WASHINGTON GEOLOGICAL SURVEY

HENRY LANDES, State Geologist

BULLETIN No. 23

THE METAL MINES OF WASHINGTON

By ERNEST N. PATTY

OLYMPIA, WASH.
FRANK M. LAMBORN PUBLIC PRINTER
1921

BOARD OF GEOLOGICAL SURVEY

Governor LOUIS F. HART, *Chairman.*
State Treasurer W. W. SHERMAN, *Secretary.*
President HENRY SUZZALLO.
President ERNEST O. HOLLAND.

HENRY LANDES, *State Geologist.*

LETTER OF TRANSMITTAL.

Governor Louis F. Hart, Chairman, and Members of the Board of Geological Survey:

GENTLEMEN: I have the honor to submit herewith a report entitled "The Metal Mines of Washington," by Ernest N. Patty, with the recommendation that it be printed as Bulletin No. 23 of the Survey reports.

Very respectfully,

HENRY LANDES,
State Geologist.

University Station, Seattle, January 15, 1921.

TABLE OF CONTENTS

PART I.

ILLUSTRATIONS

FIGURES

INTRODUCTION.

FIELD WORK

For the past several years there has been a demand for a report that would bring up to date the information on the metal mines of the State and consolidate that information under one cover.

In view of the fact that there are several thousand small prospects scattered over a wide territory in the State, and that many of these have undergone practically no development during the past few years on account of war conditions and the heavy demand for industrial labor, it was decided that this report should be confined to those properties that were show-evidences of activity. With this plan in view the writer entered the field June 24, 1919, starting near the eastern border of the State and working westward across the northern tier of counties until September 7, 1919, when the work was interrupted.

During the summer of 1920 six weeks were spent completing the field work in Pend Oreille, Stevens, Ferry and Okanogan counties. The active properties in the Cascade Range were visited by a series of short trip at odd intervals.

SCOPE OF THE REPORT AND SOURCES OF INFORMATION

In the following report there is presented such information as the writer has been able to collect concerning the active mining properties of the State. The description of the various properties should not be considered in the light of an exhaustive report. The field work was carried on without assistants and the large number of mines to be visited, scattered over an extensive area, prohibited an exhaustive study of the individual deposits. On the other hand, these deposits were studied in sufficient detail to permit a reliable description of their economic features. In a public report it would be manifestly unfair to discuss the properties as freely and candidly as is customary in private reports.

The writer feels that the greatest tangible benefits to the prospector and small operator, from work such as this, comes from personal contact with these men in the field where their

problems can be talked over informally and as far as possible solutions suggested. In this way it is not necessary that they shall wait until the report is published to learn what the investigator saw at the property and whether or not he felt inclined to encourage or discourage further development work. This is not an encroachment on the legitimate field of the mining engineer; on the contrary it more usually serves to cultivate an appreciation of the aid of technical guidance.

Except where otherwise noted practically all the information is the result of personal observations. The ore bodies as a rule were not sampled and only such assays are quoted as would serve to convey a general idea of the average grade of the deposits. Many of the smaller operators do not yet appreciate the value of systematic sampling, and it is not unusual, in the case of a non-shipping property, to find that the grade of the deposit has not been definitely determined.

At each property a few type samples of the ore and associated country rock were collected and brought into the laboratory for study. Exhaustive rock descriptions were avoided as far as possible, not because the writer fails to appreciate the value of petrography as applied to ore deposits, but because involved petrographical descriptions are not readily understood by the average reader of these reports. Detailed descriptions of the important formations of the various mining districts of the State have been presented in previous reports and to repeat them would be needless duplication.

The amount of space given to any one district or individual property is not a criterion of its relative importance. The exigency of covering so extensive an area in a limited time, caused in some instances unequal proportionment of field work, and the relative complexity of the problems encountered served roughly to measure the time given to the various districts.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the splendid cooperation of the mining men of the State, who, practically without exception, furnished the writer every facility at their command to further the study. The whole-hearted hospitality of these men

will cause the pleasant recollections of arduous trips to out-of-the-way camps to remain fresh in the memory after the discomforts have long been forgotten.

The work was greatly expedited by the use of U. S. Geological Survey and State Geological Survey reports on individual areas. These were freely drawn upon for information, and effort has been made to record these acknowledgments in the text. In certain problems the final product is composite, consisting of ideas drawn from several sources and linked with those gained from personal examinations.

The writer wishes to acknowledge the helpful assistance of his wife in the final reading and preparation of the manuscript. Professor G. E. Goodspeed, of the Geology Department, University of Washington, offered a number of suggestions which materially aided in the solution of certain problems encountered. The petrographic determinations of several rock thin-sections were made by Professor Goodspeed and Virgil Kirkham of the University of Washington.

BIBLIOGRAPHY

Aside from brief articles or paragraphs appearing from time to time in the various mining journals and in statistical reports, the following reports having direct bearing upon the metalliferous ore deposits of the State, have been published. For a complete bibliography of mining literature of Washington, reference should be made to University of Washington ton Experiment Station Bulletin No. 4, 1918. A Summary of Mining in the State of Washington: by Arthur H. Fischer.

Reports of the Washington Geological Survey:

First Annual Report of State Geologist.—Mines and Minerals of Washington: by Geo. A. Bethune, 1891. Describes early mining operations in Washington.

Vol. 1, part 2, Metalliferous Resources of Washington, Except Iron, by Henry Landes and others, 1901. A report covering an early reconnaisance examination of the mining properties of the State.

Bulletin No. 1, Wash. Geol. Survey, Geology and Ore Deposits of Republic Mining District, by Joseph B. Umpleby,

1910. A complete report covering the ore deposits and related geology of this interesting district.

Bulletin No. 5, Geology and Ore Deposits of the Myers Creek and Oroville-Nighthawk Districts, by Joseph B. Umpleby, 1911. Describes these two related districts in northern Okanogan County.

Bulletin No. 6, Geology and Ore Deposits of the Blewett Mining District, by Charles E. Weaver, 1911. This report includes a short history of the development of mining at Blewett, the topography and physiography, and a description of the geology and detailed description of the individual mines.

Bulletin No. 7, Geology and Ore Deposits of the Index Mining District, by Charles E. Weaver, 1912. The Index District in the Cascades is handled in a manner similar to Bull. No. 6.

Bulletin No. 11, The Mineral Resources of Washington, with Statistics for 1912, by Henry Landes. Annual report dealing with the output of minerals and rocks and their economic importance. Complete yearly production figures are included in the report.

Bulletin No. 16, Geology and Ore Deposits of the Covada Mining District, by Charles E. Weaves, 1913. Interprets the general geology of the district, the character of the ore deposits, and gives a brief description of the individual mining properties.

Bulletin No. 20, The Mineral Resources of Stevens County, by Charles E. Weaver, 1917. A very complete report covering the geology and economic mineral resources of Stevens County. The report is accompanied by an areal and structural geologic map of the county.

Reports of the United States Geological Survey:

Russel, Israel C., Preliminary Paper on the Geology of the Cascade Mountains in Northern Washington, Twentieth Ann. Rept., 1898-99, part II, Washington, D. C., 1900.

Smith, George Otis, and Willis, Bailey, Contributions to the Geology of Washington, Prof. Paper No. 19, Washington, D. C., 1903. Geology and Physiology of Central Washington, by George Otis Smith, and Physiography and Deformation of

the Wenatchee-Chelan District, Cascade Range, by Bailey Willis. In this paper the results of detailed areal geological work are presented. Special attention is given to the physiography and the development of the topographic features. The conclusion is drawn that there were two periods during Tertiary times of complex warping of the Cascades, separated by a period of peneplanation. No discussion of the ore deposits is attempted.

Spurr, Joseph E., Ore Deposits of Monte Cristo, Washington, 22d Ann. Report, 1900-01, part II., pp. 777-888, Washington, D. C., 1901. A report covering an area of about 20 square miles of the Monte Cristo Mining District, which at one time was one of the most active mining areas in the State. The Report is accompanied by an areal geologic map.

Smith, George Otis, U. S. Geol. Survey Geol. Atlas, Mount Stuart Folio, (No. 106), 1904. Represents detailed areal geological mapping of about 800 square miles in the Cascades. A brief description is given of several placer and loe deposits.

Smith, George Otis, U. S. Geol. Survey Geol. Atlas, Snoqualmie Folio (No. 139), 1906. Represents detailed geological mapping of practically 800 square miles in the Cascades northwest of Ellensburg. Several deposits of iron ore are noted and brief mention is made of other metalliferous deposits.

Collier, A. J., Gold-bearing River Sands of Northeastern Washington, Bull. 315, 1907.

Collier, A. J., Tin Ore at Spokane, Washington, Bull. 340, 1908. Describes an occurrence of a small deposit of cassiterite a few miles southeast of Spokane.

Bancroft, Howland, The Ore Deposits of Northeastern Washington, Bull. 550, 1910. A well prepared report describing the ore deposits and the related geology of Pend Oreille, Stevens, and a part of Ferry counties.

Jones, E. L., Jr., Reconnaissance of the Conconully and Ruby Mining District, Washington, Bull. 640-B, 1916. A comparatively recent description of the closely related Conconully and Ruby Mining Districts in Okanogan County. The interpretation of the geology is accompanied by a geologic sketch

map. Descriptions of the individual mines and brief notes on the metallurgy of the ores are included.

Pardee, J. T., Geology and Mineral Deposits of the Colville Indian Reservation, Washington, Bull. 677, 1913. A geologic reconnaissance and description of the ore deposits of the Colville Indian Reservation in the south-half of Ferry County and the southeast corner of Okanogan County. Report is accompanied by an areal geologic map.

Miscellaneous

The Mining Advance into the Inland Empire, by William J. Trimble, Ph.D., a thesis submitted for the degree of Doctor of Philosophy at the University of Wisconsin, 1914. A historical treatise on the early history of mining in the Pacific Northwest. The prospector is shown as the forerunner of civilization in this region. The subsequent economic development of the country is correlated with early mining advances.

Mining in the Pacific Northwest, by L. K. Hodges, 1897. Issued in book form by the Seattle Post-Intelligencer as a non-technical review of the mineral resources of Washington and British Columbia,—chiefly of historical value.

Northwest Mines Handbook, Vol. 1, 1918, by Sidney Norman. A directory of the mining companies of Washington, British Columbia, Montana, Idaho, and Oregon. Gives brief descriptions of mining properties and data on the organization of the various mining companies.

North American Cordillera of the Forty-ninth Parallel, by R. A. Daly, Memoir No. 38, Canadian Geological Survey, Parts I and II. An excellent report on the geology and structure of the mountains crossed by the international boundary at the forty-ninth parallel. Field work during season of 1901 to 1906 inclusive, Ottawa, 1912.

HISTORY OF METAL MINING IN WASHINGTON

Between the lines of the history of metal mining can be read the romance that attends the mining development of the Western Country. It was the quest for gold that first brought the miner and prospector into Washington Territory, when there came the rush to the placer gold finds near Old Fort Col-

ville during 1855. This gold was found along the river terraces of Columbia and Similkameen rivers and some of their smaller tributaries.

In a very interesting book,* William J. Trimble, Ph. D., recounts the birth of the mining industry in Washington and the adjacent territory, and traces the subsequent development of the country along lines of social aspects, education, religion, law, and government, that followed in the wake of mining advance. Some of the following interesting information is abstracted from his report:

"Fort Colville, on the east bank of the Columbia River, which for 30 years previous to the discovery of gold in Washington was the chief inland post of the Hudson Bay Company, suddenly became the center of early mining in the Inland Empire. The gold discoveries brought hardy bands of adventurers from the gold fields of California and Oregon and from settlements along the coast of western Washington and Oregon.

"One of the greatest factors in the mining advance was the friendship of the Nez Perce Indians, who, alone of the tribes of the Inland Empire, were not hostile to miners and farmers. Trouble with the warlike tribes broke out in September, 1855, and continued until 1856. During the progress of this war General Wool, commander of the Department of the Pacific, issued the following orders:

" 'No emigrants or other whites, except Hudson Bay Company or persons having ceded rights from the Indians, will be permitted to settle or remain in the Indian country, or on land not ceded by treaty confirmed by the Senate and approved by the President of the United States.

" 'These orders are not, however, to apply to the miners engaged in collecting gold at the Colville mines * * *'

"Probably the custom of the miners of unconscious trespassing and their claim of implied recognition to such rights on the part of the United States may have influenced the military authorities to make the exception noted in their favor."

* * * *

*The Mining Advance Into the Inland Empire. A thesis submitted for the degree of Doctor of Philosophy at the University of Wisconsin, 1914.

In the early seventies lode mining began. Some of the first locations were made on Silver Creek in the Index District and in the Blewett District during 1874. Ruins of old arrastres fashioned from solid rock remain today in the Blewett District to tell the story of early concentration of the free milling gold from the oxidized surface ores. These crude arrastres were no doubt the first attempt at concentration of ores in the Territory. About 1878 the first stamp mill was erected at Blewett, and it continued to operate successfully for several years.

During the year 1893 four prospectors descending the slopes of Old Dominion Mountain, near what is now the town of Colville, which they had ascended to find out their position in relation to the surrounding country, discovered what is now the Old Dominion Mine. The rich lead-silver ores were at first packed to Spokane on horses at a cost of $100.00 per ton. Five years later prospectors, working northward up Columbia River into British Columbia, discovered the Young America and Bonanza deposits near what is now the town of Bossburg. Following this, more attention was given to the search for ores of lead, silver and copper. Greater impetus was added by the building of the Spokane & Northern Railway into Stevens County, and the ore deposits of the Chewelah, Deer Trail, and other districts began to receive merited attention.

There was little activity in Ferry County until the north-half of the Colville Indian Reservation was thrown open for mineral entry in 1896, when development of the gold ores of the well known Republic District quickly began. During 1898 the south-half of the Reservation was thrown open for mineral entry; a rush of prospectors followed and in a short while 3,000 claims were located and the Nespelem (Moses) and Keller districts came into existence.

In Okanogan County the placers along Similkameen River were first worked in 1859. The first quartz lode was located in 1871 near Conconully. The area later reverted to the Indians and was not reopened for entry until 1886. The Ruby silver camp, 4 miles south of Conconully, was actively worked beginning in 1889, and at one time it is estimated that

there were 1,000 miners in the camp. The sudden and complete drop of the silver market in 1893 closed down all operations and only recently is the district beginning to show evidence of revival.

The first claim was staked in the Monte Cristo District during July, 1889, and during 1893 a railroad was constructed into the district at heavy expense and in the face of many complex engineering difficulties, and it is the only railroad so far in the State which has been constructed solely for mining purposes.

The discovery of placer gold along Ruby Creek in the Mount Baker District caused an invasion of miners on a scale approaching a stampede. The excitement, however, soon subsided and it was not until 1897 that the first important lode discovery was made. This was the Lone Jack, and today this mine and the Boundary Red Mountain stand out as the two most important mines in the district.

METAL PRODUCTION

Washington, during recent years, ranks approximately twelfth among the States in the production of gold, silver, copper, lead, and zinc. The yearly production of these metals based on an average for the last five years is one and one-half million dollars. Over this period gold makes up approximately 27 per cent of the production, silver 16 per cent, copper 30 per cent, lead 22 per cent, and zinc 5 per cent.

The total metal production made by the State from 1860 to 1918 inclusive, is fixed at $37,954,087. Since 1903 the State and County totals are accurate, but previous to that time the totals are largely those of the Mint and lack detailed information regarding districts or counties. The still earlier figures are based largely on estimates that are considered reasonably accurate.

The following tables were compiled from statistics prepared jointly by the U. S. Geological Survey and the Washington Geological Survey:

	COUNTY	GOLD (value)	SILVER (value)	COPPER (pounds)	LEAD (pounds)
1903	Adams	$696	.....	.....	.....
	Chelan	80,090	.....	.....	.....
	Ferry	275,397	$83,464	75,471	.....
	King	1,584	20	.....	.....
	Kittitas	4,434	7	.....	.....
	Okanogan	36,009	20,656	113,207	6,300
	Pierce	.....	.....	.....	.....
	Skagit	.....	865	.....	8,400
	Snohomish	70,661	29,876	292,863	1,200
	Stevens	2,502	54,865	19,038	389,512
	Whatcom	36,288	12,030	.....	.....
	Other counties	130	6	.....	.....
	Totals	$507,885	$201,789	500,579	405,412
1904	Chelan	$21,187	.....	.....	.....
	Ferry	113,257	$22,085	77,548	.....
	King	6,327	.....	.....	.....
	Kittitas	2,675	.....	320	.....
	Okanogan	18,066	6,152	.....	.....
	Snohomish	25,351	7,133	77,850	.....
	Stevens	11,600	40,090	194,320	1,760,309
	Whatcom	115,000	14,371	.....	.....
	Other counties	.....	.....	.....	.....
	Totals	$314,463	$89,831	350,047	1,760,309
1905	Asotin	1,025	.....	.....	.....
	Chelan	12,640	$370	.....	.....
	Clarke	100	.....	.....	.....
	Ferry	86,053	21,107	.....	.....
	King	18,657	524	2,008	.....
	Okanogan	2,313	6,457	.....	200
	Snohomish	40,425	18,087	91,252	.....
	Stevens	165,882	15,822	15,449	604,843
	Whatcom	77,983	13,360	.....	.....
	Totals	$405,078	$75,727	108,709	605,043
1906	Adams	$983	.....	.....	.....
	Chelan	290	.....	.....	.....
	Clarke	100	.....	.....	.....
	Ferry	70,742	$17,730	52	.....
	King	21,828	614	.....	.....
	Okanogan	8,799	4,394	24,363	.....
	Snohomish	2,873	3,406	138,802	.....
	Stevens	77,837	4,269	72,313	926,100
	Whatcom	38,196	312	.....	.....
	Other counties	.....	12	.....	.....
	Totals	$221,648	$30,738	235,530	926,100
1907	Chelan	$2,766	$35	.....	.....
	Ferry	4,032	9,452	131,731	.....
	King	10,345	353	.....	.....
	Kittitas	8,686	69	.....	.....
	Okanogan	9,394	2,384	26,200	.....
	Snohomish	45,504	12,797	74,837	.....
	Stevens	149,588	11,286	65,044	820,035
	Whatcom	28,759	161	.....	.....
	Totals	$259,047	$36,537	297,812	820,035

	COUNTY	GOLD (value)	SILVER (value)	COPPER (pounds)	LEAD (pounds)
1908	Chelan	$3,630	$51	.....	.....
	Clallam	3,614	4,190	.....	.....
	Ferry	17,333	918	1,144	.....
	King	12,645	58	1,689	3,500
	Kittitas	5,971	.....	.....	.....
	Okanogan	7,998	13,528	57,000	.....
	Snohomish	775	28	3,765	.....
	Stevens	183,893	28,247	248,432	1,146,929
	Whatcom	6,045	38	.....	.....
	Whitman	309	.....	.....	.....
	Other counties	21	18	.....	.....
	Totals	$242,234	$47,076	312,030	1,150,429
1909	Chelan	$4,232	$61	.....	.....
	Clallam	39	.....	.....	.....
	Ferry	210,437	27,921	606	.....
	King	10,501	385	.....	.....
	Kittitas	5,829	46	.....	.....
	Okanogan	8,907	1,689	29,405	23
	Snohomish	49	12	4,977	.....
	Stevens	121,498	11,217	220,146	288,677
	Whatcom	559	3	.....	.....
	Totals	$362,051	$41,334	255,134	288,700
1910	Asotin	$68	.....	.....	.....
	Chelan	6,867	$74	61	.....
	Ferry	714,808	100,092	.....	128
	King	19,420	1,698	.....	.....
	Kittitas	3,589	30	.....	.....
	Okanogan	13,088	1,792	24	248
	Pierce	.....	.....	1,770	.....
	Skagit	.....	2	.....	40
	Snohomish	88	17	.....	40
	Stevens	30,182	7,172	85,063	1,321,871
	Whatcom	26	.....	.....	.....
	Other counties	9	9	.....	.....
	Totals	$788,145	$110,886	86,918	1,322,287
1911	Chelan	$21,846	$254	.....	.....
	Ferry	778,526	98,177	161,158	.....
	King	11,245	1,854	.....	.....
	Kittitas	2,801	29	.....	.....
	Lewis	.....	.....	3,425	.....
	Okanogan	4,723	6,468	.....	.....
	Pend Oreille	633	851	411	11,982
	Skagit	.....	2	.....	.....
	Snohomish	433	.....	101	.....
	Stevens	27,074	21,552	153,112	836,602
	Whatcom	189	1	.....	.....
	Whitman	203	16	.....	.....
	Totals	$847,677	$129,204	318,207	848,584
1912	Chelan	$35,130	$506	.....	.....
	Clallam	256	.....	.....	.....
	Ferry	605,698	93,687	77,968	.....
	King	7,711	1,708	.....	.....
	Kittitas	2,141	22	.....	.....
	Okanogan	3,362	14,759	966	.....
	Snohomish	717	4	.....	.....
	Stevens	23,823	143,624	1,007,076	127,381
	Whatcom	2,186	16	.....	.....
	Totals	$680,964	$254,326	1,083,010	127,381

	COUNTY	GOLD (value)	SILVER (value)	COPPER (pounds)	LEAD (pounds)
1913	Chelan	$8,590	$114	.....	.....
	Ferry	645,009	98,208	55,544	.....
	King	4,568	1,835	.....	.....
	Kittitas	3,677	37	.....	.....
	Okanogan	2,837	9,918	1,070	1,639
	Snohomish	2,622	406	.....	.....
	Stevens	23,480	89,493	897,467	200,848
	Whatcom	5,492	57	.....	.....
	Totals	$696,275	$200,068	954,081	202,487
1914	Chelan	$1,575	$15	104	.....
	Clallam	110	.....	.....	.....
	Ferry	513,276	90,513	159,142	5,603
	Kittitas	4,387	39	.....	.....
	Okanogan	2,724	4,446	16,081	22,391
	Skamania	.....	.....	142	.....
	Snohomish	7,217	761	263	1,317
	Stevens	11,894	50,588	602,996	36,196
	Whatcom	15,635	106	.....	.....
	Whitman	355	.....	.....	.....
	Totals	$557,173	$146,468	778,728	65,507

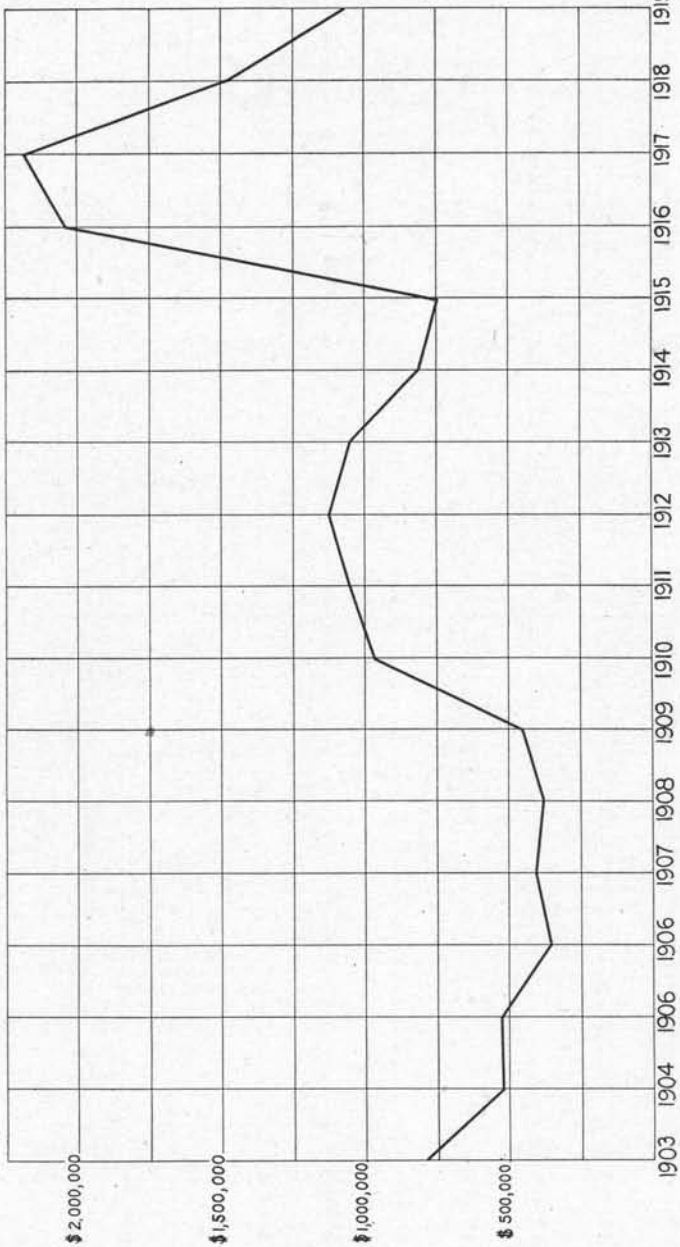


Fig. 1. Graph showing production of Gold, Silver, Copper and Lead, in Washington, 1903 to 1919.

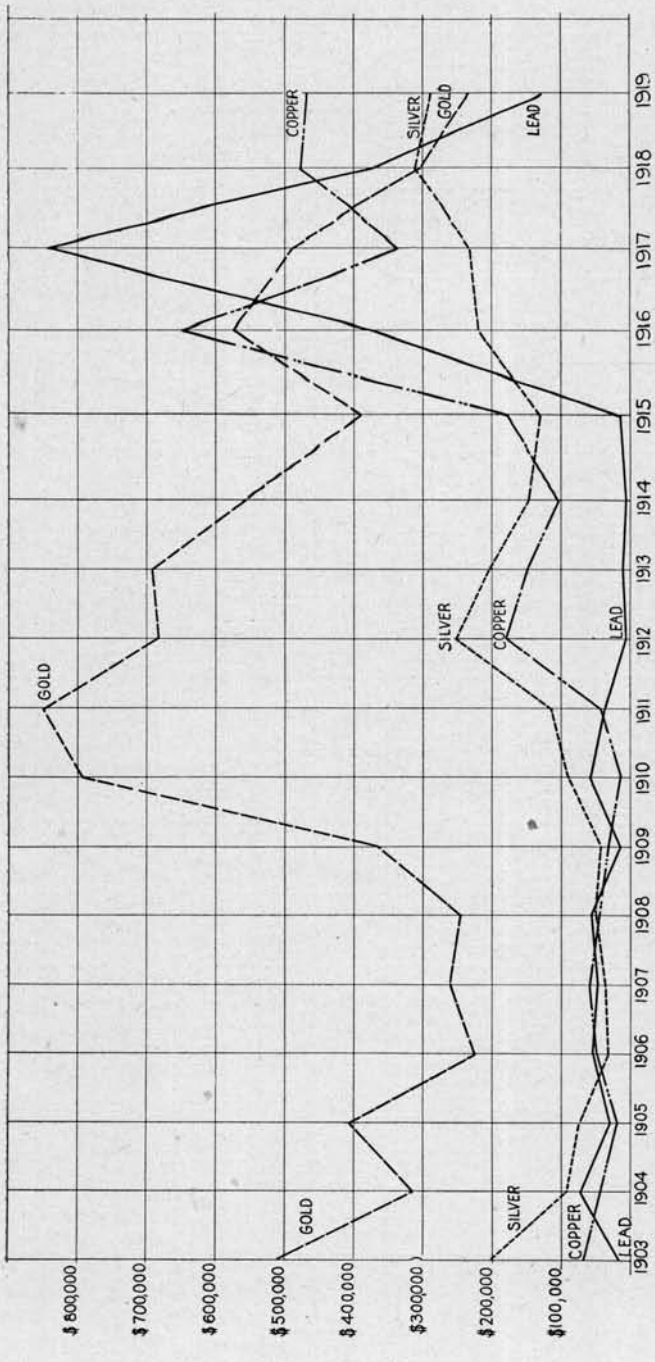


Fig. 2. Graph showing combined production of major metals in Washington, 1903 to 1919.

	COUNTY	GOLD (value)	SILVER (value)	COPPER (pounds)	LEAD (pounds)	Recoverable ZINC (pounds)
1915	Benton	$166				
	Chelan	4,279	$44	117		
	Clallam	685				
	Ferry	351,973	52,463	317,396	162	
	Kittitas	3,990	34			
	Okanogan	10,281	21,219	43,106	23,138	
	Pend Oreille					244,906
	Pierce		12	1,422		
	Snohomish	3,462	369	41,226		
	Stevens	4,063	55,643	617,659	271,915	
	Whatcom	12,520	25			
	Totals	$391,419	$129,709	1,020,926	295,215	244,906
1916	Asotin		$28			
	Chelan	$8,682	118	111		
	Clallam	372				
	Ferry	399,376	90,997	828,264	3,646	
	King	1,344	372			
	Kittitas	4,832	50			
	Okanogan	18,992	12,368	31,144	1,704	
	Pend Oreille		56		37,695	861,322
	Pierce	41	114	10,381		
	Skamania		79	1,280		
	Snohomish	1,844	1,170	295,485		
	Stevens	8,972	114,895	1,478,357	5,356,229	832,412
	Whatcom	133,200	263			
	Totals	$577,655	$220,510	2,645,022	5,399,274	1,693,734
1917	Chelan	$683	$8			
	Clallam	624				
	Ferry	332,071	80,822	273,624	1,395	
	King	5,742	2,230	4,870		
	Kittitas	4,848	80	4,002		
	Okanogan	6,403	12,044	83,524	2,455	
	Pend Oreille	170	1,279		130,324	1,176,715
	Pierce		39	3,084		
	Skagit	12	419			
	Snohomish	518	948	180,948		
	Stevens	3,757	132,675	682,740	9,655,513	18,852
	Wahkiakum	80				
	Whatcom	137,382	2,060			
	Yakima	34	28	1,486		
	Totals	$492,324	$232,632	1,234,278	9,789,687	1,195,567
1918	Chelan		$151			
	Clallam	$239				
	Ferry	276,062	101,378	127,813		
	King	4,672	2,314			
	Kittitas	2,636	38			
	Okanogan	1,585	32,110	169,899	785	
	Pend Oreille		394	149	193,878	38,873
	Snohomish	1,272	5,000	452,043		
	Stevens	8,198	168,669	1,170,488	5,077,152	
	Whatcom	9,929	39			
	Lewis			2,014		
	Totals	$304,593	$310,093	1,922,406	5,271,815	38,873

TOTAL VALUES OF THE PRODUCTION OF GOLD, SILVER, COPPER, LEAD, AND ZINC, BY COUNTIES FOR THE PERIOD 1903 TO 1919, INCLUSIVE.

COUNTY	1913	1914	1915	1916	1917	1918	1919
Asotin	.....	.....	.....	$55	.....	.....	.....
Benton	.....	.....	$167	.....	.....	.....	.....
Chelan	$8,704	$1,604	4,342	8,798	$691	$151	$137
Clallam	.....	111	688	374	628	241	.....
Ferry	751,826	625,173	459,985	694,378	487,708	409,012	319,703
King	6,403	.....	.....	1,716	9,301	6,988	3,134
Kittitas	2,714	4,426	4,024	4,882	6,020	2,673	990
Lewis	.....	.....	.....	.....	.....	497	520
Okanogan	12,993	10,182	40,131	39,138	41,460	75,171	37,917
Pend Oreille	.....	.....	30,368	118,074	132,816	17,736	497
Pierce	.....	.....	261	2,709	881	.....	609
Skagit	.....	.....	.....	.....	431	.....	.....
Skamania	.....	22	.....	394	.....	.....	.....
Snohomish	3,028	8,061	10,946	75,703	50,865	117,924	111,730
Stevens	260,018	144,002	180,576	968,666	1,418,494	826,456	651,015
Wahkiakum	.....	.....	.....	.....	80	.....	.....
Whatcom	5,549	15,739	12,545	133,463	139,442	10,026	.....
Whitman	.....	357	.....	.....	.....	.....	.....
Yakima	.....	.....	.....	.....	468	.....	.....
Totals	$1,053,135	$809,767	$744,033	$2,048,350	$2,289,285	$1,467,421	$1,126,252

TOTAL MINE PRODUCTION OF WASHINGTON

	GOLD	SILVER (fine ounces)	COPPER (pounds)	LEAD (pounds)	Recoverable ZINC (pounds)	TOTAL VALUE
Grand total 1860 to 1918	$27,753,350	7,363,533	12,845,206	32,528,919	3,193,670	$37,954,087

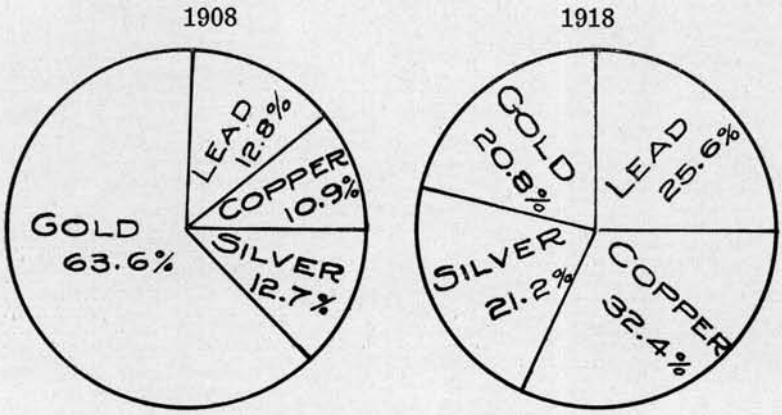
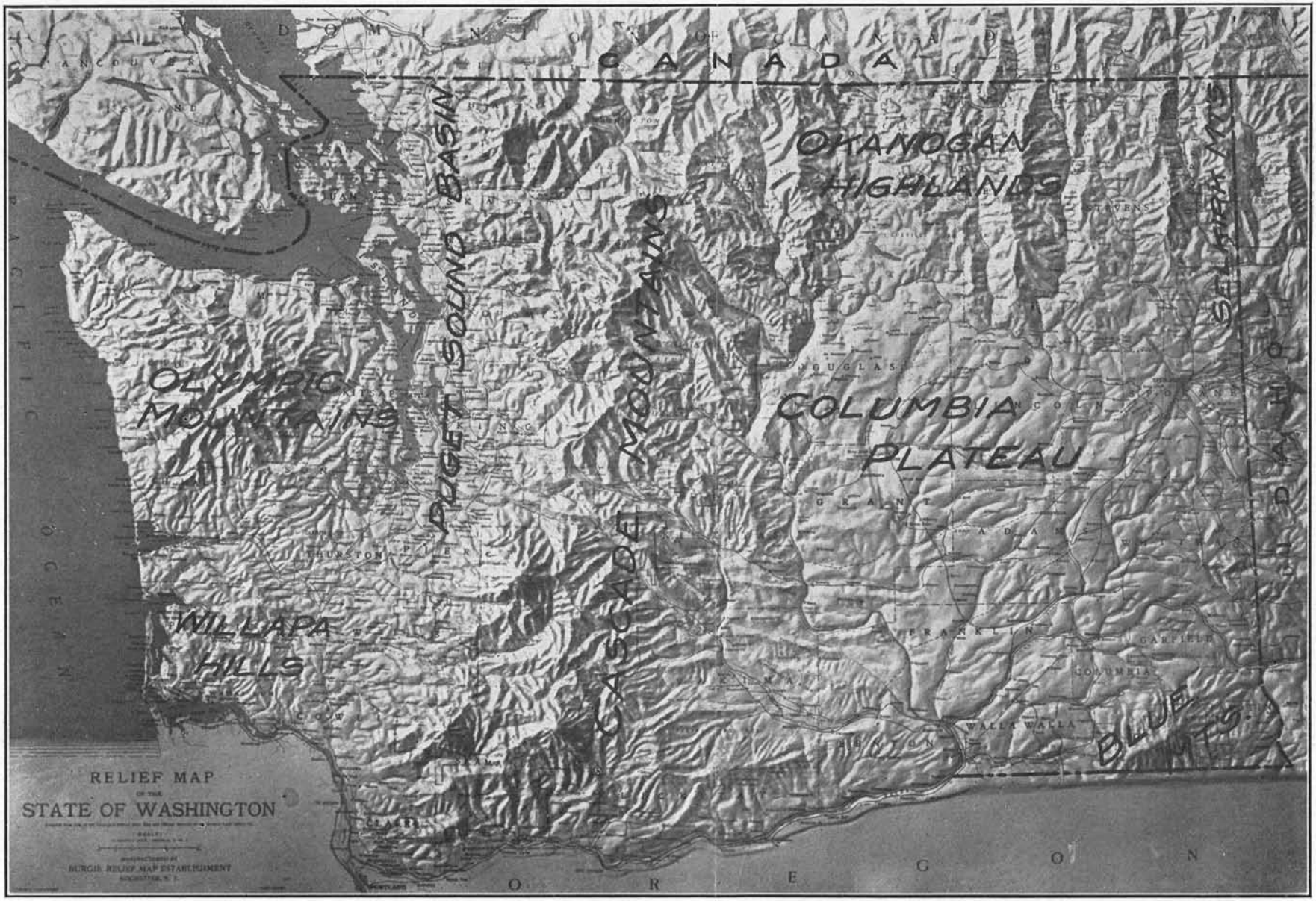


Fig. 3. Circular graph showing comparative production of major metals in Washington, 1908 and 1918.



RELIEF MAP OF WASHINGTON

GEOGRAPHY

TOPOGRAPHY

The State of Washington presents a pleasing variety of topographic features which can best be interpreted by dividing the area into eight topographic divisions: Selkirk Mountains, Okanogan Highlands, Columbia Plateau, Blue Mountains, Cascade Range, Olympic Mountain Range, Puget Sound Basin, and the Willapa Hills. The position of these will be best understood by referring to the relief map of the State, plate I.

The Selkirk Mountains cover the greater portion of Pend Oreille and Stevens counties in the northeast corner of the State. They are in reality the western front of the Rocky Mountains, and consist of a series of north-south trending ranges which cross the international boundary and trend southward 100 miles until they lose their prominence and disappear beneath the Columbia Plateau. A broad glacial trench now occupied by Pend Oreille River, subdivides the Selkirks into the Pend Oreille Range on the east and the Calispell Range on the west. In Stevens County a second large trench, known as the Colville Valley, forms a second division, the mountains on the western side of the valley being known as Huckleberry Range. The elevations of these various ranges vary from 3,500 to 5,000 feet, with occasional peaks boasting of an elevation of 6,000 to 7,000 feet above sea level. The floors of the glacial trenches vary in elevation from 1,500 to 2,000 feet above sea level.

A composite chain of north-south trending ranges which occupy Ferry County and the eastern half of Okanogan County are designated as the Okanogan Highlands. They merge into the Selkirk Mountains on the east and the Cascade Range on the west, without any conspicuous line of demarkation. The eastern limits may arbitrarily be placed as Kettle and Columbia River valleys, and the west, the Methow Valley, thus giving a breadth of 90 miles. From the international boundary, southward a distance of 75 miles, where the mountains disappear beneath the Columbia Basalt Plateau, the ridges maintain a moderately gentle and regular relief. During the Quaternary glacial period they were over-ridden by the

ice sheets, with the consequent damming and altering of rivers, the formation of glacial lakes, and the cutting of inter-mountain valleys, while the upland surface usually presents a moderately undulating topography interspersed with mountain parks. The greater portion of Washington's metalliferous ore production comes from the Selkirk Mountains and the Okanogan Highlands.

To the traveler who has crossed the State, the level monotony of the Columbia Plateau is not readily forgotten. It lies east of the Cascade Range and south of the Okanogan Highlands. This vast plateau is constructed of a great series of basaltic lava flows, known in places to have a thickness of 4,000 feet. River erosion has furrowed deep channels across the area and great stresses apparently originating from the uplift of the Cascade Range has in places warped the flows into anticlinal ridges.

The Blue Mountains occur in the southeastern corner of the State and trend southward into Oregon and eastward into Idaho, where they form important ranges. They represent an uplift of the southern extension of the Columbia Plateau. In Idaho and Oregon the Blue Mountains contain valuable ore deposits but in the Washington area such deposits are absent.

The Cascade Mountains form the major mountain range of Washington. It is a part of a great mountain chain that extends from Alaska to Mexico. Where it crosses the international boundary, its width is approximately 120 miles, but farther southward it narrows and near the Oregon boundary is approximately 70 miles in width. The range, particularly the northern segment, is noted for its alpine grandeur. It is gashed to the core with deep-cut glacial valleys from which the steep valley walls lead upward to culminate in precipitous crag-like divides at elevations of 5,000 to 8,000 feet above the valley levels. Where the gradient of the slopes and altitude permit, there are heavy stands of timber to enhance the beauty of the range. When viewed from the higher peaks, the general surface of the Cascades quickly suggests a deeply dissected, slightly undulating plain. The summits of the ridges consti-

Summit of the Cascade Range, showing characteristic topography.

tute the remnants of a former peneplain, the surface of which averages 6,000 feet above sea level. Imposed upon this deeply dissected plateau are five high volcanic cones, which, named in order of their location from north to south, are Mt. Baker, Glacier Peak, Mt. Rainier, Mt. Adams, and Mt. St. Helens. There are a number of good mining properties in the Cascade Range, but in point of mineral production, it ranks a poor second to the mountains represented by the Selkirks and the Okanogan Highlands.

The Puget Sound Basin lies between the Olympic and Cascade mountains.* It is limited on the north by the San Juan Archipelago and on the south by the low divide between Chehalis River and Puget Sound. The larger part of this basin is an undulating gravel-surfaced plain, having an average elevation of approximately 500 feet. This plain is dissected by deep and partially submerged valleys elongated in a north and south direction. The eastern side of the basin rises gradually and merges into the western foothills of the Cascades, while the western border terminates abruptly against the Olympic Mountains. The southern continuation of this province is to be found in the lower Cowlitz Valley.

