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ANTIMONY OCCURRENCES OF WASHINGTON

by
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Corrections to Division of Mines and Geology
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Page 37 - line 6, the word "Magnesian" should precede the word "Amphiboles."

Page 37 - line 8, should read "temperatures and pressures in the silica rich solutions of a neutral, weakly acid,"

Page 56 - line 15, "cervanite," should be spelled "cervantite."

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ANTIMONY OCCURRENCES OF WASHINGTON

By C. Phillips Purdy, Jr.

INTRODUCTION

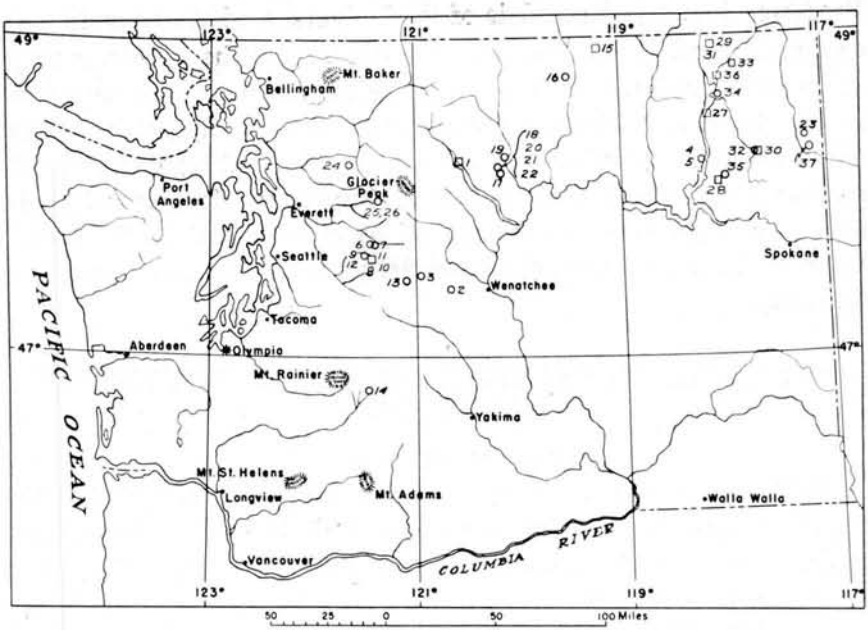
The first discovery of antimony in the state of Washington was made probably in 1892 at what is now known as the Great Republic mine, in the lower Miller River drainage in King County. Stibnite ore is definitely known to have been mined there sometime between 1900 and 1905, but no information is available as to its being shipped for its antimony content. About 1906 the Lucky Knock mine in the upper Okanogan Valley near Tonasket and the Antimony Queen mine in the Methow Valley near Carlton were discovered. During the first world war both of these properties may have shipped as much as 2,300 tons of sulfide and oxide ore between them. Since then activity has been sporadic. In 1947 a small shipment of ore averaging about 7 percent antimony was made from the Wells Fargo mine in Stevens County. In 1941 the Lucky Knock and the Antimony Queen each produced a small car of ore. In 1946 and 1947 the Cleveland mine near the town of Hunters in Stevens County produced several carloads of boulangerite concentrate which was shipped to the Midvale Smelter in Utah. The most recent activity, taking place in 1949, was the 9-month operation of the Lucky Knock mine. Seven small shipments of high-grade lump stibnite averaging about 56 percent antimony were made to Portland, Oregon.

Thus, antimony mining has never been of major significance in the state; hence, little regarding antimony mining in Washington can be gained from the literature. Nevertheless, antimony is an important metal both industrially and strategically. Though, compared with such metals as copper, lead, and zinc, relatively little of it is used each year, the special properties which it imparts to lead make antimonial lead alloys indispensable to our economy, particularly for the manufacture of such items as battery metal, bearing metal, and type metal.

Never has the United States been independent of foreign sources of antimony, principally China and South America, both of which make overseas transportation necessary. At no time was this fact of more significance than during World War II, when the U. S. Geological Survey spent much time and energy searching out all possible sources of antimony in our own country and in Mexico as well. It is obviously important that no possible source of antimony should be overlooked. With this purpose in mind, the Washington State Division of Mines and Geology instigated a project for the

purpose of investigating every known antimony occurrence in the state. The actual field examinations were made during the summers of 1947, 1948, and part of 1949. It was seen early in the work that to visit all of the antimony occurrences would be impracticable. Therefore, in order to have a reasonable program it was decided that all deposits in which the antimony mineral was either tetrahedrite (copper-antimony sulfide) or pyrargyrite (silver-antimony sulfide) would not be examined. These particular types of deposit were selected for exclusion, because neither of the two minerals contained sufficient antimony to be an economic source of that metal except under exceptional circumstances (see appendix), and neither of them is of any special mineralogic interest. However, deposits containing them are included in the appendix, where there is as complete a list as possible of all reported and known occurrences of antimony. In this manner, the investigation was narrowed down to those occurrences containing either stibnite, the usual ore mineral of antimony, or some unusual antimony-bearing mineral that might be of particular mineralogic interest. In all, 37 different antimony occurrences are covered in some detail by this report. The locations of these occurrences are shown in figure 1. The detail in which these deposits are covered was guided in part by the possibilities of their future antimony production. For example, the underground geology of the more promising occurrences was mapped with Brunton compass and tape on a scale of 1 inch to 20 feet, while at the least promising deposits, only notes as to the geologic relations were made. Specimens to be studied in the laboratory were collected from all the deposits visited, and samples taken where this was deemed essential. Detailed sampling of the kind done by engineers examining properties for private companies is not considered part of the Division's rightful work. Nevertheless, it is thought that the information gathered is ample to give an accurate conception as to the relative possibilities of the deposits and to lay an adequate foundation upon which examining engineers for private industry can build.

From the data obtained during the investigation, it has been determined that, in all, five properties would bear further investigation should the nation's supply of foreign antimony be cut off. Of these, the Lucky Knock, the Antimony Queen, and the Bales might have a chance for commercial operation when market conditions are particularly favorable. The two others, the Robert E. Lee and the Longstreet, should be explored if an emergency demand develops.



1. Orphan Boy
2. Peshastin
3. Snook and Ellen
4. Longstreet and Robert E. Lee
5. Silver Leaf
6. Gold Mountain
7. Great Republic
8. Aces Up
9. Bear Basin
10. Cleopatra
11. Coney Basin
12. Dawson
13. Denny
14. Reeves
15. Carlquist
16. Lucky Knock
17. Antimony Bell
18. Antimony Queen
19. Bales
20. Coyote
21. Jumbo
22. Stibnite
23. Pinnel
24. John Feldt
25. Monte Cristo
26. Foggy
27. Acme
28. Cleveland
29. Easter Sunday
30. Mullen
31. Pomeroy
32. Schrenberg
33. Tile Creek Mining Co.
34. Vanasse
35. Wells Fargo
36. Young America
37. Lena Belle

FIGURE 1.—Index map showing investigated occurrences of antimony in Washington. Small circles represent deposits containing stibnite, and the squares represent deposits containing other antimony minerals.

ACKNOWLEDGMENTS

Sincere thanks are expressed for the generous cooperation that was given by the owners of, and those people interested in, the mining properties investigated. Special mention in this regard is due Mr. E. A. Magill, Mr. C. L. Miles, Mr. Paul M. Sorensen, Mr. John Thomson, and Mr. H. B. Johnsten. The writer appreciates greatly the fine help given him by Mr. Kenneth P. McLaughlin and Mr. George Simmons during the summers of 1947 and 1948, respectively.

Professor Julian D. Barksdale of the University of Washington was especially kind in allowing a part of his unpublished geologic map of the Methow Quadrangle to be reproduced in this report as figure 9. The writer is indebted to the entire staff of the Division of Mines and Geology for generous assistance during the writing of the report, and particularly to Sheldon L. Glover, Supervisor, for general guidance and suggestions for clarity of expression and to W. A. G. Bennett, Geologist, for help with the petrography and microphotography.

PROPERTIES, TREATMENT, USES, AND CONSUMPTION OF ANTIMONY

PHYSICAL PROPERTIES

Antimony is a silvery-white brittle metal having a highly metallic luster. It crystallizes in the rhombohedral division of the hexagonal system. The physical properties are as follows:

Atomic weight	121.76
Specific gravity	6.62
Melting point	630° C.
Boiling point	1440° C.
Coefficient of expansion (linear)	11.29×10^{-6} per degree C.
Specific resistance	41.7 microhms at 20° C.
Electrical conductivity	low
Thermal conductivity	low
Hardness (Moh's scale)	3.0
Heat of fusion	38.26 cal./gm.
Specific heat	0.0493 cal./gm./° C.
Tensile strength of cast antimony	ca. 1,000 lbs./sq. in.

Other important physical properties are:

1. Expansion on solidifying from a melt.
2. Relatively strong diamagnetism.
3. Marked thermoelectric properties.

Antimony's properties of expansion on solidification and diamagnetism are related to the complex and relatively "open" nature of its atomic structure.[1] This structure causes a volume shrinkage when the metal is melted, by allowing the atoms to take on a statistically close-packed arrangement. This arrangement explains the reason for expansion as the metal solidifies.

[1] Evans R. C., An introduction to crystal chemistry, pp. 97-98, 100, 1948.

Certain metallic crystals, such as antimony, have loosely bonded atoms. These bonds, as shown by the relatively low electrical conductivity of the metal, appear to be essentially covalent (atoms held together by sharing electrons from their outer shells), but have some characteristics of the metallic bond (positive ions held in a field of electrons). Such crystals show a characteristic structural diamagnetism, that is, the diamagnetism (property of repelling a magnetic field) is caused not so much by the diamagetism of individual atoms as by the arrangement of the atoms and the essentially covalent character of their bonds. On heating antimony, the structural diamagetism rapidly diminishes until at the melting point it has disappeared altogether. Also, as heating proceeds through the lower temperatures the electrical conductivity increases, probably because of an increase in free electrons; but if the temperature is raised too high there is too great an agitation of the electrons, and the flow of electricity is therefore impeded.

CHEMICAL PROPERTIES

Antimony belongs to the phosphorus family along with nitrogen, arsenic, and bismuth. It has three valences, 3, 4, and 5. When it has a valence of +3 it acts as both a metal and nonmetal, and with a valence of +5 it acts entirely as a nonmetal, which is to be expected from its position between the nonmetal arsenic and the metal bismuth in the periodic table. Antimony is stable in air at ordinary temperatures, but on heating it ignites and burns to form Sb_2O_3. The metal can also be oxidized by other oxides which have the power to give up easily their oxygen component, such as manganese peroxide and lead oxide. When antimony is heated to red heat in the presence of steam it oxidizes to Sb_2O_3 and at the same time decomposes the steam. It unites with hydrogen to give SbH_3 (stibine), a poisonous and colorless gas that has a foul smell. At elevated temperatures it also combines readily with fluorine, chlorine, bromine, and iodine, a reaction that is characterized by the evolution of light and heat.

Antimony is not acted upon by either dilute hydrochloric or sulfuric acids, but with warm concentrated hydrochloric or sulfuric acid it forms the chloride and sulfate respectively. Only in a finely divided form can it be acted upon by the hydrochloric acid. Antimony reacts with nitric acid under all conditions to form oxides; it dissolves easily in aqua regia to form pentachloride; it is also soluble in alkaline solutions.

Antimony and its soluble compounds are poisonous but less so than those of arsenic.

TREATMENT

A discussion of the metallurgy of antimony is beyond the scope of this report, and little has been written on the subject. The best and most modern work is in German and is entitled "Antimony and its smelting," by Walter Wendt, published by Franz Deuticke, Vienna, 104 pages. Probably the most complete work in English is "Antimony," by C. Y. Wang, Charles Griffin & Co., London, 217 pages, 1909.

USES AND CONSUMPTION①

Antimony is one of our most vital strategic mineral resources, because of its use in alloys for which there are almost no substitutes and because of its great scarcity within the confines of the continental United States. Fortunately, a goodly portion of the antimony used as alloys can be recovered and used over again. About the only use for the pure metal is as metal trimmings for coffins because of its resistance to surficial acid solutions. As an alloy it can be combined with most of the heavy and alkali metals (i. e., sodium and potassium). It imparts to its alloys increased hardness, brittleness, fusibility, and resistance to acid and alkaline solutions. It also causes its alloys to expand when they solidify.

Lead-Antimony Alloys

Antimony's greatest single use is as antimonial lead, which consumed about 47.5 percent of the total 9,381 short tons used in the United States for metallic products in 1948. For that year, the principal metallic products using antimony, except for antimonial lead, are listed below in descending order of importance, and the percentage of total metallic products that each use represents is given in parentheses at the end of the paragraph discussing that use. The over-all use pattern has been about the same since 1946.

(a) *Antifriction metal.*—This includes babbitt, which averages about 10 percent antimony, 5 percent tin, and 85 percent lead. Alloys of many other compositions are known, some of which employ copper. Recently it has been found that cadmium can replace antimony in many of these antifriction metals. These alloys harden the lead and raise its fusing point but still allow it to retain its antifrictional properties. (19.5 percent)

(b) *Battery metal.*—Antimony, in amounts varying between 4 and 12 percent, alloyed with lead in battery plates lends a hardening property and lengthens the life of the plate. However, it has been shown that an alloy of lead containing only 1 percent calcium can be substituted for an alloy of lead containing up to 10 percent

① Data from U. S. Geological Survey Mineral Resources of the United States, and U. S. Bureau of Mines Minerals Yearbooks, various years.

antimony in storage-battery plates. Even though calcium costs about five times as much as antimony, its use would still be profitable, providing it is not too difficult to obtain a uniform alloy. (16.5 percent)

The two uses for lead-antimony alloys just listed are the principal ones from the point of view of tonnage but not the most important, as substitutes are possible in the case of antifriction metal and battery plates.

(c) *Type metal.*—This is antimony's most important and one of its oldest uses. Type metal is a lead-antimony alloy in which the antimony content varies from 2 percent in electrotype to 23 percent in stereotype metal. The antimony hardens the type and causes it to expand on cooling. This use consumes a relatively small tonnage, as the type is melted and recast repeatedly. (11 percent)

(d) *Sheet and pipe.*—The lead used as sheet and pipe in the chemical industry and that used as roofing, gutters, and similar products for the building industry ordinarily contains about 6 percent antimony to give it resistance to alkaline and acid solutions. However, when lead is used as valves and pumps in the chemical industry a harder alloy is needed and the antimony content is increased to about 12 percent.

(e) *Solder.*—The use of antimony in some solders along with tin and lead was developed during the war because of the tin shortage. One of the popular "war" solders analyzed 2 percent antimony, 30-40 percent tin, and the remainder, lead.

(f) *Castings.*—Britannia metal is used in castings and contains usually 4 to 15 percent antimony for hardening, close to 10 percent lead, and the remainder, tin. Occasionally it contains some copper.

(g) *Cable covering.*—Formerly antimony was a very important alloy with lead for strengthening and hardening cables, about 1 percent being used, but lately an alloy containing .04 percent of metallic calcium has been found to be more satisfactory, and still more recently other substitutes for antimony have come into use.

