STATE OF WASHINGTON

Department of Conservation and Development

D. A. SCOTT, Director.

DIVISION OF GEOLOGY

S. SHEDD, Supervisor.

BULLETIN No. 31

(Geological Series)

LEAD DEPOSITS

OF

Pend Oreille and Stevens Counties Washington

BY

OLAF P. JENKINS

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LETTER OF TRANSMITTAL

Hon. D. A. Scott, Director, Department of Conservation and Development, Olympia, Washington:

SIR:—I have the honor to submit herewith the manuscript for a report on the lead deposits of Pend Oreille and Stevens counties by Olaf P. Jenkins. Considerable time has been spent in years past by the Washington Geological Survey studying the geology and mineral resources of Stevens County, and the results of this work are contained in the previous reports issued by the survey. Not all of the lead properties in Stevens County are included here, as some of them were idle at the time the field work for this report was done, and hence, very little new information was available in regard to these properties.

I recommend this report be published as a Bulletin of the Department of Conservation and Development, and designated as Geological Series No. 31.

Very respectfully,

S. SHEDD,
Supervisor, Division of Geology.

College Station,
Pullman, Washington, Dec. 6, 1924.

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INTRODUCTION

SIGNIFICANCE OF THE STUDY

One of the vital metals in the industry of our country is *lead*, and the United States ranks first in its production. Many of the lead deposits are exhaustible, occurring in the form of veins, pockets and chimneys. Lead seldom occurs disseminated through huge masses or mountains of rocks, as does copper, of which a great future supply exists in such forms.

The State of Washington contributes a small but appreciable amount of lead to the total production, ranking eleventh among the states. Most of the lead has come from one locality in northeastern Stevens County, although there are many small veins and prospects in the same vicinity. The geological conditions are favorable for the finding of more deposits of lead in both Stevens and Pend Oreille counties and without much doubt further prospecting and mining will reveal more deposits containing lead as the principal ore mineral.

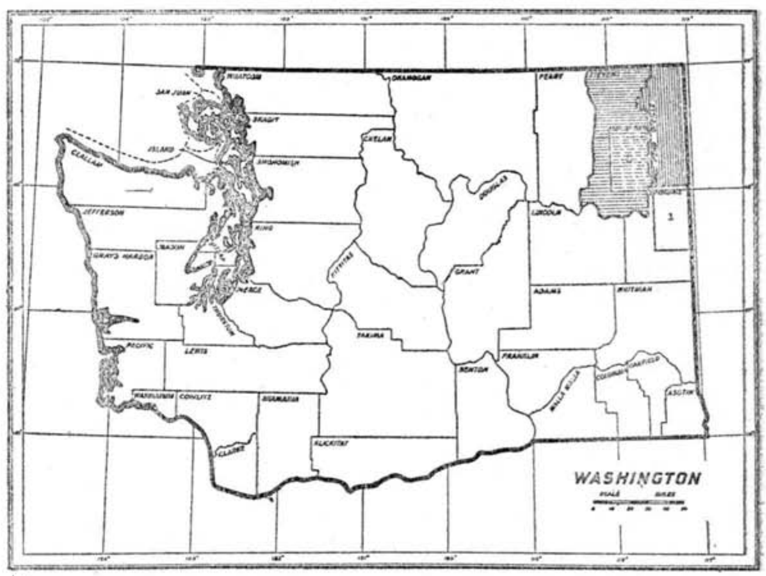

Figure 1. Index map of the State of Washington, showing especially the location of Stevens and Pend Oreille Counties. Most of the State's production of lead comes from a region in the extreme northeastern corner of Stevens County. Number 1 indicates the position of the Spokane topographical quadrangle, while Number 2 is that of the Chewelah quadrangle. The latter is at present in preparation.

PURPOSE OF THE REPORT

It is the object of this report to bring together the important known features of the lead deposits of Pend Oreille and Stevens counties relating principally to their location, occurrence, mineralogy and geology. A field study was made of most of the deposits and the results of this study are presented here, supplemented by facts found and recorded by geologists who studied the field at an earlier time.

SCOPE OF THE WORK

Although there are a number of silver-lead properties in the other northern counties of the State, Pend Oreille and Stevens counties represent the limit of the investigations included in this present report. Two months were spent in field study and a large part of this time was given to the regions about Metaline Falls and Leadpoint, where are located the most important lead deposits.

The region covered is rather large and since no published detailed topographic maps cover any portion of it, very little geological mapping was attempted. The writer feels, however, that through this method only can much further geologic work of consequence be done, except in direct connection with individual mining properties. The geology is complex and generalizations regarding its structure are misleading without much detailed map work to support ideas developed from observations made at various disconnected points.

RESULTS OBTAINED

The investigation of the lead deposits of Pend Oreille and Stevens counties has resulted in these conclusions:

1. That good lead deposits exist in the region.

2. That the deposits are for the most part irregular in shape—following fracture zones and breccia masses.

3. That the sulphide deposits were not formed near the surface, but at depths of many thousands of feet and have since been exposed through profound erosion covering a period of time geologically very long.

4. That the oxidized (carbonate) deposits are formed through surface oxidation of sulphide bodies.

5. That the extensive oxidation took place in pre-glacial times over a very long period—much longer than the time involved since the disappearance of the ice.

6. That the quartz vein type of deposit is often silver bearing.

7. That the source of the ore-bearing solutions was in the granite magma batholith below.

8. That the migration channels of ore solutions have been largely along fault zones.

9. That the final precipitation of the majority of the deposits has been in the dolomitic limestones where fracture zones favorable to ore precipitation occur.

10. That most of the deposits are, in part at least, replacement bodies.

11. That siderite is a more common iron mineral associate of galena than pyrite, except in the quartz-vein type of deposit.

12. That the thin basic dikes often associated with the ore bodies may be found almost anywhere. They have no special significance except that they followed the same lines of weakness in the rocks as did the ore solutions, and that they may have originated from the same magma. Some of the dikes are older but probably most of them are younger than the ore bodies.

13. That rock wedges formed by intersecting faults are associated with breccia zones and may often be found associated with ore.

ACKNOWLEDGEMENTS

In the field as well as in the laboratory, the writer was assisted by Virgil Barnes, who did much to broaden the scope of the work and to make possible the collection and identification of many interesting specimens. The description of the Cleveland mine is very largely his work.

Cordiality was found in every locality visited and to all those persons who helped to make the work practicable as well as pleasant, the writer is greatly indebted. Sketches and maps

were liberally given or loaned to the writer, who has, in many cases, had them reproduced for illustrations to make this report more explicit.

The writer wishes to acknowledge the help which reports previously published on the region gave him in this investigation. These reports are listed in the bibliography at the close of this bulletin. Those of special note were written by Howland Bancroft, Charles E. Weaver, and Ernest N. Patty.

GENERAL FEATURES REGARDING LEAD

MINERALOGY OF LEAD

IMPORTANT LEAD ORE MINERALS

Lead Ore Mineral	Composition	Lead Content
Galena	PbS	86.6%
Cerussite	$PbCO_3$	77.5%
Anglesite	$PbSO_4$	68.3%

The bulk of the world's supply of lead is produced from the sulphide mineral, *galena*. With galena is often associated zinc in the form of the mineral, *sphalerite* (also a sulphide), or its alteration products. Likewise in zinc mines lead is commonly present. Of the two metals, lead and zinc, the mineral forms of lead are much the more stable under the action of weathering. With galena, silver in varying amounts is often associated, generally regarded to be in the form of the sulphide. When silver is present in commercial amounts, the ore is said to be *argentiferous.*

Galena is a heavy but rather soft mineral. Crystals of it cleave into cubes, showing a brilliant metallic luster in contrast to its older surface, tarnished gray on exposure. The grain of a mass of galena may be dense and fine or may be much coarser in texture. In a few localities, the fine-grained variety (called "steel-galena") is often argentiferous. In some deposits, the mineral mass may appear stringy, which form is sometimes an indication of the presence of antimony.

With the blowpipe, galena is easily fusible on charcoal, producing a malleable button of metallic lead, sulphurous fumes, a yellow sublimate (PbO) near the assay, and a white sublimate ($PbSO_4$) far from the assay. Its hardness is 2½ and its specific gravity about 7.5.

The carbonate of lead, *cerussite*, often called "crystallized lead," is usually derived from galena, and occurs in the oxidized zone. In the Gladstone and Electric Point mines, a quantity of ore containing much of this mineral has been shipped. Although cerussite is generally light in color, white or gray, it is often found stained and mixed with the brown hydroxide of iron. The clean crystals have adamantine luster, and occur in fibrous and reticulated forms, as crusts, lining weathered-out cavities, as compact masses, and as "sand carbonate," an earthy or sandy form. The mineral is quite heavy, having a specific gravity of about 6.5. Its hardness is 3½. On charcoal cerussite may be fused easily to a metallic lead button, leaving a yellow coating of PbO. Cerussite is soluble in nitric acid with effervescence.

Like cerussite, *anglesite* is also derived from galena in the oxidized zone. In the alteration of galena, anglesite is first formed and then cerussite may be developed from anglesite by the action of carbonated waters. In the Gladstone and Electric Point mines, anglesite is common, though not so abundant as cerussite. Anglesite may form dark concentric layers or bands over a nucleous of galena. It may also occur as little tabular crystals, colorless, white, or gray, with adamantine luster, in cavities of the oxidized ore. Anglesite is heavy, having a specific gravity of about 6.3. Its hardness is 3. It fuses easily on charcoal to a metallic lead button. It is distinguished from cerussite, being soluble in nitric acid only with difficulty.

LEAD MINERALS OF LESSER IMPORTANCE FOUND IN PEND OREILLE AND STEVENS COUNTIES

Lead occurs in many forms of minerals. There are 120 lead minerals listed in Dana's Textbook of Mineralogy.* No doubt many of these could be found in the State of Washington if a special mineralogical search were made for them.

Besides the three chief lead ore minerals (galena, cerussite, and anglesite), several other kinds of lead minerals have

*Third Edition by W. E. Ford, 1922.

been found in Stevens and Pend Oreille counties. They are as follows: boulangerite, mimetite, bindheimite, galenobismutite, cosalite, pyromorphite, and wulfenite. Others may be found after further laboratory work is carried on.

The antimonial lead ore of the Cleveland mine consists for the greater part of a fibrous lead sulphantimonite associated with galena. It very closely fills the description of jamesonite, $Pb_2Sb_2S_5$, as given in Dana's Textbook of Mineralogy. Previous to the writer's investigation, however, several specimens from the Cleveland Mine were sent by Mr. L. K. Armstrong and Mr. Henry Fair to the Smithsonian Institution for identification. Mr. Earl V. Shannon reported on these specimens and makes the following statement.*

"The fibrous antimonial lead sulphosalt I believe to be boulangerite. There is a tendency, among geologists, to refer all minerals of this general nature to jamesonite, but Spencer and Schaller have, within recent years, shown that jamesonite contains essential iron, has a cleavage across the fibres, and is a comparatively uncommon mineral. So far as I know it has not been definitely identified in the United States. I have found boulangerite to be the commonest of these sulphosalts and it is a characteristic constituent of the ores at Iron Mountain, Montana, and several mines in the Wood River (Hailey) and Coeur d'Alene districts in Idaho. I have intended analyzing the mineral from the Cleveland mine but have not yet had time to do so. I am fairly certain, however, that it really is boulangerite.

"The other minerals I have identified, in addition to the common ones, sphalerite, galena, pyrite, arsenopyrite, etc., are valentinite in small rounded dirty white crystals which are orthorhombic but look like distorted octahedra; mimetite, which occurs as tufts of minute colorless acicular prisms, bindheimite, as canary-yellow ocherous material; and scorodite which forms dull greenish porous masses. Other specimens contain cerusite, calcite, and aragonite, the latter, in ocherous limonite, looking like smithsonite and calamine."

*Personal Communication, Dec. 15, 1924.

Boulangerite, $Pb_5Sb_4S_{11}$, is a soft bluish lead-gray mineral occurring in masses of fibrous crystals, often with plumose structure. In mining it breaks easily into a dirty powder. *Mimetite*, arsenic pentoxide, and *bindheimite*, hydrous antimonate of lead, are oxidation products of the original or primary lead sulphides and antimonites.

A mineral as rare as *galenobismutite*, $PbS.B_2S_3$ (a lead sulphobismutite) cannot be considered a lead ore mineral, but its occurrence is interesting from a geological standpoint, as described by Bancroft* in the Deer Trail district. It is found in the Germania mine in the fractures of the tungsten mineral, wolframite (which occurs in quartz veins in granite), and shows a second period of mineralization, probably corresponding to the lead-silver period of mineralization of the silver-lead mines herein described. Bancroft** also describes a mineral from the Tungsten King mines, cosalite, $2PbS.Bi_2S_3$, which does not differ much in composition from galenobismutite. This mineral apparently occurs in quartz in much the same way as does its tungsten associate, hubnerite.

Like cerussite and anglesite, *pyromorphite*, $Pb_{10}Cl_2(PO_4)_6$ (lead chloride-phosphate), is often found in the oxidized zone of galena deposits. Pyromorphite occurs in crusts and as little yellowish-green hexagonal crystals often associated with the carbonate ores. It is present with the ores of the Gladstone mine as well as in some of the other deposits, but it does not occur extensively enough to be classed as a prominent ore of lead.

Wulfenite is a lead molybdate mineral ($PbMoO_4$) and is sometimes found in the oxidized zones of lead deposits, though not in large enough quantities to be considered a lead ore mineral. If found in large quantities, it should be classed as an ore of molybdenum. Wulfenite often occurs in little yellowish-red, square, tabular crystals, with characteristic beveled edges. Specimens of this mineral were found in a number of localities, as in the R. J. claim of the New Leadville property, and on some of the claims on Red Top Mountain.

*U. S. G. S., Bull. 550, p. 115.
**Bancroft, Op. Cit., p. 132-133.

GENETIC FEATURES OF LEAD

The lead deposits of the United States have been classed in two divisions:

One class constitutes those commonly associated with zinc, free from much copper, and occurring in sedimentary rocks (generally limestones), and apparently not related to igneous intrusion. The origin of these deposits (which are represented by the well known lead and zinc ores of the Mississippi Valley) is a much discussed subject among geologists. Some geologists believe that a deeply buried igneous magma was responsible for the existence of the original ore-bearing solutions. Others believe that circulating meteoric waters have dissolved the metallic salts from the sedimentary beds and reprecipitated them as sulphides in rock structures favorable to such ore deposition. Brecciated zones in limestones are often the places where such deposition has occurred. The gangue minerals are largely calcite, dolomite, quartz, chert, barite and pyrite.

The other class (represented in the Rocky Mountain region by the lead and lead-silver deposits such as those of the Coeur d'Alene district in Idaho and of Leadville, Colorado) consists of ores more complex in metallic content and genetically associated (without much doubt) with intrusive igneous rocks. In addition to lead, zinc, and silver, minerals of gold, copper, antimony, iron, and manganese and other metals may be present in the ores. This class of lead deposits occurs in various ways: as replacements in limestones near contacts of igneous intrusions; as replacements of rocks along zones of shearing and fracture; and as veins in igneous and other rocks. The gangue minerals of these deposits may be quartz, calcite, siderite, chert, and some silicates.

In comparison with many other metals, lead minerals are not generally considered to be formed from solutions of very high temperature. There have been found no lead deposits of commercial value which are true magmatic concentrations in igneous rocks.

These two classes of lead deposits refer to primary (or the originally deposited) ore bodies. Secondary lead minerals, consisting for the greater part of cerussite and anglesite, form many of the surface deposits of commercial value. In the Gladstone mine, at the time of this investigation, a depth of 300 feet had been reached and carbonate ores were still being taken out, and in the Electric Point mine, 800 feet was attained on carbonate lead ores. The cerussite and anglesite of these deposits have been derived, by superficial alteration, from the primary galena. In many places in these mines, the nucleus of the carbonate ore lump is of galena, and the outer coatings of anglesite and cerussite show the transitional stages of alteration. That this alteration took place from the surface downward by the action of moisture and oxygen is evidenced by the formation of quantities of iron hydroxide broken down from the original iron carbonate mineral, *siderite*.

It is stated by Lindgren* that the most soluble form of lead is the chloride and in this form the metal may often be transported by meteoric waters. The carbonated lead is quite insoluble under ordinary circumstances and anglesite is only slightly soluble. Galena is attacked slightly by sulphuric acid but more especially if accompanied by ferric (iron) sulphate. That is, galena is affected by a strong oxidizing agent. In the laboratory, for instance, galena is readily tarnished by hydrogen peroxide.**

Where pyrite is present in the deposit, the weathering action of pyrite may result in the formation of sulphuric acid, ferric (iron) sulphate, ferrous (iron) sulphate, and the residual hydroxide mineral, limonite. Ferric sulphate is such a strong oxidizing agent that pyrite is attacked by it resulting in the formation of ferrous sulphate and sulphur. The resulting sulphur may then be oxidized to sulphuric acid.

It was the observation of the writer, however, that the most highly oxidized lead deposits of northeastern Washington did not contain pyrite, or at least any sign of its having been present in any great quantity. On the contrary, wherever intense oxidation had occurred, the limonitic clay and amorphous limonite powder associated with and surrounding the oxide, gained from the air and from meteoric waters. During

*Mineral Deposits, 1919, pp. 874-876.

**Bastin and Laney: The genesis of the ores at Tonapah, Nev., U. S. Geol. Surv. Paper 104, 1918, p. 47.

the course of the decomposition of galena to form anglesite oxidized lead ore lumps, had their origin largely in the mineral siderite, ferrous (iron) carbonate. In places, some ankerite was also identified, a ferriferrous dolomite.

Where siderite is present in a deposit, the weathering action of siderite results in the formation of carbon dioxide or carbonated waters and residual hydroxide of iron, largely the limonite.

The original reagents are water, oxygen, and carbon di- (however this may take place), sulphuric acid is formed, an important chemical reagent, which causes further action on galena to form more anglesite. The great abundance of carbon dioxide, derived from the siderite, causes the lead sulphate to be altered to the carbonate, cerussite, a very stable compound. The final amorphous hydroxide form of iron is left as the mineral limonite or its related forms.

Oxidation takes place in the part of the deposit which oxide, gained from the air and from meteoric waters. During the course of the decomposition of galena to form anglesite lies above the ground water level. In this zone oxygen and carbon dioxide of the air, together with moisture, have ample opportunity (if allowed time enough) to start the slow process of breaking down the primary minerals of the deposit. In the Gladstone and Electric Point mines, the ground water level never was reached. Moreover, the nearest spring occurs at an elevation 1100 feet below the surface workings of these mines. Ideal conditions are present for the circulation of air and moisture through the entire course of the ore chimneys, which occur in porous brecciated zones of dolomitic limestone, made even more porous by shrinkage due to the oxidation of siderite. Since the oxidation (according to the writer's interpretation of the geology) occurred prior to glaciation, the time involved is tremendous, probably having begun in the early Tertiary.

PRODUCTION AND DISTRIBUTION OF LEAD

The United States produces nearly three times as much lead as any other country in the world, or three-sevenths of the world's total production. The United States, together with Mexico, Spain, and Australia, produce nearly 80 per cent of the world's lead. One-third of the United States' lead comes from southeastern Missouri and one-fourth from the Coeur d'Alene district in Idaho. The State of Washington, for the year 1923, stands eleventh in the lead producing states of this country, and the Gladstone Mine produced most of the ore during that year.

LEAD PRODUCTION OF THE WORLD FOR 1923.*
(In metric tons)

Country.	Metric tons.	Country.	Metric tons.
United States	480,816	Italy	17,132
Mexico	167,144	France	14,000
Australia	124,752	Rhodesia	11,382
Spain	110,000	United Kingdom	6,815
Belgium	51,100	Austria	4,255
Germany	50,861	Greece	4,234
Canada	48,897	Japan	3,000
Burma	46,484	Sweden	200

*Mineral Industry During 1923, p. 405.

PRIMARY LEAD SMELTED OR REFINED IN THE UNITED STATES IN 1923.*

(Apportioned according to source of ore)

Domestic:	Short tons.
Missouri	169,323
Idaho	127,797
Utah	104,678
Oklahoma	59,602
Colorado	23,885
Kansas	20,207
Montana	18,345
Arizona	8,828
Nevada	8,044
California	5,168
Washington	2,008
New Mexico	1,638
Illinois	1,286
Tennessee	1,020
Undistributed	691
Wisconsin	601
Alaska	400
Zinc residues	362
Kentucky	66
Oregon	47
Texas	40
Total	554,036
Foreign:	
Mexico	50,193
Mexico	18,867
Canada	3,632
South America	1,461
Other Foreign	211
Africa	99
Central America	18
Total	74,481

*Mineral Industry During 1923, p. 396.

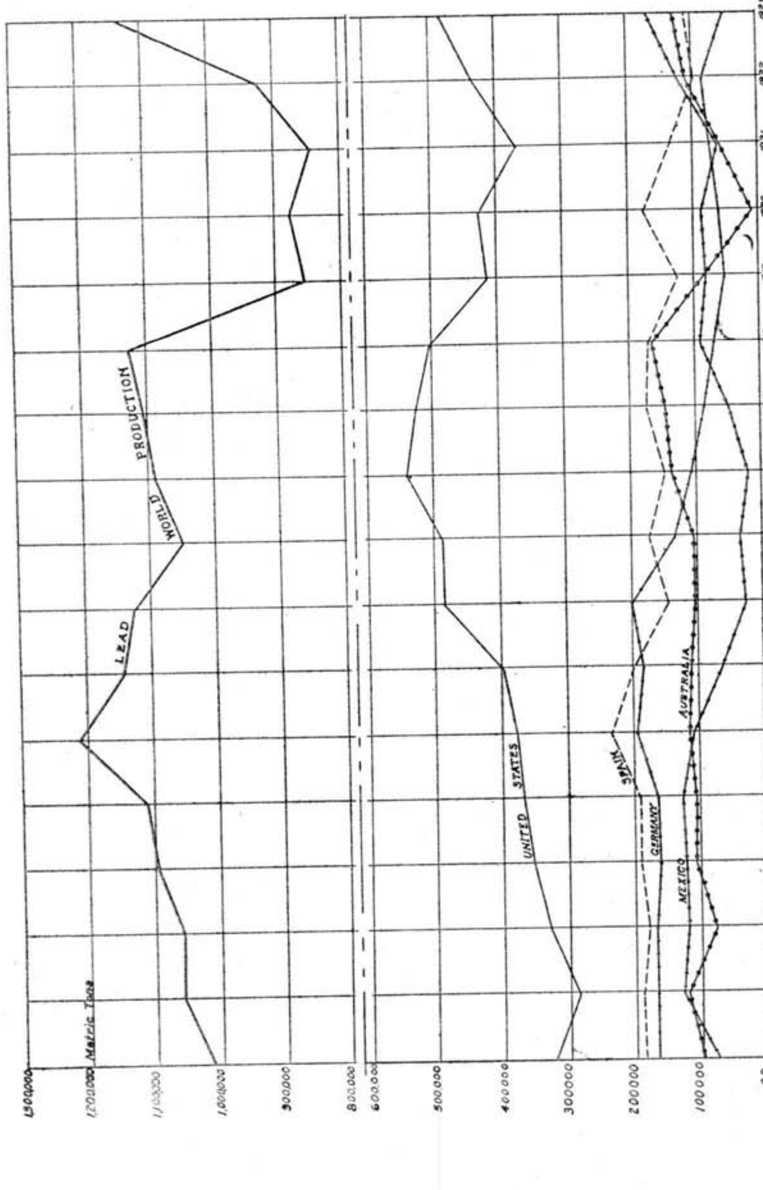

Figure 2. Chart showing the production of lead, from 1907 to 1923, in the world and in the principal lead producing countries. (Data taken from Mineral Industry.)

PRODUCTION OF LEAD IN WASHINGTON, 1898-1923.*

Year	Pounds	Year	Pounds	Year	Pounds
1898	857,555	1907	820,035	1916	5,399,274
1899	1,032,069	1908	1,150,429	1917	9,789,687
1900	1,091,945	1909	288,700	1918	5,271,815
1901	216,841	1910	1,322,287	1919	2,146,157
1902	242,516	1911	848,584	1920	5,787,247
1903	405,412	1912	127,387	1921	143,553
1904	1,760,309	1913	202,487	1922	1,381,199
1905	605,043	1914	64,967	1923	2,906,479
1906	926,100	1915	295,215		

*Solon Shedd: Mineral Resources of Washington, Div. of Geol., Dept. of Cons. and Dev., Bull. 30, 1923, pp. 28, 31.

PRODUCTION OF LEAD IN WASHINGTON BY COUNTIES, 1913-1923.*

	1913		1914		1915		1916	
County	Value	Lbs.	Value	Lbs.	Value	Lbs.	Value	Lbs.
Stevens	$8,838	200,848	$1,412	36,196	$12,780	271,915	$369,580	5,356,229
Pend Oreille.	.....	......	.....	......	......	......	2,601	37,695
Okanogan ...	72	1,639	873	22,391	1,087	23,138	118	1,704
Ferry	...	......	219	5,063	8	162	251	3,646
Snohomish ..	.....	......	51	1,317	......	......	......	......
Total	$8,910	202,487	$2,555	64,967	$13,875	295,215	$372,550	5,399,274

	1917		1918		1919	
County	Value	Lbs.	Value	Lbs.	Value	Lbs.
Stevens	$830,374	9,655,513	$360,478	5,077,152	$110,597	2,086,743
Pend Oreille	11,208	130,324	13,765	193,878	......	......
Okanogan	211	2,455	56	785	3,141	59,271
Ferry	120	1,395	......	......	8	143
Snohomish	......	......	......	......	......	......
Total	$841,913	9,789,687	$374,299	5,271,815	$113,746	2,146,157

	1920		1921		1922	
County	Value	Lbs.	Value	Lbs.	Value	Lbs.
Stevens	$460,273	5,753,409	$5,321	118,251	$74,103	1,347,328
Pend Oreille	......	......	.....	......	405	7,372
Okanogan	2,707	33,838	1,139	25,302	1,108	20,141
Ferry	......	......	.....	......	350	6,358
Snohomish	......	......	.....	......	......	......
Total	$462,980	5,787,247	$6,460	143,553	$75,966	1,381,199

	1923	
County	Value	Lbs.
Stevens	$213,945	2,827,799
Pend Oreille	3,761	53,730
Okanogan	851	12,168
Ferry	894	12,782
Snohomish	......	......
Total	$219,451	2,906,479

* Solon Shedd: Mineral Resources of Washington, Div. of Geol., Dept. of Cons. & Dev., Bull. 30, 1924, p. 28.

USES OF LEAD

The metal lead is valuable because of its softness, malleability, low fusing point, property of being readily alloyed, non-corrosive property, and high specific gravity. Its use as pipe covering, as a lining in storage batteries, as a cable covering, and as sheet lead, are very important. In such alloys as type metal, bearing or babbitt metals, shot, solder, electrical fuses, lead is a major constituent. Some of the compounds of lead which are of great importance to various industries are: white lead (basic carbonate) red lead (oxide), litharge (oxide), and orange mineral, all of which have extensive use as pigment.

LEAD CONSUMPTION IN THE UNITED STATES IN 1923.*
(In tons of 2,000 lbs.)

Storage batteries	143,000
Cable covering	131,000
White lead	130,000
Building	75,000
Red lead and litharge	46,000
Ammunition	39,000
Solder	30,000
Bearing metal	28,000
Foil	28,000
Calking	25,000
Castings	15,000
Type metal	12,000
Automobiles	7,500
Railway cars	6,000
Terne plate	4,600
Locomotive	2,100
Ship building	100
Total	722,300

*Mineral Industry During 1923, p. 394.

ECONOMIC ASPECT OF THE LEAD INDUSTRY

Metallic lead and the various compounds of lead have extremely wide and important uses. The consumption of lead is accordingly very great, but the known reserves of lead ore are not as great as should be to meet the ever increasing demand. There appears to be coming a time, therefore, when considerable activity will be displayed in the search for more deposits of lead. The price of lead has been, since 1915, for the most part, rather high and at present does not seem to be on the decline.

The majority of lead deposits are not of lead alone, but of lead and zinc or lead with copper, zinc, antimony, arsenic and other metals. Silver is often an associate of lead. Thus many of the mines producing lead produce also these other metals. In some cases the smelters "penalize" the shippers on account of the undesirable combination of metals in their ore. In such cases, a separation of the different metallic ores may be made before shipment if the size of the mine warrants the erection of the necessary mill. A few deposits, such as those of the most important lead district of southeastern Missouri, produce lead alone.

Lead deposits are distributed quite generally throughout the world, although South America seems to be, as far as known, rather lacking in this metal. The United States ranks first. Mexico, Australia, Spain, and Germany are the other great lead producers of the world. The majority of lead deposits occurs in limestone. This is the case of southeastern

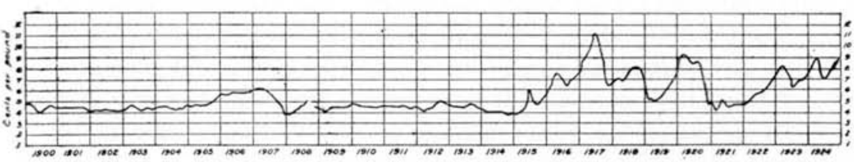

Figure 3. Graph showing the fluctuation in the price of lead from 1920 to 1924. (After the **Engineering and Mining Journal-Press.**)

Missouri; but in the Coeur d'Alene district in Idaho, the deposits are in quartzite; in Spain the largest mines are in slate and granite; while in the Broken Hill district of Australia, schist and gneiss are the country rocks.

Since the lead deposits have wide distribution through a limited known reserve, and since there is an increasing demand for lead, there is good reason for considering that the time is ripe for making a search for deposits which have not yet been discovered. A study of the occurrence of the known deposits, and especially the geological conditions involved, should at this time be a valuable asset to such a search.

GEOLOGIC HISTORY OF NORTHEASTERN WASHINGTON

GENERAL STATEMENT

There appear to be four great outstanding epochs in the geological history of northeastern Washington. The earliest of these epochs is represented by a vast series of metamorphic rocks; the second by intrusive granite; the third by the intrusive dikes, largely basic, and extrusive basic lavas; and the fourth by the various evidences of ice and water, glacially carved canyons, and immense masses of sand and gravel deposits.

The lack of fossil evidence in the rocks (excepting in the Tertiary lake beds which accompany the extrusive lavas) accounts for the uncertainty expressed by geologists in assigning any particular age to any particular geological formation of these four periods. It is generally believed, however, that the metamorphic rocks belong to the Paleozoic and earlier periods; that the granite (for the most part) forms a batholith which was intruded in Mesozoic time; that most of the lavas and accompanying basic dikes belong to the Tertiary period; and that the signs of glaciation represent the Glacial period of Pleistocene age.

Mineralization took place at a time apparently following the intrusion of the granite batholith. The rocks in which the mineralizing solutions were precipitated are in part igneous rocks and in part metamorphic. A large part of the precipitation took place, however, in the dolomitic limestones of this metamorphic series.

A vast amount of erosion has uncovered these deposits and weathering action oxidized them at the surface. In most places this oxidized zone was removed by the scraping action of glaciers, but not in all places, for in some localities the glaciers did not remove the surface mantle, but instead laid over the surface a protective covering. The result is that in some ore deposits the sulphide ores may be found unaltered at the outcrop, while in others oxidation has taken place to a considerable depth. In the Electric Point mine, thorough oxidation of lead ore chimneys was found down to the lowest workings, 800 feet from the surface.