The Olympic Mountains occupy the northwestern portion of the State and include that section east of Hood Canal and north of the valley of Chehalis River. In their rugged mountain grandeur they excel even the Cascades. Their sharp ridges, rising 4,000 to 7,000 feet above deeply incised valleys, present a jagged sky line, above which towers serrate peaks such as Mt. Olympus, Mt. Angeles, Mt. Eleanor, Mt. Constance, The Brothers, and Mt. Church, with elevations varying from 7,500 to 8,250 feet above sea level. Volcanic peaks are absent from the range. The main divide of the Olympics trends from Hood Canal in the area between Duckabush and Skokomish rivers northwesterly to Cape Flattery. The eastern slope of the mountains descends abruptly to Hood Canal, while the southern side gradually merges into the low-lying hills of southwestern Washington. On the north and west the Olym-

*Weaver, C. E., The Tertiary Formations of Western Washington. Wash. Geol. Survey, Bull. 13, p. 57, 1916.

pics are bordered by a low coastal plain averaging 600 feet in elevation and deeply covered with deposits of glacial drift, river sands and gravel. The Olympics form a rugged mountain fastness which is the least known mineral province in the State. Large deposits of manganese ore occur there and deposits of other metals have been sparingly prospected.

The Willapa Hills of southwestern Washington lie between Columbia River on the south and the Chehalis Valley on the north. They extend from the Puget Sound Basin-Lower Cowlitz Valley depression westerly to the ocean, and are composed of low-lying heavily timbered hills attaining a maximum elevation of 3,000 feet, while the average elevation is approximately 500 feet. The bed rock of these hills is composed of Tertiary sandstones and shales. The province has no metalliferous deposits of importance. Mining activity has been confined to very limited placer operations.

DRAINAGE.

The drainage of the entire area of the State east of the divide of the Cascade Range is ultimately into Columbia River and thence direct to the Pacific Ocean. Columbia River also acts as the major drainage conduit for southwestern Washington. The drainage from the western slopes of the Cascades, the Olympics and the remainder of western Washington is either into Puget Sound or directly into the ocean.

CLIMATE

The climate of Washington is the resultant of the influences exerted by the latitude, nearness to the sea, prevailing wind direction, and variation in altitude or topography. These conditions fortunately give to the State no great extremes of either heat or cold. A study of the rainfall map, fig. 4, reveals the striking difference in rainfall received by the area east and west of the Cascade Range. Western Washington, situated as it is, between a great ocean and a high barrier mountain range, receives a heavy winter rainfall, an intermediate spring and autumn rainfall and a low summer rainfall. The portion of the State east of the Cascade Range receives a moderate rainfall during the winter months with only infrequent showers during the remainder of the year.

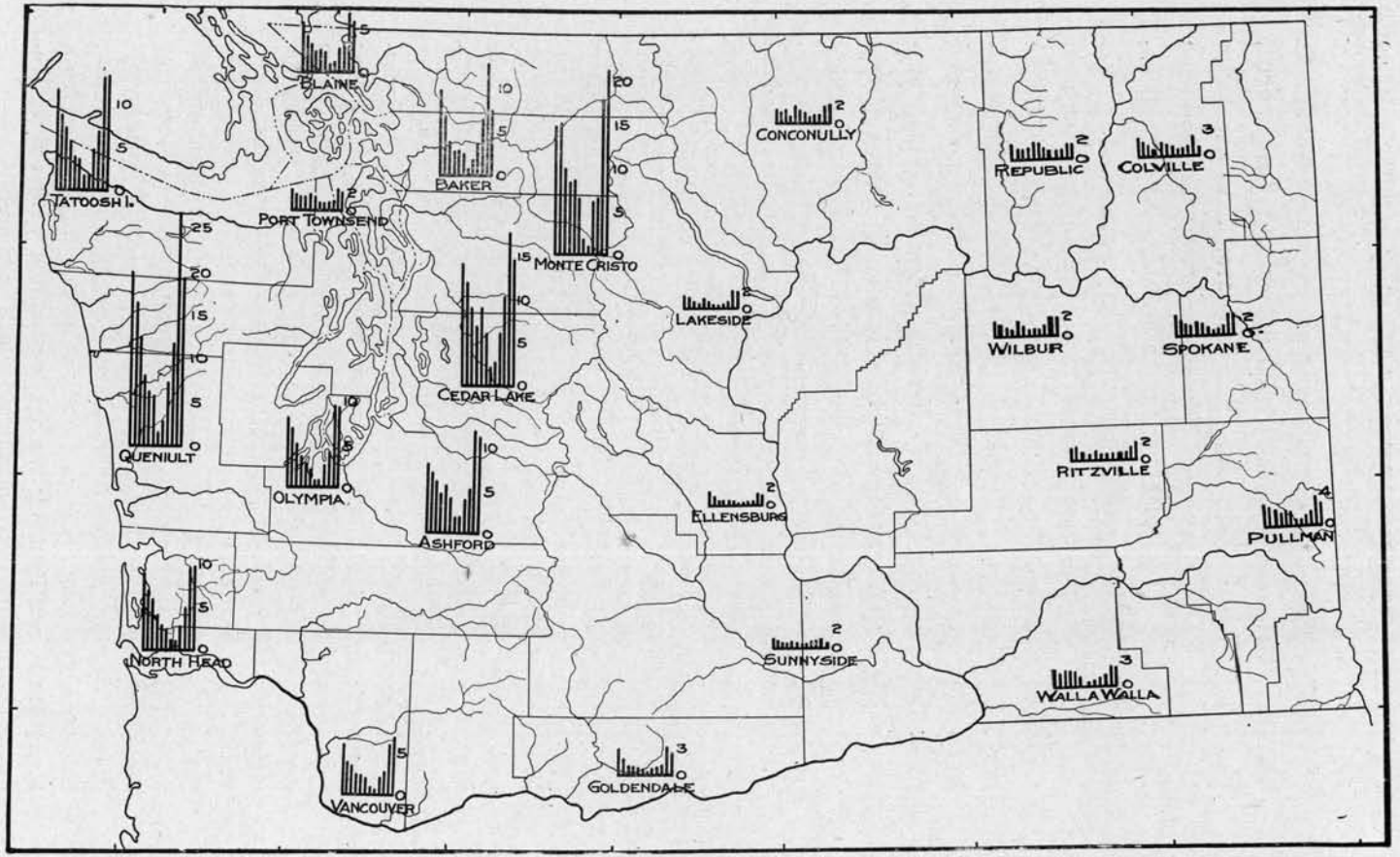


Fig. 4. Rainfall chart to show amount of precipitation, by months, at certain Weather Bureau Stations.

TRANSPORTATION

The mining districts are generally well served by railroad transportation. From the three transcontinental lines that cross the center of the State from east to west, a number of branch lines are turned northward as feeders.

Pend Oreille County is served by the Idaho & Northern branch of the Chicago, Milwaukee & St. Paul Railway, which extends from Spokane northward to Metaline Falls.

Stevens County and northern Ferry and Okanogan counties are reached over a branch line of the Great Northern Railway. At Marcus the road branches, one branch going to Nelson, B. C., via the Northport District, and the other branch extends to Oroville via Curlew. At Curlew a stub line extends southward to Republic.

Okanogan County is best served by the Wenatchee-Oroville branch of the Great Northern, which is built up the Okanogan Valley to Oroville. The Princeton, B. C., branch line connects Oroville with British Columbia points and provides transportation to the Nighthawk District.

The main lines of the Great Northern and Chicago, Milwaukee & St. Paul railways provide the nearest railway transportation for the mining districts of the Cascades. The mining camps located some distance from the railroads can usually be reached by automobile.

POWER

According to estimates compiled by the United States Geological Survey in 1908 and reviewed by the Department of Agriculture in 1916, the water power resources of the State of Washington amount to 125 horsepower per square mile, or a total of over eight and one-half million horsepower. This gives Washington first place in water power resources in the United States. Oregon ranks second with 68.4 horsepower per square mile, and Idaho third with 60.4 horsepower per square mile. The present water power development of the State totals 408,-987 horsepower,—only a small fraction of available resources.

Since the various mines are located in the mountainous areas in the northern part of the State, their power problems for the most part are reasonably simple. Several of the com-

panies are so situated that they can take advantage of local power resources and thus furnish the mine and mill with water power at a low cost. The Sunset Copper Mine at Index and the Boundary Red Mountain Mine of the Mt. Baker District form typical example of such an installation. The majority of the mining districts are served with electric power generated by nearby power plants. In the Oroville-Nighthawk District, the Okanogan Valley Power and Light Company is increasing the capacity of its plant to 2,500 horsepower and expects to sell power on mining contracts at $50.00 per horsepower year. The Metaline Mining District is well supplied with power from the large installation of the Inland Portland Cement Company.

In Stevens County the magnesite and metal mining industries are supplied with power from the Meyers Falls plant of the Stevens County Power and Light Company, and from the Long Lake plant of the Washington Water Power Company, who completed a forty-mile pole line into the Chewelah District during 1920. The Northport Smelter receives power from Bonnington Falls, British Columbia. In the Republic District of Ferry County there is an efficient installation of semi-Diesel engines using crude oil as fuel.

GEOLOGY

SUMMARY OF THE GEOLOGIC HISTORY OF THE STATE

It is beyond the scope of this report to attempt to postulate the many complex and variable conditions that have transpired during geologic time to build and fashion the formations over the area covered by the State. A brief generalized summary, however, may assist in conveying a clearer understanding of the ore deposits and their associated formations.

The total absence of fossils in the older sedimentary formations prevents the definite fixing of their age and the investigator is forced to draw conclusions from correlations with related formations in British Columbia, Idaho, and Oregon.

GEOLOGIC TIME SCALE

Eras	Periods
Quaternary or Psychozoic	Recent Pleistocene, or Glacial
Tertiary or Cenozoic	Pliocene Miocene Oligocene Eocene
Mesozoic	Cretaceous Comanchean Jurassic Triassic
Paleozoic	Permian Carboniferous Devonian Silurian Ordivician Cambrian
Pre-Cambrian	Keweenawan Huronian Laurentian Keewatin

PRE-CAMBRIAN.

But scant record remains to reveal the conditions that existed over the area during the Pre-Cambrian era. The Orient gneiss which is well exposed along Kettle River between Orient and Laurier in Stevens and Ferry counties, is definitely older than the Stevens metamorphic series and is believed to be of Pre-Cambrian age. It is possible that the quartzite and closely associated formations which form the basal members of the

Stevens series in northeastern Washington, and are also exposed in the Cascade Range, are Pre-Cambrian in age.

PALEOZOIC.

During the Paleozoic era the present mountain ranges of the State did not exist, and the northern half of Washington, and apparently the entire area occupied by the State, was covered by a large embayment from the ocean. This embayment covered also a large portion of the western United States and Canada. It existed with variant shore lines over a vast period of time. Streams draining into the sea from land areas farther eastward brought in sands and muds which formed sandstone and shale and were later metamorphosed to belts of quartzite, argillite, schist, etc. Calcium and magnesium carbonates were carried in solution by the waters, then finally deposited as limestone and dolomite. In Stevens and Pend Oreille counties, it is estimated by Weaver,* that these sedimentary beds obtained a maximum thickness of 42,000 feet,—an amazing figure when we stop to appreciate the unbelievable length of time necessary for such an extensive sedimentation. These beds of quartzite, limestone, dolomite, argillite and schist have extensive exposures today in northeastern Washington and to a lesser extent in the Olympic and Cascade ranges of western Washington. They have been complexly folded and faulted, then deeply sculptured by erosion until the maximum thickness remaining seldom exceeds 3,000 to 5,000 feet. These sedimentary belts are often found to be the host rocks for ore deposits that were introduced during a later period, and an understanding of their structure is vital to those who direct mining operations. They will be discussed in more detail later in the report in connection with the individual mines and mining districts.

MESOZOIC.

The conformity of the various beds suggests that sedimentation continued without interruption during Paleozoic time. The loss of the upper strata by erosion,obviously interrupts the records. It is believed that sedimentation continued into the Mesozoic era. During the first half of the Mesozoic there came

*Weaver, C. E., The Mineral Resources of Stevens County. Wash. Geol. Survey, Bull. 20, 1920.

great mountain-building stresses which folded, contorted, and faulted the beds with great severity. These structural deformations elevated them above sea level and vigorous erosion began to tear away the beds and thus undo the work of the previous era.

The dominant feature of the late Mesozoic was immense invasions of molten igneous magmas from below. These intrusions extended the full length of western North America. The enormous invasions engulfed and assimilated great blocks of the older rocks yet, apparently, failed to reach the surface. The belts of sediments acted as an insulating cover under which the invading magma cooled slowly through a period of years to finally crystallize as holocrystalline rocks such as granite, granodiorite, diorite, etc. During the long period of cooling ample opportunity was afforded for segregation and adjustents within the molten intrusion. As the outer crust cooled some of the basic segregations were thrown off as lamprophyre dikes and the acidic segregation as pegmatite and aplite dikes. Finally the ore-bearing gases and solutions which were collecting deeper in the magma were exhaled and ascended along fractures in the cooled granite crust and the overlying metamorphosed sediments. The vast majority of the ore deposits of the northwest are the results of this great period of metallization.

TERTIARY.

Erosion, sedimentation in local basins, and extensive vulcanism are the outstanding features of the Tertiary. Early in the era a large part of western Washington was depressed below sea level and became an arm of the sea into which waters from fresh-water lakes in eastern Washington were being drained. The present Cascade Range had not yet come into being. Tropical conditions prevailed and dense jungles grew about the bodies of water. As the basin floor continued to sink, the accumulation of decaying vegetable material was converted into beds of coal, many of which are being worked today.

During the Miocene period of the Tertiary, the southern section of the State was the center of one of the largest out-

pourings of lava in geologic history. Flow upon flow was built up until the great Columbia Basalt Plateau was completed with a foundation of basaltic lava attaining in places a present maximum thickness of 4,000 to 5,000 feet. More feeble eruptions during this period occurred in the northern half of Washington and capped sections of the older formations.

The gold ores of the Republic District and the First Thought Mine in the Orient District, as well as several deposits in the Cascades, are of Tertiary age.

QUATERNARY.

Early in the Quaternary epoch, the Cascade Mountains were steeply arched up into existence, and the Olympic Mountains were elevated higher than during Tertiary time. This was followed by a period of vulcanism during which the volcanic cones of Mounts Baker, Rainier, St. Helens and Adams were built up. From these and less prominent vents came flows of younger andesite and basalt which partially capped the Tertiary formations and preserved them for the present age.

Later followed the Glacial period, during which great ice flows gouged and carved the rugged mountain mosaic of northern Washington. The major ice sheets formed in British Columbia and travelled southward to gouge out, during their irresistible advance, the great trenches now known as Pend Oreille, Columbia, and Okanogan valleys in eastern Washington and the valley now occupied by Puget Sound in western Washington. Many large local glaciers formed on the high plateau country of northern Washington, and their advances shaped many of the present-day stream channels and lake basins. In eastern Washington the great ice advance extended slightly south of the present locations of Columbia and Spokane rivers, before it was finally halted by warm winds from the south. Then, like a vanquished army, the glaciers began their northward retreat, leaving in their wake great deposits of glacial debris which the present-day streams are still sorting over. In western Washington the glaciers which occupied Puget Sound Basin extended as far south as what is now the southern boundary of Thurston County. Parts of the basin are today covered to a depth of several hundred feet with a mantle of drift material brought in by the ice sheets.

ORE DEPOSITS

CLASSIFICATION OF THE ORE DEPOSITS OF THE STATE

The purpose of this classification is to compare the various ore deposits of the State, divide them into groups on the basis of age, form, or genesis, and then outline the most dominant controlling features of each group.

The classification is adapted as closely as local conditions permit, to that suggested by Lindgren.* This was further augmented by ideas drawn from Professional Paper No. 111 of the United States Geological Survey.†

DEPOSITS FORMED BY MECHANICAL CONCENTRATION.

Gold Placers

The production of placer gold in the State has been relatively unimportant. During the last seven years the placer production has averaged $5,000 annually. This is maintained largely from the Swauk District in northern Kittitas County from intermittent operations in the Blewett District, Chelan County, from Sultan Basin in Snohomish County, from beach sands in the vicinity of Ozette in Clallam County, and from benches along Columbia River and its tributaries in northeastern Washington. A gold dredge was put in operation near the town of Liberty in the Swauk District, during September, 1920, and if this venture proves successful the placer production of Washington will become important.

The auriferous gravels of the Swauk area are Pleistocene in age and the deposits along the stream channels vary from a few feet to a maximum of 80 feet in thickness. Colors of fine gold can be secured by panning the gravels at almost any point but according to Smith‡ most of the gold occurs close to bed rock and in channels other than those occupied by the present streams. Much of the gold near bed rock is coarse and some excellent nuggets have been found, the largest nugget reported having a value of $1,100. The larger nuggets are well rounded but on the tributary streams wire and leaf gold is

*Lindgren, Waldemar, Mineral Deposits; page 195, New York, McGraw-Hill Book Co., 1919.

†The Ore Deposits of Utah: U. S. Geol. Survey, Prof. Paper No. 111, B. S. Butler, G. F. Loughlin, V. C. Heikes and others, 1920.

‡Smith, George O., U. S. Geol. Survey, Mount Stuart Folio No. 106, Geologic Atlas of the United States, 1904.

found. The pay-streaks are erratically distributed and careful testing should precede installation for extensive operations. The source of the gold is from quartz veins in the immediate or near vicinity of the placer ground.

Those interested in placer operations along Columbia River in the northeastern part of the State should consult a report by Collier.* Quoting from this report:

"Where observed the placer gold along the Columbia is confined to the lower benches and river bars, a condition which can reasonably be expected if the sediments of the upper terraces are lake deposits and those of the lower terraces have been worked over and concentrated by the river. Moreover, the later benches and the modern river bars are progressively richer in gold, since they are the products of repeated concentration of the various upper terraces which have fallen into the river and been washed away.

"This gold is not uniformly distributed but in very small areas is concentrated enough to justify mining, especially where rich deposits occur in the bed of the Columbia, since the comparatively cheap process of dredging is here available. The bench lands, however, are not adapted to any relatively inexpensive process of mining. Hydraulicking on a large scale is ruled out by the absence of bed rock and the scarcity of water at sufficient elevation; dredging, by the height of these deposits above the river and the impossibility of floating machinery over them. Moreover, the possible profits from mining the bench lands would undoubtedly be less than the value of these lands for agriculture purposes."

In recent years there have been a few attempts to work over some of the more promising bars along the Columbia during the low water period. The traveler through this area will note many old diggings worked over years ago by Chinese. Particularly, are the old diggings evident in the vicinity of Northport and Boundary.

*Collier, A. J., Gold Bearing River Sands of Northeastern Washington: U. S. Geol. Survey, Bull. 315, 1907.

DEPOSITS FORMED BY CHEMICAL PROCESSES OF CONCENTRATION IN BODIES OF SURFACE WATERS.

Under this heading may be generally included the deposits of limonite, hematite, and such deposits of magnetite not due to magmatic segregation from igneous rocks. The limonite and hematite from the Kulzer property near Valley, Stevens County, the bedded magnetite deposits near Hamilton, in Skagit County, Elma, in Grays Harbor County, and the mixed hematite and magnetite deposits of the Cle Elum District of Kittitas County, form typical examples. These deposits are considered to be of sedimentary origin and are generally found bedded with other Tertiary formations.

The origin of the extensive deposits of manganese silicate occurring in the Olympic Mountains may later be classed under this division. At present, these deposits have not been studied with sufficient detail to justify conclusions as to their origin. The lodes are usually found directly associated with altered andesitic lava flows and with a reddish-brown, fine-textured limestone of Jurassic age. The manganese occurs in the form of a hydrous silicate bementite, which has a pale brown color and by its physical appearance might be mistaken for impure quartzite, if it were not for the higher specific gravity of the manganese. Near the surface the bementite bears the black stain of the oxide of manganese.

The deposits of magnesium sulphate in northern Okanogan County and the deposits of sodium sulphate in central Okanogan County and near the town of Warden, in Grant County, are the result of chemical saturation and precipitation in small stagnant ponds and lakes, the material being introduced from the surrounding rocks. The deposits are usually of local extent but certain ones are being profitably exploited.

DEPOSITS FORMED BY CHEMICAL CONCENTRATION OF MATERIAL ORIGINALLY DISSEMINATED IN THE ROCK

The extensive magnesite (magnesium carbonate) deposits in Stevens County may be best classed under this heading. There is yet a considerable difference of opinion pertaining to the origin of these deposits, but most of the hypotheses so far advanced would cause them to be classed under this heading.

The writer believes that the mixed salts of magnesium and calcium carbonates were originally deposited on the sea floor as such, but before dolomitization could be effected the more soluble calcium carbonate was leached from certain portions of the beds. When dolomitization was later completed, those beds which still retained the mixed salts of calcium and magnesium carbonates, were converted into dolomite (the double salt of calcium and magnesium carbonates.) The sections of the beds which had been subjected to leaching reactions, remained as magnesite. A report to be later issued by the Washington Geological Survey will give detailed descriptions of these deposits.

DEPOSITS FORMED BY CONCENTRATION OF SUBSTANCES INTRODUCED BY IGNEOUS ACTIVITY.

With but few exceptions the ore deposits within the State are closely allied with intrusive rocks and there can be no reasonable doubt but that their formation was due directly to igneous activity. Deposits of this type may be conveniently divided into three groups—those enclosed in intrusive rocks, those in extrusive rocks, and those in metamorphosed sedimentary rocks.

DEPOSITS ENCLOSED IN INTRUSIVE ROCKS.

Localizing Influences

The majority of the ore deposits in Okanogan County, in certain sections of Ferry County, in the Newport District of Pend Oreille County, and in the Cascade Range of western Washington, are found to be enclosed in granitoid rocks. When examining these various deposits it is surprisingly evident that almost without exception they occur near the margins of the granitic rocks. The interior areas of the batholiths exhibit but weak mineralization at the best. In the Newport, Nespelem, Conconully, Oroville-Nighthawk, Index, and other districts, as well as near Danville, in northern Ferry County, there are veins near the roof of the batholith adjacent to its contact with the older intruded rocks. Near the Nespelum deposits the roof rocks have been completely removed by erosion, but, judging from the surrounding horizons the pres-

ent granite outcropping on Mineral Hill represents the upper limits of the batholith near this particular locality.

As the laws governing the formation of veins and other types of metalliferous deposits are better understood, it seems safe to predict that the occurrence of ore deposits near the margins of the intrusive rocks will be more readily appreciated. It is pertinent, then, to inquire into the factors which localize the occurrence of ore deposits.

It is logical, that, following the invasion of a batholithic mass, the margins of the magma in contact with the older rocks

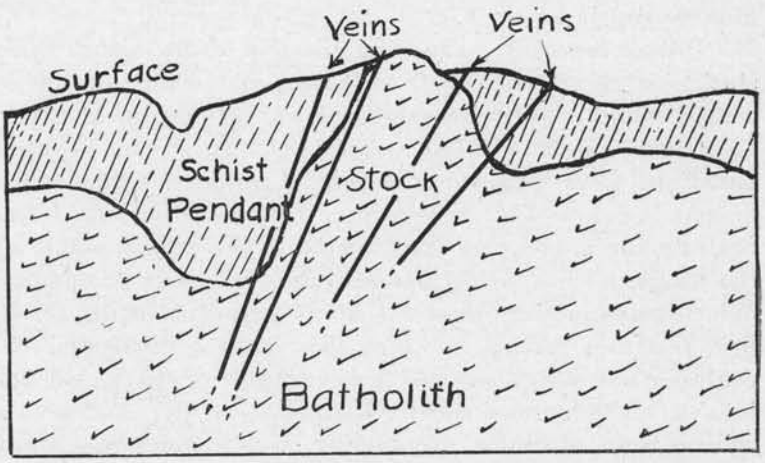


Fig. 5. Ideal section to show relation of veins to stocks and roof pendants.

would be the first to crystallize. Crustal tensions developed by shrinkage and recurrent heavings originating deeper in the partially cooled magma would develop fissures in the granitic rocks, and even across the contact into the intruded formations. Such fissures would offer excellent conduits for mineralized solutions and gases which might be exhaled from deep-seated reservoirs in the cooling interior of the magma.

Functions of Stocks and Roof Pendants.

If the protective roof rocks overlying a batholith could be suddenly stripped off, the underlying granites would be found, not with flat relief, but with an uneven, undulating surface, and with cupolas or dome-like projections above the general

level; this irregular relief originating from a series of complex conditions which caused the distribution of the intrusive forces unequally over the marginal surfaces of the mass. The idea is not new; the phenomenon has been recognized and described by numerous observers. These so-called cupolas are admirably exposed in Stevens and Okanogan counties, where erosion has stripped off part of the old roof rocks and bared small sections of the underlying batholith. An excellent example is the Chewelah District, where the ore deposits occur principally in the overlying argillites, but as a halo around the periphery of a granitic cupola, or stock.

During the cooling and crystallization of the magma these stocks had direct connection with deep-seated sources and as crystallization slowly proceeded the soluble and light, mobile constituents, such as metals, water, sulphur, silica and other materials, were expelled and moved upwards through the magma to points of lower pressure. This migration would concentrate the ore-bearing constituents in the higher points of the magma, which would naturally be the stocks or cupolas. When the outer margins of the stocks were sufficiently solidified, fractures formed in which the mobile constituents concentrated and passed out into the cooler portions of the mass or into the enclosing host rocks. The actual conditions of such a process were, of course, exceedingly more complex than those outlined. If, however, these interpretations are approximately correct we may then understand how the vein material could be drawn from a great magma to be finally concentrated into economic ore deposits.

In Professional Paper No. 111 of the U. S. Geological Survey,* an excellent summary of the current knowledge of the relations of stocks to ore deposits is given. Quoting from this report:

"It is possible that the concentration of metals near the apex of a stock is influenced by the relation of the magma at the time of the intrusion to the surface or the zone of fracture. If a magma containing gases held in solution under pressure

*The Ore Deposits of Utah: U. S. Geol. Survey, P. P. 111, B. S. Butler, G. F. Loughlin, V. C. Heikes and others, 1920, p. 201.

is forced through the overlying rock until it connects with the surface or with the zone of fracture we may imagine a condition similar to that produced by removing the cork from a bottle of champagne, when the dissolved gases move toward the region of lower pressure. In this manner there might be relatively rapid movement of previously dissolved gases into a restricted area from a large volume of magma. The expansion of gases under decreased pressure and chemical reactions would effect temperature changes that may be factors in precipitating metallic and other substances. If the magma did not reach the surface the influence of difference in pressure would not be effective or would be less effective. * * * ''

When plunging contacts, rather than those approaching the horizontal, appear between the granite and the host rocks, pendants or blocks of the older roof rocks are suspended down into the granite batholith 2,000 feet or more, and often of such horizontal extent as to measure two or three miles in diameter, all boundaries of the pendant except the upper being surrounded by the intrusive rocks. In northern Okanogan County one of these pendants was observed to be continuously connected with the roof rocks of the area, which proves that it is not a detached block immersed in the batholith, but a roof pendant projecting downward into the mass, and representing a lower portion of the roof rocks. This phenomenon of roof pendants as occurring in the Okanogan Highlands was first interpreted by Daly.*

Along the marginal contact of such a pendant favorable conditions could exist for the development of fissures which might later become channels for mineralized hydrothermal solutions and gases. Complementary to the pendant there would ordinarily exist the margin of a granitic stock. The function of the stock or cupola would be to collect and concentrate the ore-bearing solutions and gases from the remainder of the batholith. The function of the pendant would be to encourage the development of fissures by chilling the margins of the batholith. The writer wishes to advance this hypothesis

*Daly, R. A., Geology of North America Cordillera: Canadian Geol. Survey, Memoir No. 38, p. 429, 1912.

as a possible influencing factor on certain ore bodies of the State.

The mechanics of fissure development is none too well understood, and there is a tendency to pass it by with a vague sentence or two about regional compressive or tensional strains. There is little doubt that these regional forces offer the best fitting explanations for many districts, but in certain localities, at least, the factors governing the development of fissures can be traced to local causes. Particularly, in the Oroville-Nighthawk area there are found several large marginal veins which satisfactorily bear out this conclusion. The veins in certain instances trend across the contact and into the pendant rocks a distance of several hundred feet and then gradually feather out. They gain their maximum width (up to 20 feet) on the granite side of the contact, several hundred feet from the margin. As these veins are traced farther away from the contact and into the granite a distance of 1,000 to 2,000 feet, they are found to grow gradually more narrow until one of them was but one foot wide at a point half a mile from where the contact was crossed. All of the ore shoots so far developed have been found within a few hundred feet of the margin. In certain other instances the veins roughly parallel the plane of contact.

Quartz-Silver-Lead-Copper Veins

Veins of this character have a well-marked occurrence, principally in northern Okanogan County and in the Newport District of southern Pend Oreille County. The Arlington, Last Chance, Kaaba, Four Metals, Bead Lake, and Reis veins are typical examples. They are well-defined, normal quartz veins which dip at angles varying from 45 to 85 degrees. They are of the marginal type, being situated at distances varying from 50 to 1,000 feet from the contact of the granitic rocks with the intruded host rocks. The principal ore minerals are chalcopyrite, galena, and tetrahedrite, which are present in varying amounts and ratios. The sulphides are intimately intergrown and show a strong tendency to occur as bands through the vein quartz, which occurrence suggests, first, the formation of the quartz vein practically barren of sulphides, then the shattering of the quartz parallel to the walls and the injection of

the sulphides along these shatter planes. This is further confirmed by the brecciated structure of the ore, showing bunches of quartz entirely surrounded by sulphides, thus indicating that the sulphides were deposited later than the quartz.

The sulphides also exhibit a tendency to segregate into pay-shoots and the segments of the vein between such shoots is usually too low-grade to be classed as commercial ore. In certain of these deposits there is found a center filling of high-grade sulphides, and the quartz on either side of the filling is but sparsely mineralized. The pay-shoots usually have stope lengths of several hundred feet and are being mined through a vertical range of 500 to 800 feet without encountering any signs of bottoming the ore. The wall-rock alteration is slight and unimportant, the most common feature being the chloritic alteration of the femic minerals.

In certain of the western mining districts veins of this general type have shown a tendency to develop vertical zoning of the sulphides. Thus, in the upper horizon of the veins, galena is the predominant sulphide and is associated with lesser amounts of chalcopyrite, pyrite, tetrahedrite, and sphalerite. Such a horizon may have a vertical range varying from 200 to well over 1,000 feet, depending upon a number of local factors governing the precipitation of the various sulphides. Below this horizon the sphalerite assumes predominant proportions with minor amounts of galena and the other sulphides present. Below the sphalerite zone, pyrite, chalcopyrite and tetrahedrite remain and the proportions of quartz to sulphides usually increase rapidly. So far the Washington deposits have shown little tendency to conform with the vertical zoning phenomena. Mining operations have not yet been carried deep enough to fully decide the problem. Many of the deposits, however, have suffered glacial planing so that present-day outcroppings represent relatively deep-seated portions of the vein. The veins described in the Ruby-Conconully District may show an increasing zinc ratio as greater depth is reached. Ore from the present lower levels assay as high as seven per cent zinc. Assay records of the upper workings have not been preserved and it is unwise to attempt a prediction until some one of the

mines has been developed through a vertical range sufficient to indicate any advance changes in the type of sulphide deposition. As would naturally be expected, such changes are not abrupt.

Silver Veins

Certain of the deposits of the Nespelem District in southern Ferry County, the Sheridan District northeast of Republic, the Covada District in Ferry County, the Deer Trail District of Stevens County, and the Ruby ore-body in the Nighthawk District represent the chief occurrences of silver veins enclosed in granitoid rocks. The mines described under the Ruby-Conconully District are being worked principally for their silver values, although lesser amounts of lead and copper are also secured.

The Nespelem deposits occupy narrow shear zones through the granite. Replacement and alteration of the wall rocks by the ore-bearing solutions are plainly evident. The granite wall rocks are altered to a soft, waxy mass with sericite and kaolin as the chief constituents. The width of the zone, rich enough to constitute ore, ranges from a few inches to three feet. The ore is localized into tabular shoots of irregular extent. Small streaks of ore running several thousand ounces of silver to the ton are sometimes encountered. The chief metallic minerals are stephanite, argentite, pyrargyrite, galena, chalcopyrite, pyrite, and tetrahedrite. Minor values in lead and gold are usually associated with the silver.

The deposits of the Sheridan District have many properties in common with those of the Nespelem, the chief difference being that the enclosing rock is a fine-grained phonolite instead of granite and that fluorite is usually associated with some of the ores.

In the Covada District there are a number of small silver veins that are sporadically worked. These average from one to three feet in width and are chiefly enclosed in granodiorite. The distance from railroad transportation hampers their development.

The Ruby deposit, near Nighthawk, is a quartz vein which fills a gouge-lined fault plane through granodiorite. It has

been well explored and a new concentrator recently completed to treat the ores. The deposit possesses an excellent vertical and horizontal range but the mineable ore is segregated into shoots. The chief ore minerals are pyrargyrite, proustite, argentite, and with these are associated minor amounts of chalcopyrite, galena, and sphalerite. The average width of the deposit is three feet.

Pegmatitic Tungsten Veins

In southern Stevens County are a series of pegmatitic quartz veins which have been mined at various times for their associated tungsten minerals. They are usually found enclosed in the Loon Lake granite but are situated well up near the roof of the batholith. In one instance the vein has formed in the adjacent argillite. The veins usually exhibit minor amounts of tourmaline and fluorite while the ore mineral is chiefly wolframite associated with minor amounts of scheelite, ferritungstite, galenobismutite, pyrite, chalcopyrite, molybdenite and arsenopyrite. The deposits are of deep-seated origin and formed under high temperature and pressure. They represent the products of magmatic segregation from the granite batholith during its final stages of crystallization. Typical examples are the New Germania, Blue Grouse and Sand Creek deposits which have been described by Weaver.*

Copper Veins

In the Cascade Range there are a number of copper deposits which occur along brecciated shear zones through granodiorite. Such deposits usually have but one well-defined wall and the sulphides are laced through the shattered rock, partly replacing it along the zone. This gives a lode-like deposit with chalcopyrite and bornite as the chief ore minerals, while quartz is not usually prominent as a gangue mineral. Shearing movements along the fracture zone, previous to metallization, placed the walls into such juxtaposition that the ore receptacles were lens-shaped and separated by constricted pinches. The stope length of the lenses is usually 100 to 300 feet and they also exhibit an excellent vertical extent. The Sunset, Bunker Hill,

*Weaver, C. E., Mineral Resources of Stevens County: Wash. Geol. Survey, Bull. 20, 1920.

Florence Rae, and Kromona form examples, although these deposits mentioned differ somewhat from each other.

Disseminated Deposits of Copper

Handy* describes several deposits of this type which occur four miles north of Oroville. He states that the mineralization is widespread but not continuous. One of the largest continuous areas observed was 100 to 300 feet in surface extent. The exposures have not been carefully prospected or sampled and little is known of their possible potential value. Six diamond-drill holes were put down to depths of 400 to 600 feet and show, at the greatest depths reached, conditions of mineralization essentially similar to that at the surface. The assays from the drill cores were not, however, available.

The deposit of the Mineral Creek Copper Company, near the head of Little Lake Kachess, in the Cascades, is a disseminated deposit through a broad brecciated zone in the granite.

Gold-Copper-Arsenic Veins

There are a number of small but persistent veins in the Cascade Range which have as their principle ore minerals, arsenopyrite, chalcopyrite, pyrite and galena. The Apex Mine on Money Creek is the best developed property of this type. The ore body has been mined over a length of 600 feet and through a vertical range of 400 feet without exhausting the ore. The vein varies in width from six inches to a maximum of four feet. Gold has usually been the chief metal sought but during the past year the arsenic contained in the ore has become of commercial importance. The deposit of the Eagle Peak Copper Company near Longmire Springs, Mt. Rainier National Park, falls under this general heading, although copper is considered the most important metal with gold values secondary.

Deposits Formed by Magmatic Segregation

Deposits of this character are formed under extreme conditions of high temperature and pressure. They include oxides and sulphides of the metals which segregated within the magma to form irregular lenses enclosed by their mother rock. These

*Handy, F. M., An Investigation of the Mineral Deposits of Northern Okanogan County, Bull. 100, State College of Washington, Pullman, 1913.

deposits represent material associated with the magma at the time of its intrusion and during the long period of cooling and crystallization certain of the heavier oxides and sulphides collected into irregular masses and were thus imprisoned in the magma when it finally solidified. The complex conditions governing magmatic segregation are well discussed in the various text books on ore deposits and space will not be taken in this report for a repetition of the subject matter.

It is important to be able to recognize this type of deposit in order that due allowance will be made for its irregularities and limitations when directing exploration or mining operations.

The best examples in the State are the deposits of chromite which are found in the ultra-basic intrusive rocks, or their metamorphic equivalent, serpentine. The best known deposits occur on Cypress Island of the San Juan Group, in the Sister Peaks District, nine miles by air line east of Acme, in Whatcom County, in the CleElum District of Kittitas County, and on Mt. Chopaka in northern Okanogan County. These deposits occur as irregular, disconnected lenses and it is seldom that a single lense holds more than a few hundred tons of ore. During the period of domestic chrome production necessitated by the war, these deposits became of commercial importance. Under normal conditions they cannot compete with the cheaper foreign sources of supply.

Ores of nickel, platinum, magnetite, ilmenite, etc., are known to occur in deposits of this general type. So far, no deposits of these metals have been discovered in Washington.

DEPOSITS ENCLOSED IN EXTRUSIVE ROCKS

Although one-half the area of the State is mantled with flows of extrusive rocks, these flows, with certain isolated, but important, exceptions, are not known to contain commercial ore bodies.

The notable exceptions are the gold-quartz veins of the Republic District in northern Ferry County and the Orient District in Stevens County. From the Republic District now comes the major gold production of the State.

Fissure Veins in Andesite and Quartz Latite

The gold veins of the Republic District are in no way related to the other deposits of the State (certain deposits in the adjacent Orient District excepted) and they present peculiarities which are dissimilar to any other known ore bodies in the United States. The veins represent the filling of open fissures near the surface by heated solutions given off from a magma, during the Miocene period of the Tertiary. The enclosing rocks are andesite, quartz latite, and lake-bbed deposits. The vein filling is quartz with subordinate calcite. The quartz is of three types—the first being vitreous quartz which often exhibits crystal faces with a tendency to develop outward in interlocking aggregates from the vein walls and are believed to be evidence of accumulative deposition in an open fissure. Ordinary milky quartz forms a large part of the vein filling and is interbanded with a dull, cherty, dark-blue, porcelain-like quartz which might better be termed a jasperoid. The most distinct feature of the veins is the marked contrast formed by the wavy banding, roughly parallel to the walls, the alternating bands of dark jasperoid and white quartz. The ore minerals occur as dark thread-like, crinkly and concentric bands which follow roughly the banding pattern of the veins. These thread-like streaks are made up of tetrahedrite, pyrite, and chalcopyrite and carry free gold very finely divided. Some of the gold is believed to be in the form of gold selenide.

The vein pattern is closely set, all the important veins being enclosed in an area of a few square miles. The average tenor of the ore as mined varies from $12.00 to $20.00 to the ton, although pockets of rich ore are occasionally encountered. The ratio of gold to silver varies from three to eight ounces of silver to each ounce of gold. The veins have an average width of two to eight feet and have been mined to a maximum depth of 800 feet below the outcrop; several of the strongest veins can be expected to hold good values even below this depth. The district will be more fully described later in this report.

Brecciated Zones in Quartz Latite and Associated Volcanics

In the Orient District of Stevens County, Weaver* describes a number of deposits enclosed in the Rossland volcanic series. Deposits of this type are best illustrated by the orebody of the First Thought Mine where rhyolite porphyry and dikes of granodiorite have intruded the quartz latite. Along the contact are found fault planes and brecciated fracture zones which are mineralized with gold-bearing pyrite associated with a gangue of quartz and calcite. The First Thought Mine is the only deposit of this type in the district which has been extensively developed. It is credited with a production of $650,000, the ore as shipped averaging $15.00 to the ton. These deposits in the Orient District are of Tertiary age and are believed to be closely allied to the veins of the Republic Camp.

DEPOSITS ENCLOSED IN METAMORPHIC SEDIMENTARY ROCKS

Northern Pend Oreille County in the northeastern corner of the State, Stevens County adjoining it on the west, and a part of Ferry County, are well covered with an extensive series of metamorphosed Paleozoic sediments tilted to a steep angle and overlying for the most part, the intrusive granitic rocks. The ore deposits here occur as irregular replacement bodies in the metamorphic series. With more extensive development some of the larger deposits may be found to extend down into the underlying granites.

Closely associated with all these deposits are found igneous dikes which mostly approach lamprophyres and granite porphyries in character. In some cases, the ore is found in contact with these dikes, but more often, the dike is 10 to 150 feet from the ore. This association has led to a confusion of ideas and in some cases resulted in exploration work being improperly directed. These dikes are feelers from the underlying batholith which succeeded in forcing their way up through the overlying and shattered sediments. The dikes naturally sought out the shattered zones for their entrance into the metamorphosed beds, and the intrusive forces of the dikes further shattered the brittle sediments. The total result

*Wash. Geol. Survey, Bull. 20, p. 256, 1920.

was that the shattered ground adjacent to the dikes offered inviting conduits for the mobile constituents which were exhaled from the magma, a little later than the dikes, to form the ore bodies. In the United Silver-Copper Mine concrete evidence is offered to prove that the dikes are earlier than the ore, for on the 1,200-foot level a considerable portion of the vein is found filling a shrinkage crack in the dike.

Influence of Invaded Formations on the Ore Deposition

The shape, and often the extent and richness of the ore deposits, are controlled by the character of the formation into which the mineralized solutions were injected. The highly folded and tilted position of the sediments often placed them in a favorable position to receive the mineral constituents through fractures opened along the bedding and schistosity planes of the formation. The zones of weakness in such formations would naturally be along these planes. However, should the beds be so favorably oriented that the components of shattering forces were applied at certain angles to the planes, then the fractures would tend to cut the formations at angles to the bedding or schistosity planes. These two types of deposits are common to the argillites and schistose rocks in Stevens County and are well represented by the Loon Lake, United Silver-Copper, and by smaller deposits such as the Frisco-Standard and Bonanza.

Brittle formations, when ruptured, develop irregular, undulating fractures. If such a fissure should be subjected to faulting along the plane of fracture, portions of the walls would be brought into such juxtaposition that pinches and swells would be developed. These conditions are strikingly represented by the Reardon Copper deposit and to a lesser degree, in the United Silver-Copper vein. A clean-cut understanding of such a phenomenon is of material aid in successfully directing exploration work.