(h) *Collapsible tubes and foil.*—Up to 4 percent antimony is used in these products for its hardening and strengthening effects, though about 2 percent is the usual addition.

(i) *Ammunition.*—Antimony is used in the manufacture of shrapnel. It makes the lead hard and brittle so that it will fly apart. It has been used for this purpose since 1800. Besides being a component of shrapnel, it is also employed as a hardening agent for lead bullets.

Uses (d) through (i) consume 5.7 percent.

Antimony can also be alloyed with other metals—tin, copper, zinc, and aluminum being the most common. Alloys of tin have already been discussed. In order to intensify the color of copper and

brass and at the same time to increase their hardness and fineness of texture, antimony is added. With zinc, antimony forms varying crystalline compounds that decompose water rapidly at its boiling point and thus afford a method of preparing hydrogen. When alloyed with aluminum, antimony makes a product that expands on solidifying, has a low specific gravity, is hard, fairly malleable, and is unaltered by air or water at ordinary temperatures.

Antimony Compounds

The chemical compounds of antimony have as important uses as the alloys, but in peacetime their tonnage is less. In 1948 the amount consumed in the manufacture of antimony compounds was 6,074 tons. During World War II over 7,000 tons a year went into the manufacture of flameproofed textiles alone. In 1948 this consumption had dropped abruptly to 97 tons. It is important to note that where antimony compounds are used there is no recovery of secondary antimony, as there is from the alloys.

The following list of the uses of antimony compounds is in descending order of importance for 1948, with percentages in parentheses.

(a) *Sodium antimonate and antimony trichloride.*—Sodium antimonate is used in the manufacture of opaque glasses and glazes. This use doubled in the period 1945-1946. About ten times as much sodium antimonate as antimony trichloride was used in 1946.

Antimony trichloride is manufactured as a chemical reagent and employed in the making of Vitamin A. (35 percent)

(b) *Frit.*—The product of the fusing of certain chemical components is used as a basis for glazes and ceramic enamels.

In these products antimony compounds are used as coloring agents and opacifiers. This last use is increasing rapidly, and doubled in the period 1945-1946. (26 percent)

(c) *Paints and lacquers.*—Here again the antimony compounds are used as opacifiers and pigments, principally vermillion, yellows, and whites. Antimony sulfide is used as a dark pigment in camouflage paints to give the paints the same infrared reflectance characteristics as surrounding green foliage. This use was stimulated by the development of infrared photography in World War II. (21 percent)

(d) *Flameproofed textiles.*—These are best described by the following quotation: [1] "As a result of the war there has been an unprecedented demand for canvas that is flameproof, waterproof, and mildew-resistant. Canvas is endowed with these characteristics by dipping it into a compound containing antimony oxide, chlorinated paraffin, paint pigments, and several other constituents. The

[1] Schaum, J. H., Antimony: Minerals Yearbook, pp. 784-785, 1943.

treated canvas will burn if heat is applied from an external source, but it will not support combustion after the source of heat is removed." As remarked previously, this is essentially a wartime material. (6.4 percent)

(e) *Glass and pottery.*—Antimony oxides and sulfides are used as coloring agents. (5.8 percent)

(f) *Plastics.*—Powdered antimony metal is used as a catalyst in one of the steps in the manufacture of cellulose acetate. (3.8 percent)

(g) *Miscellaneous.*—Under this heading are such uses as vulcanization of rubber, manufacture of safety matches, ammunition primers, tartar emetic, color fastener in dyes, various medicinal products, and bronzing of gun barrels. (2 percent)

THE ANTIMONY MARKET AND OUTLOOK

As of January 1951, the antimony market appears to be strong and the price high. The refined metal is quoted by the National Lead Company at 42c per pound, in bulk, carload lots, f.o.b. Laredo, Texas. At this same time stibnite ore averaging 50-60 percent antimony brings prices probably varying between $5.25 per unit[1] and $6.50 per unit depending upon the buyer, the eastern markets appearing to be generally higher than the western. This condition should result in a relatively large amount of domestic production and should very materially encourage antimony mining in the State of Washington.

Whether or not there will be any significant increase in the domestic production of antimony is based principally on the availability of foreign ores. Under normal peacetime conditions most of our antimony is imported, principally from the following three countries named in order of importance: Mexico, China, and Bolivia. Mexico and Bolivia ship ore, whereas China usually ships the refined metal. As Mexico and China have customarily supplied over 80 percent of our antimony, any situation retarding shipments from these countries is serious. At the present time almost no antimony is coming from China because of the war and only a relatively small amount from Mexico because of increased costs and ore depletion. It is undoubtedly these conditions that are responsible for the present high price. However, it is indicated that Turkey and South Africa may begin shipping, which, combined with the present increased shipments from Bolivia and Peru, might tend to drive the price down. Consequently, any prediction as to the future of the antimony market is somewhat speculative, but it would seem that the present international situation and our continued defense effort should keep the price up.

[1] A unit equals 20 pounds of metallic antimony.

At present, antimony is on the government stockpiling list, and export and inventory controls are maintained.

The nearest market for antimony ore mined in Washington is Morris P. Kirk and Son's plant at 5909 Northwest 61st, Portland, Oregon, which manufactures battery-plate metal and consumes approximately 10 to 25 tons per month of high-grade lump stibnite, i. e., the ore must assay at least 50 percent antimony, contain no silver, and have less than 0.5 percent arsenic and combined impurities. Another possible market is the Bradley Mining Co., whose smelter is at Stibnite, Idaho. Here, too, the ore or concentrate undoubtedly has to contain less than 0.5 percent arsenic and combined impurities in order to prevent a penalty. Actually, the requirements of the individual smelting plants differ and a prospective seller of ore should always send a representative sample to the smelter of his choice in order to learn if the ore is acceptable and on what basis.

ANTIMONY MINERALS OF WASHINGTON AND THEIR IDENTIFICATION

The two common antimony-bearing minerals in the State of Washington are stibnite (Sb_2S_3), the principal ore-forming mineral, containing 71.4 percent antimony; and tetahedrite ($Cu_{12}Sb_4S_{13}$), containing about 25 percent antimony. The latter is, however, primarily an ore of copper, and less frequently the presence of silver makes it an ore of that metal as well. In either case the antimony is usually only a detriment to the value of the tetrahedrite. The other antimony minerals that have been found by, or reported to, the writer are one silver antimonide, several sulfosalts containing antimony, three oxides of antimony, and one antimonate. All together some 19 different antimony-bearing minerals have been described or reported from the state.

The order of presentation of the minerals is arranged essentially according to "Dana's System of Mineralogy." In the descriptions under each mineral name only those factors have been included that are believed to be of use in the identification of the minerals in the hand specimen, both by visual examination and by simple qualitative chemical tests. Since these chemical tests are discussed in detail in the standard texts on mineralogy,[1] there is no need to repeat these descriptions here. However, stibnite is described completely because of its value as the chief ore of antimony and its interesting mineralogic characteristics. Detailed descriptions of the other antimony minerals are available in the literature.[2] Likewise, complete descriptions of the minerals as seen in polished sec-

[1] Ford, W. E., Dana's textbook of mineralogy, 4th ed., 851 pp., 1932; and Brush, C. J., and Penfield, S. L., Manual of determinative mineralogy with an introduction on blowpipe analysis, 312 pp., 1898.

[2] Palache, Charles; Berman, Harry; and Frondel, Clifford, Dana's system of mineralogy, vol. I, 7th ed., 834 pp., 1944.

tion under the metallographic microscope, and full particulars concerning the reactions of the various etch reagents upon these polished surfaces are given by M. N. Short,[1] who also includes an excellent discussion of the methods of qualitative microchemical analysis as applied to ore-mineral identification.

It should be mentioned here that there are definite limitations in the identification of the sulfosalt minerals by examination of their polished surfaces. In fact, unless this microscopic work is supplemented by X-ray diffraction analysis and quantitative chemical analysis on pure material, it should be considered as of a preliminary nature only. Thus, the microscopic identifications of the sulfosalts in this report, even where assisted by spectrographic analysis, as they often were, should be thought of as only tentative.

NATIVE ANTIMONY

Native antimony (Sb) has not as yet been found in Washington, but as it is often associated with stibnite and is not uncommon elsewhere, it is included here for the sake of completeness.

Native antimony, crystallizing in the hexagonal system, is a moderately hard (3.0-3.5) brittle, tin-white, metallic-appearing mineral with a gray streak. Antimony ordinarily is massive, lamellar, and distinctly cleavable parallel to the base. It also is sometimes botryoidal with a granular texture. Less commonly individual crystals are found; these may be pseudocubic or thickly tabular in nature, and twinning is common.

Native antimony usually contains small amounts of impurities, which usually consist of arsenic, iron, silver, or copper. It is easily identified by heating in the open tube. The presence of a molten globule of antimony, white odorless fumes, and the absence of pungent yellow sulfur fumes are characteristic.

ANTIMONIDE

Dyscrasite

Dyscrasite (Ag_3Sb) was reported by Warren S. Smith[2] from the Cleopatra mine on the West Fork of the Miller River, King County, Washington. Crystallizing in the orthorhombic system, it is most commonly a massive and unusually heavy metallic mineral (S.G.= 9.75), silver white in color, but when found is invariably tarnished yellow or blackish. Its hardness is 3.5-4.0, and wherever it is scratched with a knife powder does not form, instead the blade leaves a silvery white groove. The mineral is a silver antimonide, a metallic compound carrying about 75 percent silver and 25 percent antimony.

[1] Short, M. N., Microscopic determination of the ore minerals, U. S. Geol. Survey Bull. 914, 314 pp., 1948.

[2] Smith, Warren S., Petrology and economic geology of the Skykomish Basin, Washington: Columbia School of Mines Quart., vol. 36, pp. 154-185, map, 1915.

SULFIDES

Stibnite

Stibnite (Sb_2S_3) is the common ore of antimony and is found in varying degrees of concentration in several localities within the border of the state. These are all discussed in detail in the section on antimony occurrences.

Stibnite, crystallizing in the orthorhombic system, is a soft (hardness 2) steel-gray mineral most easily recognized by its habit of forming confused aggregates and radiating groups of bladed or acicular crystals which often are bent and twisted because the planes of better cleavage act as gliding surfaces. The direction of perfect and easy cleavage is on the b-pinacoid 010, with other directions of less perfect cleavage parallel to the base, on the a-pinacoid, and on the prism; this last appears to be less common than the others on crystals observed by the writer. From a study [1] of stibnite's crystal structure it has been learned that the exceptionally perfect 010 cleavage is caused by relatively weak bonds of a partly metallic nature, perpendicular to 010, linking the continuous covalent Sb_4S_6 bands, which extend parallel to the c-axis and are flattened with the 010. This also explains stibnite's habit of forming in elongated bladed and acicular crystals. Twin-gliding parallel to the base is very prevalent, making the twin lamallae a characteristic feature and of aid in identifying the mineral, as they stand out very prominently on the fresh steely appearing 010 cleavage surfaces. These lamallae when viewed on a polished surface under a microscope with crossed polarized light give a striking "zebra banding" effect due to the strong anisotropic colors which range from white to pinkish gray, to pink, to blue, to brown, and to dark gray. A photomicrograph of this "zebra banding" is shown in figure 3. This illustration clearly shows the part deformation plays in the formation of the twin lamallae or banding. A broken black line can be seen starting near the lower left-hand corner and ranging diagonally upward toward the right. This line is a calcite veinlet. It can be seen to have been displaced by each individual band, thus indicating that the "zebra banding" was formed by deformation after the introduction of the veinlet. Undulose extinction resulting from mechanical deformation is also a common feature when stibnite is observed under the above conditions. It is not uncommon to find stibnite in the granular and massive form. In several instances specimens were observed in which both the bladed and granular forms appeared together. In the examples observed by the writer, the granulated form seemed due to a stress which had caused local brecciation and recrystallization of the coarsely bladed stibnite.

[1] Evans, R. C., An introduction to crystal chemistry, p. 142, 1948.

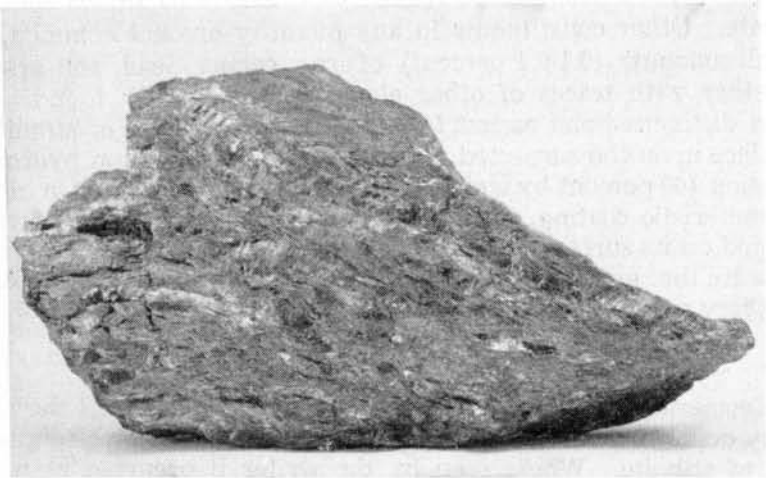


FIGURE 2.—Massive stibnite—Lucky Knock mine.

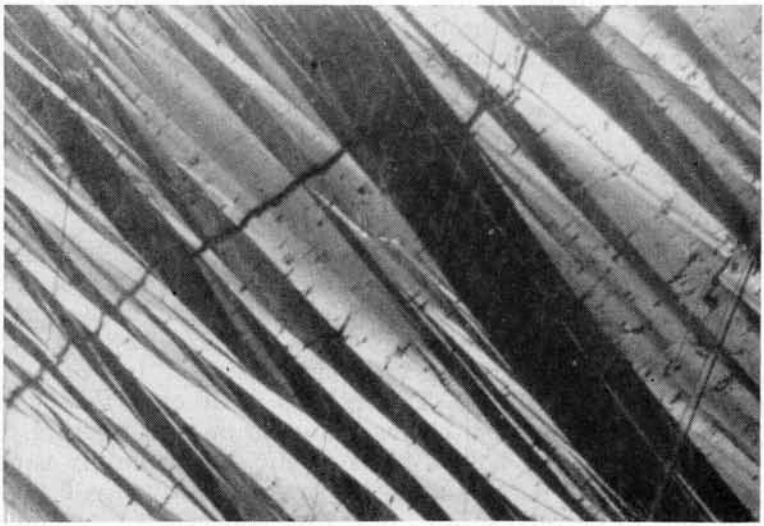


FIGURE 3.—Polished surface of massive stibnite showing calcite veinlet offset by twin lamellae. X 20. Lucky Knock mine.

When stibnite is exposed to the weather its surface takes on a blackish to iridescent tarnish. As this is also characteristic of several other minerals, it is not especially diagnostic.