THE METAMORPHIC SERIES

There are few places in the country where more different kinds and grades of metamorphism can be found than in northeastern Washington. Most of the metamorphic rocks are sedimentary in origin and occur in complex structures. Quartzite, argillite, slate, dolomite, and varieties of these rocks are found and have been mapped by Weaver* as twenty-one separate formations in Stevens County. The group as a whole is called by him the Stevens Series.

In Pend Oreille County, there are quartzites which occur in the southeastern corner of the county, while in the northern end there are argillites and dolomitic limestones as well. These limestones, argillites or shales, occurring along the International Boundary, are called by Daly** the Pend Oreille group.

The Stevens series and the Pend Oreille group are probably of the same general series of rocks. It is in this series that many of the ore deposits occur, having been deposited especially in the sheared and brecciated zones of the limestones.

There are other metamorphic rocks, gneisses and schists, whose origin is obscure and may be either igneous or sedimentary, and whose age may be considerably greater than these apparently altered and disturbed sediments. The Orient gneiss of Stevens County is one representative of this older series.

THE GRANITE BATHOLITH

In Stevens County, Weaver has mapped what he calls the Loon Lake granite. This apparently forms a large mass or batholith, exposed most prominently on the east side of the county, and in places, especially in the southern part of the county, extends out practically across the county. This

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

**Geology of the 49th Parallel, Canadian Geol. Survey, Memoir 38, 1912.

granite is apparently the same as that which is found over the greater part of Pend Oreille County, with exception of the region to the north. It is also undoubtedly a part of the granite mass in the Colville Indian Reservation, described by Pardee* as the Colville batholith. These exposures are probably all part of a tremendous batholith which is also exposed in British Columbia and central Idaho.

Many of the ore deposits in Stevens County occur not a great distance from the surface exposure of the granite. In the Metaline district of Pend Oreille County, the granite batholith may lie beneath the ore deposits, but its exposure at the surface is largely wanting.

This granite batholith has provisionally been placed as belonging to the Mesozoic period. It is thought to be responsible for the origin of many of the ore-bearing solutions, which formed the ore deposits of the region. Also it is thought to be responsible for a large part of the metamorphism of the surrounding sedimentary beds, although much of the metamorphism took place previous to the granite intrusion. The intrusion of the granite undoubtedly accompanied, or was accompanied by, or caused great structural disturbance in the rocks, which had at that time already been formed and in part deformed.

Besides this Mesozoic batholith, there were both earlier and later granites. These are apparently not exposed so extensively. The earlier granites have been metamorphosed to gneisses. The later granites are somewhat dioritic in composition and have been provisionally placed as Tertiary in age.

THE TERTIARY VOLCANIC ROCKS

Eastern Washington is noted for its great Tertiary basaltic lava flows which form the Columbia plateau. Volcanic rocks of this same series occur in the southern part of Stevens and Pend Oreille counties. Also in the northwestern part of Stevens County, there are large areas covered by surface lava flows which are probably in greater part Tertiary in age.

Innumerable basic dikes cut the rocks of the whole region.

*U. S. G. S., Bull. 677. 1918, p. 30.

These are in large part associated with the Tertiary volcanics, but many are much older and some are even found to antidate the mineral deposits.

In places there are local lake beds formed during the Tertiary period which contain lignite seams and fossil leaf impressions. These lake beds have so far been given very little attention by geologists.

GLACIAL EVIDENCES

The greater portion of northeastern Washington has been affected by glaciation in one form or another. The glaciers of this region were only a part of those which formed the continental ice sheet in Pleistocene time. The larger valleys of the region probably represent the positions of the large ice lobes, which occupied and reoccupied the trenches more than once during the Ice Age. The results of the ice sheet were that the country was worn down to a great extent by its movement, and deposition was made of sand and gravel in moraines. Deposition of sand and gravel by the huge glacial streams was also due to the presence and rapid disappearance of the ice. Innumerable lakes were also formed by glacial action, and drainage was entirely altered.

The subject of glaciation has not yet been given the attention it deserves. It is of vast economic as well as scientific concern.

GEOLOGIC STRUCTURE

The subject of geologic structure, so intimately connected with the historical study of the rocks, is of very great importance. In northeastern Washington, the structural features of the metamorphic sedimentary series and the igneous bodies which intrude into them are complex to the extreme. The minor structures are so outstanding in appearance that the major features are often overlooked. The only possible way of satisfactorily working out the major geological structures would be to map in detail both the topography and geology. This sort of work has not yet been done in any part of the region in Stevens or Pend Oreille counties.

The ore bodies seem to occur in minor structural disturbed zones such as slips and shear zones, rather than in the major

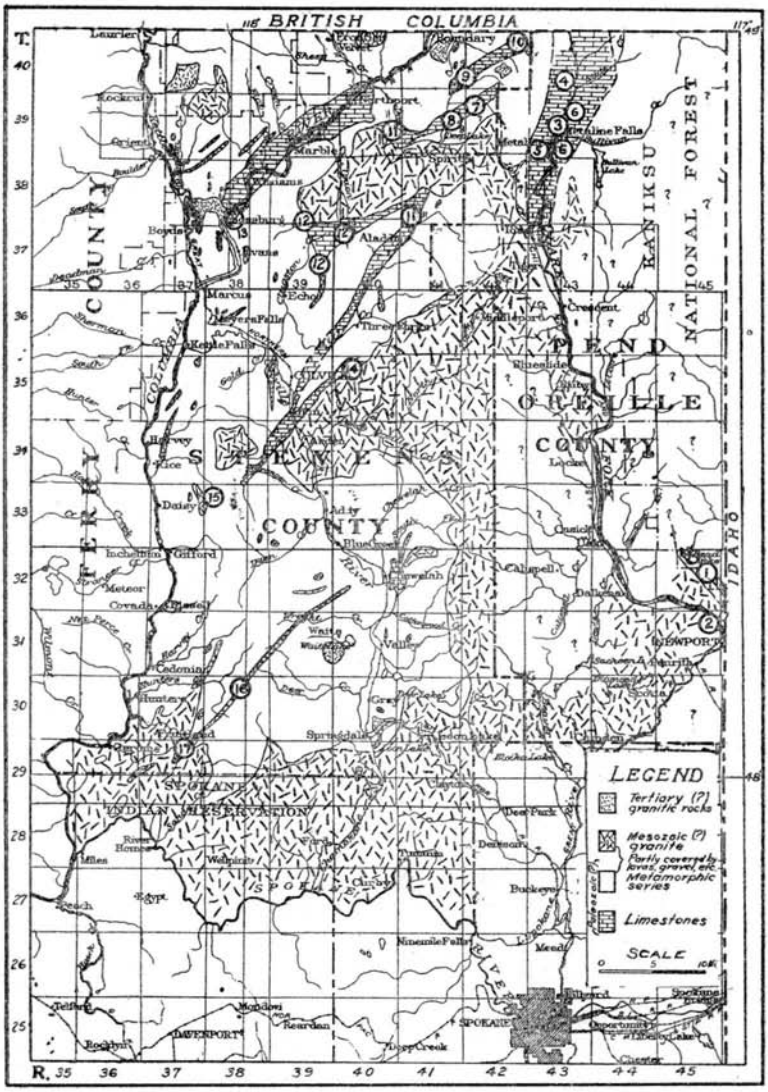

Figure 4. Map showing some of the major geologic features of Pend Oreille and Stevens counties in relation to their lead deposits. Numbers in circles locate the area described as follows: (1) Bead Lake; (2) Pend Oreille River (Ries); (3) Metaline Falls; (4) Northwest (Lead King); (5) West Metaline; (6) East side; (7) Gladstone Mountain; (8) Deep Lake; (9) Red Top; (10) Northeast boundary; (11) Deep Creek; (12) Clugston Creek; (13) Bossburg; (14) Old Dominion; (15) Silver Mountain (Daisy); (16) Hunters (Cleveland); and (17) Deer Trail. In Pend Oreille County, the area desginated as limestone includes also shales of same series. In most areas the limestones are dolomitic in character. (Base map from U. S. G. S. and geologic map of Stevens County after Weaver, supplemented by data procured by writer.)

fault zones. This feature seems to be prevalent throughout the whole area.

PERIODS OF EROSION

Before it can be stated at what depth an ore deposit has been formed, two geological features should be determined. The first is the age of the ore deposits. The second is the length of time since deposition that the surface above the deposit has been land and therefore subject to erosion. If the region has been uplifted to great heights, then erosion would be great. If such great uplifts have occurred more than once, then erosion would be vastly greater for it is rejuvenated by each successive uplift.

The region of northeastern Washington has apparently gone through a number of these uplifts and has been eroded on a grand scale after each successive uplift, exposing to present view the deposits which were once formed at a depth of many thousands of feet. In consideration of the writer's own personal observations and the works of others (principally Weaver,* Drysdale,** and Daly†), the following resume of the various epochs is here given, beginning with the earliest known periods:

1. **Pre-Paleozoic** time. Of this little is known. The Orient gneiss is said to represent the older basement rocks on which later Paleozoic sediments were deposited.

2. **Paleozoic.** Deposition of (marine?) sediments (eight?) miles in thickness. Detail of history unknown.

3. **Mesozoic.** (Possibly some unidentified sedimentation.) Deformation and mountain making period. Injection of magmas, followed by ore bearing solutions penetrating and mineralizing the deformed sediments. Intrusion of dikes. *Erosion* of the newly formed mountains.

4. **Tertiary.** *Erosion.* Sedimentation in lakes. Lavas were poured out on the surface. Intrusion of dikes. Deformation of the rocks. Continued erosion.

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

**Geology and Ore Deposits of Rossland, B. C., Can. Geol. Surv., Memoir 77, 1915, pp. 92-93.

†Geology of the Forty-ninth Parallel. Can. Geol. Surv., Memoir 38, 1912.

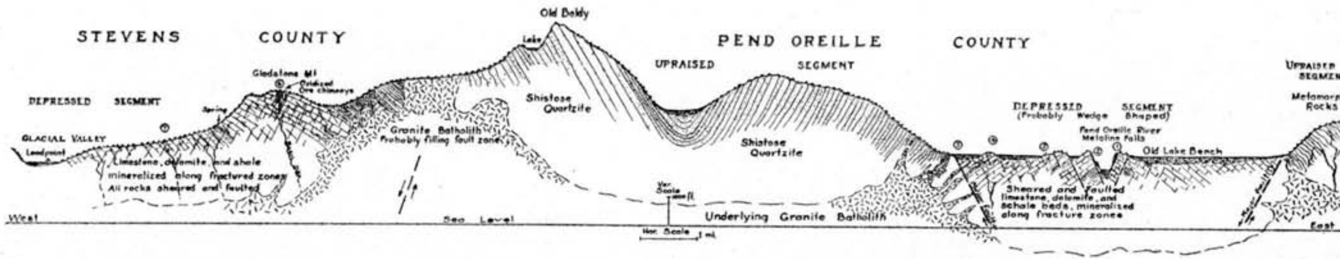

Figure 5. Ideal sketch section from Leadpoint to Metaline Falls to show the structural features of the rocks in respect to the ore deposits. The positions of the mines and prospects projected on this section are numbered as follows: (1) Grand View; (2) Washington; (3) Josephine; (4) Bella May; (5) Oriole; (6) Electric Point and Gladstone; and (7) Lead Trust.

5. **Quaternary.** Uplift and *renewed erosion,* forming deep valleys. Pleistocene glaciation and accumulation of gravel. Retreat of glaciers and further erosion.

6. **Recent.** *Erosion* and surface weathering.

The periods of erosion are therefore numerous or rather more or less continuous from Mesozoic to the present day. Oxidation of the ore deposits exposed by this erosion had ample time to take place, but glaciation removed most of the oxidized ores. Protected oxidized ores which withstood the glacial period may be expected to occur rarely. The extensive oxidized deposits of the Gladstone and Electric Point mines are pre-glacial and therefore unusually extensive, and rare in occurrence.

LEAD DEPOSITS OF PEND OREILLE COUNTY

GEOGRAPHIC FEATURES

There are two lead districts in Pend Oreille County. One is about Newport, near the broad Pend Oreille River where it crosses the Idaho boundary and enters the southeastern end of the county. The other is about Metaline Falls, in the northern end of the county, where the river flows more swiftly through a much narrower channel.

The county is cornered by British Columbia on the north, Idaho on the east, while Stevens and Spokane counties bound it on the west and south sides. Pend Oreille River (generally shown on maps as Clark Fork) is a tributary of the Columbia River and empties into that great stream on the north, near Boundary in British Columbia. The lesser stream is peculiar in that it starts on a broad scale from a series of lakes in Idaho, flows northward through Pend Oreille County, even navigable as far as Ione, and by some small crafts, to Metaline Falls, and ends on a very narrow scale. Its narrower part flows through such channels as Box Canyon and the famous power site of Z-Canyon where a foot-log allows the traveler to cross its torrent between vertical walls of limestone. The tributaries of the Pend Oreille are also peculiar in that the majority of them have a tendency to flow more southward than northward, the direction of the main stream. Some of them flow almost directly south until they get close to the river where they break through steep-walled canyons to the main stream. These peculiar features—the northward narrowing of the river and the southward trend of the tributaries—lead one at first to conclude, from a cursory examination of a map of Washington, that the river flows south instead of north.

A high bench of gravel and sand, some 500 feet above the present stream, follows the river on either side, with only a break here and there, to its extreme northern course. The material of the bench was deposited by the old Lake Pend Oreille, which once occupied a much greater position than that of the present lake and river, and was subsequently drained as the ice sheet to the north retreated and allowed the Columbia to carry off the ponded glacial waters. The name Clark Lake has been suggested for this prehistoric body of water.*

The bordering Pend Oreille Mountains on the east side of the county represent the western extension of the Selkirks. The range which divides the county on the west from Stevens is also a part of the Pend Oreille Mountains, but is known as the Calispell Range. It represents the eastern extremity of the Okanogan Highland physiographic province.

The Great Northern Railway on its eastern course, runs from Spokane through Newport, a distance of 66 miles. The Idaho and Washington Northern Branch of the Chicago, Milwaukee & St. Paul Railway also reaches Newport from Spokane, extending northward down the Pend Oreille Valley, terminating at Metaline Falls. Automobile roads connect these towns. One road extends northward to Nelson in British Columbia. From Ione, roads run westward over the mountains to Colville and Northport.

The principal towns of Pend Oreille County are: Newport, located in the southeastern corner; Ione, in the west central part; and Metaline Falls, in the northern end of the county. The towns are situated beside the river. Their population, according to the 1920 census, was as follows: Newport, 950; Ione, 541, and Metaline Falls, 153.

Newport is the county seat. Ione is a center of lumber industry and also contains limestone quarries. At Metaline Falls there is a large cement plant known as the Lehigh Portland Cement Company. In connection with the cement works, is the power plant located on Sullivan Creek. The Pend Oreille River, with its numerous falls and rapids extending from Box Canyon northward through Metaline Falls and Z-Canyon, now goes to waste. When this water power is developed, the electricity should be cheap enough to assist materially in the development of the mineral deposits of the district.

Most of the lead deposits of the region lie within short distances from roads which reach railroad stations within a

*Thomas Large: Drainage changes in Northeastern Washington and Northern Idaho since extravasation of Columbia Basalts. Pan-American Geologist, Vol. XLI, May, 1924.

few miles, and for the most part on a down hill grade. The only mine which was shipping ore at the time of investigation, however, was the Bella May.

GEOLOGIC FEATURES

The Newport district is one of intrusive igneous rocks and of bedded quartzites, while the area about Metaline Falls is distinctly one of limestones and dolomites, though shales and quartzites are also present. Consequently, the ore deposits of the two regions differ materially. In both places, the sedimentary rocks are highly disturbed and metamorphosed. In both places, glacial action has influenced superficially the deposits long after they were formed and carved by pre-glacial erosion.

In the Newport district, the lead ores consist of galena, generally argentiferous, with iron and copper sulphides, and also, in places, arsenopyrite, all imbedded in massive quartz vein matter, which occur as irregular bodies in quartz-diorite. In the Metaline district, galena is for the most part associated with sphalerite (zinc blende), and occurs in brecciated limestone or dolomite. It does not contain much silver except in the Oriole district. Rarely is galena associated with much massive quartz vein matter (except in the Oriole group), or with bodies of pyrite (except in the Washington claim) and intrusive igneous rocks are rarely exposed.

None of the solid rocks of the entire region have been definitely assigned to any particular geologic period. According to some authors, the metamorphic sediments may be of Paleozoic age, and the later igneous rocks of Mesozoic or Cenozoic.

The major structural geologic features—faults, folds and upturned beds—strike or trend north and south. The high, sharp ridges are in many cases of resistant quartzite. The limestones form bold bluffs along the sides of the river canyon, while the shales are generally more broken down by erosion, and often form local valleys covered by a mantle of glacial drift. Faults and local slips in the rocks are very numerous in the region, and many of the peculiar topographic features have had their origin and growth influenced by these structural breaks. The time when the faulting took place seems for the most part to have antedated the precipitation of the ores, for the deposits have largely been formed in the fault or shear zones. Seldom is there found definite evidence of post-mineral faulting, although it is not entirely lacking.

A genetic relationship of the ore deposits to the intrusions of the granite rocks has been assigned by nearly all of the geologists who have visited the region. In many cases, the cause of the faulting may be attributed to the rupture effect of the intrusive igneous rocks. The source of the ore bearing solutions may be from the deep-lying igneous magmas.

A special zone or vertical order of deposition of the ores cannot with our present lack of detailed knowledge, be consistently followed. The original position or depth of deposition of the ore deposits depends upon the relative position of the surface of the earth to those deposits at the time of their formation. A detailed study of the physiography of the district would throw some light on the subject.

It is the opinion of the writer that the sulphide ores were formed at considerable depth. The following historical features should throw some light on the fact that erosion has been profound in uncovering the ore deposits and that the ores (excepting the superficially altered minerals—so called "carbonates"—such as limonite, smithsonite, cerussite, anglesite, pyromorphite, etc.) were originally formed at a depth of at least thousands of feet.

1. Present stream action shows youth in canyon cutting, and ore deposits occur in and along the canyon walls, where they have been uncovered.

2. Glacial erosion was profound in carving mountains and cutting canyons, therefore exposing ore deposits.

3. Pre-glacial erosion and alluvial deposition are also in evidence. The pre-glacial erosion probably caused the cutting out of the original major topographic forms; the *valleys,* through which the glaciers passed; and the *mountains* on which the snow packs accumulated. The ore deposits for the greater part are exposed in the valleys.

4. A general uprise of the whole region is in evidence, which occurred prior to pre-glacial erosion, and probably later

than the period of general structural deformation, and igneous action. That this uprise came after the region had been base-leveled is evidenced by the even skyline of the peaks of the Pend Oreille Mountains and the Selkirks. If this base-leveling occurred, it would mean an earlier cycle of erosion which removed an unrecorded mass of rock covering.

The depth of erosion since base-leveling may be assumed as being the difference in elevation of the Pend Oreille Valley and the tops of the peaks of the Pend Oreille Mountains, which is about one mile. Erosion prior to base-leveling and since the deformation period, was probably fully as great as since base-leveling. The position of the surface of the earth relative to that of the ores at the time of their deposition may have, therefore, been a vertical distance of some miles instead of only several thousands of feet. We may not expect, therefore, to find any special order in position of the different deposits of sulphide ores relative to the present surface. If there is a special order in position, it may be arranged according to original temperature zones which were dependent upon a number of factors such as the position relative to the igneous magma, the character and heat conductivity of the surrounding rocks, etc.

The writer is of the opinion, therefore, that these sulphide ore bodies are not necessarily limited in their occurrence at depth. The limitations of the sulphide ore bodies of the Metaline district are influenced more by the limitations of fracture zones favorable for reception of ores, and favorable in their situation relative to the channels of original ore migration. The type of ore body as well as its contents undoubtedly varies according to relative position in respect to the parent rock magma (its source) and in respect to the composition as well as physical character of the enclosing country rock. It is quite likely, however, that the individual or local ore migration channel may have depositional characteristics peculiar to itself.

That the ores have their source in deep seated igneous magmas may be accepted with a little reservation. In the case of the Newport deposit, the quartz veins appear to be very closely associated with quartz-diorites. It is quite possible that in this case the quartz veins and quartz-diorite were separated or were differentiated from an original magma overburdened with silica. The excess of silica might possibly have been due to the absorption of part of the quartzite by the magma at great depth under intense heat and pressure. The quartz vein matter, however, did not crystallize until the diorite was practically solidified. The quartz veins include portions of the diorite country rock and have apparently replaced it in part and the whole appears to have solidified from a pasty condition. From the structural appearance of the quartz veins it would seem that they have been injected by force into the quartz-diorite. It is the opinion of the writer, therefore, that the Newport deposits represent typical "vein-dikes" of Spurr's* nomenclature.

The ores of the Metaline district are for the most part fillings in limestone and dolomite breccia and are associated with the gangue minerals, calcite and siderite, chert, and some quartz. When the ore bearing solutions first arrived in the breccia, they had left the igneous rocks far behind, and were probably much cooler than were the ore solutions of the Newport district at the time of their deposition. The ore solutions of the Metaline district were probably more aqueous, therefore thinner, than those of the Newport district. Calcite and siderite are not lacking in the gangue of the Newport deposits, however, but where they occur they show evidence of having been precipitated subsequent to the crystallization of the quartz vein matter.

NEWPORT DISTRICT

BEAD LAKE AREA

General Features

There are a number of mining properties which lie just southeast of Bead Lake about seven miles north and a little east of Newport, and within two miles in an air line of the Idaho boundary. The road leading to them starts on the opposite side of the river from the town, across the ferry, and climbs to the top of the gravel bench which lies 500 feet

*J. E. Spurr: The Ore Magmas, 1923.

above the river. The mining properties lie in the hills which rise above this bench, at about 3,000 feet above sea level. They are located in T. 32 N., R. 45 E.

In the region about the Bead Lake mining properties, it was found that diorites and quartz-diorites occur as igneous masses intruding quartzite. The ore bodies apparently do not occur either in the quartzite or on the contact between the two formations, but in the diorite a short distance from the contact, though roughly paralleling the contact.

In the region of the mining claims investigated, there are two strips of quartzite interspaced by diorite and bounded on the east and west sides by diorite, as if the tongues of the diorite had intruded in such a manner as nearly to surround portions of the quartzite. The direction or strike of these geologic bodies is about N. 10° W. Some of the ore bodies lie in the quartz-diorite on one side of a quartzite strip, while others lie in the diorite on the other side. The ore bodies which lie in the diorite between the two quartzite bands are those of the Conquest (in which the tunnels first cut the western quartzite strip), the Stanley, the Fractional Key, and that encountered in the lower tunnel of the Comstock. Those in the diorite on the east side are entered by the upper and east tunnels of the Comstock. On the west side of the western quartzite strip in the diorite are the ore bodies of the Fair Hope and Meteor claims; copper and arsenopyrite are the minerals predominating. The dip of the eastern quartzite strip is S. 58° to 82° W., while that of the western strip is S. 40° to 75° W., or nearly the same.

The ore bodies consist of zones of massive quartz veins and stringers irregularly formed but more or less connected. The veins include fragments of the wall rocks and in places appear to grade into the inclosing diorite without definite planes of contact, while in other places the contact between the vein and country rock is well defined. The veins appear to be ruptured by multiple faulting, but displacements are not clean cut. It would appear that the rupturing took place either while the quartz was in a plastic condition so that the material was strung out along slip planes, or that, before the formation of the quartz veins, the quartz was deposited along

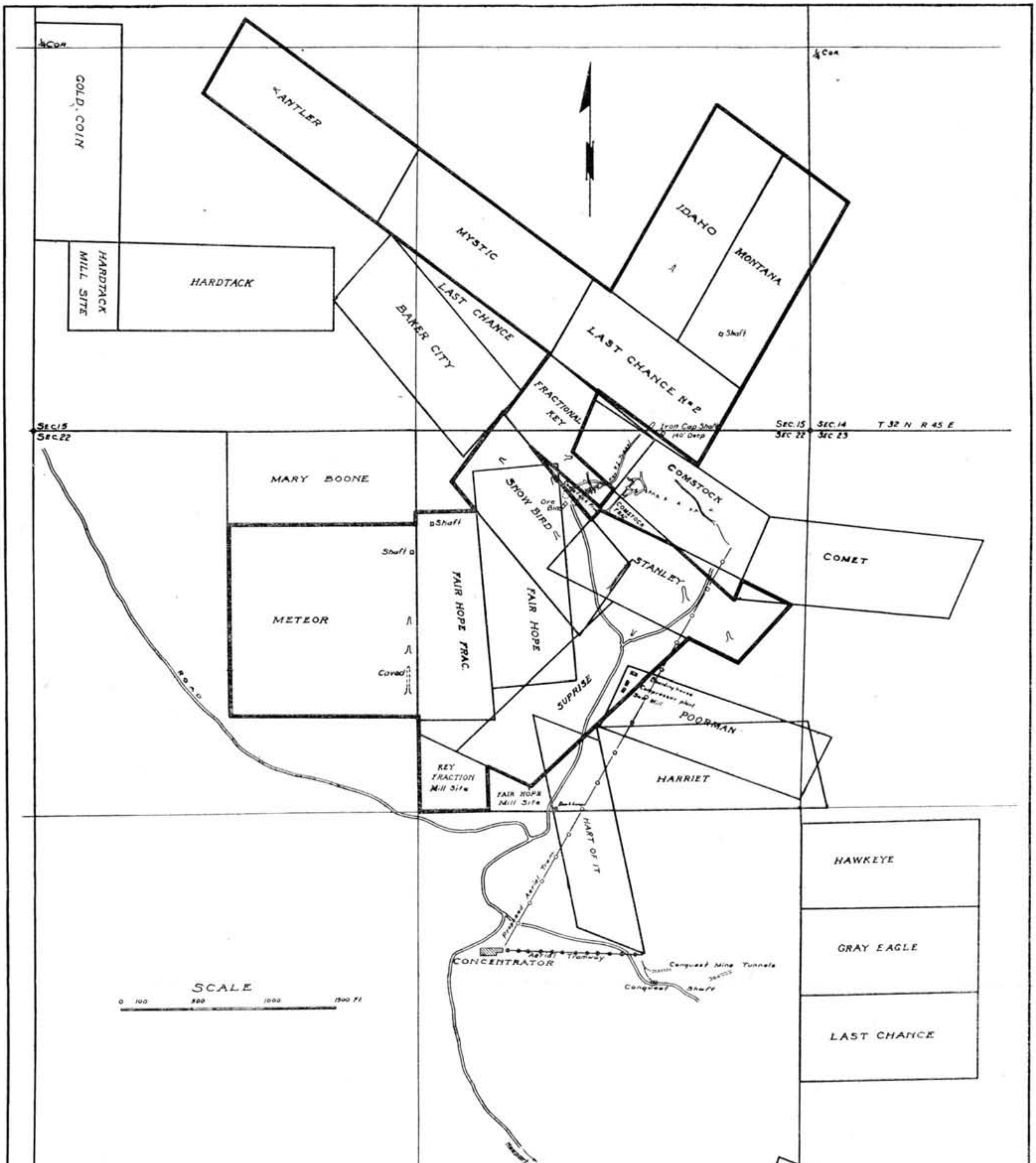

Plate I. Map showing the mining claims and mine workings of the area about Bead Lake. The group heavily outlined is the property of Alger and McCullough. The other claims are largely those of the Bead Lake Gold and Copper Mining Company. There are eight more claims which extend to the shore of Bead Lake, lying one mile to the north of the Antler claim. (After maps prepared by H. Goodsell.)

slip planes and in the drag zones, as well as in the pre-existing fracture planes of the wall rocks replacing them. The quartz matter and the enclosing diorite rocks are so intimately connected that one might infer that the veins were a differentiated product of the igneous magma. There is no particular evidence of the veins having been formed by infiltrating solutions, though there is evidence of the replacement of the country rock by the quartz. The writer is of the opinion that these veins should be classed as "veindikes" as described by Spurr.*

In most cases, it was observed that the diorite, lying next to the quartzite, was very hard and was cut into blocks by regular smooth jointing. The ore phase of the diorite is an entirely different phase of the rock, though the two intergrade with imperceptible change.

The ore minerals in the quartz veins are galena, generally argentiferous (with very little sphalerite), pyrite, some chalcopyrite, and in places an abundance of arsenopyrite. In addition to the quartz gangue, there are, in places, calcite crystals, siderite, and some ankerite.

The most serious problem in connection with mining these ore bodies is that they contain much quartz which varies from place to place in richness of ore minerals, being quite lean in one place and carrying nearly solid masses of ore in another. The freedom of the galena from zinc is much in its favor.

The region in general has suffered profound erosion which has caused the ore bodies to become exposed to view. In places the ore bodies are oxidized, but not to any very great extent.

Bead Lake Gold-Copper Mining Company Property

The largest amount of development work in the Bead Lake district has been carried on by the Bead Lake Gold-Copper Mining Company, which owns a large number of claims in the district. The most important of their workings are on the Conquest and Comstock claims, located in the west half of section 22, T. 32 N., R. 45 E. An aerial tram has been

*J. E. Spurr: The Ore Magmas.

constructed to carry the ore from the Conquest to a mill located 1,000 feet due east of the mine. A proposed aerial tram 3,200 feet long was to extend from the Comstock mine to the concentrator, in a southwesterly direction.

Conquest. The mine workings on the Conquest consist largely of a shaft 200 feet deep with deeper underground workings, which, it is said, lie 600 feet below the upper No. 1 tunnel; a tunnel (No. 2) 50 feet higher than the shaft, 800 feet long; an upper tunnel (No. 1) 250 feet long, 116 feet above the lower tunnel, connecting with No. 2 by a chute, and several other shorter tunnels and prospects above these on the steep hillside whose crest is composed of quartzite. The workings first enter quartzite and then pass into diorite in which the ore bodies occur as irregular quartz veins and stringers. Apparently quartzite occurs on the east side of the diorite as well as on the west side. The largest body of good ore came from the shaft, it is reported. Unfortunately, the writer was unable to enter the shaft, since it was full of water.

In tunnel No. 2 quartzite occurs from the portal for a distance of 160 feet, at which place it is in contact with diorite, dipping S. 84° W. at an angle of 44°. A chute (No. 1) was made at this point. Ore occurs at 180 feet from the portal. It consists of white quartz veins running irregularly through quartz-diorite, dipping S. 5° W. at an angle of 80°. At 228 feet from the portal there is a chute (No. 2) on ore extending from No. 1 tunnel. At this point the tunnel follows the ore body which strikes S. 80° W. At 256 feet from the portal is No. 3 chute. At 305 feet from the portal is No. 4 chute. At 330 feet from the portal the veins and likewise the tunnel turn, the ore body striking S. 40° E. At 435 feet, the ore turns back again. At 483 feet is located raise No. 5. The face of the tunnel is in a green serpentinized diorite rock full of white quartz veins running irregularly in various directions with but little ore.

Tunnel No. 1 also enters quartzite, dipping S. 65° W. at an angle of 48°, but it is apparently not thick here, for the stoping has been carried on 30 feet from the portal in ore which occurs in diorite. It is stated that a considerable amount of ore was taken from these stopings, between the two tunnels. Caving prevented the writer from investigating this tunnel.