Planes of contact between two formations, such as argillite and quartzite, are in some cases planes of rupture. The quartzite is not so favorable for ore deposition as the argillite and the latter yields more readily to metasomatic replacement

than does the refractory quartzite; further, the organic matter in the argillite often assumes the role of a precipitating agent for ore-carrying solutions.

Veins in Argillite

In the Stevens sedimentary series of northeastern Washington, argillites of various characters make up a large part of the sedimentary beds. These various formations grouped under the general term of argillites, vary widely in character so that they include calcareous argillite, slaty argillite, also the quartz-mica schist which forms the wall rocks at the United Silver-Copper Mine, and the graphitic schist at the Frisco-Standard and Bonanza mines.

The highly tilted and folded position of these beds often placed them in a favorable position to receive the vein-forming solutions and gases through fractures opened along the bedding and schistosity planes of the formations.

The chemical and physical composition of argillites makes them susceptible to metasomatic replacement. The platy or schistose structure presents planes of weakness which, when penetrated by the searching actions of the ore-bearing agents, are partly replaced, the vein material being deposited as a substitute. Some of the argillites were originally deposited as carbonaceous shales and during the intensity of metamorphism the carbonaceous matter was converted into free graphite. This graphite is noticeably effective as a precipitating agent on ore solutions, as attested to by the United Treasurer, Frisco-Standard and Bonanza deposits.

Veins in Quartzite

The beds of quartzite in northeastern Washington are not at all prominently identified with ore deposits. There are several isolated instances where the deposits are enclosed in quartzite but more usually the vein-filling agents have sought out the adjacent beds of argillite or limestone, or even chosen granitic rocks for their seat of deposition. This can be partially explained by the fact that the refractory quartzite offers little inducement to ore deposition and is generally impregnable to extensive replacement by ore solutions. Further, the

brittle quartzite belts, when stressed, tend to develop long, narrow and unpromising fractures. This does not mean that the quartzite cannot contain commercial deposits for, in the nearby Coeur d'Alene District, we find what is probably the same belt of quartzite, enclosing large rich deposits of ore.

Replacement Deposits in Limestone

Limestone, under favorable conditions, is readily susceptible to replacement by mineral-laden solutions and gases. A belt of limestone which has been stressed by folding and then intruded by igneous dikes will ordinarily develop irregular fracture patterns which ore solutions may later use as a conduit. The intersection of two or more fractures affords an inviting locus about which heated solutions may work to replace the limestone and deposit ore in irregular pots and chimneys.

The Northport District and the adjoining Metaline District in Pend Oreille County contain a number of ideal examples of such deposits. The structure of this particular area has placed the limestone belts in a favorable position for receiving the ore-bearing agents which emanated from the granite batholith underlying the limestone at no great depth. Limestone possesses both the chemical and physical properties to encourage ore replacement and deposition when correct temperature and pressure conditions prevail.

There is little evidence to guide in the search for these chimney-like deposits of ore, and when such a deposit is once found its irregularity of outline prevents reliable estimation of its extent. When one chimney or pod of ore is found it is probable that similar deposits are in the immediate vicinity. The best guide-posts to such bodies are shear zones trending through the limestone, and in some instances these form a thread-like connection between two deposits. The zones are not usually over an inch in width but they were the channels which guided the invasion of the mineralization, and in exploration work they should be closely followed. In deposits such as the Electric Point and Lead Trust it is evident that the location of the ore chimneys is largely controlled by a brecciated area in the limestone closely adjacent to the shear zones.

The brecciation in certain instances appears to have been accomplished by the intersection of two shear zones; in other instances, by the intrusion of igneous dikes adjacent to the line of shearing; while in certain other cases the causes are obscure.

A thorough understanding of the geologic structure of the involved formations is also vital to the successful exploration of deposits of this type.

In northeastern Washington it is generally true that the irregular replacement deposits in limestone are of two types:

1.—Deposits of lead ore carrying varying amounts of silver.

2.—Deposits of zinc ore carrying minor quantities of lead and silver.

The first type is well portrayed by such deposits as the Electric Point, Lead Trust and Gladstone. Their sizes vary from small pods of ore to a chimney 60 feet in diameter, several hundred feet deep, and well filled with high-grade ore. The galena is both fine and coarse-grained and carries from one to ten ounces of silver. Pyrite is present as an accessory mineral. The chimneys are formed from magnesium limestone which has been severely brecciated. Ore solutions later ascending along shear zones entered these brecciated areas where they partly replaced the shattered limestone and deposited galena.

The Electric Point and Gladstone deposits are severely altered to iron-stained cerussite, commonly called "sand-carbonate." In both deposits this extreme alteration extends strongly pronounced to the deepest workings (in the Electric Point, 800 feet below the outcrop). The phenomenon is more fully discussed under the individual descriptions of the deposits.

Along Deep Creek, six miles southeast of Northport, there are several deposits of zinc ores replacing limestone. The Northport Mines Company deposit is but 700 feet from the contact of the granite and limestone. It consists of parellel, pencil-like stripes of sphalerite replacing the limestone along the bedding planes and thus forming a mineralized zone of medium-grade zinc ore. On the opposite valley wall is the

Gorien zinc deposit which consists of smithsonite (zinc carbonate) one to four feet in thickness. The ore has replaced the limestone along a narrow fracture zone. The deposit has been developed for a length of 70 feet along the strike and 100 feet on the downward projection. Sphalerite has not yet appeared in appreciable amounts. Farther up the hillside from this property are the Last Chance and Great Western which are mixed bodies of lead and zinc minerals occurring as replacements along fracture zones through the limestone.

In the Metaline District, Bancroft* describes a number of irregular replacements of zinc ores in limestone.

Contact Metamorphic Deposits

When the extensive granitoid intrusions into belts of metamorphosed sediments are recalled, it is surprising that contact-metamorphic ore bodies are not so prominent in the State as might be inferred. In numerous places where the contact relations were observed the development of contact minerals such as garnet, epidote, tourmaline, vesuvianite, and actinolite, have but seldom been on a scale to compare with the extensive contact zones a few miles north of the international boundary. The cause for this is apparent, for in Stevens or Pend Oreille counties, where one would naturally except the greatest development of contact minerals, limestone is not the basal member of the Stevens series of sedimentary belts, and in most cases it would have been necessary for the intrusive magma to absorb belts of quartzite or argillite before it could reach the limestone. In places where the magma did succeed, the temperature of the intrusive mass was materially reduced and but feeble reactions resulted.

Certain of the limestone-granite contacts in northeastern Washington are the indirect result of overthrust faulting which overturned the beds of the Stevens series and placed the limestone near the base where it could be partially attacked by the later granitic intrusion.

The development of contact-metamorphic minerals is much more strongly pronounced where the molten intrusive comes

*Bancroft, Howland, The Ore Deposits of Northeastern Washington: U. S. Geol. Survey, Bull. 550, 1914.

in contact with belts of limestone. When limestone is calcined to make "quick lime" the following chemical change transpires: $CaCO_3 = CaO + CO_2$. Limestone in contact with a molten intrusive would be broken down and absorbed in this manner. For a ton of limestone so attacked about 440 pounds of carbon dioxide gas would be liberated. Such proportionately large volumes of gases liberated along the contact zone would gasify the molten material, and along such a heavily charged marginal zone chemical reactions would proceed with great intensity, and conditions would be favorable for the development of contact minerals. It should be remembered that this is but one phase of complex conditions that prevail during the formation of contact zones, and it is briefly touched on here so that the subject will receive more consideration by those engaged in developing this type of deposit. Contact zones are often found developed without appreciable amounts of ore minerals present. In the case of a limestone contact, if there are ore minerals in the vicinity, they are found often as contact deposits. In the case, however, of a quartzite contact, which is of course refractory to replacement, conditions are not favorable for the development of such deposits and the ore minerals will usually be transported to more favorable horizons for deposition. Such conclusions must be interpreted in a common-sense manner for there are obviously many variations.

The extensive Phoenix and Rossland ore bodies located a few miles north of the international border, are of the contact type and it is hoped that similar deposits will yet be found on the American side of the boundary. The zinc deposit of the Northport Mining Company is closely allied to a granite contact, as is also the Rebecca Mine in the Nespelem District.* The various district reports mention several other ore deposits of this type but none of these was active during 1919 or 1920.

*Pardee, J. T., Geology and Mineral Deposits of Colville Indian Reservation, Washington: U. S. Geol. Survey, Bull. 677, p. 80, 1918.

COMMERCIAL APPLICATION

Introduction

The investigator who enjoys the opportunity of examining a large number of ore deposits scattered over a related area should be able to offer correlations of a general nature which would be of tangible aid to those less familiar with the problems to be encountered. Those engaged in mining activity can carry on their work more effectively if they are able to gain a perspective of the related problems. The writer has attempted to present this report in such form that it will be intelligible to the average mining man. Involved technical phrasing has been avoided so far as is consistent, and there is little included which is considered to carry only an abstract scientific interest. It was thought best at this point, however, to sum up certain correlations which have a definite practical bearing.

It is highly desirable that those charged with the direction of mining enterprises should have some appreciation of general features controlling ore deposits. Chiefly, should they have knowledge of the source of the metals and their modes of deposition along rock openings. Equipped with this information they are better able to compare various deposits —also, are they less susceptible to fanciful conclusions advanced by ignorant or unscrupulous advisors.

Prospecting

It is an old saying among mining men, "That the ore is where you find it." The study of ore deposits has advanced considerably during the last score of years and with this advancement has come a better appreciation that the ore is not there purely by chance, but that there exists quite definite laws to govern its deposition, and the search for minerals today is guided largely by geologic associations.

The question is often asked: "Where is the most favorable ground in a certain area for the discovery of new ore deposits?" The writer considers that in most districts of the State the best ground for the discovery of new deposits is a zone from one to two miles wide along the margins of exposed granitic intrusives. The location of these granitic exposures in

Stevens County can be secured by referring to the areal geological map of that county prepared by Chas. E. Weaver.* It was brought out earlier in this report that a large percentage of the known commercial ore deposits of this area are found in the Stevens series of metamorphosed sediments, and reasonably near the margins of the intruded granite. Practically all these deposits are found near igneous dikes which are offshoots from the underlying granite batholith. In most cases these dikes were intruded shortly before the ore and their shattering effect on the brittle belts of metamorphosed sediments helped to open channels for ascending mineralized solutions and gases. Further, these dikes would tend to search out shattered and weakened zones in order to gain easy passage through the overlying rocks; similarly, the veins would also find these weakened zones and the close association of the dikes and veins are the natural outgrowth. When such dikes are found, the ground for several hundred feet on each side should be carefully looked over for croppings or mineralized float. The mere finding of a dike, however, should not be taken as sufficient indication to warrant any expenditure of opening drifts or cuts unless there is an encouraging evidence of mineralization. This generalization should not be misinterpreted for the writer does not wish to imply that deposits will be found only in these specified zones; instead, they are mentioned as the most favorable areas.

In Ferry, Okanogan, Chelan, and counties farther west the granite rocks are better exposed, and in many districts only remnant patches of the older roof rocks remain. A majority of the veins here occur near the margins of the batholith, and such localities whether they be near the roof of the intrusion or near a plunging contact, should be considered favorable for prospecting. These veins are more often found in the granitic rocks, although there are many instances where they cut across the contact and enter the host rocks.

*Mineral Resources of Stevens County: Bull. 20, Wash. Geol. Survey, 1920.

Faulting

The general continuity of the ore deposits is surprising when we recall the mountain-building movements that have at various intervals visited northern Washington. Serious faulting problems are not often encountered; particularly is this true in the deposits of relatively deep-seated origin.

The United Silver-Copper vein exhibits a series of three step faults with a lateral throw of from four to six feet in each instance. There are many minor faults breaking the veins in the various districts but as a general rule the displacement is unimportant. A typical example is a number of small faults with throws of from four to ten feet cutting several veins in the Ruby-Conconully District. There are many instances of both pre-mineral and post-mineral faults acting along the plane of the veins, as evidenced by slickensided wall rocks, streaks of gouge, and of vein quartz ground to a sugary consistency. As a summary it may be said that displacement of the veins through faulting is usually small, and the operator finding his vein severed by a fault should not be too readily discouraged.

The largest measurable displacements observed were the Morgan fault in the Loon Lake Copper Mine, which has a throw of 50 feet toward the north, and another at the Bead Lake Mine, which apparently offsets the east segment of the vein 135 feet to the north.

The most serious cases of faulting found were those effecting the gold veins of the Republic District. These veins rank with the youngest ore deposits in the State, but in spite of their comparative youth they present a complex faulting problem, the solution of which is of decided economic importance. The only chance, however, for a successful attack of the problem must come from an intensive study and mapping of the vein system and faults. The ground near the interruptions is exceedingly soft and at the time of visit was found badly caved; this, of course is a serious handicap to underground study.

Development and Exploration

Mining operators find it advantageous to familiarize themselves with the outstanding, controlling geologic features of the particular type of deposit in which they are interested. With this idea in mind, a classification of the various ore deposits throughout the State has been attempted. Under the various headings the most important geologic features have been outlined. Those charged with development operations may find it of practical interest to refer to this classification, also the descriptions of the individual mines mentioned as typical examples of some certain class of deposit.

The development and exploration of ore bodies invariably give rise to perplexing problems. Each mine has problems peculiar to itself and such conditions are subject to far too many variations for detailed discussion in this report. An investigator who visits the various mining camps of the State is forcibly impressed with the dogged determination and admirable optimism displayed by the small operators and the prospectors. Too often through lack of proper financial support they are forced to fight a grim, uphill battle which would soon dishearten the ordinary man. Lack of mining training, experience, and business judgment, are also the factors which are dooming many of these men to almost certain failure. It is a desire to assist rather than criticise that prompts the mention of certain of the most disastrous mistakes made by the inexperienced. This is not a reflection on many other operators who are developing their properties in as thorough and capable a manner as their finances permit.

There is a deep-rooted belief among many men directing mining exploration, that deposits grow progressively richer as greater depth is reached. Who has not heard the oft-repeated statement to the effect that all a certain property needs is deeper work? Ore deposits in the great majority of cases do not grow richer in depth—in many instances the reverse is true, and a number of the best deposits yet discovered have already been bottomed of their commercial ore. The science of ore deposits is primarily the accumulation of

observed common-sense laws which have been handed down to the present generation and even now are being further developed. The history of mining does not substantiate the "richness with depth" belief. This fallacy probably received its inspiration from districts such as Butte, where the upper zones of many of the ore bodies have been leached barren of values and these carried downward by percolating waters to enrich lower horizons. In Washington, secondary enrichment of this nature is unimportant, for during comparatively recent times, glaciation has planed off the upper segments of most of the deposits and since then the factors of climate and time have not permitted extensive alteration.

Another misleading feature in some instances is the failure to appreciate that in most ore bodies, the upper thousand feet or so of the vein have already been removed by erosion, so that the present-day outcrops represent relatively deep-seated portions of the vein.

It is this "richness with depth" fallacy that too often encourages the premature driving of long, costly tunnels to crosscut and gain depth on deposits. When the topography will not permit development through short crosscuts, it is usually better to fully determine the nature and tenor of the ore bodies by shaft development. If the ore is exposed then the expenditure for the crosscut will be warranted, and work can be pushed ahead on an efficient basis, rather, than on the basis of a blind hope that a few hundred feet difference in depth will transform an unpromising prospect into a bonanza. It is admitted that such phenomena are occasionally recorded on the pages of mining history, but their rarity reduces that type of mining exploration to a blind gamble rather than a legitimate speculative investment.

In Washington there are numerous crosscut tunnels, several thousand feet in length and representing investments of from $20,000 to $50,000, that have proved failures. In many instances the surface showings emphatically testified against such a gamble. The failure of such project brings not only heavy losses to the investors, but it places a serious handicap on meritorious surrounding properties.

In other instances it is common to find tunnels 1,000 feet or more in length which are arbitrarily located by eye rather than by survey. The final work, instead of being "as true as a die," contains jogs and curves which later have to be straightened out. With such work costing $15.00 or more a lineal foot, the survey need only shorten the tunnel a few feet to pay for itself many times over. In addition, such a survey will definitely fix the length of the proposed work and thus the perplexity of exhausting available funds with the work but half completed can be largely eliminated. These are elemental facts which should be well understood by those charged with the responsibility of developing ore bodies, but until they are, constant reiteration may finally serve to drive them home.

Financing

Mining operations are being seriously retarded in Washington by the lack of capital to carry forward decisive development work. It is difficult to encourage prospecting when more or less meritorious properties are lying idle. Many of the prospectors are disinclined to search for new deposits in areas where the known prospects are not fully exhausted, and where capital for development cannot be attracted.

The prospector, often laboring under the handicap of educational limitations plus his isolation, is in a poor position to interest the right kind of capital. In presenting his property to an outside mining company he would more often succeed in securing an examination, if, when describing the property, he would confine his description to a simple state ment of the fundamental facts. One assay from a systematic channel sample across the width of the vein will bear more weight than 10 assays of picked specimens.

A considerable number of the smaller properties of the State are held by local groups of men who possess but a limited capital for mining investments. They develop the property sporadically with the surplus of their outside business earnings, and in some cases fresh capital is added by business associates entering the organization. Usually the values are too low to make the ore of shipping grade and probably sev-

eral thousand feet of well-directed development work is required before expecting sufficient ore to be developed to warrant the erection of a concentrator. Add to these conditions the often present evil of unskilled mining management, and the sum total usually shows an unprofitable venture. On the other hand, however, there are local organizations managed by men of more than ordinary ability, who are able to secure sufficient financial backing, and who succeed in turning a promising prospect into a paying producer. Under the present circumstances it is not fair to judge this type of development too harshly for by far the greater portion of the metal production made by Washington comes from mines that were brought to the front in this manner.

Many of the large mining companies adopt the policy of waiting until a property is developed and then buying it outright. Even then some of the large companies do not want to bother with a medium-sized milling ore body. It seems reasonable to predict that within the next few years more mining development companies will be organized to develop promising prospects or semi-developed properties. The often-quoted idea that all worth-while properties have been combed over is not true. There are not enough of the type of development companies who have the courage to attempt the development of deposits having only a prospective value. A well organized and properly financed development company with an experienced staff of engineers would be able to make effective returns; certainly, such an organization offers the best means for future financing of the properties until they have become producers or the development carried to a point where negative results discourage further expenditures. If such an organization succeeded in bringing in several producing properties, they could well afford the development expended on several other negative ones.

Mining Methods

The mountainous topography of northern Washington often affords sites for adits to tap the deposits from 200 to 500 feet below the outcrops, and thus the mining and drainage problems for the upper limits of the ore bodies are consider-

ably simplified. The adit of the United Silver-Copper Mine, which has a length of 4,220 feet and taps the vein 1,000 feet below the outcrop, is the longest in the State.

Both inclined and vertical shafts are not uncommon. Excessive flows of water are seldom encountered and no heavy pump installation is necessary. The veins usually dip at angles greater than 40 degrees, the walls as a rule stand well and shrinkage stoping is the common practice. The United Silver-Copper Company uses the filled-stope method for certain parts of its vein, waste for filling being borrowed from the walls. The ground in parts of the Electric Point Mine is heavy and square-setting is resorted to. Timber for mining is secured locally about the mines and this cost item is kept relatively low.

All properties of any size have power installation for machine drilling and hoisting. There are several excellent new installations of aerial tramways. Chief among these can be mentioned the Electric Point tramway two and one-half miles in length and the Copper World Extension two miles long and with a vertical elevation of 2,700 feet between terminals.

Concentration Features

Since the major portion of Washington's future metal production must come from concentrated ore, a synopsis of the ore dressing progress in the State will be included herewith.

The early attempts at ore concentration were principally confined to the recovery of gold from its ores. These were treated in the old familiar stamp mills by amalgamation, cyanidation, gravity concentration, or combination processes. The descriptions of the more prominent older mills can be found in the Washington Geological Survey Annual Report, Vol. 1, part II, 1902, and in the various articles occurring in the files of the technical magazines.

More recently, attention has been given to the concentration of the lower-grade ores of copper, lead, silver and zinc, and a number of mills have been erected with varying degrees of success. Many of the failures were brought about because sound business and engineering principles were de-

parted from. Too often, careful mill tests have not been followed through as the first step in the design of the flow-sheet. Designs are sometimes copied from other districts and after the mill is erected these are found to be only partially suited to the new ores. Each ore deposit carries its individual metallurgical problems and the prerequisite to successful ore dressing is a carefully designed plant based on thorough preliminary mill tests performed by competent men. The necessity of actually blocking out sufficient ore to guarantee the erection of the mill and of preparing against changes in the character of the mineralization are now becoming quite well appreciated and a reiteration of the factors calling for these fundamental common-sense methods should not be necessary.

Gold.—The ores of the Republic camp are not amenable to amalgamation but cyanidation has effected a reported* recovery of 90 per cent. These offer a promising field for metallurgical investigation and the problem is more fully discussed on page 167 of this report.

The oxidized surface ores of the Blewett District were in the early days crushed in arrastras and the gold recovered by amalgamation. With depth, however, sulphides were encountered and cyanidation was necessary to effect an economical recovery. The presence of base metals made the cyanide consumption abnormally high. It is possible that flotation concentration might prove a valuable adjunct toward the solution of the problem.

The gold ores of the Mt. Baker District carry their values as free gold and experience has proven that amalgamation effects an efficient recovery.

Lead-Silver.—Over 80 per cent of the lead ores from the Electric Point Mine, the present largest lead mine in the State, is in the form of lead carbonate, cerussite. A part of this is too low-grade to stand the heavy shipping costs and is now held at the mine. These carbonates offer an unique metallurgical problem which might be solved by the use of a volitization process, or possibly by leaching the ore with salt brine or some other more favorable reagent. All the other

*Morse, C. E., The San Poil Mill at Republic: Min. & Scientific Press, Vol. 109, Sept. 19, 1914, pp. 412-419.

lead producers of any size carry their lead values chiefly as galena, associated with varying amounts of silver. At several of the mines the galena is coarse enough to be first treated by jigs, followed by table concentration and flotation. The majority of the deposits, however, are best suited to table concentration followed by re-grinding and flotation. The straight silver ores such as those of the Nespelem District and the Ruby Mine near Nighthawk, employ the combination of tables and flotation, but in certain problems it appears likely that all-flotation would simplify operations without decreasing the recovery. Each problem must, of course, be worked out individually with percentage of recovery, ratio of concentration, and cost of milling as the major deciding factors.

Copper.—The two largest concentrating mills in the State are those of the United Silver-Copper and the Sunset Copper companies. Both employ the same fundamental principles of concentration. The ore is crushed in large ball mills for table feed and the table middlings and tails are sent to a smaller ball mill and reground for flotation. The Loon Lake Copper Company has a well-designed all-flotation mill, unique in that the design calls for neither screening nor elevating devices.

General.—In gravity concentration of sulphide ores like those of copper, lead and silver, it was formerly the case that the slime losses brought the percentage of recovery below 70 per cent. Since the advent of successful flotation practice the slimes are sent to flotation, and on fresh sulphide ores a mill recovery of less than 90 per cent is not considered standard practice.

There are several small deposits of medium-grade ore, located some distance from the railroad, which in certain instances can now be made to yield a profit. Take for example a small vein of ore averaging 15 ounces of silver to the ton, the property being 20 miles from a railroad. Let us assume that the deposit has been partly developed and some high-grade ore sorted and shipped, several hundred tons of the sorting reject from these shipments still remaining on the dump. With a little development work, in certain of these

properties, enough milling ore can be developed to warrant the erection of a small temporary mill with which to clean up the ores during a period when the metal market is favorable. It should be remembered, however, that such a project requires the most skilful management, for the margin of profit will not ordinarily permit the costly mistakes of the inexperienced.

DESCRIPTION OF THE MINING DISTRICTS AND INDIVIDUAL ORE DEPOSITS

PEND OREILLE COUNTY

THE NEWPORT DISTRICT

LOCATION AND GENERAL FEATURES

In this report the Newport District includes the southern section of Pend Oreille County. It is bounded on the west by Stevens County, on the south by Spokane County and the Idaho State Line forms the eastern margin. The northern boundary is arbitrarily placed as the northern line of Township 33.

The prosperous town of Newport, with a population of about 2,000, is the center of the district, the principal industries of which are farming, dairying, lumbering and mining. The area is served with excellent transportation facilities, Newport being on the main line of the Great Northern Railway 66 miles north of Spokane. It can also be reached over the Idaho & Washington Branch line, which runs from Spokane to Metaline in the northern part of the county. An excellent auto road connects the district with Spokane.

TOPOGRAPHY

The district covers the area in the vicinity of the southern end of the Pend Oreille Trench, a broad glacial valley in places measuring two miles or more across, and which in Washington divides the Selkirk Mountain System into two north-south trending mountain ranges known as the Calispell Range and the Pend Oreille Range. Calispell, the western range, extends into Stevens County. Its average height is about 5,000 feet, its highest projection being that of Calispell Peak, which reaches 6,900 feet above sea level or 5,000 feet above the valley. The Pend Oreille Range on the east has an average elevation of 3,500 feet and its ridges follow roughly the Idaho State Boundary Line northward into British Columbia. The ranges are clothed with a heavy forest of fine timber and jeweled with several scenic mountain lakes. The Pend Oreille River enters the State near Newport and flows northward to join Columbia River near the internation boundary.

GEOLOGY

Northward from Spokane to Newport, granite is the predominating formation. This granite is in places overlain by remnants of basaltic flows. Near the border between Spokane and Pend Oreille counties, the auto road for many miles is built on the nearly level surface of a mantle of glacial drift material which was brought down during recent Quaternary time by glaciers traveling southward from British Columbia. Their irresistible march gouged out the Pend Oreille Trench and was not halted until it encountered the warm winds from the south, then during the ensuing retreat great loads of debris were dropped along the route.

The granite is no doubt a part of the batholith exposed in Stevens County and named by Weaver, the Loon Lake granite. At the properties visited near Newport the intrusive exposures exhibit a more decided basic phase approaching a diorite in composition. Just across the Idaho Line and near the shores of Freeman Lake, four miles north of Newport, an exposure of practically pure quartz totalling several million tons, was visited. This quartz is believed to be the product of magmatic segregation from the granitic intrusion during its stages of solidification. It is quite generally believed that during the slow cooling of magmas, having certain ranges in composition, the basic minerals have a tendency to crystallize out first, leaving the more acidic minerals such as quartz to later crystallize as a filling for spaces around the dark minerals. Thus there may come a time during the cooling of certain magmas that their physical state can be compared to a sponge filled with water, the crystallized basic minerals being the fibres of the sponge and the acidic minerals the water filling the open cells. If during this period the magma was subjected to compressive forces, it is easy to picture conditions wherein the quartz would be largely squeezed out or segregated into large siliceous bodies, thus robbing a certain section of the magma of its acidic minerals. This hypothesis is offered as a possible explanation for the more basic phase of the Newport intrusive in comparison to the Loon Lake granite. The phases are believed to be directly related and a part of the great batholithic intrusion under-

lying northeastern Washington and Idaho and extending northward into British Columbia.

The same belt of Paleozoic sediment exposed through Stevens County is also thought to have extended eastward over the Newport area but here they have been uplifted and so effectively eroded that only one member of the series, quartzite, was observed in the district. This was found well up on the flanks of the range directly in contact with the intrusive diorite as a remnant of the old roof.

The properties showing activity are located in a small area north of Newport. The district, however, has not been thoroughly prospected. The slopes of the ranges are heavily timbered and coated with hillside wash so that for the present the future of the district must remain an unknown quantity. Parts of the range along the Idaho Boundary are still hardly more than a wilderness which in due time may be investigated by the prospector.

The veins observed were as a rule strong and clean-cut quartz veins filling east to west fissures in the diorite. Sections of them are quite barren of values, the mineralization occurring in localized shoots. And it seems apparent that success in mining will come only from the development of these shoots.

BEAD LAKE

General Features.—The property of the Bead Lake Gold-Copper Mining Company, totalling about 300 acres, is on the east side of Pend Oreille River, six and one-half miles north of Newport, Washington, and within a mile of the Idaho Boundary. The mine workings are at an elevation of 2,800 feet above sea level, or about 700 feet above the town of Newport.

To reach the property from Newport, it is necessary to ferry across Pend Oreille River and then travel northward over the Bead Lake road. The first two miles of this journey leads up a rather steep grade until the bench lands are reached, 500 feet above and overlooking the river. From this point above the river an excellent view can be obtained far to the

north along the former glacial trench now known as the Pend Oreille Valley.

The company has an attractive camp, which is favorably located as to sources of timber and water. Bead Lake, from which the mine received its name, answers all that could be desired of a beautiful mountain lake, with its large body of water reflecting the steep and heavily timbered slopes which ascend abruptly from its shores.

Geology.—The Pend Oreille Mountains in which the Bead Lake Mine is situated from a part of the Selkirk Range which trends northward into British Columbia. The belts of Paleozoic sediments so well exposed in Stevens County extend eastward into the Newport District. The underlying batholith is well exposed, and only well up on the range does the old roof of sediments remain. Quartzite was the only member of the series observed and it was found in contact with the diorite intrusion. The intrusive rock near the mine is of a basic character and from a megascopic examination would be classed

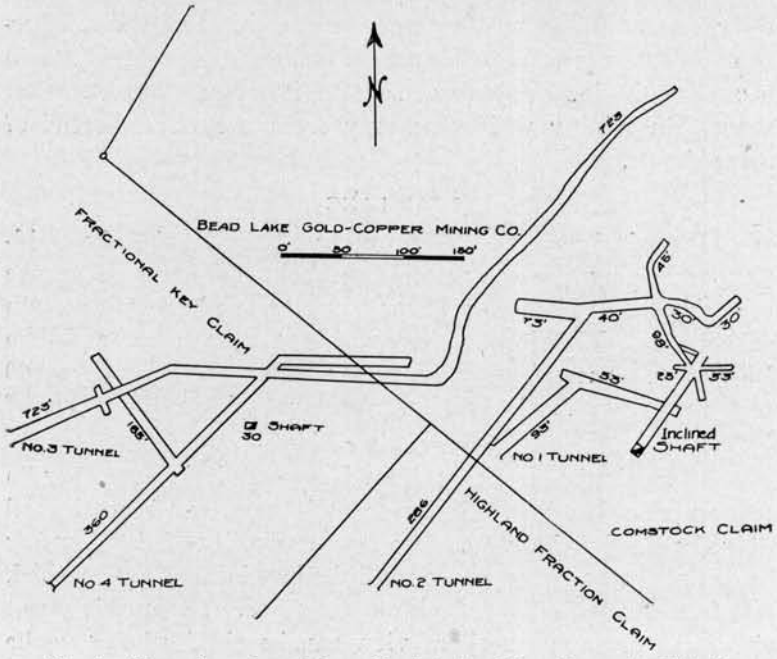


Fig. 6. Plan view of workings, Bead Lake Mine, Newport, District.

as a quartz diorite. A thin-section of the wall rocks exhibits a greenish ground-mass of serpentinized minerals with large inclusions of quartz filling the interstices. Pyrite is noticeably developed in the wall rocks at some distance from the vein.

Description of Vein and Development Work.—The Bead Lake vein fills an east-west fissure cutting the diorite; it has a width varying from two to twelve feet, with an approximate average of six feet.

The ore consists of mixed sulphides of lead, iron, copper, and zinc in a gangue composed of milky quartz, barite, and calcite. Some of the ore shows a well-banded structure, the galena, chalcopyrite and pyrrhotite displaying distinct bands, some of which are one-fourth to three-fourths of an inch in width.

In this type of vein the minable ore is found localized into pay-shoots and the vein matter intervening between the shoots is too low-grade for profitable mining. So far one pay-shoot has been opened on the vein, and it is obviously highly important that the vein be prospected along the strike for the occurrence of other ore-shoots.

The vein dips 65° toward the north. In the east end of Nos. 1 and 2 workings, it has been cleanly severed by a fault. A quartz outcrop, which has been found on the surface about 130 feet north of the vein proper, is believed to be the east segment of the faulted vein. The absence of confirmatory underground development and the failure of vein outcrops through the deep hillside-wash leaves room for doubt whether this is the faulted segment or a parallel vein. The problem is important for the fault cut through the best ore-shoot in the mine, and it is highly necessary that the east segment of the shoot be located.

The property is developed by four tunnels opened at intervals up the hillside, comprising in all about 2,000 feet of tunnel work. Tunnel No. 1, or the upper crosscut, is driven 93 feet in a northeasterly direction, where it encounters a quartz vein having a width of from five to seven feet, and carries excellent mineralization of galena and chalcopyrite. This showing, which is the best, was drifted on for 65 feet to the

east where it was cut off by the fault previously mentioned. For the first 25 feet from the portal the crosscut passes through quartzite and then enters a medium coarse-grained quartz diorite, which is intrusive into the quartzite. Tunnel No. 2 is 87 feet vertically below No. 1 and is driven 286 feet to the vein. A drift on the vein was driven 73 feet to the west and another 40 feet to the east where it was cut off by the same fault as exposed in the upper workings. An incline raise, 100 feet in length, connects the two levels and exposes ore of milling grade. The lower levels, Nos. 3 and 4, have not encountered the vein. The dip of the vein carries it further to the north, and into the hill, as greater depth is reached, so that if this vein continues to the west it must lie several hundred feet to the north of the breast of No. 4 tunnel. No. 3 tunnel is driven 723 feet in a northeasterly direction. In one place it trends due east for a distance of 200 feet following a narrow quartz vein barren of values, so that it is more of a prospect tunnel than a true crosscut to the vein. Careful calculations may show that, if desired, it is still possible to pick up the vein by extending this tunnel toward the north.

In order to explore what is probably the east segment of the faulted vein, a crosscut was started in a small ravine above the camp and driven north 45° west for a distance of 450 feet. The vein in question is exposed by surface cuts and has a width of four to six feet. The failure, so far, of the crosscut to reach the vein is due to the fact that it is directed toward the vein at a 45-degree angle. By swinging the crosscut sharply to the northeast the vein should be cut a short distance from the present face of the crosscut. This work should be done, for it is highly important to fully locate the extent of the ore shoot that should exist in the east segment of the faulted vein.

Early in 1920 the company acquired title to the adjoining holding of the Conquest property. This adds 200 acres to the company land and provides them with a suitable mill site. It is probable that some well-directed development work on the Conquest property would expose additional milling ore.

During the summer of 1920, the company began the erection of a 100-ton concentrator. Ore dressing machinery con-

sisting of Blake jaw crusher, Hardinge ball mill, Dorr duplex classifier, Allen cone, Wilfley tables, Oliver filter, 150-horsepower electric motor, and accessory equipment are already on the ground. An excellent local supply of timber encouraged the erection of a small portable saw mill and planer which is supplying lumber for the erection of the concentrator and additional camp buildings. This arrangement effected a substantial saving on lumber costs.

KOOTENAI-CONQUEST

This property has been idle for several years and was examined because of the extent of the development work coupled with the fact that no public information on developments is known to be in existence. It was owned by the Coverly estate of New York but has recently been purchased by the Bead Lake Gold-Copper Company.

The principal workings are located about 100 feet south of the Bead Lake camp and the property totals 160 acres of patented ground. It is well equipped for mining, with a 100-horsepower boiler furnishing power to a small hoist and an engine which operates a 5-drill Ingersoll-Rand compressor. Other equipment consists of two pumps, two air drills, a well-equipped blacksmith shop and auxilliary equipment, all in good repair. There are 10 tons of ore which were sorted and sacked but apparently were not of sufficient grade to encourage shipment. The property is reported to have shipped several carloads of ore, the returns of which are not available.

The development work has been poorly directed and a large expenditure of capital accomplished by erratic tunnel exploration. The main tunnel, which comprises about 2,000 feet of work, is driven into the hill in an easterly direction. The first 150 feet is in quartzite and it then passes into diorite for the remainder of this distance. Several hundred feet from the portal an aplite dike three to five feet in width was encountered and drifted on for a length of 700 feet without exposing any ore .

Vertically 150 feet above this level an upper tunnel is driven due east a length of 300 feet on a small quartz vein

averaging from ten inches to four feet in width which contains an ore shoot 100 feet in length. This shoot is well mineralized with chalcopyrite, pyrite, marcasite, sphalerite and galena. Stopes have been opened on it from the level up to the surface. It is difficult to understand why this vein was not cut in the lower workings. Mine maps were not available but the dip of the vein suggests that it would lay to the north of the lower tunnel. Short crosscuts have been run both north and south from the lower tunnel but the north crosscut has not been driven far enough to prove the existence or non-existence of the vein in that direction. Further, prospecting on the opposite side of the small ravine west from the tunnel portals might disclose the extension of the vein.

At the bottom of the ravine a shaft was sunk to a reported depth of 140 feet and 300 feet of drifts run from the bottom of the shaft. It is stated that this work encountered the vein and some ore was mined. This shaft was filled with water at the time of visit.

METEOR CLAIM

One-half mile northwest of the Bead Lake camp, H. McCullough and Ed Alger have taken a lease on 40 acres of patented land and are prospecting a 16-inch, well-defined quartz vein carrying mineralization in chalcopyrite, pyrite, marcasite, and small amounts of galena. The vein cuts the intrusive rocks, strikes north 25° east and dips 49° to the southeast. It is opened by two short drifts inot the hillside at a difference in vertical elevation of 75 feet.

RIES

This property, incorporated as the Ries Mining Company, consists of four claims and 40 acres of land held under State lease. These holdings are two miles north of Newport, on the west side of Pend Oreille River. The workings are on the bank of the river and about 100 yards from the righ-of-way of the Idaho, Washington & Northern Railway.

Recent work has been confined to an open cut 35 feet long and 25 feet deep which exposes a quartz vein five feet wide. This vein fills a clean-cut fissure in diorite. From the cut it out-

crops at the water's edge and continues under the river with an east-west strike and stands nearly vertical but with a slight dip toward the north. There is a streak of light-colored gouge about one inch thick along both walls. Where opened by the cut, the vein exposes considerable mineralization in argentiferous galena, chalcopyrite and pyrite. The best ore was observed in a two-foot pay streak near the north wall, but there was more or less mineralization over the full width. The galena, as a rule, is crystallized into coarse cubical form. In the west end of the cut the vein narrows down to two feet in width. Fifty feet west of this point a shaft was sunk adjacent to the vein to a reported depth of 215 feet and crosscuts run to the vein from the bottom of the shaft, and at a distance of 80 feet from the collar. The shaft was filled with water at the time of visit.

This vein no doubt extends further up the hillside to the west and it seems only logical that it should be prospected with shallow cuts, as the best ore will be found in localized shoots. Operating conditions are extremely favorable. The property is worked in a small way at odd intervals and the several shipments made have yielded encouraging smelter returns.

METALINE DISTRICT

GENERAL FEATURES

The many small prospects and the sporadic producing properties of the Metaline District were idle during 1919. One company, The Diamond R, built a small mill and during the first half of the year made several small shipments, but at the time of visit (July, 1919,) this property was temporarily closed. A hurried visit only was made to the district because there had been little new development work since the time of Bancroft's* visit in 1910.

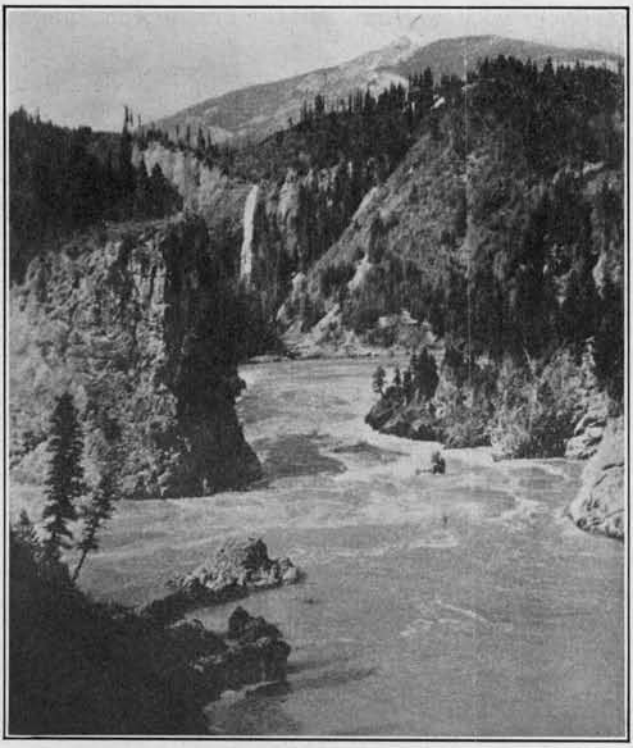
LOCATION AND MEANS OF ACCESS

The Metaline District occupies an area of 400 square miles in the extreme northeast corner of the State, or more definitely stated, it covers the entire section of the county north of Township 37.

*Bancroft, Howland. The Ore Deposits of N. E. Wash.: U. S. Geol. Survey, Bull. 550, 1910.

The district can be conveniently reached from the south over the Idaho, Washington & Northern Railway from Spokane to Metaline Falls. This road was completed in 1910 and affords excellent railroad service to the county.

The district is served by two small towns having a combined population of about 800 people. Metaline, the pioneer town of the area, is built on the west bank of Pend Oreille River. Across the river and one-half mile to the north is Metaline Falls, which was built following the erection of the plant of the Inland Portland Cement Co., in 1909. Lumbering and the manufacture of cement form the chief industries of the district.



Z Canyon on Pend Oreille River, Metaline District.

TOPOGRAPHY

The Pend Oreille, one of the large rivers of the State, flows northward through the district to the international border, where it joins Columbia River and changes its direction of flow to the south. South of Metaline Falls this river is navigable for small craft, but to the north it enters constricted, steep-walled canyons through which the waters dash at a mad swirling speed and form sources of hydro-electric power for future uses. From both walls of the river well-timbered, rugged mountain ranges attain altitudes of 6,000 to 7,000 feet above sea level, or 4,000 to 5,000 feet above the river.

South of Metaline Falls the river valley broadens to a mile or more in width and is flanked for a considerable length by terraces of silt which rise abruptly from the river to a height of 200 to 300 feet and culminate in flat-top benches. From these benches timbered slopes lead with gentle contour up to the crests of the north and south trending ranges.