Stibnite contains 71.5 percent antimony. Thus this element can easily be tested for on the charcoal block, in the closed and open tube, and by oxidizing with nitric acid. All give good positive

results. The sulfur can be readily detected by its fumes and sublimate. Other constituents in any quantity are not common, but small amounts (0.1-0.4 percent) of iron, copper, lead, and arsenic, together with traces of other elements, are usually found. The most distinctive and easiest test for the identification of stibnite is to place upon the suspected mineral a drop of potassium hydroxide solution (40 percent by weight). If the mineral is stibnite, a highly characteristic coating, the color of which is a light terra cotta, is formed on its surface. The only other mineral of which the writer is aware that gives this reaction is kermesite (Sb_2S_2O), whose color is cherry red.

Kermesite

Kermesite (Sb_2S_2O) has been recognized in almost all the antimony deposits in the state and is formed by the incomplete alteration of stibnite. Where seen by the writer it occurred as a red powder on stibnite blades or as a paste along slickenside surfaces. Crystallizing in the monoclinic system, it is a very soft (hardness 1.0-1.5) cherry-red mineral occurring, where fully developed, as elongated, lath-shaped blades. The mineral is sectile and has a perfect basal cleavage, brownish-red streak, and a semimetallic luster. Kermesite is an antimony oxysulfide containing 75 percent antimony.

SULFOSALTS

Polybasite

No occurrences of polybasite [$(Ag,Cu)_{16}Sb_2S_{11}$] have been recorded in the state,[1] but it is included here as it is a relatively common mineral occurring in small amounts in silver deposits elsewhere and may yet be found in Washington. Polybasite, crystallizing in the monoclinic system, is a soft (hardness 2-3) iron-black mineral having a black streak and metallic luster. In thin chips it is translucent and dark red. The mineral is either in short tablets or massive with no perfect cleavage and an uneven fracture. The general composition of polybasite is erratic, but generally is about 69 percent silver, 6 percent copper, 8 percent antimony, 2 percent arsenic, and 15 percent sulfur. It is distinguished from stephanite by its translucence and its positive reaction for copper.

[1] As this bulletin goes to the printer, an unpublished report on the "Geology of the Bead Lake District, Pend Oreille County, Washington" by M. C. Schroeder has just been brought to the attention of the writer. It mentions a small amount of polybasite with scatterings of chalcopyrite and pyrite in small quartz veins in argillite at the Isabelle claim located in sec. 26, T. 34 N., R. 44 E. Schroeder reports both adits were inaccessible in 1948.

Stephanite

Stephanite (Ag_5SbS_4) has been quite consistently reported from most of the old silver camps in the north-central part of the state, i. e., from the Cascade Mountains east to the Columbia River. Unfortunately, during the investigations for this report not a single specimen was found for laboratory study. From this it is probably safe to assume that what little was found has been mined out. Even though stephanite is common in silver deposits it occurs only in small amounts, usually near the surface. Stephanite, crystallizing in the orthorhombic system, is a soft (hardness 2-2.5) brittle mettalic iron-black mineral. It usually crystallizes either as short prisms or as tablets parallel to the base. Also many occurrences are massive or disseminated. Stephanite is a silver-antimony sulfide containing 68.5 percent silver, 15.5 percent antimony, and 16 percent sulfur. It is distinguished from polybasite by its lack of translucence and its negative reaction for copper, and from tetrahedrite by being softer.

Pyrargyrite

Pyrargyrite or dark ruby silver (Ag_3SbS_3) has been authentically reported in many of the mining districts in the state from the Cascade Mountains east to Idaho. However, because it is formed either by deposition from very low-temperature ascending aqueous alkaline solutions as one of the last minerals to crystallize or possibly by processes of secondary enrichment, it is not particularly available for study to present-day investigators, having been mined out in most locations. Nevertheless, the writer did observe an occurrence of primary pyrargyrite in the Meadow Creek district, on the northeast shore of Lake Chelan directly across from the town of Lucerne.

Pyrargyrite, crystallizing in the hexagonal system, is a soft (hardness 2.5) deep-red to almost black mineral with a purplish-red streak. Its degree of darkness depends largely on the length of time it has been exposed in the air, an absolutely fresh surface being a deep brilliant red. It differs from the true ruby color by having a purplish tinge that further enhances its brilliance. The mineral usually crystallizes as distorted and complex prisms with twinning commonly present. It also occurs massive and in disseminated grains. The cleavage is rhombohedral.

Pyrargyrite contains 59.7 percent silver, 22.5 percent antimony, and 17.8 percent sulfur. It may also hold small amounts of arsenic (1-2 percent). It is distinguished from proustite (Ag_3AsS_3) by a deeper red color and less translucence. It is also more common than proustite.

Tetrahedrite

Tetrahedrite ($Cu_{12}Sb_4S_{13}$) is of very common occurrence in the state, being present in minor amounts in many of the deposits in the Cascade Mountains and eastward through the northern part of the state. A fairly large deposit of freibergite, the argentiferous variety of tetrahedrite, occurs on the lower west slope of Eagle Mountain, 4 miles northeast of Chewelah in Stevens County. (See Chinto mine, p. 170, and United Silver Copper mine, p. 175.)

Tetrahedrite, crystallizing in the isometric system, is a moderately hard (hardness 3-4.5) brittle grayish-black metallic-appearing mineral. It is frequently found as small tetrahedral crystals, whence the name. More commonly, it is massive.

Chemically, tetrahedrite is a very complex mineral. It is predominantly a copper-antimony sulfide. However, iron and zinc atoms commonly substitute for the copper atoms and, less frequently, so do those of silver, mercury, and lead. When the silver atoms have substituted for copper to such a degree that silver makes up a noticeable percentage of the mineral, the mineral is known as freibergite. The antimony may interchange with arsenic in all proportions, and consequently there exists a complete series ranging from an end member containing only antimony (tetrahedrite) to one containing only arsenic (tennantite).

Tetrahedrite will give good positive results when tested chemically for copper and antimony. In simple qualitative tests the reaction for silver, because of small amounts, is not always clear. Consequently, it is always a good idea to have deposits containing tetrahedrite assayed for silver. Tetrahedrite contains up to 45 percent copper, depending upon the degree of substitution of the above-mentioned elements; up to 29 percent antimony, depending on amount of arsenic present; and about 26 percent sulfur.

Geocronite

Only one occurrence of geocronite [$Pb_5(Sb,As)_2S_8$] is known in the state and it is the variety schulzite. This is at the Young America mine, in northern Stevens County on the east bank of the Columbia River about ½ mile northeast of Bossburg.

Geocronite, crystallizing in the orthorhombic system, is a soft (hardness 2.5) massive lead-gray mineral which very rarely forms distinct crystals. Chemically, it is a lead-antimony-arsenic sulfide with the ratio of antimony to arsenic very close to unity. The variety schulzite is apparently entirely lacking in arsenic. In some instances a few copper atoms substitute for those of lead. The chemical composition for the ideal formula is about 70 percent lead, 8 percent antimony, 5 percent arsenic, and 17 percent sulfur.

Bournonite

To the writer's knowledge, the Acme property in the Kettle Falls district, Stevens County, is the only deposit in which the mineral bournonite ($PbCuSbS_3$) has been found in the state. This is quite surprising, as elsewhere it is one of the most common of the sulfosalts.

Bournonite, crystallizing in the orthorhombic system, is a soft (hardness 2.5-3.0) metallic steel-gray to black mineral which exhibits poor cleavage. Its form of crystallization is usually short prismatic or tabular. Twinning is very common, giving the mineral the appearance of a cog wheel with coarse cogs representing the individual prisms, whose c-axes are perpendicular to the plane of the wheel. In most instances the mineral is massive. Bournonite is a lead-copper-antimony sulfide containing 42.4 percent lead, 13.0 percent copper, 24.9 percent antimony, and 19.7 percent sulfur. In certain instances arsenic atoms replace those of antimony in about the ratio 1:4.

Berthierite

Berthierite ($FeSb_2S_4$) has been identified by the writer in only two localities in the state—the Harrison property (Snook and Ellen prospects), at the head of Jack Creek, in southwestern Chelan County; and the Feldt property, in Snohomish County near Darrington. Howland Bancroft [1] described a mineral from the Robert E. Lee mine in the Covada district that, according to R. C. Wells of the U. S. Geological Survey staff, more closely approached berthierite than stibnite. However, this mineral was not identified by the writer in any of the specimens collected on this property.

Berthierite, crystallizing in the orthorhombic system, is a soft (hardness 2-3) metallic mineral that is dark steel-gray with a slight brownish tinge. The streak is the same as the color. It may have an iridescent to brownish tarnish if it has been exposed to the weather. It most commonly occurs as prismatic to fibrous masses having barely discernible prismatic cleavage.

Berthierite is an iron-antimony sulfide and contains 13.2 percent iron, 56.6 percent antimony, and 30.2 percent sulfur. This mineral is usually intimately associated with stibnite and quartz.

The four lead-antimony sulfides meneghinite ($Pb_{13}Sb_7S_{23}$), boulangerite ($Pb_5Sb_4S_{11}$) jamesonite ($Pb_4FeSb_6S_{14}$), and zinkenite ($Pb_6Sb_{14}S_{27}$) have such similar chemical and physical characteristics that they are impossible to distinguish with complete accuracy except from X-ray diffraction data and complete chemical analyses. They are all soft (hardness 2-3), gray, and invariably

[1] Bancroft, Howland, The ore deposits of northeastern Washington: U. S. Geol. Survey Bull. 550, p. 196, 1914.

occur with a fine fibrous or massive habit. All four have been identified in the state. Fortunately, boulangerite and jamesonite usually may be differentiated by their reaction to potassium hydroxide (see under Boulangerite). Also, jamesonite contains from 2 to 3 percent iron, while boulangerite contains none. Zinkenite is harder (slightly above 3) than the other three. Meneghinite may give a microchemical test for copper, but the mineral is impossible to identify with assurance without X-ray diffraction work.

Meneghinite

Meneghinite ($Pb_{13}Sb_7S_{23}$) has been tentatively identified at only one locality in the state, the Mullen prospect, 3 miles east of Chewelah in Stevens County. To the writer's knowledge this is also the only occurrence in the United States. The existence of the mineral was suggested by Dr. Charles Meyer, research geologist for the Anaconda Copper Mining Co., after X-ray diffraction, chemical, and microscopic work.

Meneghinite, crystallizing in the orthorhombic system, is a soft (hardness 2.5) brittle metallic dark lead-gray mineral having perfect but interrupted cleavage parallel to the b-pinacoid. It occurs commonly as slender prisms vertically striated, but may also be massive and fibrous. It occurs in all three habits at the Mullen property. Meneghinite is a lead-antimony sulfide, containing 62.9 percent lead, 19.9 percent antimony, and 17.2 percent sulfur which can be distinguished from jamesonite by lack of iron and a negative reaction to the potassium hydroxide solution, from zinkenite by a hardness test, but from boulangerite only by recourse to X-ray diffraction data.

Boulangerite

There are four occurrences of boulangerite ($Pb_5Sb_4S_{11}$) in the state, one a few miles east of Oroville, Okanogan County, and the other three in Stevens County. The best known locality is the Cleveland mine, in Stevens County, east of Hunters.

Boulangerite, crystallizing in the monoclinic system, is a soft (hardness 2.5-3.0) metallic bluish lead-gray mineral. The bluish tinge is particularly noticeable when fresh surfaces can be observed underground. The streak is lead-gray. The mineral usually occurs as soft compact fibrous and felted masses, though at times long prismatic and acicular crystals are found which have deep striations parallel to the c-axis. The cleavage is parallel to the orthopinacoid 010.

Boulangerite contains 50.6 percent lead, 29.5 percent antimony, and 19.9 percent sulfur. It can be distinguished from jamesonite by a staining test using a 40 percent solution by weight of potassium hydroxide. Boulangerite is negative to this test. Also, boulangerite

does not have the basal cleavage of jamesonite, nor does boulangerite react to the common wet test for iron, in which reddish-brown ferric hydroxide is precipitated from an acid solution of the mineral by the addition of ammonium hydroxide.

Jamesonite

Jamesonite ($Pb_4FeSb_6S_{14}$) definitely occurs in at least three districts in the state, the Buena Vista, the Miller River, and the Monte Cristo. Probably it will be found also in others if more detailed work is done.

Crystallizing in the monoclinic system, it is a soft (hardness 2.5) steel-gray mineral, ordinarily occurring as fibrous and felted masses, and sometimes as fine acicular crystals. The cleavage is basal.

Jamesonite is a lead-iron-antimony sulfide. Lead is present to the extent of 40.2 percent, iron 2.7 percent, antimony 35.4 percent, and sulfur 21.7 percent. A drop of 40 percent (by weight) potassium hydroxide solution if placed on jamesonite will produce an iridescent stain which immediately distinguishes it from boulangerite.

Zinkenite

Zinkenite ($Pb_6Sb_{14}S_{27}$) has been tentatively identified from one property in the state—the Mullen prospect east of Chewelah in Stevens County. Here it occurs as scattered specks and blades enclosed within meneghinite blades.

Zinkenite, crystallizing in the hexagonal system, is a fairly soft (hardness 3.0-3.5) brittle metallic steel-gray mineral that has an uneven fracture. When exposed to the weather it sometimes acquires an iridescent tarnish. It seldom forms as distinct crystals, but when it does, they are thin prisms striated parallel to the c-axis. Usually it occurs as columnar to radial fibrous aggregates and massive. Zinkenite is a lead-antimony sulfide containing 32.6 percent lead, 44.7 percent antimony, and 22.7 percent sulfur. It can be distinguished from the other three lead-antimony sulfides by its superior hardness.

There are six lead-silver-antimony sulfides, which include diaphorite, freieslebenite, owyheeite, fizelyite, ramdohrite, and andorite. Andorite is the hardest of these and can be distinguished by that property. Owyheeite has a characteristic reddish-brown streak on white porcelain. The four others are extremely difficult, if not impossible in most instances, to distinguish without the aid of the metallographic microscope, and X-ray diffraction data and complete chemical analyses will be needed for reliable results.

Diaphorite

Diaphorite ($Pb_2Ag_3Sb_3S_8$) is an extremely rare mineral that may be accurately identified only by morphological and, in more recent years, by X-ray diffraction study. A specimen from Lake Chelan was identified by L. J. Spencer [1] of the British Museum in 1898. It undoubtedly came from the Meadow Creek district, as this is the only district about Lake Chelan in which silver minerals were discovered in any quantity. The diaphorite occurred as small prisms on a specimen of stephanite which had been associated with pyrargyrite, galena, quartz, and dolomite. Crystallizing in the orthorhombic system, it is a soft (hardness 2.5-3.0) brittle metallic steel-gray mineral without cleavage. It contains 30.5 percent lead, 2.3 percent silver, 26.8 percent antimony, and 18.9 percent sulfur.

Andorite

Andorite ($PbAgSb_3S_6$) was tentatively identified by the writer in Bear Basin, in the Buena Vista mining district of King County.

