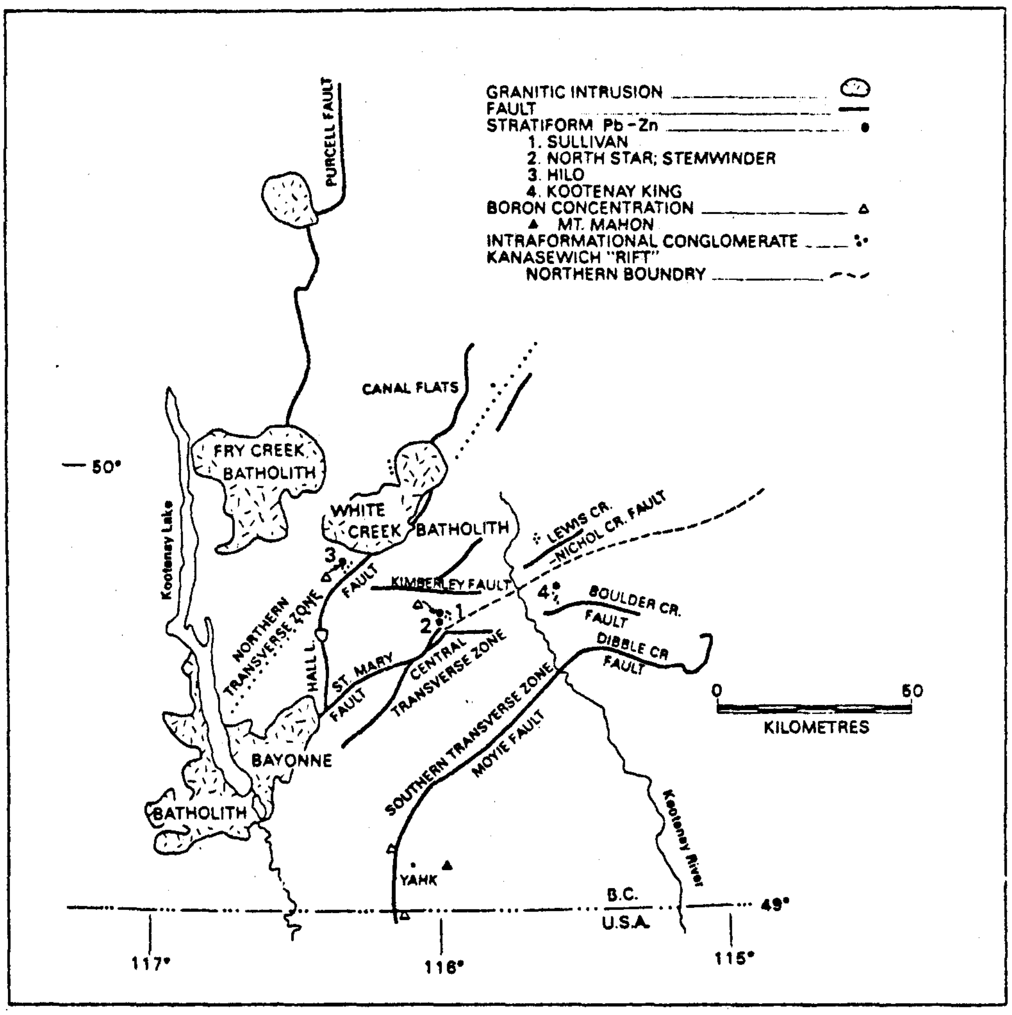


Figure 7: Location of northeast trending structures and distribution of stratiform Pb-Zn occurrences, boron concentrations, and intraformational conglomerate (data after Rice, 1941; Leech, 1960; Reesor, 1973; Ethier and Campbell, 1977; Gifford, 1971 and Hoy, 1979a).

CARBONATE-HOSTED DEPOSITS

The Mineral King, Paradise and Ptarmigan deposits occur in dolomite of the Mt. Nelson Formation (Figure 4) on the northern edge of the Purcell anticlinorium. The regional geology is described by Walker (1926) and Reesor (1973), the detailed geology of the Mineral King by Fyles (1959) and of the Paradise and Ptarmigan by Hedley (1950) and Atkinson (1977). The following descriptions are summarized from these reports.

The Mt. Nelson Formation, in the upper part of the Purcell Supergroup, consists of a prominent basal quartzite overlain by a thick succession of dolomite and interlayered argillite. It is underlain by up to a thousand metres of dark grey argillite and slate of the upper part of the Dutch Creek Formation, and overlain with angular discordance by the basal member of the Hadrynian Windermere Group, the Toby Formation conglomerate.

Until its closure in 1927, the Mineral King deposit produced in excess of 2 million tonnes grading 1.76% Pb, 4.12% Zn and 24.8 g/tonne Ag. Production of barite has continued intermittently to the present time. The deposit is described (Fyles, 1959) as replacements of dolomite by barite and sulphides in a complexly folded and faulted terrain. Mineralization consists of sphalerite, galena, pyrite and minor bournotite ($PbCuSbS_3$), in a dolomite, barite and quartz gangue. The orebodies are extremely irregular in shape, forming tabular and lenticular masses in roughly the same plane. They appear to be deformed along with the enclosing host rocks, and sulphides form structurally elongated, irregular discontinuous lenses either in the dolomite or in barite gangue.

The Paradise deposit was mined intermittently from 1901 to 1952, producing 63,000 tonnes of high grade lead-silver-zinc ore. The higher levels of the deposit consisted of irregular pockets of highly oxidized galena, sphalerite and pyrite in a "carbonate sand" matrix (Hedley, 1950); lower levels were generally less oxidized. Atkinson (1977) suggested that the Paradise deposit may be a remobilized Windermere-age deposit, due to its proximity to a block fault of Windermere age. Remobilization of the deposit into veins, faults and fault breccia zones may have occurred in Mesozoic time.

SHUSWAP METAMORPHIC COMPLEX

The Shuswap Complex is a belt of high grade and intensely deformed metamorphic and intrusive rocks in the core of the Columbian orogen in southeastern B.C. Its eastern margin is characterized by a series of domal structures that expose mixed granitic gneiss and migmatite that recently has been dated as Aphebian (2.1 b. years), (R.L. Armstrong, U.B.C., personal communication). Core gneisses are overlain by a heterogeneous assemblage of calc silicate gneiss, pelitic gneiss, quartzite and marble that has been dated as Helikian (1.5 b. years). This succession of paragneisses hosts a number of stratabound lead-zinc deposits. The deposits consists of a single layer of massive to irregularly banded sulphides or a series of discontinuous lenses within a thin calcareous schist unit. They are folded and metamorphosed along with the country rocks.

Regional mapping of the eastern margin of the Shuswap Complex by Wheeler (1965) and a number of more detailed studies (Reesor, 1965; Reesor and Moore, 1971; McMillan, 1973; and Fyles, 1970) provide a structural and stratigraphic framework for recent detailed mapping by Psutka (1978), Hoy (1979c, 1980), Read (1979), Brown and Psutka (1979) and Brown (1980). Description and general characteristics of Shuswap deposits are presented by Fyles (1970a) and Hoy (1979c).

This report focuses on mineral deposits northwest of Revelstoke in paragneisses that overlie core gneisses of Frenchman Cap "dome". These include the Cottonbelt and River Jordan deposits. Big Ledge, a stratabound zinc deposit in paragneiss surrounding Thor Odin "dome", 60 km south of Revelstoke (see Figure 2, p.3), consists of a series of sphalerite-pyrrhotite lenses in a dark pyrrhotite and pyrite-rich graphitic calcareous schist unit that can be traced more than 10 km along strike (Hoy, 1977). The paragneiss succession is correlative (Read, 1979) with the succession that hosts the Cottonbelt and River Jordan deposits. Ruddock Creek (Fyles, 1970a), located north of Cotton-gelt (Figure 2) is in a succession of calcareous schist, quartzite and impure marble that has tentatively been correlated with the Hadrynian Windermere Group (R.L. Brown, personal communication, 1979). The succession is highly deformed, metamorphosed to upper amphibolite grade and extensively invaded by pegmatite. Mineralization consists of contorted layers and lenses of sphalerite, pyrrhotite, galena, pyrite and minor chalcopyrite, locally associated with barite and fluorite, in a calcareous succession (Fyles, 1970a).

STRUCTURAL AND STRATIGRAPHIC SETTING OF FRENCHMAN CAP DEPOSITS

Aphebian crystalline basement in the core of Frenchman Cap "dome" and the overlying succession of paragneisses are exposed between the Columbia River fault zone on the east and a décollement on the west (Brown, 1980). Two main phases of deformation are evident in the southern, western and northern margins of the "dome". In the Jordan River area (Fyles, 1970a), the "early" phase produced a southwest trending, north-closing recumbent anticline fold cored by core gneiss (Hoy and McMillan, 1979). "Late" folds, with axial surfaces dipping away from core gneiss are superposed on the recumbent anticline.

Core gneisses consist dominantly of leucocratic and fairly homogeneous granitic gneiss generally overlain by a mixed assemblage of granitic gneiss, hornblende gneiss, minor amphibolite and rare calc-silicate gneiss. A heterogeneous succession of paragneiss overlying the core gneiss has been correlated around the margin of the dome (Hoy and McMillan, 1979; Brown and Psutka, 1979). It comprises a basal quartzite-conglomerate (unit 3), overlain by a heterogeneous but dominantly calcareous succession (unit 4) of calc-silicate gneiss, micaceous schist, marble and quartzite (Figure 8). The succession, which includes two important marker units, a brown-weathering stratiform carbonatite layer (McMillan and Moore, 1974) and a grey-weathering, white crystalline marble, hosts both the Cottonbelt and River Jordan deposits, and is intruded by a number of sheets of nepheline syenite gneiss. Abrupt lateral facies changes and structural and stratigraphic thinning hamper correlation of individual layers of unit 4 around the Frenchman Cap dome. Unit 4 is overlain by a second quartzite sequence (unit 5) and calc-silicate gneiss, micaceous schist and quartzite of unit 6.

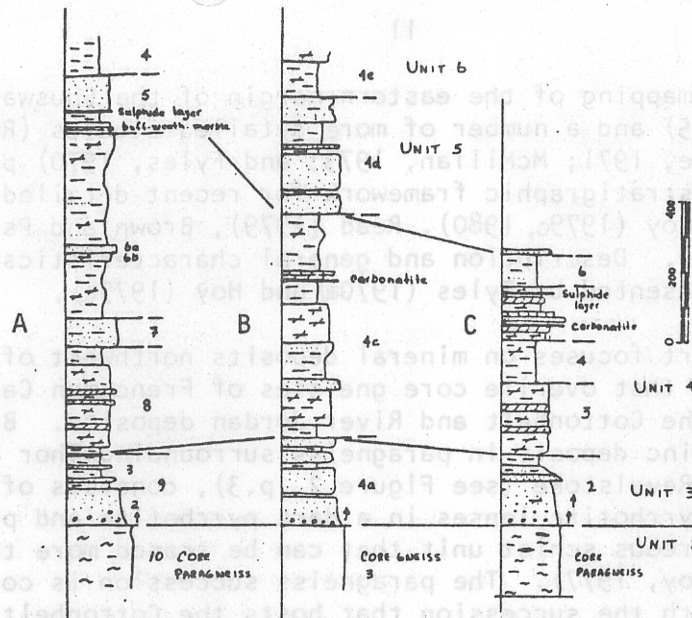


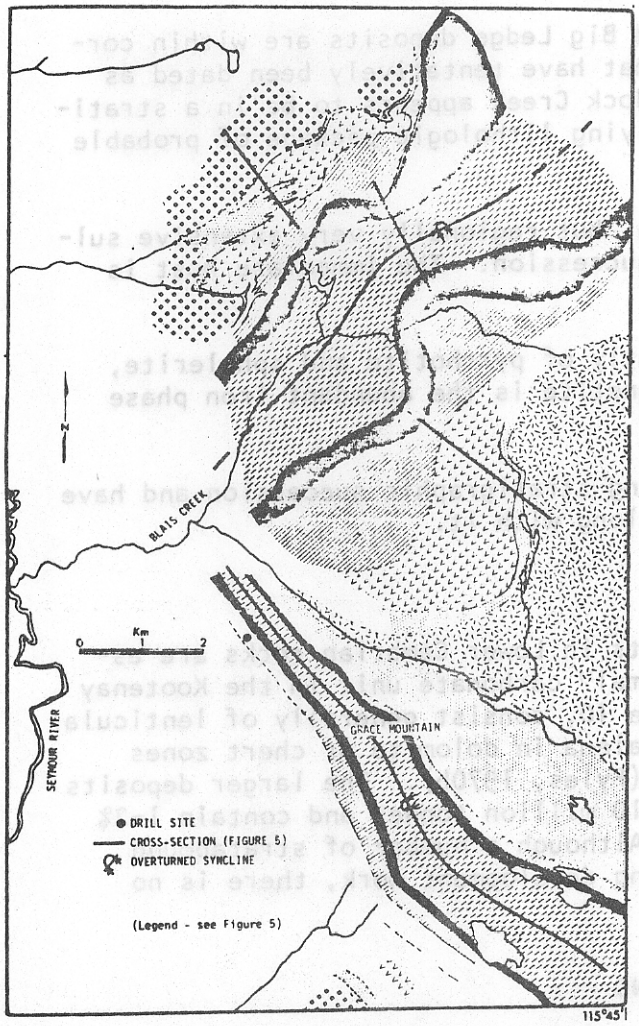
Figure 8: Correlation of units around the margins of Frenchman Cap "dome". Section A - Fyles (1970a), B - McMillan (1973), C - Hoy (1979c). Numbers on sections refer to unit numbers as used by above authors.
quartzite, micaceous schist, marble, calc-silicate gneiss

The pegmatite laced paragneiss and amphibolite (unit E, Wheeler, 1965) that hosts the Ruddock Creek deposit tectonically overlies the paragneiss succession.

Cottonbelt

The Cottonbelt property was extensively explored in the 1920's. Metallgesellschaft Canada Ltd. optioned the property in 1978 and drilled two holes in an attempt to intersect mineralization in the hinge zone of a tight synclinal structure that is draped around the northwestern margin of Frenchman Cap dome (Figure 9) (Hoy, 1979c).

Mineralization comprises an oxide-sulphide "layer" that can be traced intermittently along a strike length of approximately 5 km in the western (upper) limb of the syncline and along 2 km in the eastern limb. The layer varies in thickness from a few tens of centimetres to approximately 2 metres. Mineralization generally consists of fairly coarse grained sphalerite, magnetite, galena, and minor pyrrhotite in a dark green, pyroxene-amphibole-quartz-garnet rock, either as layers within a lighter coloured, more siliceous calcareous gneiss, or as disseminated grains in siliceous granular marble. The mineralized layer is stratigraphically underlain by calc-silicate gneiss, then impure phlogopite marble, a pure grey-weathering marble and the stratiform carbonatite layer. It is overlain by kyanite-sillimanite schist in the core of the syncline.



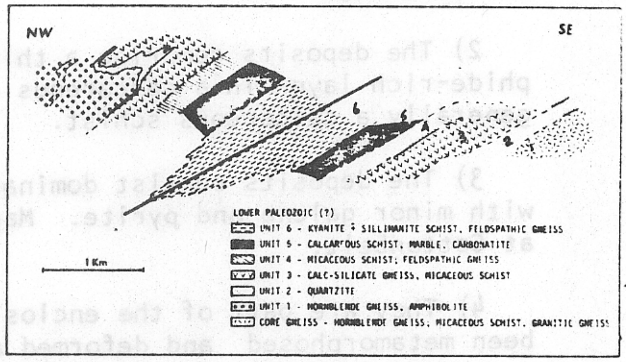


Figure 9: Regional geology and a schematic vertical section in the Cottonbelt area.

River Jordan

A sulphide-rich layer, less than a metre to 6 metres in thickness, forms a part of the lithological sequence in the Jordan River area (Fyles, 1970a). On the River Jordan (King Fissure) property it is exposed in the limbs and hinge of a tight south to southeast plunging synform called the Copeland synform. Reserves in the south limb have been calculated as 2.6 million tonnes containing 5.1% Pb, 5.6% Zn and 35 g /tonne Ag.

The sulphide-rich layer consists most commonly of a "fine-grained intimate mixture of sphalerite and pyrrhotite with conspicuous eye-shaped lenses of grey, watery quartz and scattered grains of pyrite and galena" (Fyles, op. cit. p.41). It may be well-layered, and may include minor pods and lenses of calc-silicate gneiss, schist, marble, or barite. It is within a calcareous succession of calc-silicate gneiss, micaceous schist, marble, and quartzite and is structurally overlain by a quartzite-rich succession and then a sillimanite gneiss unit.

SUMMARY - SHUSWAP DEPOSITS

A number features of Shuswap deposits are summarized by Fyles (1970a) and Hoy (1979d).

1) Cottonbelt, River Jordan and Big Ledge deposits are within correlative lithologic successions that have tentatively been dated as Proterozoic Helikian in age. Ruddock Creek appears to be in a stratigraphically and structurally overlying lithologic package of probable Hadrynian age.

2) The deposits comprise a thin, but regionally very extensive sulphide-rich layer in a calcareous succession. The immediate host is generally a calcareous schist.

3) The deposits consist dominantly of pyrrhotite and sphalerite, with minor galena and pyrite. Magnetite is the abundant iron phase at Cottonbelt.

4) They are part of the enclosing stratigraphic succession and have been metamorphosed and deformed along with it.

LOWER CAMBRIAN

Stratabound lead-zinc deposits in Lower Cambrian rocks are essentially restricted to a "platformal" carbonate unit in the Kootenay Arc. The deposits, shown in Figure 10, consist generally of lenticular masses of pyrite, sphalerite and galena in dolomite or chert zones within highly deformed limestones (Fyles, 1970b). The larger deposits generally range in size from 6 to 10 million tonnes and contain 1-2% of Pb, 3-4% Zn and trace silver. Although a number of stratabound Kootenay Arc deposits are undergoing development work, there is no present production.

STRATIGRAPHIC AND STRUCTURAL SETTING

The Kootenay Arc is an arcuate structural belt of complexly deformed sedimentary, volcanic and metamorphic rocks of dominantly Lower Paleozoic age. Its western margin is in fault contact with the Shuswap Metamorphic Complex or is obscured by Mesozoic batholiths and its eastern margin merges with the Purcell anticlinorium. The stratigraphic succession in the Kootenay Arc is illustrated in Figure 11. Coarse grained, locally cross-bedded quartzite of the basal part of the Lower Cambrian Hamill Group overlies a thick accumulation of shale, quartzite, grit, quartz-pebble conglomerate and limestone of the Horsethief Creek Group of Windermere age. The bulk of the Hamill Group comprises micaceous quartzite, quartz-rich schist, and micaceous schist but a white orthoquartzite, 60 to 200 metres thick, is a distinctive marker unit within it. The Mohican Formation (Figure 11) is a gradational unit between the Hamill Group and the Badshot limestone. It consists of a thin bedded succession of calcareous schist and quartzite, rusty-weathering micaceous schist, and limestone. The Badshot Formation is an extensive, relatively pure limestone unit several tens to greater than 100 metres thick. Irregular zones of dolomite and chert within the limestone host the lead-zinc deposits. North of the Salmo area, Badshot is overlain by up to several hundred metres of dark argillite or micaceous

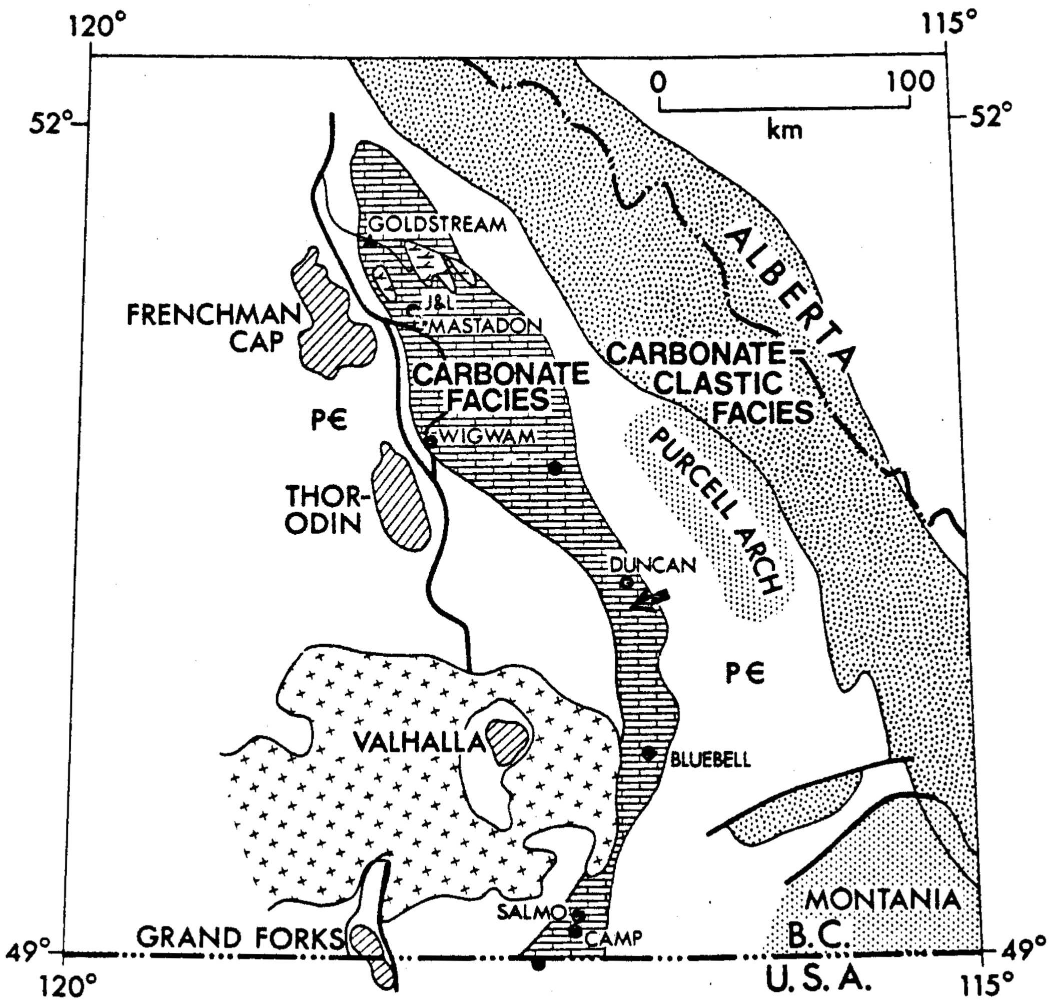


Figure 10: Distribution of Lower Cambrian rocks and location of deposits. Goldstream is a Cu-Zn massive sulphide deposit; ⊥ - basic volcanics of probable Eo-Cambrian to Lower Cambrian age (Hoy, 1979b).

schist at the base of the Index Formation, calcareous schist of the Upper Index, a succession of dark argillite and argillaceous quartzite of the Triune Formation, the Ajax Formation quartzite and argillite of the Sharon Creek Formation. Metamorphosed andesitic volcanic rocks of the Jowett Formation overlie the Sharon Creek Formation and are overlain by dominantly coarse clastic rocks of the Broadview Formation. In the Salmo area, argillite, calcareous phyllite and minor micaceous quartzite of the Laib Formation is overlain by a thick limestone-dolomite unit of Middle Cambrian age called the Nelway Formation (Fyles and Hewlett, 1959). The Nelway Formation dies out to the north, supplanted by more argillaceous rocks of the Lardeau Group (for more detail see section on Middle Cambrian deposits).