The ore minerals on the dump of No. 1 tunnel consist of galena, chalcopyrite and arsenopyrite, in a matrix of quartz vein matter and other gangue minerals such as siderite and calcite. Some pyrite is present and a little sericite occurs.

The minerals found on the dump of the shaft and of No. 2 tunnel are: galena chalcopyrite, pyrite, and a little arsenopyrite as ore minerals, with quartz and a green chloritic or serpentinized rock often intermixed. Calcite and siderite occur secondary to the other minerals. The country rock appeared to be greenish diorite, though pieces of black diabase were found. The quartzite is gray in color, banded, finegrained, argillaceous, though silicified, and greatly jointed.

Comstock. The workings on the Comstock lie on the hillside above and to the east of Fractional Key. The lower tunnel (No. 2) enters diorite in which irregular quartz veins form ore zones. One vein zone is 75 feet from the portal and another occurs 325 feet from the portal. The dip of the first is N. 80° W., 22° to 45°. The tunnel contains some 700 feet of workings and is connected by a chute to the upper No. 1 tunnel.

The upper tunnel (No. 1), some 80 feet higher in elevation, enters slaty quartzite, dipping S. 72° W. at an angle of 55°. The contact with diorite is 57 feet from the portal. At 100 feet from the portal, the vein zone begins. The dip of this zone is S. 20° W. 52°. Some ore was stoped from these workings, with values in lead and silver, it is stated. The ore from these workings consists of galena, chalcopyrite, a little sphalerite, with some carbonate minerals in the oxidized zone. Besides quartz, calcite and siderite are gangue minerals. The country rock is diorite, usually greenish and serpentinized, occurring as fragments in the massive quartz vein matter. Slickensiding is very abundant.

Farther up on the hill is an incline, said to be 100 feet long, as well as a number of other smaller prospects. The incline slopes 55°, directed S. 65° W. It is said that rich galena ore was found in this incline. In another surface prospect a quartz vein was found to be dipping N. 34° E. at an angle of 80°. The surface is stained with iron oxide.

The East Tunnel was driven in order to cut the ore body in the other workings. The tunnel is directed N. 40° W., in diorite. At 258 feet from the portal, there is a quartz vein in slickensided diorite. At 285 feet the tunnel bends to the left. At 312 feet, there is some galena in a quartz vein zone. At 472 feet there is a drift to the left on quartz veins. At 510 feet is another drift to the right on some quartz stringers. At 530 feet, which was the face of the tunnel, veins of quartz and a little calcite were observed in the diorite rock.

Alger and McCullough Property

The group of mining claims owned by Ed Alger and Harvey McCullough consist of the Last Chance, Montana, Idaho, Mystic, Antler, Fair Hope, Fair Hope Fraction, Red Wing Fraction, Fractional Key, Surprise, Meteor No. 1, and Meteor No. 2 (the last four of which are patented), and also the Key Fraction Mill Site. The Snowbird and Stanley claims formerly came in this same group when all were owned by the Newport Mining Company. They are located in sections 15 and 22, T. 32 N., R. 45 E.

The principal lead deposits of this property are located on the Fractional Key claim. Two tunnels intersect the ore body. The lower tunnel, directed N. 50° E., is 300 feet in length. The upper, directed N. 67° E., 30 feet higher in elevation, is 762 feet long, intersecting ore at 110 feet, and entering quartzite in its last 100 feet of length.

The ore consists of galena in well formed rather large cubes (said to carry silver) set in a matrix of clear white quartz. Some chalcopyrite is present but no sphalerite. Large, white, cleavable pieces of calcite occur as part of the gangue, together with some siderite. These two minerals apparently were formed later than the quartz or the ore minerals.

In the upper tunnel ore was struck at 100 feet from the portal. From this point on for 200 feet farther, the diorite country rock contains numerous quartz veins which strike due east, standing nearly vertically. Beyond this point, the diorite is not mineralized to any great extent and shows plainly its dense texture and jointed structure. At a point 750 feet from the portal is the clean cut contact with quartzite. The quartzite is bedded, fine grained, full of joint planes. It dips due west, at an angle of 41°. For the rest of the length of the tunnel quartzite is the only rock present. In places it is argillaceous but silicified. A few stringers of calcite occur in this rock. It has the appearance of having once been a calcareous shale but has subsequently been silicified by intense metamorphism.

The ore body consists of irregular branching veins and stringers running through greenish serpentinized diorite. The vein matter includes fragments of the country rock, in many places with the appearance of having absorbed or replaced the rock. Slickensides are predominant, showing the presence of innumerable slips and fault planes.

The surface outcroppings are oxidized to a red stain of iron, with some green copper stains intermixed. The iron stains reach a depth of not much over 60 feet. Galena is found in places at the surface in the outcrop, not altered to any great extent.

In the lower tunnel it is 126 feet to the first quartz vein matter. At 150 feet, there is a drift in a mineralized zone some four feet in width dipping N. 45° E. about 50°. At 280 feet, the tunnel follows vein matter mineralized with galena in a direction S. 80° E. The vein zone contains many branching veinlets of quartz containing here and there bunches of galena. In one place, a vein will be a foot or so wide, then it will narrow down to a fraction of an inch in an apparent rock offset, then will become suddenly wider again. The included fragments of country rock are of serpentinized diorite. The ore in no place is banded. The quartz is solid, massive and white.

On the Fair Hope claim, there is very little lead. A tunnel 160 feet long intersects vein matter striking N. 35° E. dipping southeast at an angle of about 45°. Some copper and arsenopyrite are present in veins in serpentinized diorite. The other workings on the Fair Hope and Meteor were not investigated inasmuch as they were largely in copper and not lead.

PEND OREILLE RIVER AREA

Ries Property

The Ries Mining Company has two claims, the Eagle and the Owl, together with 40 acres of land leased from the state. These are located about two miles north of Newport (Section 12, T. 31 N., R. 45 E.) on the west bank of the Pend Oreille River, near the Idaho, Washington and Northern Branch of the Chicago, Milwaukee & St. Paul Railway. There is an 80-foot shaft on the Owl claim and a 215-foot shaft on the Eagle claim.

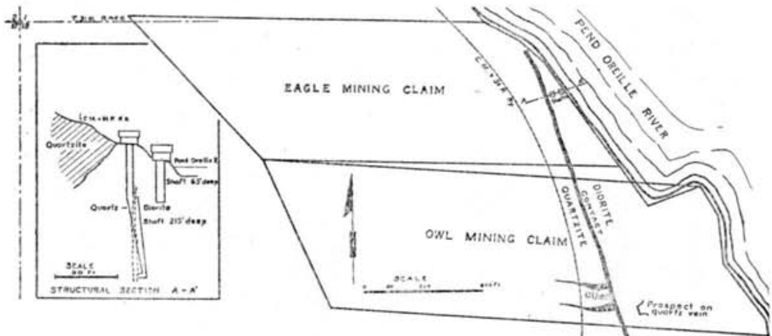

Figure 6. Map and section of the Ries property, showing the position of the ore in reference to the contact between quartzite and quartz-diorite. (Compiled from maps owned by the company and from notes taken by the writer.)

The ore consists of quartz vein matter containing galena, pyrite and some chalcopyrite. Besides quartz, calcite and siderite are gangue minerals. The chief values have been found to be in lead, silver, and a small amount of gold. The ore occurs in a quartz-diorite porphyry. The porphyry is in contact with highly disturbed and metamorphosed quartzite beds, dipping S. 86° W. at an angle of 43° and greater, but the ore is not directly on the contact. Three varieties of quartz were found—dull white, transparent white, and amethyst colored. The quartz matter as seen in specimens on the dump, grades into the porphyry country rock, in the manner of the veins at the Bead Lake property. The type of deposit is apparently the same as that of the Bead Lake.

The principal vein as developed underground is said to have an east-west strike, passing under the river, but the writer was unable to verify this for the shafts were filled with water at the time of investigation. A quartz vein, however, located a few hundred feet farther south, has this same strike on the surface.

The contact between the diorite and quartzite is well exposed on the surface in at least one place. It is clear cut and strikes N. 20° W. Small apophyses were found branching from the main diorite mass, entering the quartzite.

METALINE DISTRICT

GEOGRAPHIC FEATURES

The Metaline Mining district is in the extreme northeastern corner of Washington. It is that part of Pend Oreille County which lies north of Ione. The mining claims lie near the Pend Oreille River (largely on the west side) in T. 39 N., R. 43 E. and T. 40 N., R. 43 E. The town of Metaline Falls is situated on the east side of the river and is the terminus of the Idaho, Washington and Northern Branch of the Chicago, Milwaukee & St. Paul Railway. The older town of Metaline lies on the west side of the river two miles southwest of Metaline Falls and is situated on the main Pend Oreille highway eight miles north of Ione. Roads extend from Metaline to parts of the country on the west side of the river and one road runs clear to the boundary. The highway to Metaline Falls from Metaline first reaches the foot of a high spectacular limestone bluff known as Washington Rock and then crosses the river on a toll bridge owned by the cement company at Metaline Falls. The highway continues northward to the International Boundary, where it connects with other roads, the principal one of which goes to Nelson in British Columbia. A few other roads, all of which are local, reach out from Metaline Falls. Of these the principal one extends to Sullivan Lake, which lies four or five miles to the southeast.

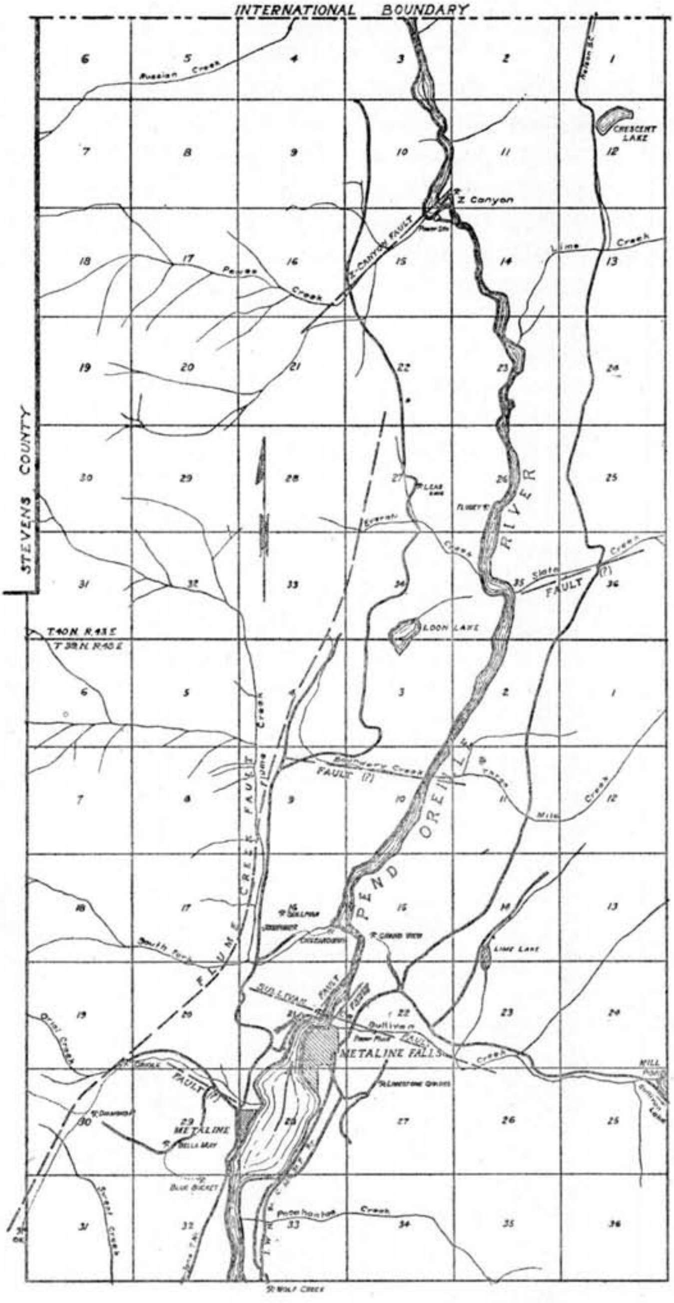

Figure 7. Outline map of the Metaline district showing the geographic features and the probable positions of some of the main faults. The principal mines and prospects are indicated by a cross-pick symbol.

The striking topographic features of the region are the narrow canyon with its torrential river cascading and falling over its rugged channel; the bold, precipitous and cavernous limestone bluffs of the canyon; the high but even gravel bench lying 500 feet above and on either side of the river, stretching out to the rough mountain ranges beyond, whose rude peaks stand sharp and serrated against the sky. Where the thick timber does not conceal the creeks from view, high water-falls may be found plunging through their narrow channels over this bench, through which they have pierced bed rock to reach the river valley. Lakes, which owe their origin to past glaciation, occur in many places throughout the region, but are concealed by bordering mountains. The district as a whole is wild and beautiful. Only in recent years has it been marred by timber cutting. The explorer soon finds his road at an end and is glad enough to continue on a well marked trail or up a ridge of barren rocks.

The lead mines and prospects occur in the limestone bluffs close to the river or a few miles west of it. At the time of investigation there were a number of places where prospecting was active. In the Bella May mine high grade chunks of galena were being dug from near the surface of the ground and hauled by a wagon to Metaline Falls. Some 250 tons have been shipped from this property to the smelter within the last year. The mine lies within a mile west of Metaline in a limestone hill which protrudes through the high gravel bench previously referred to. The haul, therefore, is principally down hill, a distance of three miles to the railroad at Metaline Falls.

GEOLOGIC FEATURES

Granite exposures, so prevalent throughout southern and central Pend Oreille County, apparently terminate at Ione, where limestones, dolomites and shales continue through the canyon to the International Boundary. West and northwest of Ione, granite was found along the Smackout Valley road, leading to the Colville-Leadpoint road; but just north of Ione, high grade limestone is quarried and shipped to the Bunker Hill smelter. Granite is reported to occur a few miles south of Metaline Falls between Sullivan Lake and the river. Some thin granite pegmatite dikes were found in the O. K. group of claims two miles west of Metaline. The mountain range which forms the natural border between Stevens and Pend Oreille counties and lies west of Metaline, extending northward to the International Boundary, is formed largely of the upturned edges of quartzite and schistose slaty rocks. On the opposite eastern side of the valley, quartzites and schists are also prevalent. Although these rocks stand higher than the limestone series along the Pend Oreille River, they probably represent an older formation—one that stratigraphically should lie below the limestones and shales, but have been thrown up by faulting and folding into this relatively higher position. The limestone series, on the other hand, forms a segment some three or four miles wide and 18 or 20 miles long, blocked by faults on its east and west sides and by the intrusive granite batholith to the south. On Daly's geologic map on the Forty-Ninth Parallel, a narrow strip of schist is shown to lie between the limestone series in Canada and a great mass of granite to the north. It appears that this granite batholith is beneath the whole area but exposed by erosion only here and there where it worked its way up and formed dome-shaped masses.

In just what position this enormous intrusive mass of granite is located beneath the formations, no one knows, but there is much evidence to indicate its existence not far beneath the quartzite which forms the mountains west of this limestone belt. The writer is of the opinion that the intrusive force of the granite (when all the formations were deeply buried beneath the surface) raised this quartzite segment to a great height. In all probability this same thing occurred on the east side of the valley, leaving the limestone segment at a relatively lower position. It appears to form a wedge block which has slipped downward. The significance of this structural feature will be later seen in the study of the ore deposits.

The limestone series contains pure limestone, dolomite, marble, shale, calcareous shales, and a number of varieties of these rocks. There is a prevalent west dip in the limestone formation on the west side of the river and an east dip on the east side. Faults and slips of varying magnitude in these rocks are abundant and especially evident through the presence of thousands of slickensiding planes. These faults, for the most part, dip in an opposite direction to the dip of the beds. Although the magnitude of the faults cannot be determined through the slickensiding (for that character may be developed by either short or long slips), shales and limestones are in places faulted against one another, showing considerable displacement. All directions and positions imaginable may be found in these faults. Of these directions, it would appear that north-south and east-west structure directions are the more prevalent, or at least, they are in general the directions of the faults of apparently the greatest magnitude. The formations and positions of prominent bluffs and of canyons cut by streams, may, in many cases, be attributed to the influence of faults.

The significance of the faults is quite evident in the study of the ore deposits. The ores, especially the higher grade lead and zinc deposits, occur almost invariably in minor faults and in fault breccia zones. It is probable that certain of the major faults acted as migration channels for ore-bearing solutions and that the last stages of deposition took place in the brecciated zones.

One of the most interesting geological studies of the region may be made along Flume Creek and its tributaries. The main portion of Flume Creek flows directly south for three or four miles along a little valley lying directly over (according to the writer's interpretation) one of the major north-south faults which divides the limestone series on the east and the quartzite series on the west. This fault (if rightly interpreted) is an enormous displacement and must have a throw of more than 6,000 feet.

The tributaries of Flume Creek flow down the mountain side across the older beds of quartzite. The head of Flume Creek exposes quartzite layers to an enormous thickness over 6,000 feet. A great syncline is cut into, which is the major structure of the mountain.

The lower course of the creek cuts the limestone series to the east following along local faults which have, in general, east-west courses. These faults in the limestones are minor displacements, or at least small in comparison to the great major fault.

Another interesting geologic study may be gained by following northward along the course of the contact between the quartzite and limestone series. This contact the writer interprets as the major fault. The beds in both formations dip westward. Prospect tunnels have entered the quartzite and have entered the limestone. Unfortunately, no open tunnel was found cutting the contact.

On the O. K. claim west of Metaline, pegmatite dikes were found intruding the sedimentary rocks near the contact or great fault zone. Metamorphic action had recrystallized the surrounding rocks more intensely than in other localities. Lean ore deposition had taken place along bands paralleling the upturned planes of the beds. A gradation between these pegmatite dikes and mineralized quartz vein matter could actually be traced in the field showing that some of the veins, at least, are in reality a segregation of the pegmatite dikes, which are in turn, undoubtedly, arms or apophyses extending out from the granite mass below.

It is thus strongly indicated that the source of the mineral deposits was originally in the granite, though the position of greatest deposition of lead and zinc deposits has not been in the major fault zone, but at a greater distance from the contact, occurring in the brecciated zones of the dolomites and limestones. This distance may be a few hundred yards to possibly a mile or more. The migration of the ore solutions may therefore have been through this great major fault zone, then through the larger of the secondary faults running east-west, and north-south, and finally, after reaching a zone of breccia, the cooled-off solutions deposited their load where now are the ore deposits exposed by subsequent deep erosion.

According to the writer's interpretation, geologic action took place in this district in the following manner.

1. At a time before the structural disturbance of the metamorphic sedimentary series, deposition of sandstones,

shales, and limestones took place in such a manner that the calcareous series of rocks was placed on top of the sandstones which were later changed in form to quartzite.

2. Granite, in the form of a great batholith, upraised the whole area, forming a great anticline. A long center segment on the east of the anticline was broken loose and lowered relatively more than a mile. The rocks of this center segment were wedged, sheared and faulted. The rocks of the higher western segment were laterally compressed. The whole series of sediments was metamorphosed by the heat and pressure involved.

3. Apophyses of granite in the form of pegmatite dikes were forced into the ruptured zones between the segments.

4. Ore-bearing solutions were then released or separated from the granite and these pegmatitic dikes and were passed upward along this great ruptured zone. The roof rocks of quartzite were tighter and more resistant to the ore-bearing solutions than the ruptured zones of the limestones. The result was that the veins did not force their way as readily into the quartzites as they did into the fractured limestones.

5. The part of the limestones in the dropped segment had, during the course of this structural disturbance, been brought into contact with the granite and were placed in such a manner that the beds dipped towards the igneous mass. This structural arrangement of the beds allowed the ore solutions to migrate up these dipping beds, and ore minerals were deposited between the layers, resulting in a banded form of texture.

6. As the further migrating solutions (especially the thinner solutions) reached the secondary faults in the limestones, their migration was made easier, and part of their ore load was left along these channels.

7. The final deposition of the ore solutions took place in the highly brecciated zones where the heat and pressure of the solutions were readily given up, resulting in rapid precipitation. These breccia zones are especially prominent where small wedges of limestone have been dropped into fault spaces and have held them open to be filled with wall rock rubble. Calcite and siderite were also deposited from the ore solu-

tions, which had acquired part of this material at least, from the surrounding calcareous rock channels while the solutions were hot and heavily charged with gas. Lead, zinc and iron sulphides and probably quartz formed the primary migrating ore solutions. Carbonate matter and calcium were no doubt picked up by the ore solutions during their course of migration through the limestones, and interchange of materials by solutions then took place.

8. Subsequent erosion tended to level the region, removing the limestone and shale from the higher segments, while the lower segments were not worn down so rapidly.

9. The area was then raised again, and again erosion set in, which resulted in differential carving. The resistant older quartzites formerly exposed stood up in relief to form ridges. The segment which was in the first place faulted down continued to form the main valley, but was also eroded greatly.

10. Ore bodies were thus exposed and weathering took place on them. Secondary carbonate ores were produced by this surficial action, effecting the more fractured areas.

11. Then came the glacial period when most of the rocks were carved, though some were protected by the ice and its deposits. Deep weathering action was stopped. Some of the deposits were deeply covered by a mantle of debris.

12. The ice sheet then retreated, leaving a long lake in front of it. This lake, which occupied the Pend Oreille Valley, had an outlet to the south. The ice sheet finally disappeared and out of the northern course of the lake, a river was developed, which started to drain the lake northward. The river, therefore, became deeply trenched in the underlying hard rocks. The river worked back up its canyon into the broader portion of the lake valley. Today, the Pend Oreille river in this broader portion looks more like a lake than a river.

13. The southerly course of the tributaries of this northward flowing lake-river is due to the tributaries following the old channels of the ancient mountain glaciers which were once the tributaries to the larger valley ice sheet.

METALINE FALLS AREA

General Statement

The town of Metaline Falls is located on the east side of the Pend Oreille River in section 21, T. 39 N., R. 43 E., and near it on either side of the canyon to the north, are numerous mining claims. These are here designated as occurring in the Metaline Falls area which include sections 21, 22, 15 and 16. Many of the assays given in this report for the Metaline district were taken from an assay chart secured from Mr. Lewis P. Larsen.

The rocks of the canyon are composed largely of limestones, dolomites, and slaty shales. There is a prominent shale formation which lies beneath a prominent limestone formation, but the two belong to the same series of rocks and both are faulted as well as folded.

On the west side of the canyon, the rocks dip westward, while on the east side, an eastern dip is more prominent, apparently forming an arch in the rocks, the crest of which the river dissects. Prominent faults on either side of the canyon, dipping toward the river, form wedge block structures. Other prominent faults run in a general east-west course and cause shales and limestones in places to come into abrupt contact with each other.

Washington Claim

On the west side of the Pend Oreille River, just below the bridge and above the falls, there are some prospects on a body of pyrite with which galena is associated. The principal workings are on the Washington claim (section 21, T. 39 N., R. 43 E.), although the Evolution claim was a later location made on the northwest-southeast extension of the strike, and there are some workings on it. On the surface, the pyrite has been oxidized to red and yellow iron hydroxide, forming a noticeable iron cap, but the galena has remained only slightly altered. The iron has even stained an overlying pocket of sand, a remnant of the old lake deposit of the valley. The deposit is located in limestone and dolomite, apparently a replacement of these rocks, in the fault zone which strikes N. 60° W. through Sullivan Creek and forms the south cliff side of Washington Rock.

At the time of investigation, a 90-foot tunnel had been driven and had encountered a solid body of pyrite at 60 feet, which lay on the footwall on the southwest side of the fault, whose dip is about 60° and whose strike is towards the northeast. Galena was found intermixed with pyrite and occurring directly on the fault. The pyrite rock is extremely hard. A drift was being extended in it along this fault towards the more prominent Sullivan Creek fault, on which ore is found at the surface. The object of the owner, Mr. Lewis P. Larsen, was to extend the drift to the intersection point of the two faults. It is thought by the writer that Sullivan Creek fault may be one of the original ore migration channels of the district. Further development may disclose geologic features bearing on this subject.

The following analysis was supplied by Mr. Larsen, representing the smelter returns on the sample of the lead pyrite ore of the Washington claim:

Gold	nil	Iron	15.4%
Silver	0.8 oz.	Insol.	1.0%
Lead	26.2%	Zinc	12.6%

Josephine Group

General Features. The Metaline Lead Company owns 15 claims, most of which are patented. They are generally known as the Josephine group, but formerly were called the Clark group, for Mr. Charles W. Clark is president of the Metaline Lead Company. The group includes practically all the claims located on the west side of Metaline Falls (in sections 16 and 21, T. 39 N., R. 43 E.), with the exception of Sullivan claim and the Washington group. The property was worked for 12 years (from 1907 to 1919) under lease and bond by the Lead and Zinc Company under the direction of Mr. Lewis P. Larsen. During that time, it is stated, the total net smelter returns amounted to about $275,000. About 40,000 tons of ore were mined. The ore contained approximately 11 per cent zinc and 2 per cent lead. The ore was milled, and 4,000 tons of concentrates were shipped. These concentrates averaged approximately 52 per cent zinc. The lead concentrates,

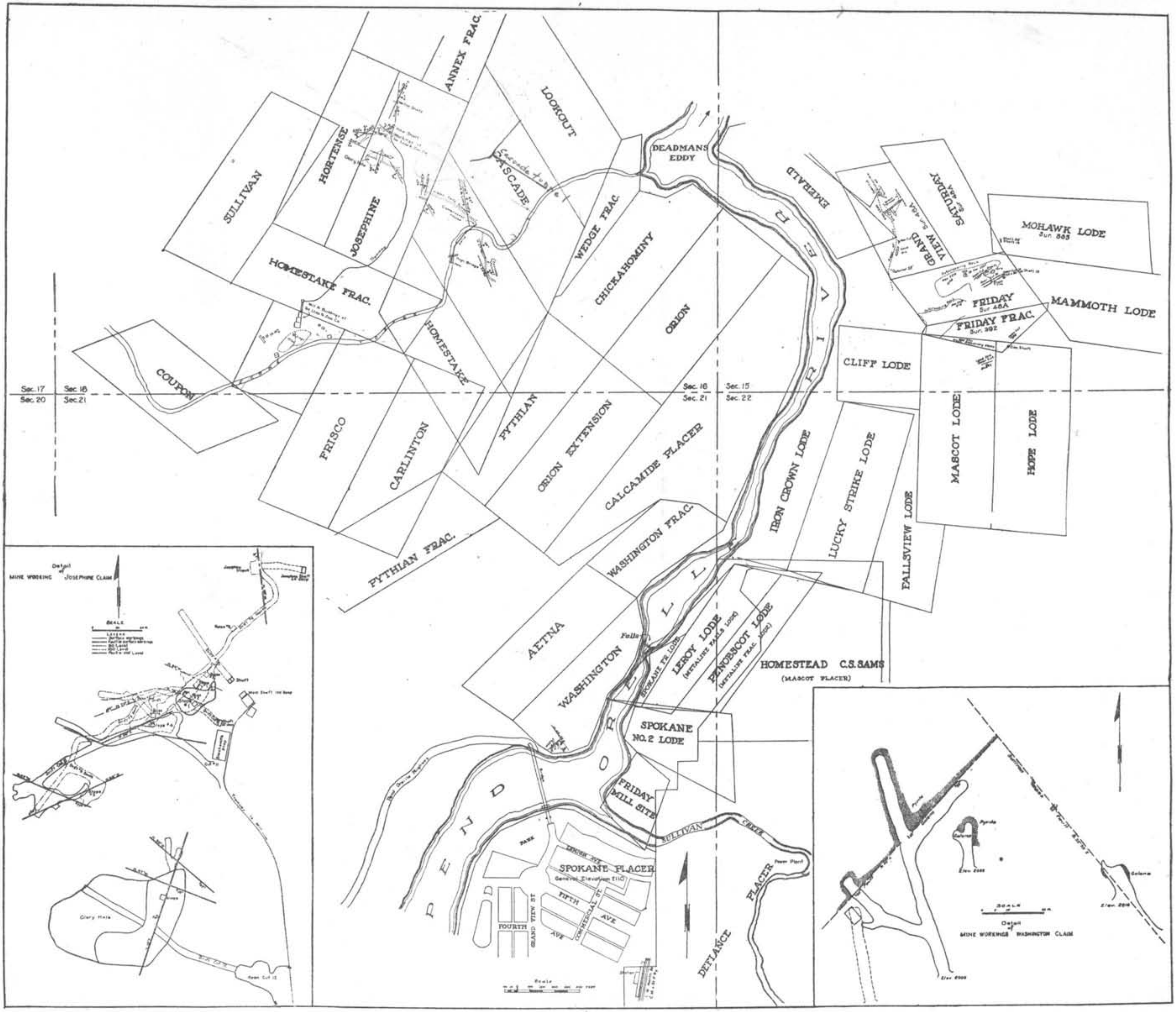

Plate II. Map showing the mining claims located about Metaline Falls. Detailed map of workings on the Washington claim shows the relation of the pyritic lead ore body to the faults. The fault intersection had not yet been reached at the time of investigation. The body of pyrite encountered was quite solid. The cut at the elevation of 2,032 feet was a fragment of the ore body which had slid down the bluff from above. The two faults shown are parallel to many other faults in this district, and may be considered as typical. The country rock is dolomitic limestone. Detailed map of workings on the Josephine claim shows the postions of some of the faults which are adjacent to the breccia ore zones. (Compilled from maps of the mining properties.)

amounting to 300 tons, averaged 50 per cent lead. At the time of mining, the price of zinc was very high. Some of the product brought in over $100 per ton and most of it over $50.

The Josephine, Hortense, and Hidden Falls claims were most extensively developed. These are located in highly disturbed (faulted and brecciated) dolomites and shales exposed as a bluff or ridge which sticks through the high gravel bench, 500 to 800 feet above the Pend Oreille River. Flume Creek cuts through the center of Hidden Falls claim, cutting a deep and precipitous canyon, reaching the river, less than a mile distant, by a series of cascades and water-falls. At the mouth of Flume Creek, just southwest of Dead Man's Eddy on the river, is situated the Chickahominy claim, where a 300-foot tunnel was driven and also a shaft was sunk. Just west of this claim on the opposite side of the river high up on the canyon wall is located the Grand View group of claims. Up the river a mile or so is the Washington group, but it is not directly reached from the Chickahominy claim by trail.

Josephine and Hortense Claims. The ore from the Josephine and Hortense claims was trammed largely from open pits and glory holes to the mill on Flume Creek. The concentrates were hauled by trucks from the mill to an ore bin, over a mile distant, located on the Metaline road on the high point overlooking the river. Here the concentrates were sent by aerial tram across the river to the railroad near the cement plant.

The ore bodies were discovered largely by surface stripping and trenching and by open pit work. The old method of "following the ore," no matter how thin the stringers of ore might be, led to the discovery of ore pockets of considerable size. For the most part, the ore occurs in breccias produced by faulting. This breccia is more in evidence at the intersection of the faults or associated with rock wedges formed by faults whose dips are toward each other. In numerous places, it was noticed that breccia occurred on one side of the fault and not on the other, also that breccia would occur below a fault wedge where the wedge had apparently been dropped into a fissure and held it apart. Slickensiding along the walls of these faults is very much in evidence. Every conceivable direction was found to be represented by these slickensiding grooves. The sulphide ore found in the deposits is largely composed of a resinous appearing sphalerite with some galena. Pyrite is not common. In the main shaft, one hundred feet deep, an iron oxidized zone was found, thought to have been formed from the oxidation of pyrite, but it has not been extensively developed. The writer was unable to see this deposit.