GEOLOGY

Dolomite and limestone, with their intermediate gradations, were the predominating formations seen in the limited section of the district visited. In the vicinity of the mines on the west side of the river were found belts of magnesium limestones, dolomite, a few narrow exposures of calcareous shales, and zones of siliceous dolomite grading into quartzite. These are a part of the Palezoic sediments of the Stevens Series so well exposed in the Northport District, about six miles by air line to the west of Metaline. Like the sediments in the Northport District, they are highly metamorphosed, dip at varying angles and contain many minor folds.

On the bank of Sullivan Creek, one mile east of Metaline Falls, the Lehigh Portland Cement Co. has opened a large quarry in dark, calcareous shales. These are thinly bedded and have developed a slaty cleavage. They contain many minor folds but the general bedding tendency is horizontal with a slight dip to the northwest. A mile to the southeast the company is also operating a large quarry in highly metamorphosed, dark-bluish limestone, which has a dip of 35° to the west and strikes north-south.

The Lehigh Portland Cement Co. has kindly furnished the following analysis of type samples:

Sullivan Creek Shales

	1	2	3	4
SiO_2	23.92	27.64	22.64	24.52
R_2O_3	13.84	16.08	13.28	15.28
$CaCO_3$	52.89	47.10	56.02	46.64
$MgCO_3$	7.63	6.93	6.60	11.14
	98.28	97.75	98.54	97.58

Limestone

	1	2	3	4
SiO_2	1.32	5.80	4.40	6.52
R_2O_3	1.04	3.96	3.44	3.52
$CaCO_3$	96.56	84.51	87.95	82.94
$MgCO_3$	1.87	5.99	4.12	7.74
	100.79	100.26	99.91	100.72

ORE OCCURRENCE

All ore deposits visited in the Metaline District consisted of irregular replacement deposits of argentiferous galena, sphalerite, chalcopyrite, and pyrite in magnesium limestone. These deposits are found along narrow zones of shearing, the shear planes acting as channels through which the mineralized solutions given off by an underlying granitic magma, worked upwards through the overlying cap rocks and at certain favorable horizons reacted with the magnesium limestones to eat away an irregular cavity into which the ore burdens were deposited. Irregular pods, lenses and chimneys are the forms generally taken by the deposits, with narrow, feeder-like stringers of ore leading into these masses from slip planes. The irregularity of the deposits and the lack of satisfactory evidence to guide the operators to these isolated bodies has served to discourage mining.

The underlying granitic batholith is not known to be exposed in the near vicinity of the deposits visited. A few miles to the west, however, it outcrops boldly and there is no doubt but that it extends under the Metaline area at no great depth.

DIAMOND R MINING COMPANY

Bella May Claim

These workings, a part of the holdings of the Diamond R Company, are situated near the crest of a range of hills flanking the precipitous range which forms a natural north-south boundary between Pend Oreille and Stevens counties. They are about 700 feet above and one and one-half miles west of the town of Metaline.

This was the only property operating in the Metaline District during the summer of 1919, and at the time of visit it was temporarily closed down. The total production for the year has not been large.

The ore is found as irregular bunches and seams of galena replacing magnesium limestone along zones of shearing and fractures, thus giving the deposit a striking similarity to the Lead Trust and other deposits in the Northport District, seven miles by air line to the west. The magnesium limestone in the vicinity are badly broken by shearing actions. The major fractures have a strike of north 15° west and are well exposed in the small quarry opening 50 feet above the main adit portal. There are also other strong fractures at right angles to the major lines of movement.

The production has been made by following irregular seams of galena filling these fractures, and in places they tend to enlarge into bunches and chimneys of ore of varying sizes. Some of these bunches will yield several tons of clean ore, and the largest chimney, which is now practically mined out, appears to have been about 10 feet in diameter and 60 feet deep. One of the walls of this chimney bears pronounced striations showing heavy vertical movements. These shearing movements opened up channels for the ore bearing solutions from below. In several of the surface openings the galena has been altered to cerussite and anglesite but this alteration is limited.

The ground is developed by a short adit tunnel from which several crosscuts have been run, a winze sunk 12 feet below the adit level, and a raise opened to the surface. Most of this work was done where small stringers or bunches of ore encouraged exploration.

A 25-ton mill was constructed during 1919. From the mine opening the ore is trammed to a 10-ton head bin and then drawn from this bin by a 24-inch belt-conveyor which discharges onto a grizzly set at one inch. The grizzly oversize is crushed in a 9x15 Blake jaw-crusher and then the crushed material and the grizzly undersize is fed to a small set of rolls. After re-crushing, the feed is elevated to a trommel which sizes the material for two jigs of the Harz type. The material ranging in size from 3 to 10 millimeters is sent to a coarse jig which makes a shipping concentrate, a final tailing product, and a middling product which is re-crushed by the rolls and returned to the mill circuit. The finer material from the trommel goes to a second jig, which makes a shipping concentrate and a tailing product which is re-treated on a Wilfley table. The grade of mill feed varies widely, while the concentrates average 60 to 72 per cent lead, two to nine ounces of silver, and one to four per cent zinc. Mr. C. L. Wickstrom, manager of the property, reports that shipments of sorted ore made during 1919 assayed as high as 78.6 per cent lead.

Electric power for the mine and mill is furnished by the Lehigh Portland Cement Company, from their Metaline Falls plant. The mill machinery is operated by a 35-horsepower motor, while a 20-horsepower motor furnishes power to a two-drill air compressor for the mine.

Diamond R Claim

The Diamond R workings are on the claim of the same name and are two miles northwest of the Bella May workings, or can be reached over an old wagon road from Metaline, a distance of two miles toward the west. The workings are at an elevation of approximately 1,000 feet above the town.

The property has been worked at various times for the past ten years, and a few scattering shipments have been made. A carload of ore was shipped during 1918 and since that time the property has been idle.

The geology and type of deposit is quite similar to the Bella May property. The work consists of about 200 feet of tunnel following small irregular streaks of high-grade

galena which partly replaces the magnesium limestone along planes of shearing. In places these streaks swell into pockets and yield ten tons or more of high-grade ore. All the known pockets have been mined out and several of the feeder-like streaks followed in search of other bodies. There is no regularity to guide prospecting, except that the major fracture should be followed and ground adjacent to fracture intersections should be thoroughly tested.

Oriole

The Oriole property, now incorporated as the Metaline Oriole Mining Co., consists of six claims on the north slope of Linton Mountain, one and one-half miles west of, and about 700 feet above, the town of Metaline.

The camp is on a small flat. To the north and west of this, steep cliffs lead up to the east front of Calispell Range, with its crest line some 3,000 feet above the workings. An excellent stand of timber surrounds the camp and a bountiful supply of water is available from a large mountain spring from which Linton Creek heads.

Grayish-colored dolomites are the predominating rocks in the vicinity of the mine; these immense beds contain occasional belts of calcerous shales, while, in some places, the dolomite is so highly silicified that it approaches quartzite in composition and appearance.

The property is opened by two adit tunnels totalling 1,300 feet of work. The upper tunnel is 100 feet above camp, while the portal of the lower or main adit is 78 feet lower and about 250 feet northeast of the portal of the upper adit. The two levels are connected with a ninclined raise from the main adit an inclined winze has been sunk for a length of 100 feet. From the bottom of this winze a 60-foot drift has been carried to the west. This winze was filled with water at the time of visit.

The work has been directed toward the exploration of sporadic mineralization occurring along a narrow shear zone in the silicified dolomite. This zone cuts through the formation in an east-to-west direction and dips at a steep angle

toward the north. The gouge filling the zone averages only a few inches in width, but in the lower level near the raise connection between the two levels, two replacement lenses were observed carrying excellent values in argentiferous galena, sphalerite, chalcopyrite and pyrite, enclosed in a quartz gangue. These lenses average two or three feet in thickness and do not appear to be of large extent. The lenses usually exhibit a well-defined and striated foot-wall and their largest dimension is along the dip of the shear-plane. The production has apparently been made from two small stopes opened on these lenses. The property was visited in the absence of the owners and it may be possible that the raise between levels was opened on similar lenses. Where open for examination several small patches of ore were found on the walls of this raise, and its irregular shape in places suggested the removal of ore. In the lower adit several pronounced slips were observed cutting at right angles across the tunnel. Smelter returns on a carload of picked ore gave 42.1 ounces of silver, 21.9% zinc, 15.3% lead and 1.12% copper.

A small mill was built on the property early in 1918, but failure to install efficient crushing machinery hampered operations. The property has been idle since 1918, but Mr. Fred N. Davis in a personal communication stated that he expected to resume work during the latter part of 1919.

STEVENS COUNTY

NORTHPORT DISTRICT

GENERAL FEATURES

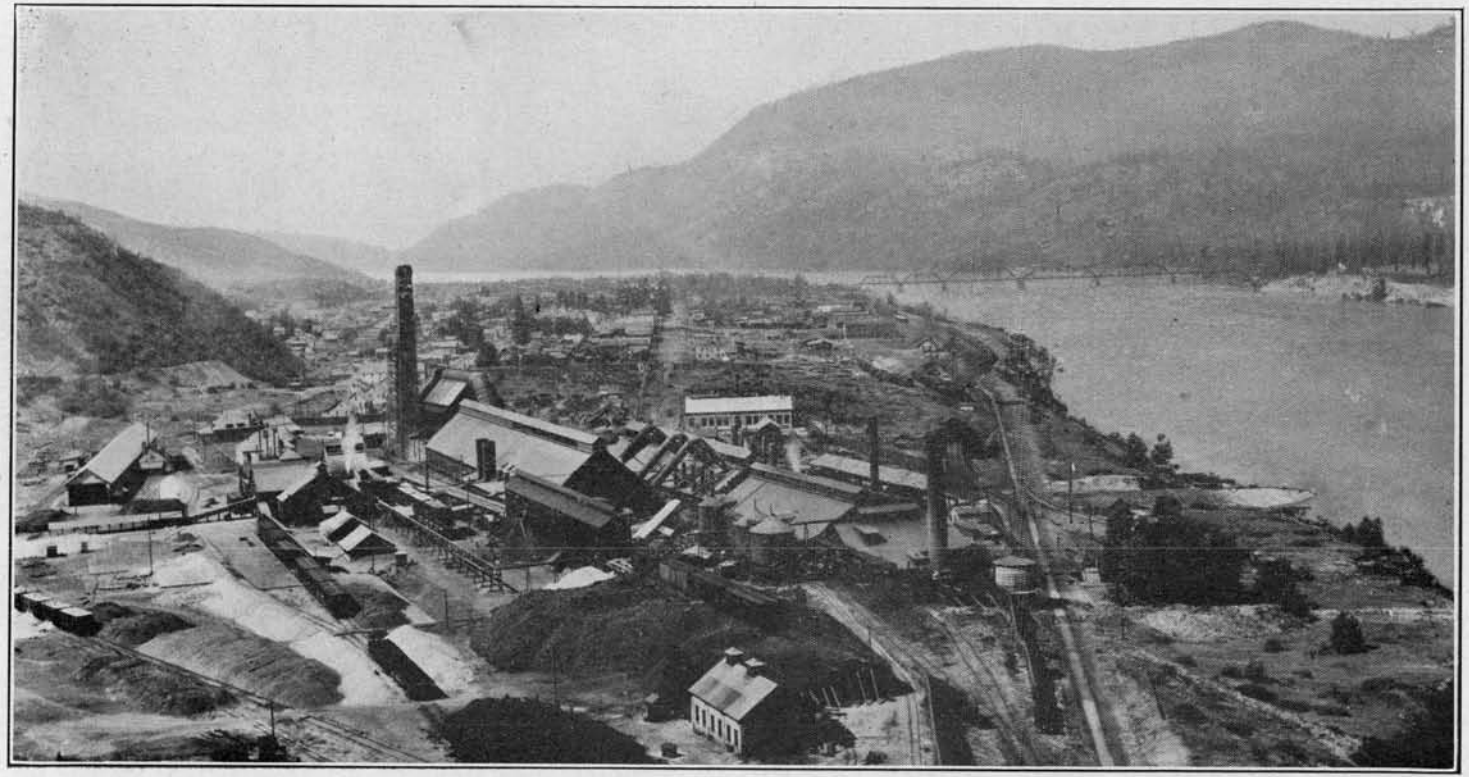
The Northport Mining District has been brought into particular prominence during the past few years by the discovery of the extensive ore bodies in the Electric Point Mine. The district includes the northeastern portions of Stevens County, being bounded on the north by the international boundary, on the west by the Orient and Fifteen Mile Creek districts, on the east by Pend Oreille County and the southern boundary line has been arbitrarily placed as the south line of Township 39 East. The Young America and Bonanza properties, near Bossburg, should, on account of their similar geologic associations, be placed in the Northport District.

The district is served by the Nelson Branch of the Great Northern Railway. Wagon roads, ordinarily suitable for auto trucks, link all the productive properties with the railroad.

Northport, with a population of 700 to 1,000, is the principal town of the district. The lead smeltery of the Northport Smelting & Refining Company, owned by the Day interests of the Coeur d'Alenes, is located here and the ore from their Coeur d'Alene mines is shipped to Northport for treatment. Some custom smelting is also undertaken. The plant employs about 200 men. Its three lead blast furnaces have a combined capacity of 900 tons of charge, each 24 hours. The smelter is also equipped with an excellent sampling mill, seven straight-line sintering machines, a Cottrell electrical fume-precipitating plant, and a refining unit was also being added during the fall of 1919.

TOPOGRAPHY

Columbia River has been the most active agent in influencing the present topography of the district. At the international border it is joined by the Pend Oreille and thus reinforced, it flows in a southwesterly course through a broad, glacial valley. From the low mountain ranges which flank the river on the east and west the drainage shapes the hills until it finds an outlet to add its share to the mighty river. The topography of the district is marked by fairly even-topped ridges



View of Northport Smelter and the town of Northport.

of ordinary ruggedness, trending north to south. The town of Northport is located on Columbia River at an elevation of 1,330 feet, while the surrounding mountains seldom exceed an elevation of 5,000 feet. The hillsides are usually covered with a thick mantle of glacial debris, which, supplemented by the dense growth of brush and timber, makes prospecting very difficult and no doubt masks the outcrops of many unknown ore deposits.

GEOLOGY

Entering the Northport District by railroad from the south the most lasting impression gained is that of the massive white bluffs of limestone flanking Columbia River from Bossburg to Northport. Along the banks of the river gravel terraces have been built up. These terraces, some years ago, were washed for their gold and from the extent of the workings the search must have met with encouragement. Southeast of Northport a large stock of granite outcrops over an area of about 100 square miles. To the north, toward the international boundary, belts of argillite, quartzite and limestone predominate, with several small stocks of intrusive diorite outcropping through the sediments. These vast beds of sediments, now highly metamorphosed, are believed to be of Palezoic age. In their present position they take the form of an old roof covering the underlying granitic batholith, of Mesozoic age, which has been intruded into the sediments. Erosion has in places stripped off sections of the roof and exposed the underlying granitic mass. Numerous lamprophyre and other igneous dikes, which are off-shoots from the granite during its period of cooling, cut the belts of metamorphosed sediments, often developing in them planes of shattering and shearing.

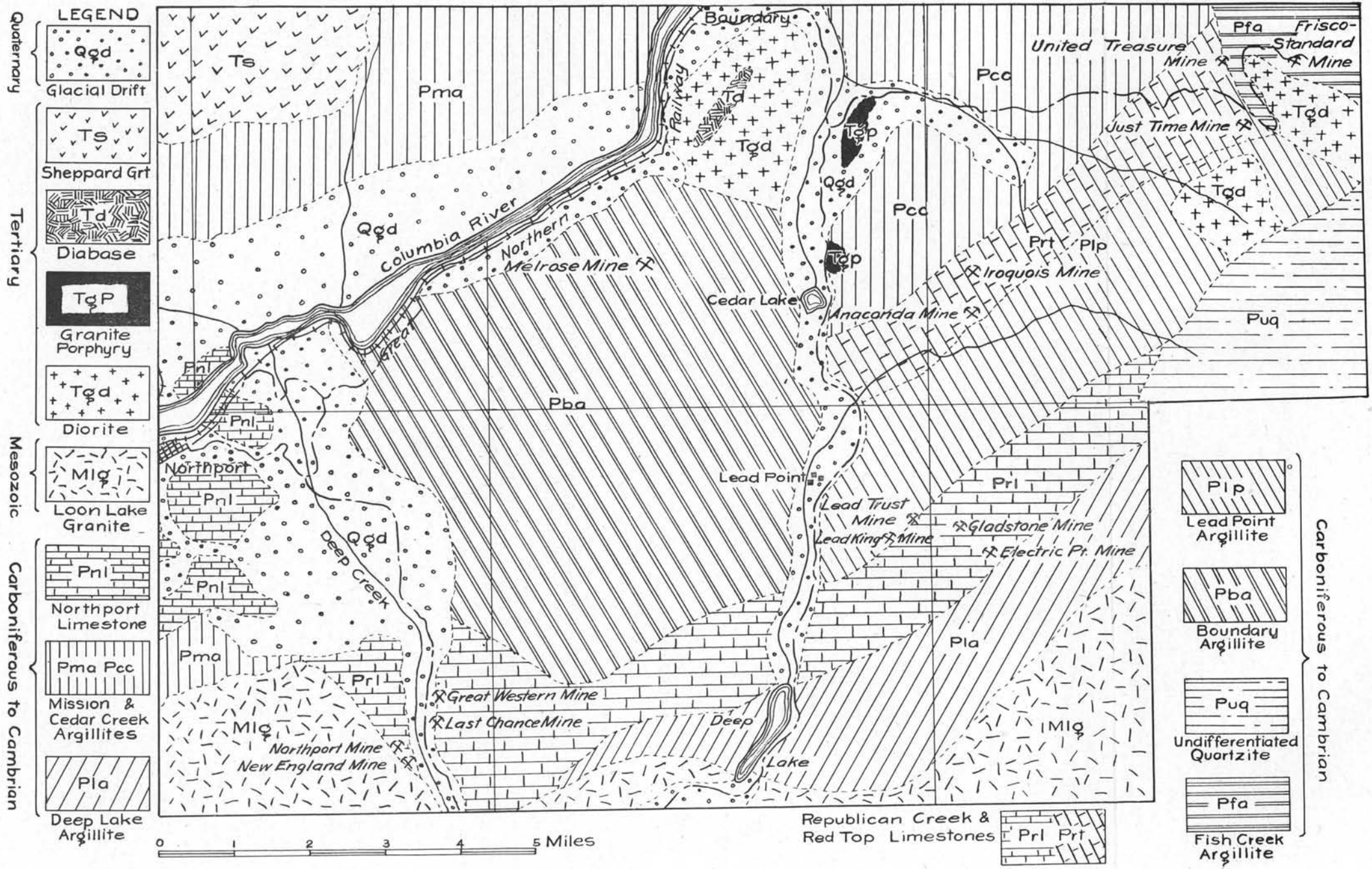
The ore deposits are found in the vicinity of these igneous dikes, and are no doubt the result of the emanations of hot mineral-bearing solutions and gases which collected while the granitic intrusion was cooling and, under heavy pressure, searched out fractures and shear zones already opened in the overlying rocks. At certain favorable horizons irregular replacement of the country rocks along these channels was effected and the sulphide minerals and siliceous gangue de-

posited in the cavities. In the limestone these solutions evidently followed upward along nearly vertical joints or slip planes; the intersection of two of such slip planes would form a favorable locus about which irregular chimneys of ore would replace the limestone to form a possible deposit of ore.

The sediments were folded before the intrusion of granite and these belts of argillites with pronounced bedding or schistosity planes, in many cases stood with these planes dipping at steep angles. Powerful forces exerted on such formations of igneous intrusion would tend to cause shearing actions and the stresses would naturally find relief along the bedding planes or schistosity, thus opening small avenues to receive possible ore-bearing solutions from below.

The predominating ore minerals are galena and tetrahedrite. The galena carries varying amounts of silver, depending upon the particular deposit. At the Electric Point Mine this galena has been largely converted in cerussite so this mineral must be given a prominent place among the ore minerals of the district. In the vicinity of the Northport and New England properties sphalerite is the principal mineral observed. Considering the district as a unit, the value of the lead produced easily exceeds all other metals, with silver next in importance. Certain of the zinc deposits bear promise of future production.

It is interesting to note that in the vicinity of the Last Chance and Northport properties, there are grouped a number of zinc deposits as replacements in magnesium limestone. As a general rule, these carry but scant lead values (the Last Chance deposit is a partial exception). Six miles northeast, the same belt of limestone is intruded by a number of lead deposits such as the Electric Point, Lead Trust, etc. This group in turn carries practically no zinc minerals. The two groups are unquestionably derived from the same granitic intrusion, and the segregated deposition of zinc and lead suggests a differentiation of these two metals within the magma just prior to their injection into the overlying limstone.



GEOLOGIC MAP OF NORTHPORT DISTRICT

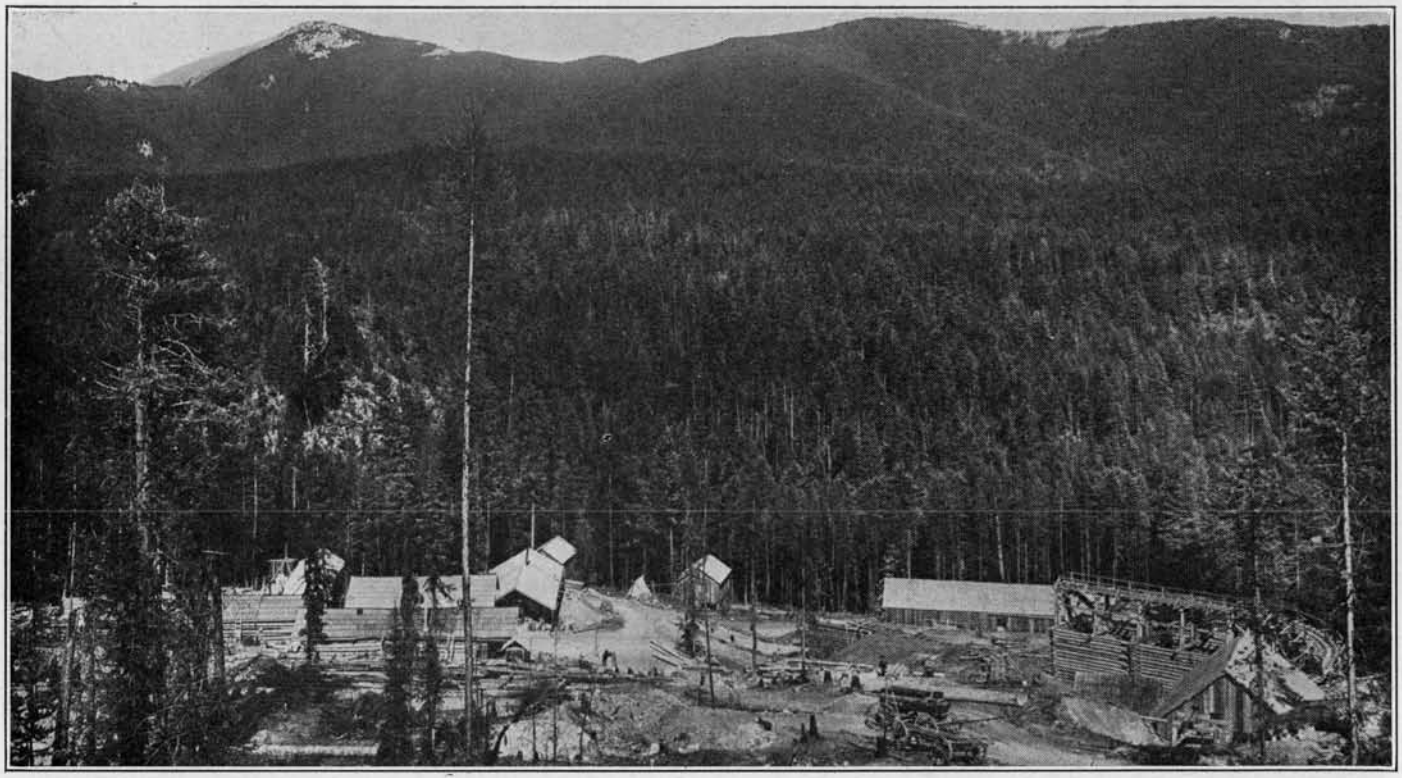
Recopied from Washington Geological Survey Bulletin No. 20.

ELECTRIC POINT

Situation and History.—The Electric Point Mine is one of the most phenomenal properties yet developed in the State. The workings are located at the very crest of a prominent point which makes up the summit of Gladstone Mountain. It is from this so-called point that the mine received its name. According to the local story, the name originated from the fact that during electric storms the lightning kept seeking out this particular spot until a great many of the trees in the vicinity of the mine were scarred and torn. The elevation of the mine is about 4,800 feet, four miles east and of 2,800 feet above the town of Leadpoint. It is 24 miles by wagon road from the mine to Northport and 14 miles to New Boundary Station on the Nelson Branch of the Great Northern Railway. The mine is connected with Leadpoint by an aerial tramway two miles in length; also by a wagon road which, during the early history of the mine, served as the only means of transportation.

The property was discovered during July, 1914, by Chris Johnson and J. E. Yoder, who, when prospecting over Gladstone Mountain, found a large float boulder of solid galena imbedded in the wash on the very crest of the "point." A few shallow pits soon disclosed the first chimney of ore made up of cerussite, mixed with limonite and carrying occasional nodules of galena. Roy Young became interested in the discovery and secured financial backing for the property until it was in a state to pay its own way. He became President and General Manager of the new company and under his successful guidance, the property began to yield dividends almost from the first.

Production.—Production began during 1916 and good-sized shipments have been maintained each year thereafter, with 1917 as the banner year. The grade of the carbonate ore as shipped is reported to average 20 per cent lead, while the shipments of clean galena averaged 70 per cent lead. During the period of 1916-19, inclusive, dividends totalling $301,625 were paid.



Camp of the Electric Point Mine, during earlier stages of operation.
The view gives an excellent idea of the surrounding country.

Economic Geology

Description of the Ore Bodies.—There are many surprising new features about the Electric Point ore bodies which would make them of interest even to the most calloused observer. The production has come from five egg-shaped large replacement chimneys in magnesium-limestone. Four of these chimneys are contained within the limits of two acres. The outcrops of three of these bodies were covered by only two to ten feet of wash, while the fourth was a blind chimney with its apex 50 feet below the surface. These chimneys stand nearly vertical; their approximate average cross-sectional dimensions are 30 feet to 50 feet and they vary in depth from 100 feet to probably more than 600 feet.

Chimney No. 1 averages about 30x40 feet in cross-section and extends to a depth of 340 feet.

No. 2 was roughly circular in cross-section, with the diameter about 25 feet, and its downward extent about 100 feet.

No. 3 averages 50 to 60 feet in cross-section. For the first 200 feet in depth, there was good ore and from that level downward the chimney appears to be filled mostly with limonite and iron-stained clay, of too low a grade to be called ore.

No. 4 was the blind chimney with its upper limits 80 feet from the surface. It appears to branch on the 300-foot level; one leg is practically barren from the 400-foot level on down, being filled with limonitic clay. The other branch has been developed to the 800-foot level, where the ore is apparently good grade. The general dip of this remarkable chimney is about 80° toward the southeast, but below the 600-foot level the dip changes to 80° toward the northeast.

The chimney fillings are essentially limonitic clay, cerussite, called "sand carbonate" by the miners, nodules of galena and remnants of badly altered lamprophyre dikes. The galena is found as isolated nodules and boulders scattered through the carbonate. In some instances masses of solid galena weighing from 1,000 to 2,000 pounds are found. The ore mined has averaged about one ton of galena for each six tons of cerussite, and the remarkable feature of the deposit is that this same ratio appears to hold true from the surface down to the

present deepest level. Further, the same pronounced limonite and clayey selvage is as prominently developed on the 800 level as it is nearer the surface.

Early in 1920 a fifth and very profitable chimney was opened near the line separating the property from the Gladstone Mine. When developed to a depth of 125 feet the ore-shoot terminated, but the limonite and other chimney filling continued. Prospect drifts from the bottom of this shaft exposed an adjacent chimney 200 feet in diameter but devoid of profitable values. A short drift to the northwest from the bottom of the shaft unexpectedly disclosed a second adjacent chimney carrying great boulders of galena loosely imbedded in heavily iron-stained carbonate sand. The ore body has a vertical range of 185 feet and measures 15 x 22 feet in diameter. It is roughly eliptical in cross-sectional outline. At the time of examination boulders of galena, some weighing as much as two tons each, were being mined from this chimney. One wall of the chimney exposes a pronounced slip plane. The limestone has been replaced in such a manner that shelves or benches of limestone project out into the chimney, and resting upon these projections are often found rich masses of galena. As the lower limits of the ore body are approached, it can be observed tapering down and finally wedges out.

Country Rock.—The ore chimneys are enclosed in a belt of magnesium limestone, often grading into dolomite, which was mapped by Weaver* as the Republican Creek Limestone. The complexity of the structure of the sedimentary beds in this area can be in a measure surmised by observing the erratic variance in position of the limestone beds as exposed along the wagon road leading up the mountain to the mine. The average strike of the beds in the vicinity of the mine is north 45° west, and the dip varies from 10° to 30° southwest. Near the Lead Trust Mine, about half way up Gladstone Mountain, the contact between the limestone and underlying argillite was observed.

A thin-section was made from one of the less altered por-

*Weaver, C. E., Mineral Resources of Stevens County: Wash. Geol. Survey, Bull. 20. 1920.

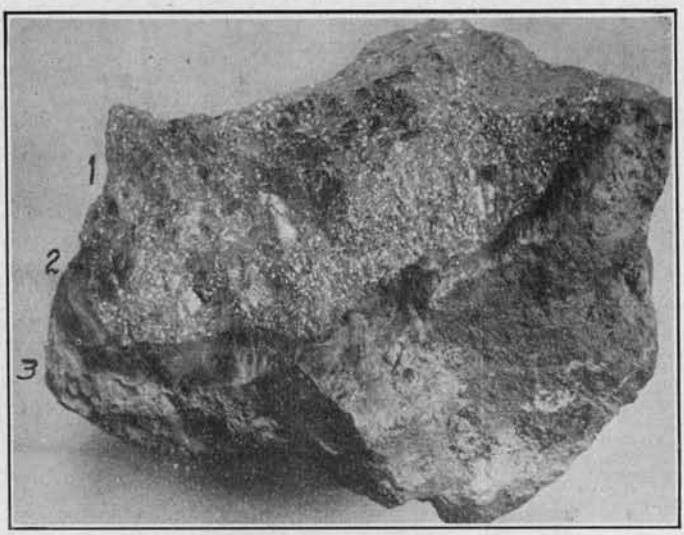
tions of one of the dikes associated with the ore bodies. Under the microscope it shows that the original rock carried about 40 per cent plagioclase feldspar, now severely altered to sericite. Biotite is prominent in the form of lath-shaped crystals, and a few small scattered crystals of augite and hornblende were observed. The dike is classed as a mica-lamprophyre.

Mineralogy.—While the greater part of the cerussite mined is the ordinary "sand carbonate" of a brownish color, strongly resembling commonplace iron-stained sand and clay, yet, some very beautiful lead mineral crystals have been found. Chief among these are crystals of cerussite aggregated in clusters of prismatic masses having a pleasing silky lustre. Other varieties present milk-white masses of fibrously interlaced crystals.

Anglesite was observed as a bluish porcelain-like crust in concentric layers enclosing nodules of galena. In several of the samples anglesite was in turn altering into cerussite. Anglesite was also observed altering direct from galena to transparent prismatic crystals having a highly adamantine lustre. The galena varies in texture from the coarse cubic crystals to the fine-grained texture of "steel" galena. The galena and cerussite do not carry over one ounce of silver for each 10 per cent of lead.

Filling a slip plane in the limestone on the 600-foot level, was found a large sheet of the so-called "mountain leather." This sheet is about one-eigth of an inch thick and about two feet square and is made up of white interlaced mineral fibers. It can be twisted into any shape and is very tough under the knife blade. The material does not ignite under the intense heat of a bunsen burner and is flame-resistant.

Conditions Leading up to Deposition of the Ore.—The writer believes that the Electric Point ore bodies were originally massive, irregular replacement chimneys of galena in limestone. The location of these chimneys appear to be controlled by well-marked shear zones traversing the limestone. Two major zones of this nature were observed in the mine; these strike north 35° east and north 55° east, respectively, and dip at 80° angles toward the northwest. At favor-



Lead ore from the Electric Point Mine showing three-stage transition of galena altering to cerussite. (1) galena, (2) anglesite (lead sulphate), (3) cerussite (lead carbonate).

able points alon gthe zone, particularly near the intersection of two shear zones, the limestone has been badly brecciated. These brecciated areas generally assumed the form of the present ore chimneys. Evidence for this statement was secured from the 500 and 600-foot levels, where prospect drifts to the downward projection of a chimney that had been productive on the upper levels, encountered an intensely brecciated zone of limestone in chimney form but devoid of ore.

Extensive exposures of granite one and one-half miles southeast of the mine indicate that the deposit is underlaid at no great depth by granite. It is from this underlying batholith that the mobile mineral constituents were derived. It is natural that these should work upward along the shear zones until they searched out the brecciated limestone areas and finding in them an easier avenue of escape continued upward until precipitated. The deposition was affected by a partial replacement of the brecciated limestone by the galena carrying some pyrite. After deposition had been completed, and previous to the alteration of the deposits to their present condition, the chimneys of ore were somewhat similar in character

to the deposits now being worked in the adjacent Lead Trust mine.

Function of the Igneous Dikes.—Another interesting feature of the ore chimneys is their association with lamprophyre dikes. In looking over the surface before entering the mine, two of these dikes were found outcropping through the limestone. One of them was traced over the surface and found on the walls of an old glory-hole of chimney No. 1. Fragments of decomposed dike rock were found in the ore chimneys in the mine. On the 400-foot level an 18-inch igneous dike dipping 55° southeast is associated with a streak of limonitic clay which fills a slip plane in the limestone. On the 500-foot level, what is believed to be the same dike was found striking south 40° west and dipping 80° northwest. A similar exposure was found on one of the lower levels. At least two lamprophyre dikes cut the ore bodies in the mine. In a great many places these dikes are badly decomposed and have suffered alteration kindred to the ore bodies. It is quite probable that the alteration of the dikes has yielded a large part of the iron-stain present in the ore chimneys.

The dikes were drawn off from the underlying granite during its period of cooling. They were intruded into the limestone just previous to the introduction of the ore. Dikes are like veins in the respect that they will choose their path of intrusion through shattered formations when possible. The presence of the dikes in the ore chimneys was definitely observed and no doubt the force of their intrusion assisted further toward the brecciation of the limestone.

Alterations of the ore body.—The thorough and even alteration of the ore chimneys from the surface down 800 feet to the deepest workings presents a problem that is worthy of considerable thought. It is the general belief of those who have examined the deposit that the alteration is due to downward percolating surface waters. In view of the evidence observed the writer cannot restrain from questioning this general opinion. He desires to call attention to the evidence that would indicate that the extreme alteration was effected by hot ascending acid waters from below, which

not only attacked the chimney fillings but also severely decomposed many of the igneous dikes in the vicinity of the mine. It is impossible to definitely state the nature of the waters that accomplished such striking alterations. The first to suggest themselves would naturally be acid sulphates waters exhaled by the underlying batholith. There are, however, many other possibilities, but such a question is too theoretical for discussion in this report.

The evidence which appears to oppose the downward oxidation theory is as follows:

1. The thorough and even result of oxidation and carbonation from the surface down to the deepest workings 800 feet below the surface appears to be the result of some action more positive and deep reaching than is true of surface oxidized zones in northern Washington.

2. The lower levels of the mine show only a slight dripping of water, and in places are dry enough to be slightly dusty. If alteration proceeded from the surface downward, it was under conditions totally distinct from those existing at the present time.

3. The topography of the country is of sharp relief which permits a rapid run-off of surface waters. During recent geologic time the area was deeply planed off by glacial action and conditions have been unfavorable since that time for deep rooted oxidation.

4. The Lead Trust Mine, about a mile distant and probably 800 feet lower in elevation, exhibits a chimney of galena in limestone with only a slight crustification of cerussite near the surface. Along the Electric Point road about the same elevation as the Lead Trust property there has been prospecting done on a dike-like mass of limonitic material similar to the Electric Point. If this were caused by surface oxidation it is difficult to understand how the galena at the nearby Lead Trust property escaped a similar fate. Similarly, in other mines and prospects through the district, sulphides are present at the surface.

5. Samples of the limonitic clay from the lower levels of the Electric Point exhibit splendid development of sericite which is believed to be of pneumatolitic development.

6. Galena is soluble with extreme difficulty in the oxidized zone. (It is, however, attacked by dilute sulphuric acid solutions, particularly in the presence of ferric sulphate.)

This evidence, however, is not sufficient to fully refute the common theory of downward oxidation. In fact, there is considerable evidence to support this theory. The writer noticed one factor in particular, which apparently had not been previously considered, that is the extreme depth of the ground water table below the surface of Gladstone Mountain. No pumping is required from even the deepest mine workings. Such a deep-set water table would afford an opportunity for the deeper penetration of free oxygen.

Development.—Three ore bodies, with the exception of the Number 5 chimney, being contiguous to each other, are all worked from a central inclined two-compartment shaft, sunk at an angle of 83 degrees to a depth of 800 feet. Stations are cut and levels opened at 100-foot intervals down the shaft. The general plan is to drift from the station to each chimney, then define the limits of each body by circular drifts encompassing it. Constantly on the look-out for blind chimneys, any streaks of iron-stained gouge-filled shear zones are followed, for they have been found in several instances to lead into chimneys of ore and offer one of the few prospecting guides available.

From the 300-foot level a 1,000-foot adit tunnel is opened through the limestone to daylight on the south slope of Gladstone Mountain, where the air compressors are located. The upper extensions of the ore bodies have been won by glory holes to the surface The underground work comprises in all about 10,000 lineal feet.

There also exists on the property several chimneys filled with iron-stained, decomposed masses which are identical with the "pay" chimneys in physical appearance, yet, they contain only minor traces of cerussite and an occasional nodule of pure galena to encourage the deeper exploration. One of these reddish-brown masses was being explored at the time of visit, and the prospect shaft was down 150 feet in material which might be mistaken by the uninitiated for "carbonate

sand." The condition of this limited section of ground being able to yield such products under intense alteration, must truly have been remarkable, and the relations of the original minerals would form the basis for an interesting hypothesis.

A deposit of this type demands constant prospecting work in order to keep substantial reserves ahead of mining operations. C. D. Belser, engineer in charge of the property, is directing this work in a systematic and skilful manner.

An area of several acres in the vicinity of the mine is dotted with prospect shafts. This extensive prospecting is costly and it might be found more feasible to explore the likely area by a system of regularly spaced drill holes. For such work churn-drilling would be more effective than diamond-drilling, and such exploration would insure the discovery of any blind ore bodies.

The ore is usually soft enough to be picked down by hand or it may be drilled with a hand auger and lightly broken with powder. All hard rock drilling is done by machine. The square set system is used principally in the stopes. The ground, as naturally would be expected, is "heavy" and requires strong timbering to hold. The fact that a plentiful supply of good timber surrounds the mine, aids in keeping this feature of the mining cost low.

The surface in the vicinity of the deposits is covered with several feet of hill-side wash and this has been extensively trenched in search of other outcrops.

The surface equipment consists of the customary office, assay and engineering buildings, boarding and bunkhouses, several cottages for the officials. The hoist is driven by a 32-horsepower gasoline engine. Three air compressors furnish unit air system for the drills. A Ford automobile engine is used to drive a small dynamo which furnishes lights for the camp. Under normal conditions a crew of 60 to 100 men are employed.

GLADSTONE

General Features.—The Gladstone Mine adjoins the Electric Point on the northwest and the principal Gladstone work-

ings are but 200 yards from the main working shaft of the Electric Point.

The holdings were located soon after the discovery of the Electric Point ore-bodies. After a year or more of active development which resulted in several ore shipments the property closed down. It was idle during the greater part of 1918 and 1919 but reopened March, 1920, under the direction of Dan Dodd and when visited during August of the same year five cars of high-grade lead ore and one car of lead carbonates had been shipped to the smelter. The five cars represent clean galena ore which averaged 77 to 79.3 per cent lead, and are believed to have been the purest lead ore yet marketed from the State.

A crew of seven men is ordinarily employed. New camp quarters have been constructed and a gasoline hoist installed. Drilling is done by hand.

Economic Geology.—The geology observed at the Electric Point Mine repeats itself at this neighboring property. The ore chimneys so far developed are not, however, comparable with those of the Electric Point either in size or richness. The deposit has yielded several carload shipments of high-grade lead ore, and future exploration work stands an excellent mining chance of developing new ore bodies.

The location of the irregular replacement chimneys in the magnesium limestone is controlled by two major shear-zones which are incident to each other at an angle of 40°. The shear zones strike south 40° west and south 80° west, stand nearly vertical and are marked sharp striated walls. It is inetresting to note that the trend of these shear zones check quite closely with the major zones controlling the Electric Point ore bodies. Each productive ore chimney so far discovered is oriented adjacent to one or the other of these shear zones, and they form the most reliable guide for directing exploration work. These zones will be found to intersect at a point down the hillside from Chimney No. 8, and the limestone near the intersection warrants careful exploration. It is evident that the mineral constituents which emanated from the underlying batholith ascended along

the narrow zones. At favorable horizons, where brecciated areas existed in the limestone adjacent to the channels, the mineralized agents entered these brecciated areas and partly replaced the limestone with galena and some pyrite. The nearest wall of certain of these chimneys is two or three feet from the shear zone and is connected with it by a narrow cross fracture less than two inches in width.

In Chimney No. 2, 102 feet below the surface a flat-dipping fault was observed. The fault plane is three feet wide and the limestone for 18 inches below this is badly shattered. This is below the zone of ore deposition at this particular point and has apparently played no part in affecting the mineralization. It is believed to be pre-mineral in age.

In physical appearance the chimneys resemble the adjacent Electric Point ore-bodies. Varying sized boulders and nodules of pure galena occur studded through a matrix of brown, iron-stained sand and clay. This latter material carries lead carbonate, which in certain chimneys is found rich enough to stand shipment to the smelter.

LEAD TRUST

This mine is located directly under the Electric Point tramway and about three-fourths of a mile northwest of that property by air line and two and one-half miles by the Electric Point road from the town of Leadpoint.