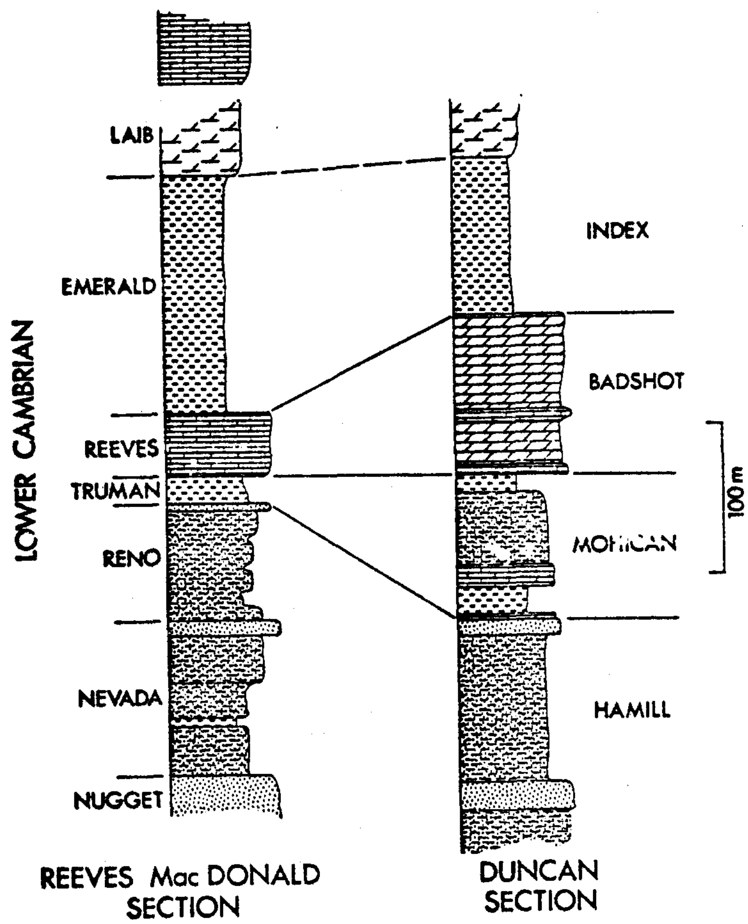


Figure 11: Lower Cambrian stratigraphic sections in the Salmo camp (Reeves-MacDonald deposit) and Duncan Lake area (Duncan deposit); adapted from Fyles and Hewlett (1959), Fyles (1964), and Muraro, 1962.

In general, the earliest recognized structures in the Kootenay Arc are tight to isoclinal, north-trending recumbent folds (Fyles, 1964; Read, 1973; and Hoy 1977). They are overprinted by more open, but locally isoclinal, north-trending phase 2 folds with upright to steeply west-dipping axial surfaces (Figure 12, from Fyles, 1964). These folds dominate the structure of the arc and account for the prominent north-south structural grain. Layer-parallel thrust and normal faults are locally important but commonly difficult to recognize without a detailed local knowledge of stratigraphy. Transverse faults locally offset the north-south structural grain.

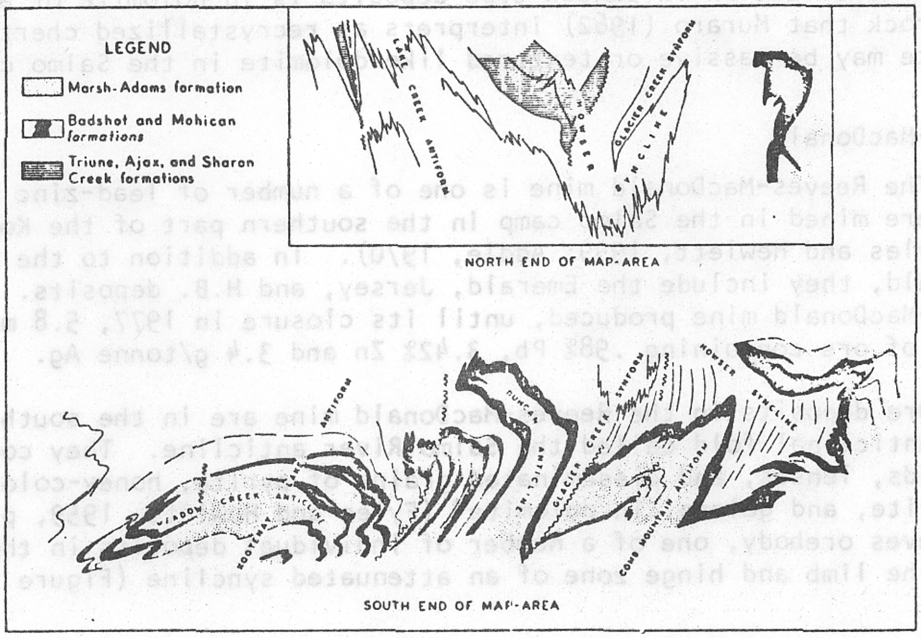


Figure 12: Idealized cross-section showing the structure of the Duncan Lake area. Width of lower section represents 18 km; from Fyles, 1964.

LEAD-ZINC DEPOSITS

Lead-zinc deposits in the Kootenay Arc are concentrated in two areas, the Salmo camp at the Southern end of the arc and the Duncan camp north of Kootenay Lake. The Bluebell deposit, described as a vein replacement deposit (Ransom, 1977), is situated on the east shore of Kootenay Lake between the Duncan and Salmo camps (see Figure 10) and the Wigwam deposit (Thompson, 1979) is at the north end of the Kootenay Arc.

General characteristics as well as details of deposits in the Salmo camp are described by Fyles and Hewlett (1957, 1959) and Fyles (1970b). Deposits in the Duncan area are described by Muraro (1962) and Fyles (1964). The descriptions that follow are summarized from these authors.

Kootenay Arc deposits are all hosted by intensely deformed Lower Cambrian marble or limestone. Dolomitization and associated brecciation of the limestone is common. The deposits consist of lenses, irregular bands, disseminated grains, or massive bodies in dolomite. They are irregular in outline and commonly elongated parallel to the regional structural grain. Contacts with country rock may be sharp or gradational.

A fine-grained dolomite hosts deposits in the Salmo camp. The dolomite is texturally different from the barren, generally well-banded limestone (Fyles and Hewlett, 1957; 1959). It may be poorly banded, flecked with black, irregularly streaked, or crackled. More massive dolomite contains only sparse mineralization. Obvious breccia zones with dolomite fragments surrounded by sulphides are common features of the Salmo deposits.

Mineralization in Duncan-type deposits is in dolomite or a siliceous rock that Muraro (1962) interprets as recrystallized chert. The dolomite may be massive or textured like dolomite in the Salmo camp.

Reeves-MacDonald

The Reeves-MacDonald mine is one of a number of lead-zinc deposits that were mined in the Salmo camp in the southern part of the Kootenay Arc (Fyles and Hewlett, 1959; Addie, 1970). In addition to the Reeves-MacDonald, they include the Emerald, Jersey, and H.B. deposits. The Reeves-MacDonald mine produced, until its closure in 1977, 5.8 million tonnes of ore containing .98% Pb, 3.42% Zn and 3.4 g/tonne Ag.

Ore deposits in the Reeves-MacDonald mine are in the south limb of an anticlinal fold called the Salmo River anticline. They consist of "bands, lenses, and disseminated grains of pyrite, honey-coloured sphalerite, and galena, in dolomite" (Fyles and Hewlett, 1959, p.144). The Reeves orebody, one of a number of individual deposits in the mine, is in the limb and hinge zone of an attenuated syncline (Figure 13).

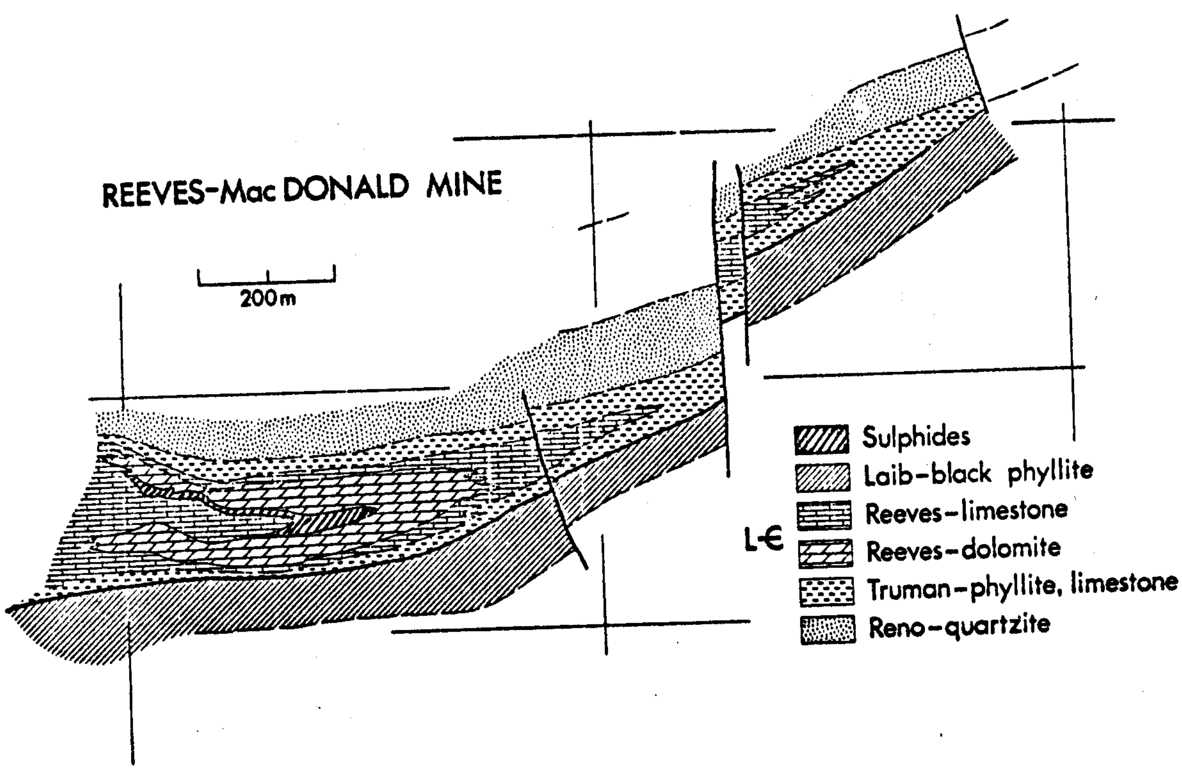


Figure 13: A section through the Reeves deposit in the Reeves-MacDonald mine (from Fyles and Hewlett, 1959). Note dolomite zone surrounding ore in core of syncline.

A dolomite zone surrounds the orebody. Much of the ore in the Reeves deposit is well-banded and is locally highly contorted. Some ore is brecciated, with angular clasts of limestone and dolomite in massive sulphide matrix.

Duncan Deposit

The Duncan deposit (Muraro, 1962; Fyles, 1964) is the largest of a number of deposits that occur on the limbs and in the hinge zone of the Duncan anticline (see Figure 12). Estimated reserves include approximately 9 million tonnes with 2.7% Pb and 2.9% Zn (Muraro, 1962).

The Ducan deposit includes a number of separate sulphide zones located in the complexly deformed and faulted hinge zone of the Duncan anticline (Figure 14). The largest, the No. 6 zone, consists principally of fine-grained pyrite with small amounts of sphalerite, galena and pyrrhotite concentrated in thin layers in siliceous dolomite or

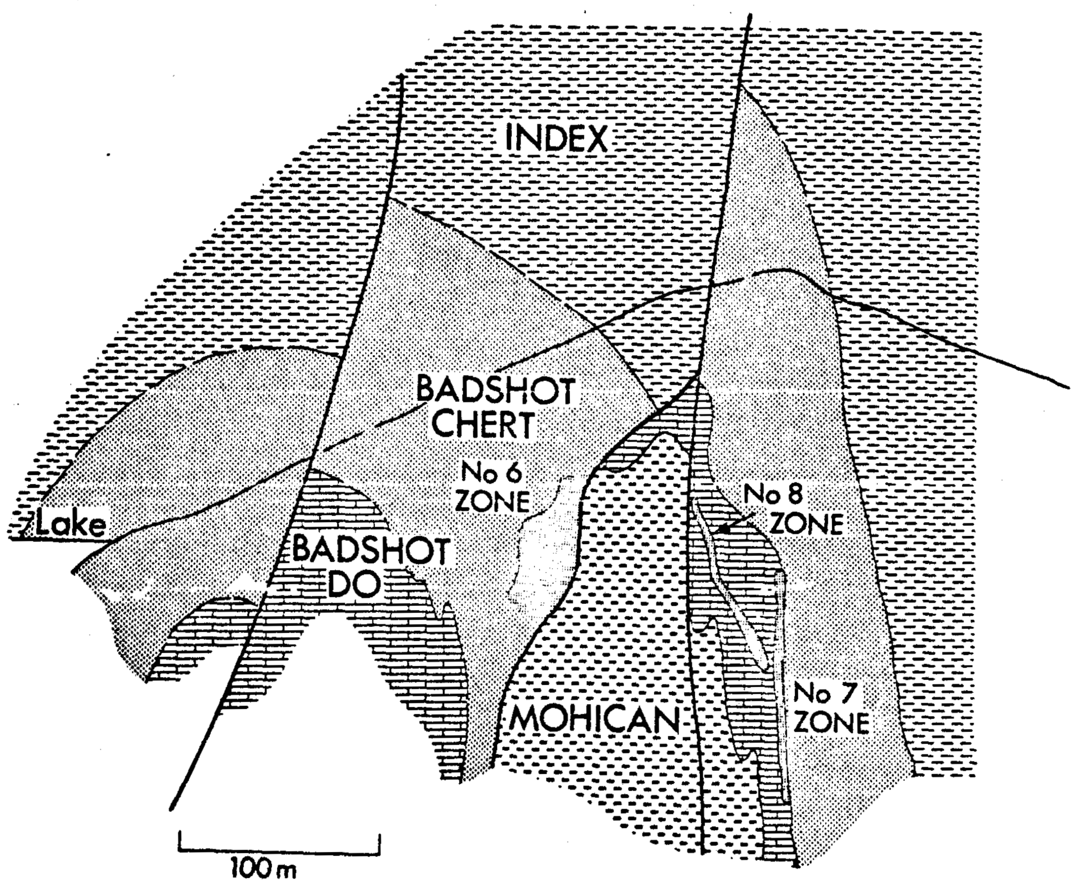


Figure 14: East-west vertical section through the Duncan deposit; modified from Muraro (1962) and Fyles (1964).

chert. The No. 7 zone is a thin vertical sheet of sulphides along the dolomite-chert contact (Muraro, 1962). It is brecciated and zoned. The stratigraphically lowest part of the zone (to the west) comprises well-layered dolomite, pyrite and sphalerite; the central portion consists of lenticular masses of pyrite, galena, and sphalerite in carbonate layers within barren chert; and the eastern part consists of disseminated grains of pyrite and sphalerite in carbonate and chert.

STRATIGRAPHIC AND STRUCTURAL CONTROLS

The origin of Kootenay Arc deposits is enigmatic. Fyles and Hewlett (1957, 1959) describe the deposits as replacement deposits controlled by phase 2 folds and locally, faults. They describe the close spatial association of mineralization to structures and the brecciated nature of some of the ore. Sangster (1970) and Addie (1970) describe the deposits as syngenetic, with sulphides accumulating in small basins in a deep-water carbonate platform. Muraro (1962), based on detailed studies of the Duncan deposit, suggests that Kootenay Arc deposits are hydrothermal replacement deposits, controlled by stratigraphy and formed before deformation and metamorphism.

A number of features that occur in most of the deposits place considerable constraints on any genetic model:

1) They are localized in a specific limestone unit, the Badshot or its equivalent, despite the fact that chemically and megascopically similar limestones occur in the underlying Mohican Formation.

2) Some of the deposits are well-layered (essentially stratiform) and, according to Muraro (1966), are deformed and metamorphosed along with the enclosing host rocks.

3) Dolomite envelopes completely or partially surround the sulphide deposits. Dolomite is obviously brecciated, or has a textured appearance suggestive of early brecciation.

4) Lead-zinc zoning in Duncan deposits is consistent with stratigraphic tops regardless of the structural position; zinc is concentrated in the stratigraphically lower dolomite, and lead and zinc in the upper dolomite (Muraro, 1962).

Muraro (1962) and Fyles (1964) describe pronounced lateral facies changes in both the Badshot and Mohican Formations in the Duncan Lake area. The Mohican contains more quartzite and carbonate and the overlying Badshot is considerably thicker and more dolomitic in the Duncan anticline section (Figure 15). Eastern Mohican facies are thicker and more argillaceous and western facies are also more argillaceous, but considerably thinner. This suggests that Mohican Formation in the Duncan anticline section may represent a carbonate-clastic shoal environment, with a basinal inner detrital facies to the east and a basinal facies to the west (Figure 16). It is possible that the thick section of Badshot in the Duncan anticline section, where the deposits are localized, is an extensively brecciated and locally dolomitized, low reef facies developed on a shoal complex. This environment would provide a suitable trap for deposition of sulphides.

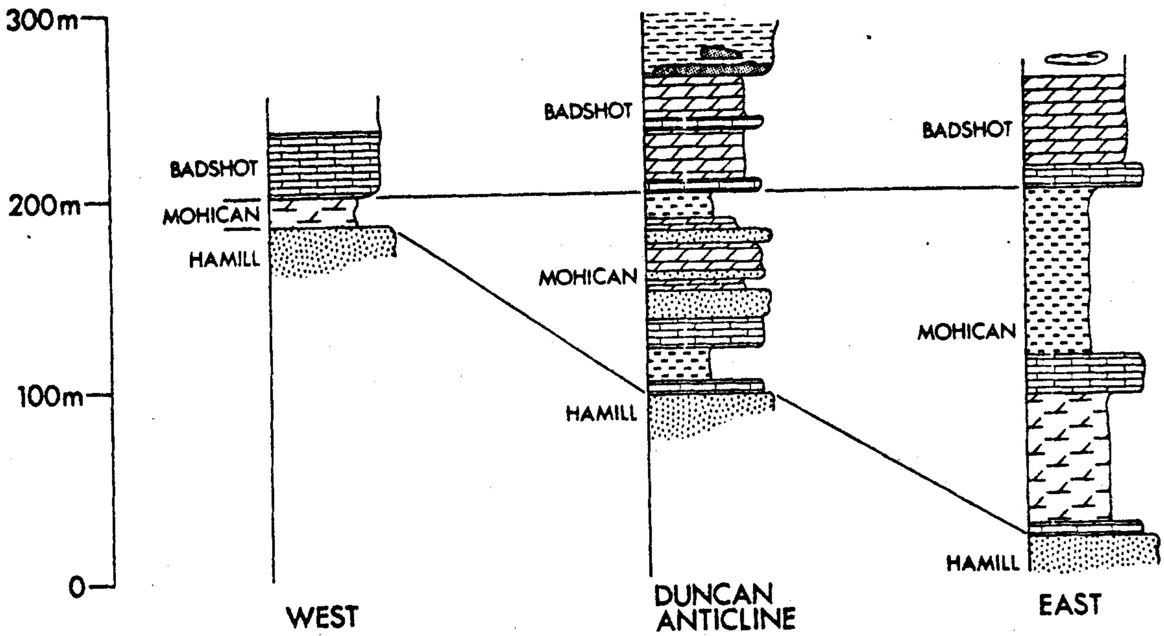


Figure 15: Stratigraphic sections in the Duncan Lake area; data from Muraro (1962) and Fyles (1964).
dolomite, limestone, sulphides, chert

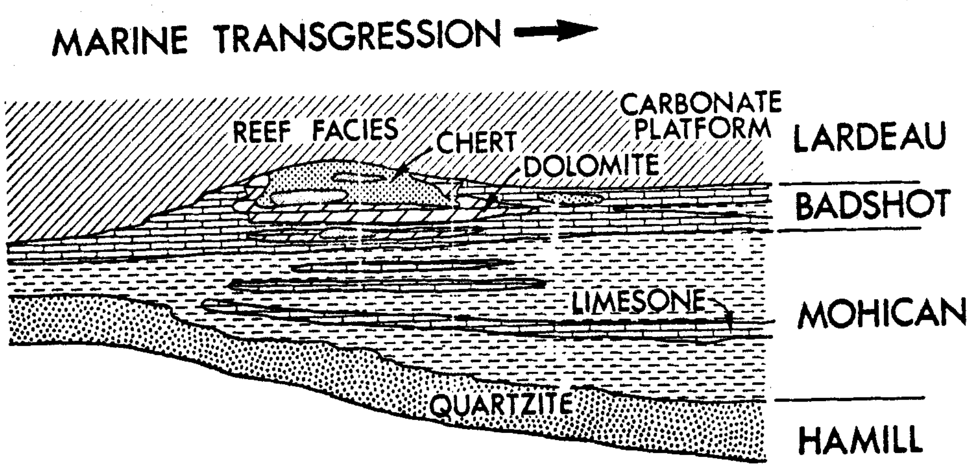


Figure 16: Lower Cambrian paleogeography, based on lateral facies changes in Mohican and Badshot shown in Figure 15.

These feature. suggest that the deposits formed "early", perhaps during late diagenesis or as laminated epigenetic ores in cavities in the Badshot limestone, or in collapsed breccia zones. External precipitation or mechanical deposition of sulphides may have occurred locally. This model is essentially similar to that proposed by Muraro (1962) and implies that the dominant control for mineralization is stratigraphic, not structural. It is also similar in many respects to both the "type" Mississippi Valley model in the United States and the Bleiberg model in the European Alps.

The structural controls cited, such as the elongate shape of the deposits, may be due to intense structural modification of originally non-deformed stratabound deposits. Features cited as evidence for a syngenetic origin, such as fine grain size and lack of permeability (Sangster, 1970), may be the result of imposed structural modifications. Other features, which are also cited as evidence for syngenetic origin such as laminated sulphides, banded appearance of sulphides and dolomite, and deformed nature of ore, are compatible with a late diagenetic or epigenetic origin. However, the dolomite envelopes around the ore and the brecciated textures are not explained in a syngenetic model, but are features of "Mississippi Valley" type deposits.

MIDDLE CAMBRIAN

Deposits within Middle Cambrian rocks occur in thick carbonate successions adjacent to laterally equivalent shale facies (Figure 17). The deposits consist of sulphides disseminated in layered limestone or dolomite, filling fractures in massive dolomite or barite, or disseminated throughout the matrix of coarse fragmental breccias. Lead-zinc ratios are variable, and silver, gold and copper values may be appreciable. The Monarch, Kicking Horse, Lead Mountain and Silver Giant mines are past producers.

STRATIGRAPHIC AND STRUCTURAL SETTING

The stratigraphic succession in the vicinity of the Monarch, Kicking Horse and Shag deposits is illustrated in Figure 18. The Cathedral Formation comprises a thick succession of massive to thin bedded dolomite and limestone. It is underlain by interlayered shale and limestone of the Mt. White Formation and a thick bedded quartz sandstone of the Lower Cambrian Gog Group. Shale and thin bedded limestone of the Stephen Formation and massive dolomite and limestone of the Eldon Formation overlie the Cathedral Formation. The deposits are located just east of a transition from platformal carbonates to dominantly shales of the lower part of the Chancellor Group (see Figure 17). This transition, described by Cook (1970) in the vicinity of the Monarch and Kicking Horse deposits and called the Kicking Horse Belt by Aitken (1971), corresponds to the outer edge of a shallow-water carbonate platform, and is characterized by a submarine scarp, slumped slope facies, and rapid lateral facies changes from subtidal to supratidal dolomite and limestone into a considerably thicker succession of basinal shale and argillaceous limestone.

The eastern platformal carbonate succession is involved in broad open folds and cut by thrust faults, whereas the western shale facies is characterized by a well-developed penetrative cleavage. This cleavage is axial planar to folds that become tight to sub-isoclinal in the vicinity of the facies boundary (Cook, 1970) and results in considerable apparent thickening of the western shale facies.