Superficially altered ore is in abundance within 15 feet of the surface, and it is clearly exposed from the glory hole where it was mined, along with the primary ore, sphalerite. Smithsonite is the principal ore of this superficial type. It occurs as the carbonated product of sphalerite, in irregular masses, botryoidal forms, and as a replacement of calcite. Large masses of coarsely crystallized calcite frequently occur in the mine. These masses are light gray to white in color and break regularly along the planes of rhombohedral cleavage. The replacement of the calcite by smithsonite has taken place along these cleavage planes of the calcite crystals. The result of this action has given a grid-iron texture to much of the smithsonite.

Besides calcite, quartz and some chert are prominent gangue minerals. The quartz occurs along with the sphalerite, often surrounding the zinc mineral and as a filling in the interstices between the pieces of rock breccia. The breccia material is composed of irregular fragments of dolomite (often found to be silicified into chert) and of black slate. The sphalerite, for the most part, is light colored. The combination of chert breccia and resinous looking sphalerite gives to the ore the appearance of the sphalerite ore of the Joplin district (Missouri). In breaking this material into small pieces for the mill, it was found that the fragments of ore minerals were generally surrounded or were adhered to by silica and not limestone.

An attempt had been made to find the ore through diamond drilling, but the irregular pockety occurrence of the deposits lead to a considerable amount of wasted work.

Hidden Falls Claim. An attempt was made to reach the ore at depth by driving in tunnels from the bottom of the precipitous Flume Creek Canyon some 400 feet lower in elevation. Hidden Falls tunnel was driven to the west and the Cascade tunnel to the east, each about 500 feet long. A little ore (sphalerite and galena) was found, but in no bodies of considerable size. In the Cascade tunnel, a vertical cave was encountered, which resulted in an influx of water and surface gravel. Hidden Falls tunnel never was driven to a point directly beneath the ore bodies of the Josephine claim.

Chickahominy Claim. A rather steep trail leads from the mill on Flume Creek down to the Chickahominy claim, which is located on the river by Dead Man's Eddy.

Although the workings were caved at the time of investigation, two fault planes with slickensided walls, dipping toward each other, were clearly exposed. Their strike is about N. 18° E. The rock wedge formed between the fault wall was apparently largely breccia filled with bunches of lead ore. On the dump, pieces of high grade "steel galena" with very little sphalerite were found. This should be an interesting property to develop further.

Sullivan Claim

The Sullivan is a patented claim adjoining the Josephine group on the west and is owned by the Sullivan Mining Company. The ore consists of lead and zinc of similar occurrence to that of the Josephine. There has been no activity on this property in recent years. The property was not investigated by the writer.

Grand View Group

Active prospecting was just beginning again, at the time of the writer's investigation, on the Grand View group of claims. The claims are said to have been patented over 35 years ago. They consist of the Grand View, Saturday, Mohawk, Friday and Friday Fraction. They are located by road two miles northeast of Metaline Falls (section 15, T. 39 N., R. 43 E.), but in an air line, about one mile. The prospects are on top of the limestone cliff overlooking and several hundred feet above the east side of Pend Oreille River. The town of Metaline Falls can clearly be seen from the property and so also can Dead Man's Eddy and the property of the Josephine Group lying across the canyon. The ore is largely galena in a brecciated dolomitic limestone with apparently very little zinc. The general course of the ore body at present being prospected is N. 10° to 15° W. Prospecting had been done by open cuts and in natural caves and by a 125-foot tunnel into the bluff where the ore body was reached 75 feet from the portal. In one natural cave it was noticed that breccia was much in evidence. Broken off pieces of brecciated rock containing galena, partly filled the cave.

NORTHWEST AREA

Lead King Group

The Lead King Mines Company, Inc., controls three groups of claims, as follows:

1. Lead King group, which consists of the Lead King, Lead King Extension, Lead King East Extension, Alameda, Mockingbird and D. Aldrich.

2. Washington group, which consists of the Washington, Washington Fraction, Etna, Spokane Fraction, Spokane No. 2, and Metaline Falls.

3. Z-Canyon group, which consists of the Sphinx, Torrantial, and some placer claims.

The Lead King Mines Company has as its president Lewis P. Larsen and as its secretary Jens Jensen. The Lead King group is discussed in the following paragraphs. The discussion of the Washington group is placed with the claims discussed under the title of Metaline Falls area. The Z-Canyon group was not investigated, and therefore is not discussed.

Two or three carloads of ore, principally lead and zinc, are reported to have been shipped from the Lead King group of claims in 1918. The claims are located (in section 27, T. 40, N., R. 43 E.) on the Boundary road eight miles by road north of Metaline Falls, and one mile in a direct line west of the Pend Oreille River on top of the high bench. Prospecting has been done on the property in the form of surface cuts, shafts, trenches and a tunnel near the line between the Lead King and Lead King Extension claims. Here the ore consists of galena and sphalerite, both of which occur in the outcrop nearly unaltered. This is undoubtedly due to the fact that the rocks were laid bare by glacial abrasion, and have not had time since to become oxidized to a great extent. These minerals occur with quartz and breccia filling and as a net work of connected stringers. The breccia is formed more in abundance and forms a massive ledge containing inclusions of the country rock. Massive quartz was found in places which contained grains of resinous appearing sphalerite.

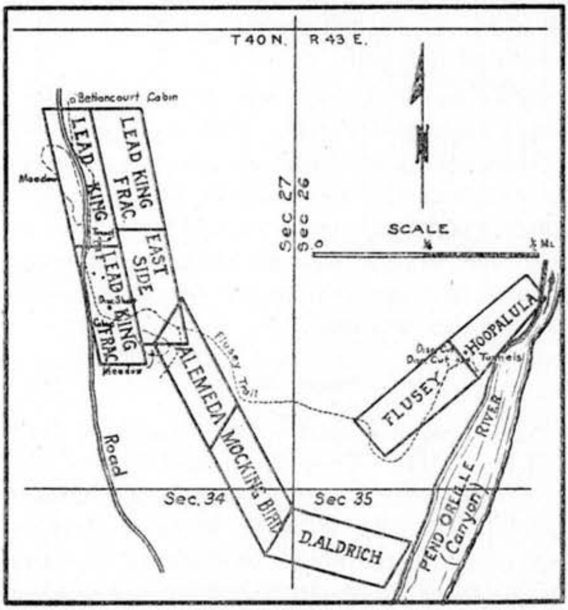

Figure 8. Map of the Lead King and Flusey groups. The canyon of the Pend Oreille is here deep, narrow, and precipitous and the Flusey workings are in the canyon wall. (From maps provided by Lewis P. Larsen.)

One specimen of a fine-grained black dolomite contained small irregular bunches of massive clear quartz, the edges of which are bounded with grains of resinous appearing sphalerite, which also extends out into tiny veinlets. Separate bunches of galena are present in the specimen. There is no sign of banding in the vein matter. In places there is a little calcite with the galena and sphalerite. The breccia is closely associated with slickensided slip planes, a prominent one of which strikes east and west, dipping south at an angle of 80°. The bedding of country rock, which is largely a blue-gray to white dolomitic limestone, apparently strikes N. 10° E. with an east dip of about 57°. The location of these outcrops is on a low ridge bordering a narrow glacial valley, running north and south. On the opposite side of the valley is quartzite. Apparently the major fault contact, previously referred to lying between the limestone and quartzite series, lies covered in this valley, a short way from this ore deposit. At the time of examination, a shaft was being sunk on the edge of the valley and it passed through gravel and had encountered some ore in brecciated dolomite.

The following analyses were supplied by Mr. Larsen: *Shaft* 7x7x14 feet, first sample, 4.12 oz. silver, and 3.5 per cent zinc; second sample, 0.84 oz. silver, and 35.6 per cent lead. *Cut* 5x7x9 feet, 2.56 oz. silver, and 3.1 per cent zinc. *Cut* 5x5x4 feet, 0.76 oz. silver, and 24.1 per cent lead. *Cut* 5x6x13 feet, first sample, 1.46 oz. silver; second sample, 1.12 oz. silver, and 70.6 per cent lead. *Discovery shaft*, 6.28 oz. silver, and 49.3 per cent lead.

Flusey Group

The Flusey group consists of two patented claims: The Flusey and Hoopalula. They are owned by the Flusey Lead Company, of which Mr. Lewis P. Larsen is president. They are located in section 26, T. 40 N., R. 43 E., just east of the Lead King group on the bluffs overlooking the deep narrow canyon on the Pend Oreille River. They are reached by trail from the road which passes the Lead King group, a distance of one mile.

The rocks are of dolomitic limestone and dip west at an angle of over 40°. Iron oxide caps certain shear zones running in a northeast and southwest direction. These shear zones evidently mark the ore bodies which apparently stand in a vertical position or dip steeply in an opposite direction from the dip of the rocks. The ore minerals consist of galena and sphalerite, associated with pyrite. The gangue is largely composed of recrystallized gray dolomite whose crystal cleavage faces appear curved.

The assay records supplied by Mr. Larsen of five samples collected from these claims gave the following results:

Sample	Oz. Silver	Per cent Lead	Per cent Zinc
1	0.44	29.8	....
2	Trace	0.0	....
3	0.68	25.0	....
4	0.48	20.6	11.9
5	0.36	11.9	2.7

The property has been prospected by a series of surface cuts and by two tunnels. In the 200-foot tunnel, which is located on the Flusey claim, pyrite and galena occur at the face between two main vertical slickensided fault planes five feet apart, which strike S. 60° W. The tunnel is streaked with a thick film of iron hydroxide and calcium carbonate.

The oxidation of the formation of this pyrite is very marked and has been dissected by the Pend Oreille River. The superficial alteration probably took place at a considerable depth previous to glaciation, and was then covered and protected by sand and gravel until recent stream cutting action again exposed it to view.

Cliff and R. E. Lee Claims

The Cliff and R. E. Lee are groups of patented claims that are owned by the San Ramone Mining Company. They were not examined by the writer since they were inactive. Bancroft* has described them in his report.

Hanley Claim

The Hanley claim is located on the west bank of the Pend Oreille River about one mile south of the International Boundary. The writer did not visit the property.

WEST METALINE AREA

Kroll Property

General Statement. The Kroll property consists of the following mining claims, located largely within a mile or so of the town of Metaline in sections 29, 30 and 32, T. 39 N., R. 43 E.: Diamond R Lode, Bella May Lode, Bella May Fraction Lode, Bella May Fraction Lode No. 3, Blue Bucket Lode, Yellow Jacket Lode, Admiral Lode, Cold Finder Lode, Lone

*U. S. G. S., Bull. 550, p. 49.

Star Lode, and Ella Lode. Of these claims, those of the Bella May group were the only ones active at the time of investigation. A few years ago, the Diamond R mined and shipped lead ore, but it is now idle.

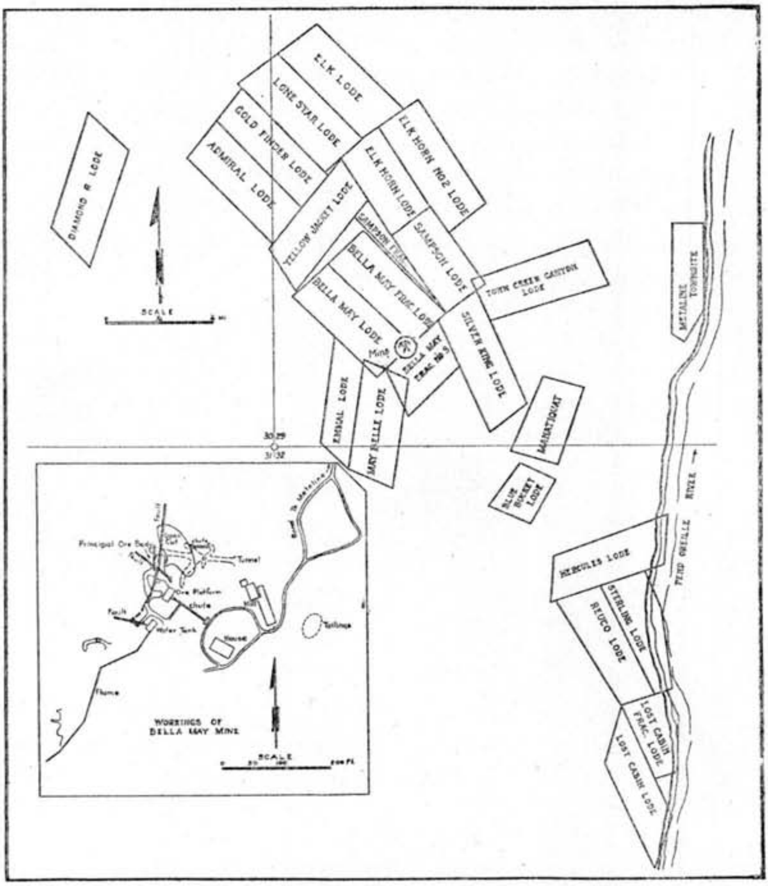

Figure 9. Map of the Kroll properties, showing in particular the Bella May Mine and the positions of faults along which ore occurs in the associated breccia zones. High grade galena ore was being shipped from this mine at the time of investigation. (Map of claims provided by the company. Mine map prepared by the writer.)

Bella May Group. At the time of investigation, mining of high grade galena was being done by Oscar DeCamp and his associates at the place where the three Bella May claims corner. During the winter of 1923-1924 and also the following spring, over 250 tons of practically pure galena were shipped to the smelter.* This material was hand picked and sent by wagon to the railroad at Metaline Falls, three miles away. A little sphalerite is found in some of the ore but this was being put aside for future separation.

Previous to this work, the property had been developed by the Diamond R Company, who had constructed a mill operated by electric power furnished from the plant at Metaline Falls, for the purpose of concentrating the lower grade ore. The property had been opened at the surface and this work connected from below with the tunnel.

The Bella May is located on a limestone ridge or bluff which sticks up through the high gravel bench, lying about 700 feet above the Pend Oreille River.

The ore occurs in fractured and brecciated zones in the dolomitic limestone. Prominent slickensiding fault planes are clearly exposed in the mine, and it is apparent that the breccia is associated with these faults. Breccia is most prominent at the intersection of the faults. This feature is clearly a characteristic one and should be given due consideration.

In one place where it is stated that a total of eleven carloads of ore have been taken out and shipped, it was noticed that at least four different faults intersected and formed a fairly regular body or chimney of breccia, which had been filled with ore. In this place the principal faulting was in a north and south direction with the ore body occurring for the greater part on the east side. Two prominent faults dip toward each other, forming a rock wedge between them. More or less ore was found to be associated with the faults and with the wedge. The highest grade ore was found just below the wedge where the fault openings, the broken rocks, and the breccia were held apart by the wedge.

In places, the weathering of the surrounding rock has left ore masses lying in a matrix of soft material composed in part of iron oxide and in part of the carbonates of lead and zinc. Also mixed with it are clay, and fine sandy particles of the dolomitic limestone. Both cerussite and smith-

*A more recent report (Dec. 10, 1924) states that altogether 18 carloads of ore have now been shipped from the Bella May.

sonite are found on the outside portion of the ore bodies. Glacial drift, or rather gravels of glacial, lake and stream origin, form a mantle covering over the oxidized portion of the deposit. The writer is of the opinion that the oxidation is pre-glacial in age.

That the best mining results have been obtained in this mine by "following the ore" is quite evident. Since the ore is irregular in occurrence, it is hard to tell where next it will be found.

The writer is of the opinion that the following features may be good indications for prospecting:

1. The presence of ore, though it may be only stringers of galena and sphalerite.

2. The abundance of iron oxide material, for the gangue of limestone composed largely of dolomite, calcite and siderite may be broken down by agents of superficial alteration, to form this residual iron-stained clay.

3. Carbonate zones (where this term means carbonates of lead or zinc and hydroxide of iron), for they are indications of sulphide bodies at greater depth.

4. Breccia zones, for it is in this material that much of the ore is deposited.

5. Slickensiding planes, especially at their intersection, for often along these planes breccia is found.

6. Calcite or siderite zones, for these minerals often form the gangue minerals of the ore.

Diamond R Claim. It is stated that several years ago the Diamond R shipped a carload of lead ore. The deposit is located half a mile west of and 300 feet higher than the Bella May. The mine was idle, however, at the time of investigation and not much could be seen. There was a 200-foot tunnel and some open pit work had been done. The ore consists of galena with a few secondary minerals occurring in the matrix of blue-gray dolomitic limestone breccia. Prominent slickensided slip planes were noticed, with which were associated bodies of breccia more or less filled with ore. A north and south fault, which had a west dip of 85° with breccia on its foot wall appeared to be a prominent feature.

Evidently the ore body was the same type of deposit as that of the Bella May.

Blue Bucket Claim. There are other claims of interest on the Kroll property, one of which is the Blue Bucket. Here also the ore is of galena (nearly free from sphalerite) and occurs in dolomitic breccia. The breccia is associated with faults which intersect and form a rock wedge. The ore body strikes N. 15° E. along the ridge, which sticks through the level of the high gravel bench and overlooks the Pend Oreille River, lying several hundred feet below. Five tons of ore, it is reported, were shipped to the smelter from this claim.

Oriole and Adjoining Claims

General Features. North of the Kroll property lie the claims of the Metaline Oriole Mining Company, which, at the time of investigation was in the hands of a receiver.

The claims of this group consist of the Oriole, Oriole Annex, Eastern Star No. 1, Eastern Star No. 2, Silver Queen, and Red Clorid. These claims lie largely in sections 19, 20 and 30, T. 39 N., R. 43 E. Several adjoining claims are owned by Mr. E. J. Hoage; namely, the North Extension, Fairview, West Extension, Oriole, Champagne and Hoosier.

The property is located about 700 feet above the Pend Oreille River, a mile northwest of Metaline and two and one-half miles from Metaline Falls, and may be reached by a road. A trail extends farther westward which passes by the Diamond R claim on its north side. At this point, it was noted that a rather dim trail branches off to the north and passes over the Calispel mountain range to the Electric Point Mine, which lies on the opposite side of this quartzite range, seven sections to the west and three sections to the north. The trail leading west, however, may be followed to the O. K. group of claims also owned by Mr. E. J. Hoage. These consist of the O. K., North Extension of O. K., Ione, Columbia, North Extension of Columbia, S. W. Silver Queen, N. E. Silver Queen, and others. The O. K. group is not of as much interest as regards lead deposits as the Oriole, but is of considerable geological interest. Neither the Oriole nor O. K.

group is entirely similar in character to the other lead and zinc properties of the Metaline district. Their ores are associated more with quartz bodies and are said to contain higher silver values as well as gold, and all the deposits lie close to the limestone quartzite contact (which is here considered a major fault) and are associated with a few small igneous dikes. The writer has reason to believe that not far beneath these deposits lies buried a mass of intrusive granite.

Oriole Claim. Most of the development work of the Metaline Oriole Mining Company was done on the Oriole claim. The principal workings consist of three tunnels. From the upper or No. 1 tunnel, it is reported that half a carload of ore was shipped. This tunnel lies 50 feet above No. 2 tunnel. The second and third tunnels are connected by a 100-foot incline, out of which, it is stated, three carloads of ore were shipped. The inclined winze continues in No. 3 tunnel to a depth of 91 feet. From the bottom of this incline, a drift 60 feet long was driven along ore, and it is stated that a carload of ore was taken out. It is said that the best galena ore was found in this drift, but the writer was unable to verify this statement, for the lower workings were filled with water at the time of investigation.

No. 2 tunnel is directed N. 35° W. in dolomitic limestone. At a distance of 261 feet from the portal, a well defined fault is encountered with a slickensided surface, striking N. 65° W. and dipping at an angle of 60° towards the north. Into this fault, other slip planes dip and form rock wedges, below which ore is present in the shattered rock breccia. The ore consists of black and brown sphalerite, galena and pyrite set in a matrix of massive quartz vein matter. The ore body at the surface is weathered to limonitic material containing blue and green copper stains and said to carry values in gold as well as copper. Some zinc carbonates are also present. Only a little galena is present on the surface.

No. 3 tunnel has a direction of N. 65° W., entering dolomitic limestone. A thin igneous lamprophyre dike, green in color, is encountered at 100 feet. Another dike, part of which is of the same character, the rest of it being brown micaceous material, quite decomposed, occurs at 144 feet. Both dip S. 50° E. at angles of 55° to 85° respectively. At 532 feet was located the hoist situated on the incline, which extends below and connects above on the fault which carries the ore body. The slope of this incline bears N. 14° E. The ore was followed on the third level until it pinched out at about 175 feet. The ore body, which is in a breccia zone, terminates at either end by faults. The main fault continues without much ore. Evidently the breccia is formed between and is bounded by faults. This factor, therefore, classes the ore body as an ore-shoot. The ore consists of sphalerite, galena, pyrite and copper carbonates, all associated or occurring within masses of quartz containing more or less sericite, filling the shear zones and brecciated matter of the dolomitic limestone. The ore body dips in general N. 10° E. at an angle of 58°.

Quartzite occurs farther up the hillside on the slope of the mountain. The contact between limestone and quartzite was evidently not reached in the mining. If this contact is the profound fault which the writer is inclined to believe, it is evident that both the dikes and the vein matter passed up and along it and were solidified or precipitated in the fracture zone produced in the limestone side of this great fault. The faults encountered in the mine are therefore secondary to the great fault. The mine would have been a more interesting study if the tunnels had extended further into the quartzite and had passed completely through this great disturbed and faulted zone.

Fairview Claim and West Extension of Oriole. On the hillside a few hundred feet higher in elevation than the Oriole mine, is a 100-foot tunnel driven in a direction N. 15° W. into solid quartzite. The rock varies from a conglomerate to a fine-grained quartzite, but all of it is extremely metamorphosed. Schistose structure is prominent together with the development of talcose and sericitic layers. The pebbles of the conglomerate have even been compressed and elongated by great pressure, which was apparently applied together with intense heat, at great depth. On the weathered surface, the rock is stained with iron and darkened with an outer growth lichen. The beds of quartzite dip N. 45° W. at an angle of 45°.

It is the opinion of the writer that this rock is on the upthrow side of a very profound displacement. In the hill above the tunnel, quartzite continues to outcrop. Apparently this snow-white quartzite lies stratigraphically very deep in the sedimentary series.

Champagne and Hoosier Claims. Adjoining the Oriole to the southwest, along the contact between the quartzite and limestone, are located first the Champagne and the Hoosier claims. A tunnel in the first of these directed S. 35° W. was caved, but on the dump was quartz associated with a green talcose or serpentine rock, having an appearance of extremely metamorphosed and silicified dolomite. Pyrite was present.

A tunnel located on the Hoosier claim is said to be 175 feet long. It is directed N. 57° W. and lies 300 feet higher in elevation than the Champagne. This tunnel was also caved. It evidently must have cut the main contact, for on the dump were both schistose quartzite and pieces of limestone containing calcite and quartz vein matter. Copper, iron and manganese stains were seen in the quartz, but no zinc or lead minerals. It is said that the ore contained values in silver, gold, and copper. A shaft 25 feet deep was located near by but was filled with water. Fragments of limestone, which included quartz masses and copper stains, lay on the dump.

O. K. Group.—The O. K. group of claims is situated on the edge of a mountain side 600 or 700 feet higher in elevation than the Oriole group about one mile to the southwest, extending into section 1, T. 38 N., R. 42 E. The two properties are connected by a trail. A trail also leads from the claim to a road located one-half mile down the slope of the hill. By road it is about four miles to Metaline Falls. It is said that the ore values of the O. K. group lie in their content of silver, gold, lead and copper. The writer, however, has seen no assays on the ore. There are a number of tunnels and surface workings on these claims. On the O. K. claim, there is a tunnel 225 feet long driven into a coarsely crystalline dolomite. The grain of this rock is like coarsely granulated sugar. Intercalated in the limestone and overlying it only a short way farther up the hillside are exposures of quartzite. The tunnel does not reach the quartzite. Therefore, the writer was unable to see a clear exposure of the contact and to ascertain whether or not it is a fault. Both series of rocks dip towards the northeast into the mountain side. At the face of the tunnel, there is a more argillaceous rock, which overlies the limestone and has prominent bedding planes. These beds dip N. 10° E. at an angle of 35°. Mineralization has taken place along these bedding planes. Layers of a massive form of clear quartz with sphalerite, some galena, a little chalcopyrite, and pyrite occur in bands more or less parellel to the bedding planes of the rock. In places these layers have bulges in them, forming little lense-shaped bodies a few inches long and a fraction of an inch wide. Generally the center of the lense is quartz, while the periphery is chiefly sphalerite. The mineralization is apparently more abundant in the bedded argillaceous dolomite than in the massive limestone or dolomite. This banded ore very closely resembles that which occurs in the New England claim in the Northport district. The deposit of the New England claim lies close to the granite contact and the beds which dip toward the granite contact. It would appear that, in both cases, the mineral-bearing solutions had passed upwards along the bedding planes from the igneous magma below, and had, in part at least, been deposited there.

The banded structure of the wall which invariably has a clear quartz matrix is apparently characteristic of this group of claims. Also the sugar-like dolomite is strikingly characteristic. The rock is truly a marble. These features were seen in many of the surface workings of the claim.

A tunnel in the Ione claim is about 200 feet long, directed N. 12° W. It also pierced a massive sugar-like dolomite with the object of cutting an ore ledge found further up the hill. In this latter part of the tunnel, a fault plane was followed which has a due north strike, dipping east at an angle of 86°.

On the O. K. claim, there are three or four surface openings on a narrow pegmatite dike, which disclose some extremely interesting geologic features, bearing on the origin of the ore deposits. These openings were made by the prospector who was attracted by the occurrence of a peculiarly colored blue mineral. The mineral has since been determined in the laboratory to be glaucophane. The dike discloses a varying width from a few inches to a few feet. The minerals occurring in this igneous dike are largely quartz, muscovite, and feldspar. It is of interest in the study of this dike to note that the quartz in places is in the form of grains like those which occur in ordinary granite, but in other places the quartz is segregated in masses, stringers and veins. The vein matter has exactly the same appearance as the quartz vein matter, which occurs in the dolomite limestone and carries the ore. In fact, a few crystals of galena and some copper stains were found in the quartz-muscovite portion of the rock. The intruded rock was originally dolomitic limestone, but has been silicified locally, the silicification having taken place along the bedding planes of the rock. The strike of this dike rock was found in the prospect to be N. 55° E., and dips S. 35° east at an angle varying from 75° to vertical. The limestone dips into the hillside in an opposite direction and at a lower angle than the dike. The narrow pegmatite dike is probably an apophysis (or branching arm) which extends out from the granite mass below and not far distant.

EAST SIDE AREA

General Statement

The Grand View and Z-Canyon groups lie on the east side of the Pend Oreille River. The Grand View group has already been described elsewhere in this report.

The Z-Canyon group is located just east of Z-Canyon and consists of the Sphynx and Torrancial claims. The writer did not investigate these properties.

The Schallenburg, Riverside and Meade prospects, which lie on the east side of the river, were not examined by the writer. They were reported as having been completely abandoned. Bancroft has amply described them in his report.*

*U. S. G. S., Bull. 550, pp. 49-51, 1914.

Wolf Creek Group

The Wolf Creek group is located two miles south of Metaline Falls, on the east side of the river, not far from the railroad track in section 4, T. 38 N., R. 43 E. The group consists of five claims (Bull Moose, Silver Horde, Snow Shoe, Milwaukee, and St. Paul) and occur in a dolomitic limestone hill, not far above the railroad. The development work consisted largely of a tunnel directed N. 20° E. and an incline shaft 85 feet long, sloping 44° in a direction S. 85° E., located near the portal of the tunnel. It is stated that a railroad siding is to be put in for logging purposes, which could also be used for loading ore.

The ore consists of brecciated blue-gray dolomitic limestone with some galena, pyrite, and a little sphalerite. The ore body which has been exposed consists of a breccia zone occurring between two intersecting shear zones having a strike of S. 50° E. and S. 35° W. respectively.

An experimental smelter was constructed on this property in 1923. It was to have a 10-ton capacity and to use oil for fuel. The enterprise apparently failed.

LEAD DEPOSITS OF STEVENS COUNTY

GEOGRAPHIC FEATURES

Stevens County is considerably larger than Pend Oreille County, which lies along the greater part of its eastern side. Ferry County adjoins Stevens on the west, the Kettle and Columbia Rivers forming the boundary line. To the south, the Spokane River, a tributary of the Columbia, flows along the boundary line, with Lincoln and Spokane counties on its south side. From the International Boundary to the Spokane River, Stevens County measures 82 miles, while its width in most places is not over 35 miles.

The Columbia River enters Stevens County at the town of Boundary, flows southwestward by Northport, and, after joining the Kettle River at Marcus, its course is directed southward until it reaches a point a few miles beyond the mouth of the Spokane River. Here it flows, in general, westward. The Colville River, though a small stream, flows through the most populated portion of the county. It rises in some lakes that lie in southeastern Stevens County, and flows northward through a broad valley until it reaches a point just north of Colville where it swings to the west and joins the Columbia River at Kettle Falls. A range of rough hills, known as the Huckleberry Mountains, rising to 4,500 feet in elevation, lies between these two streams. To the east, between Stevens and Pend Oreille counties is the Calispell Range, which is somewhat higher. The county as a whole is made up of irregular rough mountain ranges and valleys. The topographic relief is diversified and affected much by glaciation. The county lies in the semi-arid intermontane belt, known to physiographers as the Okanogan Highlands.

The Great Northern Railway traverses the county. It enters the town of Clayton in the southeast corner and passes northwestward through Springdale, Chewelah, Colville, Myers Falls, and branching at Marcus, one road runs up the Columbia and the other up Kettle River, the latter line following for the most part on the Ferry County side. A branch of the railroad runs from Northport northward up Sheep Creek, joining with the Canadian Pacific Railway which extends to Rossland and Trail, British Columbia. A line owned by the Washington Water Power Company runs from Spokane to Long Lake and from there northward to Springdale. This is known as the Chamokane Construction Company Railroad. The Phoenix Lumber Company has a logging railroad extending westward from Springdale for a number of miles.

Automobile roads dissect the country pretty thoroughly. Some of these roads are good highways, but many are very rough. Constant hauling by huge lumber and pole trucks, in places, keeps the roads in bad shape.

The most prominent lead deposits which have been discovered in the state, occur in the northeastern corner of Stevens County, the principal interest having been located about the Electric Point and Gladstone mines. These deposits lie on the opposite side of a mountain range seven miles due west of Metaline Falls. Nearly all the other important lead, lead-silver, and lead-zinc properties in the county lie along a belt extending in a southwesterly direction from this district. Important examples of these are the Black Rock, a zinc mine; the Old Dominion, a silver-lead mine; and the Cleveland, an antimonial-lead mine.

Southeastern and northwestern areas in Stevens County are mineralized with copper, gold, silver, and other metals, but they are not important lead producers.

Besides the activities in metal mining, Stevens County is a very important producer of magnesite, and of clay products.

In addition to mining, the principal industries of Stevens County are lumbering and agriculture. Since the timber is of small size, the pole industry has developed and made considerable progress.