Crystallizing in the orthorhombic system, it is a fairly soft (hardness 3.0-3.5) brittle dark steel-gray mineral that shows no cleavage. It has a smooth conchoidal fracture. It usually occurs as masses, but where crystals are found they are usually stoutly prismatic and striated parallel to the c-axis. Crystals form also as both thick and thin tablets.

Andorite is a lead-silver-antimony sulfide with copper sometimes substituting for the silver in amounts up to 2 percent by weight. It contains, in the pure form, 23.7 percent lead, 12.4 percent silver, 4.19 percent antimony, and 22.0 percent sulfur. It is best identified by its hardness and by the chemical elements present. Also it is almost always associated with stannite, the occurrence at Bear Basin, King County, being a case in point.

OXIDES

There are four oxides of antimony that form from the oxidation of antimonial minerals, principally stibnite. These are senarmontite, valentinite, cervantite, and stibiconite. With the exception of senarmontite, all have been identified in the state by the writer. They had formed as coatings and crusts on the antimonial minerals, in some places to the extent of becoming pseudomorphic after the minerals. The antimony oxides are uncommon on the west side of the Cascade Mountains and very much in evidence on the east side.

[1] Spencer, L. J., Diaphorite from Washington and Mexico: Am. Jour. Sci., 4th series, vol. 6, p. 316, 1898.

Senarmontite

To the writer's knowledge senarmontite (Sb_2O_3) has not been identified in the state but is included here for the sake of completeness.

The mineral is soft (hardness 2.0-2.5) brittle and white to grayish white with a resinous luster and white streak. According to the X-ray study of Borzorth,[1] at ordinary temperatures the mineral is triclinic and pseudoisometric by twinning. The cleavage is poor. It contains about 83.5 percent antimony and is dimorphous (similar chemical composition but different physical properties) with valentinite. It can best be identified by its association as crusts on stibnite or other antimonial minerals and by its optical properties as examined under the petrographic microscope.

Valentinite

Valentinite (Sb_2O_3) has been positively identified in the state only from the Cleveland mine, in Stevens County east of the town of Hunters, where it occurs as one of the alteration products resulting from the weathering of boulangerite.

Crystallizing in the orthorhombic system, it is a soft (2.5-3.0) brittle mineral varying from colorless to white, to grayish, and occasionally showing a yellowish or reddish tinge. The mineral is usually found as fan-shaped aggregates or bundles of prismatic crystals which have excellent prismatic cleavage. It also may be massive or granular. The luster is adamantine and the cleavage faces may have a distinct pearly appearance.

Like senarmontite, with which it is dimorphous, valentinite contains 83.5 percent antimony. It can best be identified from its genesis as an oxidation product of stibnite and other antimony minerals, and is more common than senarmontite. It can best be identified positively by its optical properties under the petrographic microscope.

Cervantite

Cervantite and stibiconite, both having the possible formula $Sb_3O_6(OH)$, are the antimony oxide minerals most commonly found. They can be seen wherever there are appreciable quantities of antimony minerals present in the north-central and northeastern parts of the state.

Cervantite, crystallizing in the orthorhombic (?) system, is a moderately hard (hardness 4-5) gray to yellow mineral, usually occurring as fibrous crusts or powder on and in the close vicinity of antimonial sulfides. It is an anhydrous oxide of antimony and contains about 79 percent antimony. It is best distinguished from

[1] See Palache, Charles; Berman, Harry; and Frondel, Clifford, Dana's system of mineralogy, vol. I, 7th ed., p. 545, 1944.

senarmontite and valentinite by its hardness and from stibiconite by its optical anisotropism and high birefringence. However, stibiconite, which is isotropic, is usually intermixed with cervantite. Their indices of refraction vary from 1.6-2.0, though all the material examined by the writer had an index between 1.62 and 1.68.

Recent work by Mason and Vitaliano [1] on the naturally occurring antimony oxides indicates that the two minerals cervantite and stibiconite are not actually two individual minerals, but a single isometric phase with the ideal composition $[Sb^{+3}Sb^{+5}{}_2O_6\,(OH)]$. The extreme variability of the chemical and physical properties is considered to be caused by other elements readily substituting for the antimony and by the incomplete filling of some of the lattice positions. This latter characteristic is undoubtedly responsible for the extreme variability of the density and index of refraction, and perhaps of the birefringence as well.

Stibiconite

Stibiconite $[Sb_3O_6\,(OH)\,?]$ is an isometric moderately hard (hardness 4-5.5) pale-yellow to yellowish-white mineral, usually found as crusts and powder in and around the antimonial sulfides. It is a hydrated oxide of antimony containing about 75 percent antimony. Methods of identification were discussed under cervantite just preceding.

ANTIMONATE

Bindheimite

Bindheimite $(Pb_2Sb_2O_7nH_2O)$ has been identified at the Cleveland mine, near Hunters in Stevens County, as a yellow powdery oxidation product of boulangerite.[2] It is also commonly found as the oxidation product of other lead-antimony sulfides.

Bindheimite is an opal-like moderately hard (hardness 4) yellow to greenish-gray mineral. It is rare and has not been studied extensively. As the writer was unable to find any bindheimite, no first-hand information concerning the best means of identifying it was obtained. Microscopic work combined with chemical tests for lead and antimony would probably give the best results.

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[1] Mason, B., and Vitaliano, C. J., A preliminary account of the naturally occurring antimony oxides: Abstract, Mineralog. Soc. Am., 30th Annual Meeting, 1949.

[2] Fernquist, Charles, Minerals of the Cleveland mine: The Mineralogist, Sept. 1941, p. 348.

ORIGIN OF MINERAL VEINS AND ASSOCIATED ANTIMONY MINERALS

In order to present an understandable discussion concerning the origin of the antimony-bearing sulfides, it is necessary first to review the origin of mineral veins in general. This review is mandatory because the antimony-bearing sulfides have developed within the earth's crust under a wide range of temperature and pressure conditions. Also, it is hoped the review will be valuable to those who would like to have a better understanding of the origin of mineral veins and a knowledge of what some of the better-known authorities in this field are doing and thinking but who do not have the facilities for obtaining this information so widely scattered through the literature.

A POSSIBLE ORIGIN FOR SOME STRUCTURES CONTROLLING AND RELATED TO VEIN FORMATION

At the present time primary mineral deposits are generally considered to be the final products that have evolved from the fractional crystallization of a magma, which, simply described, is molten or dissolved rock material that, depending on its chemical composition, may contain up to 10 percent water.[1] The deposits are, therefore, the final expression of igneous activity in any given mineralized area. An interval of 15 million years is probably not an unreasonable estimate as to the length of time that elapses between the beginning of a period of igneous intrusion and activity and its end. In this connection, a point that deserves particular emphasis before proceeding further with the discussion is the separation in time and place between the consolidation of a magma and the later formation of sulfide veins from the final products of the fractional crystallization of that magma. This time interval has been measured by Urry[2] in the Grass Valley area in California by means of the "helium method." The results of this work show that the interval between the consolidation of that part of the batholith exposed in the area and the formation of the veins exposed was of the order of several million years and might have been as much as 12 million. The actual measurement of this interval in years is particularly interesting because it supports the conclusions drawn from the observed structural relations between igneous masses and associated sulfide veins; namely, that there is only an indirect genetic relationship between them. In this connection, it should be stressed that the igneous body and the sulfide veins have in common only the same original source. The sulfide veins are

[1] Goranson, R. W., The solubility of water in granite magmas: Am. Jour. Sci., 5th ser., vol. 22, pp. 481-502, 1931.

[2] Urry, W. D., and Johnston, W. D., Jr., Age of the Sierra Nevada granodiorite: Abstract, Geol. Soc. America Proc. for 1935, p. 114.

located in the vicinity of an igneous mass partly because the vein material has a magmatic source, and largely because the intrusion and consolidation of the igneous body is responsible for the structural preparation of the ground previous to the introduction of the mineralizing solutions. It should be mentioned also that regional deformation is most important in the preparation of ground for mineralization and that areas of diverse rock types, such as are found in regions of igneous activity, are most susceptible to complex fracturing. However, the fact that some of the fractures may become mineral veins indicates that igneous activity has not ceased. Thus, even though the fractures have been caused by regional deformation, it in turn may well be related to deep-seated igneous activity on a broad scale. This type of activity can be expected during periods of mountain building, which seem to be generally favorable for the formation of mineral veins. Therefore, for the sake of simplicity this discussion has been limited to a single igneous intrusion and its accompanying deformation. All the factors mentioned above must be operative for the formation of mineral veins. With the relationship of an igneous mass and its associated sulfide veins firmly in mind, an outline of a process by which an intruding igneous body can prepare the crust for the emplacement of sulfide veins is valuable.

While the magma assimilates and/or stopes the rocks of the earth's crust, as it forces its way up into them because of lithostatic and hydrostatic pressure and lesser density as compared to the surrounding rock, stresses are necessarily set up that strain the rock mass being intruded. The magnitude and effect of these stresses vary, of course, with the size and shape of the intrusive body. The stresses are possibly of a compressional nature, which can produce thrust faults. According to Balk, [1] the thrust faults connected with a magmatic intrusion are not necessarily in its close vicinity. This thrust faulting may be prevalent over a wide area as the igneous mass is emplaced. After the magma has reached its destination within the crust, say at a depth of 3 to 4 miles, cooling and crystallization commences. The upper portion or roof of the magma chamber may have the general shape of an arch, but it is highly irregular. Pendants of rocks extend down from the roof, and cupolas of molten material extend up into the roof. Cooling first takes place along the roof and walls of the chamber. Even after these portions of the magma are crystallized to a partly consolidated aggregate, additional material is undoubtedly continuing to push up from below at longer and longer intermittent intervals. As this action takes place it causes linear and platy flow structures (i. e., gneiss) to form parallel to the walls; with further cooling and pressure from below, cross joints

[1] Balk, Robert, Structural behavior of igneous rocks, Geol. Soc. America, Memoir 5, pp. 126-128, 1937.

form perpendicular to the flow structures and may even extend into the wall rocks. As cooling continues and pressure is exerted from below, forcing the intrusion up and outward, further readjustments of the cooling intrusion and wall rock are necessary, which in steep-walled intrusions may take the form of zones of marginal upthrusts and fissures. Into these thrusts and fissures are intruded granite dikes, aplite and pegmatite dikes, and pegmatitic quartz veins. At this same time or just previous, the roof portion will have expanded by means of flat-lying normal faults arranged in order to allow for a more or less horizontal expansion.[1]

During the cooling of the magma and the accompanying major structural adjustments just described, vast quantities of heat are dissipated into the surrounding rock. Since rock is an extremely poor conductor of heat, heating of a very large volume of rock is tremendously slow unless a considerable number of fractures are available to increase conductivity. Their prevalence no doubt depends upon the depth below the surface at which the magma crystallized. As this heating process in the wall rock proceeds concurrently with the crystallization of the intrusive, there occurs an expansion of the wall rock—greater close to the intrusive body than far away. This expansion, coupled with the intrusive forces, furthers extensive deformation in the surrounding rock. After the crystallization of the intrusive, the cooling process is accelerated. As this cooling continues, both the intrusive and its wall rock decrease rapidly in volume at first, because the coefficient of thermal expansion for rock materials varies with temperature, being greater for higher temperatures. This volume change is greatest in and near an intrusive and gradually diminishes away from it. Thus accompanying fracturing, of a minor nature compared to that produced during the period of intense and expanding igneous activity, is greatest at the start of the cooling and greatest in and close to the intrusive, gradually diminishing in intensity with time and distance from the center of the intrusion. Hulin[2] estimates that this type of thermal contraction produces a volume decrease of 16 percent, 10 percent of which is in the igneous mass, and 6 percent in the wall rocks. Of course the shrinkage is complete within the igneous mass before it is in the wall rocks. Such a shrinkage sequence is beautifully adapted to keep the igneous body and its wall rocks well fractured and prepared for the emplacement of sulfide veins, whenever the necessary mineralizing solutions become tapped at great depths by the extensive contractive fracturing. In this manner the pre- and post-mineral faults common to all mineralized districts are easily explained as a necessary part of the mineralizing sequence, which in turn is the final phase of much intrusive igneous activity.

[1] Balk, Robert, op. cit., p. 123.
[2] Hulin, C. D., Factors in the localization of mineralized districts: Trans. A. I. M. E. vol. 178, pp. 45-92, 1948.

From the above brief account, which is admittedly highly generalized but is nevertheless based upon the field observations and conclusions of many geologists, it can be visualized how the crust can be prepared for the mineralizing solutions and how throughout the period of igneous activity and the later mineralizing processes the rock can be kept permeable by continual fracturing as it readjusts to changing temperature and pressure conditions.

ORIGIN AND NATURE OF THE MINERALIZING FLUID

Crystallization of Magma

Now that the structural conditions under which mineral deposits may form have been considered, an account of the origin and nature of the mineralizing fluids which permeate and precipitate within these structures should be attempted. Most intrusive bodies associated with mineral deposits are composed of sialic igneous rocks, that is, they contain more silica, potassium, and sodium than the mafic igneous rocks that contain more iron, magnesium, and calcium. Aluminum is distributed fairly evenly among all rock types except those composed largely of the minerals olivine, a magnesium-iron silicate, and augite, a calcium-iron-magnesium silicate. These seven principal rock-forming elements are present as silicate minerals. From the study of these silicate minerals both in the field and laboratory and from the study of volcanic phenomena, it has been determined that an igneous mass before consolidation is composed of a high-temperature (700°-900°C.) mutual solution of silicates, metallic oxides, silica, and dissolved volatile substances. These volatiles are most important in transporting the metals of ore deposits, and consist chiefly of water and subordinate amounts of carbon dioxide, hydrogen sulfide, ammonia, hydrogen chloride, sulfur, fluorine, chlorine, and boron. Though these substances are probably largely dissipated during the consolidation of the magma, the portions that remain act to lower the magma's melting point, decrease its viscosity, and, as pointed out above, collect and transport the material of mineral deposits.