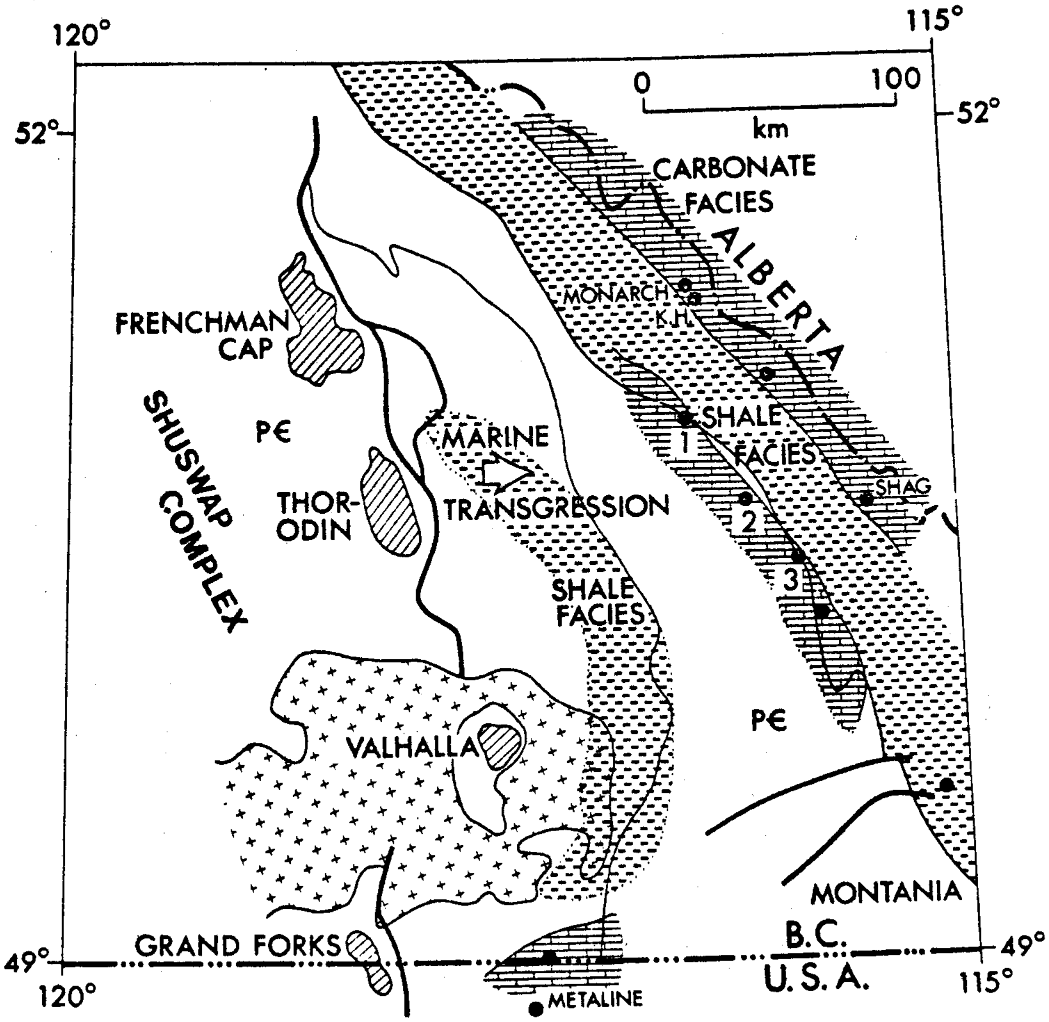


Figure 17: Distribution of Middle Cambrian rocks and location of deposits. 1 - Lead Mtn., 2 - Silver Giant mine, Jubilee Mtn. prospect, 3 - Steamboat

	Kootenay Arc	Steamboat Mtn Jubilee Mountain	Western Shale facies	Monarch-Kicking Horse Shag
UЄ		McKay	McKay	Bison Creek Lyell
		Jubilee	Chancellor	Sullivan Waterfowl Arctomys Pika Eldon Stephen Cathedral
MЄ	Nelway			
LЄ	Laib Reno Quartzite Range	Eager Cranbrook		Mt Whyte Gog

Figure 18: Correlation of Middle Cambrian stratigraphy.

A number of deposits also occur in the Jubilee Formation, a thick succession of massive to thin bedded dolomite and limestone of Middle to Upper Cambrian age that straddles the Rocky Mountain Trench (Figure 18). It overlies argillaceous dolomite and limestone, argillite and argillaceous quartzite of the Eager Formation and quartzite of the Cranbrook Formation, and is overlain by dark shale and argillaceous limestone of the McKay Group (Reesor, 1973). The Jubilee Formation is a shallow-water platformal carbonate that developed on a topographic high, the Purcell arch (Figure 17), that was intermittently emergent during Lower Paleozoic time. East of the arch are thicker and more complete Lower Paleozoic successions, represented in part by the deeper water Chancellor Formation.

A thick Middle Cambrian carbonate, the Nelway Formation, is exposed at the southern end of the Kootenay Arc in southeastern B.C. It hosts a small Pb-Zn occurrence, the Caviar prospect. Correlative Metaline Limestone in the State of Washington (Figure 17) hosts a number of large irregular lead-zinc orebodies. The Nelway Formation is underlain by argillite and argillaceous limestone of the Laib Formation, the Reeves limestone, and quartzites of the Reno and Quartzite Range Formations (Figure 18). It is supplanted to the north by more argillaceous rocks of the Lardeau Group, and is therefore interpreted to form the northern edge of a platformal succession adjacent to a deeper-water shale basin (Figure 17).

In summary, Middle to Upper Cambrian deposits occur in shallow-water platformal carbonates adjacent to shale basins. It is probable that the distribution of Lower Paleozoic platformal bank margins were in part related to early fault scarps. The Nelway bank margin, for example, is situated along the western extension of a transverse structural zone that was active in Late Proterozoic time (Hoy, in press; Lis and Price, 1976) and Lower Paleozoic time (Leech, 1960). Jubilee Formation carbonates developed on a Lower Paleozoic arch that was separated from platformal Cathedral carbonates to the east by a shale basin that trended approximately north-northwest, parallel to the dominant structural trends in southeastern B.C.

The following section outlines the geology of a number of "type" Middle Cambrian deposits, emphasizing the local stratigraphic and structural controls.

Monarch and Kicking Horse

The Monarch and Kicking Horse deposits occur on the steep cliffs on either side of the Kicking Horse River just east of the town of Field. The deposits have been described by Ney (1957b) and Westervelt (1979) and the regional stratigraphic and tectonic setting by Cook (1970). Total production from both deposits, from 1888 until their final closure in 1952, total .62 m tonnes containing 5.63% Pb, 8.85% Zn and 31 g Ag/tonne.

The deposits occur as a number of separate and discrete mineralized zones in massive to brecciated dolomite within a 60 metre stratigraphic interval in the lower 125 metres of the Cathedral Formation (Figure 19).

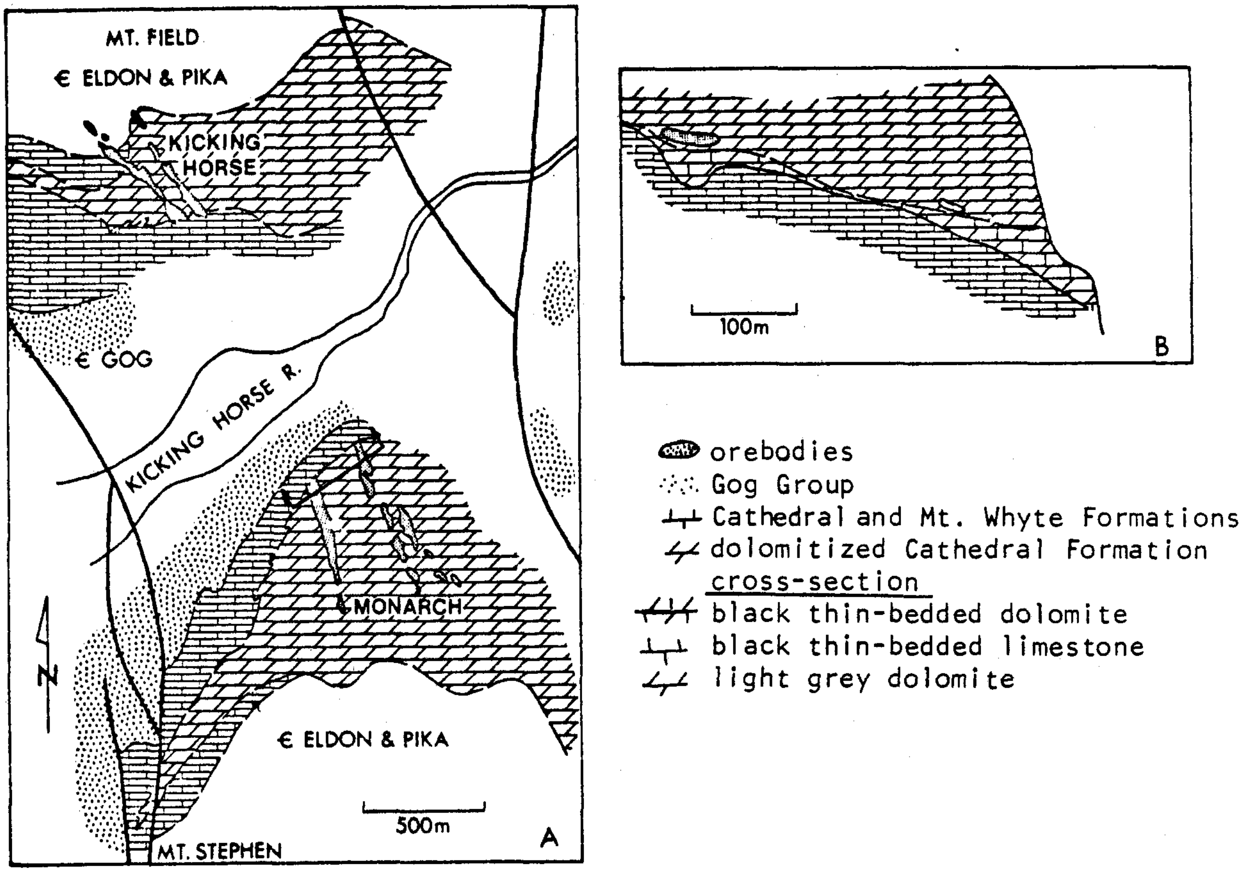


Figure 19: Surface geology in the vicinity of the Monarch and Kicking Horse mines (A), and generalized cross-section, viewed to northwest, of the Monarch deposit (B); after Ney, 1957b.

The dolomite zone cuts sharply into underlying well-bedded limestone and dolomite, and is overlain by similar well-bedded carbonate rock. The brecciated dolomite that hosts the orebodies consists either of a stockwork of white dolomite "veins" in grey dolomite, or of light grey dolomite fragments in dark grey dolomite. Immediately underlying the orebodies are dolomite alteration zones in which original bedding is preserved. The dolomite zones (and orebodies) trend northerly, parallel to both late normal faults and the abrupt facies change to basinal shales described earlier.

The orebodies occur as narrow elongate runs with sharp lateral boundaries in brecciated dolomite. They die out gradually along trend into barren, unmineralized dolomite. Sulphides, consisting of amber-coloured sphalerite, galena, minor pyrite and trace chalcopyrite, occur most commonly as disseminations in the dolomite matrix of breccias and also as irregular veinlets cutting both matrix and fragments. Coarse sphalerite and galena commonly rim dark dolomite fragments with spar-dolomite filling remaining vugs.

Dolomitization and the development of breccia and associated cavities cannot be directly related to any late fault structures. Faults cutting the deposits are not conspicuous and one of the two boundary "faults", the Stephen-Dennis fault (Allen, 1914), is a stratigraphic and not a structural break (Cook, 1970). The Monarch-Kicking Horse deposits (and most other Middle Cambrian deposits) are preferentially distributed within a dolomitized breccia zone adjacent to a plaformal bank margin. This suggests that there is a regional stratigraphic control.

Shag

A number of small lead-zinc showings were discovered by C. Graf in 1977 in Cathedral Formation limestone and dolomite about 35 km east of Radium. The following description of the showings is summarized from Assessment Report 7036 (Bending, 1978) and from a brief visit to the property in July 1980. The showings occur in generally heavily wooded drainage of Shag Creek, a southern tributary of Albert River. Work by the owners, Rio Tinto Canadian Exploration Ltd., includes geological mapping, prospecting, soil sampling and diamond drilling.

Nine widely scattered showings occur within a thick, massive to well bedded limestone-dolostone unit that has been correlated with the Cathedral Formation. It is overlain by a red-coloured shale horizon, the Arctomys Formation(?) and McKay Formation shale (Figure 18). Less than one kilometre to the west, Cathedral Formation carbonate is supplanted by shale and argillaceous limestone of the Chancellor Formation (Figure 17).

Most of the showings consist of concentrations of galena and pale yellow to amber to orange sphalerite in a granular or brecciated dolostone beneath dark laminated limestone. The sulphide concentrations appear to be restricted to two horizons, although a number of megascopically similar horizons occur in the succession. The dolostone at the BM, the largest of the discovered showings, consists of a number of cyclical beds, each a few centimetres thick, and each consisting of an erosional basal surface overlain by massive or irregularly laminated dark dolomite and capped by a coarse fragmental breccia or fenestral dolomite. This succession of cyclical beds is capped by dark, well layered limestone. Coarse, recrystallized sphalerite, minor galena and trace amounts of pyrite occur with sparry dolomite or dark argillaceous limestone that is interstitial to breccia fragments, and as disseminated grains through more massive dolomite. A second, similar horizon hosts scattered sulphide occurrences over a wide area. The mode of mineralization is generally the same, although locally coarse galena and minor sphalerite occur in cross-cutting calcite veins and shears.

The finely disseminated nature of some of the sulphide minerals and their restriction to specific horizons suggests a syngenetic to early diagenetic origin. The host rock is an intertidal dolostone that was repeatedly emergent and subjected to erosion, solution and local brecciation. Dark argillaceous limestone between dolomite fragments probably represents concentrations of less soluble residue, and interstitial sparry dolomite, late diagenetic cavity filling. The favourable horizons developed just prior to or during a pronounced marine transgression that resulted in deposition of subtidal laminated limestone. A possible regional stratigraphic control is the proximity to the Cathedral plaformal-Chancellor shale facies change, less than a kilometre to the west.

Jubilee Mountain Area

The Silver Giant mine, Lead Mountin mine and Jubilee Mountain prospect are silver-lead-zinc-barite "replacement" deposits in the upper part of the Jubilee Formation.

The Jubilee Mountain prospect (Buckley, 1976, 1977) contains galena, sphalerite and pyrite disseminated in massive to bedded limestone, in irregular veins with barite, and with barite in vugs and cavities. Breccia zones with angular clasts of dense dolomite and limestone in a granular carbonate matrix contain abundant disseminated sulphides and numerous barite and sulphide-filled vugs. Buckley (op. cit.) suggests that brecciation and barite-sulphide mineralization may be related to collapse of solution cavities and associated karst development in a Middle Cambrian reef environment. Local sea-floor irregularities, perhaps related to underlying fractures, controlled the distribution of reefs, collapse breccias, and associated mineral deposits.

The Silver Giant mine produced sporadically between 1908 and its closure in 1957. Since 1960, barite has been mined and recovered from the tailings of the former lead-zinc mine by Baroid of Canada. Mineralization occurs in the upper part of the Jubilee Formation (Reesor, 1973) and consists essentially of disseminated galena and sphalerite in a massive barite gangue. Buckley (1976) believes that mineralization is hosted by reefs that developed above a faulted scarp.

A number of stratabound lead-zinc-barite replacement deposits, including the Silver Giant mine and the Jubilee Mountain, Lead Mountain to the north, and Steamboat, on Steamboat Mountain (see Figure 17), occur in platformal carbonates of the Jubilee Formation. The upper part of the Jubilee Formation in the region of the mineral deposits comprises a carbonate shoal complex that developed west of a deeper-water shale basin. Breccia zones that appear to be related to cavern and karst development in reefs (Buckley, 1976, 1977) are the local ore controls.

DEVONIAN

The distribution of Upper Devonian rocks east of the Kootenay Arc is shown in Figure 20. They comprise shallow-water platformal carbonates of the Palliser Formation. Stratabound lead-zinc showings occur on the SOAB mineral claims, located in the Rocky Mountains near the headwaters of the Bull River.

SOAB, Alpine, Boivin

The following descriptions of the lead-zinc showings and their setting is summarized from Assessment Report 7489 (Gibson, 1979) and from a brief visit to the property in September 1980.

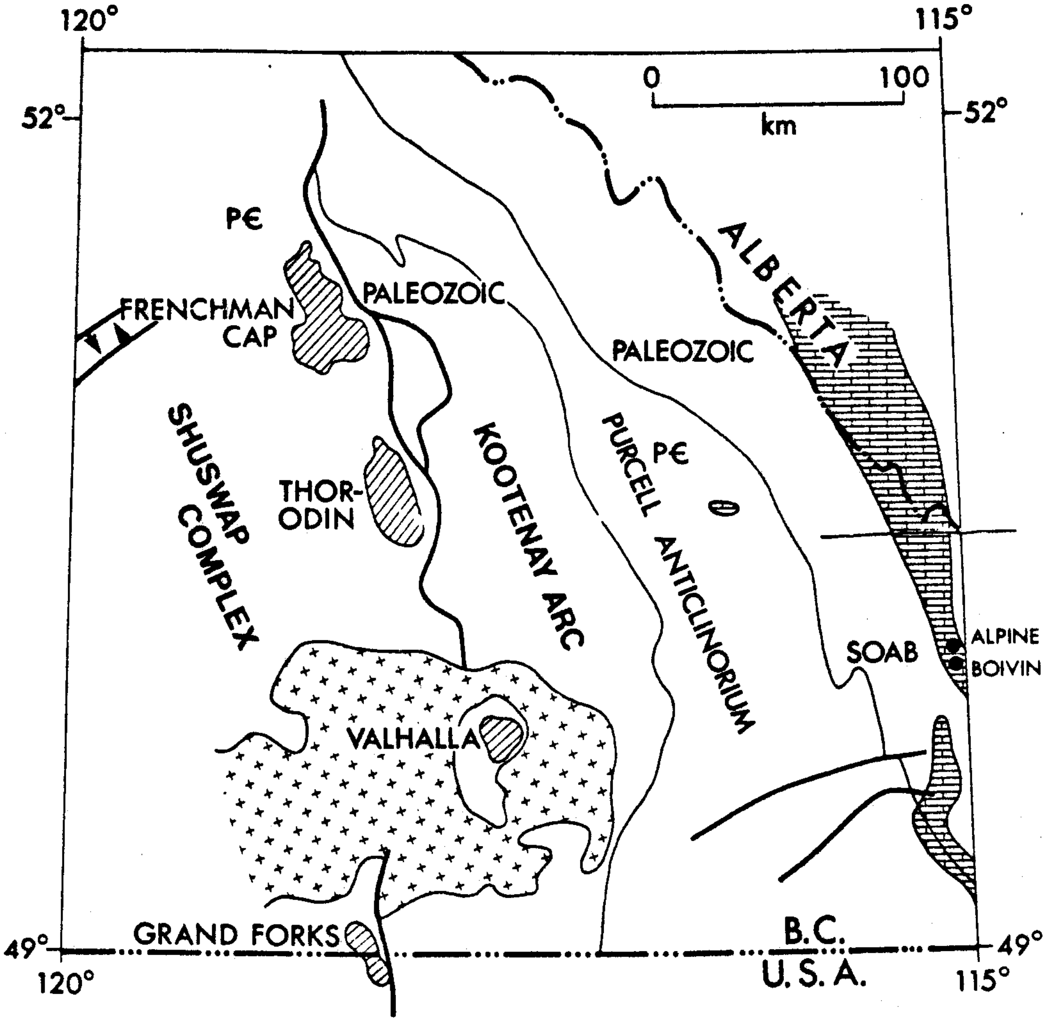


Figure 20: Distribution of Devonian rocks and the Alpine and Boivin occurrences.

The SOAB occurrence was discovered in 1972 by Silver Standard Mines during follow-up on a regional stream sediment anomaly; the Alpine and Boivin showings were discovered in 1977 and 1978. Limited drilling of the SOAB and Alpine and blasting and sampling of the Boivin has evaluated these occurrences.

Mineralization is restricted to a unit within the lower (Morro) member of the Palliser Formation. The unit is in the lower overturned limb of an eastward-verging assymmetrical anticlinal fold that is thrust against Mississippian carbonates to the east. Overlying Cambrian-Ordovician strata to the west are assumed to be in thrust-faulted contact with the Devonian package (Gibson, 1979).

A distinctive carbonate rock, termed "zebra facies", characterized by fenestral (and geopetal) spar dolomite crescents in a fine-grained granular dolomite matrix, hosts the mineralization. It is interpreted to be of supratidal algal origin. It is underlain and overlain by massive, subtidal limestone. Pale yellow to almost clear sphalerite is disseminated through the granular dolomite, concentrated along the periphery of spar dolomite patches, and occurs within the spar dolomite. The mineralization is concentrated in a number of discrete zones generally less than a metre thick and a few metres in length. The Boivin showing measures approximately 12 metres in length and 2 metres in width and contains up to 20% zinc (Gibson, 1979).

The disseminated nature of the sphalerite and its restriction to a specific carbonate unit within a thick succession of carbonates suggest an early syngenetic to diagenetic origin. The general paucity of zinc-lead mineralization in Devonian rocks in southeastern B.C., as compared with those in the northeast Cordillera, may be related to levels of exposure. The host bank margin environment and shale basin facies of the northeast sulphide accumulations is not exposed in southeastern B.C.; only the platformal environment is exposed.

SUMMARY

The distribution of clastic-hosted Proterozoic deposits, such as Sullivan, North Star, Stemwinder and Kootenay King, is largley controlled by northeast trending tectonic elements that transect the dominant northerly stratigraphic and structural trends. These deposits, and associated tourmalinization and intraformational conglomerate, are concentrated along the northern edge of a northeast trending rift structure that transected the Purcell basin in Helekian time. Local deposit controls appear to be more northerly trending fractures within the rift zone. Replacement deposits in upper Purcell platformal carbonates may be related to block faulting of Windermere age.

One of the important regional controls for carbonate-hosted deposits of Lower Cambrian and Middle Cambrian age appears to be proximity to carbonate bank margins. Lower Cambrian deposits are concentrated along the western limits of exposure of platformal carbonate rocks in brecciated and dolomitized limestone that is interpreted to be a reef that developed above a carbonate-clastic shoal complex. Middle Cambrian deposits are in intertidal to supratidal carbonates adjacent to shale basins.

The northeast trending rift zone, that appears to have controlled the distribution of Purcell clastic-hosted deposits, also appears to have been important in localizing Lower and Middle Cambrian deposits at the southern end of the Kootenay Arc. The largest concentration of Kootenay Arc deposits, the Salmo camp, and a Middle Cambrian platform edge, are along the projected strike of the pre-Cambrian rift zone.

In summary, transverse structural zones and regional facies changes that are in part related to the transverse zones, are important regional controls for the distribution and localization of many stratabound deposits in southeastern B.C. The transverse zones coincide with deep crustal structures that appear to have controlled the outflow of metal-charged formation fluids or deep crustal or mantle fluids, leading to the formation of deposits in their vicinity. Hosts for sulphide accumulations include clastics along the northern, probably faulted margin of a rift that paralleled the zone in pre-Cambrian time, and platformal carbonates of Cambrian age along the western extension of the zone.

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REFERENCES

Addie, G.G., 1970, The Reeves MacDonald Mine, Nelway, British Columbia: in Bull. No.61, State of Washington, Dept. of Natural Resources: "Pb-Zn Deposits in the Kootenay Arc, N.E. Washington and Adjacent British Columbia", p.79-88.