According to the 1920 census, the principal towns of Stevens County had the following population: Colville, 1,718; Chewelah, 1,288; Northport, 906; and Marcus, 551. Colville is the county seat. Chewelah has a large magnesite kiln near it. There was located in Northport until a few years ago, a smelter, which is now dismantled. Marcus is a railroad center.

GEOLOGIC FEATURES

For a complete description of the geology of Stevens County, the reader is referred to Bulletin No. 20 of the Washington Geological Survey, "The Mineral Resources of Stevens County," by Charles E. Weaver. A map is included in this report which shows the general distribution of the various rock formations.

In general, the geologic features of Stevens County, consist of a complex series of metamorphic sedimentary rocks, intruded by a great mass or batholith of granite, which is exposed on the east side of the county. Three huge tongues of this granite extend nearly across the county in its northern, central, and southern portions. Numerous dikes of various kinds and sizes also intrude the metamorphic sedimentary series. Many of these dikes may represent differentiated products of the original granite mass. In the southern and northern portions of the county, surface lava flows of basic character are present.

Practically the entire county has been affected in some way by glaciation, either by rock removal or by deposition of loose gravelly material. The ponding of bodies of water is a very prominent glacial feature of the region, and numerous well defined terraces of sand and gravel mark the shores of ancient and extinct lakes. Some of these lakes were indeed very large in size.

Weaver has provisionally placed the metamorphic sedimentary series in the Paleozoic period, while the igneous rocks are later in age, probably of Mesozoic and Tertiary time. The metamorphic sedimentary rocks consist, for the greater part, of quartzites, argillites, and dolomitic limestones, and lithologic or metamorphic varieties of these groups. Of this various assortment of rocks, the dolomitic or magnesian limestones (which we may for convenience refer to as simply limestone) have undoubtedly the most significance in relation to ore deposition. The reason of this, in the writer's opinion, lies in two characteristic features of the rock. First, the limestone when sheared forms breccia and fracture zones favorable to the entrance of ore bearing solutions. Second, the limestone is more susceptible to replacement by ore bearing solutions.

The most significant major structural feature relative to ore deposition is the position of the majority of the mineral deposits between the major tongues of the granite batholith. The ore deposits would appear to lie embayed, so to speak, between these great igneous arms and undoubtedly above the buried connecting mass of granite.

That the ores were genetically related to the original granite magma, seems to be the consensus of opinion among most geologists who have studied the region. This does not necessarily mean that the best deposits lie exactly on the contact of the granite with the metamorphosed sediments. Ore bearing solutions were probably given off by the magma soon after its consolidation and these solutions penetrated the rocks intruded. All this happened, it must be understood, while the rocks were deeply buried beneath the surface of the earth. The reason they are now exposed is that the rocks were upraised by great earth movements and were subsequently worn off by erosion.

The most important minor structural features of the lead deposits would appear to be their position in brecciated or sheared and faulted zones in limestones. This feature has a great deal of significance, for these zones of brecciation are irregular in size and their position depends largely on extremely intricate faulting.

There appear to be three prominent gangue minerals in the lead deposits, the preeminence of any one in particular depending upon rather obscure conditions. These minerals are: quartz, crystalline and massive; calcite, often in large crystals showing prominent rhombohedral cleavage; and siderite, which breaks down under weathering conditions so readily as to form when present in large amounts, quantities of iron hydroxide. These three minerals, quartz, calcite and siderite, occurring in varying proportions, appear to have closely accompanied the lead bearing solutions and were deposited with the galena in the shattered or fault zones, generally after the deposition of the galena.

The lead deposits and the lead-zinc deposits appear to occur in much the same manner. It was the experience of the writer, however, to find sphalerite more in evidence as a replacement in limestone where that rock was not very far from its contact with granite. Wherever much crystalline quartz is present, forming distinct quartz vein matter, it appears that the galena is more silver-bearing. Also it would appear that under the latter conditions, pyrite is present in greater quantities and, in places, some copper minerals (chalcopyrite, generally found altered) may accompany the lead ore.

Although basic dikes (for the most part lamprophyres) are abundant in occurrence, they apparently have had little or nothing to do with the deposition of ore in the region. In places they occur with the ore, but it would seem that both dikes and ore had sought out the same lines of structural weakness. In a few places, the intrusive action of the dikes appears to have made zones of structural weakness by their own force, along which zones later ore solutions followed.

Pegmatite or aplite dikes, on the other hand, may, in some places, as in the Bonanza and the Old Dominion mines, be genetically related to the ore bodies. It is quite possible that, in some localities, the quartz veins are differentiated products of a pegmatite magma, as in the Deer Trail district.

We may consider the igneous magma as a solution under intense pressure and heat, in which, when some of these energies are partly given up, the greater part of the mass gradually consolidates, releasing a remaining part kept in solution by the peculiar nature of contained substances, often called "mineralizers" and accompanied by released gases. This part may be pegmatitic in composition and it may go through the same performances as the original magma, consolidating in part, while a remaining gaseous solution is passed on, migrating to another position. This action may keep repeating itself, always with the remaining solution becoming thinner and more aqueous in composition until finally carbonates of calcium, magnesium, and iron are precipitated but with little silica from cooler water solutions. The release of ore minerals by the wayside must depend upon the nature and composition of the solution which is migrating, upon the conditions of temperature and pressure, and upon the materials encountered on the way.

In general, the following geologic actions appear to the writer to have taken place in Stevens County:

1. Massive deep-seated intrusion of granite magma.

2. Differentiation of part of the magma into
   a. Acid dikes (pegmatites and aplites) often containing ore, or genetically associated with ore.
   b. Basic dikes, for the greater part sterile of ore, which were intruded generally after the ore was formed.

3. Differentiation of pegmatitic dikes into
   a. Feldspathic and micaceous rocks without ore.
   b. Quartz veins with ore.

4. Release from the magma of replacing minerals (such as sphalerite) along the contacts with limestones.

5. Release from the magma of gaseous solutions containing iron, lead, and zinc sulphides, and also silver together with silica, along faults and fracture zones—the migration channels.
   a. Early precipitation of quartz, pyrite, some argentiferous galena, and sphalerite, but with little calcite, dolomite and siderite.
   b. Silicification of limestones only locally along ore migration channels.
   c. Precipitation in breccia zones in limestones and dolomites of galena and sphalerite together with large quantities of calcite, dolomite, and siderite (part of which the solutions acquired while passing through the limestones). The gaseous ore-bearing solutions were sent upward with a force which probably varied considerably in different cases. Upon reaching large brecciated zones, ore chimneys were sometimes formed by rather complete and immediate (accumulated) precipitation. Replacement of the country rock in part by the ore-bearing solutions also accompanied or immediately followed the precipitation of the ore.

No definite set of actions, however, can be said to have taken place regularly throughout the field, because of the great variety of conditions. The important influencing factors appear to the writer to have been as follows:

1. Original character, composition, and structural position of the magma.

2. Nature of the magmatic differentiation.

3. Character, composition, and structural position of the rocks intruded both by the magma and by its differentiated products.

4. Character and composition of the ore bearing solutions given off by the magma and its differentiated products.

5. Character, composition, and combined effects of materials added to the migrating solutions encountered during their upward course.

6. Rapidity in cooling and in the losing of pressure by the ore bearing solutions.

7. Other influencing conditions of which little or nothing is definitely known.

Each different mineralized area, generally speaking, appears to have its own peculiar character. For instance, the group of lead and iron prospects and mines about Leadpoint all have recognizable characters as a group, even as to the texture of the ores. Similarly have the zinc and lead properties of Deep Creek. The peculiar grouping of ore deposits may be explained by consideration of two features: First, source of material, and second, conditions of migration and deposition.

The source of mineral solutions is of importance in a regional study of ore formation, and must of necessity be highly theoretical. The conditions necessary for concentration and precipitation of the ores, on the other hand, is of local, and therefore of more immediate practical interest. This side of the discussion should then be given the greatest attention in this present study.

Too little attention has hitherto been given to the physiography of the district. A study of the physiography should of necessity include also a detailed study of glaciation. Taken together, the results of such work should give us some idea of the erosional history of the country and its relation to the history of ore deposition. It is the opinion of the writer that the exposed sulphide ore deposits of the region were originally formed at a depth of at least several thousand feet and have since been exposed by erosion. That is to say, a mile or more of overlying rock formations has been carried away and the ore deposits exposed to view. There is evidence enough to prove, according to the writer's opinion, that all extensive surface alterations, such as that which caused the formation of lead carbonates found in the Electric Point and Gladstone mines, have taken place prior to the Glacial period. These mines represent points on the earth's surface which were oxidized prior to glaciation and the oxidized zones were not removed, or at least in part only, by glacial carving. The primary sulphide ores were undoubtedly formed at a period earlier than the pre-glacial erosion period.

NORTHPORT DISTRICT

GLADSTONE MOUNTAIN AREA

General Features

The greatest lead producing mines in the State of Washington are situated on Gladstone Mountain which lies a few miles northeast of Deep Lake, eight miles (in an air line) south of the International Boundary, and a few miles west of the Pend Oreille County line.

The greater part of the mining has been done in a limited area (in sections 17 and 18, also in 19 and 20, and some in section 7, T. 39 N., R. 42 E.) from several rich chimneys of lead ore, extensively altered by oxidation to the formation of limonite and lead carbonate. In addition to the high grade ore there is considerable low grade material which has not been shipped and much of it not even mined.

Leadpoint is the nearest postoffice. This settlement may be reached from Boundary, a railroad station nine miles by road to the north of it, or from Northport, by way of the Deep Creek road, 18 miles distant in the opposite direction. Another automobile road runs from Colville to Leadpoint, which is a distance of 35 miles.

The Gladstone and Electric Point mines are situated on the top of Gladstone Mountain, some 2,000 feet higher in elevation than Leadpoint and connected with it by a rather steep road four miles in length.

The Electric Point mine transported its ore by aerial tram to Leadpoint. At the time of investigation, the tram as well as the mine was idle and the ore from the Gladstone mine was being hauled in wagons and a sled drawn by a caterpillar to Leadpoint. From Leadpoint the ore is taken by trucks to the railroad station at Boundary.

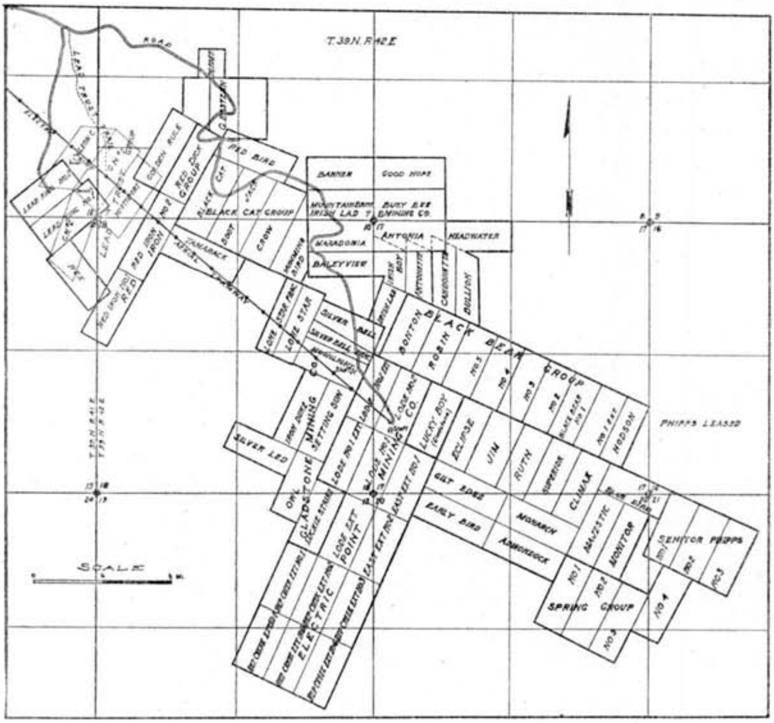

Figure 10. Map showing the approximate locations of the various claims on Gladstone Mountain. The road leads to Leadpoint towards the west. Mining activity at the present writing is in the Gladstone mine located on the eastern end of the Moonlight claim. The gravity tramway starts at the man shaft of the Electric Point mine, but it is not active now, owing to a controversy with the government over an additional assessment of income tax. (Compiled from mine maps of the Electric Point, Gladstone, and Lead Trust mines and from a sketch of the whole area prepared by Tom Rouston.)

There is no water available at these mines. It is hauled from a spring situated two miles down the road and 1,100 feet lower in elevation. This is a significant fact inasmuch as the Electric Point mine reached the 800-foot level with no water in the mine, and the ore was found to be oxidized down to this depth.

The rocks exposed on Gladstone Mountain are principally dolomitic limestone and argillite or shale. The beds are contorted, faulted, sheared and intruded by small basic igneous dikes. The detail of the geologic structure of these rocks has never been worked out, but it appears very complex.

The high mountain ridge to the east is composed of resistant beds of quartzite. Between Gladstone Mountain and this ridge is one of the most northerly exposures of granite which forms the batholith in both Stevens and Pend Oreille counties. Farther to the north this granite disappears, according to Weaver's map, and the quartzite is in contact with the limestone and argillite, apparently with a decided structural break between them, which marks the line of a profound faulting of great displacement. The exposure of granite at this particular point would therefore occupy a position along the zone of displacement. This geological condition is not unlike that found in the Metaline district on the opposite side of the high quartzite dividing ridge.

The top and sides of Gladstone Mountain are strewn with sand and boulders, some of which are striated, showing transportation by ice. It would appear that the top of Gladstone Mountain, in the region of the Electric Point and Gladstone mines, did not suffer much glacial erosion. A thin mantle of drift material is deposited on the surface, but this material rests upon the older weathered surface of the underlying rocks.

The extensive oxidation of the ores in the Gladstone and Electric Point mines to a depth much greater than in any of the other deposits of the region investigated, may be explained by consideration of the following facts: The protective action of the mantle covering on the surface and lack of glacial wearing; the locally great depth of the water table; and the fact that the oxidation took place or commenced action long before the glacial period.

The primary lead ore, galena, may be considered as having its source in the granite magma which now lies, undoubtedly, beneath the deposits. The migration of the ore solutions probably took place along fault and fissure lines and the deposition occurred in breccia zones. The breccia zones were formed along many of the faults. Where such fault breccia zones intersect, the total brecciation is very great. The ore chimneys of these richer lead deposits may be explained as a deposition in and a replacement of the breccia zones formed by the multiple intersection of faults.

There is considerable evidence that the mineral siderite was one of the original gangue minerals of the galena and this iron carbonate substance has been responsible for the extensive development of the soft limonite in the deposits and also of the development of cerussite (lead carbonate) by the action of released carbon dioxide coming from the broken down siderite. Apparently the change to cerussite from galena came about through an intermediate stage in the formation of anglesite (lead sulphate), which envelopes the oxidized galena nodules. Pyrite may have been present in the original deposit, but there was found no definite proof of its occurrence, at least its occurrence in abundance. In the change from siderite to limonite, there is a considerable shrinkage in volume. This would account for the somewhat porous condition of the ore bodies. In the formation of cerussite, however, there is an increase in volume, and it is quite probable that the porosity has been partly compensated by this expanding action. The presence of numerous clastic dikes of limonitic clay running throughout the chimneys may be accounted for by the filling of cavities formed by this shrinkage.

There is very little quartz in these rich ore chimneys, but there are quartz veins occurring in other places on Gladstone Mountain. Some of the chimneys contain very little ore, being nearly all limonite. Apparently the original deposit in such cases was siderite.

The small basic igneous dikes found in the Electric Point Mine are reported to cut the ore bodies. If this is true, they were intruded at a later time than that of the ore deposition. The source of these dikes may be in the underlying granite batholith. Their association with the ore bodies, however, is a matter of geological structure rather than of intimate genetic relationship. Both ore solutions and igneous dikes apparently followed lines of structural weakness in their upward migrating course.

The primary deposition probably took place at considerable depth and the region has since been eroded to a depth of thousands of feet. A large part of the erosion apparently took place prior to the glacial period.

Electric Point Mine

The Electric Point Mining Company owns thirteen claims (Republican Creek Extension No. 1, No. 2, No. 3, No. 4, No. 5, No. 6, Electric Point Lode No. 1, No. 2, East Extension No. 1, No. 2, Electric Point Lode Extension, Electric Point Extension No. 1 Lode, No. 2 Lode, for the last seven of which patents have been applied for) located in sections 17, 18, 19 and 20, T. 39 N., R. 42 E. A wagon road, four and one-half miles long, runs from Leadpoint to the Electric Point mine located in a very limited area largely on two claims (the Electric Point No. 2 Lode and Electric Point No. 1 Lode). The ore was transported in a 1,400-foot aerial tramway to the bunkers at Leadpoint, and thence to Boundary by auto trucks.

The first ore shipments were made in July, 1916, and the last in October, 1920. It is reported that smelter returns on the ore amounted to over one million dollars during this time.

The mine consists of 9,680 feet of workings not including surface excavations. There are two shafts and eight 100-foot levels from which the ore chimneys were reached. A tunnel on the 300-foot level extended to the surface on the south side of the hill on which the mine is situated.

The Electric Point mine has been the greatest lead producer in the state, but by reason of additional assessment of income tax for 1917, issued in 1920, which the company was unable to pay in 1920, the mine was forced to discontinue its work. The following data on production, received from the managers of the property, represents, it is reported, all the known tonnage of ore in the mine down to the 800-foot level.

Year	Sulphide Ore	Carbonate Ore
1916	515,420	4,300,840
1917	3,722,300	2,889,240
1918	1,639,860	14,709,780
1919	374,300	6,369,740
1920	15,317,266	2,168,410
Total	21,569,146	30,438,010

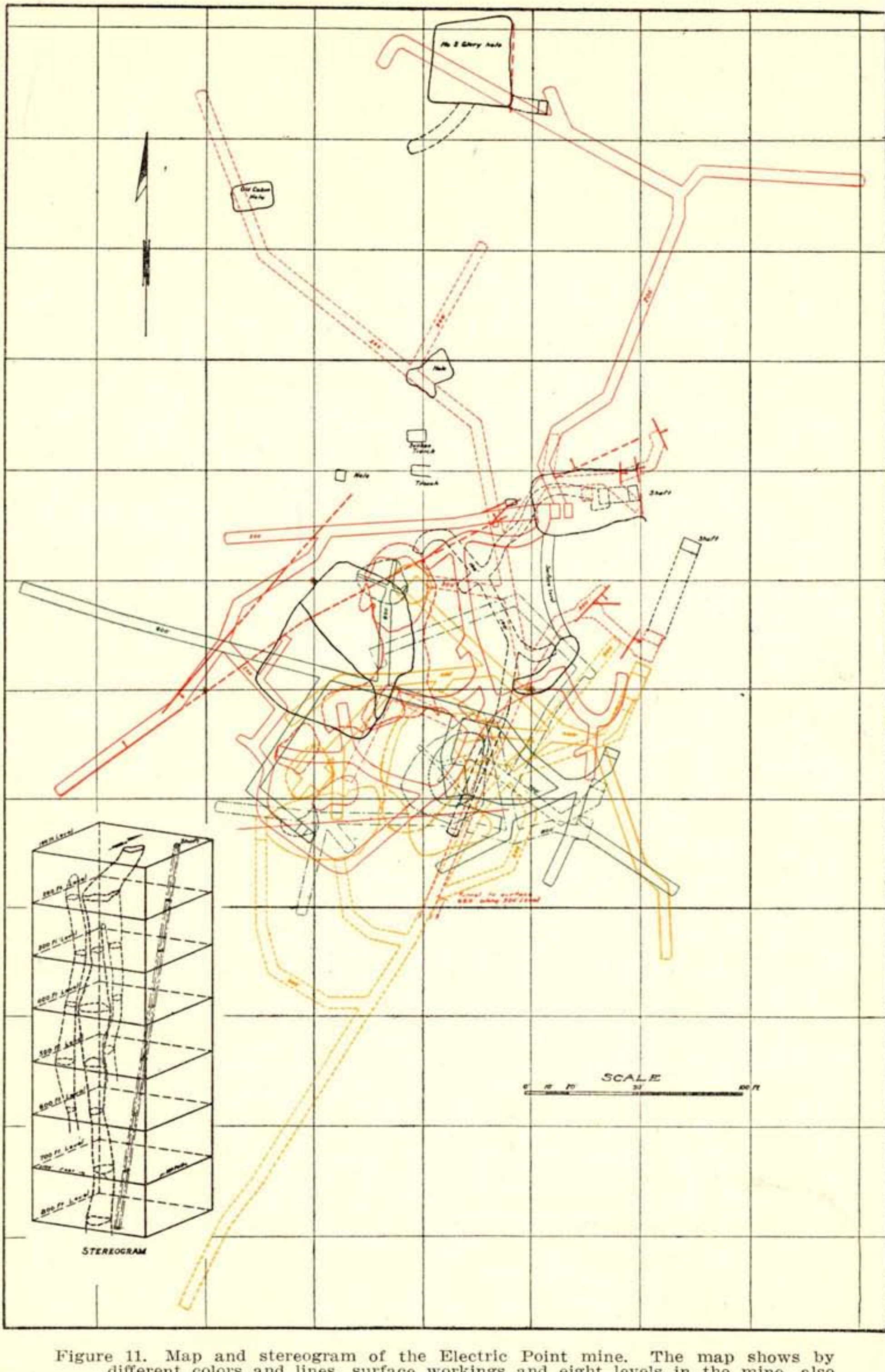

Figure 11. Map and stereogram of the Electric Point mine. The map shows by different colors and lines, surface workings and eight levels in the mine, also various ore chimneys. The surface workings and 100-foot level are shown in black; the 200- and 300-foot levels are in red; the 400- and 500-foot levels in orange; and the 600-, 700- and 800-foot levels in green. The stereogram pictures, in a vertical position, the principal ore chimneys. It is a projection of the part of the map more heavily outlined and reduced to 3/10 its scale. (Compiled from maps of the Electric Point Mining Company.)

The carbonate ore, it is reported, averaged about 25 per cent lead, while the sulphides averaged 69 per cent lead. The carbonate ore contained, as a rule, some sulphide ore, and in the sulphide, a little carbonate matter. The silver content was so low it was not counted in the values. The company was never penalized for zinc in the ore.

That the ore was high grade may be recognized in the following tabulated data, received from the records of the company:

SMELTER RETURNS ON PERCENTAGE OF LEAD CONTAINED IN ORE SHIPPED.

1916	Sulphide Ore	Carbonate Ore	1916	Sulphide Ore	Carbonate Ore
July	76.7	28.8	Oct.	68.05	20.17
Aug.	71.04	27.35	Nov.	69.34	22.5
Sept.	70.46	22.28	Dec.	67.6	19.25
1917	**Sulphide Ore**	**Carbonate Ore**	**1917**	**Sulphide Ore**	**Carbonate Ore**
Jan.	67.6	20.87	July	73.2	31.2
Feb.	71.8	26.95	Aug.	68.91	26.73
Mar.	70.7	25.5	Sept.	72.95	22.27
Apr.	67.8	20.45	Oct.	73.15	21.52
May	70.9	24.38	Nov.	74.5	27.79
June	68.72	31.58	Dec.	76.3	25.43
Average 1916 and 1917.. ..	70.53	23.39			
1918	**Sulphide Ore**	**Carbonate Ore**	**1918**	**Sulphide Ore**	**Carbonate Ore**
Jan.	72.97	.....	Sept.	62.65	25.77
April-May	69.1	25.42	Aug. and Sept..	.....	25.24
June	65.3	29.2	Oct.	79.8 (Oct.–Dec.)	26.6
July	62.75	32.67	Nov.		23.33
Aug.	72.4	28.56	Dec.		26.63
Average 1918............ ..	69.01	27.27			
Average 1919............ ..	67.91	32.25			

In the Electric Point mine the ore occurred in large columns or "chimneys" of iron oxide, galena, cerussite, anglesite, and brecciated country rock (dolomite or magnesian limestone), standing in a nearly perpendicular attitude piercing through stratified layers of magnesian limestone. The ore bodies of the Gladstone mine were found to occur in a similar manner. The writer could not enter the underground workings of the Electric Point mine at the time of investigation, but studied surface conditions, the glory holes, and also the underground conditions in the adjoining Gladstone mine, situated a few hundred feet away. The reader is therefore referred to the reports of Weaver* and Patty,** who studied the mine while it was in operation.

It is stated that several ore chimneys were found and mined. The longest was not exposed at the surface, but commenced at a depth of 80 feet, branching at the 300-foot level, one branch being almost barren of ore from the 400-foot level on down, while the other branch extended to the 800-foot level. It is said that it contained good ore at this depth. The chimney stood in a nearly vertical position, and was found to be oxidized as far down as it was mined.

The degree of oxidation in each chimney is said to have been fairly uniform for the whole length of the particular chimney, even for the longest. The different chimneys, however, were found to differ from each other in content and in degrees of oxidation.

The materials of the chimneys consisted of iron hydroxide (limonite) intermixed with clay and a peculiar form of sand (derived from the breaking down of the dolomitic limestone country rock into a sugar-form of material), small particles of cerussite, lumps of heavy but porous ore (composed largely of cerussite but often containing a nucleus of galena, filmed over with dark layers of anglesite), and sometimes huge lumps of galena only slightly altered on the surface, weighing hundreds of pounds or even a ton or more each. The term "sand carbonate" is given to the broken up cerussite ore intermixed with limonitic clay and decomposed limestone. At times beautiful specimens of silky white, reticulated cerussite were taken out. Also crystals of anglesite were found with their characteristic adamantine luster. Some of the galena was coarse grained and some quite fine grained. Since all the oxidized material is soft and porous, the heavy lumps of ore were extremely easy to break down in mining.

The limestone country rock is magnesian or dolomitic in composition, called by Weaver the Republican Creek limestone. Intense structural deformation of the rock in Gladstone Mountain is apparent. In the region of the Electric Point and Gladstone mines, however, the beds are lying nearly

*Weaver, Op. Cit., pp. 305-307.
**Patty, Op. Cit., pp. 93-102.

flat in places. Patty records the dip in the Electric Point mine as being southeast, at an angle of 10° to 30°.

Faults, slips, shear zones, brecciated zones, and slickensided walls are numerous throughout the mines. There is considerable evidence to show that the ore chimneys have followed certain brecciated zones occurring at the intersections of a number of faults. Some of the breccia zones, however, are barren. Some of the breccia zones contain chimneys of iron oxide with but very little lead ore. A careful plotting of the breccia zones, faults, and slips on a careful survey of both the Gladstone and Electric Point mines together might reveal much data of practical value. It is the writer's understanding that thin stringers of ore in places have been found leading off from the chimneys along fault zones. In following some of these stringers, new chimneys, which were not exposed on the surface, were in this way discovered in the mine. It is also the understanding of the writer that some of the chimneys "bottomed" or terminated at depth in a rounded or bowl-shaped way. Beneath such a terminated chimney is solid limestone rock, like the solid rock which bounds the sides of the chimney.

Two mica lamprophyre dikes are exposed in the open and caved-in glory holes at the surface which trace the surface beginning of chimneys. These dikes are very badly weathered and occur in faulted and fractured zones of the dolomitic limestone. They are reported to cut the ore in the mine.

A feature exposed in these glory holes which seems to the writer quite significant, but has not been given recognition heretofore, is the unconformity between the oxidized zone below the surface and the overlying glacial drift which forms the surface mantle covering. In studying this geologic feature, the writer has come to the conclusion that the oxidation of the ore body took place previous to the Glacial period. Evidently the ice did not remove the surface rocks or oxidized zones in this particular vicinity.

In these glory holes, there are many other interesting things to be seen. Clastic dikes of limonitic clay ramify through the soft oxidized material of the chimneys. These dikes are beveled off at the surface with glacial drift overlying them unconformably. Tremolite-asbestos, in sheets as thin as paper (known as "mountain leather") lie between the fragments of rock breccia and connect in such a manner as to give to the masses of broken rock the property of clinging together as if interwoven with cloth and threads. Thin layers of calcium carbonate occur in a series of closely spaced sheets in a decomposed green lamprophyre dike.

A number of faults and slips with their slickensided walls and accompanying breccia zones are exposed around the edge of each glory hole. They appear to form many intersections and dip at different angles besides striking in different directions. Rock wedges formed between faults sloping toward each other are common, and are always accompanied by breccia.

In places in these glory holes, the limestone is broken down to a fine sand. A laboratory examination shows this sand to be composed of calcium, magnesium and iron carbonate. The iron, however, is in most cases broken down to hydroxide. The limestone, forming the wall of the chimney, was found in places to be composed of tiny interlocking crystal grains of these three minerals. As the iron carbonate (siderite and in places ankerite) oxidized, the calcite and dolomite grains were released in the form of sand. It is said (and the writer has verified the statement by observation in the Gladstone mine) that in the ore chimneys there was nearly always a layer of this sand next to the limestone wall, while the ore, occurring in lumps with masses of iron oxide material, occurred next to it. Where this loose material next to the wall was very plentiful, the ore was generally in the form of the carbonate, but where the ore body was "frozen" to the walls, the ore was generally in the sulphide form.

Gladstone Mine

The property of the Gladstone Mining Company lies, for the most part, in the western half of section 18, T. 39 N., R. 42 E., consisting of the following claims: Lucky Strike, Owl, Silver Lead, Setting Sun, Iron Duke, Moonlight, Silver Bell, Silver Bell Fraction, Lone Star, Lone Star Fraction, and

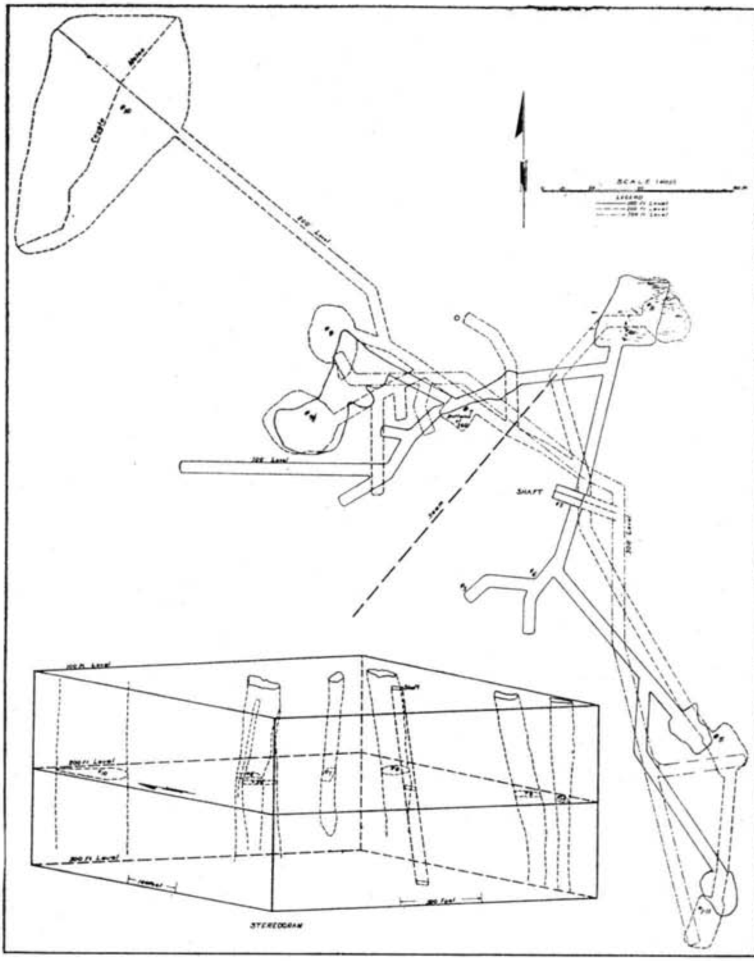

Figure 12. Map and stereogram of the Gladstone mine, at the present writing the largest producer of pure lead ore in the State of Washington. Three levels are shown and the position of each chimney encountered is indicated by its number. It will be noted that the pitch of each ore chimney is nearly vertical. The stereogram is a projection of this map reduced to one-half its scale. (After a Brunton compass traverse made by Dan Dodd, superintendent of the mine.)