The holdings which consist of four and a fraction claims were located in 1900 by Charles Scaman. A few scattering shipments of high-grade lead ore have been made at irregular intervals. The property is now being developed by Fred Scaman, son of the original locator. A crew of eight men was employed at the time of visit.

Small log buildings serve as bunk and boarding houses for the crew. Air for the drills is furnished by a Sullivan 8x10-inch compressor which is driven by a 20-horsepower Nagle steam engine, wood being used as the fuel. The property is favored with a good supply of water and wood. A small steam saw has been rigged up to cut the wood for the boiler.

The work is directed toward the development of an ir-

regular replacement of magnesium limestone by a large lens or a chimney of high-grade galena. The ore occurs wholly in the limestone but near the contact of limestone and the Deep Lake argillite. The principal discovery consists of irregular lenses of galena showing some alteration to cerussite. These were opened, and within a few feet of the surface developed into a good-sized lens of ore which has already yielded several shipments of high-grade lead ore. The lens pitches down at a 60-degree angle toward the southeast. From the side hill a crosscut tunnel was driven south 20° east for a distance of 210 feet, where it encountered the lens about 30 feet below the surface. From this level an incline winze was sunk on the lens to a depth of 30 feet. About 30 tons of high-grade galena were shipped from this winze and there are bunches of ore still frozen to the walls. Ore is also exposed in the bottom of the winze.

The development of this chimney is controlled by a narrow shear zone which can be well observed near the collar of the winze. This line of movement trends north 60° east and dips 50° south 30° east; leading from it are several minor fractures. By directing development work along this major zone, it is probable that additional ore can be developed. A prospect drift from the upper level northeast through 15 feet of barren limestone disclosed a new body of ore occurring in a brecciated limestone belt adjacent to the major slip. The ore is galena, laced through with broken limestone in a manner that was probably similar to the Electric Point ore bodies previous to their alteration. This zone has been developed for a length of 60 feet; the profitable ore will average five feet in width. In this block about 1,000 tons of ore can be developed which will assay in the neighborhood of 10 to 15 per cent lead.

A lower crosscut tunnel is being driven to gain a depth of 125 feet on the ore chimney. By August, 1920, this crosscut had been advanced 450 feet and it should require less than 100 feet of additional work to reach the downward projection of the chimney, providing, of course, that it extends to that depth. Seventy feet back from the present face, a slip,

carrying a narrow streak of galena, cuts across the tunnel. The trend of the slip is north 65° east and it dips 45° to the southeast. This merits exploration work by prospect drifts from the tunnel level.

About 100 feet from the ore lens in the upper tunnel a dark, rather coarse-grained dike cuts across the tunnel. A specimen examined in thin section under the microscope shows phenocrysts of bleached biotite occurring in a fine-grained ground mass of lath-shaped plagioclase and biotite crystals. This ground mass is severely altered to green chlorite with occasional patches of serecite. The dike is a mica-lamprophyre.

From the outcrop for 150 feet south, a narrow belt of the limestone is flecked with small bunches of galena. This showing has been but sparingly prospected with shallow surface cuts. About 100 feet down the hill from the lower tunnel several small lenses of high-grade galena have been opened in the limestone, yielding from a half to one ton of ore each. These are isolated pots of ore replacing the limestone. The ore entered through small seams, some of which are still evident in the bottom of the pits.

During August, 1920, an experimental run was being made by a 30-ton mill just completed. The ore is crushed in a Blake jaw-crusher and rolls and is passed through a three-compartment Harz jig which makes a concentrate, a tailing product which at present is sent direct to waste, and a hutch product which is treated on a Deister-Overstrom table. When the mine development warrants it, a ball mill and flotation cell will likely be added. Steam power is used, wood being used as fuel. In its present state the mill will probably effect a recovery of about 65 per cent. The ore as mined carries bunches of high-grade galena, and in view of the present mill losses the operators will find it profitable to hand sort this from the mill feed.

LEAD KING

About one-quarter mile south and 300 feet above the Lead Trust Mine is located the Lead King property. The holdings consist of two and a fraction claims owned by Roy

Young and associates, who spent several thousand dollars in exploration work on the property during 1918 and 1919.

The main adit tunnel is driven into the steep hillside a distance of 326 feet. The direction of the tunnel for the first 233 feet is south 46° east and it then changes to south 73° east for the remainder of the distance. It was driven for the purpose of exploring some promising surface showing of replacement of limestone by irregular small masses of galena. For the first 230 feet the adit cuts thinly bedded argillites then a large lamprophyre dike which merges into a 14-foot monzonite porphyry dike. After cutting through this second dike the tunnel next passes through twenty feet of limestone where it intersects a small tight fracture varying from a few inches to two feet in width, striking north 50° east and carrying considerable amounts of galena and cerussite. This small vein was drifted on for thirty feet toward the northeast along a well-defined wall. The best ore here appears to be bending out of the tunnel toward the lamprophyre dike and should be explored farther.

Not certain that they had yet encountered the lower extension of the surface croppings, the tunnel was extended ninety-three feet farther. This extension cut several small vertical slips filled with gouge and badly iron-stained material, all of which stand practically parallel to the small vein. The present face of the drift gives a depth of about 200 feet below the surface.

NORTHPORT MINING COMPANY

The holdings of this company adjoin the New England property on the northwest. The claims total about 280 acres extending from the Last Chance Mine on the east side of Deep Creek, across Deep Creek and up to the rim of the west valley wall.

About 100 yards from the west bank of Deep Creek at an elevation of 1,900 feet the company has opened an excellent deposit of low-grade zinc ore. This deposit is in marbleized magnesium limestone 700 feet from the granite contact exposed on the New England claims. The ore is deposited as narrow, irregular, pencil-like bands of sphalerite replacing the mag-

nesium limestone along its original bedding planes. These planes stand nearly vertical and trend north-south. In some places the sphalerite occurs as irregular bunches in the limestone, these bunches varying from the size of a pinhead to an inch across.

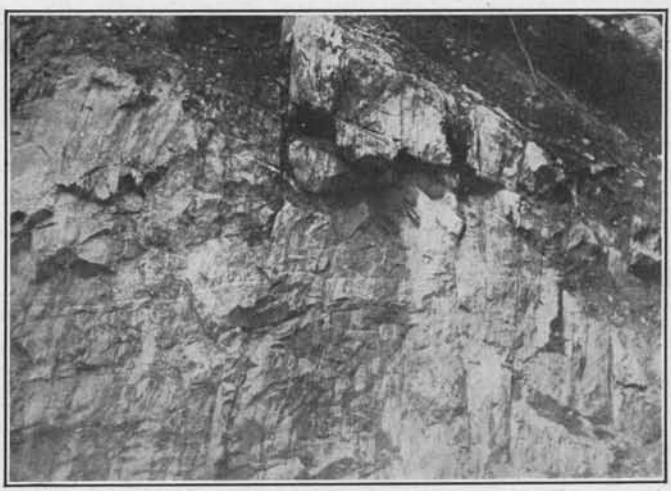
The ore in the form of mineralized gases appears to have worked up into the limestone from the underlying granite. The force of the granitic intrusion shattered the limestone along the bedding planes and when the granite began to

WASHINGTON GEOLOGICAL SURVEY BULLETIN NO. 23 PLATE VIIIa

Quarry opening on zinc ore at the deposit of the Northport Mining Company.

solidify the mineral-bearing gases were expelled and in turn they replaced the limestone along these planes.

The deposit has been opened along the steep mountainside by two quarries and several open cuts. The main quarry begins at the New England side line; the maximum width of the mineralized zone here appears to be 40 feet and the owners state that careful channel samples taken along the quarry face averaged 10 to 12 per cent zinc. Fifty feet northwest of the main quarry, another exposure has been opened and several hundred tons of medium-grade ore broken down. It is highly probable that this is a segment of the main



Vertical pencil-stripe banding of sphalerite through dolomite, Northport Mining Company's deposit.

deposit, which has been displaced by a transverse fault. The mineralization at the southern end of this deposit terminates in a bold streak of crushed limestone, thus defining the line of the fault. There is another series of openings about 150 feet up the hillside which also expose a limited tonnage of ore.

During 1917 three diamond drill holes were put down to further prospect the deposit. These holes were started in the limestone 100 feet back from the quarries and the holes pointed toward the deposit at an angle of 45 degrees. Mr. Gorien, treasurer of the company, states that one of the holes encountered the ore at 93 feet and passed through it at 116 feet. The other two holes did not encounter commercial ore.

To reach some upper workings of the company, the writer followed the limestone-granite contact up the mountain side rather than the trail. Along this contact numerous sporadic deposits of sphalerite were found in the limestone. The deposits observed appeared to be small and irregular. On several of them, claims had been located and small amounts of development work done, but nothing of commercial value developed.

Near the crest of the mountain an open cut exposes a lens of high-grade sphalerite, partly altered to smithsonite, 20 feet

in height and varying from two to eight feet in width. Near this lens a tunnel was driven several hundred feet through limestone, evidently in an endeavor to intersect a continuation of the lens, but no ore was exposed.

Exploration work at present should be confined to the lower deposit exposed in the quarries near Deep Creek. A considerable tonnage of low-grade zinc ore is already partially developed here, and a limited amount of carefully directed exploration work stands a promising chance of developing a sufficient tonnage to warrant the erection of a small mill. The ore should be easily susceptible to ordinary concentration practice. The property is favored with good transportation facilities, as well as a plentiful timber and water supply, which makes for suitable mining and milling conditions.

NEW ENGLAND CLAIMS

These holdings consist of five claims located in sec. 23, T. 29 N., R. 40 E., six miles southeast of Northport, on the west side of Deep Creek, about one-half mile west of the Leadpoint road. The claims are being worked in a limited way by Ben Stout and L. W. Cook.

At the base of the mountain, near the level of Deep Creek, an exploratory tunnel has been driven for a distance of 350 feet along the contact of the intrusive Loon Lake granite with the Republican Creek limestone. The contact has an average strike of north 30° west and stands at about a 30° angle with the limestone forming the hanging-wall of the drift and granite the foot-wall. There have been intense movements along the plane of the contact and both the limestone and granite exhibit well-defined striated walls. Between these walls there exists varying amounts of gouge matter. The limestone is badly iron-stained and also shows considerable dendritic stains of manganese dioxide. In places the granite has been altered to a talcose serpentine. Only an occasional stringer of sphalerite was found for the first 150 feet in the drift. An irregular mass of low-grade zinc ore, associated with small amounts of galena, was then encountered and as cut by the drift this mass appears to be about five feet thick, but its extent has not been determined. The drift has been extended

about 200 feet beyond this point without exposing any commercial ore.

The most interesting feature of this property is a large massive body of low-grade sphalerite exposed by a quarry-like opening in the limestone near the northwest corner of the property. This ore body runs into the adjoining property of the Northport Mining Company, and since it is more fully developed there, it is described under that property.

GORIEN ZINC

An important find of zinc ore was made April 20, 1920, by Gust Maki, a farmer on Deep Creek, six miles east of Northport. The deposit is but 100 feet up the hillside from the county road between Northport and Leadpoint; it is also but 300 feet from the Maki farmhouse.

The property was taken under a lease and bond by John Gorien, of Minneapolis, and until August, 1920, six cars of ore averaging 40 per cent zinc had been shipped to Mineral Springs, Wisconsin, for treatment.

The ore is in the carbonate form, being the mineral smithsonite, often spoken of as "dry-bone" ore. It occurs filling a fracture which trends parallel to the bedding planes of bluish-gray dolomite. The deposit trends north 30° east and dips to the east at angles varying from 30 to 60 degrees. Some of the best ore is found at points where the dip flattens out. The deposit varies in width from one to four feet, with 30 inches as an average. It has been explored by a shaft to a depth of 98 feet and good ore still shows in the bottom. At a depth of 35 feet below the collar of the shaft, drifts have been run 30 feet toward the southwest and 40 feet toward the northeast. The chances of developing additional ore toward the northeast are not exhausted and a drift from the bottom of the shaft should be extended to the northeast until the fracture zone closes down. In the southwest drift a post-mineral fault cuts the fracture. The ore has followed into the plane of this fault for a length of three feet and thus developed a lens-like mass.

The ore body is not a bedded deposit but is of supergene (secondary) origin. The fracture was originally occupied by a deposit of sphalerite (zinc blende) which is one of the most

mobile sulphides when attacked by oxygenated waters. The zinc solutions thus formed did not travel far until they were arrested by the dolomite and precipitated as the carbonate, in which form it is quite insoluble. Fragments of sphalerite, replaced in part by smithsonite, were found in the deposit. There are many small vugs which are found lined with well-developed botryoidal masses of smithsonite crystals.

It is not to be expected that the deposit will develop extensively. It will, however, yield a good tonnage of profitable ore. The cost of mining averages about $4.00 per ton. It costs $2.00 per ton to deliver the ore by auto truck to the railroad at Northport, and the freight charge, including the recent advances, to the Wisconsin smelter is about $13.00 per ton.

FRISCO STANDARD

Situation and History.—This deposit is in the extreme northeastern corner of the county, sec. 12, T. 40 N., R. 42 E., and is about one and one-half miles from the international border. From New Boundary Station on the Nelson Branch of the Great Northern Railway the property is reached over a 14-mile wagon road which takes the traveler up into splendid pine-covered mountains, giving an opportunity for a panoramic view southward over the Northport District and north into British Columbia.

The deposit has been worked intermittently in a small way for many years and the limited production made was hauled out with teams to the railroad. At the time of visit (June, 1919), J. Astloford and W. E. Hightower, of Northport, held a lease and bond and were cobbing and sorting some of the richer ore for shipment.

Economic Geology and Development.—The mine is opened in argillite a short distance from an exposure of diorite. Intense metamorphism has altered the argillite into graphitic schist with the free graphite so well developed that it smears the hands when handled. The formation trends north 27° west and dips 40° to 50° toward th enortheast. The ore is found in a lenticular quartz vein replacing the graphitic chist along its bedding planes. Shearing stresses

found relief along the bedding or schistosity planes and thus opened a limited channel for the vein solutions and gases. The replacement of the schist was not carried to completion along the channel so that there now exists layer-like inclusions of the graphitic schist in the quartz vein thus presenting a very showy black and white contrast.

As would naturally be expected in such a replacement vein, it pinches and swells with pronounced frequency both on the strike and dip, thus causing the vein to vary in width from a few inches to six feet. The vein strikes south 65° east and dips to the southwest at angles varying from 20° to 40°. A small creek cuts the vein a tright angles to its dip and has eroded a considerable section of the deposit. The principal work has been done on the upper limits on the east side of the creek. This section has been opened by four short drifts and a limited amount of stoping, which explores the ore body for 150 feet on its dip and 500 feet on the strike. The average width varies between two and four feet, the values averaging fairly well, although it is too low-grade to stand the heavy transportation charges without very careful cobbing and sorting. It would make good milling ore if it were not for the fact that the silver minerals have been partly altered into silver chloride and bromide. These silver salts would slime badly and resist ordinary concentration practice.

The principal values are in silver and lead. Tetrahedrite and galena are the predominating ore minerals. In the tetrahedrite the lead has largely replaced the copper. As previously mentioned, the upper workings show violet-blue stains of cerargyrite, (lead chloride), and the straw-yellow bromyrite (silver bromide), secondary minerals derived from the oxidation products of tetrahedrite by infiltrating surface waters carrying chlorine and bromine.

Across the small ravine, toward the west, the vein has been picked up on its dip and a drift run southeast for a length of 350 feet. The first 300 feet of this drift was not encouraging, the ore being but sparsely scattered through the quartz. For the last 50 feet the work has been in an excellent pay-shoot, the vein being five to six feet wide and quite well mineralized.

The values here are carried in the sulphides, tetrahedrite and galena, and no evidence of alteration was observed.

Stoping has not been attempted on this side of the creek, but at the time of visit the drift was being extended to determine the length of the pay-shoot.

Taking the average dip of this vein and roughly projecting it across the ravine causes the imaginary extension to strike considerably above the vein opened there. This hints that the vein exposed on the west side of the creek may be an overlying vein and parallel to the one on the east side or else the present ravine represents a fault which has elevated the west portion of the vein, as suggested by Weaver.*

Igneous activity is represented by a lamprophyre dike having the composition of a minette, which is exposed by the workings on both sides of the gulch.

The smelter returns on several small shipments of sorted ore from the property are as follows:

Shipment Number	Gold (ounces)	Silver (ounces)	Lead (per cent)	Copper (per cent)
1	.01	72.8	9.6	2.7
2	.Tr	72.0	16.8	4.6
3	.00	49.2	7.0	3.2

UNITED TREASURER

About a mile and one-half before reaching the Frisco-Standard property, a branch road leads down the hillside 400 yards to the United Treasurer deposit. This consists of three claims in sec. 11, T. 40 N., R. 42 E.

The geology is similar to that of the adjacent Frisco-Standard. The immediate country rock is the same belt of graphitic schists, while not far distant the Red Top limestone formation is well exposed. The vein material replaces the formation along its planes of schistosity. The trend of the vein is northwest and its dip varies irregularly but maintains a low angle toward the northeast. Pinches and swells are observed with recurrent frequency, causing the vein to vary in width from six inches to four feet. The vein has been opened along the trend at intervals over a length of 400 feet. The

*Weaver, Charles E., The Mineral Resources of Stevens County: Wash. Geol. Survey, Bull. 20, 1920.

most striking feature about the deposit is that for the most part it directly overlies a small igneous dike and at several places vein material on both the upper and lower sides of the dike was observed. It is not believed that the vein represents segregations from this small dike, but that it came in a little later and simply took advantage of the channel already opened through the metamorphic rocks. This is confirmed by a lower prospect tunnel opened for 270 feet along the hanging-wall of a similar lamprophyre dike without finding any appreciable amount of ore.

The vein is explored by three short drifts. No. 1 tunnel is in 80 feet and at the portal the planes of the graphitic schist lie nearly horizontal. Forty feet from the portal the drift encounters an 18-inch lamprophyre dike overlaid by a two-foot vein carrying ore of average grade. This showing has been drifted on for forty feet.

Fifty feet above No. 1 tunnel a prospect drift has been opened along a small lamprophyre dike which strikes north 20° east and lies almost horizontal for the first fifteen feet. It is overlain by a small vein from which some good ore has been mined. About 15 feet from the portal the vein and dike dip suddenly toward the northwest at a 25-degree angle. They have been followed down 10 feet and the small vein exposes some excellent ore. It was stated that several tons were sorted and shipped and gave returns averaging about 50 ounces in silver. This exposure is worthy of further development.

In No. 2 tunnel a small flat stope has been opened and several hundred tons of ore mined. Fifty to 60 tons of this ore are said to have been sorted and shipped. This opening exposes a vein varying in thickness from six inches to 24 inches underlying an 18-inch lamprophyre dike, and a vein averaging about 12 inches in thickness resting on the dike.

Workings No. 4 consist of two parallel drifts driven on the vein about 30 feet apart. They aggregate about 800 feet of tunnel and are a needless duplication of work. Several tons of ore were shipped from these drifts and considerable ore of probable milling grade was observed on the dump and in the workings.

The claims are owned by Newton Hartman and Wm. F. Kuhnert, who work them in a limited way each year.

MELROSE

This property, formerly known as the Paragon, is in sec. 28, T. 40 N., R. 41 E., four miles south of, and 1,500 feet above, the station of New Boundary on the Nelson Branch of the Great Northern Railway. It is one and one-half miles by wagon road from the railway. The first location was made about 1900 and since then 1,600 feet of tunnel work has been accomplished. O. M. Matthews, who is in charge of the property, reports that during the past few years only a small amount of new work has been attempted. He has shipped 75 tons of sorted ore which returned a gross value in silver of $8,000.

The deposit is explored from two levels opened from the wall of a small tributary gulch known as Bush Creek Canyon. The upper tunnel is 500 feet in length and exposes a quartz vein six feet in average width. The vein is enclosed in the Boundary argillite, which in the vicinity of the mine, can best be described as thinly-laminated graphitic schist. The vein exhibits irregular bunches and small seams of tetrahedrite, galena, sphalerite and pyrite. This mineralization is generally too thinly scattered to permit profitable mining. From this level an inclined raise was driven 60 feet to the surface. The raise encountered a three-foot vein of practically barren quartz. Near the breast of the tunnel a winze was sunk 84 feet below the level in order to explore a seam of tetrahedrite. A car of ore was shipped from this winze.

Three hundred feet down the hillside a cross-cut tunnel is driven souht 50° west a distance of 950 feet, to explore the downward extension of the vein. A large lamprophyre dike, conformable with the schistosity of the argillite, was cut at a point 300 feet from the portal. Six hundred feet from the portal, the vein exposed in the upper level was supposedly intersected. In this lower tunnel it consists of irregular stringers of quartz adjacent to an altered lamprophyre dike two feet in width. This showing was explored 80 feet

both north and south from the crosscut. The crosscut was continued 360 feet beyond this point, and a tabular lense-shaped mass of quartz three and one-half feet in thickness encountered. This contains several small streaks of ore, and a stope has been opened for a length of 70 feet on the downward projection for 30 feet along the strike of the vein. The ore mined was sorted and shipped. Some of the fines were successfully concentrated by a large hand-jig. The workings should be surveyed to determine what relation, if any, this latter deposit bears to the vein exposed in the upper tunnel.

BONANZA

After an idleness covering a number of years this property was re-opened in June, 1919, by Spokane interests and since that date development work has been progressing steadily. The original location of the deposit dates back to 1885, and a production totalling several thousand tons of lead-silver ore has been made. The location of the mine is at an elevation of 2,200 feet in sec. 11, T. 37 N., R. 38 E., five miles by wagon road east of Bossburg.

Associated Formations.—The rocks in the vicinity of the deposit are graphitic schists, chlorite schists, and ferruginous schists, all badly contorted and showing the ravages of intense shearing actions. These formations have a prevailing north-south strike and dip 40° to 50° west. A small outcrop of granite was observed one-quarter of a mile west of the mine and 50 feet up the hillside from the collar of the shaft a large, light-gray igneous dike outcrops boldly. This dike is particularly well exposed on the 400-foot level of the mine. A thin-section was examined under the microscope and the rock found to be composed of phenocrysts of quartz and plagioclase in a dark, fine-grained ground mass of labradorite feldspar. The quartz crystals show rounding due to resorbtion. Grains of the magnetite are sprinkled through the rock. The dike is classified as a plagioclase aplite and is no doubt related to the underlying granite from which the segregation of quartz and feldspar were drawn off and injected into the overlying schists. One hundred feet northeast of the compressor house

another igneous dike was found and 20 feet above this, numerous outcroppings of conglomerate along the hillside. The conglomerate is made up of coarse and fine-grained igneous boulders, well rounded and held together by calcareous cement.

Description of the Deposit.—The deposit is opened to a depth of 700 feet by an inclined shaft sunk at a 45° to 55° angle. Levels are developed at 100-foot intervals and all ore between the 500-foot level and the surface has been mined. The ore occurs as irregular lenses replacing the formation along the planes of schistosity. The deposit conforms to a shear zone which acted along the plane of contact between the chlorite schist overlain by graphite schist. Previous to the introduction of the ore-bearing solutions these formations were badly contorted, and the replacing solutions have attempted to conform to the position of the formations. Post-mineral folding and faulting has further twisted and broken the ore body.

The ore minerals are "steel galena," pyrite, and minor amounts of sphalerite associated with a gangue of siderite and quartz. The ore as sorted and shipped averages about 20 per cent lead and 5 ounces of silver to the ton. The "steel galena" exhibits an unusually fine texture which is evidently the result of mechanical deformation of coarser crystals by vigorous, post-mineral, shearing movements.

The deposit has been explored along its strike for a maximum length of 1,000 feet. Both to the south and north of the shaft small bodies of ore have been found, some large enough to permit profitable mining. The best ore observed in the mine occurs in a shoot which starts 200 feet north of the shaft and develops a stope length of 100 feet. This shoot rakes toward the south. It is being explored by a prospect raise to connect the 600 and 500-foot levels. Work on the 700-foot level has so far exposed the same shoot with a stope length of 50 feet, but on this level the ore occurs in large bulges six to eight feet thick. Beyond these lenes the ore pinches out by the drift should be carried farther north in search of additional ore.

The property is equipped with three gas engines, a 50-horsepower engine which runs the compressor, another of

25-horsepower for operating the hoist, and a third of 12-horse power which operates a dynamo for lighting. During the summer of 1920 a crew of 10 men was employed.

YOUNG AMERICA

This property was one of the first to be located in this section, being discovered in the early eighties by prospectors working northward up Columbia River into British Columbia. It is credited with a considerable production of good-grade ore extracted at different times by various leasors. Some of the better shipments are said to have averaged 20 per cent lead, 50 ounces of silver, $3.00 in gold, 25 per cent zinc and 5 per cent iron. The property was re-opened late in 1918 under bond and lease by the Cuprite Mining Company with Frank Scanislawski as general manager. Five men were employed in development work at the time of visit.

The property is about 400 yards northeast of and 400 feet above the town of Bossburg. The workings are along a nearly vertical bluff of limestone overlooking Columbia River.

The ore has been taken from a series of flat-lying, parallel, lenticular bodies which formerly outcropped on the face of the limestone cliff. These lenses strike norht 75° east and dip 18° to 20° toward the north. These lenticular bodies conform closely to the original bedding planes of the formation along which mineralized solutions have replaced the limestone.

Northport limestone, bluish-white in color and of fine-grained texture, is the predominating formation in the vicinity of the mine. The limestone has suffered considerable disturbance causing the development of slip planes and joints. A mile to the east, granite outcrops and several lamprophyre dikes were observed cutting the sediments in the near vicinity of the mine. Bancroft* mentions an intrusive dike observed on the hill above and states that the dike trends north 21 degrees west, dips approximately 60 degrees west, and is about four feet wide.

The two important series of lenses are parallel, one being about 30 feet vertically below the other. The lower lens is

*U. S. Geol. Survey, Bulletin 550, p. 62.

developed by a stope opened in the face of the cliff which follows the ore back a maximum of 35 feet. This stope is about 100 feet long and 10 feet high, although the maximum thickness of the zone of mineralization is not over six feet. The ore minerals are galena, sphalerite and pyrite enclosed in a gangue of quartz and calcite. This stope has been depleted of commercial ore. At the north and lower end of the stope the ore bodies pitched down suddenly at a steep angle; they were followed with a 40-foot incline shaft which is now caved. It is said that there was ore for the first 20 feet in the shaft, then gravel carrying occasional boulders of ore was encountered and after sinking through 10 feet of the gravel the shaft was abandoned. If this statement is correct, it would suggest that during the time when the valley was being eroded past this level, the limestone cliff was undercut slightly by water or ice and gravel deposited in the cavity. This would indicate that the lower extension of the deposit might be recovered. It is possible that this downward bend of the ore means that the ore here came up along a nearly vertical joint until it reached a favorable channel along the bedding planes of the limestone, where it worked out in more of a lateral direction.

The upper series of lenses are 30 feet vertically above those just described. They exhibit the same downward bend on the north end as found on the level below. The stope is 30 feet wide, 10 feet high and 75 feet long. On the east wall there still remains a 30-inch vein of zinc-lead ore; above this are five feet of bluish-white limestone, then a second vein two feet in width. This ore is high in both zinc and lead and this complex character gives it but little value in the present state. On the south end of the stope the ore has been cut by a four-foot vein of calcite which dips to the west at a 70-degree angle. This calcite represents solutions later than the ore. On cutting through the calcite the ore was again picked up.

The present company has driven a drift near the foot of the cliff and 160 feet from the portal they have started a raise evidently in search of a lower extension of the ore.

A small 15-ton experimental mill was erected on the property early in 1919 with the expectation of treating the dumps

while an attempt was being made to develop new ore. The mill was idle at the time of visit on account of a shortage of water and the difficulty encountered in making a clean separation between the galena and sphalerite on the tables. This separation could be better effected by grinding the ore a little finer and giving the tables a classified or screen-sized feed. This, however, is hardly practical with but two tables in use. The mill flow-sheet is as follows: The ore is fed into a Blake jaw-crusher, having a 14x12-inch jaw and breaking to one inch. The ore is again broken in a small set of rolls and fed to a 30-inch ball mill grinding to pass about 30-mesh. An ordinary free-settling box-classifier divides the feed between the Overstrom tables.

CHEWELAH DISTRICT

LOCATION AND GENERAL FEATURES

The Chewelah District, comprising an area of about 450 square miles, is in the east-central part of Stevens County. The Colville Valley, in some places two miles or more across, traverses the county with a general north-to-south course from Myers Falls to the southern border. Colville River, which is only a small stream, out of all proportion to the impressive valley it occupies, meanders lazily northward to join the Columbia. The valley is the dividing line between the east and west sections of the county. Its form is that of a broad trench dividing two north-to-south trending ranges of mountains. To the west, the valley is flanked by a low range of foot-hills which gradually merge into the main flank of the Huckleberry Range. On the east, a similar range of hills culminate in the Calispell Range. Both have an average elevation of 4,000 feet, but boast of an occasional summit which rises to an elevation of 5,000 to 6,000 feet. The level of the valley floor averages 1,700 feet. The flanks of the ranges are well timbered and the formations carry a mantle of glacial drift which seriously hampers systematic prospecting. The town of Chewelah, on the Great Northern Railway, is the principal distributing center of the district.

The Stevens County magnesite deposits, the largest in

the United States, have been developed along Huckleberry Range but a short distance west of Chewelah, and this prosperous industry has injected new life into the district. The large calcining plant of the Northwest Magnesite Company is located about a mile south of Chewelah. The United Silver-Copper Mine was the only producing metal mine in the Chewelah District during the summer of 1919. There are several potential mines in the area but these were not active at the time the district was visited.

GEOLOGY

The predominating formation over the area consists of belts several thousand feet in thickness made up of argillite, quartz-mica-schist and quartzite. These have been cut by granite intrusions and lamprophyre dikes.

Most of the mines credited with substantial production are located around the border of a granitic cupola, which is intruded through the belts of metamorphosed sediments. This granitic stock is connected to the underlying batholith and is essentially a part of the granite so well exposed a little farther west and northeast. If the sediments which hem in this stock of granite could be stripped away, and the granite bedrock exposed, the stock would probably appear as a dome-shaped peak rising above the immediate section of the batholith. This stock outcrops about four miles east of Chewelah. Its present outlines take roughly the form of an elipse with its major axis three miles in length and the minor axis one mile. The ore deposits occur, not in the granite itself, but in the metamorphosed sediments bordering the rim of the granite outcrop. The combined agencies of shearing and metasomatic replacement opened channels along the bedding planes of the formations which were filled with vein material. Basic dikes having the composition of lamprophyres were drawn off from the underlying batholith and injected into the overlying metamorphosed sediments. The ore-bearing veins were also drawn off from the cooling magma. In this district the veins do not usually lie directly along the dikes but tend to parallel them at distances varying from 10 to 150 feet.

There are a few scattered properties on the west side of

GEOLOGIC MAP OF THE CHEWELAH AND SURROUNDING DISTRICTS

Recopied from Washington Geological Survey Bulletin No. 20.

LEGEND

- Quaternary
  - Qgd — Glacial Drift
- Tertiary
  - Tc — Camas Basalt
  - Td — Diabase
  - Tgp — Granite Porphyry
- Mesozoic
  - Mlg — Loon Lake Granite
- Carboniferous to Cambrian
  - Pca — Chewelah Argillite
  - Pma — Mission Argillite
  - Paq — Addy Quartzite
  - Pda — Deer Trail Argillite
  - Psd — Stensgar Dolomite
  - Peq — Eagle Mountain Quartzite
  - Pul — Undifferentiated Limestone
  - Pua — Undifferentiated Argillite
  - Pdl — Deer Lake Argillite

R 38 E — R 40 E — T 32 N — T 30 N

0 1 2 3 4 5 Miles

Colville Valley, but all those visited were of limited size and extent.

UNITED SILVER-COPPER MINE

This property is the largest and most consistently producing mine in the State. It was organized as the United Copper Mining Company in 1906 with head offices at Spokane. The workings at that time were limited to a prospect shaft and meager development on the outcrop of the vein, but the development work soon met with decided encouragement and by 1908 power machinery was installed and the work began advancing steadily. During 1909 land was purchased for the site of a long adit crosscut to gain depth on the vein. This adit was driven a length of 4,220 feet to the vein, the work being completed in 1914 at a cost of about $50,000. The first unit of the milling equipment was placed in operation during 1913 and since that date the production has gained steadily each year until the value of production for the past three years has averaged between $200,000 and $300,000 annually. During 1919 the name of the property was changed to the United Silver-Copper Mining Company.

The holdings comprise seven claims and five fractions located on the western slope of Eagle Mountain, about five miles by wagon road northeast of Chewelah.

STATEMENT OF TONNAGE AND PER TON COSTS OF MINING AND MILLING FOR THE YEARS 1912 TO 1918 INCLUSIVE

Year	Tons Mined	Tons Milled	Mining Costs	Per Ton	Milling Costs	Per Ton
1912	13,395	7,680	$104,033.41	$7.76	$16,748.33	$2.18
1913	14,938	10,755	76,129.88	5.23	23,821.54	2.21
1914	18,527	15,110	64,711.03	3.49	26,341.05	1.74
1915	30,000	25,000	80,747.20	2.69	39,918.43	1.20
1916	50,000	45,000	131,694.00	2.60	65,847.00	1.46
1917	60,000	56,000	132,504.00	2.20	66,252.00	1.18
1918	66,181	62,559	158,246.64	2.39	80,366.46	1.28

Economic Geology.—Geologically, the mine is situated in the Stevens series of highly metamorphosed sediments of Paleozoic age. The predominating varieties are quartz-mica schist, locally known as "silver shale," argillites and quartzite. The schist stands with its bedding or schistosity planes

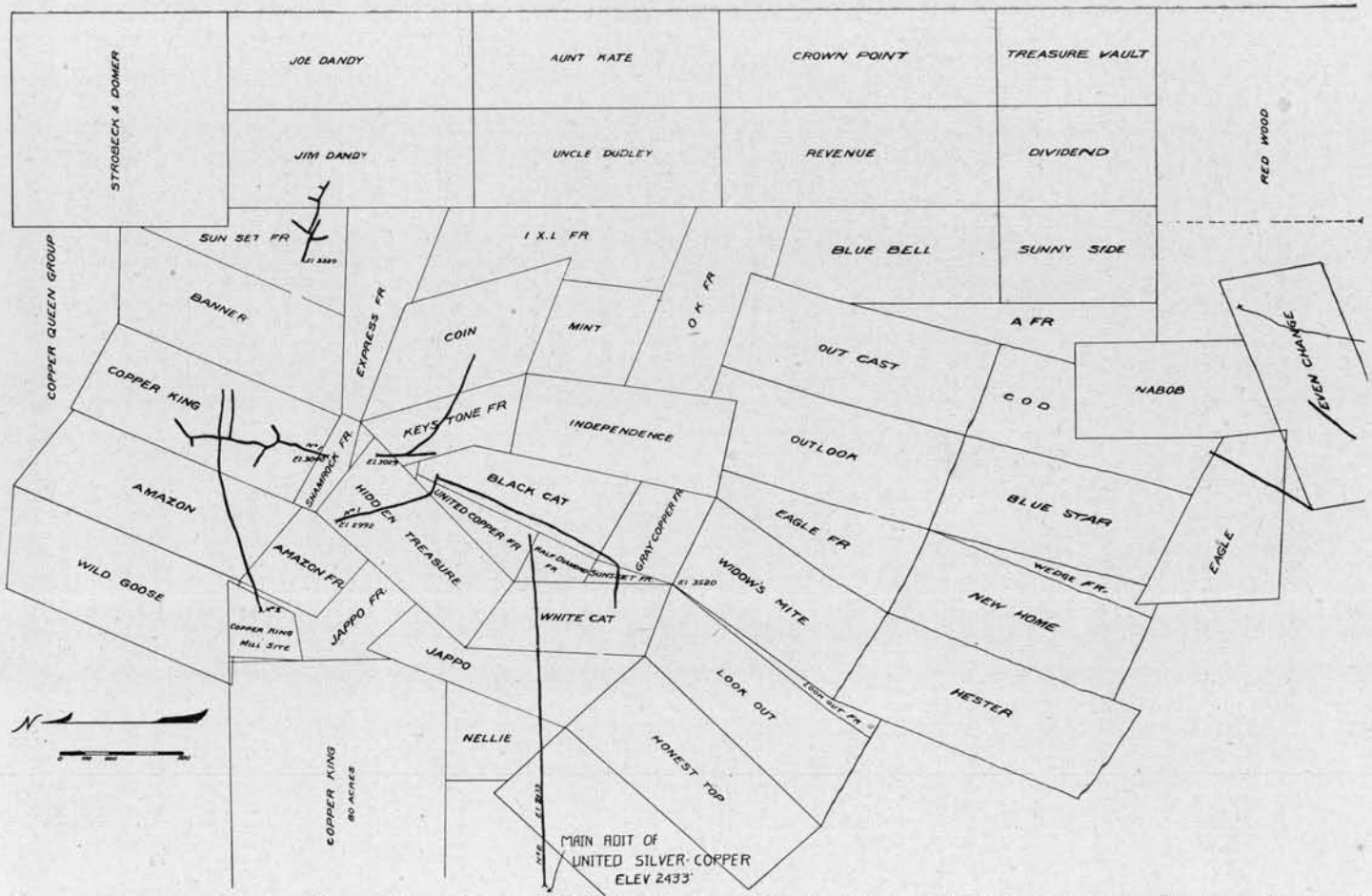
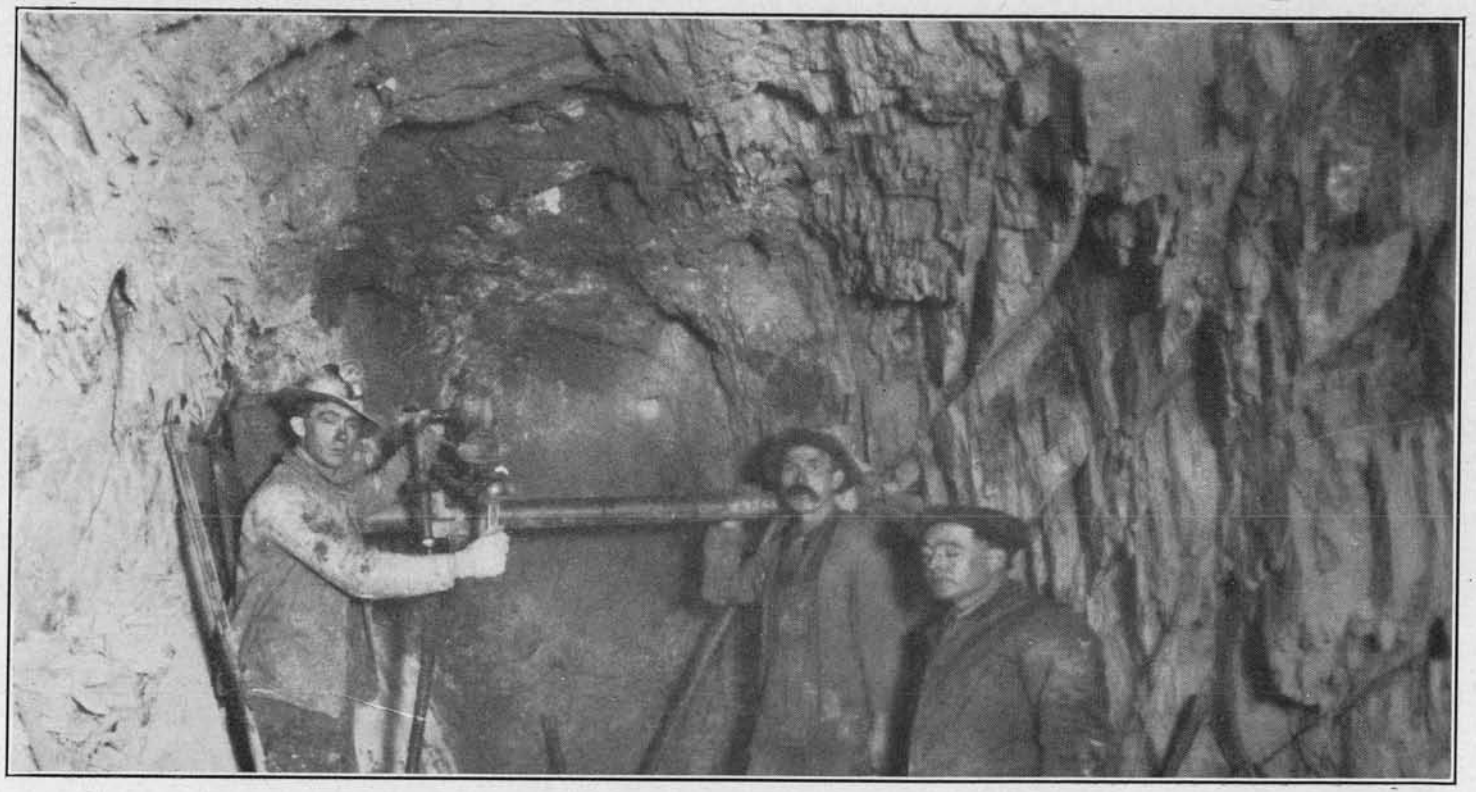


Fig. 7. Claim map of that portion of the Chewelah District in the vicinity of the United Silver-Copper and Copper King Mines.

nearly vertical. A large stock of granite outcrops about a mile distant and the schist is cut along the bedding planes by several vertical lamprophyre dikes, adjuncts from the underlying granite batholith. The metamorphic rocks have suffered intense shearing and shattering and many small faults resulted, but no large ones were observed in the vicinity of the vein. The various drifts south of the adit crosscut expose a series of three-step faults, each of which displaces the south segment of the vein four to six feet toward the west.

The vein follows a zone of shearing and partial replacement along the bedding planes of the schist, thus standing nearly vertical and striking north 20° east. Pinches and swells are prominent, causing the width of the vein to vary between 3 and 15 feet, with six feet as an approximate average. By July, 1919, it had been explored over a horizontal range of 1,500 feet and to a vertical depth of 1,140 feet below the outcrop.