Aitken, J.D., 1971, Control of Lower Paleozoic Sedimentary Facies by the Kicking Horse Rim, Southern Rocky Mountains, Canada: Bull. of Canadian Petroleum Geology, Vol.19, No.3, p.557-569.

Allan, J.A., 1914, Geology of the Field Map-area, B.C. and Alberta: Geological Survey of Canada, Memoir 55.

Atkinson, S.J., 1977, Surface geology of the Paradise basin: in Geology in British Columbia, 1975: B.C. Ministry of Mines and Petroleum Resources, p.7-12.

Bending, D., 1978, Shag Claims, Golden Mining District, 82J/11 & 12: B.C. Ministry of Energy, Mines and Petroleum Resources Assess. Rept. 7036, 17p.

Brown, R.L., 1980, Frenchman Cap Dome, Shuswap Complex, British Columbia; Current Research, Part A, Geological Survey of Canada, Paper 80-1A, pp.47-51.

Brown, R.L. and Psutka, J.F., 1979, Stratigraphy of the east flank of Frenchman Cap Dome, Shuswap Complex, British Columbia; Current Research, Part A, Geological Survey of Canada, Paper 79-1A, pp.35-36.

Buckley, R.A., 1976, Geological Report - 1975 Work Program, Jubilee Mountain, British Columbia. Dekalb Mining Corp., private report.

Buckley, R.A., 1977, Geological Report, Jubilee Mountain Prospect, British Columbia. Dekalb Mining Corp., private report.

Collins, J.A. and Smith, L., 1977, Genesis of cupriferous quartz arenite cycles in the Grinnell Formation (Spokane equivalent), Middle Proterozoic (Helikian) Belt-Purcell Supergroup, eastern Rocky Mountains, Canada: Bulletin of Canadian Petroleum Geology, v.25, p.713-735.

Cook, D.G., 1970, A Cambrian Facies Change and its Effect on Structure, Mount Stephen-Mount Dennis Area, Alberta-British Columbia: in Structure of the Southern Canadian Cordillera, G.A.C. Special Paper No.6, pp.27-39.

Ethier, V.G. and Campbell, F.A., 1977, Tourmaline concentrations in Proterozoic sediments of the southern Cordillera of Canada and their economic significance: Canadian Journal of Earth Sciences, v.14, p.2348-2363.

Fyles, J.T., 1959, Mineral King (Sheep Creek Mines Ltd.): B.C. Minister of Mines Annual Rept., 1959, pp.74-89.

Fyles, J.T., 1964, Geology of the Duncan Lake Area, Lardeau District, British Columbia: B.C. Dept. Mines and Pet. Res., Bull.49, 87p.

Fyles, J.T., 1970a, The Jordan River area near Revelstoke, British Columbia; B.C. Ministry of Energy, Mines and Pet. Res., Bulletin 57, 64p.

Fyles, J.T., 1970b, Geological Setting of Pb-Zn Deposits in the Kootenay Lake and Salmo Areas of B.C.: in Bull. No.61, State of Washington, Dept. of Natural Resources: "Pb-Zn Deposits in the Kootenay Arc, N.E. Washington and Adjacent B.C.", p.41-53.

Fyles, J.T. and Hewlett, C.G., 1957, Reeves-MacDonald Mine: in Structural Geology of Canadian Ore Deposits: CIM Congress Volume, p.110-115.

Fyles, J.T. and Hewlett, C.G., 1959, Stratigraphy and structure of the Salmo lead-zinc area: B.C. Ministry of Mines and Petroleum Resources Bulletin 41, 162 pages.

Gibson, G., 1979, Geological Report on the SOAB 4 and SOAB 5 Mineral Claims within the Boivin Group, Fort Steele Mining Division, 82J/3E, 82J/14E: B.C. Ministry of Energy, Mines and Pet. Res., Assess. Rept. 7489, 9p.

Gifford, R.G., 1971, Geological Survey, Hilo claim group, Fort Steele Mining Division: B.C. Ministry of Mines and Petroleum Resources Assessment Report 3300, 12 pages.

Hamilton, J.M., Bishop, D.T., Morris, H.C., Owens, O.E., (in press), Geology of the Sullivan Orebody, Kimberley, B.C., Canada: Geol. Assoc. Can. Special Paper.

Hedley, M.S., 1950, Monarch and Kicking Horse: B.C. M.M. Annual Rept., 1950, p.205-208.

Hoy, T., 1975, Geology of the Riondel area, southeastern British Columbia: B.C. Ministry of Mines and Petroleum Resources preliminary map 16.

Hoy, T., 1977, Big Ledge (82L/8E): in Geology, 1975, B.C. Ministry of Mines and Pet. Res., p.G12-G18.

Hoy, T., 1979a, Geology of the Estella-Kootenay King area, Hughes Range, southeastern B.C.: B.E.M.E.M.P.R. preliminary map 36.

Hoy, T., 1979b, Geology of the Goldstream: B.C. Min. Mines Bull.71, 49p.

Höy, T., 1979c, Cottonbelt lead-zinc deposit; B.C. Ministry of Energy, Mines and Pet. Res., Geological Fieldwork 1978, pp.18-23.

Hoy, T., 1979d, Stratigraphic and structural setting of stratabound lead-zinc deposits in the Shuswap Complex; in Evolution of the cratonic margin and related mineral deposits, Cordilleran section, Geological Association of Canada, p.18.

Hoy, T. , 1980, Geology of the Bews Creek area, southwest margin of Frenchman Cap Gneiss dome; B.C. Ministry of Energy, Mines and Pet. Res., Geological Fieldwork 1979, pp.17-22.

Höy, T. and McMillan, W.J., 1979, Geology in the vicinity of Frenchman Cap Geniss dome; B.C. Ministry of Energy, Mines and Pet. Res., Geological Fieldwork 1978, pp.25-30.

Kanasewich, E.R., Clowes, R.M., and McCloughan, C.H., 1969, A buried precambrian rift in western Canada: Tectonophysics, v.8, p.513-527.

Leech, G.B., 1958 , Fernie map-area, west half, British Columbia: Geological Survey of Canada paper 58-10.

Leech, G.B., 1960, Geology Fernie (west half), Kootenay District, British Columbia: Geological Survey of Canada, map 11-1960.

Lis, M.G. and Price, R.A., 1976, Large-scale block faulting during deposition of the Windermere Supergroup (Hadrynian) in southeastern British Columbia: Geological Survey of Canada, paper 76-1A, p.135-136.

McMechan, M.E., 1979, Geology of the Mount Fisher-Sand Creek area: B.C. Ministry of Energy, Mines and Petroleum Resources, preliminary map 34.

McMechan, M.E., Hoy, T. and Price, R.A., (in press), Van Creek and Nicol Creek Formations (New); A Revision of the Stratigraphic Nomenclature of the Middle Proterozoic Purcell Supergroup, Southeastern British Columbia: Bull. Can. Assoc. Pet. Geol.

McMillan, W.J., 1973, Petrology and structure of the west flank, Frenchman's Cap dome, near Revelstoke, British Columbia; Geological Survey of Canada, Paper 71-29, 87p.

McMillan, W.J. and Moore, J.M., 1974, Gneissic alkalic rocks and carbonatites in Frenchman's Cap Gneiss dome, Shuswap Complex, British Columbia; Cdn. Jour. Earth Sci., Vol. 11, pp.304-318.

Morton, R., Goble, E., and Goble, R.J. 1973, Sulphide deposits associated with precambrian Belt-Purcell strata in Alberta and British Columbia, Canada: in Belt Symposium v.1: Idaho Bureau of Mines and Geology, p.159-179.

Muraro, T.W., 1962, Stratigraphy, Structure and Mineralization at the Duncan Mine, Lardeau District, British Columbia: Unpublished M.Sc. thesis, Queens University, Kingston, Ontario.

Muraro, T.W., 1966, Metamorphism of Zinc-Lead Deposits in Southeastern British Columbia: in Tectonic History and Mineral Deposits of the Western Cordillera, CIMM Special Volume 8, p.239-248.

Ney, C.S., 1957a, Kootenay King Mine: in Structural Geology of Canadian Ore Deposits, CIM Congress Volume, p.153-160.

Ney, C.S., 1957b, Monarch and Kicking Horse Mines: in Structural Geology of Canadian Ore Deposits, CIM Congress Volume, p.143-152.

Price, R.A., 1962, Fernie map-area, east half, Alberta and British Columbia: Geological Survey of Canada, paper 61-24.

Price, R.A., 1964, The precambrian Purcell System in the Rocky Mountains of southern Alberta and British Columbia: Bulletin of Canadian Petroleum Geology, v.12, p.399-426.

Price, R.A. and Lis, M.G., 1975, Recurrent displacements on basement-controlled faults across the Cordilleran miogeocline in southern Canada: Geological Society of America, abstracts with programmes, p.1234.

Psutka, F.J., 1978, Structural setting of the Downie slide, northeast flank of Frenchman Cap Gneiss dome, Shuswap Complex, southeastern British Columbia; unpublished M.Sc. thesis, Carleton University, Ottawa, Ontario, 70p.

Ransom, P.W., 1977, Geology of the Sullivan orebody: in Hoy, T., ed., Lead-zinc deposits of southeastern British Columbia: Geological Association of Canada fieldtrip guidebook 1, [illegible]

Read, P.B., 1975, Lardeau Group, Lardeau Map-Area, West-Half (82K W½), British Columbia: Geol. Surv., Canada, Paper 75-1, Pt. A, p.29,30.

Read, P.B., 1976, Lardeau Map-Area, West-Half (82K W½), British Columbia: Geol. Surv., Canada, Paper 76-1A, p.95,96.

Read, P.B., 1979, Geology and Mineral Deposits, Eastern Part of Vernon East-Half, British Columbia: Geol. Surv. Can., Open File 616.

Reesor, J.E., 1965, Structural Evolution and Plutonism in Valhalla Gneiss Complex, British Columbia: Geol. Surve. Can. Bull.129, 125p.

Reesor, J.E., 1973, Geology of the Lardeau map-area, east half, British Columbia: Geological Survey of Canada memoir 369, 129 pages.

Reesor, J.E. and Moc , J.M., 1971, Petrology a Structure of Thor-Odin Gneiss Dome, Shuswap Metamorphic Complex, B.C.: G.S.C. Bull. 195.

Rice, H.M.A., 1937, Cranbrook map-area, British Columbia: Geological Survey of Canada memoir 207, 67 pages.

Sangster, D.F., 1970, Metallogenesis of some Canadian Lead-Zinc Deposits in Carbonate Rocks: Geol. Assoc. of Can. Proceedings, V.22, p.27-36.

Walker, J.F., 1926, Geology and Mineral Deposits of Windermere Map-area, British Columbia: G.S.C. Memoir 148, 65p.

Wheeler, J.O., 1965, Big Bend map-area, British Columbia; Geological Survey of Canada, Paper 64-32.

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TWO PHASES OF DEFORMATION IN THE KOOTENAY ARC

Preface

In a paper which appeared in the March issue of this journal, examples of the use of geological knowledge in exploration in the Kootenay arc were given. In that paper the importance of geological structure was emphasized, but the structure of the Kootenay arc was not described. In the following pages, two episodes in the long and complex structural history which the arc has undergone are described, and their general significance in exploration is briefly outlined.

TWO PHASES OF DEFORMATION IN THE KOOTENAY ARC*

By James T. Fyles**

The Kootenay arc is a relatively narrow curving structural belt in southeastern British Columbia extending southeast from near Revelstoke, south along Kootenay Lake, and southwest across the International Boundary into Washington. It is of great importance to mining in British Columbia because it contains mines which have produced a high proportion of the province's silver, lead, zinc, and tungsten, and substantial quantities of gold and copper. This production has come from the Lardeau, Slocan, Ainsworth-Bluebell, Nelson, Ymir, Sheep Creek, and Salmo mining camps. The Phoenix and Rossland camps are west of the arc; the Sullivan and mines of the east Kootenays are east of it.

The arc is in the Selkirk and Purcell Mountains and is a geological structure forming an integral part of a much larger deformed mountain system. It is a highly deformed belt of relatively steeply dipping sedimentary and volcanic rocks bowed about and lying mainly east of a major granitic area containing the Nelson and Kuskanax batholiths. Granitic stocks more or less closely related to the batholiths intrude the arc and extend some distance to the east of it. West of the batholithic area in the western part of the Selkirks and in the Monashee Mountains is a major gneissic complex. East of the arc in the Purcell Mountains

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**Geologist, Mineralogical Branch, Department of Mines and Petroleum Resources, Victoria, B.C.

is a belt of open folding thought to have the form of a broad anticlinorium. The Purcells are separated from the Rockies to the east by the Rocky Mountain Trench.

Because of past production and potential mineral wealth in the Kootenay arc, and in order to aid and stimulate exploration, the British Columbia Department of Mines and Petroleum Resources has been maintaining a programme of geological work in the arc for a number of years. This work has been mainly detailed mapping of relatively large areas in and close to mining camps together with studies of the form and occurrence of mineralization at various mines. To date, five studies in widely separated parts of the arc have been completed and two are in progress. Only in the last few years has it been possible to recognize a unity of structural pattern between the areas studied. Although the work is still in progress and much remains to be learned, it is possible now to give a preliminary account which correlates certain important structural features of the arc.

Deformation in the Kootenay arc has taken place over an extended period of time. Several phases of deformation are recognized. The general features of the two oldest known phases of deformation are described in the following pages and illustrated by three cross-sections: one northeast of Trout Lake, a second at the north end of Kootenay Lake, and a third in the Salmo district near the International Boundary (*see* Fig. 2).

Geological information between these sections and beyond them is not yet detailed enough to permit the construction of other sections but it is known that the patterns found in the areas studied in detail and presented here are characteristic of the deformation of the arc in general.

Summary of General Geology

The Kootenay arc contains a thick succession of sedimentary and volcanic rocks ranging in age from earliest Cambrian to late Mesozoic. The succession is essentially a conformable one though a disconformity is thought to be present in the late Palaeozoic and probably others exist which have not yet been found. One of the most significant markers in the succession is a limestone known as the Badshot in the Lardeau and Kootenay Lake country and as the Reeves limestone south of Nelson near Salmo (*see* Fig. 1). The Reeves limestone contains Lower Cambrian fossils and it is almost certain that the Badshot is also Lower Cambrian though no fossils have yet been found in it within the Kootenay arc. The limestone, which is repeated by complex folding, outcrops in a belt, locally as much as 10 miles wide, along the eastern side of the arc. Rocks to the east of this belt in general are older than the limestone and those to the west are younger. The older rocks pass downward into the Precambrian, and the younger ones comprise a thick succession extending into the Jurassic.

The names and lithologies of some of the Palaeozoic formations are summarized in the accompanying chart. In the Lardeau district are three groups: the Hamill, Lardeau, and Milford. The Hamill is quartzitic, the Lardeau has a lower calcareous section, containing the Badshot limestone, overlain by a thick succession of schists and quartzites with lenticular masses of volcanic rock. One of the most distinctive markers in the schist-quartzite succession is a grey, massive quartzite known as the Ajax. In the Salmo district the lower part of the succession is very similar lithologically to that in the Lardeau district. The lowest group (Quartzite Range and Reno formations) is quartzitic and the overlying Laib has a lower calcareous part, containing the Reeves limestone, beneath a thick succession of schists and minor quartzites. The overlying Nelway, which is limestone and dolomite, and the Active formation of dark slate and argillite occur widely especially in Washington but are not found far north of the latitude of Ymir. Cambrian fossils are present in the Nelway and Ordovician in the Active. The Milford group of slate, chert, and limestone which contains late Palaeozoic fossils has been known for some time north of Kaslo but is only tentatively identified to the south.

In general rocks comprising the arc are in the muscovite-chlorite grade of regional metamorphism. The grade increases near Kootenay Lake and rocks along the lake are mainly in the garnet grade. Locally on both sides of the lake near the shore at Ainsworth, Bluebell, and south to the West Arm of the lake the

PALAEOZOIC FORMATIONS - KOOTENAY ARC

SALMO DISTRICT			LARDEAU DISTRICT		
Milford (?)		Argillite, chert, and limestone	Milford		Slate, chert, and limestone
Disconformity (?)					
Active		Slate and argillite	LARDEAU	Broadview	Grit, phyllite, minor volcanic rocks
				Jowett	Mafic flows and pyroclastics
				Sharon Creek	Dark grey siliceous argillite
Nelway		Limestone and dolomite		Ajax	Grey quartzite
				Triune	Dark grey siliceous argillite
Laib	Upper Laib	Phyllite and schist; minor quartzite and limestone		Index	Grey and green phyllite and minor limestone
	Emerald	Black argillite			
	Reeves	Grey limestone		Badshot	Grey limestone
	Truman	Phyllite and argillite; minor limestone		Mohican	Phyllite and minor limestone
Reno		Micaceous quartzite	HAMILL	Marsh Adams	Micaceous quartzite
Quartzite Range		White and micaceous quartzite		Mount Gainer	White and micaceous quartzite

rocks reach the sillimanite grade.

Central Lardeau District

The structure of the rocks in the central part of the Lardeau district is characteristic of the northwesterly trending part of the arc and is representative of the oldest deformation known. The pattern of folding is shown in section A-A' of Figure 3. The northeastern part of the section is along a tributary of Lardeau Creek, called Gainer Creek, which cuts deeply across the structure. The southwestern part of the section crosses Silvercup Ridge northeast of Trout Lake. In general the rocks are folded on axes which have a low plunge and into folds which have the cross-sectional form of a letter N as seen looking to the northwest. The shape of the folds in the oldest rocks near the eastern end of the section is outlined by the Badshot formation, a banded grey and white limestone a few hundred to as much as 1,000 feet thick. On Badshot Mountain about 10 miles northeast of Trout Lake the limestone dips steeply to the southwest. It is on the southwestern limb of an almost isoclinal anticline. Northeast of the anticline the limestone occurs in the trough of a tight syncline, and the anticline and syncline together form an N-shaped fold. Southwest of Badshot Mountain the limestone, or a limestone stratigraphically close to it, is repeated several times in a series of isoclinal folds which together have the same N-shaped form.

To the southwest and higher in the stratigraphic succession folds are outlined by the Ajax quartzite, a blocky grey massive quartzite a few tens to several hundred feet thick. Three miles southwest of Badshot Mountain the Ajax quartzite dips steeply to the southwest. It overlies an isoclinally folded and sheared series of phyllites and limestones and the base of the quartzite is a smooth shear plane. The quartzite itself and the overlying argillites, quartzites, and volcanic rocks are folded into a series of more or less concentric folds which are step-like and N-shaped in section. About 3 miles farther to the south-west the quartzite is repeated twice on the limbs of a large anti-cline known as the Silvercup anticline. The anticline together with the syncline to the northeast have the N-shaped form. South-west of the Silvercup anticline as far as Trout Lake there are no major folds which again bring the quartzite or older rocks to surface. Structures in the younger rocks have the same form.

The pattern of N-shaped folds implies a relative move-ment of the southwest upward and over the northeast. Shapes of individual folds and the attitudes of related shear planes seen in the field vary widely but this same sense of relative movement may be deduced from almost any exposure. Deformation with this sense of relative movement is recognized throughout the arc. It is the oldest known deformation and structures associated with it are referred to as phase I structures.

South Lardeau Structure

In the southern part of the Lardeau district around

Duncan Lake and the north end of Kootenay Lake these phase I structures have been folded. Phase I folds are isoclinal and extremely attenuated. In general, convergence of the limbs cannot be measured in the field and the point where the limbs meet, called the hinge of the fold, cannot be seen. The folds are recognized from a knowledge of stratigraphic relationships and by tracing rock units relatively great distances. These folds plunge to the north at about 10 degrees.

Structures resulting from the deformation of phase I folds are referred to as phase II structures. They consist of faults and folds which in the south Lardeau plunge at about the same angle to the north as the phase I folds. The folds range in shape from very tight to relatively open, and in size from a few feet across to folds with axes several miles apart. These folds can be seen in the field and in general are outlined by the attitudes of foliation planes. Ideally complete phase II folds are composed of an anticline lying east of a complementary syncline giving the form of a reversed letter N (И).

Both phase I and phase II folds are shown in section B-B' of Figure 3. The section is along the steep north slope of Hamill Creek where the topographic relief is 4,000 to 5,000 feet. It crosses the Duncan River valley just north of the north end of Kootenay Lake. The folds are outlined by the Badshot and adjacent formations and the major structure is confirmed by minor structures which are plentiful particularly in the Hamill quartzites. At the eastern edge of the section is a large phase II double fold. The fold consists of a relatively tight anticline lying east of an open upright syncline. The distance between the axis of the anticline and that of the syncline is about 3,000 feet. The stratigraphic succession in general is upside down; quartzites which are stratigraphically beneath the Badshot limestone are in the trough of the syncline and the flanks of anticline. The axial planes of relatively small isoclinal phase I folds are more or less parallel to the foliation and follow around the phase II folds. Phase I folds are difficult to define in the field and are complexly disrupted by flow and by slip on a steeply dipping cleavage. This cleavage is approximately parallel to the axial planes of the phase II folds. Lineations and dragfolds indicate that the axes of the phase I and phase II folds plunge less than 10 degrees to the north and are essentially parallel.

Two to 3 miles to the west the Badshot and underlying rocks are repeated. They form an isoclinal anticline, known as the Duncan anticline with a series of subsidiary isoclinal folds immediately west of it. These are phase I folds. Their axial planes are sharply warped so that in the vertical interval provided by the topographic relief the axial planes are concave to the west. The axis of the warp appears to plunge gently to the north as does the axis of the Duncan anticline. A steeply west-dipping cleavage and the projection of attitudes of foliation from down the plunge suggest that the warp which is concave to the west has a complementary warp above it which is concave to the east. This form is indicated diagrammatically in section B-B', Figure 3.

A mile or two to the west, on the eastern side of the Duncan Valley where the Badshot and underlying quartzites are again repeated, the foliation dips at moderate angles to the east. It gradually flattens farther west, and on the west side of the valley dips gently to the west. The foliation is more or less parallel to axial planes of isoclinal phase I folds and the arch which straddles the Duncan Valley is in fact a broad, upright, phase II fold. It plunges to the north and is well defined 2 to 3 miles north of the section. Geological studies west of the Duncan Valley, though incomplete, suggest that the axis of a relatively tight phase II syncline sketched diagrammatically at the west edge of section B-B', Figure 3, lies a short distance west of the valley.

In general in the south Lardeau, phase I folds have the same pattern as in the north Lardeau. Stratigraphically the rocks become progressively older toward the east. Phase I folds before folding probably formed a more or less step-like sequence rising to the east. They can be regarded as N-shaped in section, seen from the south, from which it may be inferred that they formed by a relative movement of the west upward and over the east. Phase II folds have the opposite cross-sectional form, that is, the form of a reversed letter N (И), and it may be inferred that they developed in response to a relative movement of the east upward and over the west. This inference is supported by field observations of minor structures.

Salmo Structure

The structure of the Salmo district is complicated by faults, granitic intrusions, and an abrupt swing in the regional strike. Section C-C', Figure 3, is across a part of the area where the regional strike is north and the plunge of the folds is low. In spite of this, structures are recognized which fit the pattern of phase I and phase II structures known in the Lardeau. Structures belonging to several phases of deformation are pronounced in the Salmo district but the two oldest recognized have the same form and indicate the same patterns of relative movement as those in the north. On the eastern edge of the section the Reeves limestone is repeated on the limbs of an isoclinal syncline, the Laib syncline, west of which is a complementary anticline known as the Sheep Creek anticline. These are phase I folds, and are typical of structures in the Eastern belt of the Salmo district. These structures are followed to the west by a complex deep syncline called the Black Argillite belt and containing incompetent rocks of the Ordovician Active formation. West of the Black Argillite belt are complexly folded rocks belonging to formations between the uppermost members of the Quartzite Range formation and the top of the Laib formation. They are in the Mine belt and in broadest structural form are anticlinal. The Mine belt and the synclinal Black Argillite belt together with the Sheep Creek anticline and Laib syncline form a sequence of phase I folds which before phase II deformation probably had a pattern similar to that in the Lardeau sections, and a relative movement of west over east is inferred.