Lucky Boy (the last of which is in section 17). The group adjoins that of the Electric Point on the northwest. These mines are at an elevation of about 4,200 feet. At the time of investigation, the Gladstone mine was very active, two loads of ore, some 20 tons in each, being hauled to the bunkers at Leadpoint daily. Part of the ore was the sulphide and the rest was in the carbonate form.

Several chimneys (Numbers 1-11, 5, 7, 8, 9 and 9½) of ore were being mined, largely from the eastern end of the Moonlight claim, at that time. The mine consisted of a shaft standing nearly vertically but sloping slightly, directed S. 40° E. extending to the 300-foot level, with drifts to the chimneys at the 100, 200 and 300-foot levels. Most of the chimneys were first mined, it is stated, to a depth of some 50 feet, before their lower courses were explored by these drifts. A recent surface discovery of a new and very large chimney (No. 10), however, led to the exploration and subsequent discovery of it at the 200-foot level by drifting to a point lying directly under the surface exposure. The surface exposures were not easily detected, owing to the mantle covering of glacial drift.

According to the Gladstone Mining Company, the production of lead ore from the mine has been as follows:

	Tons of Ore	Value of Ore
First Mining in 1917 from Setting Sun Shaft....	Not recorded	$11,507.83
Inactivity during the following two years.		
Activity in new workings from Moonlight Shaft—		
1920 (Approx.)............................	312	19,217.37
1922	325	17,203.41
Total tonnage in 1923	3,082.7	Not given
Total tonnage up to Oct. 22, 1924	3,150	Not given

The amount of ore mined from the individual chimneys is reported for 1923 as follows:

No. 1. Stoped 20 feet above 100-foot level produced 25 tons of high grade ore.

No. 2. Main shaft sunk on this chimney, which bottomed on the 100-foot level, producing 150 tons.

No. 3. Not developed underground.

No. 4. Not developed underground.

No. 5. From surface shaft produced 300 tons. From 100-foot level, 200 tons.

No. 6. Not developed underground.

No. 7. From 100-foot level to surface and from 15 feet on 200-foot level, produced 350 tons. (This chimney "bottomed" at 260 feet in 1924.)

No. 8. From 100-foot level to surface, produced 170 tons.

No. 9. From 100-foot level to surface produced 1,500 tons; on 200-foot level, 75 tons. This chimney split into two smaller chimneys on 100-foot level.

No. 10. Chimney was discovered at 200-foot level in 1924. No ore yet extracted. Size of chimney, 240x40 feet.

The following notes were taken on chimneys Nos. 1-11 at the 200-foot level. The chimney measured 24 feet by 18 feet with nearly square corners. The walls consisted of black dolomitic rock. Where cleaned off from the iron oxidized ore body material, the surface of the rock had the appearance of a surface outcrop of limestone, which might be seen anywhere on the side of the hill outside the mine. The dip of the limestone was S. 20° E. at the low angle of 20°. In places, slickensiding was present on the surface of the rock. The strike of one of these slip planes was S. 50° W. The ore body itself was composed of soft limonite and turgite, with lumps of galena of various sizes, oxidized largely to the carbonate of lead, all of which was filled with fragments of decomposed dolomitic limestone breccia. The altered lumps of galena were each covered with thin black layers of lead sulphate. Covering the sulphate were generally thicker layers of cerussite, showing a transition into the carbonate form, which is more stable than the sulphate. Also pyromorphite occurred, which appeared in most cases to be secondary to both the sulphate and carbonate. Throughout the ore body there were little clastic dikes of limonitic clay ramifying in all directions. The dikes were composed of clay layers, whose laminae ran parallel to the walls of the little dikes themselves. The whole ore body was porous and slightly damp, but not wet. The mining was carried on as in all the other chimneys, by means of square sets, placed in tiers, seven feet apart.

On this same 200-foot level, No. 5 chimney measured 20 feet square. Some of the other chimneys were much less regular. Number 10 chimney measured 150 to 240 feet by 40 to 80 feet. Parts of the various chimneys were rich, while other parts were nearly all of limonite and clay. Not all of the chimneys were developed, especially from the 300-foot level. Number 7 chimney terminated or "bottomed" at 260 feet. In developing a newly struck chimney, first "coyote holes" were made, which are quite narrow openings dissecting the chimney and exploring its bounds as well as content.

Numerous slip planes were seen in the mine, with prominent slickensided walls. Breccia zones, in many places, accompany these faults. The ore bodies are, in every case, associated with such breccia zones, but not all the breccia zones contain ore. The greatest breccia zones are apparently located at the intersections of numerous slips and faults. Thin ore seams were found, in places, to run out from the chimneys along the slip planes, but these seams were apparently not common or not prominent in their occurrence.

The country rock is composed largely of dolomitic or magnesian limestone. Some varieties of the rock are almost black, while others are nearly white. Veinlets of siderite were found in the fractured zones in the country rock. This iron carbonate mineral weathers rapidly to form limonite. The origin of the limonite, found to be so abundant in the ore chimneys, is probably from such iron carbonate material and not from the decomposition of pyrite. The cerussite of the deposits undoubtedly received its carbon dioxide from the gas released from the decomposition of the iron carbonate in its transformation to limonite.

Lead Trust Mine

The property of the Lead Trust Mine consists of four or five claims (Leon C, Great Northern No. 1, Great Northern No. 2, and Northport lode) and 20 acres of deeded land. It is located two and one-half miles up the road leading from Leadpoint and the Gladstone and Electric Point mines, at an elevation of about 3,000 feet. The property lies under the old aerial tram of the Electric Point mine on the northwest slope of Gladstone Mountain (in sections 7 and 18, T. 39 N., R. 42 E., and sections 12 and 13, T. 39 N., R. 41 E.). No work was being done at the time of the investigation. The previous company had been dissolved and the property had just gone into the ownership of Mr. Wm. McCue.

The mining development on the properties consists of a number of open cuts and tunnels located for the most part on the Great Northern claim No. 1, and on the Leon C. Unlike the Gladstone and Electric Point mines, ground water is reached in the workings and was used to supply water to a small mill on the property. Occasional shipments of lead ore have in the past been made from the Lead Trust mine, which have amounted in all, it is reported, to 30,000 tons. The ore consists largely of galena, though some carbonate ore is present.

The principal upper surface workings consist largely of a glory hole opened on an irregular shaped chimney of ore. A 216-foot tunnel directed S. 21° E. and driven into the hill at a lower position, cuts the ore body and stopings have been made on it to the surface.

The ore occurs as irregular bunches of galena in a zone of brecciated limestone, which strikes N. 73° E. dipping southeast at an angle of 60°. Besides the rock breccia, crystals of dolomite form the gangue with some siderite, which has been partly altered to limonite. Where this has taken place, nodules of galena occur weathered separate from the rest of the rocks and associated with some lead carbonate material. An inclined winze 30 feet deep directed S. 24° E. sloping 75° was sunk on the ore in the tunnel. A green porphyry dike three to fifteen feet wide (identified by Patty as a mica-lamprophyre) occurs 120 feet from the portal of the tunnel. It appears to have followed the fracture zones in the rocks it intrudes.

A tunnel lying about 150 feet lower in elevation than the above described tunnel is over 500 feet long, driven in dolomitic limestone. The face of the tunnel was in a faulted and brecciated rock with some galena in the fracture zone forming an ore body from 16 inches to two feet wide. The galena occurs as irregular veinlets surrounded by crystals of dolomite and some siderite. The strike of the ore zone encountered is N. 55° E. dipping southeast at an angle of about 85°. The ore body lies, for the most part, on the hanging wall side of a fault.

There are numerous places on the surface of the hillside where patches and irregular stringers of galena can be found impregnating or replacing the fractured limestone. There is a wide distribution of these scattered patches of high grade ore in this property.

Lead King Group

The Lead King group consists of three claims (Lead King No. 1, No. 2, and Rex) lying just south of and higher in elevation than the Lead Trust mine (sections 12 and 13, T. 39 N., R. 41 E.). The main tunnel of the property enters the hillside below a talus slope at the foot of a very steep bluff, which rises several hundred feet higher. At the time of investigation, the mine was closed and the writer did not enter it. On the dump were found a few pieces of galena and sphalerite in dolomitic limestone. Some large specimens of aragonite associated with limonite were also found. Patty* has described this mine in his report.

Red Iron Group

There are a number of claims located between the Lead Trust and the Gladstone mines which are situated on the slope of Gladstone mountain. Among these are the claims of the Red Iron group (Red Dick, Red Iron No. 1, Red Iron No. 2, and Tamarack), located in sections 7 and 18, T. 39 N., R. 42 E. at an elevation of about 3,800 feet.

There are a number of surface cuts, trenches and shafts on these properties, but no great amount of lead ore was found. On the dumps of one or two of the shafts were found crystals of quartz three or four inches long and clear colorless quartz vein matter occurring in dolomitic limestone. In another prospect were found some perfect examples of siderite altering to limonite through surface oxidation. This material occurred in brecciated dolomitic limestone.

Active prospecting was being done by J. E. Yoder on the Tamarack claim at the time of the investigation. A shaft 50 feet deep had been sunk and a little lead carbonate ore in iron oxide material had been found.

*Patty, Op. Cit., p. 107.

The reader is referred to Weaver's* report for a description of this group of claims as well as for the adjoining Black Cat group.

DEEP LAKE AREA

General Features

Some of the iron deposits,** occurring in the limestone belt by Deep Lake, contain also lead minerals. The deposits are geologically significant for they show evidence of how the minerals were formed and altered. The iron is largely in the form of limonite and goethite, also some turgite, formed by the superficial alteration of siderite, which occurs in zones of limestone breccia along sheared and faulted places in the rocks. These iron deposits lie half way between the group of lead deposits of the Electric Point and Gladstone mines and the group of zinc and lead deposits about the Black Rock mine, in the same belt of dolomitic limestones. A total distance of eight miles in a northeast-southwest line would reach all of these mineral groups.

Thompson Property

In the northern half of section 23, T. 39 N., R. 41 E., there are five claims (Iron Rich, Iron Farm, Iron State, Iron Tunnel, and Iron Slope) located on deposits of limonite and owned by Ernest Thompson. The property lies one mile north of Deep Lake, overlooking it at an elevation of about 3,000 feet. In only one of these claims, the Iron Slope, located in the northeast quarter of the section, has there been found a little lead and zinc with oxidized iron material.

As pointed out by the writer, in the previous publication referred to, the limonite was formed through surface oxidation of veins of siderite occurring in the limestone. In one place on the property, there is a bluff which exposes a cross-section of one of these veins or oxidized zones in the limestone. Siderite can be found here in places, as the original mineral of a sheared or faulted zone in the limestone, but for

*Weaver, Op. Cit., pp. 308-309.

**For further description of these iron deposits, see Bull. 27, Div. Geol., Dept. Cons. & Dev., pp. 47-54, 1922.

the most part, the siderite has been changed by weathering into limonite, with a resulting shrinkage of the whole mass, leaving it in a porous condition. In this particular case the iron mineral zone does not continue at depth more than about 50 feet, stopping at a nearly horizontal fault. The fault does not appear to be a post-mineral fault, but the breccia zone containing the iron minerals terminates at this portion. This may explain in some cases why the chimneys of lead ore in the Electric Point and Gladstone mines "bottom" or terminate rather abruptly at depth. It was noticed, however, that smaller stringers of the iron minerals continue laterally along the horizontal fault. It is quite possible that in following these stringers, other iron ore zones would be found at other brecciated places in the rocks.

Bechtol Properties

A lead deposit occurs half way between the Iron Slope claim and Deep Lake. It is owned by William Bechtol. Three claims (W. J. Bryan, Kismet, and Mannering) cover the deposit which lies in sections 23 and 26, T. 39 N., R. 41 E. From surface workings some 90 tons of galena ore are reported to have been taken out and shipped. A very crooked tunnel at a lower elevation had been driven but had not reached any ore body at the time of investigation.

Though this lead deposit is apparently small, its occurrence is somewhat similar to the larger deposits located a few miles to the north. In the surface workings, where most of the ore has been removed, it was found that the galena ore occurred as nodules or lumps in a matrix of soft limonite, clay and decomposed limestone or lime sand. This material is closely associated with fault planes and with their accompanying breccia zones. Glacial gravel and sand partly cover the ore body and were evidently deposited since its alteration. Some of the lower edges of the overlying glacial sand and gravel contain a little iron hydroxide which has apparently been drawn up by water seepage and capillarity.

The main ore body pitches N. 10° E. about 35°. It is an oxidized zone lying between layers of limestone. White lime powder or sand (an alteration product of the limestone formed by the oxidation of siderite grains occurring in the limestone) and the brown iron hydroxide clay material are irregularly arranged in bunches, but striking in outline, and contrasted in color. Bunches of galena, which are partly altered to the carbonate, are also easily distinguished, if broken, by their characteristic glistening form and color, and easily extracted in mining. Oxidized branches of the ore body extend laterally, for the most part, in directions N. 50° E. and S. 50° W. In one place the ore body is flat-lying. In another, at the intersection of two fault zones, it reached the surface as a short chimney. The irregular stopes extend over 100 feet into the hillside and to a depth of 20 or 30 feet.

The various phases of alteration from solid rock containing bunches and stringers of ore to the oxidized product containing ore nodules can be clearly studied in this deposit. The galena originally occurred as irregular bodies and stringers in the fracture zones and breccia of the dolomitic limestone. Siderite, dolomite, calcite, and breccia fragments of the country rock form the gangue. Of these materials, siderite is much the more readily altered. Through its transformation into residual limonite and into solutions charged with carbon dioxide, the oxidizing action of the whole deposit was apparently started, even to the alteration of the outside portion of the lumps of galena. The bunches of galena weathered away from their more soluble rock matrix and on their surfaces was formed a crust of lead carbonate material. The appearance and structure of this lead carbonate-galena ore is quite similar to that found in the Gladstone mine.

Across the valley, on the west side of Deep Lake in section 27, T. 39 N., R. 41 E. is the Idler claim, owned by David Bechtol. Limonite deposits similar in appearance and occurrence to those of the Thompson property occur here.

RED TOP AREA

General Features

Red Top is a dome-shaped mountain standing over 4,000 feet in elevation, situated just east of Cedar Lake, three miles northeast of Leadpoint. There are lead properties on top of this mountain and on its sides. They are reached by a good trail and are within a mile or so of a secondary road connecting with the Leadpoint-Boundary road. The distance to Boundary is about five or six miles.

Red Top is composed largely of metamorphosed dolomitic limestone and argillite with numerous small igneous dikes (lamprophyres) cutting through the formation. The ore bodies occur as replacements in the limestone along the contact between it and the argillite, and in fracture or brecciated zones, in the limestones. In places the ore bodies occur near lamprophyre dikes. The dikes, however, are apparently later in age than the ore bodies.

Besides the properties described or mentioned in the following paragraphs, the reader is referred to Weaver's* report for descriptions of the Scamen and Evergreen groups.

Lucile Group

A group of six claims, known as the Lucile group, adjoins the Copper King and Anaconda claims to the east, in sections 19 and 30, T. 40 N., 42 E. The claims consist of the Tip Top, Winner Cabin, Lucile, Comet, Silver Tip, and Effie, and belong to E. C. Owen of Spokane, Washington. The locality, known as Owen's Camp, is situated on Red Top Mountain.

Apparently most of the development work has been done on the Lucile claim. A quantity of high grade galena ore had been mined and stacked in piles and about the mine. The ore is reported to be argentiferous and to contain subordinate amounts of gray copper, which carry a high silver content.

The principal workings consist of a tunnel (situated at an elevation of 3,615 feet) crosscuts and stopings connecting the incline to the surface above. The incline follows a contact between marbelized limestone and schistose argillite, which dips into the hill. Ore occurs in banded form in the limestone side of the contact, and consists of sphalerite and galena. Irregular shaped ore chimneys, more or less vertical in outline, extend from the tunnel level up to this contact. Stoping has been done in these chimneys. The ore has been altered very little by surface weathering.

*Weaver, Op. Cit., pp. 297-298, 301-303.

The main tunnel has a total length of 230 feet, directed into the hill in a northeasterly course. Several thin igneous dikes (micaceous lamprophyres) intersecting the formation were cut by the tunnel. The first, within 50 feet of the portal, is one to three feet thick, with no associated ore. The second (86 feet from the portal) is two to three feet thick, standing in a vertical position, with no associated ore. A third dike (104 feet from the portal) two feet wide, striking N. 55° E. and dipping to the southeast at an angle of 43°, has ore beneath its footwall in the shattered limestone. A fourth dike (137 feet from the portal) two to three feet thick, striking N. 40° W., dipping southeast at an angle of 50° to 60°, also has ore under its footwall side in a shattered zone of the limestone. A distinct fault also occurs at this point, running obliquely to the strike of the dike. In the upper workings, this fault appears to cut off the ore body. In this part of the mine, ore occurs in the brecciated side of the fault. Several small chimneys of ore in the crushed and brecciated zone, running roughly parallel with the dike and the fault, have been partly mined, and the ore has been stacked in piles. Most of the galena occurs in masses which, when broken, show the coarse texture of the mineral in rather large cleavable cubes.

The face of the tunnel was in schistose argillite near the limestone contact. Galena ore occurs on the contact with banded texture. The dip of this contact ore body is N. 75° E., 45°.

The upper workings connect by an incline (65 feet long) with the lower tunnel. It follows the ore body which lies on the contact between the limestone and the overlying argillite. The incline also connects with the more nearly vertical stoping on one of the irregularly shaped ore chimneys from below. At the entrance of the incline is exposed an interesting relationship between the dikes and the country rock. Here two dikes are standing in a nearly vertical position parallel to each other and two feet apart, cutting the limestone and argillite, and, apparently, the ore body which lies on their contact. One of the dikes is green colored, basic, and fairly solid. The other is of the same composition but is decomposed to such an extent that it crumbles to a brownish dirt full of mica flakes.

The argillite is badly weathered and oxidized next to the dikes.

It would appear that the ore-bearing solutions coming from below had precipitated their load in the fractured zones of the limestones, replacing the rock more or less. The overlying argillite probably acted as a more resistant or impervious layer. The principal ore channel may be on the contact between these two formations, while the higher concentrations occurred in the more open spaced condition of certain breccia zones of the limestone. At a later time, igneous dikes penetrated the rocks, following some of the planes along which the ore solutions had passed.

Flugel Brothers Property

The Copper King and Anaconda groups of claims (two in each) are located near the common section corner of sections 19 and 24, T. 40 N., R. 41 E. and sections 25 and 30, T. 40 N., R. 42 E. They are reported as belonging to the Flugel Brothers of Colville, Washington. For a description of this property, the reader is referred to Weaver's report.*

Hazel or Lake View Group

The Hazel or Lake View group, consisting of six claims (Hazel, Wild Cat, Gumbo, Silver Bell, Silver Horse, Little Creek), is located near the center of section 19, T. 40 N., R. 42 E. on the north side of the highest point of Red Top. The claims are owned by H. V. Rieper. The ore value consists largely of silver. The ore is of quartz containing a little galena and some silver sulphides. Tiny crystals of pyromorphite were also found in the oxidized portion of the ores.

Iroquois Property

There is a deep, but not extensive valley just east of Red Top Mountain, and on the east side of it in a mountainside is located the Iroquois property (largely in sections 29 and 30, T. 40 N., R. 42 E.). It may be reached by road from Boundary eight miles distant by way of Cedar Lake. It consists of three claims (Columbia, Prosperity and Progress), and 120 acres

*Weaver, Op. Cit., pp. 299-301.

of land. Formerly this property was known as the Flannigan Mine.

A tunnel, 770 feet long, is directed S. 45° E. into the hillside in the direction of the dip of the sedimentary rocks it cuts. It lies at an elevation of 2,600 feet. Its purpose was to cut the downward extension of the ore bodies which are found in the hill several hundred feet higher in elevation. There are several places in the tunnel where irregular patches and veinlets of galena and sphalerite occur in the shaly dolomitic limestone, and especially along a contact between the more argillaceous rocks which are found in the first part of the tunnel and the more limy rocks in the deeper parts of

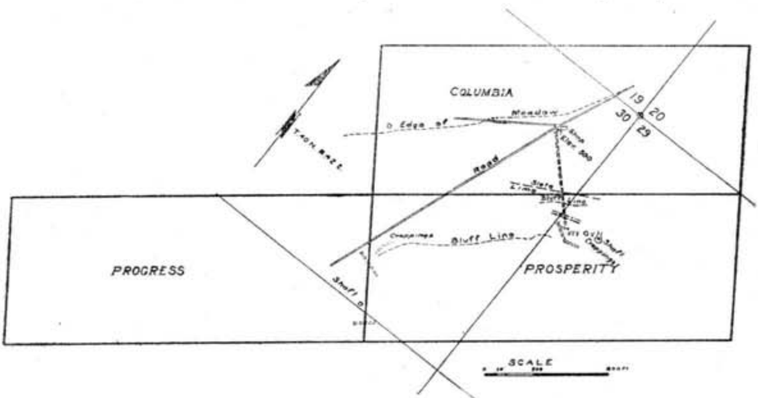

Figure 13. Map of the Iroquois property showing the tunnel in relation to the surface workings. (After map provided by the owners.)

the tunnel. The face of the tunnel is in dolomite, and 75 feet back of it is an exposure of a narrow black hornblende igneous dike. This dike may be a part of the same dike found in the surface workings above.

Nearly 300 feet above the lower tunnel there is another tunnel which is directed S. 52° E. for 111 feet. Still higher on the hillside surface workings to a depth of 50 feet disclose some ore. It is stated that a few tons of lead ore were shipped from here. A very basic igneous dike about two feet thick lies parallel to the bedding planes of slaty limestone. The dike dips south at an angle of 65°. On its footwall is a zone of serpentinized slaty limestone while on its hanging wall side is dolomitic limestone which has been faulted, crushed and brecciated in places. Slickensiding is common. Irregular patches and stringers of galena occur in this fractured rock. There are still other workings on this same property.

NORTHEAST BOUNDARY AREA

General Features

In the northeastern corner of Stevens County, not far from the International Boundary or from the Pend Oreille County line, there occur a number of mines and prospects. The geology is complicated in the extreme. The ore deposits are not essentially lead, but lead-silver and also copper. They are not replacements of limestone but occur as quartz veins in such rocks as argillite.

Frisco-Standard Mine

The Frisco-Standard mine was not being operated at the time of investigation, so the writer did not examine the property. It is located in the northeastern corner of Stevens County, within one-quarter mile of the International Boundary line, in section 12, T. 40 N., R. 42 E., at an elevation of 3,400 feet. The property consists of seven patented claims (H. R. H., Big Strike, Frisco, Buffalp, Standard, Syndicate and Boulder) owned by George Harrington. It is reported that lead-silver and copper ore has been shipped from this mine. The haul is 12 miles by wagon road to Boundary, eight miles of which are on a secondary road. For a description of this property, as well as the United Treasure, the reader is referred to descriptions in the reports of Weaver* and Patty.**

United Treasure Group

The United Treasure group is located one and a half miles from the Frisco-Standard, in the center of section 11, T. 40 N., R. 42 E. at an elevation of about 3,450 feet. It consists of three claims, United Treasure No. 1, No. 2, and No. 3, owned by Newton Hartman. Most of the workings are in claim No. 1 and consist, for the greater part, of four tunnels 343, 105, 127 and 215 feet long, respectively. The last two

*Weaver, Op. Cit., pp. 303-304.
**Patty, Op. Cit., pp. 112-116.

of these are connected with drifts and some ore has been stoped out. The mine is said to have produced several thousand dollars' worth of ore in values of silver, copper, lead, and gold. A little work was being done at the time of investigation.

The country rock is a slaty, graphitic schist. A two-foot altered igneous dike or sill occurs as an intrusive in the rocks lying for the greater part in a nearly horizontal position, or dipping to the north about 5° to 8°. The ore body consists of quartz vein matter occurring as interlocking stringers within the plicated schist, in most places lying just below the igneous dike, but in some places it is found above it and in some on both sides. The vein zone varies from a few inches in width to three or four feet. The ore minerals consist of fine-grained galena, tetrahedrite, pyrite and some secondary malachite, and azurite as well as oxides of iron.

In one place the igneous sill has been faulted, the rock having been displaced about 20 feet. On the upthrow side, the ore lies below the dike and follows down the fault zone filling and taking a position above the dike on the downthrow side. This shows that ore deposition occurred later than the fault, and therefore later than the dike. The mineral solutions evidently filled the fracture zones on either side of the dike and also the fracture zone of the fault.

Judging from a study of the rough topographic features of the country, the region has undergone considerable erosion, which exposed this deposit which was originally formed at considerable depth below the surface.

Just Time Claim

The Just Time or Star claim is located near the center of Section 15, T. 40 N., R. 42 E., near the Frisco-Standard road nine and one-half miles from Boundary. It is owned by Herman and H. V. Rieper. Lead and zinc ores occur in a body of quartz in dolomitic limestone. At the time of investigation, the shaft and workings were not in shape to be entered. On the dump, brecciated gray dolomitic limestone occurs and many pieces of the rock are full of small quartz and white dolomite veins. The ore on the dump is of pure white quartz, with a little galena. Some large crystals of calcite were found.

DEEP CREEK AREA

General Features

A mass of granite extends in a southwesterly direction from the Smackout road in Pend Oreille County, through the southern tip end of Deep Lake, across Deep Creek in the direction of Bossburg. A strip of limestone described by Weaver as the Republican Creek limestone parallels this granite, separated from it by argillite for about twelve miles, and then is cut off abruptly by the granite intrusion on Deep Creek some five or six miles southeast of Northport. The limestone occurring along this contact and some distance from it has been recrystallized to marble, which weathers on exposure to sugar-like grains. Apparently continuing in the same direction on the southwest side of the granite mass, is a limestone belt, which the writer is inclined to believe is the same formation. It is described by Weaver as the Clugston limestone. A number of ore deposits occur in the Clugston Creek area, as is described elsewhere in this report. One deposit on the east end of this limestone, near Aladdin, is described as the Blue Ridge mine, and is included in this Deep Creek area. Along the northern strip of this limestone there are a number of important properties. At the northeast end are the Gladstone and Electric Point lead mines. At Deep Lake are located iron prospects with a little lead. On Deep Creek close to the granite contact are a group of zinc properties, such as the Black Rock, Great Western, and New England claims, and also the Last Chance, from which much lead has been shipped. Of this last group, the Black Rock mine was the one active property.

These properties were all visited by the writer, but it was not possible to make a thorough examination (except in the case of the active properties) for most of the underground workings of the inactive properties were not in shape to be entered.

The Last Chance mine (located in sections 24 and 25, T. 39 N., R. 40 E., at an elevation of 2,700 feet) is known locally as having in the past been a good lead producer. The reader is referred to the reports of Bancroft,* Weaver,** and Patty† in this regard.

The Great Western mine adjoins the Last Chance mine on the north in section 2, T. 39 N., R. 40 E., at an elevation of 3,120 feet. Both lead and zinc minerals (sulphides and carbonates) were taken from this mine. For further description, the reader is referred to Weaver's‡ report.

The original sulphide ores in both the Last Chance and Great Western mines probably originated in the granite magma and were deposited in the fractured rocks (limestones) when these rocks were deeply buried. Since then, erosion has exposed the rocks and the ore bodies. The granite-limestone contact is exposed to the southwest not one-half mile away.

Black Rock Mine

The Black Rock mine, a recent development described by Patty# as the Gorien Zinc, is located just north of the Great Western and Last Chance mine, on the east side of Deep Creek, six miles northeast of Northport. The portal of the mine is situated 30 feet above the main Colville-Leadpoint-Northport road. At the time of the investigation the mine was just resuming activity after a short period of idleness, and was shipping ore composed for the greater part of zinc minerals—both of sphalerite and smithsonite. Some galena occurs with part of the ore.

The most striking feature about the Black Rock mine is the occurrence of very pure smithsonite altered from the sulphide (sphalerite). All stages of alteration can be found and beautiful specimens were collected. Translucent botryoidal forms of the carbonate (smithsonite) were common. The principal alteration has taken place from the surface to a depth of 160 to 180 feet, but along certain underground water courses, cavities lined with the carbonate were being formed at the deepest point in the mine, 250 feet below the surface. The sphalerite occurs in places as a solid body. In places galena in rather large crystals occurs in minority with

*Bancroft, Op. Cit., p. 55.
**Weaver, Op. Cit., pp. 309-310.
†Patty, Op. Cit., pp. 182-184.
‡Weaver, Op. Cit., p. 311.
#Patty, Op. Cit., pp. 111-112.

the sphalerite, which is black to dark brown and resinous in color.

The ore was found at the surface as smithsonite, occurring on a fault which had a decided drag on its hanging wall. The ore body was followed down by an incline shaft. From the surface, this incline bears S. 55° E. sloping at an angle of 48°. At a distance of 160 feet from the surface, it is met by the main tunnel, which is 260 feet long. At this point the hoist is located. The incline extends for 250 feet, which was the lowest level of the mine at the time of investigation. The ore was followed by the incline to a depth of 150 feet below the tunnel level, where the ore shoot crossed it to the south and was reached by drifts at the 200- and 250-foot levels.

A cross section of the ore shoot is exposed at the end of the tunnel level. A fault plane lies on the footwall side of the body, striking S. 25° W. dipping 64° to the southeast. This fault lies in the plane of the dipping beds on its east side, but the beds in the tunnel west of the fault dip in an opposite direction. On the south side, another fault with vertical slickensiding strikes S. 35° E., which is in the direction of the dip of the limestone bedding planes it cuts off to the south. A third fault bounds the ore body on the north side, striking N. 29° W. and dipping toward the incline, which it crosses 150 feet lower, thus leaving the ore on the south side of the shaft. The ore body is largely confined to the sheared and brecciated zone between these faults. At the tunnel level, the ore body is 30 and 40 feet wide and three or four feet thick, rudely box-shaped, pitching 65° diagonally across the inclined shaft to the south side. The incline continues on down the dip of the formation. The dimensions of the ore body where it has been stoped were approximately 14 feet thick and 50 to 100 feet wide. Considerable stoping has been done from the 200-foot level, the ore commencing there within 35 feet of the shaft. At the 250-foot level, the ore commences about 80 feet from the shaft. These levels are directed a little west of south. Other faults at these depths complicate the structure and other pockets and shoots of ore may be disclosed through later development. The faults form wedge blocks of rock with which are associated the fractured zones.