The ore is chiefly chalcopyrite, tetrahedrite (gray copper), and pyrite in a gangue of milky-quartz. Of considerable importance to the property is a shoot of high-grade tetrahedrite traversing a section of the vein. On account of the high silver content of the tetrahedrite it is technically classed as freibergite. This shoot has a strong vertical range from the upper workings downward, but is more strongly pronounced on the lower levels. The horizontal extent of the shoot in the vein varies from 100 to 200 feet and it rakes to the north at a high angle. The width of this high-grade streak averages from 2 to 12 inches and it assays from 75 to 300 ounces of silver to the ton. When the streak widens beyond 12 inches the values seem to rapidly decrease. In mining, this high-grade streak is sorted out from the milling ore and shipped crude. The line of demarcation between it and the rest of the vein material is quite sharp, and all the other mine evidence suggests that the high-grade streak of tetrahedrite was brought into the vein by a second period of mineralization. A polished section of the high-grade was studied under the microscope which revealed an intimate and irregular intergrowth of tetrahedrite and chalcopyrite. Quartz is irregularly intergrown



Drifting on the United Silver-Copper vein, 1,200-foot level.

with these sulphides and there were also found several well-shaped crystals of some silver mineral, believed to be stephenite.

Genesis.—The vein material is a product derived from the underlying granitic batholith which segregated out from the magma and was injected along a channel opened by shearing forces acting along the bedding planes of the schists. The mineral agents in the form of hot solutions and gases possessed also the power of metasomatic replacement so that the opening along the zone of shearing was materially enlarged. The wall rocks of the vein are shattered both along the bedding planes and at right angles to these planes. The searching action of the solutions cemented these fractures and ore of milling grade is often found a foot or more back of the apparent walls.

In the long adit tunnel, 115 feet before reaching the vein, a two-foot lamprophyre dike was intersected, which runs practically parallel with the vein. Twenty feet further, the adit cuts a second lamprophyre dike averaging 15 to 20 feet in thickness and also trending roughly parallel with the vein. About 500 feet north of this point the vein and large dike intersect. Near the intersection a large tongue of the vein is found filling an apparent shrinkage crack in the dike. This important bit of evidence tends to confirm other field evidence which indicates the vein is a little younger than the dike and again suggests that the dike played a part in fracturing the adjoining formations and thus assisted in opening up channels for the ore-bearing solutions. This question is of more than academic interest for an understanding of the true relationship between the dike and vein is necessary for directing intelligent development work.

Development.—The deposit was formerly worked through No. 1 crosscut to the vein about 300 feet below the outcrop. During 1909 the long adit tunnel was started from a point down the mountain side at an elevation of 2,300 feet. This was driven due east 4,200 feet to a point where it intersects the vein about 1,000 feet below the outcrop. Several hundred feet of drifts were run north and south on the vein and raises and stopes opened to the upper levels. A two-compartment

shaft was sunk 240 feet. This shaft was started in the hanging wall of the vein but after pasing the 1,100 foot level it cut through the vein and into the foot-wall. From the 1,200-foot level a prospect winze was sunk 148 feet to what is called the 1,400-foot, or lowest, level. At this depth drifting had just begun (July, 1919) and had been carried 28 feet to the north of the winze and 65 feet to the south. The high-grade streak is well-defined here, being about 12 inches wide. The 1,200-foot level is well developed and at the time of visit large stopes were being broken between the 1,200 and 1,100-foot levels.

Shrinkage stoping has been largely used but has led to difficulties. The schist walls exhibit a strong side-thrust, often powerful enough to split the cap timbers. When the stopes are drawn this lateral thrust causes the wall rocks to slab-off in such quantities that the grade of mill feed is lowered. To avoid this, the fill system is now being largely employed, the broken ore being shoveled down crib-chutes. These chutes are carried up through the stopes at intervals of about 30 feet. Waste is borrowed from the walls for stope filling. In other parts of the mine the walls stand better and shrinkage stoping is used.

All the ore is hoisted to the 1,000 level and handled to the mill through the long adit tunnel. An automobile engine made over into a mine locomotive is giving excellent service.

During the summer of 1920 mining operations had temporarily been transferred to the upper, or 400-foot, level of the mine. There are large blocks of ore between the 400-foot level and the surface that have not yet been mined. Stopes are now being opened and the ore will be dropped down chutes to the 1,000-foot level and handled to the mill through the main adit.

The vein on the 400-foot level is opened by a crosscut, the portal of which is near the camp of the Copper King Mine. Fifty feet west of the vein the crosscut passes through a 20-foot lamprophyre dike and ten feet east a three-foot dike is cut. The large dike is the same exposed by the lower crosscut. On the 400-foot level the vein has been drifted on for a length of 1,000 feet. The back of this drift exposes first a shoot 300 feet in length carrying ore that should prove of milling grade.

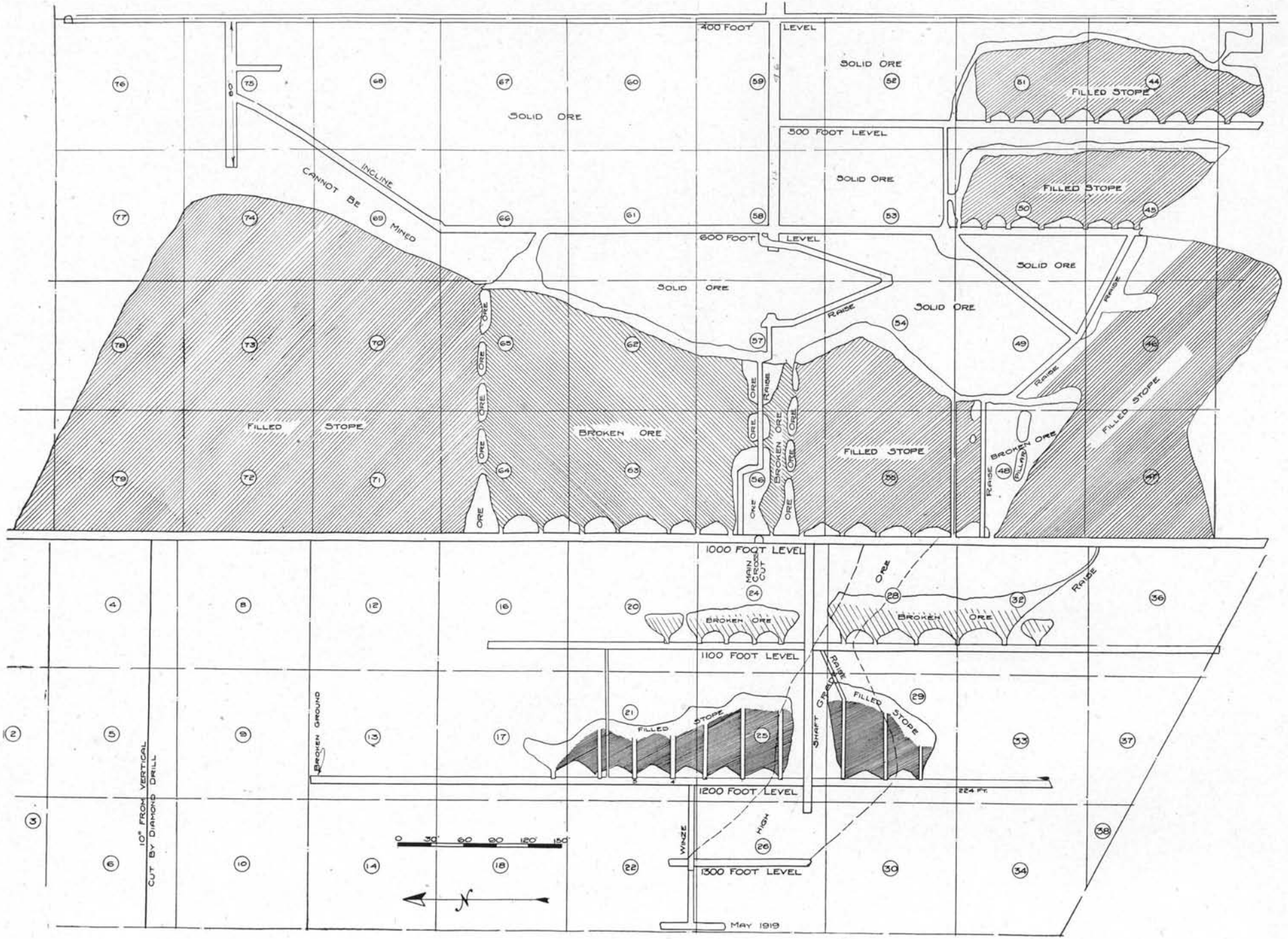


Fig. 8. Longitudinal section along plane of vein, United Silver-Copper Mine.

The next 200 feet is ore of questionable milling grade. Near the hoist room a shoot 150 feet in length exists. This shoot carries some tetrahedrite and is the best ore observed on the level. Between the level and the surface there exists 300 feet of possible stoping ground. The copper sulphide minerals in portions of this upper zone, however, are in part altered to malachite and other secondary products not readily amenable to ordinary concentration practice. Between the 400 and 600-foot levels there is a block of ore 350 feet in stope length that should provide good milling ore. South of the shaft most of the ore between the 400 and 600 levels is mined out. Practically all the ore is stoped between the 600 and 1,000 or adit level.

Description of Concentrating Mill.—The mill is near the portal of the long adit tunnel. Its present maximum capacity is about 350 tons each 24 hours, but only 150 tons were being milled at the time of visit on account of shortage of mine labor. The mill was built in 1913 with stamps as the finer-crushing medium and all concentrates made on tables. Since that time the mill has undergone many alterations. Chief among these is the replacement of the stamps by ball mills and the addition of a flotation unit for treating the table tails. The mill feed averages about 1.5 per cent copper and 3½ ounces of silver to the ton. A recovery of about 85 per cent is effected.

From the mill bins the ore is fed to a Blake 18 by 20-inch jaw-crusher which reduces it to pass a two-inch ring. A Symons gyratory crusher is held in reserve for emergency use. The ore is next fed to a large ball mill 10 feet long and 9 feet in diameter. This large mill, using 4-inch steel balls and working in closed circuit with a drag-belt classifier, has a maximum capacity of 300 tons each 24 hours, when receiving a 2-inch feed and crushing to pass 40 mesh. There are two of these ball mills, one for emergency use in order to avoid delays when one mill is down for repairs. These large mills have not proven entirely satisfactory for they must be run at full capacity, otherwise there is a strong tendency for them to crack the head plates. Each is driven by a 200-horsepower motor.

The oversize from the drag classifier is returned to the mill for further grinding and the overflow is elevated to a classifier which divides the pulp between five Deister-Overstrom tables. These tables make three products. The concentrates averages about 20 per cent copper and 80 ounces of silver to the ton and go direct to the bins for dewatering and shipment. The middlings are returned to the ball mill for regrinding and the tails go to the flotation unit.

The flotation unit is built near an old tailing dump, about 100 yards from the mill proper. This dump contains several thousand tons of tailings carrying low values in copper and silver and is being retreated in the flotation unit when the mine tonnage decreases. A small ball mill was used for regrinding during 1919 but this was finally discarded and all material going to this unit is sent direct to flotation. The table tails from the upper mill are flumed to the flotation unit and discharged into the roughing cells.

Some of the ore minerals, particularly the partly weathered material from the old dump, do not float readily and to secure a high recovery the pulp is successively treated by several flotation machines. Mechanically agitated machines and Pachuca air-agitated machines are used as roughers and the various concentrates are recleaned twice in Callow pneumatic cells. This recleaning is necessitated by the development of sericite and talcose material in the wall rocks; these secondary silicates are greasy and float readily. It is necessary to treat the froth forming on the concentrate settling tanks with a spray of cold water; this tends to sink the sulphides while collodial gangue material still floats and is carried off in the overflow. There are four rectangular settling tanks, each 15′x12′x12′. The thickened pulp is drawn from the bottom of these tanks and treated on a nine-foot Oliver filter. A steam coil in the concentrate bin removes an additional four per cent moisture and thus lowers the moisture content to about 14 per cent.

Water for the mill is secured from the mine and from Chewelah Creek by a two-mile flume.

Power and Surface Equipment.—The Myers Falls plant

of the Stevens County Power & Light Company furnishes power for both the mine and mill. It is received as 33,000 volts and transformed at the mine to 2,200 volts. The total power consumption is about 500 horsepower. For the mine, 175 horsepower is used and the balance is consumed in the mill. The nearby Magnesite industry has increased the load on the Stevens County plant to such an extent that the mine and mill have been forced on several occasions during the past two years to close down for short intervals.

A 15-drill capacity Chicago-Pneumatic, electric driven air compressor furnishes air for the mine. This is supplemented by a three-drill Ingersoll-Rand machine for use on the "graveyard" shift.

The company is fulfilling a long felt requirement by the erection of twelve new four-room cottages for family use and a modern bunk house for their unmarried employes.

COPPER KING

Location.—The Copper King property is about one-half mile northeast and 550 feet above the camp of the United Silver-Copper Mine. The holdings are but a few hundred feet north of the United Silver-Copper ground and on a continuation of the same general north-to-south vein system.

Development.—The Copper King Mining Company has developed its property by two sets of workings. The older workings are on the upper limits of the vein at an elevation of 3,040 feet. The drift is opened on a vein and runs north 25° east for the first 75 feet and then zigzags irregularly for the next 350 feet but tends to approximate the same general course of the vein. About 350 feet from the portal a crosscut is driven 80 feet to a more westerly vein which is then drifted on for several hundred feet. From this level a raise has been opened to the surface and considerable ore stoped; a shaft has also been sunk to 100 feet below the level. Another crosscut was run to the west which picked up a third vein. In the development and mining of these three veins about 1,500 feet of tunnel work was accomplished; two shallow shafts were sunk on the vein and

several raises opened to the surface. Some stoping has been done and a production of several thousand tons is reported from this level.

The property was later opened by a crosscut tunnel which starts on the Amazon ground at an elevation of 2,848 feet or 192 feet lower than the upper workings, and is driven north 79° east for a distance of 950 feet to the west side line of the Copper King property. From this point it is 192 feet to the main Copper King vein and the tunnel continues easterly 350 feet after cutting the vein. This tunnel crosscuts five nearly parallel veins, three in the Copper King ground and two in the Amazon. The Amazon property is owned by other interests and will be discussed separately.

The three veins in the Copper King ground are numbered one, two and three in the order in which they are cut. Number 1 vein has been explored only by a short drift to the south. The vein as exposed here is seven feet wide and contains scant mineralization of chalcopyrite and pyrite. Associated with it is a small lamprophyre dike. The vein deserves further exploration for it may develop ore-shoots. The principal development is an old raise which has left the vein and been driven in an erratic manner through barren ground.

Number 2 vein is about 150 feet farther east in the tunnel. It strikes north 30° east and like all the others stands nearly vertical. The exploration work consists of a drift on the vein 100 feet to the south and a stope has then been opened for a vertical height of 90 feet. Copper ore which appears to average between one and two per cent is exposed in the back and face of the stope. The vein consists of small bunches and specks of chalcopyrite and pyrite scattered through a quartz and siderite gangue. The vein has an average width of six feet. Deeper exploration has not been attempted.

Number 3 or the main Copper King vein is much more strongly defined on this level than in the upper workings. Short drifts have been opened on the vein to the north and south. In the north drift, the United Silver-Copper Company, who held a lease and bond on the property during 1918, opened

a large stope and mined 6,000 tons of ore averaging 1.5 per cent copper. This stope is about 100 feet long and the average width of the body mined varies from 15 to 30 feet. This represents one of the large bulges which characterizes the veins.

Economic Geology.—The formations of argillites and quartz-mica schists so prominently exposed in the United Silver-Copper property, extend into the Copper King and Amazon ground. The United vein was described as replacing the metamorphic rocks along zones of shearing which followed the bedding planes of the wall rock. The veins in this property carry the same essential characteristic, such as pinches and swells, a general north-to-south trend, a dip that it is nearly vertical, etc. The Copper King ground, however, shows evidence of more intense faulting. Weaver* mentions two sets of faults observed, one of which strikes north 85° east with a steep angle of dip toward the north, and the other with a strike of north 45° west.

Several small lamprophyre dikes were observed paralleling the veins. The large dike associated with the ore in the United property was not observed in the limited examination made of the Copper King workings. A strong dike of this type should extend into these workings and if it has not yet been cut there exists the possibility that the northward extension of the United vein may lie to the east of the present Copper King workings and this possibility would warrant the cost of diamond drilling the ground to the east. As these various veins appear plotted on a map this suggestion does not appear unreasonable, for the United vein would necessarily require but a slight bend to the east to throw it beyond the most extreme easterly workings in the Copper King ground.

The Copper King veins as exposed in the upper workings, 192 feet above the main adit, vary in width from a few inches to eight feet. The ore zone at this level shows unmistakable signs of oxidation, such as considerable limonite, manganese oxide stains and some malachite. There are also

*Weaver, Chas. E., Mineral Resources of Stevens County: Wash. Geol. Survey, Bull. 20, 1920.

small bunches of unaltered chalcopyrite and pyrite scattered through sections of the vein, and so apparently, if there has been downward enrichment it has not been complete and no large zones of secondary enrichment are believed to exist. Comparatively recent glacial erosion over this area also mitigates against a zone of extensive enrichment.

Economic Considerations. — Although the development work on the Copper King property has been poorly directed, it at least proves the existence of a large lode of low grade copper ore. It is highly probable that within the next few years this property will again become productive. It is unfortunately true that the veins do not carry appreciable quantities of tetrahedrite which "sweetens" the United vein with silver, but, judging from the United vein there is a mining chance that shoots of silver ore may yet be encountered. If the lode consistently averages between one and two per cent copper with small amounts of gold and silver, it should be capable of yielding profits under skilful management.

The logical method for economic, efficient development of these deposits, if such could be arranged, would be the consolidation of the United Silver-Copper, Copper King and Amazon properties under one management, and the erection of a large up-to-date mill for treating the ores from all three properties. The Amazon and Copper King veins could probably be best worked by extending the 1,000-foot level of the United into the Copper King ground. It of course would be necessary before undertaking any such ambitious, large scale production, to further diamond drill and explore the Amazon and Copper King ground.

AMAZON

This property, which is owned by J. Oppenheimer of Chewelah, consists of several unincorporated claims joining the Copper King property on the west. By a working agreement with the Copper King Company the lower adit tunnel of that company passes through the Amazon property for a distance of 950 feet to reach the Copper King ground. Vein No. 1 as cut in this tunnel averages from three to five feet in

width and is well mineralized with chalcopyrite and some tetrahedrite. The vein has been developed by an 85-foot drift to the south and some stoping has been done from this drift. A lens of high-grade ore was mined and shipped from here which is said to have averaged about 40 ounces of silver. This lens is at the intersection of a small east-to-west fissure with the main vein and this possibly influenced the localized enrichment. Ore of apparently milling grade remains in the face of the south drift.

Vein No. 2 is about 100 feet east of, and parallel to, vein No. 1. It is surprising that it has been explored only by a 15-foot drift to the south. In this south face the vein has widened to 12 feet. The vein material is mostly quartz carrying chalcopyrite and pyrite in apparently sufficient quantities to be called ore of milling grade. This vein is not far beneath the surface yet little signs of secondary alterations were observed. Both veins are approximately parallel to those of the Copper King.

KETTLE RIVER DISTRICT

The Kettle River District is the name used to designate an area in western Stevens County, which lies west of the Huckleberry Range and east of the town of Daisy. From the railroad it is reached by a good automobile road from Addy, a distance of 25 miles. The area is also served by a highway extending up the valley of Columbia River.

Mining operations began in the district 30 years ago, but no extensive production has yet been made. During 1919-1920 three properties were under development. Of these the Daisy Mine has now attained to a point where it has a good tonnage of milling ore partially blocked out.

Colville quartzite, and the Mission and Chewelah argillites are the prevailing formations in the vicinity of the deposits. These metamorphosed sediments are intruded by dikes and a stock of granitoid rock, the phases of which vary from granite to diorite. The Daisy and Tempest mines occur just at the margin of a large stock. The Silver Queen vein is closely allied to a large granodiorite dike.

SILVER MOUNTAIN MINING COMPANY

This property, which is better known as the Daisy Mine, is located in sec. 7, T. 33 N., R. 38 E., in the west central part of the county about five miles east of the town of Daisy and on the western slope of the Huckleberry Mountains at an elevation of 3,400 feet. The property can be reached by the Great Northern Railway to Addy, and thence by stage to Daisy by way of Gifford.

The ore is too low grade to consistently stand the cost of the 18-mile haul to the railroad, hence only a limited production of several hundred tons has been made from the property. Work is now in progress in an effort to develop sufficient tonnage to warrant the erection of a small concentrating mill. At the time of visit a crew of five men was employed.

Geology.—The mine is located at the border of a granitic cupola and near its contact with metamorphosed belts of quartzites and argillites. As has previously been described under other sections of the County, the quartzites and argillites are large belts of metamorphosed sediments considered to be of Paleozoic age, while the intrusive diorite is probably of Mesozoic age. The diorite cupola is simply a dome-like projection from the granitic batholith underlying Stevens County. The rock is more basic than many other exposures observed in other sections of the county. Examined in thin-section under the microscope, the rock exhibits well-shaped crystals of hornblende in an altered ground-mass of plagioclase feldspar. The rock is classed as hornblende diorite.

Description of Property.—Two veins have been developed in a limited way. They are roughly parallel, of irregular outlines and strike about north and south. They have been best developed by the Terry Tunnel which is driven due east as a crosscut for a length of 600 feet. Banded quartzites predominate for the first 100 feet, then the crosscut enters diorite. The contact between the quartzite and diorite stands nearly vertical and strikes north 35° west. About 150 feet from the portal there is exposed a large aplite dike enclosed in the diorite. This exposure of quartz diorite is in the form

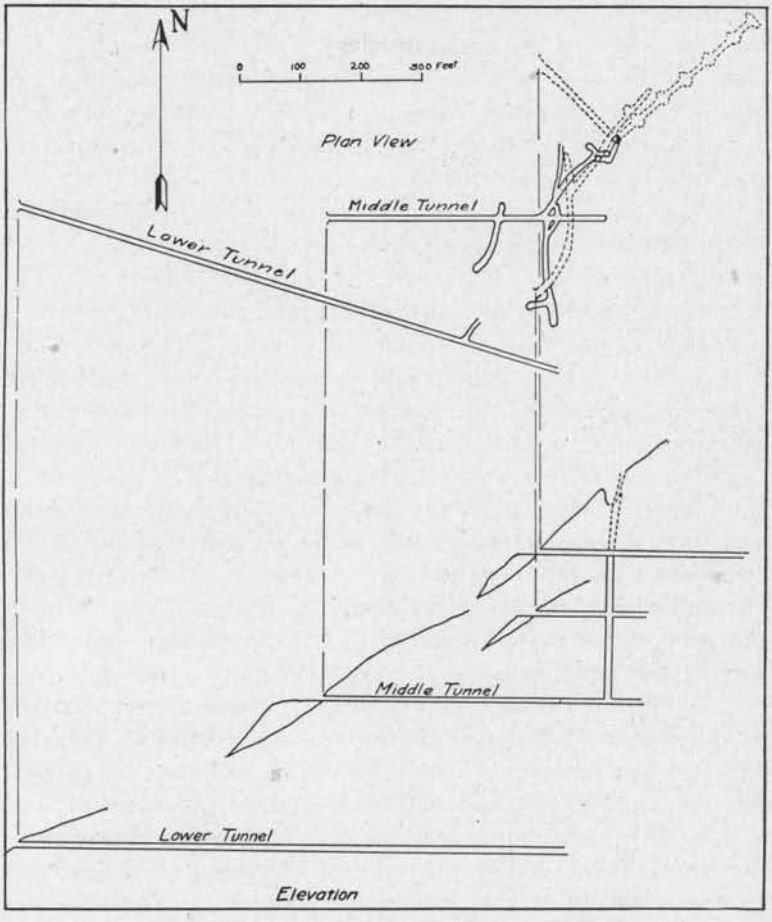


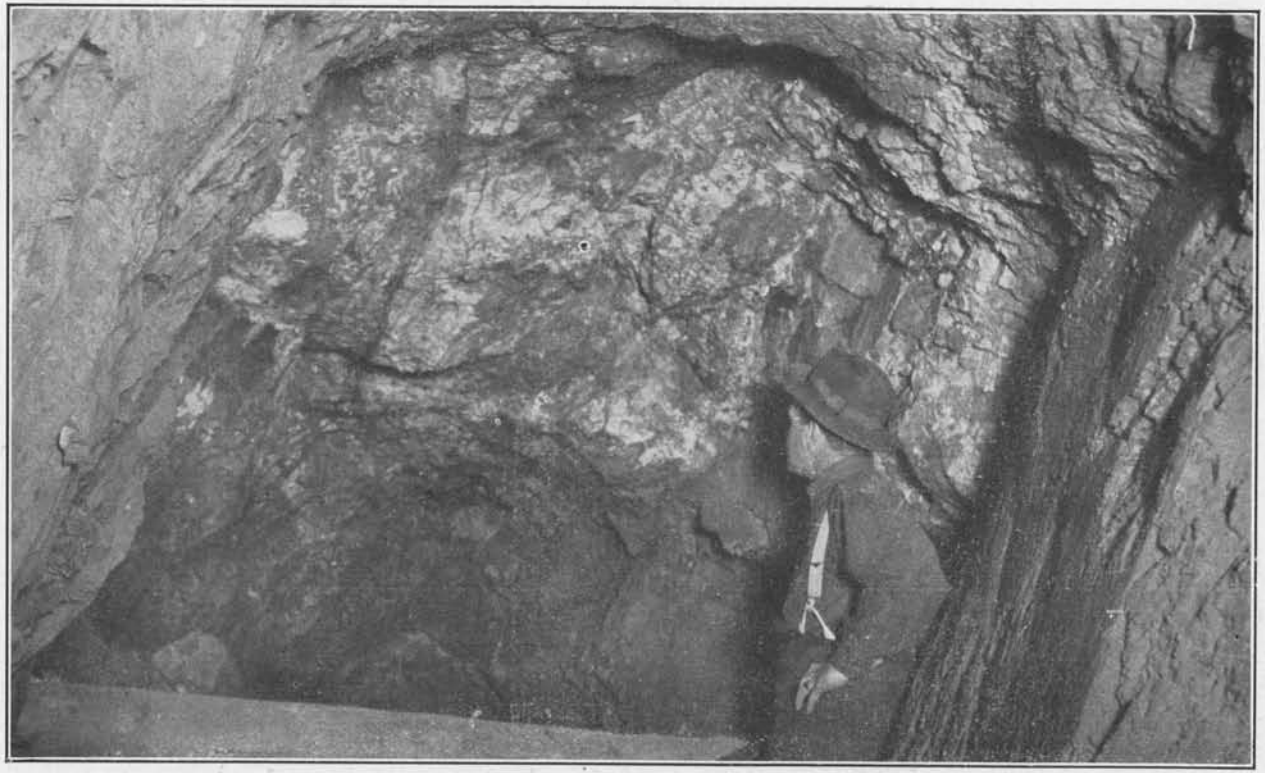
Fig. 9. Map of workings of Daisy Mine, Kettle River District.

of an apophyses from the main stock. Its width in the Terry Tunnel is approximately 250 feet with quartzite bounding it on both the east and west. Three hundred feet from the portal a 20-inch mineralized quartz vein was encountered and short drifts were driven to the north and south to explore this lead. The largest amount of development has been toward the south and it shows the vein to pinch and swell from 10 inches to six feet in width. The strike of the vein is 52 degrees west and the dip 70° west. The quartz is well min-

eralized with sphalerite, chalcopyrite, marcasite, and pyrite; the chief value of the ore is in silver. This vein lies along the plane of contact between the intrusive diorite and the argillite. It stands nearly vertical and both walls are intensely striated and exhibit from two to six inches of gouge as further evidence of the intense movement. A small stope has been opened above the south drift. A 20-foot drift north of the main tunnel shows the vein to carry the same pronounced erratic pinches and swells.

Ninety feet farther east, the main tunnel intersects a second irregular vein on which drifts have been carried 300 feet to the north and about 100 feet to the south. In places, this vein is six feet wide and then it pinches down and disappears from the drift to again appear farther on. Several small stopes have been opened above the north drift and a raise driven 265 feet to the surface. This raise was caved and the intermediate ground could not be studied. The same shoot near the surface has been mined by a large open cut and yielded several cars of shipping ore. The values in the surface cut were apparently in the carbonate and oxide forms and represented an enriched section of the vein.

To further develop the property, a lower crosscut known as the Seelye Tunnel was driven to gain a vertical depth of 125 feet on the veins. This crosscut is 1,000 feet in length; for the first 800 feet quartzite and argillite predominate, and beyond this is the intrusive diorite. At a point approximating 800 feet from the portal the vein was intersected. A drift to the north on this vein exposes pods of mineralized vein material up to a maximum width of seven feet. These pinch down and swell again irregularly and the deposit is further broken up by a number of small faults. These movements are predominantly post-mineral and in places smoothly polished faces have been developed on the ore. The walls are well developed and exhibit smoothed surfaces. The vein roughly



Vein exposed in breast of stope, Daisy Mine, of Silver Mountain Mining Company. Note polished foot-wall.

follows the contact between quartzite and the diorite, though in places both walls are in quartzite. The quartzite strikes north 30 degrees east and the trend of the vein is in the same direction.

After following the vein for a short distance the drift was swung to the northeast to crosscut Number 2 vein. This work was being carried on at the time of visit.

The Tempest group of claims are about one-half mile south of the Silver Mountain Group. Between the workings

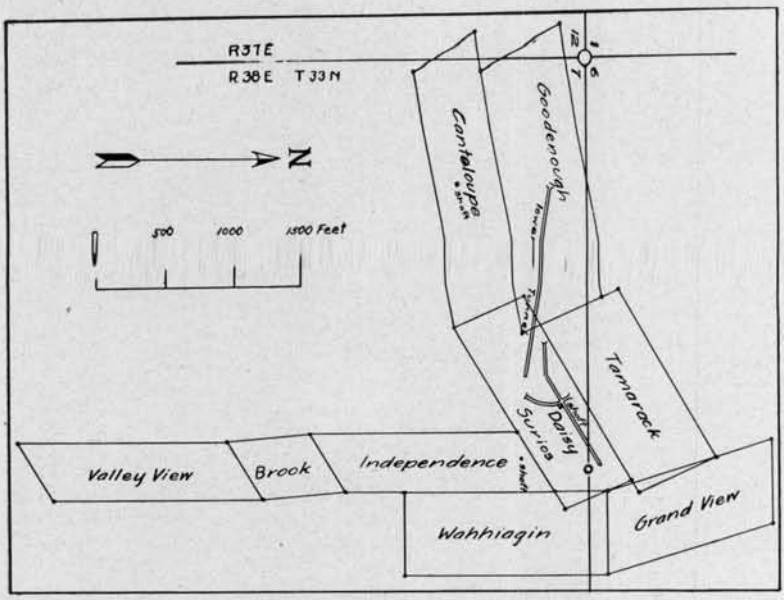


Fig. 10. Map of Daisy Mine, showing location of claims and principal workings.

on these two groups, several outcrops of two strong parallel veins were observed trending north 15° east. A few surface cuts and shallow shafts have been opened, but these veins deserve more thorough prospecting in an effort to locate pay shoots.

TEMPEST MINING & MILLING COMPANY

The Tempest group is made up of six claims located near Horton's Ranch, about one-half mile south of the Daisy Mine, sec. 7, T. 39 N., R. 38 E., at an elevation of 2,920 feet.

The property was located by J. N. Horton in 1887 and is now incorporated as the Tempest Mining & Milling Company, with head offices at Spokane.

The geology of the property does not essentially differ from that of the adjoining Silver Mountain holdings. The development work has disclosed two veins lying near the contact of diorite and quartzite which are so well exposed in the adjoining mine.

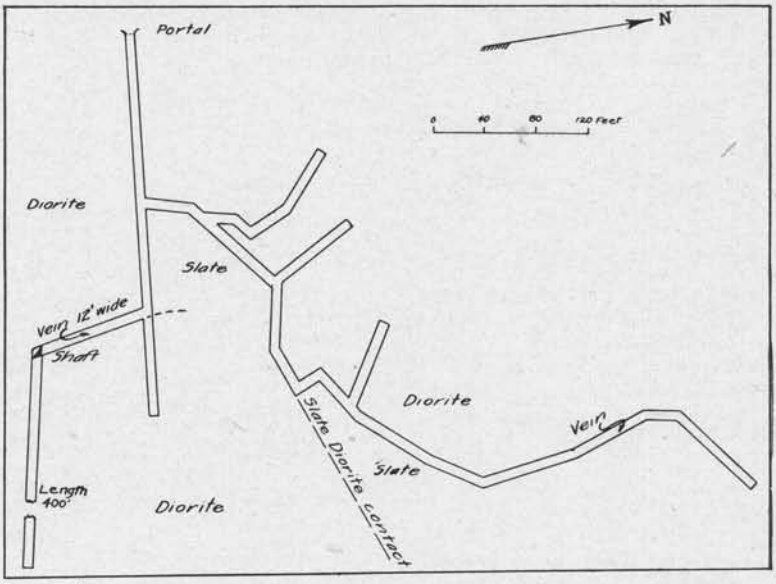


Fig. 11. Map of workings of Tempest Mine, Kettle River District.

In all, about 2,500 feet of tunnel work has been driven to develop the property. Unfortunately, 2,000 feet of this is dead work for a large part of the tunneling has been devoted to following small mineralized quartz stringers lying along the plane of contact between quartzite and argillite on the east, and diorite on the west, instead of exploring a strong quartz vein which the workings crosscut.

From the hillside a crosscut tunnel was driven due east for a distance of 350 feet. One hundred feet from the portal a four-foot vein of white quartz carrying some values in sphalerite, chalcopyrite and pyrite was intersected. This

vein strikes north 25° east and dips nearly vertical. A drift was driven along the side of the vein for 100 feet to the north, where it pinches down. The drift then bends to the northeast, intersects the contact between the quartzites and diorite and follows sporadic quartz stringers along the plane of contact for a distance of 900 feet. These quartz stringers might appear sufficiently continuous to be called a small vein had the drift followed them instead of along the plane of contact.

Two hundred feet from the portal, the main crosscut intersects a 12-foot vein of white quartz striking north

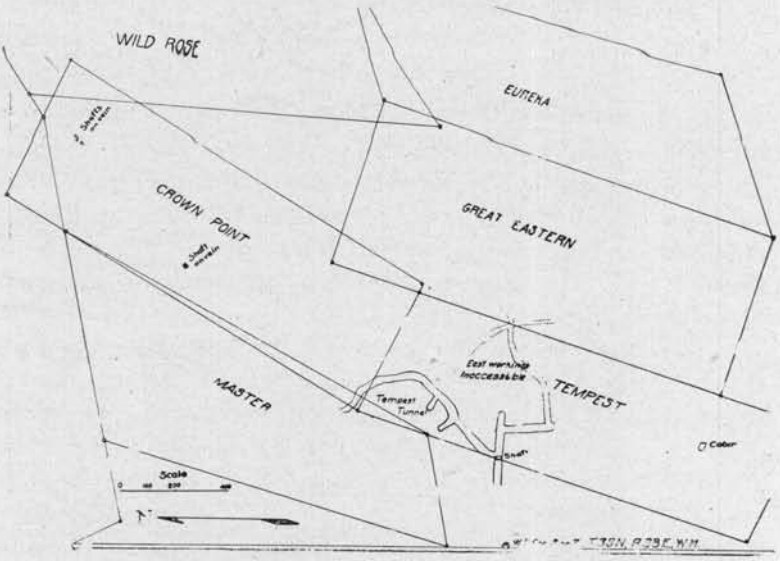


Fig. 12. Claim map of Tempest Mine, Kettle River District.

15° east and dipping nearly vertical. The vein is impregnated with limited amounts of sphalerite, chalcopyrite, and pyrite. The chief values of the ore are in gold and silver. A drift was run on the vein 90 feet to the south and other drifts continue 200 feet further to daylight on the south slope of the mountain. The vein has not been explored to the north of the main crosscut excepting in one place where it has been intersected by an exploratory crosscut.

The statement is made that several shipments of high-

grade ore were made several years ago from a shallow shaft sunk on the surface croppings. This shaft is now caved. While this ore near the surface probably carried some secondary enrichment the shipments suggest the possibility of an ore shoot and the ground in the vicinity of the old shaft would then offer the most likely point for prospecting. The property has two well-defined veins but success in mining operation must come from the location of one or more ore shoots in the veins. Since the veins outcrop more or less prominently, it would seem that surface prospecting along the trend of the veins would be the best method of attack for a company possessing but limited capital.

SILVER QUEEN

A company organized as the Ark Mines Company has, since 1905, been intermittently developing a group of seven claims which are known as the Silver Queen property. The holdings are situated in sec. 11, T. 35 N., R. 37 E., on Rickey Mountain, three and one-half miles south of the town of Kettle Falls. The camp is 350 above and one-half mile east of Columbia River.

At an elevation of 250 feet above the camp there are two closely adjacent inclined shafts sunk to explore a large quartz lode. The principal shaft was sunk on the vein at a 45-degree angle to a depth of 125 feet. The lode as exposed varies from a width of three feet to a maximum of 20 feet with an average of over 10 feet. Mineralization in the form of tetrahedrite, chalcopyrite and pyrite is sparsely sprinkled through the lode; where observed these minerals were not present in commercial quantities. The vein conforms to the bedding planes of the Mission argillite, in which it is enclosed. The strike of the formation varies from north 80° west to north 35° west and the dip averages 40° west.

At the camp level a crosscut has been driven south 35 degrees east for a distance of 925 feet (August 20, 1920) and is intended to explore the vein at a depth of 250 feet below the upper workings. The argillite, through which the crosscut is being driven, exhibits so much free graphite that it

might better be called a graphitic schist. The work has exposed several small stringers of barren quartz. At a point 125 feet back from the present face, a raise from the level penetrated the vein at 55 feet and is reported to have passed through 20 feet of quartz. At the time the property was visited, the ladders had been removed from this raise and it could not be examined. The argillite at the face of the crosscut dips at a 21-degree angle toward the south and if the measurements in the raise are correct, the crosscut should catch the vein 40 feet north of the present face.

It is the writer's opinion that the surface showings did not yet warrant the driving of a 1,000-foot crosscut. However, since the work has been practically completed, it would be well after cutting the vein, to explore it with a drift toward the east in search of a pay-shoot of profitable ore. Three hundred feet northwest of the crosscut portal a 50-foot dike of granite porphyry was observed cutting the argillite. The intersection of this dike with the vein would seem to offer the most favorable ground for prospecting. Four hundred feet southwest of the portal the lode outcrops to exhibit a width of 20 feet of barren quartz. On account of the hillside wash it cannot be traced any distance on the surface.

A crew of three men are ordinarily employed. A 35-horse power boiler supplies steam to operate a two-machine air compressor.

DEER TRAIL DISTRICT

LOCATION AND ACCESSIBILITY

The area embracing the Deer Trail (Cedar Canyon) District is located in the southwestern corner of the County. The properties visited in this district were all within a short radius of the old town of Turk, but there are several other properties, now dormant, scattered along the slopes of the Huckleberry Range.

Springdale on the Great Northern Railway, 47 miles north of Spokane, is the nearest shipping point. The center of the district may be reached from Springdale over 25 miles of ordinary wagon road, suitable during the summer months only for auto trucks. Transportation has been improved dur-

ing the recent years by the construction of the Phoenix Lumber Company's logging railroad from Springdale to within 10 miles of the producing properties, and the major portion of the shipments go out over this road. From the west, the district may be reached from Fruitland in the Columbia River valley, on the stage-line between Davenport and Myers Falls.

TOPOGRAPHY

The properties are located along a series of north-to-south trending ridges which make up the Huckleberry Range. The average elevation of the ridges is about 3,800 to 4,000 feet or 1,500 to 2,000 feet above the valley floor. The range approaches Colville Valley on the east, Columbia River on the west, and Spokane River on the south, with gently sloping flanks heavily forested with excellent timber and deeply incised by turbulent mountain streams. The major portion of the drainage from the range flows westward into Columbia River.

GEOLOGY

Highly metamorphosed and folded Paleozoic sediments, varying in thickness from a few hundred to several thousand feet, cover the major portion of Huckleberry Range. These are composed of various gradations of argillites, quartzites, dolomite and limited exposures of limestone. Along the southern extremity of the range extensive outcroppings of the underlying granitic batholith are exposed. It is near the borders of these exposures that the most noteworthy deposits occur. They are the result of filling and replacement along zones of shattering and shearing traversing the metamorphic rocks. These deposits usually follow the bedding or schistosity planes of the formations. These shear zones so opened offered avenues of escape for mineralized gases and solutions exhaled from the underlying magma during its later stages of cooling. The ore minerals are principally those of silver and copper, although there is also included within the area the Germania Tungsten Mine, which has been responsible for the larger portion of the State's production of tungsten.

CONDITION OF MINING ACTIVITY

A few small, scattering shipments comprise the production during 1919 of a district which in former years has been the scene of considerable mining activity. The best ore bodies have been mined and the future of the district must depend upon the development of new ore bodies or the economic working of lower grade ores. The high transportation costs forbid the shipment of any but high-grade ores. There are several dormant properties in the district which may, with further development, disclose sufficient tonnages to justify the erection of a small concentrating mill. The reject dumps made when sorting out high-grade ore contain several thousand tons of probable milling ore. A centrally located small custom mill, in the vicinity of the Deer Trail camp, should be able to draw ore from the mines and adjoining dumps if such a project were intelligently managed.

A small smelter was built at Turk in 1904 but its distant location from railroad transportation and coal supply foredoomed it to immediate failure.

REARDON COPPER

This property, formerly known as the High Grade Mine, has in recent years been the most steadily producing property in the Deer Trail District. It was first located in 1881 and a road was built into the district by army officers stationed at old Fort Spokane. During 1918 a crew of 20 to 25 men was employed and shipments went forward steadily. Early in 1919 the unsatisfactory copper market caused a shut-down and since that time only a limited amount of exploration work has been carried on by a crew of two men.