Phase II folds predominate in the Mine belt and phase I folds are relatively obscure. Minor structures, particularly dragfolds, suggest the presence of phase I structures and large phase I folds, strongly sheared, are recognized from repetitions of the stratigraphic succession. Phase II folds are defined by the attitudes of foliation planes and are readily seen and mapped. They range from tight to relatively open and the form of the folds and related faults indicates a relative movement of east over west. Probably the best-known folds of this type are in the Jersey mine. In the northern part of the Mine belt near the Jersey mine, axes of phase I and phase II folds appear to be nearly parallel.

Phase II folds are also present in the Black Argillite and Eastern belts. Although structural details are poorly known in the Black Argillite belt it is clear that the axial planes of isoclinal folds have been folded on gently plunging axes. Normally steeply east dipping axial planes flatten in dip, then steepen again upward to the west. Similarly in the Eastern belt axial planes of the phase I folds are warped on axes with a low plunge. Locally tight dragfolds indicating a relative movement of east over west are superimposed on phase I folds.

The structural belts in the Salmo area are separated by faults. They are strike faults, in general steeply dipping in the north and moderate to gently east and southeast dipping farther south where the regional strike swings to the west. They appear to be thrust or reverse faults with a relative movement of east up and over west.

Thus in the Salmo area two phases of deformation can be recognized which, though complicated by later structural events, show the same patterns of relative movement as are found in the Lardeau district.

Regional Extent

Interpolation of the structure between the Salmo country and the north end of Kootenay Lake is difficult because little is known of the structural detail in the 40 to 50 mile stretch between northern Kootenay Lake and Ymir. Some generalized structures can be inferred from regional maps. Foliation dips persistently at moderate angles to the west along Kootenay Lake and on the hills south of the West Arm. The two oldest phases of folding are recognized in these westward dipping rocks in current work in the Ainsworth camp. The regional foliation appears to be parallel to axial planes of isoclinal phase I folds which probably have a low plunge. These folds are folded on gently plunging axes into small and large folds which cause a pronounced steepening of the foliation and locally a reversal to an eastward dip. Regionally dips of foliation along the lake are to the west. At higher elevations west of the lake the dips are steeper and at many places they are to the east. In general phase II deformation has produced a huge fold of the foliation and hence of phase I folds which is concave to the west. Elements of this fold which can be inferred from regional maps suggests that it extends through the country west of Kootenay Lake and southward toward Salmo. Near Kaslo a major split of the fold swings to the northwest between the Nelson and Kuskanax batholiths. In the Slocan camp a fold with similar form, concave to the southwest with dominantly northeastward dips, has been carefully studied and is referred to as the Slocan fold (see Hedley, 1952). The recent recognition of the two phases of deformation implies that the Slocan fold like the closely parallel counterpart of it to the southeast is a phase II structure.

Regional extrapolation beyond the Kootenay arc is even more speculative than interpolation of structures within it. On a broad scale structures in the Purcell Mountains to the east are overturned toward the east and thrusting indicates a relative movement of west over east. Possibly phase I folds in the Kootenay arc are part of a much larger set of structures formed in response to this same sense of relative movement. Phase II structures may be more local, dying out toward the north and west and becoming more intense toward the south.

Other Phases of Deformation

The two phases of deformation described in the foregoing pages are only part--the oldest known part--of the deformation of the Kootenay arc. Details of the complete structural history are still poorly known and no additional fold or fault patterns of regional extent are yet recognized with certainty. In all areas in which detailed studies have been made, phase I and phase II structures are more or less warped, sheared, broken by faults, or intruded by igneous and plutonic masses.

The Nelson and Kuskanax batholiths and many of the granitic stocks have local zones of intense deformation around their margins. On the northern edge of the Nelson batholith the Slocan fold is buckled downward within a mile or so of exposed granitic rocks. On the eastern edge of the batholith north of Ainsworth phase I and phase II folds are warped sharply upward within 3,000 feet of the granitic rocks. The Hidden Creek stock in the Salmo district is surrounded by a zone in which the regional strike is deflected into near parallelism with the margins of the stock. A few miles to the north, the Porcupine Creek stock is ringed by upturned sedimentary rocks. Regional maps of the northern part of Kootenay Lake show an abrupt swing in strike near the Fry Creek batholith and to the east the White Creek batholith has a spectacular peripheral deformed zone. It is possible that warps of this type preceded and controlled the formation of the granitic masses and forceful intrusion further modified the warps.

Fold axes near plutonic masses commonly plunge steeply but steeply plunging folds are also found far from plutonic masses. They are associated with cross warps or strike-slip movements of one sort or another. Because of the plunge they cause a change in the formational strike. Patterns of small steeply plunging folds have been delimited by detailed studies of local areas and large-scale trends in strike are outlined on regional maps. Correlations of such patterns and trends have not yet been made. One key to a complete understanding of the structural history, the sequence of igneous and plutonic rocks, is still to be studied.

Relation of Structure to Mineralization

Geological studies in the Kootenay arc by the British Columbia Department of Mines and Petroleum Resources have been of mining camps and have been aimed at learning more of the occurrence and localization of orebodies and mineralized zones. One general conclusion of these studies, of considerable importance in exploration, is that mineralization is controlled by structure. This control may be in determining the form and continuity of the host rock or it may be in influencing deposition of the sulphides. Some examples of the importance of structure in exploration at specific properties have been given in a preceding paper. Only the general significance of phase I and phase II structures is considered here.

Phase I folds have controlled the distribution, continuity, and thickness of the host rocks and in many places have also determined the mechanical and chemical properties of favourable beds. Recognition of phase I folds is of considerable practical importance in exploration. Favourable rocks that are folded into an isoclinal syncline with low plunge cannot be expected to extend indefinitely in depth. Folded layers at the trough or crest of the fold have longest dimensions parallel to the fold plunge. A layer mineralized on one limb of a fold may also be mineralized on another limb. Repetitions of favourable layers are to be expected in the Kootenay arc. Phase I folds are isoclinal or nearly so, and fold hinges are rarely seen. Beds on the limbs of folds may continue for such great distances down the dip that an isoclinally folded sequence may for practical purposes be regarded as a homoclinal succession. On the other hand beds may pinch out very rapidly on fold crests.

Phase I structures are important in exploration because they control the geometry of the host rocks but continued studies have shown that they are not commonly mineralized. Mineralized zones frequently are found which follow phase II folds and related shears. Veins and lodes and associated replacement zones occur in a variety of later structures which may or may not be influenced by phase II structures. It appears that it is some modification of the phase I structures and not the phase I structures themselves that have controlled mineralization.

Studies of the Salmo lead-zinc deposits have shown that many orebodies there are associated with phase II structures (see Fyles and Hewlett, 1959, pp. 87, 103, 118).* At the Jersey mine the A zone follows a faulted dragfold overturned toward the west. The C and D zones are along a broad anticline plunging gently to the south that is a phase II fold. The Reeves orebody is in a steeply plunging syncline which is regarded as a phase II structure. In the Duncan mine and on the Bannockburn property in the Lardeau district the mineralized zones are closely associated with phase II folds and shears. Replacement at the Bluebell mine (see Irvine, 1957) has extended outward from cross fractures along a number of favourable structures. Some of these are phase II folds.

The recognition of structural types in the field is difficult and may be most puzzling in the early stages of prospecting and exploration when it is most useful. Geological studies on a regional basis will give the background necessary for the recognition and understanding and will show some of the significance of controlling structures. Only continued and careful observations made on a property as exploration, development, and mining proceed will give the data necessary for a full understanding of structural control. In conclusion it is clear that the two phases of deformation described in this paper are extremely important in exploration in the Kootenay arc.

*The terms primary and secondary used in Bulletin No. 41 are synonymous with phase I and phase II as used here.

References

Fyles, J. T. (1962): Recent Developments in Exploration and Prospecting in the Kootenays, Western Miner and Oil Review, February, 1962.

__________ and G. E. P. Eastwood (1962): Geology of the Ferguson Area, Lardeau District, British Columbia, B. C. Dept. of Mines, Bull. No. 45.

__________ and C. G. Hewlett (1959): Stratigraphy and Structure of the Salmo Lead-Zinc Area, B. C. Dept. of Mines, Bull. No. 41.

Hedley, M. S. (1952): Geology and Ore Deposits of the Sandon Area, British Columbia, B. C. Dept. of Mines, Bull. No. 29.

Irvine, W. T. (1957): The Bluebell Mine, Can. Inst. Min., Structural Geology of Canadian Ore Deposits, Vol. II, pp. 95-104.

Little, H. W. (1960): Nelson Map-Area, West Half, British Columbia, Geol. Surv., Canada, Mem. 308.

Mathews, W. H. (1953): Geology of the Sheep Creek Camp, B. C. Dept. of Mines, Bull. No. 31.

Reesor, J. E. (1957): Lardeau (East Half), Geol. Surv., Canada, Map 12-1957.

__________ (1958): Dewar Creek Map-Area, British Columbia, Geol. Surv., Canada, Mem. 292.

Rice, H. M. A. (1941): Nelson Map-Area, East Half, British Columbia, Geol. Surv., Canada, Mem. 228.

Walker, J. F. and Bancroft, M. F. (1929): Lardeau Map-Area, British Columbia, Geol. Surv., Canada, Mem. 172.

GEOLOGY AND EXPLORATION IN THE KOOTENAYS, BRITISH COLUMBIA

James T. Fyles

ABSTRACT

This paper is concerned with the recent geological work and its bearing on exploration in a part of the Kootenay district of southeastern British Columbia known as the Kootenay arc. The Kootenay arc is a curving belt of lime-bearing sedimentary and volcanic rocks bowed around the eastern margins of two granitic batholiths, the Kuskanax batholith in the north and the Nelson batholith in the south. The arc contains most of the major mining camps in the west Kootenay district; these are (from south to north) the Salmo, Sheep Creek, Ymir, Nelson, Bluebell-Ainsworth, Slocan, and Lardeau camps. They have produced impressive quantities of lead and zinc and substantial amounts of gold, silver, copper, and tungsten.

Rocks comprising the arc range in age from late Precambrian to late Mesozoic. The Palaeozoic formations are shown in the accompanying table. Mesozoic rocks lie to the west of the Palaeozoic between the two batholiths and south of them, and Precambrian rocks lie to the east.

The structure of the arc is dominated by complex folds which have developed over an extended period of time (probably all within a late Mesozoic orogeny) under varying structural conditions. The oldest structures recognized, called phase I structures, are isoclinal or nearly isoclinal folds and related shears. The folds have a low plunge. Axial

planes in general dip steeply, but they are folded. Together phase I folds have a pattern indicating a relative movement of rocks on the west side of the arc upward and over those to the east.

Phase I structures have been folded and disrupted by phase II folds and faults. In general, phase II folds are open or tight and have a low plunge more or less parallel to the plunge of the phase I folds. Complete phase II folds have a form suggesting an opposite sense of relative movement to that of the phase I deformation, that is, the east side upward and over the west.

Phase I and phase II structures are present throughout the arc and each though differing in detail shows a consistent pattern of form. They are illustrated by three cross-sections: one in the central Lardeau, one in the south Lardeau, and one in the Salmo district.

These structures swing gradually in strike with the trend of the arc but locally are warped by folds that may be regarded as phase III structures. Phase III structures vary in form from place to place. They may be broad open warps or tight local folds. Commonly they have a relatively steep plunge or cause phase I and II structures to plunge steeply.

The structure of the arc has affected the localization of mineral deposits in many ways and a knowledge of the structure is essential to a full understanding of camps, mines, and orebodies. Phase I structures largely control the geometry of the host rocks. Phase II structures have produced channelways and sites of deposition for the Salmo type lead-zinc replacement deposits. Phase III structures in conjunction with older ones have controlled other types of mineralization.

Deposits of the Salmo type are replacements of pyrite, sphalerite, and galena in calcareous rocks. Mainly deposits of this type are in a lower Cambrian limestone-dolomite formation, but locally they are found in other formations. One of the most important features of these deposits is that the longest dimension of the known orebodies is parallel to the plunge of folds in the surrounding rocks. In the northern part of the Salmo district the plunge is low, a fact which before it was appreciated cost heavily and caused much waste of time and effort. In the southern part of the Salmo camp the plunge is steep and surface exposures show only the smallest dimensions of the ore-shoots. At Duncan Lake, a few miles north of the north end of Kootenay Lake, recently developed mineralized zones are on the eastern limb of an isoclinal anticline that plunges at low angles to the north. The mineralized zones are along a contact between dolomite and siliceous dolomite, and ore-shoots within the zones plunge northward parallel to fold axes in the enclosing rocks. To the north the favourable contact plunges beneath Duncan Lake on the crest of the anticline. To the south the contact has been traced on both limbs of the anticline and scattered mineralization has been found along it for as much as 10 miles south of Duncan Lake and several zones have been drilled.

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PALAEOZOIC FORMATIONS - KOOTENAY ARC

SALMO DISTRICT			LARDEAU DISTRICT		
Milford (?)		Argillite, chert, and limestone	Milford		Slate, chert, and limestone
Disconformity (?)					
Active		Slate and argillite	LARDEAU	Broad-view	Grit, phyllite, minor volcanic rocks
				Jowett	Mafic flows and pyroclastics
				Sharon Creek	Dark grey siliceous argillite
Nelway		Limestone and dolomite		Ajax	Grey quartzite
				Triune	Dark grey siliceous argillite
Laib	Upper Laib	Phyllite and schist; minor quartzite and limestone		Index	Grey and green phyllite and minor limestone
	Emerald	Black argillite			
	Reeves	Grey limestone		Badshot	Grey limestone
	Truman	Phyllite and argillite; minor limestone		Mohican	Phyllite and minor limestone
Reno		Micaceous quartzite	HAMILL	Marsh Adams	Micaceous quartzite
Quartz-ite Range		White and micaceous quartzite		Mount Gainer	White and micaceous quartzite

RECENT DEVELOPMENTS IN EXPLORATION AND PROSPECTING IN THE KOOTENAYS*

By James T. Fyles**

Prospecting and exploration in the Kootenays have gone on for many years. Most of the major camps were discovered before the turn of the century. Since that time a great deal of new ore has been found mainly in old properties and old camps. Mining has been continuous, although relatively few mines have produced for more than fifteen consecutive years. Production and reserves have been maintained only through active exploration. In mining much has been learned about the form and occurrence of orebodies, and some progress has been made in understanding the localization of mineralized zones and camps. This knowledge forms the basis of recent exploration.

Because economics plays a controlling part in the development of a mine, the importance of new discoveries is difficult to assess. The re-discovery of a showing abandoned long ago as uninteresting under the economic conditions of the time, the recognition in an old deposit of a material that has recently become valuable, or a new understanding of the potential of an old showing may be more important than the discovery of a new showing. New showings are being found in the Kootenays but the reassessment of old showings, mines, and camps is increasingly important.

Basic knowledge on which both reassessment and new prospecting depend has been gained through years of experience

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**Geologist, Department of Mines and Petroleum Resources, Victoria, B.C.

in mining and exploration. It has been obtained by individuals, by companies, and through government surveys. Much of the information was collected as mining progressed. To be of value now, it had to be gathered years ago. In the same way data are being collected now that will be of value in the future. Much of this information is geological. Geological data are particularly important in the Kootenays because many of the mineralized rocks are amenable to geological studies and much of the mineralization is controlled by discernible geological factors. Many deposits occur in deformed sedimentary and metamorphic rocks in which rock types can be traced and mapped, and stratigraphy and structure determined. Studies have shown firstly that mineralization and chemically favourable rock types are widespread in the Kootenays. Secondly, most mines and camps are not spatially related to granitic masses. Orebodies which are associated with granitic masses are either within a relatively narrow aureole of thermal metamorphism or in a structurally favourable zone related to intrusion. Finally, it is clear that orebodies and mineralized zones are locallized by structure. Structure has affected mineralization in a number of ways which may be classed broadly as the control of the geometry of the host rocks and the control of the deposition of the sulphides. A knowledge of the structure is essential to an understanding of the distribution of favourable rocks and in predicting the form and occurrence of mineralized zones.

In the following paragraphs recent developments in exploration and prospecting are discussed as examples of the use of geological knowledge in finding new mineralization. The importance of the structure is emphasized. Most of the examples are from the Kootenay arc, largely because this is the part of the Kootenays with which I am most familiar. The Kootenay arc is in the West Kootenays extending southeast from Revelstoke, south along Kootenay Lake, and southwest across the International Boundary. It includes the Lardeau, Slocan, Ainsworth-Bluebell, Nelson, Ymir, Salmo, and Sheep Creek mining camps. Rossland is to the west and Kimberley well to the east. Although the examples taken are from only a part of the Kootenays, developments in the Kootenay arc represent the greater part of the recent developments in the Kootenays in general.

The first examples are of replacement lead-zinc deposits of the type that are currently being mined in the Salmo district (<u>see</u> Fig. 1). The next are of examples of recent activities near Revelstoke and the last is a discussion of recent work in the Ainsworth camp.

Salmo District

Exploration, mining, and geological studies in the Salmo lead-zinc district have gone far enough that considerable geological data is now available. The area is readily accessible, and has been prospected for many years. It seems likely that most of the surface showings have been found and in the intense search for lead and zinc that was made between 1947 and 1953 only one new showing came to the attention of the writer and it may well have been discovered previously and passed over. Recent exploration has therefore been directed toward extending the known mineralized zones and toward testing old prospects and whatever covered ground may be close to them.

A generalized geological map of the Salmo area (Fig. 2) shows that the major lead-zinc deposits lie in a belt, known as the Mine Belt, which runs southward east of the Salmo River and curves westward across the Pend d'Oreille. Essentially all the ground in the obviously favourable parts of the Mine Belt is held and much of it has been drilled or otherwise tested. Regional geology suggests that there should be favourable ground on the eastern side of the structural belt lying east of the Mine Belt but there are very few showings and little encouragement for even wildcat exploration.

The lead-zinc deposits in the Mine Belt are replacements of dolomitized limestone by pyrite, sphalerite, and galena. One of the most important facts to be considered in exploration is that the long dimension of the known orebodies is parallel to the plunge of folds in the surrounding rocks. In the northern part of the belt the plunge is low, a fact which before it was appreciated cost heavily and caused much waste of time and effort. In the south the plunge is steep, so that surface exposures show only the smallest dimensions of ore-shoots. The plunge is not always constant and recent exploration at the H.B. has been directed toward following the main orebody through a series of warps of the plunge. At the Reeves MacDonald where the plunge is steep, exploration has been aimed at following the main orebody down the plunge (see Fig. 3). The orebody plunges about 55 degrees to the southwest and is broken by northerly trending faults. Two faulted segments have been known for some time. Recently a third, called No. 4 zone, has been found east of the other two and appears to be up the plunge from them. The main zone has been developed below the 1900 level and recent drilling indicates that it continues down the plunge at least to the 500 level. By adding together the lengths of the four faulted segments a total plunge length of at least 5,000 feet is indicated.

Continued exploration for lead and zinc in the Salmo area depends initially on the analysis and interpretation of geological data. Exploration will be mainly a search for orebodies that are not exposed. Their discovery depends on an understanding of the complex geometry of the favourable rocks and an anticipation of structural sites which may be favourable for mineralization. Recently two old properties, the Aspen, north of the H.B., and the Lucky Boy, south of the H.B., have been drilled after an analysis of the geological data. Currently drilling and underground work are being done on the same basis at the Red Bird property southwest of the Reeves MacDonald.

South Lardeau District

Deposits of lead and zinc similar to those in the Salmo area have recently been developed on Duncan Lake a few miles north of the north end of Kootenay Lake (see Fig. 1). The Duncan mine is an old property on which several individuals and companies have worked intermittently for a number of years. The present exploration programme by The Consolidated Mining and Smelting Company of Canada, Limited was based on a thorough geological study. The most valuable facts obtained in the study were a detailed knowledge of the local stratigraphy and the determination of the plunge of small as well as large scale structures.

Drilling and underground exploration at the Duncan mine on the peninsula on the east side of Duncan Lake (Fig. 4) has outlined zones containing pyrite, galena, and sphalerite along the contact between a dolomite and a siliceous dolomite in a calcareous rock unit known as the Badshot formation. Ore-shoots within the mineralized zones plunge at low angles to the north parallel to the axes of folds in the enclosing rocks. On the peninsula and adjacent mainland to the south seven shoots are known each of which contains a substantial tonnage of low-grade lead-zinc ore.

The mineralized zones are on the eastern limb of an isoclinal anticline that plunges northward and to the north carries the favourable contact beneath Duncan Lake. To the south the Badshot formation occurs on both limbs of the anticline.

The success of the exploration programme at the Duncan property stimulated prospecting in the surrounding country. The prospecting was geologically guided. Prospectors learned the lithologic succession and know where favourable structures and contacts are to be found within the succession. They have followed and mapped the limestones and dolomites tracing them southward from the Duncan mine, and have been successful in finding scattered occurrences of lead-zinc mineralization. Two mineralized zones discovered by this work, the Mag property on Lavina Mountain east of the south end of Duncan Lake (see Fig. 1) and the Sal on Mount Willet east of Kootenay Lake have recently been drilled by the Consolidated company.

Replacement deposits of the Salmo-Duncan type are found in the Badshot-Reeves limestone, a lower Cambrian formation widely exposed in the arc by repetitive folding. Although this horizon contains the most productive zones now known, the mineralized zones are controlled primarily by structure and to a lesser degree by stratigraphy.

A deposit somewhat similar to those on Duncan Lake which has received attention recently is the Shelagh "vein" on the Bannockburn property about 20 miles northwest of Duncan Lake. It is on the south side of and near head of Hall Creek in mountainous country at an elevation of about 6,000 feet. Fine-grained galena and sphalerite are disseminated in a limy quartzite a few feet to as much as 40 feet thick, several hundred feet stratigraphically below the Badshot limestone. The mineralized zone has been traced intermittently for 3,500 feet along strike and similar mineralization in the same structure is found on the north side of Hall Creek a mile to the north. Mineralization appears to be controlled by structures which have a low plunge and are similar to the controlling structures at Duncan Lake. The average grade of the mineralization is probably no more than 4 per cent combined lead and zinc, mostly lead. The deposit is significant because it shows that replacement mineralization of the Salmo-Duncan type is not confined to one horizon, and that favourable rocks and structures are present for a considerable distance northwest of Duncan Lake.

Revelstoke District

A natural extension of the Kootenay arc lies northwest of the Lardeau country, north and south of Revelstoke. In this northwesterly extension in the last five years several lead-zinc deposits have received attention, considerable prospecting has been done, and at least one new large mineralized zone has been found.

The River Jordan property on the northern slope of Mount Copeland 12 miles northwest of Revelstoke is held by American Standard Mines Limited and was explored by them in 1956 and by Bunker Explorations Ltd. in 1958. The mineralized zone has been described as a sheet-like mass of fine-grained pyrite, pyrrhotite, galena, and sphalerite and which has the form of an essentially isoclinal syncline. The sulphides appear to have replaced a single stratigraphic bed lying close to a white marble. Mineralization is extensive and more or less continuously exposed along the limbs of the syncline for 7,500 feet. Grades as high as 10 per cent combined lead and zinc over widths of 1 to 8 feet are reported.

Mineralization very similar in character and association to that at the River Jordan property has been found recently by Ventures Limited near the head of Ruddock Creek 60 miles northwest of Revelstoke. Somewhat similar mineralization has been known for many years on the Wigwam property 20 miles south of Revelstoke and is currently being explored by the Consolidated company. These three properties have some features in common with those at Duncan Lake and in the Salmo district. Probably lessons learned in these areas will be of value in exploration of the properties near Revelstoke.