Judging from various evidence, the writer is of the opinion that the secondary alteration of the sphalerite, to smithsonite, although it may be continuing slowly at the present time, was done very largely during pre-glacial times, and this particular side of the hill was not to any great extent torn away by glacial action. This superficial action of weathering is much greater at this point than in the zinc properties occurring on the opposite side of the valley, where glacial erosion was much greater. This mine, together with others in the neighborhood, lie not far from the contact with granite, which forms a great mass to the southwest. The source of the ore solutions was probably in this granite magma and the replacement of the limestone by the metal sulphides undoubtedly took place at depth in the fracture zone of the limestone which were produced by the force of the intrusive action. Pre-glacial erosion was probably responsible for their exposure at the surface as well as for their secondary alteration. The limestone is largely magnesian or dolomitic in character, in places metamorphosed to a form of crystal rock or marble.

The faults in the mine for the most part antedate the formation of the ore which followed the fracture zones thus produced. There is, however, some post-mineral faulting. For example, a good specimen of brecciated sphalerite was collected—the ore breccia being filled with smithsonite.

Blue Ridge Property

The property of the Blue Ridge Mining Company, formerly known as the Aladdin Mining Company, is located on the west side of Deep Creek Valley, four miles north of the village of Aladdin, in sections 19, 20, 30 and 29, T. 38 N., R. 41 E., within one-half mile of the Colville-Deep Lake road. The property consists of four claims: Troublesome, Mistake, In Place, Original (or Skookum), Rite, Champion and Protect lodes. Active development work was being done by Mr. T. R. Roberts at the time of investigation, in a tunnel on the north end of the property. The older work consists of five tunnels numbered consecutively from north to south, most of which were directed into the hills to the west, varying from 100 to 400 feet in length. Formerly there was a mill on the property, but it was abandoned, together with much of the former work. It is stated that in the past, this mine shipped ore, for the most part lead-silver.

In nearly all of these workings, there are exposures of contacts of intrusive rocks with dolomitic limestones and argillites. The intrusive rock is largely granitic in form and along the contacts metamorphism has taken place. These intrusive rocks are undoubtedly apophyses (branching arms) of the larger granite mass exposed between this region and Deep Lake. In one place, an exposure of one of these apophyses showed it to have pegmatitic texture and to contain small crystals of molybdenite.

In the tunnel to the north where active prospecting has been done, the igneous intrusive rock was more basic in character. In an unaltered exposure, it appeared to be a gabbro. Where it intruded the limestone by narrow fingered dikes, both rocks were altered to a serpentine form of material. This tunnel is directed N. 88° W. and first passed through a ten-foot overburden of glacial gravel, which conceals much from view on the surface. Several irregular quartz veins occur in this altered rock along larger vein zones, which apparently follow sheared zones in the country rock. The ore minerals occurring in this quartz vein matter consist of galena, black sphalerite, chalcopyrite and pyrite. In places the limestones are silicified and in other places they grade over into argillite and quartzite. All the rocks show intense slickensiding. An inclined raise, reaching to the surface in this tunnel, follows the quartzitic zone five feet thick, which dips S. 80° W. at an angle of 40°. The hanging wall is a fairly solid limestone, with serpentine layers, while the footwall is an igneous dike, serpentinized. The vein zone has a peculiar layered structure dipping in the same direction as the dip of the whole zone, with lense or pod-shaped bodies of quartz and ore between thin layers of greenish serpentine material. Throughout the mine, the igneous dikes seem to be sill-like in structure. That is, they lie in and parallel to the bedding planes in the limestone. Brecciation is present but not common. The mineralization seems to have taken place also between and parallel to bedding layers. This is especially true of the more shaly phases of the rock. Mineralization is not marked or very well localized. The metamorphism seems to be in both igneous and sedimentary rocks alike, so that in places, it is hard to distinguish between the two. Faulting and shearing are prominent and have made the structure very complex. The continuation of the incline below the level of the tunnel was inaccessible, being filled with water. It is said that a good grade of ore was found in it. It would appear that the ore body had been partly separated out from the igneous rock and had partly replaced the limestone. Since the igneous bodies, for the most part, were lying parallel to the bedding planes instead of across them, the incomplete separation might be explained by the fact that the bedding face of the sedimentary rock is harder to act upon than more open edges would have been had the intrusion cut across the beds.

In other places on the property, in the older workings, exposures of contact replacement are noticeable. The igneous rock in one place is a granodiorite. The replacement of black sphalerite, some galena, pyrite and siderite in crystallized dolomitic limestone is very clear. Superficial alteration has acted upon these minerals to a slight depth with the formation of smithsonite, iron and manganese hydroxide. Along fault and fracture zones extending from the granodiorite into the limestone, this mineralization has been more intense. In some of the workings, the sphalerite and pyrite crystals are quite large in size. According to Weaver's map, this ore zone is on the thinning edge of a limestone formation in which the Clugston Creek ore deposits occur.

COLVILLE DISTRICT

CLUGSTON CREEK AREA

General Features

There are a number of prospects which contain lead and silver-lead ores occurring in the shattered zones of the dolomitic limestone belt, lying twelve to twenty miles north of Colville (largely in T. 37 E., R. 39 N.) on the headwaters of Clugston Creek, a small stream which empties into the Colville river. Farther north, exposed on the head-waters of

Onion Creek, which flows north into the Columbia River, is a large intrusive mass of granite. Weaver* has called attention to the fact that the granite intrusion probably was the cause of the doubled up structure of the limestone in this locality, and the subsequent mineralization of the fracture zones in the metamorphic sedimentary rocks.

Of the several properties located in this area, the writer investigated only two—the Chloride Queen and New Leadville, although the Big Chief adjoining the Chloride Queen on the north, and the Tenderfoot or Avondale-Dome, situated to the east and on the opposite side of the Canyon, were hurriedly visited. Between the Big Chief and New Leadville is located the Neglected group.

It has been reported that a new discovery of lead ore has been found on the Rusch property, situated on the opposite side of Clugston Creek or west of the properties investigated.

Farther north of the New Leadville by the granite-limestone contact is located the A and C group and by the granite argillite contact, farther to the northwest on Bruce Creek, is the Silver Trail or Dead Medicine. These properties are distinctly valued for silver and the ore bodies as described are quite siliceous. Farther to the west of the New Leadville in the same dolomitic limestone belt, are located the Ibex, Lucky Boy and Galena Farm. Descriptions of the properties which were not investigated by the writer will therefore not be given here, but the reader is referred to Weaver's report.**

It will be noticed, if these descriptions are read, that around the periphery or edge of the intrusive granite mass there is a zone of siliceous deposits—quartz veins and siliceous replacements, which are more or less ore bearing. The values in this siliceous zone are largely silver-lead, the majority of these ore deposits lying in the adjacent limestones. A mile or two away from this contact, however, pure galena with

*Weaver. Op. Cit., pp. 235-237.

**Weaver. Op. Cit., A and C claim, pp. 241-242; Silver Trail property, pp. 246-248; Ibex claim, p. 244; Galena Farm claim, pp. 245-246; Lucky Boy claim, pp. 244-245; Big Chief group, pp. 237-239; Avondale-Dome group, pp. 239-241; Neglected group, p. 241.

less silver content and not an abundance of quartz vein matter is found as occurring in limestone breccia along intersecting fault zones. The siliceous fissure zone on the Chloride Queen is one exception.

Chloride Queen Property

The Chloride Queen group consists of a number of claims (Chloride Queen, Chloride Queen Extension, Tamarack, Mother Lode and Center Star), located fifteen miles by road north of Colville, largely in sections 23 and 24, T. 37 N., R. 39 E. The property was originally prospected in 1887. The mine is situated on the side of a small canyon at an elevation of 3,400 feet. From the Chloride Queen mine, it is reported that some years ago four carloads of silver-lead ore were shipped to the Tacoma and Everett smelters. Two carloads of ore were shipped to the Northport smelter in 1914, and one car to Kellogg quite recently. In the early days when there was no railroad in the country, iron ore (limonite) carrying some lead was sent to the Colville smelter, which existed at that time. At the time of investigation, a mill was being constructed to concentrate the ore at the mine.

There are two apparently separate ore bodies in the Chloride Queen. One is on the side of the canyon at an elevation of about 3,400 feet and the other is 600 or 800 feet higher on the top of the hill. The lower is a fairly well defined quartzose body carrying values principally in silver, while the upper is an irregular shaped lead deposit occurring in brecciated dolomitic limestone. Adjoining this deposit to the south is the Big Chief.

The strike of the lower vein is about N. 65° W., with a northeast dip of 70° to 85°. The vein consists of a well defined silicified zone in dolomitic limestone. The ore minerals are sphalerite, pyrite, and a little galena. The principal gangue mineral is quartz. Near the surface are oxidized products of these minerals, such as iron hydroxide and cerussite. Along some fracture zones in the deeper parts of the mine, iron hydroxide persists. The vein was mined from the surface by a tunnel (now called the Upper tunnel) which followed the strike of the vein and is connected with a lower tunnel as well as with the surface by a rather extensive inclined raise. The siliceous zone evidently lies in the shattered zone of a fault. It varies in width, having in places a thickness of four, six and even eight feet. It has been partly stoped out by an intermediate level between the upper tunnel and the surface.

On top of the hill, the ore deposit wheih is present there has not been extensively exposed by mining. A little surface

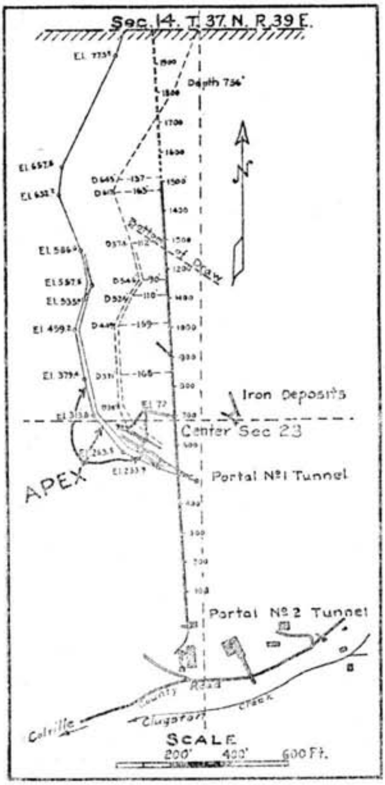

Figure 14. Map of the Chloride Queen property. (From map provided by the company.)

work has been done, which shows galena occurring in bunches branching out in tiny stringers in brecciated gray dolomitic limestone. Small crystals of dolomite and siderite are associated with the galena as gangue, but there is no great amount of quartz. The breccia zones are associated with fault planes. In one place, four fault planes were found to be so arranged that a block of breccia was formed between them, which was quite highly mineralized with galena. The limestone lies in contact with shale or argillite. This contact bears N. 10° W.

The lower tunnel bears N. 8° W. from the portal and extends for a long way into the hill, directed towards a point lying beneath the lead deposit on top of the hill some 800 feet above it. It passes near but does not intersect the main line in the upper tunnel. It is thought by the operators that the mineralized zone exposed on the surface may extend to this depth and if intersected, could be worked advantageously from this lower tunnel. In driving a tunnel, occasional small irregular bodies of ore were cut. A black basic igneous dike, two or three feet wide, was cut through at a distance of 500 feet from the portal.

New Leadville Property

The group formerly known as the Yo Tambien is now called the New Leadville mine. It consists of the following claims: Bye-Joe, Una, Monarch, Blue Bell, Surprise, Aspen, Botts, Crackerjack, Tamarack, and R. J., and also the claims of the Uncle Sam group, located largely in sections 3 and 10, T. 37 N., R. 39 E. The proposed tunnel site and main buildings of the property are situated 12 miles by road (a cut-off to Northport) north of Colville and at an elevation of about 3,000 feet.

The workings on the R. J. claim are about twenty years old. They lie 800 feet higher in elevation than the tunnel site and are reached by trail around the intervening limestone bluff, 400 feet southeast of the Uncle Sam. The proposed tunnel located on the Tamarack, if extended for a distance of 1,500 feet eastward, would reach a point directly under these workings. The ore consists of galena, with secondary carbonates. A little wulfenite is also present in the weathered zone. The gangue, largely calcite and siderite with a little quartz, has been acted upon by surface weathering, the siderite being oxidized to limonite. These minerals occur in the brecciated zone in dolomitic limestone, which also has been weathered in places to a lime sand, with residual cherty masses. Veins of calcite and of white quartz also occur in the rocks. The ore body has been stoped out to a considerable extent near the surface, early shipments having been made from these workings. The outline of the ore body was apparently irregular and bunchy, having roughly a strike of N. 10° W., dipping westward 50° and more.

There are a number of other surface cuts, shafts and tunnels on the various claims of the properties, which lie along the steep limestone bluff. In many of these limonite is present, which the writer found in most cases at least, to be a weathered product of siderite. No zinc minerals were found on the properties.

The Uncle Sam mine, controlled by option by the New Leadville Company at the time of investigation, was also worked some twenty years ago. A chimney of lead ore of considerable extent was taken out and shipped. Two tunnels were driven into the limestone bluff, the upper being over 100 feet above the lower, and the lower being at an elevation of 3,000 feet, near the edge of the valley. The lower tunnel is some 200 feet long, bearing S. 73° E. At the end of the tunnel, there is a raise which connects with the upper workings. There is a drift to the left in the lower tunnel. The upper tunnel bears S. 85° E. and is 65 feet long. A drift at 15 feet, which evidently follows the fault zone, bearing S. 5° E. encountered an ore chimney 20 feet from the tunnel. The ore chimney was extracted from the upper tunnel by means of a raise extending to the surface, a distance of 85 feet, and from the lower workings by another connecting raise over 100 feet long. The chimney, therefore, had a total length of over 185 feet. In cross section, the chimney must have been eight feet by four and one-half feet. It dipped westward at an angle of 85° to 90°. The ore minerals apparently were galena, in oxidized bunches, and its weathered products, lead carbonate, with iron hydroxides, evidently formed from the oxidation of siderite. A little sphalerite and smithsonite were found on the dump. Some quartz was associated with the ore. The ore body occurred in a highly brecciated zone, which had this peculiar chimney shape, in dolomitic limestone. The occurrence of this deposit, as well as that on the R. J., suggests a similarity of deposition to that of the more extensive chimneys of the Electric Point and Gladstone mines. The secondary formation of carbonates also probably took place in a similar manner.

BOSSBURG AREA

General Features

Two mines were investigated in the region about Bossburg, the Young America and the Bonanza. The Young America was not active at the time of the investigation. The Bonanza was not in such a condition the underground workings could be entered. The operators of the Bonanza were working on the mill in order to get it in shape so that ore from the dump as well as from the mine, could be concentrated. These two mines have been described previously by Bancroft,* Weaver,** and Patty.†

Young America Mine

The Young America Mine can be seen from the town of Bossburg. It is on a steep limestone hillside one-half mile distant from the town in a direction N. 70° E. and several hundred feet above the Columbia River. It is situated in section 28, T. 38 N., R. 38 E., at an elevation of about 1,600 feet. It was worked during the early days of mining activity in Stevens County. Several thousand dollars' worth of high grade silver-lead ore was shipped, it is reported, from pockets on the surface of the bluff occurring in fault zones in a highly metamorphosed dolomitic limestone, and as bands along the bedded planes of the rock. The ore bodies are irregular in outline and are undoubtedly replacements in the limestone. The bluff cuts the deposit along the dip, so that the tunnels (four or five in number) run in on the ore following about on the strike. One of these reaches several hundred feet in length. Stoping has been done laterally and between these tunnels. The general effect of the mine workings is cavernous in appearance.

The most characteristic feature of the ore is the black sphalerite occurring in bedding plane bands which on the surface have been altered to smithsonite, showing all stages

*U. S. G. S. Bull. 550.
**Wash. Geol. Surv. Bull. 20.
†Wash. Geol. Surv. Bull. 23.

of alteration between these two zinc minerals. Galena and fine-grained pyrite are also present. Masses of white and pinkish calcite and some siderite occur in the mine. At the surface, the siderite has been altered to iron hydroxide, which alteration extends back in the mine for a short distance.

The dip of the ore body in one place is N. 17° W. about 25°. Slip planes and brecciation are quite in evidence. The ore occurs in breccia as well as in banded layers along joint and fault planes in the country rock. Some silica is present, largely in the form of chert.

On the opposite side of the river, there occurs, according to Weaver's map, a mass of intrusive granite porphyry of probable Tertiary age. Alluvium covers the space between the limestone bluff where the mine is located and the exposure of granite porphyry. It is quite possible that the deposit once stood very close to the contact between these two rocks. The banded character of the ore is not unlike other banded sphalerite deposits located near granite contacts, for example, that of the New England claim on Deep Creek near Northport. Erosion in the region about Bossburg has been intense. The deposit of the Young America was undoubtedly originally formed at depth but has since been uncovered.

Bonanza Mine

The Bonanza mine is located five miles by road southeast of Bossburg and two and a half west of Evans Station on the Great Northern Railroad. The mine is situated on top of a hill at an elevation of 2,200 feet. The property consists of 60 acres of patented land, 40 acres of which lie in section 11, and 20 acres in section 2.

The mine, unfortunately, had not been unwatered at the time of investigation, so that the writer was unable to go underground. Mr. G. Vervaeke, who controlled the mine under lease and bond, was constructing a mill to concentrate material which had in the past been thrown on the dump. This consisted of fine-grained galena ore, through which was mixed fine-grained pyrite. The ore fragments on the dump were covered with iron oxide. They contained shattered fragments of a black slaty rock. In addition to these fragments of country rock, the gangue consisted principally of quartz and siderite.

The mill under construction was to have a capacity of five or ten tons per shift. The ore apparently contains little, if any zinc, and is said not to run much over seven per cent silver. About $40,000 worth of lead-silver ore is reported to have been shipped from the mines in the last ten years.

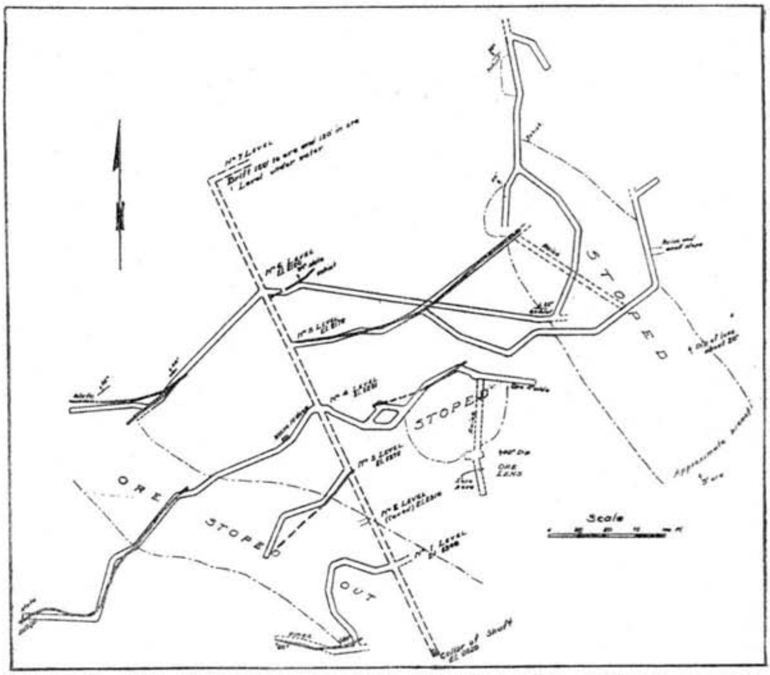

Figure 15. Map of the Bonanza mine, located 5 miles southeast of Rossburg in sections 2 and 11, T. 37 N., R. 38 E. (After compass survey made by J. E. Berg, Nov. 12, 1920.)

The Bonanza mine was originally worked in 1885. The ore body then outcropped boldly on the surface, where it was first mined. Later, underground work was carried on until now the mine consists of an inclined shaft sloping 45° to 55°, 700 feet long, with 100-foot levels branching off from it on either side. In all, the mine contains over 3,000 feet of workings. The ore above the 500-foot level is said to have been largely worked out. The last work done in the mine was on a raise, which has followed the ore within 200 feet of the surface. The mine has been worked spasmodically and apparently with varying degrees of efficiency. The ore bodies are described as being lens-shaped and as occurring in the schist.

The formation is composed of two varieties of slaty schists. One is a black graphitic and the other is a greenish chloritic schist. These rocks dip in general towards the northeast, at an angle of 45° and the enclosed lenticular ore bodies lie conforming to this dip, varying in thickness. The ore occurs in the shear zone, which is associated with an aplitic dike occurring within the mine and also on the surface. Specimens of the dike show it to be also mineralized, containing quartz stringers which grade into ore.

On the east side of the property, there is a fill which is apparently composed of loose materials of a glacial moraine. A tunnel was driven into it but no solid rock was reached.

The ore body and the aplite dike may in some way be genetically associated. They both occupy a fissure zone in schist. Both have been exposed by extensive erosion prior to glaciation. They must have been formed at considerable depth.

OLD DOMINION AREA

Old Dominion Mine

In 1883, about the first mining done in Stevens County was started on the Old Dominion Mine. The ore was then taken to Spokane on pack animals at a cost of $100 per ton, but later wagons were used. The silver-lead ore was, therefore, of very high grade. The mine is located seven and a half miles by road east of Colville, and 1,300 feet higher than the town in the foothills of Old Dominion Mountain, whose elevation is about 4,500 feet. It is reported that in the early days, over half a million dollars' worth of silver-lead ore was taken from the mine, most of which was within 75 feet of the surface. There was a long period of time, some 25 years, when the mine was inactive. At the present time, however, a high grade body of silver-lead ore has been struck and is being mined 70 feet below the lowest tunnel.

The mine is owned by the Dominion Silver-Lead Mining Company. Mr. W. H. Linney is president and general manager. It is reported that since the reopening of the old mine in 1915, $40,000 worth of ore has been taken out. During three of these years, the mine was not in operation because of litigation. The principal value of the ore has been in the silver, though lead has always been present. In the early days, there was a mill on the property, but at the time of this investigation, it was gone. Another mill is to be built in the course of time.

The main surface workings, known as the Ella, lie at an elevation of about 3,375 feet, which is 450 feet above the lowest tunnel. Very high grade ore was mined here in the early days to a depth not over 100 feet. The ore body apparently dipped to the northeast at low angles of 10° to 20°, occurring in the fractured zone of limestone near a fault striking northeast and dipping southeast at a steep angle of nearly 80°. The fault parallels a granite-aplite dike which lies some 15 feet to the southeast. As this ore shoot was being mined out, superficially altered ores, such as cerussite and anglesite, were found. Iron hydroxide is also present here and is found along some of the fractured zones even extending to the lowest level. It is thought by some that the iron hydroxide represents the oxidation of pyrite, but to the writer, it is considered largely the product from siderite, which is more readily and thoroughly acted upon and which is one of the gangue minerals of the ore.

The lowest tunnel (No. 1) follows the contact between granite on the south and limestone on the north to over 2,000 feet in a general northeasterly direction, until it encounters a well defined slickensided fault running N. 62° W., which it follows for over 3,000 feet. Both the contact and the fault were found practically barren of ore, but crosscuts, drifts, raises, and winzes disclosed ore bodies lying roughly parallel to the contact and within a few hundred feet of it. These ore bodies occur in the shattered and brecciated zones of minor faults, occurring in the dolomitic limestone. It is from a compound shattered fault zone that the present rich ore body is being extracted. Three fault zones, forming a triangle of breccia and shattered rock, are largely responsible for the precipitation of the ore. The ore bodies are irregular in shape and size and their position is dependent upon the fracture zones in which they occur. Closely associated with the ore bodies are aplite dikes. These dikes are not mineralized, but it has been observed by Mr. Linney that invariably the ore bodies occur in the shattered zones which lie below the underside or footwall of these dikes.

Tunnel No. 2 lies 157 feet above and is connected with the lower more extensive workings. It is some 500 feet long. A third tunnel is 93 feet higher and is the same length as the second. The two principal formations at the Old Dominion mine are dolomitic limestone and granite. Argillite and quartzite are also present. The limestone is for the most part nearly white in color and crystallized. Underground, in places, near the granite contact, pieces of white wollastonite-asbestos may be found lying between the fracture planes of limestone. On the surface near the granite-aplite contact at the Ella workings, the limestone contains in places lemon-green bloches of ophicalcite. The main contact between the limestone and granite as exposed in the lower tunnel, presents a clean wall with slickensides that run at an oblique angle from the vertical. This evidence and the fact that few metamorphic minerals are present on the contact has lead Mr. Linney to the opinion that the contact is not one of intrusion, but has been produced by faulting. The writer is of the opinion that the contact is a fault but one produced along the original plane of contact.

The main fault, which was followed for a long distance from the lower tunnel, is not mineralized to any great extent. It was formerly thought that this is the same fault as that found in the surface workings and known as the Ella fault, but this correlation is now questioned by Mr. Linney. Vertical slickensiding is very prominent on this main fault.

Although there is evidence of very little post mineral faulting, some of the faults with the breccia zones are not mineralized, while others are. The question then arises as to why this should be. Are there definite channels of ore migration along which connected breccia zones were first mineralized while others were not? If the ore solutions came from great depth, perhaps they could find more nearly continuous migration channels along the fracture zones produced by the aplite dikes and perhaps, in that case, they did not escape from their footwall sides as readily as from beyond their hanging wall sides. Not all of the aplite dikes, however, have been found to be accompanied by ore bodies.

The ore minerals of the present workings are principally galena, sphalerite and pyrite. Some sulphides of silver and even wire silver have been found. In the surface zone carbonates were found and mined. The principal gangue mineral is quartz, quite clear and massive in form. Calcite, dolomite and siderite are also gangue minerals of the ore. The ore solutions probably came or were differentiated from the magma at greater depth than the rock now exposed. This magma may also have been responsible for producing the intrusive igneous rocks now exposed in the mine.

Aside from geologic structural evidence, the physiography of the region indicates that there has been great erosion throughout the country since the rocks and ore deposits were formed. Their exposure has come about by very deep and profound erosion. It is not impossible that such erosion may have uncovered a mantle which had a thickness of miles rather than thousands of feet. The variation of the kind of ores in the different parts of the mine (aside from the change by surface alteration) may be due to their different positions relative to their distances from the ore channels, and not to their relative distances from the present surface.

DAISY DISTRICT

SILVER MOUNTAIN AREA

General Features

The mining district known as the Daisy, is a part of that generally referred to as the Kettle River district. It is located by road 18 miles west of Addy, a town on the Great Northern Railway situated between Chewelah and Colville. The Daisy and Tempest mines are located at an elevation of 3,000 feet and greater, on the west slope of the Huckleberry

Range. They are within five or six miles of the Columbia River. The ore bodies are closely associated with a dioritic intrusion which has cut into a metamorphic sedimentary series of rocks, consisting for the greater part of argillites, and quartzites. The argillites vary in composition, being siliceous, graphitic, and calcareous. These mines are not essentially lead properties. They are valued largely for their silver content. A proper method of milling the ore may put the mines on a commercial basis.

Daisy District

The Consolidated Silver Mountain Mines Company, formerly known as the Silver Mountain Company, was at the time of the investigation preparing to do further mining and milling of the ore from the Daisy group of claims. This property is located in sections 6 and 7, T. 33 N., R. 38 E. A large ore body had been blocked out by underground work which included diamond drilling within the mine. The ore minerals consist of arsenopyrite and pyrite which occur in abundance, sphalerite and galena, chalcopyrite and some tetrahedrite. The metal values lie principally in silver, but also in copper and lead. Oxidized products of these minerals are found in the mine as well as on the surface. The gangue is principally composed of massive quartz and some calcite. These minerals occur in veins which cut through, in every conceivable direction, shattered portions of the country rock. The rock consists principally of calcareous argillite and graphitic argillite. The veins are grouped as mineralized zones along sheared fault planes and also along the sheared contact of the metamorphic sedimentary rocks with intrusive diorite or granodiorite. The granodiorite itself is partly mineralized and the contact is there obscured by the shattered mineralized zone.

The mine consists of surface workings and four levels, all of which are connected by raises. The lower (No. 4 or Seelye) is 980 feet long, directed S. 70° E. After, passing through quartzite, it cuts diorite grading into granodiorite, 800 feet, but does not pass through it. A drift to the left or north at 700 feet from the portal was driven for a distance of 375 feet. It encounters a fractured zone. In this drift, three diamond drill holes were made. One directed a little southeast reaching granitic rock at 182 feet, with ore on the contact, also cut ore at 101 feet. A second hole directed in the opposite way a little north of west cut a small ore body in argillite. A third diamond drill hole, pointed in the same direction as the drift was headed, cut a rich ore body which directly underlies a rich ore shoot opened in the northern drift of the overlying third or Terry tunnel. The ore zone occurring in the drift of the lower tunnel lies in the fractured rock wedge formed by two faults, which dip toward each other. Slickensiding, especially in the graphitic argillite, is very prominent. It is thought that the mineralized zone of the drift connects with the contact zone of the granodiorite. The ore in the drill hole at 100 feet is thought to connect with the mineralized faulted zone within the granodiorite, exposed in the tunnel at 900 feet. If this is true, it would appear that the mineralization took place along faults occurring after the intrusion and consolidating in the granodiorite. This would mean that the contact zone was mineralized, not by contact metamorphism, but because the mineralizing solutions entered a favorable precipitating fracture.

The third level, or Terry tunnel, is 130 feet above the fourth level. At a point in the north drift of this tunnel was encountered a rich part of an ore body which had in the past been mined to a considerable extent. Three well defined mineralized shattered fault zones intersect, forming a roughly shaped ore shoot which might be called chimney of ore. The faults strike N. 80° W., N. 80° E., and N. 10° to 15° E. respectively. It is stated that ore running 110 ounces in silver has been taken from this place. It is the downward extension of that ore body which the diamond drill cut in its northern course in the lower tunnel. An ore body has, therefore, been blocked out for development from the lower tunnel. This same ore body apparently extends from the Terry tunnel to the surface. The leaner ore zones radiating out from this richer portion are also rudely blocked out and may be of future value as low grade milling ore. The writer did not examine the mine further, but it is stated by both Patty and Weaver in their reports that a dike of granite rock was cut through in the Terry tunnel. One of the quartz veins occurring along the shattered fault zone is from four to six feet thick in places, but is not very rich ore.

The writer feels that there is enough evidence to indicate the following conclusions regarding the geology of this mine:

1. That some of the faulting, at least, took place after the intrusion of the granodiorite.

2. That the intrusive granodiorite may have been moved and faulted after consolidation.

3. That mineralization took place along the shattered fault zones especially at their more shattered intersections, and also along the shattered contact zones, as well as in the fault zones of the granodiorite itself.

4. That much of the shattered country rock is not true breccia, but horses of rock completely surrounded by ore matter, indicating that the ore was injected and not infiltrated.

5. That the quartz vein material may be a differentiated product of an igneous magma, but not necessarily of the granodiorite, which is exposed in the mine.

6. That the ore bodies were formed as well as were the igneous rocks, at a great depth, and have since been uncovered by profound erosion.

Tempest Property

The holdings of the Tempest Mining and Milling Company are located one-half mile north and 500 feet lower in elevation than the Daisy mine. The values are largely in silver, the ores consisting of dark brown sphalerite, some galena, and tetrahedrite, pyrite, and chalcopyrite. The ore minerals occur in a gangue of quartz. At the time of investigation, this mine was not entered. It is described, however, by both Weaver and Patty in their reports. Apparently some of the veins, at least, are a continuation of those of the Daisy. The geology is essentially the same type. From the appearance of the rock on the dump, the granodiorite shows plain evidence of its being an intrusion into highly metamorphosed argillite and quartzite.