It is located one mile by good wagon road southeast of the old town of Turk in sec. 6, T. 29 N., R. 38 E., a short distance west of the summit of Huckleberry Range at an elevation of 3,300 feet. The mine is about 25 miles west of Springdale by wagon road and 42 miles north of Davenport. The ore from the mine is hauled up a steep switch-back road a distance of one mile to the Deer Trail road where it is loaded into auto trucks and hauled to the logging railroad of the

Fig. 13. Cross-sectional sketches showing probable method of formation of the ore lenses at the High Grade Mine, Deer Trail District.

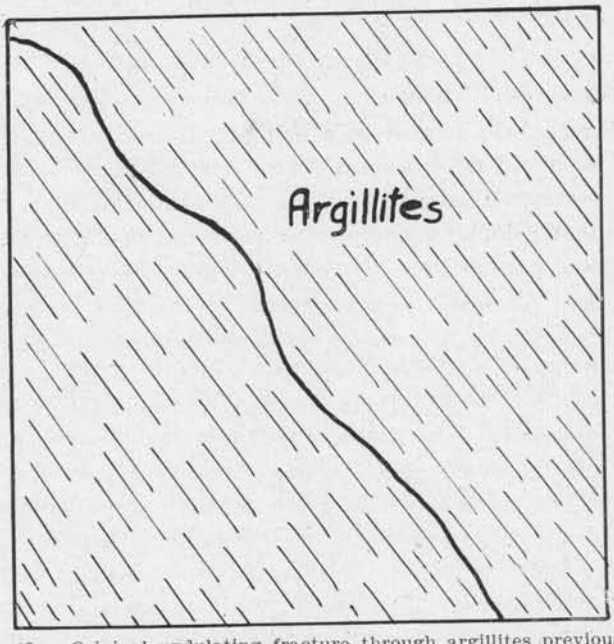


Fig. 13a. Original undulating fracture through argillites previous to faulting or mineralization.

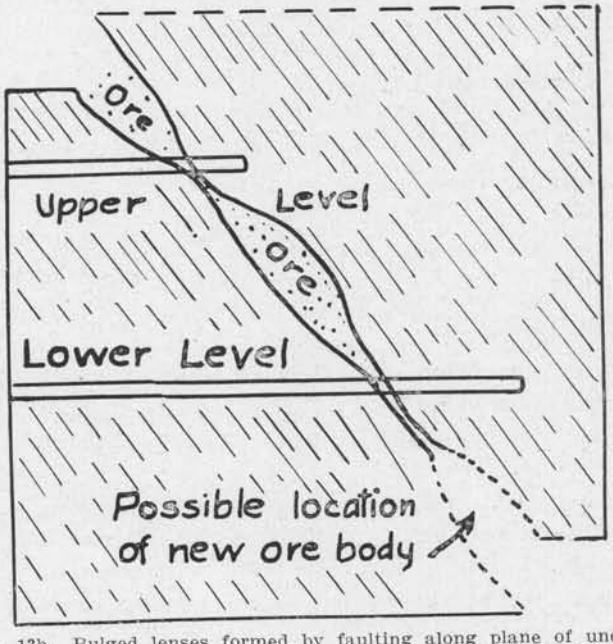


Fig. 13b. Bulged lenses formed by faulting along plane of undulating fracture. These lenses were subsequently filled with ore.

Phoenix Lumber Company, who in turn transport it to the railroad at Springdale.

The mine is located in a belt of calcareous and silicified argillites about 800 yards northeast of the margin of an extensive granitic exposure. The extension of this granitic batholith no doubt underlies the argillites at the mine.

The production has come from two lenticular ore bodies which are connected by a narrow ribbon-like neck of ore. These lenses strike roughly north-south and the dip varies from 20° to 45° to the east. The ore in the lenses average about six feet in thickness, extend for probably 125 feet across the strike, and the combined lenses have been mined for a length of several hundred feet on the dip. The foot-wall is a calcareous argillite and the hanging-wall silicified argillite, approaching quartzite. The wall rocks show evidence of intense shearing action combined with shattering and faulting. The ore minerals are principally chalcopyrite, malachite, pyrite and marcasite, carrying small values in gold and silver.

The upper lens outcropped at the surface. In the early history of the mine some work was done on this outcrop and later a crosscut was driven in the hill several hundred feet in a northwesterly direction, which, after following several cross fractures carrying a few inches of ore, finally reached the ore body. The chalcopyrite of this lens is partially altered to bornite, malachite and tenorite. The ore was stoped out to the surface and then by underhand stoping followed down 20 feet below the level where it pinched down to a narrow ribbon. This ribbon was followed down an additional 15 feet and found to open into a second large lenticular body. To mine the lower lens a cross cut tunnel was run at a depth of 110 feet vertically below the upper level. Again, small cross fractures, filled with an inch or two of vein material or gouge, enticed the driving of the tunnel in a circuitous direction. This crosscut encountered the lower tip of the lens and allowed overhand stoping on the body.

Practically all the commercial ore developed in the mine has now been mined and at the time of visit the exploration

work was confined to a drift on the lower level following a cross stringer filled with barite. This stringer trends out toward the mountain side and there is little likelihood that it will disclose commercial ore. On the lower tip of the second lens there is a faint ribbon of ore exposed in the bottom of the adit which lines up well with the general dip of the lenses above. It is only reasonable that this should be followed down with the hope that it will lead into a third or lower lens of ore. The underground evidence suggests that the metamorphosed formations have been severely shattered and that the irregular major fractures trended in an undulating course through the ground later occupied by the ore bodies. Following the fracturing, a fault displaced the formations along the irregular fracture zone and brought the fractured formations into juxtaposition (see figs. 13a and 13b) thus opening up large receptacles which were filled by ore bearing solutions working up along the fault.

DEER TRAIL MINE

This property is situated near the head of the south fork of Cedar Canyon at an average elevation of 3,600 feet, in secs. 1 and 12, T. 29 N., R. 37 E. From Springdale, the nearest shipping point, the mine is reached over 25 miles of ordinary wagon road, the last 10 miles of which present several steep mountain grades.

There has been no new development work on the property since the report of Weaver*, and as the underground workings are now badly caved no examination was attempted.

At the time of visit (July, 1919) the property was involved in litigation. Fred Clark of Spokane was mining some of the old stope fillings and pillars and hauling out about 12 tons a day for shipment. This ore is said to average about 20 ounces per ton in silver. It is hauled 10 miles by auto truck to the Phoenix Logging Railroad and then handled by the log trains to the railroad at Springdale.

*Weaver, Chas. E., Mineral Resources of Stevens County: Wash. Geol. Survey, Bull. 20.

GIANT SILVER MINING COMPANY

This company was recently organized to operate under lease and bond the Red Cloud group of claims, located two miles southeast of Turk and about one-half mile off the Deer Trail road, at an elevation of 3,400 feet.

The claims were located 20 years ago and at varied intervals since then considerable exploration work has been accomplished on some irregular showings near the crest of the mountain.

Geologically, the property is situated in a belt of quartzite and near the margin of an extensive outcropping of granite. A dike of granite 20 feet wide, an apophyses from the batholith, invades and shatters the quartzite in the workings and thus materially aided in opening up channels for mineralized solutions.

The mineralized ledge matter outcrops at the very crest of the hill. A shaft, now caved, was first sunk on the croppings. Later, a crosscut was started about 150 feet down the hillside and driven southwest 100 feet to the ledge. Fifty feet of circuitous drifting on the ledge proved it to be a badly broken up, irregular mass heavily stained with limonite and malachite, and filling irregular shatter zones in quartzite. About 100 feet farther down the hillside another crosscut was run south 70° west, 200 feet to intersect the ledge. A 20-foot badly decomposed granite dike was cut 100 feet from the portal and the quartzite in the vicinity is badly shattered. Beyond the dike 100 feet, irregular fractures are filled with a quartz, calcite, and siderite gangue, carrying considerable chalcopyrite and pyrite; there also are present some extremely small specks of a sulphide mineral hardly visible to the undaided eye, probably a silver sulphide. The mineralized material as exposed by the development has no apparent regularity of direction or size.

Near the level of the camp a third crosscut is now being driven south 54° west to gain a depth of 260 feet on the deposit. The erratic nature and extent of the upper showings, militates against the possibility of this lower tunnel exposing commercial ore. It is now in 160 feet through

banded quartzite. The quartzite exhibits bedding planes which dip approximately 20° toward the northeast. The formations are broken with a series of nearly vertical fractures some of which are cemented with veinlets of calcite two inches to four inches wide.

A crew of four men was employed at the time of visit. Two well constructed cabins have been built for the camp and a four-drill capacity steam driven air-compressor installed to speed up the exploration work.

BONANZA COPPER

On the Deer Trail road about 20 miles from Springdale and four miles before reaching the Deer Trail Mine, a branch road turns off one and one-half miles northward to the Bonanza Copper claims. The property was discovered in 1907 and has since been organized as the Bonanza Copper Company with head offices at Spokane. Because the ore is too low-grade to meet the long haul of 20 miles to the railroad at Springdale one small shipment only, has been made.

The deposit is located in a belt of argillites and quartz-mica schists. These have a prevailing strike to the north and dip almost vertically where exposed in the workings.

Development works consist of about 1,200 feet of tunnels. An upper drift is opened on the vein for a length of 250 feet, and driven north 5° east at a depth of 75 feet below the outcrop. It exposes a small irregular vein averaging from a few inches to two feet in width of quartz carrying chalcopyrite partly altered to bornite and malachite. One hundred and fifty feet vertically below the upper workings a cross-cut tunnel was driven north 55° west for nearly 800 feet where it intersected the lead 225 feet below the outcrop. The vein is enclosed in quartz-mica schist which stands nearly vertical and has been badly shattered and sheared. The ore fills a zone of shearing and replacement parallel to the bedding planes. It has a width of five feet and in the center of the zone there is a five-inch quartz vein carrying considerable chalcopyrite, and numerous small veinlets parallel it on each side acting as a filling to cement the bedding planes of the

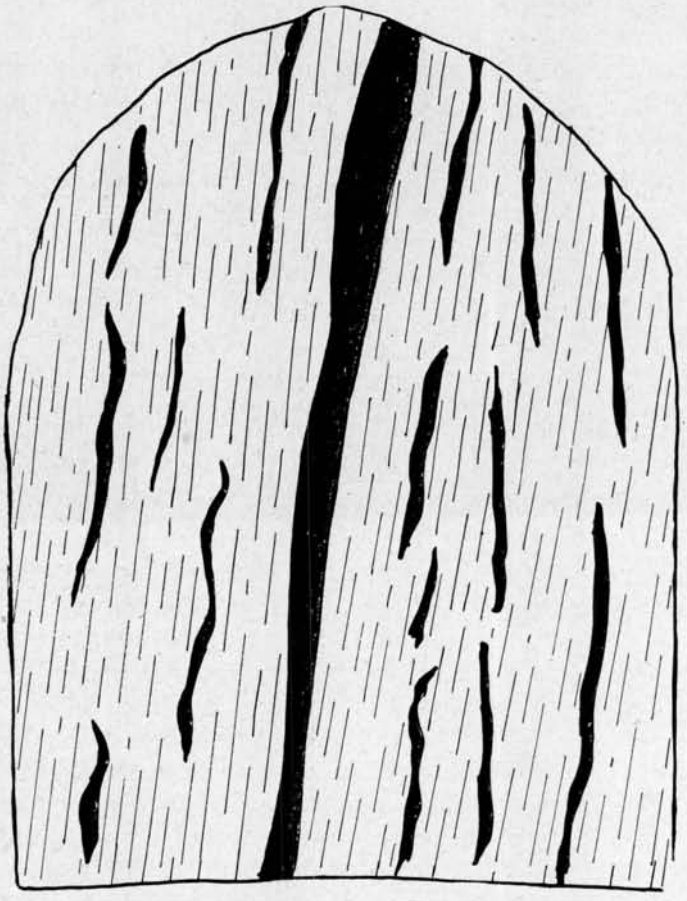


Fig. 14. Sketch of drift face Bonanza Copper Mine, shows chalcopyrite replacing argillite along the schistosity planes.

formation along the zone of shearing. The sulphides carry considerable copper, but on account of the intimate inclosure of the veinlets within the schist it would have to be mined also and would serve to reduce the grade, probably past the point where it could be called ore. The strike of the mineralized zone is south 10° west. From the lower levels drifts have been carried 130 feet to the south and 20 feet to the north.

OTHER MINES IN STEVENS COUNTY

LOON LAKE COPPER

General Features.—During 1919 this property ranked as the second largest copper producer in Stevens County and the third largest producer in the State. As the Kemp-Komar Mine, it was first worked in the early '90's by Patrick Clark of Butte. Dispute with the Great Northern Railway over the title finally resulted in cessation of work and the property remained idle for many years. In 1915 it was reorganized under the direction of George A. Crane and considerable high-grade ore was stoped and shipped from between the 200-foot level and the surface. The shaft was deepened and lower levels developed. Within the past year there have been several changes in the ownership and new officers elected. W. L. Zeigler was appointed manager and under his direction the mine has been put in shape for steady production, and a concentrating mill of excellent design was completed during June, 1919.

During the close of 1919 the company owning this mine was forced into receivership. This failure was probably caused by assuming too great an indebtedness; certainly it cannot be entirely attributed to the physical condition of the mine and mill.

The property is in the N.½ of sec. 33, T. 31 N., R. 41 E., six miles by excellent wagon road north of Loon Lake, a station on the Spokane Falls & Northern Branch of the Great Northern Railway, 35 miles north of Spokane. The mine openings are at an elevation of about 2,600 feet.

Geology.—The mine is in the Deer Lake argillite belt. Quartzite forms a prominent ridge a short distance west of the workings and extensive granite outcroppings are found two miles to the east. The argillites have been severely crushed and sheared. Their general trend varies from north to north 35° west, and the dip averages about 60° to the west.

The ore occurs in a strong quartz vein varying in width from four to 20 feet with an average width of approximately six feet, and filling an east to west fissure or fracture zone

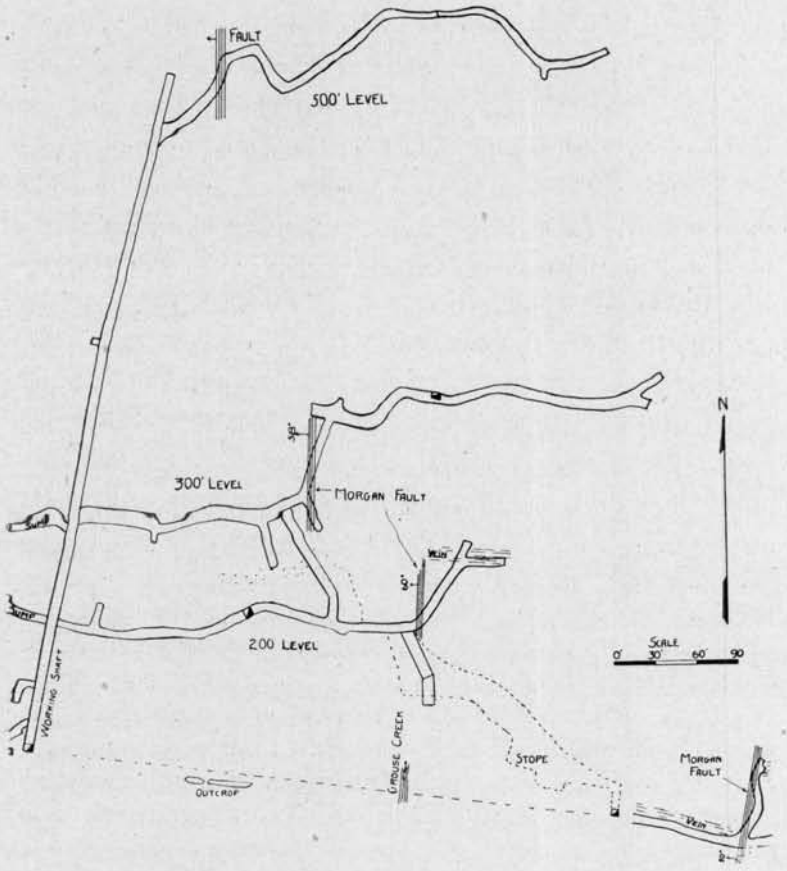


Fig. 15. Plan view of workings of Loon Lake Copper Mine.

through the argillites. The dip averages 60° to the north. This vein is known to have considerable extent but mining has been confined to working a pay-shoot which has an approximate length of 200 feet along the strike of the vein; and with a steep rake to the west, its vertical extent passing beyond the 500-foot level.

An important underground feature is the Morgan fault, which seems to follow the trend of the pay-shoot and faults the vein on all levels. There has been a relative displacement between the east and west ends of the vein of 50 feet north. The fault and pay-shoot have the same downward trend and the best ore is found on east side of the fault. This has naturally encouraged the belief that the ore is later

than the fault and used it as a channel. The mine evidence as observed by the writer opposes this hypothesis. In a stope above the 300-foot level the fault was observed cutting off the vein and included pay-shoot as cleanly as though sliced with a knife. The vein near the fault is shattered, showing that it suffered from the force of the faulting and must therefore be earlier. No small feeder veinlets were found filling the plane of the fault. It is difficult, on the other hand, to explain the close association of the pay-shoot and fault, unless it is that the stresses causing the fault found this the zone of least resistance.

Secondary enrichment is strongly evident from the 200-foot level to the surface and no doubt accounts for the shipments of high-grade ore which went out from the property during its early history. The ore minerals here are bornite, malachite, azurite, cuprite, and a few crystals of atacamite were observed. A sample from the 200-foot level exhibits a thin coating of tetrahedrite partly painted over with malachite stains. The ground west of the fault is somewhat shattered and the alteration has proceeded down to the 300-foot level. To the east of the fault little alteration was observed below the 200-foot level, except that the chalcopyrite bore an occasional thin skin or bornite. Dark colored argillites form the wall rocks of the deposit. In several places stringers of the country rock were found included in the vein. The vein material is milky quartz mixed with some orthoclase feldspar. The feldspar is partly kaolinized and the material is comparatively soft. The ore minerals in places show a tendency toward irregular banding through the vein, or they may be inclosed as irregular bunches.

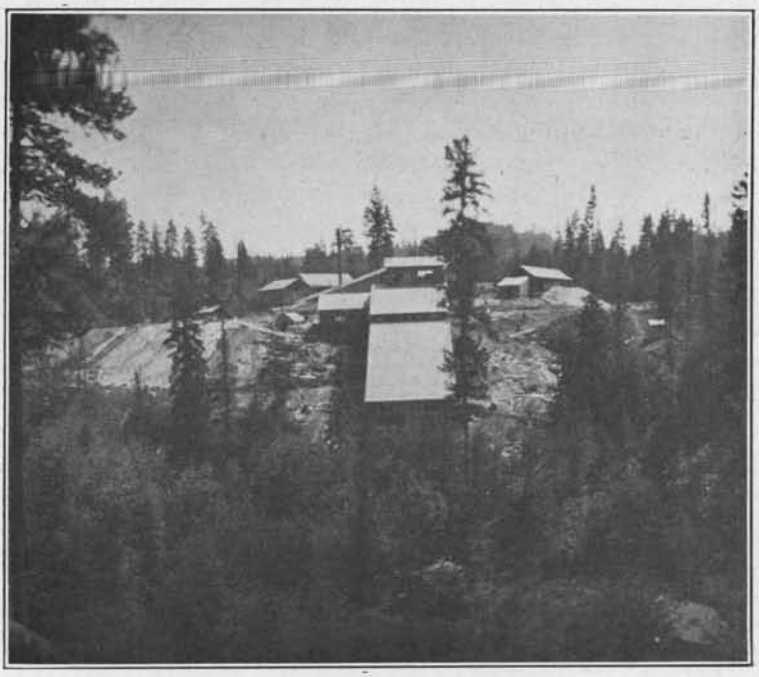
On the hillside, 500 feet northwest of the mill, there is found a porous heavily iron-manganese stained outcrop of a vein striking north and south and dipping 80° to the west. This vein follows closely the planes of the argillites and is said to be traceable for some distance on the surface. The croppings observed were typically an iron gossan, and the fact that it contains no copper stains probably accounts for the limited prospecting it has received. The trend

is at right angles to the Loon Lake vein and the intersection of the two could be reached from one of the lower levels by drifting west from the shaft.

Development.—The mine is worked through a 60-degree inclined shaft sunk as closely as possible on the dip of the vein to a depth of 500 feet. Practically all development is to the east of the shaft. Short 50-foot drifts have been run to the west but these should be extended in search of pay shoots west of the shaft. On the 200-foot level a drift has been driven on the vein for a length of 500 feet to the east and stopes opened through to the surface. On the 300-foot level about 700 feet of drifting has been carried to the east and stope opened on the pay-shoot to connect with the 200-foot level. During the summer of 1919 mining was being carried on from both the 200 and 300-foot levels. The 500-foot level was caved at the time of visit, but it has since been reopened and it is understood that late in the year of 1919 ore was being broken between the 500 and 300-foot levels. On the 300-foot level about 300 feet east of the shaft the workings were caved, thus preventing an examination of the eastward extension of the vein.

On the surface the one-ton skip dumps into a two-compartment double wedge bin having a combined capacity of 200 tons. One compartment of the bin is for ore and the other receives the waste. The 50-horsepower Ottumwa hoist receives its power from a 40-horsepower coal-fired boiler. A 35-horsepower distillate engine runs the motor which furnishes power to the mine pumps and light for camp use. A small saw mill has been built which draws its supply from the timber in the vicinity of the mine.

Description of Concentrating Plant.—The recently completed mill of the Loon Lake Company is one of the few well-designed mills in the State. The ore is readily susceptible to concentration and an all-flotation system has been designed, unique in that there are no screens or elevating devices in the plant. The mill has a maximum capacity of 100 tons each 24 hours and is said to have been erected (exclusively of



All-flotation mill of the Loon Lake Copper Mine.

power installation) at a total cost of between $20,000 and $25,000. This cost has been accomplished only by eliminating mill refinements or expensive types of equipment.

The mill feed averages about 2.0 per cent copper and a few ounces of silver. This is concentrated to 25 per cent copper and 10 ounces of silver to the ton, while the tails carry only one-tenth of one per cent copper.

From the 100-ton skip bin the ore passes over a grizzly set to two inches which by-passes the fines. The oversize is fed to a 9″x15″ belt conveyor which delivers to a 24-inch Symons disc-crusher where the material is broken to one-half inch. A 130-foot inclined 14-inch belt conveys the material to a 150-ton storage bin at the head of the mill proper. The coarse crushing unit is housed in a separate building and being oversize it operates only one shift to supply the demands of the mill.

The minus one-half-inch material is fed from the mill to two 4′x4′ ball mills grinding in closed circuit with dragbelt classifiers to pass about 100 mesh for flotation. Each mill handles its own oversize. Pine oil for flotation is added at the head of the mill. The classifier overflow goes to a Zeigler five-compartment flotation machine. This machine, which combines both mechanical and air agitation, was designed by the manager of the company, who states that the mechanical agitator consumes about seven horsepower and that the air is introduced under ten pounds pressure. There are two flotation machines in the mill but during the summer of 1919 the mill had not yet worked up to full capacity and one machine was capable of handling the feed. The tailings from flotation go direct to the tailing dump, and the concentrates, without cleaning, are sent to a Dorr-type thickner, 24 feet in diameter and seven feet deep. The thickened pulp is drawn off with a moisture content of about 50 per cent. It then goes to a three-leaf, four-foot American continuous filter which reduces the moisture content to about 15 per cent. These concentrates drop to a storage platform and are then hauled by auto truck to the railroad for shipment to the smelter at Trail, B. C.

The water is lifted from the creek just below the mill by a Gould triplex pump to a tank reservoir on the top deck of the building.

LOON LAKE-BLUE BIRD COPPER

This group of claims is in the N. E. ¼ and the N. W. ¼ of sec. 34, T. 31 N., R. 41 E., about one-fourth of a mile southeast of the Loon Lake Copper workings. The vein under development has the same general strike and the dip of the Loon Lake Copper vein and is closely related to it. The holdings, which consist of four claims, have been prospected intermittently for many years. During October, 1918, work was started by a company incorporated as the Loon Lake-Blue Bird Mining Company, financed principally by Duluth, Minn., capital, with H. H. Schelenberg of Spokane as manager. Work has been continuous since that time, a crew of

six men being employed on exploration work during July, 1919. No production has yet been made.

A well-defined quartz vein, five to ten feet wide, striking roughly east-west and dipping 47° to 50° to the north is exposed for a length of several hundred feet on the property. On the east side of a small creek flowing through the camp this vein has been drifted on for 240 feet toward the east. This drift exposed no pay-shoots, although the vein over practically the entire distance shows scant mineralization of chalcopyrite, pyrite and some malachite. Careful channel sampling would be necessary to determine whether this is of high enough grade to be called milling ore. About 500 feet west of this portal and near the west end of the Blue Bird claim, shaft No. 1 was sunk to a depth of 40 feet on the vein. This shaft is now caved. No. 2 shaft is 125 feet east of No. 1 and has been sunk to a depth of 200 feet at an angle of 60°. Forty feet from the collar a short crosscut has been run to the vein where it averages 10 feet in width and carries appreciable values in secondary copper minerals. At the second 40-foot interval another crosscut was driven to the vein and is said to expose good values. This crosscut was caved at time of visit. At the 200-foot level a crosscut was driven north 20° east for a length of 100 feet to the vein. Exploratory drifts were run on the vein 170 feet to the east and 80 feet to the west. On this level the vein averages six to ten feet in width but the mineralization appears to be too scanty to be called ore. The vein quartz is shattered and iron stained and the ore minerals are altered at this depth. The vein is enclosed in thinly bedded, siliceous argillites and impure quartzites, which have been badly shattered and contorted with many minor folds. From the vein small quartz stringers fill fractures in the wall rocks at right angles to their bedding planes. At the time of examination a raise was being driven on the vein from the 200-foot level, in search of the downward continuation of the ore exposed in the upper workings.

The property is equipped with a comfortable camp and enjoys a good supply of water and timber. A two-drill compressor and 12-horsepower hoist are operated by steam.

O-LO-LIM COPPER

Several carload shipments of good-grade copper ore have during the past two years, directed attention toward this property which is on the Spokane Indian Reservation, in the S. E. ¼, T. 28 N., R. 37 E., three and one-half miles northeast of Detillion Bridge across Spokane River. The mine is 27 miles by road from the town of Davenport on the Great Northern Railway. The property was discovered many years ago but it was not until 1917 that Mr. James Keith and associates of Spokane undertook its active development. Since that time 10 cars of ore have been shipped which averaged 7 to 10 per cent copper and one to two ounces of silver to the ton.

Calcareous argillite is the predominating rock in the vicinity of the mine and quartzite is less conspicuously exposed. One-quarter mile from the mine there are extensive exposures of the Loon Lake Granite, intrusive into the argillite and quartzite. The metamorphosed sediments are but a basal remnant of the Stevens Series, so well exposed northward in the county. At all points about the mine they are underlain at no great depth by the granite and it was from this granite that the ore was originally derived.

The vein occurs near the plane of contact between argillite and quartzite. In places it is entirely enclosed in argillite and elsewhere argillite forms the foot-wall and quartzite the hanging-wall of the deposit. The vein varies in width from two to six feet with three feet as a general average. The primary ore minerals are chalcopyrite and pyrite with which are mixed a gangue of fibrous tremolite and ribs of quartz. Alteration has extended to the 100-foot level and in the stopes above the level, malachite and the black copper oxide form prominent ore minerals.

The trend of the vein is north 10° east and the dip is 79° toward the east. The tremolite and quartz of the vein have resisted erosion so effectively that an unusual outcrop is formed and for a short distance near the shaft the lode projects five feet above the level of the surrounding surface. This prominence, however, soon disappears and 100

Outcrop of O-lo-lim lode projecting above level of surrounding surface.

feet north of the shaft open cuts are necessary to expose the continuation of the deposit.

A vertical shaft 220 feet deep has been sunk near the vein. On the 100-foot level the vein has been explored along its strike for a length of 100 feet and the apparent limits of the pay-shoot defined. Stopes opened above this level yielded the shipments of ore that were made. From the bottom of the shaft a crosscut was driven 16 feet to the vein where it at first encountered good ore. When the property was visited but a small amount of drifting had been accomplished on the 200-foot level, but this has raised some question as to whether the downward projection of the vein has yet been encountered. To dispel any possibility of displacement of the lower segment of the deposit by a horizontal fault, it would

seem advisable to raise from the 200-foot level until the pay shoot is definitely exposed. An intermediate crosscut to the vein might shorten up the work.

The property is equipped with a 25-horsepower distillate engine operating an 8″x21″ Gardner compressor. The hoist is driven by a six-horsepower distillate engine. Accessory mining equipment and a good camp have been provided and a crew of three to five men are ordinarily employed. Timber for mining purposes is at hand on the property, but during the summer months only a limited supply of water is available.

GALENA HILL

This property, formerly known as the Kettle River Mine, was organized during 1911 and incorporated as the Galena Hill Mining Company. A small concentrating mill was built and one car of concentrates shipped. The property was then idle for a number of years and the mill was sold to pay off outstanding indebtedness. During 1918 work was resumed with a crew of five to ten men and has been carried on regularly since that time.

The workings, which consist of five and a fraction claims, are located on the east bank of Kettle River one-quarter mile north of Rockcut and ten miles north of Orient. The Republic and Oroville branch of the Great Northern Railway from Spokane is on the opposite side of the river and offers excellent transportation facilities. A splendid stand of timber surrounds the property and Kettle River furnishes a near supply of water so that mining can be carried on quite economically.

A 60-horsepower wood-fired boiler furnishes power to operate the mine pumps, hoist and a two-drill compressor. During August, 1920, a large oil engine and four-drill compressor were installed to replace the lighter equipment.

The vein was first explored near the surface by a 60-foot drift along the contact of an intrusive diorite dike and schists. Limited mineralization of galena, pyrite and sphalerite in a calcite, dolomite and quartz gaugue encouraged deeper exploration and a two-compartment vertical shaft was sunk to a depth of 270 feet. The collar of this shaft is on a

small cliff which forms the east bank of the river. From the shaft two crosscuts have been run to the vein which was then drifted on for length of several hundred feet. From the 270-foot level an 80-foot incline winze was sunk on the vein. This was filled with water at the time of visit thus confining the examination to the workings above the winze. The drifts and crosscuts total about 1,000 feet of work.

The formations exposed on the claims consist of granitic and dioritic gneiss, schist, quartzite and marbleized limestone. These are cut by large dikes having a composition of a diorite. A mile to the east of the shaft there is exposed a large mass of diorite and the dikes at the mine are evidently off-shoots from that intrusive body. The Orient gneiss and schists are believed to be the oldest formations exposed in Stevens County and are probably of Pre-Cambrian age.

The vein has a strike of north 75° west and on the upper levels the dip averages 65° but with depth it is straightening up and on the 270-foot level the dip is 75° to the southwest. It varies in width from six inches to six feet with three feet as an approximate average. The ore minerals are galena, sphalerite, pyrite and chalcopyrite enclosed in a vein filling of calcite, dolomite, quartz and brecciated country rock. There are several inches of gouge matter on both walls. The vein is directly associated with a dioritic apophyses from which the ore is likely derived. The wall rocks are badly altered and their primary minerals obscured by secondary developments. On the 270-foot level, 105 feet east of the collar of the incline winze, a pay-shoot was encountered in the vein and drifted upon for 75 feet. This shoot is also exposed in the levels above. Assay values are not known. The ore occurs mainly as small veinlets from one-sixteenth of an inch to four inches in width running irregularly through the vein matter. One hundred feet east of the pay-shoot the drift encounters some small seams and sporadic bunches of ore and it is possible that another ore-shoot may be developed here, but sufficient work has not yet been done to determine this question.

FIRST THOUGHT

The First Thought Mine has been the only gold property of importance in Stevens County. From 1904 to 1910 it maintained a steady production and is credited with an output of $650,000.

The mine is at an elevation of 2,900 feet and is two and one-half miles by air line northeast of Orient, or three and one-half miles by wagon road. An aerial tramway 13,000 feet in length links the mine and railroad. This tramway is now in poor condition.

The property is expected to reopen when gold mining conditions are stabilized and for this reason it was thought best to include a brief description of the property in this report. It has been idle since the report by Bancroft* in 1914, and by Weaver† in 1917, hence no re-examination was attempted. The following data are abstracted from the reports just mentioned.

The deposit has been formed in fracture zones in the latite lava and usually near intrusive granite dikes. The main deposit lies in a zone of intense brecciation. The width of the mineralized belt is 100 feet and it has a known strike length of 700 feet. The brecciated zone is intersected by minor fault zones and the richer ores are said to have been encountered near these intersections. The brecciated zone has been cemented with siliceous and calcareous solutions carrying pyrite and gold. The ore as shipped averaged $15.00 to the ton.

The mineralization is of Tertiary age and is believed to be closely allied to the gold veins of the Republic District, 30 miles by air line to the southwest.

The ore body is developed by three adit levels, and from the lower level a winze has been sunk 130 feet. The best portions of the vein above the adit have been stoped. The property is well equipped for mining operations.

---

*Bancroft, Howland, Ore Deposits of Northeastern Washington: U. S. Geol. Survey, Bull. 550, p. 72, 1914.

†Weaver, C. E., Mineral Resources of Stevens County: Wash. Geol. Survey, Bull. 20, 1920.

FERRY COUNTY

REPUBLIC DISTRICT

LOCATION AND ACCESSIBILITY

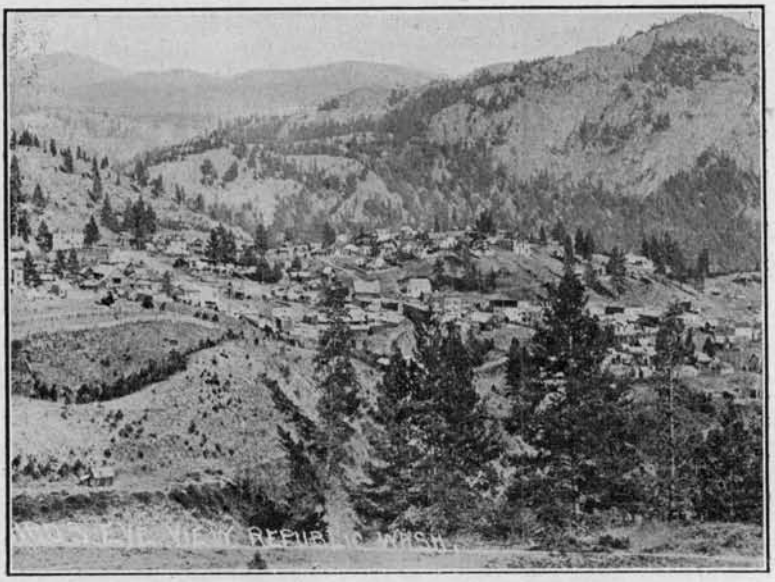
The Republic District is in the northwestern part of Ferry County, 25 miles south of the international boundary. While the legal boundaries of the district embrace practically 400 square miles and include a part of the Sheridan District and the Belcher District, yet the mineralized area characteristic of the Republic District proper, is included in an area of not over 20 square miles surrounding the town of Republic. The properties in the area operating during 1919 are all in the near vicinity of Eureka Gulch, just north of the city limits of Republic and can be included in an area of one square mile.

Republic, the principal town of the district, is reached from Spokane over the Spokane, Republic & Oroville Branch of the Great Northern Railway, a distance of 178 miles. This line branches at Curlew, 22 miles north of Republic; one branch continuing on to Republic and the other trending westward to Oroville, where it connects with the Wenatchee-Oroville Branch of the Great Northern Railway, thus connecting the district with the Coast Cities. The Spokane & British Columbia Railway formerly maintained a tri-weekly service between Republic and Danville, but during 1919 this road ceased operations. Railroad spurs from Republic extend up Eureka Gulch and practically all the producing mines load directly from their mine bunkers into railroad cars.

By automobile from Spokane the district can be reached over a road which follows up Sanpoil River. It can also be approached from Stevens County via Laurier.

POWER

Lack of adequate and cheap power facilities is one of the retarding features of the district. Electric power for mining and milling is not now available. The nearest power plant is Bonnington Falls, British Columbia. The construction of a transmission line about 30 miles in length into Republic was started several years ago but the work was abandoned on account of financial difficulties. The Similkameen Power Com-



Town of Republic, view gives excellent idea of topography of surrounding country.

pany near Oroville in Okanogan County is developing a large power plant and may later extend its lines into Republic. Steam, distillate and crude-oil engines at present meet the power requirements. Timber is plentiful around Republic and wood for steam power can be secured at a nominal cost. Distillate in tank-car lots costs 21 cents per gallon during 1919, and crude-oil nine cents per gallon. The most efficient power installation is that at the mine of the Northport Smelting and Refining Company. This plant includes a 180-horse power Bessemer crude-oil engine, with a similar type 80-horse power engine for reserve use.

COSTS

During 1919 the freight rates to the Tacoma, Northport and Trail smelters were between $3.00 and $4.00 per ton. The treatment charges were between $3.50 and $4.00 per ton. Thus the freight and treatment charges ranged between $6.00 and $8.00 per ton, depending upon the smelter contracts and freight rates. In view of the intermittent mining operations, the mining costs are difficult to approximate. Under ordinary

conditions the mining costs probably average about $3.00 per ton and under certain local conditions it is undoubtedly costing some of the companies as high as $6.00 per ton to mine their ores.

METHODS OF MINING

The mining methods of the district are comparatively simple. Shrinkage stoping is practiced and since the veins have filled open fissures the walls stand well without timbers. Many of the old stopes, mined more than 20 years ago, are still in good shape. The veins all stand at angles steeper than 45 degrees and the ore is drawn from the stopes by gravity. The topography in the vicinity of the deposits is not rugged; the highest points of the veins are never over 300 feet above Eureka Gulch and consequently mining by adit tunnels is effective only on the upper limits of the deposits. The general practice was to sink vertical or inclined winzes from the adit tunnel, thus putting the hoist room underground. In the early history of the camp there was a variety of small companies each working one or a very limited number of productive claims. This practice resulted in a variety of small and individual workings. The tendency in later years has been toward consolidation and the working of a group of claims through a central shaft.

METALLURGY

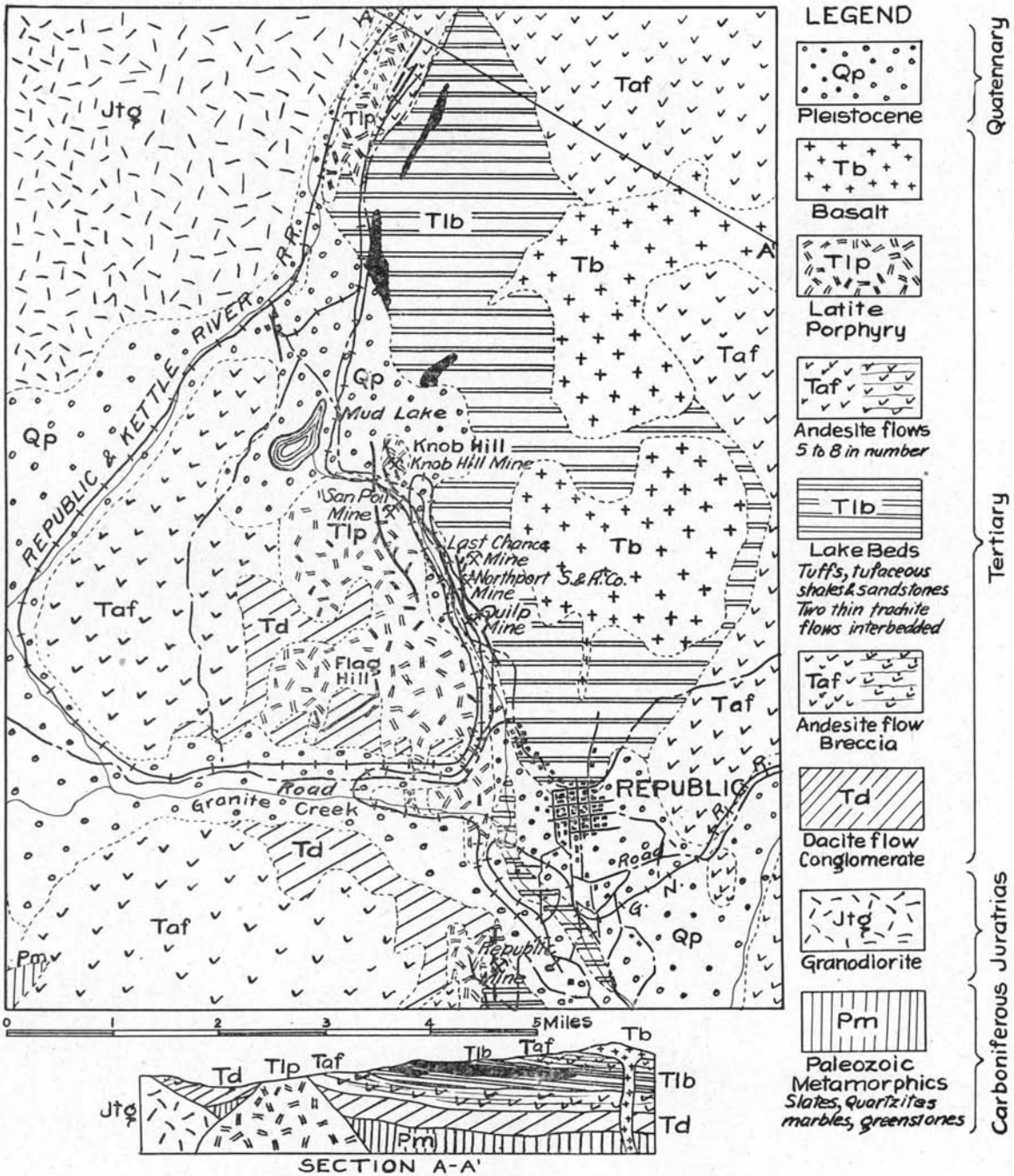
The Republic District will not return as a substantial producer until the metallurgical problems of dressing its ores have been economically solved. Five mines during 1919 were shipping limited tonnages of crude ore to the smelters, averaging $10.00 to $15.00 per ton. All the properties mine largely through shafts sunk to varying depths and as the workings are carried deeper the mining costs are mounting rapidly. Freight rates have advanced and treatment charges at the smelters have remained favorable because at certain plants the siliceous ores are needed to flux the heavy sulphide ores from other districts.