Seventeen miles north of Revelstoke at the Mastodon mine relatively small shoots of high-grade zinc ore have been mined in recent years. The shoots are replacements of limestone, dolomite, and schist at structurally favourable sites along almost bedded shear zones. The rocks are isoclinally folded and the shear zones cut the folds at a slight angle (<u>see</u> Fig. 5). In places the shear zones themselves have been mineralized forming more or less tabular orebodies. More commonly plunging folds transected by the shear zones are mineralized and locally cleavage planes cut obliquely by the shear zones are also mineralized. The folds do not have the same plunge throughout the mine, and this together with the long angle at which the shear zones intersect the folds makes an exceedingly complex distribution of rock types and mineralized zones. An understanding of this distribution is the key to the exploration and mining of the orebodies. The orebodies plunge at a low angle to the north. They lie on or close to the shear zones. Because of these facts a shear zone which may be well mineralized on two adjacent levels may be barren for a greater part of the distance between the levels. Orebodies die out along the plunge because the folds are not parallel to the strike of the shear zones.

Ainsworth

As a final example of recent exploration in the Kootenays the work of The Consolidated Mining and Smelting Company of Canada, Limited and Western Mines Limited in the Florence and Lakeshore section of the Ainsworth camp will be considered. It has long been recognized that in some respects geology of the Ainsworth camp on the west side of Kootenay Lake is similar to that at the Bluebell mine directly across the lake. A careful study of the mineralogy, ore controls, and geological form of the Bluebell orebodies has been continued by the Consolidated company since it began production in 1952. The Bluebell silver-lead-zinc mineralization is in a layer of limestone which dips at moderate angles to the west under Kootenay Lake. The limestone is broadly arched and the axis of the arch is more or less down the dip of the layer. Mineralization follows fractures associated with the arch and replacement of the limestone extends outward from the fractures and is guided by a variety of structures. Search of the Ainsworth camp showed that an arch not unlike that at Bluebell is present near the Florence and Lakeshore mines (see Fig. 6). A number of fractures cutting marble are known and they contain the same minerals as the Bluebell orebodies and locally replacement extends outward from them. On the basis of the geological similarities between the Bluebell and the Florence-Lakeshore deposits a programme of geological mapping, drilling, and underground work was carried on between 1954 and 1957. A number of mineralized fractures were found but replacement does not extend more than a few feet from them. Although considerable ore was found the hopes for large tonnages were not realized in the ground tested. The geological basis for the exploration was apparently correct but additional factors, which are still not well understood, have limited replacement. Possibly structures with a low plunge, which have controlled replacement and the localization of oreshoots in veins in other parts of the arc and which are now known to be present in the Ainsworth camp, will prove significant. A more complete geological picture may open up a new basis for exploration.

Conclusion

In the foregoing paragraphs no attempt has been made to describe all recent developments in exploration in the Kootenays. The examples used have outlined the trend toward geologically guided exploration in this part of British Columbia. Both individual prospectors and exploration or mining companies make use of geological knowledge gained through their own experience, obtained from published or unpublished reports, or derived from association with experienced people or organizations. Anyone who has worked in even the best known parts of the Kootenays has realized that geological data of value in exploration are relatively scarce. Because of this the Mineralogical Branch of the Department of Mines and Petroleum Resources has made a number of studies in the Kootenays particularly in the Kootenay arc. These studies are continuing. A bulletin has been published recently on the structure of the Ferguson area and field work is in progress in the Ainsworth camp and at Duncan Lake. At the University of British Columbia studies of the origin of the lead deposits in the Kootenay arc have been started which will provide basic data on the isotopic composition and trace element content of galena. These studies and possibly also some of the field studies may at present appear to be of strictly academic interest but they will produce the fundamental data that in the future may be the basis of exploration.

References

Minister of Mines, B. C., Ann. Repts., 1929, p. 334 (Wigwam); 1959, pp. 108-118 (Mastodon).

Reed, Bruce (1961): Ore Deposits of the Bannockburn Basin, Lardeau-Area, British Columbia, Econ. Geol., Vol. 56, pp. 392-401.

Riley, Christopher (1960): The River Jordan Lead-Zinc Deposit, Revelstoke Mining Division, B. C., Can. Inst. Min., Vol. LXIV, pp. 268-272.

Structural Geology of Canadian Ore Deposits, Can. Inst. Min., Vol. II, pp. 95-131, 1957.

The Reeves Macdonald Operation, Can. Inst. Min., Trans., Vol. LXIV, 1961, pp. 113-117.

Warning, G. F. (1960): Geology of the H.B. Mine, Can. Inst. Min., Trans., Vol. LXIII, pp. 520-523.

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Figure 1. Map showing the location of the Kootenay arc.

Figure 2. Map of the major structural belts in the Salmo district.

Figure 3. Isometric sketch showing the Reeves orebody on the west and its faulted segments east of the B.L. and O'Donnell faults. A third faulted segment is east of the block shown. The basal block is about 3,500 feet from east to west.

Figure 4. Airphoto showing part of Duncan Lake and the location of the portal of the Duncan mine, the axis of the Duncan anticline, and the Badshot formation on the crest and eastern limb of the anticline. R.C.A.F. photo.

Figure 5. Diagrammatic vertical sections of mineralized zones at the Mastodon mine looking in the direction of the plunge.
A--mineralization in cleavage above shear zone
B--fold crests transected obliquely by shear zones
C--mineralization in a fold crest above a shear zone.

Figure 6. Geological map of an area near the Florence and Lakeshore mines, Ainsworth, showing the curve in the strike of the formations forming a broad anticline plunging down the formational dip.

HISTORY OF MINING IN KOOTENAYS

The early development of mining was influenced by the location of the C.P.R. through the Kicking Horse Pass and by the general growth of rail and smelter facilities in the American northwest. The final decision in the course of the railroad was made in 1882 and in 1883 a mineral claim was located, presumably the Lanark, on the Illecillewaet River. The same year, 1883, saw 4 claims recorded at what is now Ainsworth, and the number increased in 1884 to 14.

At first prospecting was more intense along the general course of the new railroad than on Kootenay Lake, and in 1884 135 claims were staked in the general Illecillewaet - Kicking Horse region, most of which were on the Spillimacheen River. Some lode gold discoveries were made, but mostly the claims were staked on silver showings. In 1885 a company was reported to have the machinery for a 10-stamp mill at Ottertail Creek, east of Golden, to reduce silver-lead ore, but is seems not to have been in operation. Prospecting spread into the Big Bend in 1885 and increased generally throughout the Railway Belt.

General.

Indexed.

Development work went forward at the Lanark mine at Illecillewaet station east of Revelstoke and it became one of the first shippers of ore with the export of 422 tons to San Francisco in the years 1887-88. The Monarch shipped 600 tons to a short-lived smelting plant at Vancouver in 1888.

Meanwhile the number of claims on the west side of Kootenay Lake reached 49 in 1884 but activity in the Hot Spring camp as it was then called, and at the Bluebell across the lake, seems to have been light until about 1888. By the later year prospectors appear to have spread out into all parts of the West Kootenays with the possible exception of the Slocan.

Prospector's pushed up the Salmo River from the Pend d' Oreille, and late in 1886 the large and rich silver, copper deposits, later the Hall Mines, were staked on Toad Mountain and also then or soon after the Granite-Poorman gold properties west of Nelson. In 1888, 228 claims were staked on Toad Mountain and some ore was shipped to American smelters, and the number of claims on Kootenay Lake had greatly increased. This was a year of great activity throughout the district at large with much prospecting going on and many of the more promising discoveries under development.

The famed gold-copper deposits of Rossland were discovered in 1890, following the location in 1889 of the Lily May claim in the silver-lead bearing belt south of the main gold-copper camp. This camp at once attracted attention and broadened the interest of the Kootenays to the outside world.

In the late '80's ore had to be shipped out of the country for smelting, although a plant was built in Vancouver in 1888 (?) to treat ore from the Monarch mine at Field. In 1891 a smelter was in operation at Revelstoke but was unable to operate profitably. A small roasting plant at Woodberry Creek north of Ainsworth proved unsuccessful. A smelter was started in 1891 at Pilot Bay, designed to treat ore from the Blue Bell and also to receive custom ore; this smelter came into production early in 1895. The Hall Mines copper smelter was blown in on January 14, 1896 and the Trail smelter, built by the B.C. Smelting and Refining Co. was blown in in Feburary 1896. This was bought about two years later by the Canadian Pacific

Railway and has grown into the famous metallurgical works of the Consolidated Mining and Smelting Co., Ltd. The Nelson and Fort Sheppard Railway was built from the Columbia River to Nelson in 1893?. The Northport smelter was built in 1897.

Although silver-lead discoveries continued to be made for many years the discovery of the Slocan camp dwarfed all others and is perhaps without parallel in the speed of its development. The report of a find 13 miles west of Kaslo in August, 1891, started a number of prospectors up Kaslo Creek and over the divide. The Payne was the first location, on September 9, and by the end of the year there was 140 claims recorded including the Slocan Star and other famous mines. Most of the known mines in the Slocan were discovered by the end of 1892 and several had already shipped some ore.

The response to the Slocan discoveries was immediate. In 1892 a wagon road was built by private subscription from Kaslo to Bear Lake and was later extended to Cody. The Nakusp and Slocan Railway was started in 1893 and reached Sandon by 1895 and the Kaslo and Slocan Railway reached Sandon the same year. Transportation on the lake was improved. Capital was interested from the start, and in 1892, the year following discovery, 340 transfers and bills of sale were issued, aggregating $550,000. A total of 750 claims were recorded in the Slocan in 1892 and a list of the most promising on which work was being done that year includes most of those which later became the largest producers.

Ainsworth camp also was booming in the early '90's, in company with most other mining camps in the Kootenays. A setback was felt in the general recession of 1893, when the price of silver fell, but the recovery, particularly in the Slocan, was rapid. Locations were widespread, indicating that prospectors were reaching out over the entire Kootenays, with little apparent regard for accessibility or ease of travel. The North Star at Moyie Lake was located in 1892 and shortly afterwards the Sullivan.

The first concentrator in the Kootenays was that on the Granite-Poorman, in 1889 but the first to handle silver-lead ores was a small plant at the Number One mine at Ainsworth, in operation in 1894. The second was a customs mill at the mouth of the Howson Creek, which treated ore from the Idaho and Alamo mines. 1895 The Slocan

Star and Washington concentrators were in operation the following year. Other concentrators were built in succeeding years, amongst which the one at the Lanark mine deserves mention, although its operation was short-lived.

In the later '90's there was great activity in silver-lead mining, which waved somewhat about 1900 or shortly after in terms of the number of active properties. It became increasingly apparent, about 1900 that the presence of zinc in the silver-lead ores presented a serious problem. A Commission was appointed in 1905 "to investigate the zinc resources of British Columbia and the conditions affecting their exploitation" and the Commission's report was published in 1906.

It is interesting to note that early reports contained little or no reference to zinc, and in 1896 the report by W.A. Carlyle, Provincial Mineralogist, the first authoritative report on the Slocan makes only passing reference to this metal. Zinc at that time had no ready market, its metallurgy was not perfected, and its ready separation from lead in ores was not to be worked out satisfactorily for many years to come. "Ore" in the '90's and for years after meant silver-lead ore to the miner on account of its higher value than the zinc-bearing material and on account of metallurgical difficulties then inherent in mixed ores whereby penalties were imposed against an ore with an appreciable zinc content. Even today lead ore containing certain percentages of zinc is penalized and zinc is paid for only if it is above a certain percentage that allows the ore to be treated as an ore of zinc.

SLOCAN MINING DIVISION

The Slocan Mining Division includes the former Slocan City and Arrow Lakes Mining Divisions. Most of the known ore deposits are in the Slocan camp, which includes part of Ainsworth Mining Division.

The most important sedimentary rocks are those of the Triassic Slocan series. These rocks are principally argillaceous, but include volcanic and pyroclastic materials between Slocan and Upper Arrow Lakes. They rest on the dominantly volcanic Kaslo series, also of Triassic age, and are intruded by the Nelson and Kuskanax batholiths. West of Slocan Lake there are extensive areas of schists and gneisses.

The Slocan series is steeply and complexly folded in detail, but the structure of most significance is a great arc between Kootenay and Arrow Lakes. The formational strike along Kootenay Lake to a point a little north of Kaslo is north, it then swings north-west through the Slocan camp and, west of Slocan Lake, is north-west by west. In the angle of this arc is the northern and northeastern margin of the Nelson batholith.

To facilitate discussion smaller mineralized areas will first be mentioned before dealing with the Slocan camp proper. The camp extends into Ainsworth Mining Division, but it is best considered as a whole.

Vicinity of Burton.

On Caribou Creek north-east of Burton there are a number of claims located upstream from a point known as Mineral City. This area has not been completely mapped geologically but the rocks are almost certainly members of the Slocan series, including some greenstone as well as sediments. There is some granitic intrusion but the extent of the granitic rocks is not known.

Mineralization in quartz veins and chiefly within the sediments includes pyrite, galena and sphalerite and some grey copper and arsenopyrite. A little development work has been done on about a dozen properties. Only three have been productive, the Millie Mack, Paladora and Chieftain, and have shipped a total of 369 tons containing 357 oz. gold, 21,266 oz. silver and 41,959 lb. lead. These are gold-silver properties, but the Millie Mack shipments averaged 8 per cent. lead.

Big Ledge.

This is the name given to a consolidated group of properties west of Upper Arrow Lake opposite St. Leon hot springs and west of Pingston Creek. The property is given a full description in the Geological Survey Summary Report, 1928, Part A, which need not be summarized here. This is an extensive bedded or near-bedded deposit containing some zinc, which has been traced for a length of three miles.

Slocan Camp.

The Slocan camp is a mining district east of Slocan Lake with Sandon as its approximate centre. The part lying in Slocan Lake drainage is included in the Slocan Mining Division and the part lying in Kootenay Lake drainage in Ainsworth Mining Division. The camp has never been accurately defined, and local usage varies to some degree, but for present discussion it refers to the area covered by the two Geological Survey Maps, Sandon Sheet (No. 273 A) and Slocan Sheet (No. 272 A). Anyone interested in the camp should read the two excellent publications of C.E. Cairnes of the Geological

Survey, Memoirs 173 and 184. The former deals with the geology of the camp and the latter with individual properties up to the year 1933. Memoir 184, in addition to describing the geology, summarizes the history of each property, using for the historical summary many facts obtained from Annual Reports of the Minister of Mines.

Most of the ore deposits occur in lodes which occupy fractures or shear-zones in argillites and quartzites. Some lodes lie within the Nelson batholith and there are a few limestone replacement deposits. The average or typical ore body contains lead, zinc, or commonly both lead and zinc in excess of 5 per cent. of the ore, and the value of the base metal content is, in addition to that of silver, as a rule essential to the success of an operation. There are many exceptions to this rule, and the relative value of silver and base metals within individual ore bodies varies widely throughout the camp. The Lucky Jim during the past few years has produced zinc only, and the McAllister and Ottawa have produced little other than silver. Silver and gold-silver lodes are most numerous east and north-east of Slocan City, within Nelson granite. There is a tendency for high-silver deposits to occur on the periphery of the camp, although some do occur near the centre of it, but the greatest concentration is in the southern part, within the granite. Farther south, about Lemon Creek, the deposits contain principally gold.

The amount of gold recovered for the camp is small and in many prpperties is unrecoverable. A few properties such as the Chapleau and Meteor have produced one half ounce or more of gold per ton as an average of rather small shipments and a few, such as the Molly Hughes and Monitor, between one and three tenths of an ounce of gold per ton. The Molly Hughes has produced a little lead and zinc in addition to gold and silver. The output of gold properties has not been included in the following tables; a few properties whose proper classification is in doubt might have been omitted, but their production has been so small that the overall figures are not appreciably affected.

PRODUCTION OF SLOCAN PROPERTIES

IN 5-YEAR PERIODS, 1892-1945.

SLOCAN MINING DIVISION.

Years	Tons	Gold, Oz.	Silver, Oz.	Lead, Lb.	Zinc, Lb.
1892-95	19,946	175	2,646,706	13,869,800	--
1896-1900	129,480	192	12,863,124	113,208,619	--
1901-05	217,592	988	8,552,924	54,567,929	3,691,529
1906-10	129,466	375	3,714,005	25,236,325	1,852,807
1911-15	482,703	181	7,880,730	76,458,403	30,397,305
1916-20	616,073	317	7,196,612	59,091,469	64,482,707
1921-25	237,407	1,279	4,192,972	26,781,949	21,366,004
1926-30	242,947	939	3,604,783	19,854,670	26,905,450
1931-35	38,827	208	623,359	4,503,419	2,350,817
1936-40	185,180	594	1,247,877	5,538,758	9,200,133
1941-45	513,815[x]	364	1,434,816	6,678,241	92,106,361
Total	2,934,236	5,612	53,957,908	405,789,582	252,353,113

[x]Does not include 119,300 tons of tailings dredged from Slocan Lake at Silverton, and 1,500 tons of tailings recovered from Enterprise mine. The metal content is included.

AINSWORTH MINING DIVISION

Years	Tons	Gold, Oz.	Silver, Oz.	Lead, Lb.	Zinc, Lb.
1892-95	554	229	68,407	418,840	--
1895-1900	13,760	380	992,726	8,718,201	--
1901-05	10,960	130	702,165	5,279,337	1,366,065
1906-10	87,850	530	1,257,382	10,777,975	6,914,431
1911-15	16,600	136	585,286	3,008,702	1,113,992
1916-20	21,502	78	661,470	3,677,188	2,359,701
1921-25	40,465[1]	87	221,325	2,282,252	1,020,108
1926-30	73,148[2]	390	365,373	3,660,886	13,371,392
1931-35	16,868	48	156,787	2,698,886	2,155,359
1936-40	20,514	192	76,711	988,261	2,408,063
1941-45	69,186	16	32,114	618,149	6,825,551
Total	371,407	2,216	5,119,746	42,128,667	37,534,662
Grand Total	3,305,643	7,828	59,077,654	447,918,249	289,887,775

[1]Does not include 480 tons of tailings recovered from Kaslo Creek in 1925 by Metals Recovery Company Limited. The metal content is included.

[2]Does not include 37,321 tons of tailings recovered from Kaslo Creek in 1926-29 by Metals Recovery Company Limited. The metal content is included.

The tables follow the procedure of the Annual Reports of the Minister of Mines. From 1892 to 1924, inclusive, the figures represent gross metal content of ore or concentrates. From 1925 to 1945 the figures represent the gross metal content less calculated smelting and refining losses.

It is not possible to state the exact number of properties which have produced ore since the earliest shipments in 1892, owing to changes in name, regrouping, etc., but the number is approximately 250. The most active year, one of peak metal prices, was 1918, in which year there were 48 productive properties. The most active year in terms of the number of productive properties alone was 1906, when production was recorded from 59 properties; the number in 1928 was 38.

Cairnes in Memoir 173 (pp. 12-19) listed the productive properties, giving the tonnage and total value. The record of many properties has not changed at all since then and few have changed appreciably, but the Standard, Mammoth, Lucky Jim, Whitewater and Noble 5 have had a considerable additional production. Other smaller properties have produced and have substantially increased their individual record since 1933, and many shipments have been made under lease, but the above named have furnished the most important additions since 1933. At the present time the Standard-Mammoth, Silversmith-Slocan Star, Lucky Jim and Whitewater are the major productive properties, with a combined total output to the end of 1945 of 1,693,436 tons containing 2,823 oz. gold, 18,643,873 oz. silver, 181,822,828 lb. lead and 228,581,884 lb. zinc.

The first shipments were from six properties in 1892. Fourteen others shipped for the first time in 1893, four in 1894, and eleven in 1895. These were shipments of selected silver-lead ore from oxidized zones at or near the surface. Zinc was of no practical value and was discarded. Silver-bearing lead ore has continued to be the mainstay of the camp up to the present day, but the lower priced zinc ore is of great importance.

It seems extraordinary now that the early reports on the camp, made in about 1896, barely mentioned the presence of sphalerite, even though many of the outcrops known at that time contained prominent amounts of that mineral. The first shipment of zinc ore, almost massive sphalerite, was made from the Bell mine in Jackson Basin in 1901. The next shipments were in 1903, of zinc ore from the Enterprise, Springfield and Wonderful, and of zinc concentrates from the Payne. Other properties followed suit, including the Whitewater in 1904 and the Lucky Jim in 1905, but not every property mining mixed ores shipped the zinc-bearing fraction even when equipped with a concentrator. Most of the earliest gravity concentrators in operation simply wasted the zinc, and it was not until about 1910 that selective shipments of lead and zinc concentrates became the rule. It was not until the early 1920's that selective flotation was perfected to the point that relatively complete extraction and clean separation could be made between sphalerite and galena, so that most of the values in the ore could be recovered and the best smelter rates could be obtained.

During the growth of the district first the saleability of zinc and second the improvements in selective concentration allowed more properties to mine from veins containing mixed ores after the relatively clean lead ore bodies had been extracted. At the present day milling ores produce both lead and zinc concentrates in most cases and shipping ore in most cases is sorted to either a high or a low zinc content.

Although the effect of metallurgical technique has been important, variation in metal prices has proved the most important factor governing the mining of Slocan ores. The peak of production was reached in 1918 when metal prices were at a record high level. With recession of prices at the close of the first World War the Slocan suffered a serious setback from which it has never fully recovered. A rise in prices in the late '20's brought a real boom which subsided rapidly with the depression, and a mild boom was experienced in 1937-38 when prices again advanced.

At the start of the second World War the only milling operation in the Slocan was that of the Western Exploration Company, Limited, and in addition there were, in 1940, 18 small shippers of sorted ore. In 1943, armed with war contracts for shipment of concentrates to American smelters at somewhat advanced prices, the Whitewater, and Noble Five mines again came into production, while the Lucky Jim mine preceded them at current market prices and has since continued to operate as the largest producer of zinc and one of the largest producers of all time in the Slocan.

In 1946 a strengthening of the position of lead and zinc and a marked increase in the price of silver created an interest that was dampened by labour troubles and by the difficulty in obtaining men and supplies. Production ceased owing to a general strike from July 3rd to November 15th, but some of the minds affected were able to continue with development work. The strike was aimed at producing mines only, and so new development was not hampered directly by it. The uncertainty of the times, however, prevented some projected developments from taking place.

Few of the older workings are accessible, and even of those properties currently being worked some parts are caved. Many of the workings date back 40 to 50 years and in these all but the wettest timber has rotted. Drifts on the larger lodes are caved with few exceptions and crosscuts are apt to be blocked where large faults are encountered. Adit portals are caved in most instances and the outer parts of the adits which penetrate overburden may be completely collapsed. Those adits which are collared in rock may as a rule be entered, but most of the lower adit levels in the camp are driven for some distance through overburden before bedrock is reached.

The air in many of the longer unventilated workings is deficient in oxygen, which deficiency can be detected with a lighted candle. Old, strange workings should not be entered with an electric light alone unless there is a positive current of air.

The cost of making examinations may, as a result of the condition of the workings, be high. If only a short portal section is caved access is relatively cheap and easy, but the cost of opening up long caved sections of tunnel either in overburden or strongly sheared rock may excede the cost of driving a new heading. There is little chance of estimating the extent of caved or open workings in advance; study of maps may help, although maps of older workings are rather scarce and do not as a rule indicate the character of ground encountered. Unfortunately there is a great dearth of underground geological information, and the older maps and reports are incomplete or entirely lacking in geological detail. Even reports made in more recent years are to a degree incomplete in this respect because they were of necessity based on examinations limited to those parts of a mine that were accessible. Few assay maps can now be obtained, so that the distribution of values and the variations in metal content in stoped ground are matters for conjecture.