SPRINGDALE DISTRICT

HUNTERS AREA

Cleveland Mine

The Cleveland mine is located in the Huckleberry Mountains 18 miles by road west of Springdale, a town on the Great Northern Railway, and ten miles east of Hunters, a town on the Davenport-Kettle Falls Highway. The Phoenix Logging Railroad, however, reaches within six miles of the mine. The mine is located in sections 3, 4, 9, and 10, T. 30 N., R. 38 E., at an elevation of about 3,000 feet. The Santa Rita Mining Company owns the mine and a number of claims (Cleveland, Olympia, Ona, Etta, Etta Fraction, Triangle Fraction, Lucky Boy, Stewart Fraction, Copper King, Copper Queen, Copper Bell, Tom Sawyer, Santa Rita No. 1, No. 2, No. 3, No. 4 and Santa Rita Fraction).

A large portion of the ore from the Cleveland mine has come from lens-shaped bodies occurring in fractured and brecciated zones of dolomitic limestone. These ore bodies lie in parallel zones that strike in a northeasterly direction. The principal ore body, part of which still remains below the lower tunnel, has been taken out, leaving a large underground chamber, known as the Glory Hole. This ore body strikes N. 45° E., dipping at a very steep angle towards the southeast. Slickensiding planes are prominent in the walls. The largest body of lean ore at present known in the mine lies between two branches of a main fault which is described below.

The ore consists of galena and boulangerite* (an antimonial lead mineral); also there is present sphalerite, pyrite, siderite and quartz. Some copper was observed in the form of tetrahedrite associated with siderite. The principal values have been in lead and some silver.

No definite statements were secured as to the production of the mine, but it is reported that several hundred thousand dollars' worth of ore have been shipped, a large part being in the form of concentrates. It is the writer's understanding that

*See previous description under "Mineralogy of Lead."

the shipments were penalized on their content of arsenic, antimony, and zinc. The mine was located in 1892 and has been worked spasmodically since then. For the last two or three years, the mine is reported to have shipped several thousand tons of concentrates. At the time of investigation, about three tons of concentrates were being shipped daily, and besides a little high grade ore.

The workings consist of a shaft and two main tunnels with crosscuts and drifts. The lower tunnel was driven S. 64° E., for 800 feet. At that point a fault was cut. The tunnel turns and follows this fault in a direction, N. 40° E., for 120 feet to the shaft, and 45 feet beyond to a point where the fault divides. The left branch was followed N. 20° E. for 40 feet. The right branch was followed N. 67° E. 220 feet to the ore body, which is at present being mined. A crosscut, which was driven to the left before the ore body was reached, is 115 feet long, directed N. 40° W. Near the end of this crosscut, there is a 15-foot drift, from which a 30-foot raise was made to reach an area cut by a diamond drill hole that showed promise of ore.

The upper tunnel, directed N. 64° E., reaches the shaft at 120 feet. A 90-foot crosscut, directed S. 24° E. from the shaft, cut the fault exposed in the lower tunnel. The upper level extends 215 feet from the shaft in a northeasterly direction. At this point, the tunnel turns in a direction due east for 40 feet, where it cuts the left branch of the fault, following it for a distance of 260 feet. The upper tunnel was continued 60 feet farther in a direction S. 60° E., where the fault was cut. At this point, it turns northeasterly for 120 feet, where it terminates. A crosscut was driven southeastward from a point near the center of this portion of the tunnel to the main ore body. This crosscut intersected a stringer of antimonial lead a foot wide, but the ore was not extensive enough to mine.

Half way between the upper and lower levels, there is an intermediate level that opens into the shaft. In one place on this level, the left branch of the fault observed in the lower level has been followed for a distance of 95 feet.

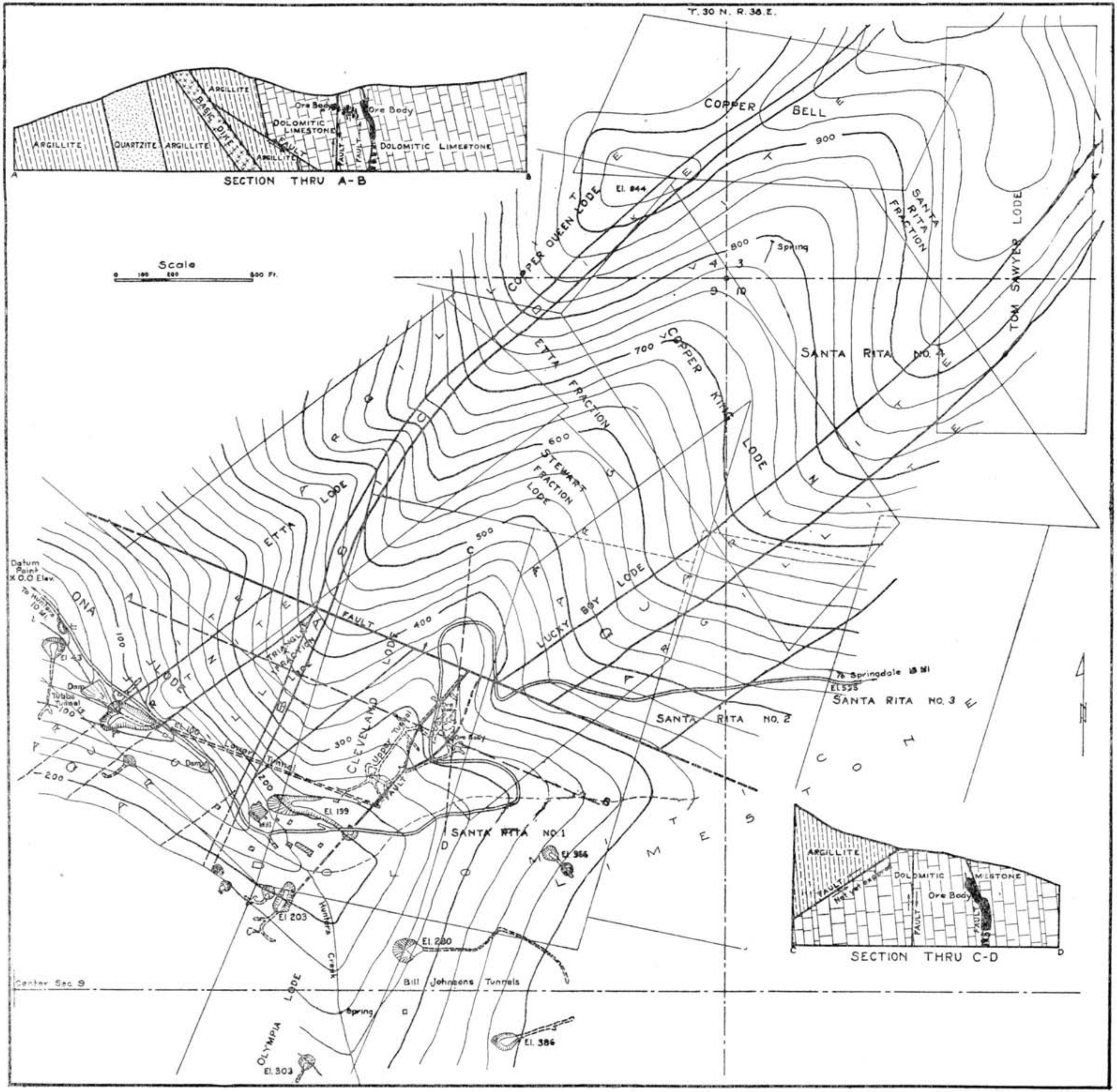

Plate III. Topographical and geologic map of the Cleveland mine and vicinity. Two structural sections are also shown along lines A-B and C-D, the positions of which are indicated on the map. (Prepared by Virgil Barnes under the direction of the writer.)

On the lower level between the shaft and Glory Hole, a raise of 50 feet has been made along the fault. From the top of the raise, the fault was followed into the Glory Hole, where a large body of ore has been removed. This ore body was in the shape of a lens and extended from a point 30 feet above the upper level to the lower level and to an unknown distance below it.

The older workings of the mine are located between the upper level and the surface. These workings consist of raises, shafts, stopes, drifts, and one small glory hole or surface pit. At present, these workings are badly caved and most of them are not accessible. In the past, however, they yielded considerable ore.

There are four kinds of rocks exposed in the vicinity of the Cleveland mine, namely, quartzite, argillite, dolomitic limestone, and a series of basic dike rocks.

Thirty feet west of the portal of the lower tunnel a formation of quartzite 150 feet wide extends up the hillside, striking N. 60° E. This quartzite outcrops in a vertical cliff 75 feet high along the road and forms a ridge to the northeast. The rock is a hard, massive, pink colored quartzite, which has been so badly metamorphosed that no bedding planes are now apparent.

On both sides of this quartzite body, argillite occurs. The strata on the east side are 350 feet wide. The strike of the argillite is N. 62° E. and its dip bears S. 28° E., at an angle of 80°. The argillite has a slaty cleavage and is calcareous. The lower tunnel cuts through a fault contact between argillite and limestone. The argillite in the lower tunnel is much fractured and faulted. In the 400 feet of argillite cut by the mine workings, there are 50 to 75 fault fractures, some of which apparently have a small displacement.

A belt of dolomitic limestone occurs, apparently conformable with the argillite, over 1,000 feet wide and strikes in the same direction as the other formations. The dip of the limestone is about the same as that of the argillite. The limestone is hard, massive and gray. It has been much fractured and faulted.

Dark green basic dikes intrude the older formations. They are very hard and resistant to weathering. One of these dikes cut in the lower tunnel is 25 feet wide. It was traced on the surface for over a mile northward, varying from 25 to 75 feet in width. This dike is found along the crest of a ridge. In the mine several small dikes are exposed a foot or two in thickness. In no place were dikes found cutting the ore body, nor in any place was an ore body found cutting a dike.

A fault was observed on the surface, 100 feet north of the mine workings. The formations are here sharply offset 900 feet. The fault which produced this displacement strikes S. 70° E., and, judging from a study of the geological features in and about the mine, the fault plane dips 30° to 45° in a northerly direction.

The ore lies along the minor fault planes and in places has followed small fissures and precipitated in joint and bedding planes of the limestone. In the Glory Hole the fault has a curved surface, and movement of one side of the area at right angles to this curved surface has left an opening along the fault, where ore deposition has taken place.

The ore mined in the past came from the oxidized zone near the surface. A surface pit or small glory hole, having an elliptical cross-section of 45 feet by 15 feet and 20 feet deep, north of the shaft, contributed some high grade ore. Northeast of this glory hole and connecting with it is a stope 70 feet long, 10 to 15 feet wide, and 25 to 30 feet high, which has yielded some good ore. The walls of this stope still contain ore that may extend farther to the north. One hundred feet northeast of this stope occurs another, 10 feet wide, 30 feet long, and 30 feet high. Still another stope occurs between the two fault branches and about fifty feet in a southeasterly direction from the last mentioned stope. This is said to have yielded good ore. There are undoubtedly other small bodies of ore worked in this mine which were inaccessible to investigation.

A body of lean ore that is not profitable to mine under present conditions occurs in the upper level just northwest of the Glory Hole. This body of low grade ore is about 90 feet long, 15 feet wide, and the vertical extent is only approximately known. It does not, however, extend down to the intermediate level. Therefore it must be limited to less than 50 feet.

On the intermediate level in the region of the shaft occurs a body of ore six feet wide containing much zinc. The minerals occurring in this body are sphalerite, galena, boulangerite, siderite, pyrite, and quartz. Some of the pyrite in this body has been altered to limonite.

In driving the lower tunnel a small body of galena was cut 700 feet from the portal. The ore occurs in a gangue of calcite. This body was not extensive, only a few tons of ore having been removed from it. Another low grade ore body of doubtful extent was cut at a point 50 feet from the Glory Hole.

The Glory Hole is elliptical in cross-section at the upper level. The dimensions of this cross-section on this level are 50 feet long by 15 feet wide. This general shape prevails to the intermediate level where the ore flattens out to the southeast. A cross-section of the ore body on the intermediate level is nearly circular. The ore body then follows vertically down to the lower level and at that level is circular in cross-section. The ore in this body is mostly boulangerite with some galena. The gangue is composed of quartz and calcite, with some siderite and sphalerite.

General oxidation extends from the surface down to an area near the upper level. All the workings above the upper level are in oxidized ground. Along water courses and fault planes, oxidation extends to considerably greater depths. In the lower tunnel, the argillite has been so completely oxidized in one place that timbering was necessary to keep the tunnel from caving. On the upper level near the shaft a fault or joint plane has been weathered out, and has been filled with surface material. When cut by a drift the material in this crack rushed out into the tunnel. The opening left was wide enough for a man to stand in, and extended back thirty feet and up to the root zone, a few feet from the surface. The deepest oxidation observed in the ore bodies was that mentioned as occurring around the shaft at the intermediate level. The ore in the main Glory Hole is not oxidized.

There is a marked absence of glacial drift in this particular region, indicating that the area has not been eroded by the ice sheet. The oxidation probably began in pre-glacial times, but has not been as extensive as that in the Gladstone and Electric Point mines. This is probably due to the sharp relief of the country, enabling erosion to keep pace with oxidation. Besides the surface of the ground was apparently not protected from water erosion during the glacial period by any mantle covering.

DEER TRAIL AREA

General Features

Since the Deer Trail District contains no important lead mines, very little space will be devoted to it in this report. The reader is therefore referred to previous reports, namely those of Bancroft,* Weaver,** and Patty.†

The principal silver-lead deposits of the Deer Trail district are located in the rough hills which constitute the southern end of the Huckleberry Range, some 25 miles by road west of Springdale. The Phoenix Logging Railroad runs from Springdale within ten miles of the mine. The nearest post office is Fruitland, which is located six miles to the northwest on the Davenport highway. The metamorphic sedimentary rocks occurring in the district are, according to Weaver, a continuation of those found at the Cleveland mine, which lies on the northeast strike of the beds some eight miles distant in an air line.

Copper, silver, and tungsten are the chief metals of the Deer Trail district. The deposits carrying these metals are located more or less in separate zones—the copper deposits in one zone, the lead-silver in another, and the tungsten in the third. The claims on which occur the silver-lead ores consists principally of the following groups: Venus Silver mines (formerly known as the Deer Trail group), Queen and Seal, and Aichan Bee.

*U. S. G. S. Bull. 550, pp. 111-118.
**Wash. Geol. Surv Bull. 20, pp. 189-204.
†Wash. Geol. Surv. Bull. 23, pp. 144-152.

Geological Significance

The significant features of the Deer Trail silver-lead deposits are as follows:

1. That they are all quartzose in composition.

2. That the galena contained in them is argentiferous.

3. That the group, though occurring in metamorphic sedimentary rocks, is nearly completely surrounded by intrusive granite which undoubtedly also underlies them.

4. That the more calcareous country rocks are apparently more favorable to the concentration of the ore than the more siliceous, though the ore bodies are largely of quartz.

5. That the ore occupies shear zones in the metamorphic sedimentary rocks.

6. That the main ore body is cut off by a basic igneous dike.

At least two periods of mineralization were noticed by Bancroft. The tungsten quartz veins in granite were the first, while the second were the silver-lead quartz veins. On one property, the Orchid, a silver-lead vein is reported as occurring in granite.

The interpretation which the writer gives to these geological features is as follows:

1. The intrusion and consolidation of the granite magma which occurred at a very great depth below the surface of the earth, were followed by the release of siliceous solutions separated from the magma. Three and possibly four separations were made in these solutions.

2. The first to consolidate were the tungsten veins, which may be considered as a differentiated product of the granite crystallizing without much further migration.

3. The second precipitation was by the silver-lead siliceous solutions which migrated to the shear zones, produced in the metamorphic sedimentary rocks by the action of the granite intrusion, and there crystallized, in part replacing the country rock itself.

4. Following or nearly accompanying this action were the intrusions of the basic dikes.

On the Togo claim, located on the opposite side of the canyon from the Deer Trail group, it was noticed that ore bodies of arsenopyrite and chalcopyrite occur paralleling a diorite dike and within a little over 100 feet of it. The ore minerals are closely associated with the mineral tremolite, a metamorphic product of the recrystallized limestone country rock. The ore bodies follow fissure zones and bedding planes. The diorite dikes probably followed planes of weakness in the rocks, and the precipitation of the ore bodies apparently followed the intrusion of the dikes. This mineralization may represent a fourth period separation from the magma.

It is quite evident, in the writer's mind at least, that all rocks and ore bodies exposed in the Deer Trail district were once very deeply buried and have been exposed through long continuous and profound erosion. The character of the veins may be found to change as they are followed towards or away from their original source. The parts of the veins precipitated nearest the parent granite magma may be the more siliceous. The greatest replacements may be found in the sheared zones of the limestone.

Venus Property

At the time of investigation, the only activity displayed was by the Venus Silver Mines. This company had recently bought the Deer Trail group (located largely in sections 1 and 12, T. 29 N., R. 37 E.) and were preparing to use the ore already on the dumps to run through a mill which was being prepared for that purpose. It intended also to utilize the fills left in the mines and do some further mining. They had commenced underground work on the Elephant and Cameron tunnel.

The Old Deer Trail mining camp at one time was quite active and a considerable amount of high grade silver-lead ore was shipped out. The claims now under control by the Venus Silver mines are over twenty-one in number. The main workings are on the Deer Trail No. 2, Hoodoo Extension, Legal Tender, Elephant, Victor Fraction, Royal and others. These are located at an elevation of about 3,600 feet. The ore consists, according to Weaver, of argentiferous galena, sphalerite, silver sulphide and silver chloride. The gangue is largely quartz and some calcite. Fragments of silicified country rocks, largely argillite, occur in the ore as breccia. Weaver,* states: "The deposits occur along the fissure zone in which there has been replacement along intersecting fractures."

The underground work at the time of investigation was being carried on in the Legal Tender and Elephant tunnel. The dip of the ore body, which is here two and a half feet thick is S. 45° E., 30°. This ore body flattens out in a nearly horizontal position where it has previously been stoped out. Part of the ore mined was left as fills. These are the fills which the company intends to remove and run through the mill.

On the Deer Trail No. 2 workings, the ore was found to be cut off on the west by what is considered by the miners as a fault. Abundant slickensiding occurs at the point where the ore body comes to an abrupt end. The rock beyond, however, is an igneous dike, serpentinized. The dike was probably intruded through the ore body and not merely faulted against it. The ore body at this point dips S. 80° E., 45°. It is a four-foot quartz vein carrying silver-bearing galena and zinc. The country rock is argillite.

Along the ridge above the mines it was noticed that dark colored igneous dikes more than once cut the argillite. Some of the dikes are sill-like in character.

It is said that the highest grade silver-lead ores have been mined and shipped from the properties and the remaining part of the ore body is of lower grade. The writer noticed that the ridge above the mines is of quartzite overlying argillite and dipping steeply in the opposite direction to the dip of the vein. The ore body apparently cuts through all the sedimentary rocks, including both the quartzite and the argillite. The argillite is in places calcareous or dolomitic in composition. Although the deeper workings of the mine were not accessible at the time of investigation, it seemed to the writer that possibly the richer part of the vein was the portion cutting through the calcareous argillite and the leaner part was that

*Wash. Geol. Surv. Bull. 20, p. 196.

portion which intersected the quartzite. This would seem reasonable, for replacement in calcareous rocks is generally more prominent than in siliceous.

Queen and Seal Property

The Silver Basin Mining Company was not in operation at the time of investigation, and the workings of the Queen and Seal claims could not be entered. The property is located near the center of section 11, T. 29 N., R. 37 E., one mile west of the Venus property and on the opposite side of a sharp ridge on the Springdale road, at an elevation of 3,800 feet. The property is not important as a lead producer but has in the past shipped some high grade silver ore. According to Weaver, "The ore consists of white quartz, often iron stained, carrying as its chief value silver in the forms of argentite, and chloride, together with subordinate amounts of pyrite, galena, and sphalerite. Sometimes azurite and malachite are present. The ore occurs in shoots having a predominating pitch to the northeast." The country rock is a light colored crystalline dolomitic limestone, in places brecciated and silicified. The limestone is a member of a sedimentary series, which, for the greater part, consists of argillite and quartzite. Within one-fourth mile both east and west of the property are exposures of intrusive granite. This granite nearly surrounds all the silver-lead property of the Deer Trail district. It is in this granite that the quartz veins of the Germania Tungsten mines occur.

Aichan Bee Property

The property of the Aichan Bee Silver-Lead Mining Company, Inc., consists largely of a claim formerly known as the Austin. It is located in the northeast quarter of section 15, T. 29 N., R. 37 E., on a road which passes from the Davenport road four or five miles to the west, up a steep grade towards the Queen and Seal, one and a half miles to the northeast.

The workings on the property consist largely of a tunnel over 600 feet long having a northeast course. The first part of the tunnel is largely in argillite, while the latter part is in quartzite. The property lies very close to the contact of intrusive granite. At a distance of 190 feet from the portal, where the main tunnel is following a fault plane bearing N. 14° E., a crosscut follows the slip vein of another fault, having a course of S. 54° E. In the fracture zone of this fault, some ore occurs consisting of very dark brown sphalerite. Large cubes of galena and pyrite. The ore appears to have replaced clear colorless quartzite in which it is imbedded. At a distance of 450 feet from the portal, white quartzite and black argilliceous quartzite come into contact.

CONCLUSIONS AND RECOMMENDATIONS

GEOLOGIC CLASSIFICATION OF THE LEAD DEPOSITS

In the foregoing descriptions, there are certain statements regarding conditions of ore deposition which have been repeated for each of many of the prospects and mines. Bringing these like statements together and grouping them accordingly, we may classify the lead deposits of northeastern Washington as follows:

I. Silver-lead quartz vein type, which may carry copper and arsenic.

a. Occurrence in igneous rocks near quartzite contact, "veindike" type.
Examples: Bead Lake and Ries properties.

b. Occurrence partly as replacements in calcareous and siliceous metamorphic sedimentary rocks, generally near igneous contacts.
Examples: Daisy, Deer Trail, Oriole, United Treasure, Silver Trail and Chloride Queen (older tunnel).

c. Irregular (probably replacement) type in limestone near and paralleling granite.
Example: Old Dominion.

II. Galena-sphalerite type.

a. Replacement of limestone and calcareous argillite near granite contact towards which beds dip. Texture of ore banded, generally zinc is predominant.
Examples: New England, O. K., and probably Young America (with silver ore pockets).

b. Distinctly contact metamorphic replacement deposits in calcareous argillites next to granite contact; pyrite present in abundance.
Example: Blue Ridge.

c. Replacement of limestone along breccia zones; sphalerite predominant; quartz surrounds ore mineral.
Example: Josephine group.

III. Galena-pyrite type.

a. Occurrence in fault zones largely as replacement of limestone.
Example: Washington claim.

IV. Pure galena type, generally without much silver content.

a. Irregular bodies in breccia zones of limestones, associated with very little sphalerite, probably in part, at least, replacement bodies. Gangue minerals include siderite, dolomite and calcite, without much quartz.
Examples: Bella May, Diamond R, Chicahominy and Grand View.

b. Distinct chimney type of ore body. Masses of galena, in part, at least, replacements, forming columns along vertical localized breccia zones in limestone; siderite as one of the chief gangue minerals; generally with very little zinc; oxidation to unusual depths causing enrichment by leaching.
Examples: Electric Point, Gladstone, and Uncle Sam.

c. Replacement zones by galena and sphalerite, near argillite-limestone contacts.
Examples: Lead Trust and Lucile.

V. Galena-antimonial lead type.

a. Deposits in fault breccia zones of dolomitic limestone; replacement in part, at least; galena occurs with boulangerite; sphalerite and siderite abundant; some copper and silver present; quartz present in rather small amounts.
Example: Cleveland mine.

STRUCTURAL FEATURES

The occurrence of ore bodies in brecciated zones of limestones (generally dolomitic limestones), the breccia having been formed through faulting and shearing, is extremely prominent throughout the whole field. In many places (especially in the Metaline district) the prominent breccia zones are associated with rock wedges formed and bounded by minor faults.

Those deposits which are not formed in limestones are generally more siliceous than the limestone breccia ore bodies.

Major structural features related to the ore deposits appear to be in the form of major faults which are not uncommonly associated with granite exposures. The original migration channels of the ore solutions probably followed these major channels before they passed out into the minor fault zones where conditions for deposition and replacement were more favorable.

The position of the granite batholith relative to the ore deposition is significant. If, as it is thought, the granite was the source of the ore solutions, the structural relationship of the underlying granite to the overlying limestones is of considerable practical importance.

EPOCHS OF MINERALIZATION

The subject of epochs of mineralization has not yet been satisfactorily worked out. It would appear, however, that the one great epoch is that which followed the intrusion of the Mesozoic (?) granite batholith. In the Tertiary period there were also intrusions including granite (according to various geologists) and in some parts of the State of Washington, we know that mineralization followed this Tertiary intrusion period (for example, the Republic Mining district in Ferry County). It is possible, then, that this second great mineralizing epoch may have been present in Stevens and Pend Oreille counties, following or accompanying the Tertiary intrusion period, even though the Tertiary batholith is not frequently exposed. For example, the Bonanza mine is located near a comparatively small exposure of granite porphyry whose age is placed by Weaver as probably Tertiary.

SIGNIFICANCE OF OXIDATION

In glaciated regions, there is generally very little oxidation found on the upper positions of ore bodies. It requires great periods of geologic time for extensive oxidation to take place, and the removing action of glaciers is generally much more rapid than that of water erosion aided by weathering. In northeastern Washington, most of the sulphide ore bodies may be found outcropping on the surface where they have been laid bare by the carving action of the great ice sheet. Even sphalerite, which is very readily oxidized to the carbonate, is often found in rock exposures.

In some particular deposits, however, oxidation is found occurring at great depths—complete and profound oxidation. Not only is sphalerite found changed to the carbonate form as deep as 250 feet from the surface (as in the Black Rock mine), but galena occurs oxidized completely to the carbonate form at a depth of 800 feet (as in the Electric Point mine) and probably even deeper, for further mining has not yet been done on that ore body. This is an astonishing fact, but not so unbelievable when the oxidation is considered as a pre-glacial action, having started not a few thousand years ago, but millions of years ago in the Tertiary period.

The unconformity between the oxidized portion of the deposit (including the beveled off clastic dikes produced by oxidation within the ore body) and the overlying glacial drift is considered by the writer as a proof that the oxidation is pre-glacial in age. The writer is of the opinion that most of the oxidized ore bodies occurring at considerable depths should be recognized as pre-glacial oxidized zones, or at least portions of such zones.

Such great depth of oxidation indicates that an arid climate existed in northeastern Washington in pre-glacial (Tertiary) times.

The extensive oxidation of the lead bodies has formed enriched zones by the leaching of the gangue. It also has made the gangue soft; and accordingly in mining, the separation of the gangue from the ore is more readily accomplished than where the ore occurs as bunches and in stringer zones impregnating solid rock.

DEPTH OF ORE DEPOSITION

The writer has come to the conclusion that the lead ore bodies investigated in Stevens and Pend Oreille counties were deposited at a depth not merely of thousands of feet from the surface, but more likely miles from the surface. Since they were deposited they have been gradually uncovered by profound erosion, which has taken place over a long period of time, namely, since late Mesozoic, in all probability. This conclusion has been reached from consideration of the following conditions: (1) The time of deposition; (2) the length of time that the area has been a land surface from then to the present day; (3) the period of rejuvenated erosion after periods of base-levelling; and (4) the close association of many of the deposits with their apparent source—the granite batholith which itself must have been formed at great depth.

Some of the deposits (such as those in brecciated limestones with gangue minerals of calcite, dolomite and siderite) may have been formed under lower temperature conditions than those of a quartz vein matrix. That does not necessarily mean, however, that they were formed nearer the surface of the earth.

Some of the ore bodies have been altered and have been enriched near the surface by the leaching out of gangue minerals. This condition may not be expected to continue at very great depth.

The sulphide ore bodies may or may not change at depth, depending upon local conditions. In some cases, at least, the position of the zones which have been favorable to ore deposition governs the persistence or dying out of the ore body. The relation of the ore bodies to the original ore migration channels (if they can be recognized) should also be taken into close consideration in this regard.

It would appear that quartz veins often occur not a great distance from the granite batholith and lead ore in such veins is often silver bearing. It would also appear that contact metamorphic action between a granite and a limestone may often produce banded ores largely of sphalerite.

GUIDES IN PROSPECTING

The first guide in prospecting is the presence of ore. The second is to dig where the ore is found. If the surface digging reveals a large enough body to mine, then some other method may be employed (if it is a conservative method) such as reaching the body by a short tunnel from below—if not too far below.

The irregular bodies of lead ore in the area investigated have not been found to be continuous for such great distances or in bodies large enough to ordinarily justify the taking of a chance by driving a very long tunnel, many hundreds of feet lower in elevation, towards the vertical projection of an ore pocket found at the surface.

The method of drilling is of value where there is enough evidence to warrant the placing of a hole directed towards the region where information is desired. Holes placed without intelligent consideration of known facts may entirely miss the ore bodies (especially if they are in the form of chimneys), and still be within a few feet of a rich deposit.

It seems to the writer that *following the ore* is not a bad method of prospecting, at least in the case of the lead deposits under consideration. In addition to this method, such areas as fault and shear zones, brecciated masses, and intersecting minor faults should be looked upon as important areas to investigate. Since siderite is a persistent gangue mineral of the lead deposits, breccia zones with siderite and its altered product limonite, should be considered favorable zones for prospecting.

A general study of the various deposits, their peculiarities, and the geological conditions in general, should be a helpful guide to the prospector. Special thought should be given to the limestone areas, their structure, and their relation to the great underlying granite mass below. The occurrence of basic igneous dikes apparently has little or nothing to do with the ore bodies. They are often intruded after the ore has been formed. They may be derived from the same magma, however, and probably are associated with the ore bodies because of the presence of easy channels for the passage of the dikes.

SUCCESSFUL MINES

The successful lead mines of Stevens and Pend Oreille counties have been those whose activities have stayed in close proximity to the ore bodies first discovered. They have not been the mines where long tunnels have been driven without the necessary preliminary steps of thoroughly proving the existence of a commercial body of ore. They have not been the mines which have first built a mill and bunkers in case ore might be found. They have been the properties where the ore was found to be present and was then followed persistently. They have been the mines where common sense and good judgment have been employed.

An ore body should be quite worthy of investigation if it will pay commercially, even where the mining activities are carried on by *ideas* rather than *ore*, or where the location of the tunnel site is convenient for driving to and from town, rather than in a place suitable for cutting a known ore shoot.

ECONOMIC ASPECT

A collection of many beautiful specimens of lead ore was made during this investigation, and to look over this collection and to examine the map showing the areas from which the specimens came, cannot but impress the fact on one's mind that good lead ores occur in both Pend Oreille and Stevens counties. Then to look at the location of mines which may be classed as producers, it is rather astonishing to see what limited spots the commercial bodies occupy. Then, when one realizes that vast areas are covered by a mantle of glacial drift, it is a wonder that these spots have ever been disclosed.

These facts as well as many others do not point unfavorably toward the future mining of lead in Pend Oreille and Stevens counties. With the apparent future increasing demand for the lead, further prospecting should be stimulated and thus new ore bodies should be discovered.

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