If a plant of several hundred tons capacity, and capable of treating $5.00 ore at a profit, could be designed it should

be capable of drawing a large tonnage of $5.00 to $8.00 ore from the numerous mines of the district. Such a mill should probably be started as a 100-ton unit and then as the operating problems were solved additional units could be built as required.

When studying the history of the mills of the district it is found that they ultimately failed. In certain instances the failure was due to metallurgical difficulties and in others they were due to the violation of certain economic and business laws. The metallurgy of the ores has evoked considerable discussion. The outstanding features seem to be that the values are carried chiefly in tetrahedrite, small amounts of chalcopyrite and pyrite, free gold very finely divided, and some gold selenide. The most successful extraction has been effected by subjecting the ore to very fine grinding, followed by cyanidation. The Sanpoil Mill, which was the last to operate in the district, reported an extraction of 90 per cent and its failure is attributed to unsound financial condition of the company rather than a metallurgical failure.

Ore dressing practice has made effective strides during the last 10 years. The grinding costs which were a big item in former Republic mills could be materially reduced by the installation of modern coarse crushing machinery followed by ball and pebble mills. As far as is known, systematic flotation experiments have not been attempted on the Republic ores. The sulphide minerals in the ore should float readily when ground finely enough to be unlocked from the quartz and some excellent results have been reported from the flotation of finely divided free gold. If flotation is not fully effective, then cyanidation and possibly flotation treatment of the cyanite tails might offer an avenue of attack. In view of the present milling practice and the tonnages of medium low-grade ores available, it is not tenable that these problems should go unsolved.



GEOLOGIC MAP OF REPUBLIC DISTRICT

Recopied from Washington Geological Survey Bulletin No. 1.

GEOLOGY

The geology of the Republic area has been well interpreted by Umpleby*, Bancroft and Lindgren†. The scope of this report is not to attempt a duplication of their work, and for complete information the reader is referred to these reports.

The following summary statement of the general geology is quoted from the report of Umpleby: "The geologic history of the Republic district has as its great features sedimentation in the Paleozoic, erosion with minor vulcanism in the Mesozoic, igneous activity and erosion in the Tertiary, and continental glaciation in the Quaternary.

"The oldest rocks exposed in the district are the metamorphic equivalents of a great series of shale, sandstone, limestone, and lava flows which are of Paleozoic age, and are provisionally assigned to the Carboniferous. After the deposition of the series, the area passed through a long period of crustal disturbance, which, although not developing sharp folds, metamorphosed the beds and raised the area far above sea level. Either during this period of crustal disturbance or shortly thereafter great batholithic masses of granodiorite were intruded into the Paleozoic series.

"From the time of the granodiorite intrusions, which are probably of early or middle Mesozoic age, to middle Tertiary times, there was a great period of erosion which may be divided into two parts: a first, during which the entire area was reduced probably to base level (Eocene surface); and a second which was introduced by decided elevation and during which broad valleys at least 2,500 feet deep were developed.

"The next rocks in order of formation are of Oligocene age, and occupy one of these broad, deep valleys. They are dacite flows, including great quantities of stream gravels. Overlying these, unconformably, are andesite breccias, lake beds, and andesite flows all of which occur within the old

*Umpleby, J. B., Geology and Ore Deposits of Republic Mining District: Washington Geol. Survey, Bull. 1, 1910.

†Lindgren, Waldemar, and Bancroft, Howland, The Ore Deposits of Northeastern Washington: U. S. Geological Survey, Bull. 550, 1914.

erosion valley. Next in order of age are intrusive latite porphyries with which the ore deposits are thought to be genetically related.

"From the time of the latitic intrusion to the Pleistocene, erosion was the dominant process, although during this time there was a short period of basaltic eruption. In the Pleistocene period, the Cordilleran ice sheet covered the entire area."

VEIN SYSTEM

The Republic vein system is made up of a series of north-south filled fissures which form the major vein mosaic. The north-south system is made up of from one to four practically parallel veins, which vary in strike from 7° east to 30° west of north, and dip toward the east. Cross fractures lead out from the major fractures and often form a connection between two parallel veins. The cross fractures seldom extend over several hundred feet in length. Their strike is northeast and they are characterized by a steep southerly dip. This vein series is confined to an area one mile wide in an east-west direction and five miles in length. It is best exposed along Eureka Gulch, where is found the most closely set vein pattern in the State. The Surprise vein appears to fill the major fracture of the area. Its most southerly known extremity is the south workings on the Quilp claim and it has been mined at several places to the north for a distance of over a mile.

The veins are of contemporaneous origin, with the north-south trending veins filling the major fractures and the east-west veins filling cross fractures between the parallel north-south fractures. The cross fractures in some cases are minor fractures turned-off at approximately right angles to the main fractures by complex stresses set up in the formations.

VEIN STRUCTURE

Three types of quartz were observed in the unaltered vein fillings. The first is a vitreous quartz often exhibiting crystal faces. These crystals show a tendency to develop outward in interlocking aggregates from the vein walls and are considered to be evidence of accumulative deposition in an open fissure. Ordinary milky quartz forms a large percentage of the vein filling and is interbanded with a dull cherty, dark-

blue, porcelain-like quartz that might better be termed a jasperoid. Drusy cavities coated with brownish calcedony are not uncommon throughout the veins. In thin-section the veins appear to be made up of quartz, chalcedony, opal, calcite, and adularia with minor amounts of metallics.

The most distinguishing feature of the veins is their wavy bandings roughly parallel to the walls. The alternating bands of dark-bluish chert and white quartz forms a marked contrast. The ore minerals occur as black, thread-like, crinkly, and concentric bands which follow roughly the banding system of the veins. These thread-like bands are made up of tetrahedrite, pyrite, chalcopyrite, and carry free gold extremely finely divided; free gold is rarely visible to the unaided eye. Gold selenide is also believed to be present, and the question of its occurrence has been a much mooted problem. To determine this problem, if possible, the following analysis of the Republic ore was made in the laboratory of the U. S. Geological Survey.*

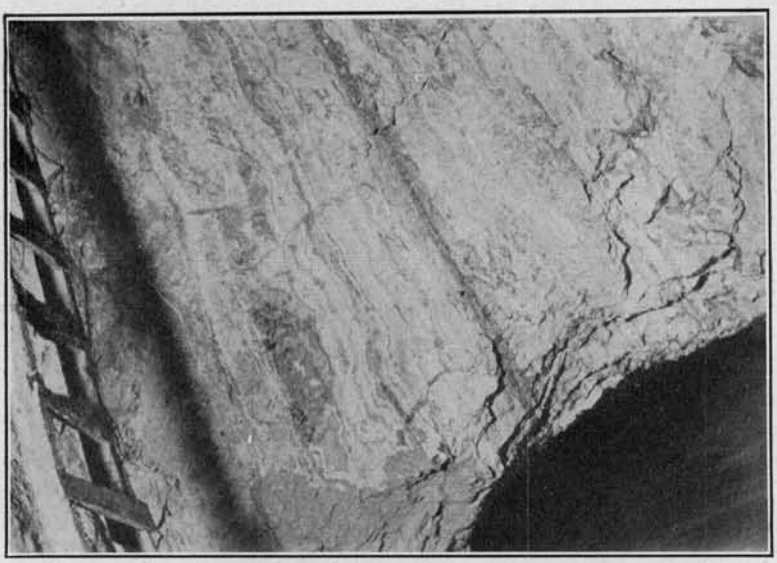
	Analysis	Metallic Mineral constituents recalculated to 100%
Cu	15.72	22.90
Ag	14.01	20.41
Fe	3.75	5.46
Zn	1.12	1.63
S	15.40	22.43
Sb	12.06	17.57
As	1.80	2.62
Au	2.99	4.36
Se	1.80	2.62
Gangue (calculated)	31.35	....
	100.00	100.00

From this analysis and a series of leaching tests using solutions of sodium sulphide the conclusion was reached that the evidence pointed toward the existence of a normal auric selenide (Au2Se3) as present in the gold ores from the Republic mines.

The veins vary in width from a narrow streak to 15 feet, while five to six feet is probably a general average for those veins now being worked.

The values are localized in ore-shoots and in certain sections of the shoots are found small lenses of very rich ore carrying free gold. This bunchy nature of the rich ore holds true

*Bancroft, Howland, Ore Deposits of N. E. Washington, U. S. Geol. Survey, Bull. 550, p. 149.



Vein as exposed in stope on 400-foot level of Last Chance Mine. Note crinkly banding of vein, also inclusion of andesite wall-rock near footwall of the vein.

for many gold veins of Tertiary age, those of Nevada and Colorado forming prominent examples. The ore-shoots usually rake toward the south at a steep angle. Their length along the strike varies up to several hundred feet and they are strongly continuous on the dip of the vein. The gold-silver ratio has a considerable latitude of variation. An average of several thousand tons of ore shipped from the Last Chance Mine gives 7.85 ounces of silver to each ounce of gold.

The deposits were planed by glaciation during comparatively recent time. The water level is high and the zone of oxidation comparatively shallow. High-grade ore often starts at the grass roots and many of the pay-shoots have been stoped through to the surface. The silver values have been subjected to limited leaching reactions in the upper zone, but this is only of minor importance.

The deepest workings in the camp are on the Quilp claim, 800 feet below the outcrop. The vein here is strong, clean-cut, and well mineralized. The veins filling the major fractures show promising evidence of continuing to reasonable depths below the present workings. There are other

Eureka Gulch, Republic District. Surprise vein trends parallel to the gulch and outcrops in the railroad cut shown in the left of the view.

smaller veins in the camp which indicate that they will pinch down to small seams at depths of 300 to 600 feet below the level of Eureka Gulch.

ALTERATION OF THE WALL ROCKS

Bancroft and Lindgren* made a thorough study of the wall rock alterations and the following is quoted from their report:

"Over a considerable area along the vein system and spreading half a mile or more from the veins themselves, a process of alteration has gone on during the epoch of vein formation. It has affected both andesite and quartz latite porphyry, making the two rocks in places difficult to distinguish. The alteration has changed the color of these rocks to a dull green and has peppered them with small crystals of pyrite. The alteration is typically propylitic. The secondary products are calcite, chlorite, epidote, and pyrite; sericite is less prominent, though feldspar crystals are partly replaced by it. In places the alteration of the feldspar has resulted in adularia. The groundmass of the rocks is usually least altered. Calcite is the most prominent mineral. This greenish rock usually adjoins the quartz veins and bleaching due to complete sericitization is rarely if ever observed. In places a silicification has occurred for a short distance from the vein. The altered and propylitic rock contains practically no gold."

GENESIS OF THE DEPOSITS

The Republic ores appear in no way related to other deposits throughout the State (except veins of the First Thought type near Orient), and they represent an individual type of vein formation restricted to a very limited area. The several investigators who have reported on the district agree that the veins were formed in open fissures near the surface by ascending hot waters.

These fissures were evidently developed by the intrusion of the latite porphyry. The vein matter was brought in as a part of the intrusion; it collected in the lower zones of the cooling magma, and after the outer crust had been partly solidified and fractured, the vein filling was injected into the open fissures in the form of hot solutions. Umpleby* has pointed out that as the veins cut a series of formations which accumulated in a post-Eocene valley eroded in a peneplain which rose only 1,800 to 2,300 feet above the present elevation of the veins, they could not have been formed at a greater depth than 2,500 feet below the surface, the average present elevation being taken at 3,200 feet. In all probabili-

*U. S. Geological Survey, Bull. 550, p. 152, 1914.
*Washington Geological Survey, Bull. 1, p. 42, 1910.

ty the present outcrops were less than 1,000 feet below the surface of the lavas at the time of the vein formation.

Since some of the veins cut lake bed formations considered to be early Miocene in age*, and also flows of andesite which rest conformably on the lake bed formation, and some of the veins are in turn cut by dikes of basalt, the intrusion of the latite porphyry and the subsequent vein formation evidently took place following the flows of andesite and before the outpourings of the basalt. They are probably late-Miocene in age.

The existence of an open fissure before the coming of the veins is suggested by the stability of the walls after the vein is mined out. The quartz crystal intergrowth, drusy structures, parallel banding, beautiful crustification and propylitic alterations all tend to strengthen the evidence that the veins were formed in an open fissure at shallow depth by ascending hot waters.

The occurrence of the Republic ores is without a known similar parallel in the United States. The veins of Tonopah, Nevada, bear the strongest relations. However, a striking similarity is found in the Rodjang-Lebong field in southern Sumatra. According to Beck† the veins are enclosed in andesite. The bluish-gray quartz is beautifully banded in thin concentric crusts of "fibrous quartz." The rich ore is indicated by thin dentritic crusts similar to the Republic ores.

KNOB HILL

General Features.—A small dome shaped hill at the head of Eureka Gulch gives the Knob Hill Mine its name. The holdings which consist of three patented claims known as the Knob Hill, Alpine, and Mud Lake, are located on the northern extremity of the Republic vein system.

Active development of the property began about 1910, and, according to the company's statement, the production from August 1, 1910, to January 1, 1912, was 7,192 tons of shipping ore which had a gross value of $224,795. This ore yielded 10,850 ounces of gold and 31,914 ounces of silver and

*Idem. p. 25.
†R. Beck, Lehre von den Erzlagerstatten, Vol. 1, p. 488, 1909.

the net returns were $149,005. Since that date the property has produced more or less regularly. During 1915 and 1916 production went ahead steadily, giving a total of 10,433 tons of ore shipped with an average value of $18.00 per ton. During 1917, 1918 and 1919, approximately 20,000 tons of ore were shipped. The total production is in the neighborhood of 50,000 tons at a total value of between $700,000 and $1,000,000.

By 1913 the company had distributed $70,000 in dividends. During 1917 an additional $35,000 was paid, making a total of $105,000.

During the first half of 1919 a crew of 10 men were employed. The production averaged about 300 tons per month of ore assaying $14.00 per ton. Operations were suspended during the last half of 1919 and again resumed early in 1920.

Surface equipment consists of a 50-horsepower distillate engine which operates a five-drill compressor. Power is furnished to the hoist by a 15-horsepower distillate engine. Other surface equipment includes an assay office, and a well-equipped blacksmith shop. The ore from the mine is dumped into a chute leading to the ore bin from which it is loaded directly into railroad cars.

Development.—The underground workings of the Knob Hill Mine total several thousand feet, and are open to the surface on three levels. The veins outcrop on the slope of Knob Hill and are opened by a drift on the Knob Hill vein 100 feet below the outcrop from which an extensive level known as the 100-foot level has been developed. Two other veins, known as the Alpine and Cross veins are opened on this level.

Near the mine buildings and 132 feet vertically below the 100-foot level, a crosscut is driven westward 250 feet and the 300-foot level developed by approximately 2,000 feet of drifting, crosscutting, etc. From the 300 level stopes have been opened on the three veins to the surface. A winze has also been sunk on this vein and an intermediate, called the 375-foot level, developed.

A short distance north of the portal of the 300-foot adit a vertical shaft has been sunk to a depth of 300 feet. A cross-cut has been run to the Knob Hill vein and the 500-foot level developed. Three large stopes, numbered A, B, and C, have been broken through on the Knob Hill vein to the 300-foot level.

The walls of the stopes stand permanently without timbering, and this combined with the favorable dip of the vein promotes reasonable mining costs.

Geology.—Latite porphyry is the predominating formation of Knob Hill. This formation has been cut by a vein pattern of three parallel northwest trending veins, two of which are joined by a cross-vein. A dark, fine-grained dike five to fifteen feet wide and post-mineral in age, trends north 40 degrees east and cuts the veins displacing them slightly. This dike is badly altered and its identity obscured. In composition it approaches basalt. North of Knob Hill the sur face is covered with morainal material which is directly underlain by tuffaceous lake beds. The line of strike of the north-south trending veins carries them into the lake beds on the low hill east of Mud Lake. The vein fillings are the several varieties of quartz so typical of the veins of the district. The gold-silver ratio averages about three ounces of silver for each ounce of gold.

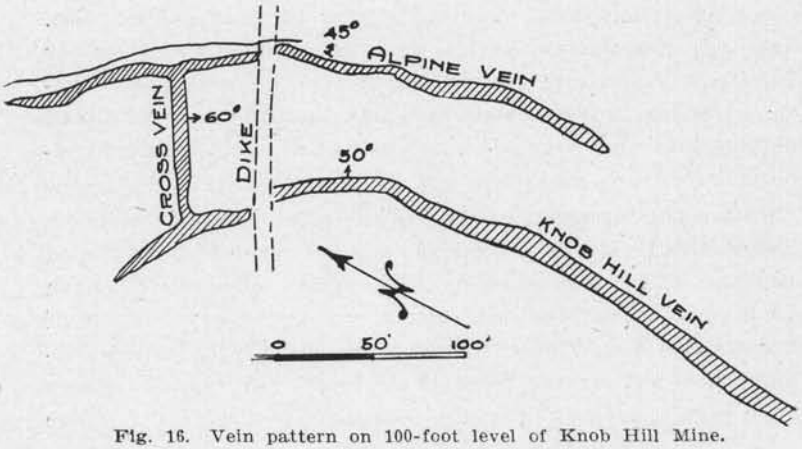
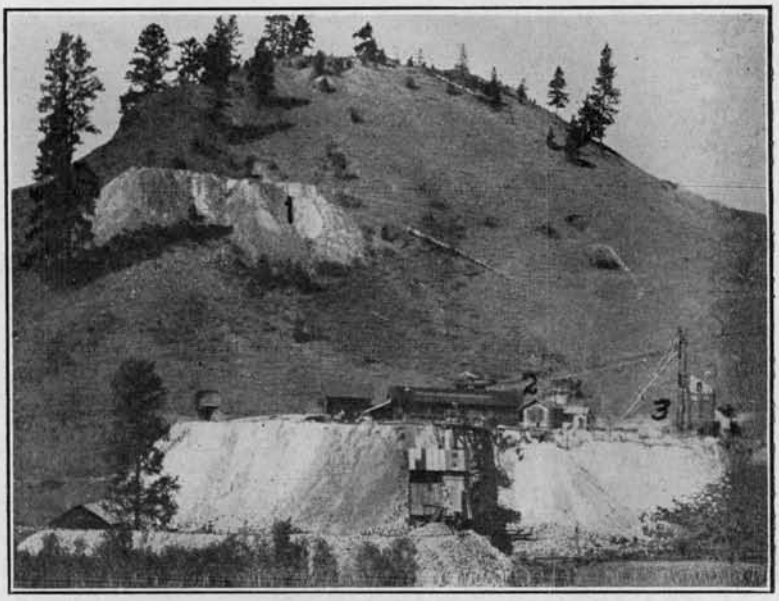


Fig. 16. Vein pattern on 100-foot level of Knob Hill Mine.

WASHINGTON GEOLOGICAL SURVEY BULLETIN NO. 23 PLATE XVIII



Knob Hill Mine, Republic District. (1) Upper, or 100-foot level, (2) Portal of 300-foot level, (3) shaft.

Veins.—The workings disclose a rather complex but exceedingly interesting vein system. The first and most productive of the veins is known as the Knob Hill. It trends in the form of a flat convex toward the west; the average strike is north 25° west and the dip 45°—50° northeast. The location, general characteristics, and dip suggest that it may be a continuation of the Black Tail vein. Since the Republic veins all tend to curve slightly, rather than to follow a straight course, it may be a northerly extension of the Surprise vein, although the difference in dip of the Surprise and Knob Hill veins argues against this hypothesis.

The shipping ore contained in the Knob Hill vein between the 500-foot level and the surface has now been largely stoped out. On the 100-foot level the ore has been mined for a length of about 400 feet, the vein having an average thickness of three to five feet. These figures hold fairly true for the 300-foot level, but on the 500-foot level the pay-shoot appears to be about 300 feet long and the vein to have an average

thickness of two to three feet. Further production of ore from this vein must come largely from below the 500-foot level.

During 1920 the shaft was sunk an additional 100 feet. Eighty feet below the 500 level the shaft passed through the vein and 20 feet below this point a crosscut was run 20 feet from the bottom of the shaft to the vein. At the time of visit drifting had just been started on this vein. It is much smaller than on the levels above but not enough work has been done to determine the extent and value of the pay-shoot on this lowest level.

Closely paralleling the Knob Hill is a second vein known as the Alpine, which is noteworthy for the fact that although quite small it has yielded some very rich ore. On the 100-foot level the two veins are separated by about 75 feet of country rock but on the 300 level this distance has increased on account of the dip of the Alpine being at a slightly lower angle. The Alpine vein occurs as a narrow filling in the fractured country rock which has been cemented by quartz and some rich shoots of ore. Pillars remaining in the old stopes between the 300 and 100-foot levels indicate that it had an average thickness of two and one-half feet and a stope length along the vein of approximately 400 feet. On the 375-foot level this vein pinches down to a few inches in width, and then disappears. It has not been found on the 500 level, but the exploration work there is not conclusive.

Several hundred feet northwest of the dike the Alpine vein enters tuffaceous lake bed formations. This softer material allowed the vein to gain an average width of three to four feet. Approximately 400 feet northwest of the dike the vein is cleanly severed by a fault. Beyond the fault the face of the drift exposes a spectacular formation made up of rounded and angular granite boulders cemented into a breccia conglomerate by a dark, fine-grained, extrusive flow. The whole is now decomposed into a soft crumbly mass.

From near this fault on the 300-foot level, a crosscut was driven 350 feet southwest where a new vein known as the Mud Lake was encountered. This vein varies from eight to

fifteen feet in thickness, strikes about north 25° west and dips 50° northeast. It is made up largely of dark to light porcelain quartz, which in places exhibits wavy bands and is said to average about $4.00 per ton in gold and silver. An exploratory raise was opened on the vein to the surface.

Connecting the two veins is a third or cross vein, about 80 feet in length and having an average width of three feet of good ore. This strikes north 70° east and gives the vein pattern the shape of the letter "H."

Genesis.—Before the coming of the ore solutions, a series of open parallel fissures developed along what is now Eureka Gulch. Where these parallel fissures were quite close together, strains that existed in the crustal rocks found relief in cross fractures between the parallel fissures. These fractures were later filled with ore minerals and give the vein-mosaic to the area. The cross vein in the Knob Hill Mine has no extension beyond either the Alpine or Knob Hill veins; it simply forms a connection between these two fissures and then terminates.

QUILP

The Quilp Mine is situated on the east side of Eureka Gulch, partly within the northern city limits of Republic. First known as San Poil, it was one of the pioneer properties to be located after the reservation was thrown open for mineral entry, but was later relocated as the Quilp.

Production.—Total production for the Quilp Mine, 1900 to 1920 inclusive, is 57,334.6 dry tons. Smelter values equals 95 per cent of gross or $720,938.70; the shipments contained gold, 30,210 ounces; silver, 241,525 ounces.

Development and General Feature of the Deposit.—The deposit is worked through two shafts, sunk near the north and south extremities of the vein respectively. The older workings are near the southern end of the vein and are reached through a vertical shaft with a depth of 400 feet. The hoist room for the vertical shaft is built in the mine at the adit level and about 100 feet below the outcrop of the vein. From this shaft drifts have been driven on the vein, and pay-shoots

stoped to the surface. The vein varies in thickness from 6 to 12 feet and the pay-shoot was evidently about 150 feet long. Blocks of ore said to average $6.00 to $8.00 per ton have been left standing in the mine. On the 400-foot level a drift has been driven northward to connect with the 600-foot station of the Surprise incline shaft.

The vein.—The location of the Quilp claim covers the most southerly known extremity of the Surprise vein. From the Quilp ground this vein can be followed north directly into the Surprise claim, but toward the south it has not been successfully traced beyond the Quilp property. The average strike is north 25° west and the dip is variable with 65°—70° northeast as the general average. Above the railroad cut along the east side of Eureka Gulch, it can be observed outcropping boldly at several places. The wall rock is a dark-green propylitic andesite. As is common to the district, the vein is made up of glassy, milky, and porcelain-banded quartz, through which are concentric, crinkly black ribbons carrying the values. The width of the vein varies from two to 15 feet in thickness and consistently averages seven to eight feet. It has been explored on its dip for a depth of 800 feet below the outcrop, the greatest depth so far gained in the district. On the 800-foot level the vein averages about eight feet in thickness and is apparently well mineralized. Larger amounts of pyrite and chalcopyrite were observed here than elsewhere in the Republic veins, and it is possible that with depth, the character of the mineralization may undergo some changes. The strong appearance of the vein on the lower levels argues encouragingly for its persistence to still greater depths.

On the lower levels the brecciation, caused by movements along the plane of the vein, is more pronounced and the walls are sharply defined and slickensided. One hundred and fifty feet south of the winze on the 800-foot level the vein in the face of the drifts is ground to a friable mass.

On the 100-foot level 90 feet north of the vertical shaft, the vein is severed by a fault along which there is four feet of plastic gray clay showing strong striations. Mixed through

the gouge matter were found rounded pebbles of vein material. The direction of the fault is north 30 degrees west and its dip 55 degrees northeast.

Near the hoist room a small stope, known as the "Black Damp," has been opened on a small vein striking south 70° west and dipping 35° south. This vein is said to carry appreciable silver values, but for some reason it has been but little explored. While its junction with the Surprise vein has not been reached, it apparently is a branch fissure leading off from that vein.

Through a working agreement with the Lone Pine Surprise Company, the northern end of the Quilp ground is being worked through the Surprise incline shaft. This shaft is located practically on the south end line of the Surprise claim and has been sunk to a depth of 700 feet. An ore-shoot, which apparently had its upper limits within the Surprise ground, has with depth raked toward the southeast and into the Quilp property. The ore-shoot on the 700 level in the Quilp ground is about 150 feet in length, and the vein has an average thickness of eight feet. All shipping ore above the 700 level has now been mined out and during 1919 ore was being shipped from stopes between the 700 and 800-foot levels. At the time of examination approximately 3,500 tons of ore were broken in the stopes ready for shipment. These two lower levels are connected by a small winze on the vein, and it is the plan of the management to deepen this winze and develop a 950-foot level.

LAST CHANCE

General Features.—The Last Chance Mine is located to the east of the Lone Pine claim. The surface plant is situated at the head of a small ravine that follows closely the south end lines of the Lone Pine claim until it opens into Eureka Gulch.

The property is managed and largely owned by C. P. Robbins, who was one of the first locators and active operators in the Republic district. The production up to and including 1919 totals approximately 24,000 tons, having an av-

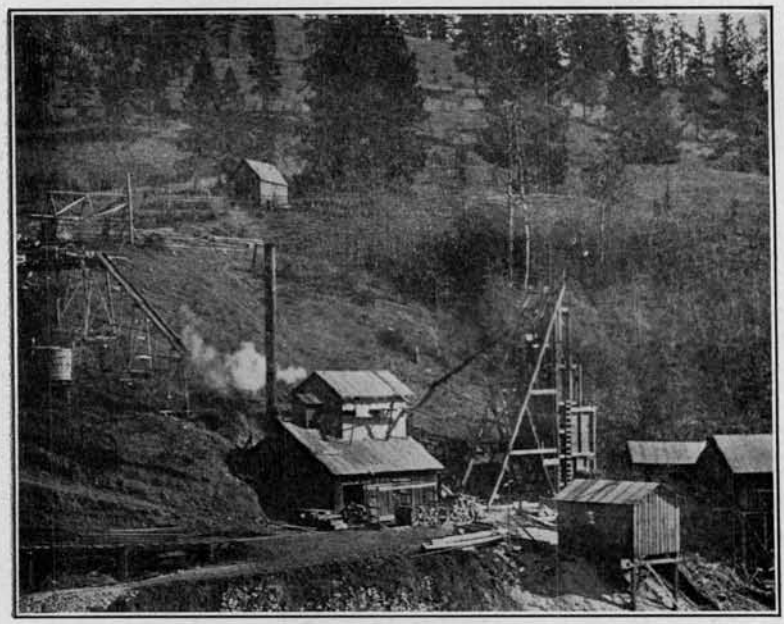
erage of about $13.00 per ton. During the first half of 1919 the production averaged about 50 tons per day, this being shipped to the Tacoma Smelter.

Surface equipment includes a five-drill compressor and a 35-horsepower hoist, steam power being furnished by a wood-fired boiler. The deposit is opened through a two-compartment vertical shaft sunk to a depth of 690 feet. The drifts and crosscuts total about 1,200 feet of work; from these extensive stopes have been opened.

The Vein.—The Last Chance production has come from the Lone Pine vein No. 2. This vein extends through the east side line of the Lone Pine claim, passes through the Insurgent Fraction and enters the Last Chance claim through its west side line. It has been productive of good ore in all three claims but has now been largely mined out above the 500 level. The strike averages north 27°—40° east and the dip varies from 70°—80° southeast. The vein is enclosed in andesite flow-breccia and is of the type characteristic of the camp, being composed of white and chalcedonic quartz banded with narrow concentric ribbons carrying the values principally in free gold, tetrahedrite, and pyrite. Crustification of calcite interbanded between the quartz causes the lime content to vary between 5 and 10 per cent. Angular fragments of the wall rock are often found included in the vein. In places these inclusions are 20 feet or more in length with other corresponding dimensions causing them to assume the proportions of horses in the vein. In places along the ore-shoot the values extend a foot or more into the wall rocks. The values are erratically distributed throughout the vein and require constant sampling vigilance to determine the changes. The ratio of the precious metals averages 7.85 ounces of silver to each ounce of gold.

The pay-shoot within the Last Chance claim varies between 100 and 150 feet in length, with its depth not yet determined. It appears to rake toward the northeast.

All the shipping ore between the 500 level and the surface has been practically stoped out. The old stopes between the 500 and 400-foot levels vary from 8 to 20 feet in



Shaft head-frame and power-house, Last Chance Mine, Republic District.

height and judging from pillars of ore left in the stopes, the vein must have averaged at least 8 feet or more in thickness.

The lower levels, now being mined, are known as the 500, 575 and 650-foot levels. The vertical elevation between the 650 and 575 levels is 104 feet. At the time of visit a raise was being driven from the 575-foot level to the 500 level as a preparation for stoping. The vein is reached from the 650 level by a 120-foot crosscut from the shaft. This work has but recently been completed and plans have been made for the opening of stopes. Between the 500 and 650 levels the vein is strong and clean-cut. It averages from 6 to 12 feet in thickness and is said to be of average value.

East of the shaft on the 500-foot level the vein begins to pinch down until it gives way to three to five feet of gouge matter carrying brecciated pieces of quartz. The gouge seams here suggest movements along the plane of the vein.

NORTHPORT SMELTING & REFINING COMPANY'S MINE

General Features.—The Republic Mines Branch of the Northport Smelting & Refining Company now owns the Black Tail, Lone Pine, Surprise, Pearl, Northport and Hercules claims, and the Belligerent, Apex and Ranney fractions. This group is now known as the Lone Pine Surprise Mine. The holdings of the company are situated on the east side of Eureka Gulch and extend to the north of the Quilp ground and west of the Last Chance.

When the Lone Pine workings were visited mining operations had been temporarily suspended to await the results of a pending suit brought against the Lone Pine Surprise Consolidated Mining Company (owners of the Last Chance Mine) to secure alleged extra-lateral rights on Lone Pine vein No. 2. Mine maps were not available for use, and the workings were visited unguided, hence ample opportunity was not afforded to make a satisfactory examination in the limited time available for the work.

The shipments during the first half of 1919 were reported to be approximately 50 tons daily, this being sent to the Northport Smelter where it is used as a siliceous flux.

Power Equipment.—In Eureka Gulch, near the collar of the Surprise shaft, an excellent power plant has been installed. This is now used to furnish power to both the Lone-Pine Surprise and Quilp properties. It consists of a 180-horse power Bessemer crude-oil engine which drives an Ingersoll Rand Imperial type compressor capable of developing 1,350 cubic feet of air per minute. This air is used for the mine drills and to operate a 75-horsepower Ottumwa hoist. Crude oil cost during 1919 approximately nine cents per gallon laid down at the mine; the 180-horsepower engine consumes about 120 gallons each shift. For reserve use the plant is equipped with a Bessemer 80-horsepower crude-oil engine, connected with a three-drill compressor.

Development.—Since the Black Tail, Lone-Pine, Surprise and Pearl claims were at one time individual properties, they have been developed more or less independently of one another.

Surprise Claim.—This claim extends northward from the Quilp ground and the Surprise vein can be easily traced through both end lines of the claim. The Surprise incline shaft has been sunk to a depth of 700 feet on the vein. Near this shaft a highly productive ore-shoot was encountered during 1910 and a large production made. This apparently is the same ore-shoot which raked to the southeast into the Quilp ground.

The average trend of the Surprise vein through this claim is north 30° west and it dips 65°—70° northeast. It exhibits the typical banded quartz of the Republic veins with a width of 4 to 12 feet. The vein is inclosed in propylitic quartz latite, which is difficult to distinguish from the adjoining andesite. Farther north the vein is opened by crosscuts driven from Eureka Gulch. A part of this ground is reported to be badly broken up by faults.

Black Tail Claim.—The Black Tail claim joins the Surprise on the east and was worked through a crosscut tunnel which has its portal near the level of the railroad grade on the west side of Eureka Gulch. The crosscut starts on the Surprise claim and is driven north 25° east. About 80 feet from the portal it intersects the Surprise vein. Three hundred and fifty feet farther, the crosscut intersects the Black Tail vein and drifts are carried to both the northwest and southeast. This vein trends north 40°—60° west, dips 45°—50° northeast, and is enclosed in latite porphyry and andesite. It is irregular in width and values and only a limited amount of stoping has been done. Southeast of the crosscut 120 feet, the vein has been cut off by a fault. The apparent direction of the fault is south 25° west and the striations suggest a vertical movement. Beyond the fault is found a soft crumbly formation which probably represents the tuffaceous lake bed series. In the crosscut tunnel about 50 feet before it cuts the Black Tail vein, is found a fissure filled with soft decomposed gouge-like material. This trends northward into the Black Tail vein and suggests an open fissure which was filled with foreign material before the introduction of the vein. Approximately 150 feet from

the portal of the Black Tail adit a crosscut has been driven northward to a vein known as No. 3 vein. This vein strikes north 45° east and dips 87° southeast, thus placing it at almost right angles to the other veins. The Surprise, Black Tail and No. 3 veins no doubt represent an irregular fracture pattern of contemporaneous origin.

Lone Pine Claim.—There are five veins on the Lone Pine claim, which have received more or less development. Of these the No. 2 vein has been the principal producer. This vein is reached through No. 2 adit tunnel which has its portal near the junction of the Lone Pine Gulch and Eureka Gulch. About 300 feet from the portal this tunnel intersects No. 2 vein and it is drifted on 300 feet further to the east side line of the claim, and above the drift stopes were broken through to daylight on a pay-shoot over 200 feet in length. This pay-shoot extends through the east side line of the claim into the Insurgent Fraction and has been mined by the Insurgent Company.

Near the line between the two claims an incline winze was sunk on the vein to a depth of 600 feet and near this point a vertical working shaft was sunk to the 500-foot level. Practically all commercial ore between the 500-foot level and the surface has been stoped out. The 600 level was under water at the time of examination. Judging largely from the size of the stopes and the pillars of ore remaining, the pay-shoot must have a length of about 200 feet in the Lone Pine ground. The vein is strong and clean cut, varying in thickness from 6 to 12 feet, and its structure is identical with the banded veins of the district. The best values are usually found near the walls with the foot-wall generally favored, although in many instances the reverse is true. Southwest of the pay-shoot the ground has been prospected without developing any new shoots of ore. On the 400-foot level about 600 feet southwest of the incline winze, the vein begins to show evidence of intense movements resulting along the plane of the vein. Streaks of quartz ground into a sugary mass and mixed with gouge trend through the vein parallel to the walls. The drift extends beyond this point but was caved and could not be followed.

Pearl Claim.—The Surprise vein extends the full length of the Pearl claim but has received little development work. The vein outcrops boldly in the railroad cut near the north end of the claim, also at the junction of Lone Pine and Eureka gulches near the south end line of the claim. The extent of its mineralization is not known to the writer. The property has recently been diamond drilled and there is some talk of sinking a large working shaft in Eureka Gulch to develop the vein with depth both on the Surprise and Pearl claims. From this shaft the Black Tail and Lone Pine veins could also be developed.

SANPOIL

The Sanpoil Mine is on the west side of Eureka Gulch, almost opposite the Lone Pine claim, and a short distance south of the Ben Hur Mine. The property was closed at the time of visit to the district and could not be examined.

Umpleby* states that the vein, which is enclosed in latite porphyry, extends throughout the entire length of the claim, and has the banded vitreous appearance characteristic of the entire camp. It is the southward extension of the Ben Hur vein.

A 100-ton cyanide mill was built on the property and successfully operated during 1914 and 1915. An excellent recovery is reported to have been effected by this mill, but in spite of this, financial difficulties reached a crisis and the property passed to a receiver. The Consolidated Mining & Smelting Company of Trail, B. C., subsequently purchased the property and it is worked by this company intermittently to furnish a needed supply of siliceous ore for smelter flux. The property was idle during the greater part of 1919 and 1920, but it is stated that approximately 10,000 tons of ore are broken in the stopes ready for shipments when needed at the smelter.

*Umpleby, J. B., Washington Geol. Survey, Bull. 1, p. 62, 1910.

PARK CITY DISTRICT

CASTLE CREEK MINING COMPANY'S PROSPECTS

On Castle Mountain in the Park City District, 25 miles southwest of Republic are located the workings of the Castle Creek Mining Company. This property has not yet advanced beyond the prospect stage although it has had a more colorful history than many of the large producers. It was first brought into prominence in 1906 when G. W. Loper organized and financed the Colville Mining & Smelting Company, began extensive exploration work on Castle Mountain and started the construction of a smelter at a small mining settlement called Park City. An excellent camp was constructed which included a modernly appointed log bungalow that might be mistaken for a hunting lodge transplanted from the Maine woods. By 1909 the failure of the venture became apparent and eastern investors, in an effort to alleviate their losses, organized the Castle Creek Mining Company and carried on extensive ill-advised exploration work. Platinum was reported from the analyses of the shales cut by several of the tunnels and a freak treatment plant for platinum recovery was constructed before the error was discovered. The smelter at Park City was never completed and the rusting machinery and deserted settlement mark another of the "ghost towns" of western mining history.

E. M. Cross and associates have recently taken a lease on a part of the Castle Creek holdings and during the summer of 1919 were employing a crew of five men to carry on further exploration work. This is the only new work in the Park City District since the visit of Bancroft* in 1910 and Pardee† in 1913. Therefor the district will not be discussed in detail in the present report.

The journey to the property from Republic, the nearest shipping point, involves a trip down Sanpoil River a distance of 14 miles to a small settlement called West Fork. The road then leaves the main highway and trends in a southwest direction along West Fork Creek for four miles

*Bancroft, Howland, The Ore Deposits of Northeastern Washington, U. S. Geol. Survey, Bull. 550, 1914.

†Pardee, J. T., Geol. and Mineral Deposits of the Colville Indian Reservation, Washington. U. S. Geol. Survey, Bull. 677, 1918.

and thence an additional six miles up its tributary, Gold Creek, to the camp of the Castle Creek Company. The camp is picturesquely situated near a chain of small woodland parks and is bountifully supplied with timber and water. Its elevation is 3,700 feet above sea level or 1,200 feet above Republic.

The claims are located along the contact of black shales, with the intrusive Colville granite, and a broad north to south trending belt of granite porphyry. The argillaceous shales are no doubt a part of the sedimentary series so well exposed in Stevens County to the east. The Colville granite is a part of a large granitic batholith which outcrops over an area of several hundred square miles in the Colville Indian Reservation and is fully described by Pardee*.

The broad belt of porphyritic granite that occurs in the Nespelem District extends northward into the Park City area and a tongue of this intrusion penetrates northward into the shales, to form the prominent ridge known as Castle Mountain.

Ore Deposits.—Along the contact of the shales and the intrusive granite are found sporadic lenses of quartz carrying values in argentiferous galena, pyrite, and marcasite. Occasionally, rich bunches of shipping ore are found but on the whole the possibility of developing a continuous body of commercial ore is not promising.

Other than the Mountain Boy property, which will be discussed later, a small production has been made from a series of irregular lenses of high-grade ore occurring in a small isolated patch of limestone near the crest of Castle Mountain. These lenses have yielded about 50 tons of galena averaging about 30 per cent lead and 20 ounces of silver to the ton. It is the search for the downward continuation of these deposits that has resulted in a series of adit tunnels being opened along the side of the mountain. This is particularly true of the Summit Tunnel, which has its portal at an elevation of 4,350 feet and is driven 350 feet through granite to gain depth under the lenses of ore exposed on the crest of the mountain. The few small bodies of galena inter-

*Pardee, J. T. U. S. Geol. Survey, Bull. 677, 1918.

mixed with quartz found along a shear zone in the granite was the only mineralization of note disclosed by the tunnel.

Four tunnels have been opened at various elevations on the north slope of the mountain about three-fourths of a mile southwest of the camp. The upper tunnel is well up near the crest of the mountain and has been driven for a length of about 1,000 feet through the roof rocks of shale, a few stringers of white barren quartz offering the only variations. At a slightly lower level No. 2 tunnel is opened along the contact of the intrusive granite and overlying roof of shale. The shale has a flat angle of dip and is noticeably faulted and contorted. Along the contact it shows evidence of alteration effected by the heat of the intrusive mass. Fifty feet from the portal a two-foot vein of quartz carrying scattering bunches of galena appears in the tunnel but the dip of the vein carries it under the floor of the tunnel. One hundred feet further a dark-green, fine-grained dike was encountered. Along the contact of this dike there is a vein of white quartz having an average width of three feet and carrying meager values in galena and pyrite. Neither of the veins cut in this tunnel has been prospected. Because the dike was exceptionally hard to drill an incline raise was driven to avoid it; this raise encountered the overlying shale and resulted in additional dead work.

No. 3 tunnel is opened about 120 feet farther down the hillside, and is driven south 80° for 100 feet through granite. No mineralization of note was observed in this opening.

The lower or No. 4 tunnel was being driven at the time of visit. Its direction is south 42° east through shale for a distance of 60 feet where the contact between the shale and granite was encountered. The contact has an irregular trend to the southwest and stands nearly perpendicular. Along the contact were found irregular small bunches of quartz carrying mineralization of galena and pyrite.