In 1922 Bowen[1] made a most important contribution to geologic thought by enunciating the principle of the reaction series. He stated, "The minerals making up the rocks of an igneous sequence can be arranged as a reaction series, and it is the existence of such a series that controls the crystallization and differentiation of the rocks of the sequence." Thus there is a definite order of crystallization always tending toward an increase of silica and of the alkalies, potassium and sodium. The reaction series provides that during crystallization, once minerals are formed, they react exothermi-

[1] Bowen, N. L., The reaction principle in petrogenesis: Jour. Geology, vol. 30, pp. 177-198, 1922.

cally (with the evolution of heat) with the enclosing magmatic material, which reaction results in the formation of additional new minerals. In this manner considerable heat and energy are evolved and the composition of the magma is undergoing continual modification. Bowen formulated this idea in the laboratory, and as the order of crystallization suggested by the reaction principle closely approximates that observed in thin sections of igneous rocks, the principle has been widely accepted. The following chart (fig. 4) shows how crystallization of the magma proceeds according to Bowen. Of course, in a given igneous rock not all of the minerals

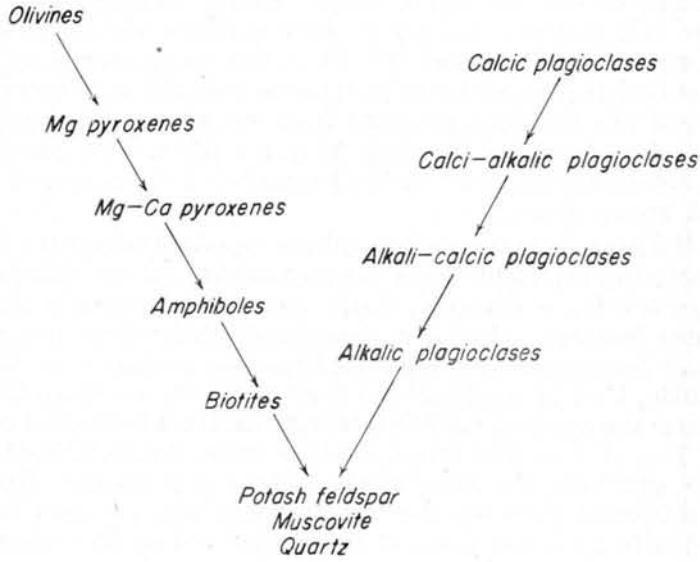

FIGURE 4—Bowen's reaction series.

indicated by the chart are present. The minerals on the left-hand side make up a discontinuous reaction series, that is, as crystallization proceeds the minerals undergo a change of both their physical and chemical properties. The minerals on the right-hand side make up a continuous reaction series, that is, they undergo a change in their chemical properties while maintaining the same crystal system (triclinic) throughout their course of crystallization.

Thus, as this fractional crystallization proceeds, a fraction rich in silica, alkalies, water, and the volatile constituents gradually collects. The exact nature of this material and the manner in which it occurs in the partly crystallized magma is not definitely known. However, it seems that the residual liquor probably left as interstitial filling is segregated at various points deep within the igneous body, possibly by the squeezing of the interstitial liquor through the crystal mesh as force is applied to the igneous body from below.

During further cooling, this residual liquor may well separate further into two immiscible fractions,[1] a more viscous silicate solution, and a less viscous watery or hydrothermal solution. Both of the immiscible fractions contain silica, potassium, sodium, boron, and phosphorus. The silicate portion has, in addition to the above, aluminum and other such components as columbium, tantalum, zirconium, lithium, beryllium, and titanium, plus a small amount of fluorine and chlorine, together with trace amounts of the material in the hydrothermal fraction. In addition to the silica and other principal components, the hydrothermal fraction contains water, the metals, carbon dioxide, hydrogen sulfide, ammonia, hydrogen chloride, sulfur, and considerably more chlorine and fluorine than is present in the silicate solution. From the above discussion it can be visualized that many types of mineral deposits may be evolved from these two solutions, provided fractures of the proper type are available for tapping at the right time and place. The question of timing seems all-important in the formation of that greatest of all oddities, an ore deposit.

For instance, from the viscous silicate liquid, provided the timing and fracturing are right, come the pegmatites, aplites, and pegmatitic quartz veins as described in the section on a possible origin of structural features. Also, it is conceivable that where pegmatites show such features as hydrothermal alteration, replacement, and the odd sulfide, i. e., bismuthinite, as they often do, the hydrothermal material is the result of further fractionation from the initial silicate liquid. From the hydrothermal solution comes the metallic-mineral deposits, providing the same nicety of timing is present. The viscosity difference between the two fractions may account for the separation in time and place of pegmatites and sulfide veins.

Nature of the Hydrothermal Solution Fraction

This paper has to do with the origin of the antimony-bearing sulfides, so the discussion will be confined to the nature of the hydrothermal solution fraction. As the temperature of this fraction can be more than 400° C., and perhaps even as high as 600° C.,[2] the question may well be asked: Is the hydrothermal fraction below or above critical conditions; in other words, can it be a liquid or must it always be a gas? Much has been written on this subject, but the answer seems to be missing because of a lack of knowledge. Even if the hydrothermal fraction were in the gaseous phase, it would be so dense because of the hydrostatic and lithostatic pressure that the fraction would no doubt behave more like a liquid than a gas. How-

[1] Smith, F. G., Transport and deposition of the non-sulfide vein minerals. III. Phase relations at the pegmatite stage: Econ. Geology, vol. 53, pp. 535-546, 1948.
[2] Smith, F. G., The ore deposition temperature and pressure at the McIntyre mine, Ontario: Econ. Geology, vol. 43, no. 8, pp. 627-636, 1948.

ever, it is well to mention the facts that dictate whether or not there might be a gas phase. In this connection, the following quotation from Fenner[1] concerning the hydrothermal fraction is interesting:

> The chief constituent is probably water; the critical temperature of this, when pure, is 374.5° C., and above this temperature no amount of pressure reduces it to a liquid. Important accompanying emanations are CO_2, H_2S, and HCl (probably N and H also), and as the critical temperatures of these (respectively 31.1°, 100.4°, and 51.4°) are much lower than that of water, their presence tends to reduce the critical temperature of the mixture. In addition to these, we believe, are many other volatile substances, among which various chlorides of alkalis and of common metals (iron, aluminium, zinc, copper, lead, etc.) are important. The critical temperature of only a very few of them is known, but with most chlorides it is undoubtedly considerably higher than that of water. These substances of high critical temperature tend to raise the critical temperature of the mixture, but as their amounts are hardly likely to be large in comparison with the first-mentioned constituents, their effect is not great.

Thus Fenner believes the hydrothermal fraction exists as a gas phase because there are insufficient chlorides to overcome the effect of the critical temperature of water. If this is true there naturally must be a gas phase, but many geologists, including Ross, Bowen, and Lindgren, feel that a gas phase exists only under the unusual circumstances of a sudden decrease in pressure. These authorities believe that the hydrothermal fraction normally decomposes the silicates, resulting in the formation of sufficient soluble hydrates, carbonates, chlorides, and other compounds of low volatility to eliminate critical phenomena altogether. Lindgren also mentions the presence of silica as an important deterrent on critical phenomena. Along with these ideas there is a good piece of observational evidence, stated in the following paragraph, which indicates that the gas phase, as already mentioned, is either nonexistent or so extremely dense that it may be considered to behave as a liquid.

A good many minerals contain minute primary inclusions so small that a magnification of 500 diameters is necessary to examine them successfully. These inclusions are found to contain a gas bubble and a liquid which is usually a solution of sodium or potassium chloride plus minor amounts of carbonates, silica, and other compounds. In most instances, including the Cornwall tin deposits,[2] the liquid occupies considerably more volume than the bubble, and as the inclusions formed at the time the mineral crystallized, they must have been filled in a liquid environment. In the light of the above evidence it would seem that where an igneous body has formed at some depth below the surface, critical phenomena are probably not important and the hydrothermal fraction can be considered as a liquid except possibly under the circumstances of a sudden decrease in pressure.

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[1] Fenner, C. N., Pneumatolytic processes in the formation of minerals and ores: Ore deposits of Western States, Lindgren volume, p. 71, 1933.

[2] Smith, F. Gordon, Laboratory testing of 'pneumatolytic' deposits, Econ. Geology, vol. 44, pp. 624-625, 1949.

Another question can now be asked: Does the hydrothermal solution leave the crystallizing magma as an acid or a base, and is it acidic or basic when depositing minerals? Here again little is definitely known, particularly about the first part of the question, because the answer can be based only on chemical knowledge without any observational assistance. The average igneous rock contains nearly 60 percent feldspars, and the later their period of crystallization the stronger their concentration in sodium and potassium. Also, the hydrothermal solution undoubtedly contains abundant silica, which is weakly acidic, and potassium and sodium, which are strongly basic; also this solution could tend to become more basic through the hydrolysis of feldspars. Thus, it appears that even though the solution contains such substances as chlorine, fluorine, carbon dioxide, and sulfur, they are so outweighed in importance by the alkalies that the solution is probably basic. If these basic conditions prevail, the only way in which an acid condition can originate is by sudden decrease of pressure, which allows the more acid and volatile elements to seek this area of lower pressure and thus form an acid solution and perhaps also a gas phase. Such a situation is likely to prevail only under near-surface conditions, probably no deeper than 2 miles.

Considering the variety of conditions that may exist within the earth, it is of course possible for the hydrothermal fraction to vary all the way from a strong base to a strong acid; although, as already indicated, alkalinity probably predominates. In 1944 the work of Garrels[1] on the solubility of metal sulfides indicated that weak and dilute acids, regardless of composition, temperature, or pressure are incapable of carrying sufficient metal to be ore carriers. However, it is not known whether this strictly chemical analysis of the subject is supported by field evidence. Nevertheless, it would seem that Garrels is on firm ground when he arrives at this conclusion, particularly as later work on hydrosynthesis seems to have substantiated it. It is known also that strongly acid and strongly alkaline solutions under most conditions are capable of carrying large quantities of the majority of metallic sulfides in solution. Recent work[2] indicates that weakly alkaline solutions at ordinary temperatures can dissolve gold and sulfides of mercury, bismuth, antimony, arsenic, and tellurium, but sulfides of the other metals seem to be insoluble. Briefly, as the mineralizing solution approaches the neutral point conditions become more favorable for deposition.

Because chemical investigations may be correlated with field data, the question as to whether or not minerals are actually deposited from an acid or alkaline solution can be given a more defi-

[1] Garrels, R. M., Solubility of metal sulfides in dilute vein-forming solutions: Econ. Geology, vol. 39, p. 472, 1944.

[2] Smith, F. G., Experiments on the transportation and deposition of sulfides in alkaline sulfide solutions: M. Sc. Thesis, Univ. of Manitoba, 1939.

nite answer than can the question as to the nature of the hydrothermal portion as it leaves the crystallizing magma. At the present state of our knowledge it seems that in general alunite, kaolinite, and in places sericite are characteristic of an acid environment; whereas zeolites, chlorite, and in many instances the montmorillonite group indicate an alkaline environment. Amphiboles and pyroxenes are stable in alkaline solutions, and feldspars at high temperatures and pressures in solutions of a neutral, weakly acid, and weakly alkaline nature. It is apparent that mineral deposits have been precipitated from both alkaline and acid solutions, both weak and strong. The East Tintic district in Utah is an excellent example, and the following is quoted from Lovering's report[1] in which he summarizes the solution changes during the various stages of wall rock alteration:

> It seems probable that nearly neutral chloride solutions dominated the early barren stage and that acid chloride and sulfate solutions caused the argillic [forming of clay minerals] alteration of the mid-barren stage, giving way to neutral and possibly alkaline bicarbonate-sulfate-chloride solutions during the late barren and productive stages.

Many mining districts probably have a complex history of mineralization similar to that described above. It is worth noting that Lovering believes that the deposition of the ore minerals possibly took place in alkaline solutions. This is in accordance with the work that F. Gordon Smith is doing at the University of Toronto on the hydrosynthesis of vein minerals. Up to 1950 Smith and his students had successfully synthesized in alkaline sulfide solutions tourmaline, cassiterite, galena, sphalerite, silver and lead sulfantimonites, silver arsenites, and the gold telluride, calaverite.

However strong our evidence seems to be for deposition under alkaline conditions, the meticulous work of Sales and Meyer[2] in the Butte district has shown that a remarkably heavy mineral deposition took place during a single surge of acid mineralizing solutions through a complex vein system. The manner in which these conclusions were reached through a combination of field and laboratory work, and the proving of the concept that under certain conditions wall-rock alteration is contemporaneous with ore deposition rather than like that in the Tintic district, where the stages of wall-rock alteration are separated by time intervals, is most interesting.

Extensive geologic mapping underground of the complex Butte vein system over a period of at least 40 years has disclosed a universal and characteristic sequence of wall-rock alteration. The vein system traverses quartz monzonite, which is a silica-rich rock con-

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[1] Lovering, T. S., Rock alteration as a guide to ore—East Tintic district, Utah: Econ. Geology Monograph I, p. 43, 1949.

[2] Sales, R. H., and Meyer, Charles, Wall rock alteration at Butte, Montana: Am. Inst. Min. Met. Eng. Trans., vol. 178, pp. 9-35, 1948.

Sales, R. H., and Meyer, Charles, Results from preliminary studies of vein formation at Butte, Montana: Econ. Geology, vol. 44, pp. 465-484, 1949.

taining essentially biotite, hornblende, a small amount of augite, and approximately equal amounts of sodic labradorite and soda-bearing orthoclase. Beginning with the unaltered quartz monzonite and proceeding toward the vein, the following alteration zones with intergradational contacts are encountered: first, the argillized zone, divided into two clay phases, a green montmorillonite (hydrous iron-magnesium-aluminum silicate) phase and a white kaolinite (hydrous aluminum silicate) phase; second, a white mica or sericite (hydrous potassium-iron-aluminum silicate) zone; third, a quartz-pyrite zone, which might well be considered part of the vein proper; and, last, the vein proper or sulfide zone. The pyrite of the third zone was formed by the iron, originally indigenous to the quartz monzonite, absorbing sulfur from the hydrothermal solution during the deposition of the metallic sulfides. Depending upon the intensity and duration of mineralizing conditions, the kaolinite phase or the sericite zone may not be present. The important thing to remember about the Butte alteration halo is the fact that the *sequence* of (1) quartz monzonite, (2) argillized zone, (3) sericite zone never changes, no matter how complex the structure. This persistent sequence seemed to indicate that the wall-rock alteration was simultaneous with the sulfide mineralization, but it had to be proved.

For many years the mineral sericite was considered by most geologists to be indicative of alkaline ore solutions, but in 1944 Grunner[1] showed that sericite can be produced at temperatures above 350° C. from feldspars in an acid environment, in fact in solutions as acid as pH 1 if an excess of potassium exists. Below that temperature kaolinite forms. Also, kaolinite can be formed only in an acid environment. Thus, providing temperatures of 350° C. have been reached, a mechanism is available for the simultaneous formation of the Butte ores and their alteration halo. The temperature of formation of the ores is determined by a study of liquid inclusions, such as the type already described. A polished plate of a mineral is placed on a heating stage attached to a microscope, and as the temperature of the stage is raised it is noted at what temperature the bubble disappears. This is the temperature of formation of the mineral, provided the original pressure did not exceed significantly the vapor pressure of the solution. If the original pressure is in significant excess—and for minerals formed within the earth it usually is—a correction must be made for pressure. The theory of this method[2] has been checked against synthetic crystals whose pressures and temperatures of formation were known, and the results were within the limits of error of the experiments. Meyer checked liquid inclusions in Butte vein minerals and found after

[1] Grunner, John W., The hydrothermal alteration of feldspars in acid solutions between 300° and 400° C.: Econ. Geology, vol. 39, pp. 578-589, 1944.