Unfortunately, little is known regarding ore controls. Geological factors which influenced the deposition of ore can be determined in parts of some workings. Most of these are structural features such as have been many times described in textbooks and papers on the controls of ore deposition, but the structural framework of few properties has been worked out sufficiently well to be certain of the major factors and to direct development with any degree of certainty. The same is true of the major correlations between properties insofar as they may affect long range development of the camp.

It has been proved in many instances that folded structures in the sedimentary rocks have produced a marked influence on the localization of ore bodies, as well as on the localization of faults and shears, whether or not thesewere mineralized. The working out of structure underground is as a rule very difficult, and the working out of structures on the surface on such a scale that they may be correlated with those underground may be equally difficult. This is due not only to the abundance of overburden on one hand and the inaccessibility of workings on the other, but to the intricacy of some of the structures in question.

It is known that in some properties ore was deposited preferentially in one rock type, as in quartzite or thickly bedded argillite but was not deposited in thinly bedded argillites. This is a matter of relative competency of the rock and is of general enough occurrence to be considered by many as an invariable rule. It is not an invariable rule, however, and much ore has been mined from thinly bedded, incompetent argillites that in another property would be considered not likely to contain any ore. Although little is understood, and much research work remains to be done, even the least competent rocks under some conditions of folding may maintain fractures and become the site of ore deposition, providing the fractures meet the bedding at a proper angle and the fracturing has not been too intense.

A widely accepted theory in the Slocan is that the ore has a zonal arrangement within the camp, namely that high silver, siliceous ores occur at higher levels and grade down through lead ore into zinc and finally into uneconomic pyritic mineralization. Cairnes has well summarized the evidence and points out also that the ideal sequence appears to be represented at all levels within a couhtry of 5,000 feet of natural relief. The lead-bearing horizon cannot be represented by a plane or even by a simple curved surface, but is apparently a highly irregular zone which is as irregular as the topographic surface to which it may be likened in general form. The thesis is not proved beyond doubt because at no time has it been possible to gather together sufficiently full data on metal distribution throughout the depth range of a sufficient number of mine workings to furnish uncontestable proof. The origin of this thesis lies probably with mining practice in the history of the camp. The earliest shipped ores were strongly oxidized, high in silver and lead and low in zinc. Later mining was carried out near the surface from shallow workings and inexpensively on ore that was sorted to be as nearly "clean lead" as possible and the zinc was discarded. Lower workings, involving longer adits, became more expensive and the zinc became more important as a necessary adjunct to make the work pay. If the lowest adit encountered zinc and little lead all further exploratory work was frequently stopped, because in most cases the zinc ore was not of sufficient value to pay the expenses of operation. In point of view of production the early mining for many years was of silver-lead ore alone and, although the amount of zinc recovered increased statistically for the camp this was certainly in part due to the increasing efficiency of selective concentrating methods and to the fact that with more efficient mills it became economically feasible to mine entire sections of a lode rather than to select merely those parts relatively high in lead. The relative value to the mines of sphalerite and argentiferous galena can be judged by the fact that in the accessible, abandoned workings very little galena is to be seen and remnants of ore are dominantly sphalerite.

The zinc-lead ratio in some mines does increase with depth, but before applying the theory of metalliferous zoning to the Slocan in general and to any particular property or area, it should be determined whether a change in metal content is brought about by a change in geology. At the Whitewater the higher workings are on silver-lead-zinc ore in a shear-zone in slates, whereas the lower workings are on zinc-lead replacement ore in limestone. In the Lucky Jim mine local conditions in the upper workings containing some lead appear different from local conditions in the lower workings which contain zinc but no lead. The continuity of metal content in individual ore shoots and the variations in metal content between different ore shoots in the same property has not been sufficiently studied. In at least one property on a single lode there are different shoots, localized by different factors, which have a different metal content on the same mine level.

It has been a matter of some concern to companies planning long term mining that the Slocan appears to be a shallow camp. Individual mines on a single lode have shown a depth as great as 1,300 feet, but the vertical range over which mining has been conducted in the vicinity of Sandon is about 4,000 feet. Many mines are shallow, meaning that an ore body has been worked close to the surface and that deeper development, if it has been attempted, has failed to demonstrate a profitable downward continuation of that ore body. Most but not all of the more important ore bodies cropped out at the surface and those that have been entirely delimited underground occurred somewhat like plums in a pudding. The statistical record of ore bodies which were followed down from surface until they played out and the mine abandoned, points to a shallow camp inasmuch as most ore has been found close or relatively close to the surface, no matter what the elevation of the outcrop. The few ore bodies which were found in more or less isolated positions underground are too few to balance the foregoing, but the fact that they occur leaves room for doubt that some of the older and larger mines have been bottomed or otherwise worked out. Additional work might find ore bodies at greater depth or farther along the course of the lodes, but in many instances the cost of doing this additional exploratory work from workings in poor repair is a serious consideration.

Detailed mapping underground and on the surface indicates that the controls of ore deposition and the localizing factors may be many. Mapping in some instances should be extended over a relatively large area in order that the setting of a known ore body may be properly understood. Detailed surface mapping to date has shown that interpretation of structure is not as a rule easy. Overturning of strata has taken place locally over large areas and it may be that overturns in some instances provide a favourable site for ore deposition. In some instances drag folds bear an important relation to ore.

There is an important relation between folds and faults. Lodes and post-mineral faults tend to follow bedding in many instances, and the course of a lode or fault may be deflected round a fold, particularly if the normal course of the fissuring is tangential to the fold. For this reason the relative movement and the amount of displacement on a given fault or vein fracture are often hard to determine, and in transecting complex folded areas it is probable that the amount of movement varies from place to place. Some crosscutting lodes or faults can be seen to turn rather abruptly to follow along bedding planes, and it is then commonly a matter of doubt whether the crosscutting relationship may be resumed, and if so - where.

The importance of drag-folding is illustrated in the Lucky Jim, where the favourable host rock, limestone, is greatly thickened by drag-folding to provide sites for larger ore bodies than could otherwise have occurred. The same is true in the lower part of the

Whitewater mine.

The foregoing remarks apply to those deposits in sedimentary rocks. Deposits in Nelson granite present simpler problems, and, although the lode fractures in granite may be complex in detail some of the lodes appear to form relatively simple and continuous breaks.

Slocan

BIBLIOGRAPHY.

Carlyle, W.A. (1896): Slocan, Nelson and Ainsworth Mining Districts - Minister of Mines, B.C., Ann. Rept., Bull. 3, pp. 35-74.

Robertson, W.F. (1904): Ainsworth, Slocan, and Slocan City Mining Divisions - Minister of Mines, B.C., Ann. Rept., pp. 147-196.

McConnell, R.G., and Brock, R.W. (1904): West Kootenay Sheet, scale 4 miles to 1 inch - Geol. Surv., Canada, Map No. 792.

Ingalls, W.R. (1906): Report of the Commission Appointed to Investigate the Zinc Resources of British Columbia and the Conditions Affecting Their Exploitation - Dept. of Mines, Canada.

Robertson, W.F. (1911): Slocan Mining District - Minister of Mines, B.C. Ann. Rept., pp. 134-153.

Galloway, J.D. (1915): Slocan Mining Division, Minister of Mines, B.C., Ann. Rept., pp. 122-133.

Drysdale, C.W. (1916): Geol. Surv., Canada, Summ. Rept., pp. 56-7, Map 1667 of Slocan Mining Area.

Cairnes, C.E. (1928): Geological Reconnaissance in Slocan and Upper Arrow Lakes Area - Geol. Surv., Canada, Summ. Rept., Pt. A, pp. 94-108, Map 232A.

Cairnes, C.E., and Gunning, H.C. (1928): Big Ledge (Consolidated) Property, Upper Arrow Lake - Geol. Surv., Canada, Summ. Rept., Pt. A, pp. 109-118.

Cairnes, C.E. (1934): Slocan Mining Camp - Geol. Surv., Canada, Mem. 173.

Cairnes, C.E. (1935): Description of Properties, Slocan Mining Camp - Geol., Surv., Canada, Mem. 184.

Hedley, M.S. (1945): Geology of the Whitewater and Lucky Jim Mine Areas - B.C. Dept. of Mines, Bull. 22.

Hedley, M.S. (1947): Slocan District - ~~Dept.~~ Minister of Mines, B.C., Ann. Rept., pp.

Annual Reports: B.C. Minister of Mines.

LOCALIZATION OF LEAD-ZINC ORE

IN THE KOOTENAY ARC.

By M. S. Hedley and J. T. Fyles,
British Columbia Department of Mines.

The West Kootenay region in southeastern British Columbia is one of the province's most important mining districts. Mining has been carried out since 1883 in the Revelstoke, Lardeau, Slocan, Ainsworth, Bluebell, Nelson, Ymir, Salmo, and Sheep Creek camps that line up along the general route of travel provided by the upper Columbia River, Lardeau River, Kootenay Lake, and the Salmo and Pend d'Oreille Rivers. The wealth and potential are so great that geological study of this region is a natural concern, and a good deal of work has been done in it in varying detail during the last sixty years.

In the past twelve years the British Columbia Department of Mines has devoted a considerable amount of energy to more detailed mapping than was attempted before, at scales ranging between 200 and 1,000 feet to the inch. The results on the whole have been gratifying, and a more accurate picture is emerging, both as to regional structural relationships and the localization and control of ore deposits. The region is geologically complex, and it has been found that a reasonable interpretation of either local or regional structure may be obtained only through detailed studies of relatively large areas.

This paper deals with some conclusions regarding the localization of lead-zinc deposits that have been reached as a result of detailed work. Only lead-zinc deposits are considered because they are widespread and are the chief products of the region. Other deposits are not considered, partly because they have not been studied in as much detail and partly because inclusion of all the various types of mineralization would introduce too many complexities for a straightforward presentation.

Areal mapping in the past has shown that except for a few veins in granite, ore occurs in a variety of sedimentary rocks ranging in age from Lower Cambrian to Triassic. In the West Kootenay region lithological continuity has been indicated, but no clear idea of the structure, beyond the fact that no single regional pattern has been recognized. Localization of ore has been related to the presence of fractures or of limestone, and only in the Sheep Creek gold camp has a structural control been by any means obvious. It has been generally believed that the ore is related to the Nelson batholith, following genetic theory no less than the fact of over-all distribution.

More detailed and more recent work does not show any major break or unifying structure for the region as a whole, and far more complexity is recognized now than was seen by previous workers. However, some over-all concepts are emerging, which will be discussed.

The simplest and most general observation that may now be made is that a great belt of heterogeneous sedimentary rocks trends southeast in the Lardeau, south along Kootenay Lake, and southwest on the Pend d'Oreille River. This curving belt of sedimentary rocks is named the Kootenay Arc, which is economically the most important major structural element so far recognized in British Columbia. The outer or eastern edge of the Kootenay Arc is taken as the Badshot-Laib limestone of Lower Cambrian age, being the base of the lime-bearing series and the general eastern limit of lead-zinc mineralization. East of the Badshot-Laib mapping is too incomplete to indicate the full limit of the arc. In the northern and central parts the western limit is the granite of the Nelson and Kuskanax batholiths, in the gap between which lies the Slocan camp. In the south, the western limit is roughly the eastern edge of Mesozoic volcanic rocks and very nearly a line of granitic bodies which are satellitic to the Nelson batholith.

Throughout the Kootenay Arc orebodies occur as fissure fillings in a variety of rocks or as replacements of limestone in a variety of structural situations. In the course of studying ore occurrences we have looked for but have not found some unifying pattern of form - instead, we recognize the beginnings of a unifying pattern of process, in which modification and timing were perhaps of first importance.

A study of the granites has not been made, but from studies of the marginal rocks some inferences concerning the structural effects of intrusion can be drawn. Little is known about the Kuskanax batholith beyond that it appears to be an intrusive mass younger than the Nelson batholith. This lack of knowledge is not too surprising in view of the fact that peripheral mineral deposits are generally lacking. The Nelson batholith is a large and important granitic mass that is generally considered to be Jurassic or Cretaceous in age. The eastern part seems plainly to be intrusive, but the western part grades into a large area of complex granitization that occupies much of south central British Columbia. Many lead-zinc mineral deposits are rudely peripheral to the Nelson batholith, and a few occur within it. The Kootenay Arc is bowed about the eastern front of the batholith, and some individual structures appear definitely to be related to that part of the granite that was intruded forcefully.

Although the Nelson batholith occupies the central bow in the Kootenay Arc, and the sedimentary structures are affected by it, the Arc is not solely the result of intrusion. Structures attributable to intrusive forces along the north batholithic margin are superimposed upon earlier regional structure of northwesterly trend, and near the Washington border a series of important structural events occurred before emplacement of granitic stocks which are satellitic to the Nelson batholith. The arcing of the sedimentary formations appears to be a structure of great antiquity that perhaps localllized intrusion and certainly was modified by it.

Emphasis is placed upon the Nelson batholith for the very good reason that lead-zinc deposits occur along its northern and eastern margins and along the line of satellites to the south. Although very little is known of the chemistry of intrusion, no evidence has been found to indicate that any one deposit is genetically related to a specific part of the batholith. If ore-forming solutions were derived from some magma chamber it must be sought far beyond the limits of practical exploration. More is known about the physical effects of intrusion, particularly concerning peripheral modification of pre-existent structures by intrusive forces to form situations that were favourable to ore deposition. The observed relations between intrusion and ore are physical rather than chemical, and while we do not deny consanguinity between ore solutions and granitic rocks we have not found the hypothesis helpful in studying ore deposits in the Kootenay Arc. On the other hand the concept of structural modification is very helpful and provides a reason for the occurrence of many deposits. Some but not all of this modification occurred at the time of intrusion.

Detailed study of many deposits and their structural situations indicates that deposition of most if not all lead-zinc mineralization was contingent upon the structure of the sedimentary rocks in which they occur. The localizing structure in a great many cases was not that of the early folding, which may be referred to rather loosely as primary, but was a secondary, tertiary, or even later modification of it that was superimposed in response to forces that in some instances were not the same as those which produced the primary folds.

The significant reason for this appears to be that the primary folding was stratiform and was accomplished by slow interbed adjustment, rock flowage, and recrystallization that kept the rocks tight, whereas later modification stressed the rocks beyond their capacity to adjust uniformly, and they were locally wracked and buckled. Apart from the presence of fissures which in any event are necessary to entry of solutions, the wracked zones provided sites of reduced pressure which favoured deposition from solution.

Primary folds are, however, extremely important, inasmuch as they are the framework, the modification of which may localize an orebody. Moreover, they determine the over-all position and limits of any favourable rock, no matter what particular events led to its mineralization.

In the case of fissure lodes, the fissure that crosscuts beds of varying attitude may meet strata of a given competency at an angle that promotes brecciation and the formation of zones of reduced pressure, whereas elsewhere it may meet rocks of the same competency at angles which promote dissipation of movement or the production of tight, gougy zones. Primary folds thus provide panels of different attitude that are favourable or unfavourable for ore deposition, and if ore occurs in a panel of preferred orientation the initial folds govern the size and locus of that panel. In general, the form of folds does not alone control the formation of orebodies. The apex of a fold is an ideal theoretical site for veins in brittle rocks or for replacement ore beneath an impervious hood, but unless mineralizing solutions have access to the apex no ore is formed. In the Kootenay Arc there are examples of such localization, but they are of minor and not general significance because channelways did not follow a fold apex except in rare instances.

Primary folds may be the only geological features which can be projected with reasonable certainty, and the initial form of a fold must be understood before modification of it can be recognized. It is acknowledged that evidence of modification is often too tenuous to be of direct benefit at the prospecting stage, but its recognition is very important in mine development.

A factor almost as important as that of structural modification is timing. A given wracked, buckled, or shattered zone favoured ore deposition at the time of its formation, if solutions were then available. This is especially true of the type of orebody in which ore follows planes of bedding, fracture, or shear - the site must have been stressed in such fashion that the rock tended to part readily along these planes, or little ore would form. A site favourable to contemporary solutions would not remain so indefinitely, particularly if the site were a breccia zone in limestone.

Given a favourable site and a supply of mineral-bearing solution, an orebody is likely to form. Primary fold structures, tending to be constant in attitude over regional distances, do not localize ore as readily as zones of modification because the conditions of early, regional folding were not as productive of relatively low pressure sites. The fact of modification may be apparent, but the agent of that modification may not in every case be known. In some instances the cause was intrusion, but in others it may have been a shift in application of regional stresses.

Several modified structures may exist in one district, and mineralization of any would depend upon availability of solutions at the time of structural activity.

In support of the foregoing generalizations a few situations of ore zones in the north central, southern and central parts of the arc will be described.

North Central Part of Arc

The Slocan camp is in the gap between the Nelson and Kuskanax batholiths. Heterogeneous thin-bedded sediments trend northwest through most of the camp, dipping dominantly southwestward at low elevations, and dominantly northeastward and overturned at the higher elevations. The over-all form is that of a huge recumbent fold, open to the southwest, with a nearly horizontal axial plane. In detail, this recumbent fold is very complex, with many minor recumbent folds, pleats, and crumples, particularly in the general vicinity of Sandon. Near Kaslo the entire fold is warped round the northeast corner of the Nelson batholith to a north-south strike.

The recumbent Slocan fold has been strongly modified along the northern margin of the Nelson batholith. A whole series of recumbent pleats swings through about 90 degrees in strike and warps downwards, to meet the batholith in steep tangential pleats which are dragfolded along steep axes in response to the bending and warping stresses.

Another modification of the Slocan fold, less dramatic than the downwarping but even more important in terms of ore, is a major crosswarp that extends from near Silverton on Slocan Lake for 12 miles across the entire width of the Slocan group of sediments. The crosswarp constitutes a culmination in regional plunge and is a zone half a mile or more wide marked by buckled and locally jack-knifed minor folds. The crosswarp is related to the most accentuated downwarping, and the two structures meet near Silverton, in an area that is a focus of modifying and disruptive stresses. Many of the larger lode-bearing faults in the camp stem from this area.

The downwarping and crosswarping of the Slocan fold are related to the intrusion of the granite. They are structures superimposed, not at a date much later than the formation of the Slocan fold, but at a time when the recumbent structure was attaining its final form. It can readily be argued that the recumbent structure is a modification of a still earlier one, but it is sufficient to state that it came into being during formation of the Kootenay Arc in pre-granite time. What the truly initial form was we do not know.

The Slocan fold is considered for purposes of argument to be a primary structure. Fissure lodes in it are localized to a considerable extent in panels of preferred orientation that dip to the southwest. The most productive lodes are in the zone of crosswarping and in the zone of change from primary recumbent to downwarped modified forms. Orebodies are also associated with second generation dragfolds in the downwarped northeasterly striking rocks. Ore occurs preferentially in the wracked zones in general, and in local situations that are characterized by brecciation rather than by shear. To emphasize to the point of belabourment, the ore is in the zones of wracking brought about by structural modification. There is no lack of fissuring in any part of the Slocan, but the fissures contain ore only in zones that were structurally active at the time of availability of solutions.

Many examples of ore localization in the Slocan could be given were space available. The already enunciated principles are perhaps sufficient for the fissure-lode deposits, but two examples of control of limestone replacement ore are worth mentioning. Replacement is rare in the Slocan, in spite of the fact that limestone forms the walls of lode-fissures in many situations. It appears to be a fact that replacement is contingent upon more than the presence of a fissure crossing limestone.

In the Whitewater mine the ore zone is partly fissure filling in slates and partly replacement of limestone. Ore has spread from the fissure lode into the limestone, in bedded sheets and along troughs above slate. The limestone is in the form of a large dragfold that has been severely wracked at the northeast end of the Slocan crosswarp. The modification of the dragfold permitted entry of solution and favoured replacement of the limestone. At the Lucky Jim mine, dominantly zinc ore is in dragfolded limestone between slaty rocks. It is localized by steep cross fractures and also by longitudinal fissures. The ore as a whole contains very little galena, but in the uppermost levels galena was prominent, and several chimneys of relatively massive ore were mined. The chimneys were localized by cross fractures which were more abundant and relatively more open in a local area of crosswarping or doming on the westward-plunging structure. The crosswarp was too small to be responsible for the ore zone as a whole, but it localized silver-lead ore because, throughout the camp, galena tends to occur in the more open fissures and in situations of reduced pressure.

Southern Part of Arc

The Salmo-Pend d'Oreille lead-zinc belt occupies a 20- to 25-mile section around an abrupt swing in the trend of the Arc. Mineralized zones occur in a belt extending from about 7 miles northeast of Salmo southward almost to the International Boundary and westward along Pend d'Oreille

River. The structure has developed in response to deforming forces acting in different ways over an extended period of time. Only the major features of the complex sequence of deformation have been recognized.

The rocks that contain the lead-zinc deposits have been folded into primary isoclinal anticlines and synclines with amplitudes and distances between crests measured in thousands of feet. The axial planes dip eastward and southward and the axes plunge gently. These folds have been secondarily folded about axes of which some are parallel and some are not parallel to the primary axes of folding.

In the northern part of the Salmo area the primary isoclinal folds are overturned or recumbent, with axial planes dipping eastward or gently southward. Both limbs of these folds have been secondarily folded into open synclines and anticlines whose axes are essentially parallel to the primary fold axes. In the southern part of the area the primary isoclinal folds plunge gently westward and the secondary folds plunge 50 to 60 degrees southward. These secondary folds are z-shaped dragfolds formed on both limbs of the primary isoclinal folds. They are therefore not directly related to the primary isoclinal folds but are later structures superimposed on them.

The mineralized zones are deposits of sphalerite, galena, and pyrite replacing dolomitized limestone. Stratigraphically they all occur in the same limestone member but probably not at the same horizon. The orebodies are elongate, and those that have been extensively mined are a few thousand feet long, a few tens of feet thick, and may measure a few hundreds of feet in the third dimension. In cross-section they are irregular, with poorly defined walls.

The best known orebodies in the Salmo area, at the Reeves MacDonald and Jersey mines, were controlled by secondary structures. At the Reeves MacDonald mine, about 12 miles south of Salmo, the main orebody occupies a tight syncline superimposed on the right-side-up limb of a primary isoclinal anticline. The anticline plunges gently westward, and its limbs dip steeply southward. The syncline is part of a secondary z-shaped fold plunging steeply southwestward. At the Jersey mine, 7 miles southeast of Salmo, the orebodies occur on the upper limb of a major, recumbent, primary isoclinal anticline. The ore has been at least partly localized by a series of relatively open, gently plunging anticlines and synclines, which, although they plunge parallel to the major anticline, are late structures superimposed on it. Hence the orebodies at both these mines were controlled by secondary modification of primary structures.

Study within the mineralized zones suggests one reason for the localization of ore in secondary rather than primary structures. Most of the limestone in the mine belt has a pronounced black and white banding. Orebodies are associated with dolomitized zones that contain streaky, brecciated, or mottled textures. These textures represent modification of the primary banding by brecciation and shearing that created sites favourable for mineralization.

The structures that localized ore represent only one event in a long continued process of deformation. Other structures produced by modification of the primary folds have been recognized, and although they might be presumed to be favourable for mineralization, no ore has been found in them. The reason for this is not known, but an important factor has undoubtedly been the relation between the time of formation of the favourable structures and the time at which mineralizing solutions were available.

Central Part of Arc

In the north, near Kaslo, the Slocan recumbent fold is wrapped round the northeast corner of the Nelson batholith with a swing in strike from southeast to south. To the south, near Ymir, the structure is characterized by isoclinal folding about northward trending axes. In the intervening 30-mile stretch, in which lies the Ainsworth camp, neither of these types of structure has been recognized; the strongly metamorphosed rocks dip westward with little evidence of folding, and even dragfolds are comparatively rare.