[2] For another technique based on this same theory see Scott, H. S., The decrepitation method applied to minerals with fluid inclusions: Econ. Geology, vol. 43, p. 637, 1948.

making a pressure correction for a depth of burial at time of formation of 3 kilometers that the temperatures of formation for the minerals ranged from 300° to 370° C. Thus, the necessary temperatures were available for the formation of sericite. Consequently, both the field evidence and chemical evidence point to the same conclusion, namely, that the principal Butte ore deposits were formed by a single continuous surge of acid mineralizing solutions through a complex vein system and that the resultant wall-rock alteration and vein deposition always took place in a given sequence, the completeness of which depended on the thermal intensity, chemical composition of the solutions, and the length of time these solutions were able to circulate.

To reiterate, as shown by the work of Lovering, Sales, and Meyer, ore deposits are not restricted to acid or alkaline solutions; the problem is far more complex than that. The essentials for ore deposition are favorable structure and favorable solutions joined together at the auspicious moment under favorable conditions of temperature and pressure. Hence it is simple to see that an ore deposit is a miracle. Nevertheless, geologists do know something of the details and circumstances that bring about this miracle.

Factors Causing the Solutions to Rise

So far in this report the solutions have always been regarded as ascending. This is because of hydrostatic and lithostatic head, relatively low viscosity, and the development of pressure through crystallization.[1] This last may need some explanation. Contrary to what would be expected from a consideration of the general gas law, the pressure increases with decreasing temperature and continuing crystallization, because of the formation of the hydrothermal fraction with its accompanying volatile materials which lower the temperature of crystallization of the hydrothermal fraction and build up its vapor pressure. Pressure of this nature[2] is built up and is most effective after crystallization has put a stop to the power of magmatic movement and the intrusive forces have spent themselves. Thus, energy is available to provide for a vigorous upward flow of mineralizing solutions when they are tapped by fracturing.

Factors Controlling Precipitation

The precipitation from the ascending solutions is controlled principally by changes in the relative solubilities of the constituents. These solubilities in turn are controlled by the nature of the constituents and by variations in their concentrations and by changes of temperature and pressure which effect the entire hydrothermal

[1] Morey, G. W., Development of pressure in magmas as a result of crystallization: Washington Acad. Sci. Jour., vol. 12, pp. 219-239, 1922.

[2] Ross, C. S., Origin of the copper deposits of the Ducktown type in the Southern Appalachian region: U. S. Geol. Survey Prof. Paper 179, p. 49, 1935.

system. Each of these changes is brought about by the different internal and external conditions which have been brought to bear on the system. Unlike laboratory experiments, veins are formed in open chemical systems that are rarely if ever in equilibrium. For this reason the laws of physics and chemistry have to be applied with care, but their application is by no means futile.

Temperature changes on a long-term basis are of course downward, and consequently are continually encouraging precipitation. However, on a short-term basis, the rock becomes heated at the commencement of mineralization by the incoming solutions and its temperature is increased progressively with the continuing intensity of the mineralizing activity. This increase in temperature may well cause deposition of higher-temperature vein minerals along with some re-solution of the original lower-temperature vein minerals that are deposited when the rising solutions first come into contact with wall rocks that up until that moment have been part of the normal geothermal gradient. Besides this temperature rise due to increased intensity of mineralizing activity, two processes produce heat just as the mineralization wanes and cooling begins. The first of these is dependent on the percentage of water in the mineralizing solution: the greater this quantity the greater will be the solution's heat-distributing capacity as the temperature is falling. This is because of the relatively greater specific heat of water than rock or sulfide melts. The second process producing heat takes place because cooling in many instances promotes exothermic reactions, and thus still more heat is developed. As a consequence, even as the mineralizing activity ceases and cooling begins the temperatures are temporarily sustained and the cooling process retarded, thus allowing the minerals to crystallize with extreme slowness. The lack of time for this type of slow crystallization is no doubt a good part of the explanation as to why it is so difficult to reproduce in the laboratory natural minerals of a size analogous to those found in nature.

Pressure changes may be brought about by surface erosion, by earth movements, and by exothermic chemical reactions. Erosion, of course, would normally cause a very slow, gradual change, which would require some time for its effects to be felt. However, considering the length of time available during a cycle of igneous activity, there is no question that appreciable changes in hydrostatic pressure can be brought about. On the other hand, it would seem that except under circumstances permitting extremely rapid erosion, no significant changes in hydrostatic and lithostatic pressure would be caused during the relatively short time that mineralization is in process. Pressure changes brought about by earth movements and exothermic chemical reactions would be more important during any given period of mineralizing activity.

Earth movements are very important in providing greater porosity by brecciation, or in providing the formation of alternating open and tight areas by the displacement of curved fault planes. Both of these actions tend to increase volume and thereby decrease pressure; consequently, a much greater cooling area is made available, particularly in the case of brecciation. This enlargement of cooling area combined with the decrease in velocity of the fluid gives considerable impetus to precipitation. Also recent work by Kennedy[1] shows that at temperatures at and above the critical point a drop in pressure without change of temperature can bring about a relatively large decrease in solubility. These factors are most important in the formation of commercial mineral deposits. Exothermic chemical reactions probably are effective only in a limited manner and where the reactions are of an explosive nature. These tend to increase the pressure.

The concentration of the different constituents in the hydrothermal solution is determined at the beginning by the fundamental composition of the magma, which of course may vary greatly in different magmas. Also, changes in concentration are continually being made as fractional crystallization takes place, and substances are added from below or dissolved from the wall rocks.

The relative solubilities of the different constituents in the hydrothermal solution are, as already mentioned, particularly important. Changes in solubility and therefore, as will be shown later, changes in mineralogy, may be brought about by changes of temperature, pressure, concentration, and nature of the different constituents, and of the acidity and alkalinity of the solutions. Generally speaking, the more volatile constituents have a greater ability to act as solvents. The acidity and alkalinity are in a sense controlled by changes in concentration of the chemical elements, though fundamentally, of course, by changes in the hydrogen ion concentration.

With this number of variables in action within and affecting all mineralizing solutions, mineral deposition of necessity is an extremely complex process, and the attainment of equilibrium a rarity. Thus, Gibb's phase rule would be difficult if not impossible to apply rigidly in the study of ore deposits under natural conditions.

Except in near-surface fractures where considerable open space filling may take place, and replacement is of secondary importance, the major part of the deposition takes place through the process of equal-volume replacement. This is a process probably unique to geology and was described and discussed by Waldemar Lindgren[2] at the turn of the century. Equal-volume replacement means that as the mineralizing solutions precipitate their load they replace with new

[1] Kennedy, G. C., A portion of the system silica-water: Econ. Geology, vol. 45, p. 639, 1950.

[2] Lindgren, Waldemar, Metasomatic processes in fissure veins: Am. Inst. Min. Met. Eng. Trans., vol. 30, pp. 578-692, 1901.

minerals the old pre-existing minerals while the volume of the whole remains constant. It is simple to see that this is an anomalous relationship when we consider that sulfides replace volume for volume the silicates, which have a much lower specific gravity. Thus, there must be a continual exchange of material at the replacement front as it advances. The incoming vein material has to be delivered while the rock material has to be taken away. According to the relative densities of the minerals taking part in the replacement, more material may have to be added than is taken away, or vice versa. The principal factor that governs replacement is the relative solubilities of the substances involved in the replacement reaction. It is only their relative solubilities at the time and under the pressure, temperature, and concentration conditions of the reaction that counts, the more soluble mineral always being replaced by the less soluble.[1] In order to keep the process of replacement active, there must be a continuous flow to and from the replacement front. If the flow is stopped at either the inlet or outlet, replacement will cease. An interesting application of this principle can be made in connection with explaining the work of the so-called impermeable barriers. For instance, an impervious shale bed overlying a fractured sandstone would form such a barrier. Naturally, rising mineralizing solutions, because of decrease in velocity, would be forced to deposit their load in the fractured sandstone below the shale, but if very extensive replacement of the sandstone is to take place the barrier cannot be completely impermeable, for replacement and deposition can only go on where a continuous flow of the solutions is maintained.

Therefore, the conditions most favoring replacement are to be found where there is a sudden decrease in the velocity of flow of the mineralizing solutions, such as a spot where those solutions enter a zone of finely brecciated limy or dolomitic rock, that previous to the introduction of the solutions has been part of the normal geothermal gradient. Under these circumstances there is a sudden decrease of pressure, a large surface area effecting rapid cooling, and the most reactive type of wall rock. However, under the above postulated conditions any type of wall rock would be more or less favorable.

Order of Precipitation

Complicated as the process of mineralization is, a broad pattern for the order of precipitation of the various elements and their associated minerals is apparent. This pattern depends principally on the thermal intensity and composition of the solutions. In general, and roughly in the following order of decreasing intensity,

[1] Newhouse, W. H., The time sequence of hypogene ore mineral deposition: Econ. Geology, vol. 23, pp. 647-659, 1928.

deposits of tin, tungsten, molybdenum, iron, copper, arsenic, and gold occur under higher temperature conditions than do deposits of zinc, lead, manganese, silver, antimony, and mercury. The order of precipitation of the minerals making up these deposits, according to Verhoogen,[1] depends principally upon the manner in which the ratio of the solubility products of the minerals varies with the temperature. A solubility product may be defined as the maximum product of the ionic concentrations of a solution which can exist in equilibrium with the undissolved phase at any one temperature. Naturally, these solubilities will be controlled by the complex factors already discussed. Thus it is impossible to predict, in the case of a hydrothermal solution of many components acting on wall rocks of different composition and porosity, what minerals will be deposited and when and where, and what minerals will be attacked and their substance carried away. Consequently, extreme irregularity of detail rather than regularity is to be expected from all mineral deposits.

VEIN FORMATION AND MINERAL ZONING

The two principal ways in which a vein may form in rock are by means of open space filling and by means of replacement. The first method, as will be shown later, is particularly important in the formation of stibnite deposits. It operates, as a general rule, in mineral deposits formed at relatively shallow depth. Here, because of relatively low hydrostatic and lithostatic pressure, the rocks are more likely to have open spaces available for filling by the mineralizing solutions. The open spaces may be made either by direct tensional stress on the rock or by shearing in the rock along irregular fracture surfaces. During either of these processes the rock may be broken and crushed, thus forming a breccia, through which many open spaces will be available for filling. Provided mineralizing solutions are ready at the time of fracturing to dump their loads in the available spaces, veins and/or mineralized zones develop in and around the openings. As will be shown later, the second method, forming veins by means of replacement, is important in the formation of deposits containing some of the more complex antimony-bearing sulfides, such as those containing lead. This method operates most prevalently in those deposits formed at relatively deep horizons. Here the same types of movement take place as at shallow depths, but, because of the greater hydrostatic and lithostatic pressure, lines of weakness and thin fractures form rather than open spaces. Thus in order for veins to form along these fractures, the wall rock must be replaced by the mineralizing solutions in the manner already discussed in the section on "Factors controlling precipitation." Also

[1] Verhoogen, Jean, Thermodynamics of a magmatic gas phase: California Univ., Dept. Geol. Sci. Bull., vol. 28, no. 5, p. 133, 1949.

in some instances, probably during the initial formation of a vein, it appears that thin fractures, formed at either relatively shallow or great depths, may have been materially widened by mineralizing solutions being forced into them at a tremendous pressure, which is transmitted by the solutions to the walls.[1] The pressure is perhaps analogous to that which is active during volcanic eruptions.

Naturally, all methods of vein formation can go on at the same time, but in the majority of veins replacement seems to have predominated. In order to give a better portrayal of vein formation, the following material is quoted from Sales and Meyer[2] describing the vein-formation processes at Butte:

> Briefly stated, . . . replacement of wall rocks by vein minerals appears to have been the dominant process in vein growth at Butte. According to this concept, the growth of a vein is essentially the final act of the alteration process. The effort of the hydrothermal solution to supplant fresh quartz monzonite silicates with quartz and sulphides is sometimes accomplished over a transition zone which we recognize as the silicification subzone of alteration. In other instances, however, the line of demarcation between vein and wall rock is megascopically well defined; the transition zone may not be more than one mineral grain wide. But even in the latter case, where quartz and pyrite form the marginal facies of the vein, these minerals encroach by replacement on the wall rock silicates. Frequently well-formed quartz crystals, which on their veinward sides project out into sulphides, may be observed by growth rings to have accreted to themselves more silica at their bases, so that the bases are growing away from the channel. The quartz-pyrite marginal zone is a kind of advancing mineralogical vein front, growing into the rock by consummating the final expulsion of the last silicate, sericite, and leaving only the two mineral products which are most commonly stable in the vein channel itself—quartz and pyrite. These two minerals are the common vein framework at Butte, but they are often joined in their direct encroachment on the granite by the ore mineral constituents of the veins, notably chalcocite and enargite in the Central zone, sphalerite in the Zinc zone, and rhodochrosite in the Peripheral zone.
>
> It should be noted that according to this concept the advancing front of vein growth is an actively migrating part of the vein, and that while the pyrite and quartz of the framework are being replaced within the body of the vein by ore minerals, more pyrite and quartz are forming farther out contemporaneously with the continuing mineralization of the vein and with the advance of each alteration zone out in the wall rock. Symmetrical fulfillment of this vein growth process is limited to fractures of simple unit history—an exceedingly rare circumstance even among tiny veinlets. But degree of departure from this simple form in large veins is purely a function of repetition, at ever increasing intensity levels, of the fundamental chemical processes involved in the formation of a unit veinlet.

From this description it can be seen that the fundamental process is an outwardly migrating intensity front; that is, after the initial deposition, as the intensity and duration of mineralization increase, the outward edge of each individual zone encroaches on and replaces the inward edge of the adjacent zone of lower intensity. Thus, while mineralizing activity continues, the minerals of higher intensity are

[1] Graton, L. C., Reconnaissance of some gold and tin deposits of the southern Appalachians: U. S. Geol. Survey Bull. 293, p. 59, 1906.

[2] Sales, R. H., and Meyer, Charles, Results from preliminary studies of vein formation at Butte, Montana: Econ. Geology, vol. 44, p. 468, 1949.

replacing those of lower intensity. When mineralizing activity eventually ceases and cooling predominates, other types of mineralogic changes take place, among which the process of unmixing from a solid solution is probably the most important. After certain minerals have crystallized and cooled to a given temperature, another mineral, whose atomic structure is related to that of the parent, will separate out or unmix by means of selective migration or diffusion of particular atoms to certain lines of weakness in the parent mineral, such as its grain boundaries or cleavage planes. An example of this process is the separation of chalcopyrite blebs from sphalerite along cleavage planes at 350°-400° C.

Closely connected with the processes of vein formation is the origin of mineral zones within a given vein or system of veins. In order for zoning to originate without a progressive change in the chemical composition of the hydrothermal solution at its source an unusual set of nicely balanced conditions must have obtained. On a purely deductive basis founded upon what is known of the physical chemistry of ore deposition, these conditions would seem to be about as follows: There would be present rock of uniform chemical composition situated in a portion of the earth's crust that is maintaining with depth a smoothly rising geothermal and pressure gradient. This rock would have to contain an open fracture system through which flowed continuously a solution of constant volume, temperature, composition, and concentration suitable for the development of zoning.

Under the conditions just indicated, the deposition of minerals necessarily proceeds in an orderly sequence throughout the period of mineralization, since all factors bearing on the system are either constant or affecting the system at a constant rate. According to Verhoogen,[1] as already mentioned, the order of precipitation of minerals depends principally on the manner in which the ratio of the solubility products of the minerals vary with the temperature. In this hypothetical case, which has been set up to give the optimum conditions for zoning, the chief factors, exclusive of temperature and pressure, affecting the concentrations of the solutions and thus the solubility products of the resulting minerals, are the influence of the chemical composition of the wall rock and the changes in the relative concentrations of the constituents that are brought about by crystallization. Even these effects are of constant magnitude in the hypothetical system if the temperature and pressure are constant throughout. However, temperature and pressure steadily decrease toward the surface, and thus the mineralogy likewise progressively changes toward the surface. Also, when the ascending mineralizing solution continues to flow past any given point in the fracture system, the pressure at that point remains constant, the temperature

[1] Verhoogen, Jean, op. cit., p. 133.

is increased, and the minerals deposited successively from the walls toward the center of the vein change to those indicative of higher and higher intensity as equilibrium is sought between the ascending solution and the wall rock. From the foregoing considerations, it is readily seen that when mineralizing activity ceases, the result is a zonal arrangement of minerals extending outward and upward from their source at depth. Inasmuch as at constant temperature and pressure each point in the hypothetical system is chemically the same as any other point, and, as already shown, even though at any given point pressure remains constant, the mineralogy still changes with increased temperature and continued solution flow. Temperature must therefore be the prime controlling factor in zoning where a continuous surge of an ascending mineralizing solution of original constant composition is assumed. Of course, if over a period of time the solution does change in composition at the source, the resultant zoning is not caused by temperature change, though naturally temperature is still extremely influential.

As the Butte district is famous for its zoning, the following quotation from Sales and Meyer[1] portraying an ore shoot in the Badger mine, is particularly illuminating:

> . . . chalcocite, enargite, and a little bornite [are] at lower horizons, with increasing bornite and sphalerite and scattered chalcopyrite toward the top. It is capped finally by peripheral zone mineralization containing much sphalerite with large amounts of quartz and carbonate and silicate of manganese, but with very much less pyrite than in the deeper copper zones. Generally present is a narrow transition halo of tennantite and chalcopyrite between the rich copper ore and the zinc capping. Residuals of sphalerite occur with diminishing frequency deeper in the copper zone where they nearly always appear to be replaced by the copper minerals.

Zoning such as that just described must have originated under conditions very similar to those outlined in the first paragraph in this discussion of zoning. At Butte,[2] the important zonal control is considered to be the changing concentration of the sulphur present in the system. In the deeper copper zone, characterized by complete wall-rock alteration and the minerals pyrite, chalcocite, enargite, and minor amounts of bornite, the ratio of sulphur ion concentration to copper-iron ion concentration is higher than in the shallower copper zone, characterized by less complete wall-rock alteration, chalcopyrite, bornite, and smaller amounts of pyrite and chalcocite. This difference in ratio is apparently because in the deeper high-intensity zone sulphur was abstracted from the hydrothermal solution by the iron in the wall rock to form pyrite. This lowered the sulphur ion concentration, and hence at shallower zones a different mineralogy prevailed, even though the temperature at the bottom of the shallower low-intensity zone and at the top of the deeper high-intensity zone was undoubtedly the same. It is probable that

[1] Sales, R. H., and Meyer, Charles, op. cit., p. 469.
[2] Sales, R. H., and Meyer, Charles, idem, pp. 476-480.

the continuing higher temperature in the deeper zones was responsible for stimulating the chemical reaction between the wall-rock iron and the sulfur in the hydrothermal solution to form pyrite as equilibrium was sought. For, as mineralizing activity continued and the temperature gradient steepened, the deeper zones encroached on and replaced the higher zones. The Butte zoning is considered by most geologists to be unique, and from the preceding discussion it can be visualized how the zoning was controlled by a delicately maintained balance of gradually changing physical and chemical conditions as the surface was approached.

In most mining districts, as would be expected, the fine balance necessary for clear-cut zoning did not exist. Consequently, only a rough zoning or no zoning at all is more common. Nevertheless, reference to Butte is helpful, as it does show in a clear-cut way the correlation between mineralogy, temperature, and distance from center of mineralization or depth upon which any mineral zoning is dependent and the general processes that must have gone on in the formation of veins in most other mineral districts, even though the zoning is less pronounced or nonexistent.

Granted the above discussion gives perhaps an over-simplified picture of vein formation, nevertheless the essentials are all included. Briefly, in different mineral districts the relative importance of any of the given factors, such as temperature or concentration of elements, may vary widely. For instance, in many districts, unlike Butte, the veins were formed by mineralizing solutions rising in two or more successive surges, each of which was initiated by fracturing and/or brecciation and separated from the next younger by a period of quiescence. Also, in some districts each younger surge of mineralizing activity progressively deposited a mineral suite indicative of a lower-intensity environment, whereas in other districts a younger surge may have deposited a mineral suite indicative of a higher intensity environment. In this manner an extremely complex vein or vein system can be built up.

THE CLASSIFICATION OF THE HYDROTHERMAL ORE DEPOSITS

In 1911 Waldemar Lindgren, undoubtedly the world's greatest student of ore deposits, presented before the Geological Society of Washington, D. C., a new classification of mineral deposits which has been almost universally accepted, though some geologists are seeking to modify it. Only that part of the classification will be considered here that has to do with mineral deposits formed by hot ascending solutions, namely, the hydrothermal ore deposits. The classification of these deposits is genetic and is based upon the manner in which the temperature and pressure (depth) conditions at the time of deposition have influenced the type of mineralogy to

be found in a given ore deposit. In a sense, therefore, the classification is based on the concept of mineral zoning on a large scale embracing the characteristics of mineral districts the world over. To be sure, at no one locality can the mineralogy of a vein be traced from that indicative of low temperature and pressure through to that indicative of high temperature and pressure. Nevertheless, that such mineral changes do occur will be seen in the following description of the classification. Its great practical use is that once a vein system or mining district has become sufficiently well known to be classified, the engineer or geologist has some idea as to what may be expected regarding possible persistency of mineralization with depth and the mineralogic changes with depth or distance from the apparent center of mineralizing activity.

Thus, the hydrothermal mineral veins are divided into the following three groups in order of decreasing intensity: hypothermal, mesothermal, and epithermal. These groups are all completely intergradational one with the other. Before discussing the individual characteristics of each group, it would be well to mention that quartz and pyrite are perfectly at home in any one or all of the groups. However, usually pyrite in quartz veins forms more perfect crystals the higher the temperature at the time of their formation.

The hypothermal group seems to have been deposited at great to moderate depths and from temperatures varying between 600° and 300° C. The common gangue minerals are pyroxenes, amphiboles, garnet, tourmaline, topaz, chlorite, biotite, and spinels. Where such deposits are related to carbonate rocks the minerals are epidote, andradite (garnet), hedenbergite (pyroxene), cummingtonite (amphibole), and certain varieties of biotite. The ore minerals are the simple sulfides—pyrrhotite, arsenopyrite, sphalerite, chalcopyrite, molybdenite, and pentlandite; the oxides—magnetite, specularite, ilmenite, and cassiterite; and the iron-manganese tungstate series—hübnerite, wolframite, and ferberite. The hypothermal veins are characterized by an extremely irregular shape, a generally coarse-grained and irregular texture, and a general lack of sericitization of the wall rocks; rather, the wall rocks are often replaced by the gangue minerals of this class, thus these veins have strong walls. Replacement tends to be highly irregular and selective. These deposits have a large vertical range and a persistence and evenness of grade.

The mesothermal group is considered to have a temperature range from 350° to 175° C. and to vary greatly in depth of deposition. The common gangue minerals are quartz and carbonates, with fluorite and barite being important locally. The ore minerals are principally sulfides, arsenides, sulfantimonides, and sulfarsenides. The last two types are somewhat diagnostic of the lower-temperature portion of this group. Particularly diagnostic, however, is the lack

of the gangue minerals of the hypothermal group, and in place of them sericitization and argillization of the wall rocks. The fissures are apt to be regular in strike and dip, the walls smooth, and slickensides common. The fissures contain neither the extreme brecciation of deposits formed near the surface, nor the irregular and lenticular form of the deep-seated deposits. As open spaces were present, vugs of drusy quartz are not uncommon, but they are usually small. Along the fissures, alternating bearing surfaces and more open zones are not uncommon. The replacement deposits characteristic of limestones and dolomite are commonly of this group. Occasionally replacement deposits of this group also occur in quartzite and igneous rocks. Although deposits of this group are usually along persistent fissures, the grade of ore may be erratic, and mineralogic zoning is common.

It is into the lower-temperature portion of this group that the copper, lead, and lead-silver-antimony sulfides fall. Probably the copper-antimony sulfides and the lead-antimony sulfides incline to a slightly higher intensity environment than do the lead-silver-antimony sulfides, which may grade into the epithermal group. In Washington the copper-antimony sulfide, tetrahedrite, and the lead-antimony sulfides boulangerite, jamesonite, meneghinite, geocronite, and zinkenite have been found. All of the minerals appear to be consistently younger than the pyrite, arsenopyrite, and sphalerite with which they are often associated. Often, too, they fill drusy quartz vugs in a generation of quartz that is younger than the pyrite, arsenopyrite, and sphalerite. Galena is usually younger than the lead-antimony sulfides. Stibnite, berthierite, and the silver-antimony sulfides are invariably younger than the lead-antimony sulfides where observed in this state. In the ore deposit at Bear Basin, in which some idea could be gained of the relationship between the lead-antimony sulfide, jamesonite; the silver-rich copper-antimony sulfide, friebergite; the silver-lead-antimony sulfide, andorite; and the antimony sulfide, stibnite, there was clearly a decrease in intensity of environment. The jamesonite and friebergite are in a quartz, pyrite, arsenopyrite, sphalerite environment; the andorite is in a pink manganese-magnesium-calcium carbonate showing crustification banding; and the stibnite is enclosed in a drusy quartz vein cutting the pink carbonate.

Recently some interesting work was done on the hydrosynthesis of lead-antimony sulfides by S. C. Robinson.[1] He found that the optimum conditions for formation of lead-antimony sulfides, at least in the laboratory, are moderately alkaline sulfide solutions, the presence of sodium chloride, and relatively low metal-to-solution ratios. Further, he found that yields could be improved by increasing the time of reaction, temperature of reaction, and, to a lesser degree,

[1] Robinson, S. C., Synthesis of lead sulfantimonites: Econ. Geology, vol. 43, pp. 293-312, 1948.

the pressure. Strangely enough, the commonest of the naturally occurring lead-antimony sulfides, boulangerite, was not noted in any of the experiments. Rather, the more rare lead-antimony sulfides, such as the plagionite group and zinkenite and some not known to be duplicated in nature, were produced. However, it was shown that boulangerite is stable in the alkaline solutions and could be produced in a vacuum by heating to a point below their melting points the mineral products that were obtained experimentally. The reason for the absence of boulangerite in hydrosynthesis is not clear, but according to Robinson, he used relatively high temperatures (300°-400° C.), pressures (up to 2,000 atmospheres), and concentrations to drive his experiments to completion. Under natural conditions with ample time for crystallization and lower temperature, pressure, and perhaps concentration, the more stable boulangerite could presumably form.

In one experiment Robinson added some silver to his more customary chemical components and was able to produce in an alkaline-sulfide solution the silver-lead-antimony sulfide, andorite, as well as pyrargyrite, galena, zinkenite, semseyite (a lead-antimony sulfide of the plagionite group), acanthite (a silver sulfide), and a synthetic silver-antimony sulfide.

These experiments all lend support to the alkaline-sulfide theory of mineral deposition, which seems to play an important but not clearly defined role in nature.

The epithermal group appears to have been deposited under temperature conditions ranging from 200° to 50° C. and at moderate to shallow depths. Areas in which deposits of this group occur usually have been subjected to less erosion subsequent to mineralization than those areas in which mesothermal and hypothermal deposits are found. Consequently, the epithermal deposits are normally found associated with igneous activity of a relatively youthful geologic era, i. e., Tertiary, whereas the two older groups of deposits are often found associated with igneous activity of older eras. The gangue mineral in epithermal deposits is chiefly quartz, usually fine-grained or drusy, but chalcedonic and opaline varieties are also common. Adularia, the potassium feldspar found in veins, is widespread and characteristic of this group. Calcite, dolomite, rhodocrosite, barite, and fluorite are locally prevalent, and, less commonly, rhodonite. Zeolites are present in a few deposits. The ore minerals are gold, mercury, antimony, silver, argentite, and complex silver-antimony and silver-arsenic sulfides. Stibnite and cinnabar are common. Sphalerite, chalcopyrite, galena, silver-bearing tetrahedrite, and the ever-present pyrite are also common, and fineness of grain size is characteristic. Arsenopyrite is rare in this group. All high-temperature gangue minerals are conspicuous by their absence.

As the fracturing which formed the vein structure took place close to the surface, the fissures are usually short and irregular; open cavities, brecciation, crustification, comb structure, colloform banding, and open space filling are common. Replacement is of relatively minor importance, being largely confined to wall-rock alteration, which consists of silification, sericitization, kaolinization, propylitization (formation of chlorite and pyrite), and alunitization (formation of a hydrous potassium aluminum sulfate). Possibly, ground water mingling with the rising mineralizing solutions under proper conditions can cause rapid precipitation of colloidal particles and is therefore responsible for many of the characteristic colloidal features of these veins, such as deposits of opal or amorphous silica with their colloform banding formed by diffusion of metallic ions in a colloidal gel.

The precious metals are characteristic of this group, and though the base metals are present it is usually in such small amounts relative to the gangue that they cannot be mined economically. Thus, after the extraction of the precious metals, mining in this group usually ceases. The economic preponderance of precious metals over base may well be due to the fact that openings of suitable size for the economic deposition of precious metals are far too small to act as loci for the economic deposition of base metals. This is a point to be kept firmly in mind when prospecting for precious metals, i. e., areas of strong faulting are not necessarily favorable. Lack of persistence, rapid mineralogic changes with depth, and erratic values are characteristic of the veins in this group. In the past they have been noted chiefly for their bonanzas, which were mined out relatively close to the surface. Extrusive igneous rocks are the characteristic habitat of this group.