Nevertheless, despite the lack of direct evidence, it is believed that in the vicinity of Ainsworth isoclinal folding has been partly obliterated by subsequent movement. There is suggestive evidence that this is the case, but the scarcity of cross-sections makes proof very difficult. The mechanism by which the isoclinal folds have been partly obliterated is not known, but the situation is marginal to the Nelson batholith, and it is probable that outward thrusting of the batholith was accompanied by attenuation of folds through flowage and shearing.

Structural continuity between Ainsworth and Ymir is thus a distinct possibility. Continuity between Ainsworth and the Slocan fold near Kaslo appears less probable, but isoclinal pleats of major size occur within the Slocan fold, and it follows that the apparent difference between that fold and the structure at Ainsworth is largely one of attitude of axial planes. There appears to be a crude rifling of the major structure as it passes round the Nelson batholith, a rifling that has changed the attitude of the isoclinal folds.

At the Bluebell mine east of Ainsworth the ore is in lower Palaeozoic limestone which strikes north and dips west under Kootenay Lake. The ore is controlled by steeply dipping cross fractures essentially perpendicular to the strike. The orebodies occur at open rolls or flexures in the limestone band, where the cross fractures were most abundant and were more or less in tension. It is not known whether the cross fractures were extension joints normal to the primary fold axes, formed at the time of primary folding, but the fact that the open rolls trend down the dip of the limestone indicates that the rolls were later than the primary folding. It is believed that late flexing of the limestone tended to open the cross fractures, whether or not they were formed at an earlier time.

At Ainsworth the most productive vein is the Highlander-Banker. A large bedded fault is quartz-filled to a width of 50 to 150 feet and the vein is a late fissure in the quartz, averaging about 7 feet wide. Other veins in the Ainsworth camp in places have associated replacement ore. Replacement is not a general accompaniment of the veins, in spite of the fact that much limestone is cut by them, and replacement is apparently restricted to situations where the limestone has been stressed more than ordinarily. Imperfectly as the over-all structure is known, it appears that the localized stressing was not related to the primary folding of the limestone, but was a modification of it.

In summary, the Kootenay Arc is seen to be an ancient structure. It grew by modification of initial folding and provided a site for intrusion of the mobile front of a major area of granitization. The arc was further modified by the intrusion. Apparent major differences in form in different parts of the arc may be the result of rotation. Some of the later but not necessarily the latest modified structures were mineralized, when they were active and solutions were available.

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Not used. ?
Why then ?
what for ?

MINERAL DEPOSITS IN THE SOUTHERN ROCKY MOUNTAINS OF CANADA[1]

M. S. HEDLEY[2]

INTRODUCTION

Placer gold was discovered on Wild Horse River in 1863, and on Bull River in the same year or shortly after. The only other stream in the Rocky Mountains known to contain placer gold is Maus Creek, a short distance south of Wild Horse River. The total production of placer gold is not known because records were not kept in the earliest days, and the most accurate statement that may be made is that more than one million and possibly several million dollars worth of gold was produced.

The earliest prospecting for lode was in the vicinity of the placer diggings, and a good deal of exploratory work was done prior to 1900. No source of the placers has been found, inasmuch as no vein containing important quantities of gold is known. Most of the deposits are of copper, lead, and zinc minerals, with associated small amounts of gold and silver.

Prospectors in search of lode were active in the years of the early railroad building, starting in 1883, and principally in the general area between Windermere and Golden. The metal chiefly sought was silver, in the early recognized absence of gold ore, and because of the common association of metals many deposits of lead and zinc were investigated, in the hope of discovering silver ore high enough in grade to be worked. In this second period of activity discoveries were made chiefly in the Purcell Mountains, but some were also made in the Rockies, and many prospectors must have worked east of the Rocky Mountain Trench.

The Monarch lode in Mount Stephen was discovered in 1884 when float was found on the location line of the railway. The Kicking Horse lode was discovered at a somewhat later date, and did not receive much attention until 1925. Development of the Monarch was rapid, and shipments of ore were made from it to Vancouver in 1888. A comparatively late discovery was that on Hawk Creek in 1929. In 1912 lead-zinc ore was discovered in Alberta at the head of Oldman River, and in 1951 silver-lead mineralization was discovered near Windermere.

G. M. Dawson's report of 1885 mentions "lead and copper ores, containing silver" between the Ottertail River and Field, copper about 5 miles north of Castle Mountain, copper on Copper Mountain on the south side of the Bow River, lead on the east side of Mount Ball, and copper on the Cross River.

Production has come from the Monarch and Kicking Horse mines, and in recent years from the Estella and Kootenay King. Shipments of a few tons of ore have been made from two or three prospects in past years.

It has been the practice to look upon mineralization in the Rocky Mountains as a rarity, and to consider it to be in a somewhat different category from mineralization in the Purcell Mountains. The important ore deposits at Field have been referred to as related genetically to the Ice River Complex, that being the nearest known body of igneous rock, in spite of the fact that the deposits are separated from it by 12½ miles. This attitude has cast doubts on the possibility of finding additional important ore deposits in the Rockies as a whole, whereas evidence of mineralization actually is widespread, and deposits are known even farther from any known igneous rock than Field is from the Ice River Complex. The structures in the western Rockies are not greatly different from those west of the Trench. There is no definite information on the age of mineralization, but deposits on the west side of the Trench are more likely post-

[1] Published by permission of the Chief of the Mineralogical Branch, British Columbia Department of Mines.
[2] Senior Geologist, British Columbia Department of Mines.

Cretaceous than not. Whatever the structure of the Trench may be, it had an early beginning, probably long before the appearance east of the Trench of syenite dykes that are considered to be probably Tertiary in age (Rice, 1937, p. 24).

All other production is dwarfed by that of the giant Sullivan mine near the western edge of the Trench, a fact that tends to minimize the fact that the southwestern Rockies are reasonably well mineralized. Were it not for the Sullivan, the Monarch and Kicking Horse mines would be more widely recognized as major deposits.

In the western Rocky Mountains most of the quartz vein type of deposits have been found in the Precambrian rocks north and south of Wild Horse River, and so might express an affinity for those rocks, but such deposits have not been found south of Elko, or farther north near Canal Flats, where rocks of the same age are known to occur. There is a suggestion from their distribution that many of these deposits are related to faulting along the Trench margin, and to diagonal faults near Wild Horse River. Only a relatively few square miles of this region have been mapped in detail, and additional work may throw light on the structural situation of many occurrences of mineralization.

Many of the mineral deposits in the Precambrian rocks are related to bodies of diorite and syenite. It has not been established whether this means that the deposits are related genetically to the igneous rock, and if so how direct the relationship may be. In some instances it appears that the relationship is structural, and that fracturing has been localized in or marginal to a sill or dyke.

Any discussion of mineralization in the Rocky Mountains must include the Sullivan and Silver Giant mines; the Sullivan because it is the most important single deposit in Western Canada, and the Silver Giant because it is in lower Palaeozoic rocks and is related to structures typical of the Western Rockies.

PRODUCING MINES

SULLIVAN MINE

The great Sullivan mine of the Consolidated Mining and Smelting Company of Canada, Limited, is 1½ miles northwest of Kimberley, on the west side of the Rocky Mountain Trench. The lead-zinc ore is concentrated and shipped to the company's smelter at Trail. Ore is mined at the rate of about 10,000 tons a day, and in 1952 a total of 2,699,533 tons was mined, with a gross metal content in concentrates of 2,846,304 ounces of silver, 215,000,283 pounds of lead, and 258,139,395 pounds of zinc.

The ore is a sulphide replacement of a stratigraphic zone 200 to 300 feet thick, in the lower part of the Precambrian Aldridge formation. The principal sulphides are galena, sphalerite, pyrrhotite, and pyrite. Small amounts of chalcopyrite and arsenopyrite are present and locally boulangerite. Magnetite is fairly common and cassiterite is present in small but commercial amounts. The footwall rock, particularly above the 3900 level, is strongly tourmalinized to a product that resembles dark coloured chert. Chloritization of the hangingwall is extensive; albitization of the hangingwall is more restricted but locally extends higher than the chloritization. Replacement was of uniformly bedded, and for the most part finely laminated, argillite and silty argillite. The relatively great permeability of these rocks may be ascribed to their laminated character, and to the fact that the section shows great uniformity throughout long distances; individual beds have been traced for thousands of feet in spite of the fact that they are at most 20 feet thick.

Bodies of Purcell intrusives, occurring commonly as sills or as sheets at small angles to the bedding, are common in the area. They are gerally referred to as diorite, but their composition has a considerable range. They produced some metamorphism of the intruded rocks.

The ore zone is in the hangingwall of the east-west striking Kimberly fault, one of the major breaks in the general region. Three smaller northerly trending faults in and near the mine area apparently have an overlapping age relationship to the Kimberley fault.

In the mine area the regional dip is to the east and north, on the eastern flank of a broad anticline. The regional dip is modified by gentle warping and by minor sharp folds. Within the actual ore zone minor complex folding is common, and there are indications that folding and mineralization were to some degree contemporaneous or overlapping.

The origin of the ore zone is related to a major fault and minor faults that indicate repeated movement. These provided access for solutions from an unknown and possibly distant source. The extraordinary stratigraphic uniformity of the ore zone appears to have contributed to the formation of an exceptionally large and continuous orebody, and the fine laminations of the replaced beds seem to have been more important than their exact composition. Swanson and Gunning (1945) point out that there is evidence indicating either two stages of mineralization, or one long and variable stage. They find insufficient evidence to determine whether the mineralization was related in time and origin to the Purcell intrusives, or to the much later intrusives of Cretaceous or early Tertiary age.

SILVER GIANT MINE

The Silver Giant mine is on the west side of Jubilee Mountain about 7 miles by road from Spillimacheen. It is in Jubilee magnesian limestone just east of a major westerly dipping fault, on which Horsethief Creek strata, of Precambrian age, are thrust over the lower Palaeozoic. The mine is west of the Rocky Mountain Trench proper, between the Trench and the subsidiary trench of the Spillimacheen valley.

Lead-zinc ore is mined at the rate of about 500 tons per day. The grade of ore mined has been less than 1 ounce of silver per ton, about 4 per cent lead, and about 1 per cent zinc. Ore has been mined through a vertical range of about 700 feet, from a surface glory hole to No. 7 level, which is reached by an internal shaft from No. 6 adit level.

The ore zone is in an overturned nose of Jubilee limestone, which plunges 45 degrees in the direction south 75 degrees west. Black slates are wrapped around the nose and there is some faulting and brecciation. Paper slates are seen in the crosscut for 900 feet southwest of the nose, and are different from limy slates on the surface to the northeast. They may be Horsethief Creek strata, but the main regional thrust is believed to lie farther to the southwest, and only subsidiary faults occur in the mine workings.

Replacement of the limestone by barite and more or less fine-grained silica has occurred in the nose, and, to a lesser extent, along both limbs of the fold. The ore is confined to the barite zone and consists of fine-grained galena, and scattered pyrite and sphalerite. There are local small amounts of chalcopyrite, bornite, and a grey copper-arsenic mineral. Some of the ore is highly siliceous and is marked by clots and wisps of dark grey silica which represent silicified slate fragments at and near the limestone-slate contact.

The steeply plunging ore-bearing structure is strongly at variance with a low southeasterly plunge, evident from about 1,500 feet to 1 mile northwest of the mine. There is obviously a marked change of direction of plunge. The ore structure appears to be anomalous, but outcrops are very scanty and detailed areal mapping has not been done. A line of showings, containing barite and small amounts of sulphide, extends eastward on the line of the ore structure to the crest of Jubilee Mountain. Presumably these showings represent the roots of the eroded ore structure, which plunged at a somewhat steeper angle than the line of showings.

Other showings of lead-zinc mineralization occur on Jubilee Mountain and on the eastern side of it, but have not been sufficiently developed to indicate their size. There is no exploration activity at the present time.

THE MONARCH AND KICKING HORSE MINES

These are described in some detail on other pages of this Guidebook, by C. S. Ney. It is sufficient to emphasize here that they constitute the largest orebodies at present known in the Rocky Mountains. Continuity of the orebodies across the 3,800-foot gap of the Kicking Horse River cannot, of course, be proved, but it seems probable that the dolomitic alteration zone in which they occur was continuous between the two mines, and that the several orebodies are parts of a single, although not necessarily continuous, ore zone. If so, the original ore zone was of major proportions, being at least 7,000 feet long.

OTHER MINERALIZED LOCALITIES

OTTERTAIL RIVER

Several old prospects on the Ottertail and its tributaries received attention at the time of completion of the Canadian Pacific Railway, and ores from this source as well as the Monarch deposit were considered in early attempts at smelting. At the head of Silver Slope Creek a bed, 6 feet thick, of Chancellor limestone, is cut by mineralized calcite stringers, and is impregnated with irregular lenses of galena, sphalerite, and pyrite, and small amounts of chalcopyrite and probably argentite. At the head of Haskins Creek a prospect shows chalcopyrite and pyrite associated with quartz veins in slates. On Frenchman Creek quartz-calcite veinlets in slates contain galena, tetrahedrite, azurite, malachite, pyrite, and some arsenopyrite. One-half mile from the railway, chalcopyrite, galena, sphalerite, pyrite, tetrahedrite, and in one place fluorite, are associated with quartz and calcite stringers in slaty rocks of the sheared Chancellor formation.

ICE RIVER

On Shining Beauty Creek, a tributary of Ice River, a quartz-calcite vein 2 feet wide contains pyrite, galena, and a small amount of chalcopyrite. Pockets of arsenopyrite and quartz occur in limestone, locally wit hassociated sphalerite and bornite. In Zinc Valley a band of siliceous limestone 2 to 3 feet thick, between argillites, contains a lenticular mass of sulphides consisting of sphalerite, bounded successively by arsenopyrite and pyrite.

MOOSE CREEK

On Zinc Mountain, at the head of Moose Creek and close to the eastern margin of the Ice River Complex, lenses of sphalerite, pyrrohotite, galena, and chalcopyrite occur in limestone and calcareous shales. Knopite and magnetite were reported from the vicinity of Moose Creek in 1925 (Geol. Surv., Canada, Sum. Rept. 1925, p. 230), and in 1952 and 1953 the occurrence of minerals containing titanium, niobium, thorium, and uranium was reported,

HAWK CREEK

A lead-zinc deposit was discovered on the north side of Hawk Creek in 1929, about 2 miles east of the Banff-Windermere Highway. Permission to do assessment work was refused by the National Parks Board in 1932, but the showings were diamond drilled in 1942 as a war-time measure to investigate possible reserves of lead and zinc. No further work has been done on the property.

The rocks in the area consist of a series of interbedded limestones and argillites, of probable Upper Cambrian or Ordovician age. At the showing the beds dip gently or are horizontal, and are cut by a shear zone that dips 45 to 70 degrees to the southwest. The deposit is localized at the intersection of the shear zone and a limestone bed. The ore consists largely of sphalerite, replacing limestone, and is banded parallel to the shear, but the controlling factor in deposition appears to have been lithological. At the surface the ore zone is an irregular shaped body about 55 feet wide and as much as 18 feet thick. Drilling has indicated a pencil-like body of variable outline, with a low rake to the northwest. An interpretation by Henderson (Minister of Mines, British Columbia, Ann. Rept., 1953) of the diamond drilling data indicates the presence of 29,500 tons of ore, averaging 12.5 per cent zinc. The lead content is reported to be low and the silver content negligible.

CROSS RIVER

On the Cross River two main diorite sills and a few small sills and dykes occur. The main sills contain many small transverse quartz, calcite, and quartz-calcite veins; some of the last named contain small amounts of pyrite and chalcopyrite, and, rarely, tetrahedrite, galena, and sphalerite.

OLDMAN RIVER

The Bearspaw lead-zinc deposit at the head of the Oldman River was discovered in 1912, by hunters, but was not staked until 1950. It is on the east side of the Elk Range, at an elevation of about 7,000 feet, and is accessible from the Kananaskis road by a rough truck road completed in 1953. It is at present under option to Western Canada Colleries, who have done some surface work.

The deposit is a replacement by galena and sphalerite of dolomite, near the top of the Devonian, about 200 feet above a sole fault on which Palaeozoic strata are thrust over Cretaceous sandstones and shales along a 40-mile front. The mineralization is, according to early reports, about 4 to 4½ feet wide, and is in a strongly fractured zone dipping 40 degrees westward. Lead and zinc are present in approximately equal amounts, but initial sampling did not indicate a particularly high grade. One other small occurrence of similar material has been found several miles distant.

SWANSEA MOUNTAIN

On Swansea Mountain, east of Athalmer, a deposit of copper has been known for many years. A breccia zone in upper Jubilee dolomite contains narrow and discontinuous stringers in the calcite and hematite cement. The stringers contain bornite and chalcopyrite, and secondary malachite and azurite.

MADIAS CREEK

On the western front of the Rocky Mountains, a mile north of this creek, a discovery of lead-zinc mineralization in dolomite was made in 1951. An apparently isolated pod as much as 15 feet wide, and exposed for 35 feet on the slope, consists of highly oxidized, brecciated, dolomite partly replaced by galena and a little sphalerite.

WASA CREEK

At the head of Wasa Creek, 9 miles northeast of Wasa, a quartz vein 2 feet thick is reported to contain tetrahedrite and copper carbonates.

LEWIS CREEK

Old reports mention a 4-inch quartz vein containing copper mineralization, and a quartz vein 6 to 8 feet thick containing galena stringers.

ESTELLA MINE

The Estella mine is at the head of Tracy Creek in the western range of the Rockies, east of Wasa and 11 miles north of Fort Steele. The mine is accessible from the mill-site at Wasa by a good road 16½ miles long.

The mine is a very old one that was investigated at various times in the past. The present owners, Estella Mines Limited, acquired the property in 1950, and built a 200-ton mill that was in operation late in 1951. The readily available ore was exhausted early in 1953 and subsequent development to the end of 1953 was not encouraging, and in consequence all operations ceased.

The rocks are in the transition zone between the Aldridge and Fort Steele formations, intruded by a body of diorite which is sill-like in over-all form. A small body of syenite occurs at one adit portal. The lode dips to the southwest and is a zone of fracturing and light shearing semi-bedded in the sediments, and penetrating diorite in the mine workings. The ore is a replacement by sphalerite, galena, and pyrite, accompanied by more or less silica. Vein quartz is not abundant and as a rule is not mineralized. The zinc to lead ratio averages about 2 1/8:1, and about 1 ounce of silver per ton is present. A small amount of cobalt is associated with the sphalerite. Ore occurs in grey argillite, in quartzite, and in diorite; the reasons for localization are not obvious, but there may be a relation to the diorite contact.

About 70,000 tons of ore have been mined, with a grade of 14 per cent combined lead and zinc.

HERBERT CREEK

On this small creek 8 to 9 miles north of Fort Steele three showings have long been known. One is a breccia zone in quartzite, mineralized with chalcopyrite and pyrite. Another consists of quartz-calcite lenses in the upper part of a large diorite sill, and containing galena, pyrite, and chalcopyrite. The third comprises several quartz veins as much as 24 inches wide, in limestone, and containing iron sulphides.

KOOTENAY KING MINE

The Kootenay King mine is on the north side of Wild Horse River, 10 miles northeasterly from Fort Steele. The lowest adit is at an elevation of 7,100 feet. This is another old property which was explored at intervals over the years. It was equipped with a mill in 1951 and started to produce the next year. Production was continuous from March to December of 1952, when low prices forced curtailment. Some broken ore was milled during a short period in 1953, and all activity then ceased.

The ore is a replacement of dolomitic argillite, intercalated with quartzite bands in the transition zone between the Aldridge and Fort Steele formations. The ore zone is localized within a minor dragfold in the steeply dipping strata. The argillite is a soft, dense, grey rock with a total width across two bands of about 60 feet. It is crumbled in the dragfold and is cleaved axially to the fold. The dragfold plunges at a low angle to the north. The ore is a replacement by fine-grained sphalerite, galena, and pyrite.

About 16,000 tons of ore were milled, containing between 6 and 7 per cent each of lead and zinc, and about 2 ounces of silver per ton.

WILD HORSE RIVER

A number of old properties are known in the basin of Wild Horse River and its tributary, Boulder Creek. Rather more work was done on these showings than the indications would normally warrant, because a source of the local placer deposits was sought diligently in the early days. All of the showings consist of quartz veins and quartzose zones, cutting Precambrian and Cambrian sediments, and in many instances associated with syenite dykes. The dykes are locally shattered and partly altered, and quartz occurs in or alongside them as vein stringers and replacement masses, a few inches to a few feet wide. The minerals present are galena, chalcopyrite, pyrite, and a little sphalerite. Quartz stringers containing visible gold have been noted in the Big Chief group.

MAUS CREEK

The Victor group at the head of Maus Creek, east of Fort Steele, is in Creston argillaceous quartzites. Three adits have been driven on a quartz-filled fissure about 2 feet wide, which is irregularly mineralized with galena, sphalerite, and pyrite. A 50-ton concentrator was build thirty years ago, but only a few tons of concentrate were shipped. Of two showings on Maus Mountain south of Maus Creek, one consists of a quartz vein in the Aldridge formation and contains pyrite and chalcopyrite; the other is a quartz vein, 4 feet thick, in a diorite sill, and contains small amounts of chalcopyrite and pyrite.

SUNKEN (LOST) CREEK

At the head of this creek, 7 miles southeast of Fort Steele, a quartz vein or quartz stringer zone has had two adits and a shaft driven in it. Stringers and pockets of "copper" are reported and the presence of tetrahedrite is mentioned.

BULL RIVER

South of Bull River and about 5 miles from its mouth, hematite is reported to fill fractures at right angles to the formation, and to spread out into bodies replacing "porous rock." The best of many showings is said to be 10 feet wide. At 6 to 7 miles from the mouth of Bull River, and on both sides of the river, mineralization is associated with a prominent diorite dyke. Minerals occurring in cleaved and fractured zones along the dyke margins include sulphides of copper, lead and zinc.

LITTLE SAND CREEK

At the head of this creek, between Elko and Bull River, a "strong quartz filled fissure" is reported to contain siderite, galena, sphalerite, pyrite, and some chalcopyrite. At a lower elevation a quartz-filled fissure in slates is reported to contain mineral, but only at cross fractures.

SAND CREEK

On Sand Creek, 7 miles northwest of Elko, several old properties are known. On the south side of the creek a bedded fissure vein, as much as 3½ feet wide, consists of hematite, with largely silica impurities. On the north side of the creek quartz veins of narrow to moderate widths contain lead, zinc, and copper sulphides; on the Burt property the vein is in a diorite dyke and contains galena and sphalerite. Similar mineralization occurs 3 to 5 miles northwest of Sand Creek.

ELKO

North and south of Elko, quartz veins with copper or lead-zinc mineralization are known on the western front of the Rocky Mountains, and on Sheep Mountain, which is west of the Elk River on the edge of the Trench. Although proof is lacking, it is suggested that these mineral showings may be related to faulting marginal to the Trench.

BIBLIOGRAPHY

Dawson, G. M. (1886): Preliminary Report on the Rocky Mountains; Geol. Surv., Canada, Ann. Rpt. 1885.

Allan, John A. (1914): Geology of Field Map-area, British Columbia and Alberta; Geol. Surv., Canada, Mem. 55.

Rice, H. M. A. (1937): Geology of the Cranbrook Map-area, British Columbia; Geol. Surv., Canada, Mem. 207.

Evans, C. S. (1933): Brisco-Dogtooth Map-area, British Columbia; Geol. Surv., Canada, Sum. Rpt. 1932, Pt. A II.

Henderson, G. G. L. (1954): Geology of the Stanford Range; British Columbia Dept. of Mines, Bull 35 (in press)

Swanson, C. O., and Gunning, H. C. (1945): Geology of the Sullivan Mine; C.I.M.M., Trans., Vol. XLVIII, pp. 645-667.

Minister of Mines, British Columbia, Annual Reports, particularly 1898, 1917, 1924, 1925, 1927, 1930, 1949, 1951, 1953.