Many of the characteristics of today's hot springs are to be found in epithermal veins. Thus, a study of hot springs leads to a better understanding of epithermal deposits. The hot springs at Steamboat Springs, Nevada, have long been famous, and as stibnite is being deposited from them today, it is particularly appropriate that they be described in this report. According to Brannock et al.,[1] Steamboat Springs, Nevada, is located about 10 miles northeast of Lake Tahoe near the west-central border of the state. The springs are in an area of volcanic flows dating from mid-Tertiary to Recent. The most recent activity was the extrusion of volcanic domes of pumiceous rhyolite. The springs themselves are associated with recent north-south faults, and are no doubt related to the same magmatic source as is the pumiceous rhyolite. Large sinter terraces elongated northward have been built up. These terraces are broken by long sinuous fissures trending slightly west of north and averag-

[1] Brannock, W. W., et al., Preliminary geochemical results at Steamboat Springs, Nevada: Am. Geophys. Union Trans., vol. 29, pp. 211-226, 1948.

ing about 3 inches wide. Many of them are hundreds of feet long and have been widened in places as much as 6 or 8 feet by cracking and disintegration of the walls. The hot waters are just below the boiling point, around 200° F., and carry 2,000 to 2,500 parts per million of mineral matter, composed largely of sodium, chlorine, carbonate, bicarbonate, silica, sulfate, and considerable boron. The deposits consist principally of siliceous sinter and minor amounts of calcium carbonate. The springs range from very slightly acid to moderately alkaline. From time to time in 1945 and 1946 a very fine-grained, dark-gray to black mud was deposited by the springs of highest temperature and most abundant discharge. The mud contains minute light-colored particles, that are believed to be silica gel or opal; minute acicular crystals and clusters of stibnite making up 0.2 to 4 percent of the mud by weight; pyrite; and gold in an unknown form, but often in commercial amounts. Silver, mercury, arsenic, and copper are present in lesser amounts. Most of the mercury seems to be present in the high-temperature vapors associated with the springs. These vapors are composed largely of carbon dioxide, hydrogen sulfide, and nitrogen. The muds are believed to have precipitated in the water a few tens of feet below the surface and to have been carried mechanically to the surface. The discharge from the springs varies with the rainfall and atmospheric pressure and is also effected by salinity and temperature. Thus, meteoric water seems to play an important role. It is possible that the mud is precipitated in a colloidal state as the meteoric waters mingle with the mineralizing solutions, changing their temperature, alkalinity, and concentration—all vital in bringing about precipitation. There seems to be little doubt that here an epithermal mineral deposit is in the process of formation. Particularly does this appear to be true when it can be seen that a large quantity of originally porous sinter has been reworked and filled with opal, chalcedony, and some quartz by the hot water after its burial under younger sinter. According to Lindgren, colloform structures are by no means uncommon in this material. Radial clusters of acicular stibnite crystals are to be seen in the walls of small cavities and embedded in opal in the reworked sinter. It is interesting to note that these crystals are three to four times as long as those transported to the surface by the hot springs. Cinnabar was found in many parts of the older, more eroded portion of the sinter west of the presently active springs. Also in this same area on the dump of an old shaft, arsenopyrite, pyrite, stibnite, and some cinnabar occur in sinter and altered gravels. Apparently these minerals were deposited within 40 or 50 feet of the surface.

From the above description it would seem that colloidal phenomena must be quite important in the formation of at least the lower-intensity portion of the epithermal group. Possibly the silica

of such deposits, before it sets to a gel previous to forming opal and/or chalcedony, is precipitated as an amorphous silica sol, probably where the rising mineralizing solutions come into contact with the meteoric waters. Simultaneously and in a similar manner gold and the sulfides may be precipitated as crystalline[1] sols, depending upon their concentration and solubility in the solution—the more concentrated and insoluble they are the greater the probability of the formation of fine crystals of colloidal size. The above statements readily explain the presence of opal and chalcedony along with pyrite and stibnite crystals in the siliceous material at Steamboat Springs.

According to Brannock, some bedrock alteration has taken place, all of which seems to be of an acid type (kaolinite), probably owing largely to oxidation of hydrogen sulfide to sulfuric acid. This occurs even above springs which are alkaline but emit acid vapors. Donald E. White reports that at depth where mild alkalinity prevails the alteration minerals consist of montmorillonite clays, zeolites, and serpentine. It would be interesting to know the nature of the mineralizing solutions before they mingle with the meteoric water. At the surface the hottest springs have the highest alkalinity.

Antimony-bearing sulfides are common throughout the entire range of the epithermal group. Stibnite and the silver-antimony sulfides are the most common. In Washington a number of old silver properties are now closed because of the shallowness of the occurrence of pyrargyrite and other more rare silver-antimony sulfides. These deposits had a brief rich life while the pyrargyrite was mined, and when it gave way to the scattered base-metal sulfides, mining had to cease. As these occurrences are now worked out and the openings caved, the writer was unable to study these deposits. When these properties were being worked, the geologists who investigated them seemed to feel that the pyrargyrite had resulted from secondary enrichment, but as the few sulfides left seem to be extremely low or lacking in silver and antimony, one cannot help but wonder about the validity of their conclusions; ascending solutions would perhaps be the more logical answer.

Stibnite in Washington shows no particular affinity to any individual rock type. Commonly, stibnite occurs, (1) as all or part of the cementing material in breccias, (2) as irregular masses erratically distributed in quartz veins, or as disseminated particles or clusters throughout quartz veins, (3) as replacement deposits associated with fractured and/or silicified areas in limestone, and (4) as small lenticular bodies, veins, veinlets, and disseminated particles throughout hydrothermally altered zones, or it is erratically distributed along shears in those zones. In all of these instances the stibnite proves to be the last sulfide mineral to have formed, which

[1] Dean, Robert B., Modern colloids, D. Van Nostrand Co., Inc., p. 257, 1948.

attests to the very low temperature and pressure conditions that seem to be most favorable for its development. As is characteristic of the epithermal group, the stibnite deposits are erratic and unreliable in the extreme, the majority of them the world around only reaching to comparatively shallow depths, possibly not over 2,000 feet, and containing ore of extremely irregular grade along the strike and dip. Most deposits, probably because of erosion since they were formed, seem to die out within a few hundred feet of the surface.

Thus far in this discussion of classification, deposits formed at high temperatures and at deep to moderate depths, deposits formed at moderate temperatures and at deep to shallow depths, and deposits formed at low temperatures and at moderate to shallow depths have been considered. The majority of mineral deposits appear to have distinctive characteristics which make them amenable to this, the Lindgren classification.

However, as has been asked by Buddington,[1] what of those deposits formed at high temperatures and at shallow depths? These have certain characteristics which are unique and do not allow classification in the more normal manner expounded by Lindgren. Indeed, deposits containing minerals that are characteristic of the hypothermal type of deposition, but having also minerals, textures, and structural characteristics common to the epithermal type have been quite often described. Buddington [2] has appropriately named these deposits xenothermal, from the Greek word "xeno," signifying strange or different.

During the course of this work on antimony, three deposits that might be classified or associated with this type were noted and described—the Orphan Boy in the Meadow Creek district of Chelan County, and the Monte Cristo and Foggy mines in the Monte Cristo district of Snohomish County. The reader is referred to the descriptions of these three properties for further discussion. At the Orphan Boy, the anomalous relationship between pyrrhotite, a high-temperature mineral, and low-temperature pyrargyrite and crustification bandings should be noted. In the Monte Cristo district the association of pyrrhotite and of radiating clusters of tourmaline, both diagnostic of high temperature, with the lower-temperature drusy quartz, galena, jamesonite, stibnite, and realgar should likewise be considered.

In closing this discussion relating to the origin of mineral deposits in general and the antimony-bearing sulfides in particular, emphasis is placed on the fact that exceptions exist to most of the generalizations presented and that the remarks are intended to be

[1] Buddington, A. F., High-temperature mineral associations at shallow to moderate depths: Econ. Geology, vol. 30, pp. 205-222, 1935.

[2] Buddington, A. F., idem, p. 209.

only a generalized and correlated summation of what this writer believes are some of the better thoughts, as of 1949, that bear on the origin of mineral deposits. Such a summation is useful because it serves as a framework, temporary though it may be, on which to hang the scattered observations relating to the origin of mineral deposits that continually are being brought forth. This summation also enables the relationships of these observations to be evaluated with a reasonable sense of proportion. A knowledge of the origin of mineral deposits is important, as it places the geologist in a better position to estimate the life expectancy of known mining properties and to discover new properties by having as complete an understanding as possible of the geologic conditions that influence and are influenced by the formation of the particular type of deposit being sought.

OXIDATION OF THE ANTIMONY MINERALS

In the northern part of Washington the products of oxidation are more prevalent on the east side of the Cascade Range than they are either in the range or on its west side. Since the entire northern part of the state has been glaciated and most of the products of previous oxidation removed, the difference in oxidation intensity is necessarily caused by the conditions on the east side closely approaching those of the optimum for rapid oxidation, i. e., high temperature, generally low to moderate relief, low to moderate altitude, slow erosion, deep water table, adequate precipitation, and brittle rocks that are permeable to both air and water.

In the Cascade Mountains themselves the high relief, heavy rainfall, and a generally shallow water table all contribute to good ground-water and air circulation, but nevertheless oxidation is a comparatively slow process. More than likely, this is because the high relief and rapid erosion prevent oxidized zones from originating, and because cool temperatures the year around very materially decrease the solvent action of the water. This last factor is probably of great importance in accounting for the oxidation intensity difference between the Cascade Mountains and the country to their east. In the eastern region high summer temperatures significantly affect the oxidation process; for instance, Locke [1] says, "The temperature is a significant variant. While at 10° C. (50° F.) a reliable sample from copper ore might be taken after five years' exposure to air, at 30° C. (86° F.) such a sample may be obtainable for only a few days after the face is opened."

As is to be expected, these factors just discussed apply as well to the oxidation of the antimony-bearing sulfides. Briefly, oxidation is brought about by water carrying dissolved oxygen and carbon dioxide reacting on the common iron sulfides pyrite and/or pyrrho-

[1] Lock, Augustus, Leached outcrops as guides to copper ore, p. 59, 1926.

tite to create sulfuric acid and ferric sulfate, both strong acidic solvents; ferric hydroxide and ferrous sulfate are also formed. These solvents break down and oxidize the remaining sulfides and also react with the wall rocks, kaolin being a common resultant product. The antimony-bearing sulfides are not easily taken into solution, and particularly the mineral stibnite is very slowly attacked by either sulfuric acid or ferric sulfate, and what little antimony sulfate is formed hydrolyzes to form an insoluble antimony oxide which prevents any extensive migration of the antimony. Thus, there is no chance for secondary enrichment [1] by the carrying of antimony in solution and reprecipitation of it as stibnite below the water table. Despite this relative insolubility in sulfuric acid and ferric sulfate, stibnite readily oxidizes in the presence of air, or air and water, to any or all of the four antimony oxides, senarmontite, valentinite, cervanite, and stibiconite, the last two being the most common. As the oxides contain 10 percent more antimony than stibnite and are often the form in which the antimony is desired, they constitute the more valuable ore bodies.

The more complex antimonial minerals behave in a similar manner toward the processes of oxidation. Below are listed some of the more common complex minerals and their oxidation products.

Primary antimony minerals	*Oxidation products*
Tetrahedrite ($Cu_{12}Sb_4S_{13}$)	Malachite, azurite, and antimony oxides
Pyrargyrite (Ag_3SbS_3)	Cerargyrite (silver chloride), native silver, and antimony oxides
Boulangerite ($Pb_5Sb_4S_{11}$)	Bindheimite or anglesite, cerussite, and antimony oxides
Jamesonite ($Pb_4FeSb_6S_{14}$)	Bindheimite or anglesite, cerussite, and antimony oxides, plus small amounts of limonite
Geocronite var. schulzite ($Pb_5Sb_2S_8$)	Anglesite, cerussite, and antimony oxides
Berthierite ($FeSb_2S_4$)	Antimony oxides and limonite

The type of oxidation product depends upon the ease with which the original mineral goes into solution, the chemical elements in that mineral, and the behavior of these elements in the particular variety of solution at hand; that is, the solution's degree of acidity and the relative concentrations of the elements present in it.

Nowhere in Washington since the retreat of the glaciers has oxidation been sufficiently thorough to form ore bodies of antimony oxide. In the relatively short time interval, about 20,000 years, since the last ice melted from the principal mining areas, only enough oxidation has taken place to form a coating of antimony oxides on the antimonial minerals. This type of oxidation appears to have been formed directly through exposure to air, or air and water, rather than as a result of attack by acid waters and reprecipitation, as is evidenced by little or no iron sulfide being present in the deposits where the antimony oxides were seen.

[1] Emmons, W. H., The enrichment of ore deposits: U. S. Geol. Survey Bull. 625, p. 409, 1917.

PROSPECTING FOR STIBNITE

The following remarks are confined to prospecting for stibnite and its oxides, because at the present time they are the only minerals that are economically important for their antimony content alone. As has just been described in the section on origin, stibnite characteristically occurs in a depositional environment of low temperature and low pressure. This is the geologic setting for which the prospector must search. The most likely place to look for this type of environment is in well-fractured sedimentary or volcanic rocks on the outskirts of mining areas mineralized during the upper Mesozoic or Tertiary eras. It is unusual for rich deposits of stibnite to occur in intrusive igneous rocks, and only rarely do they occur in highly metamorphosed rocks. Commonly, stibnite occurs (1) as all or part of the cementing material in breccias, (2) as irregular masses erratically distributed in quartz veins, (3) as disseminated particles or clusters throughout quartz veins, (4) as replacement deposits associated with fractured and/or silicified areas in limestone, and (5) as small lenticular bodies, veins, veinlets, and disseminated particles throughout hydrothermally altered zones, or erratically distributed along shears in those zones. The mineralogy of the stibnite deposits is usually simple, being confined largely to quartz and calcite as gangue minerals, and stibnite, cinnabar, galena, sphalerite, arsenopyrite, pyrite, and gold as ore minerals. These last three minerals often compose an earlier high-temperature phase of the deposition. Sphalerite and galena are ordinarily present in only small amounts, sphalerite occurring in smaller amounts than the galena.

Unfortunately, electrical and magnetic geophysical methods of prospecting cannot be applied to stibnite, because, like sphalerite, stibnite is non-magnetic and has extremely low electrical conductivity. This is because stibnite has covalent bonding. For this reason the electrical and magnetic methods so widely employed in prospecting for the common metallic sulfides and oxides are useless. In fact, about the only possible geophysical method is gravimetric surveying, and this would undoubtedly prove impractical because of the small masses in which stibnite usually occurs. However, geochemical prospecting of the type being currently investigated for copper, lead, and zinc deposits should be considered as a possible aid in the finding of antimony deposits.

Thus, because of stibnite's physical properties and nature of deposition, the old maxim, "Get on the ore and stay with it," is the best practical advice that can be given. Systematic mining and the development of ore reserves is all but impossible. "Gophering," hand cobbing, and sorting are the mining methods that must be followed, and these are expensive. This is the reason that antimony

mining on a profitable scale is difficult in this country with its high-cost labor. To the writer's knowledge the only antimony property at which systematic mining is carried on is the Yellow Pine mine in Idaho, where the stibnite occurs with pyrite, arsenopyrite, gold, and scheelite in veins, veinlets, and disseminated throughout shear and brecciated zones in quartz monzonite. This deposit is uniquely low grade (1.25 percent antimony) and duplicates are not likely to be found. However, the Longstreet and Robert E. Lee properties in Ferry County might be considered similar to it.

ANTIMONY OCCURRENCES INVESTIGATED

CHELAN COUNTY

Orphan Boy Prospect

SW¼ sec. 12, T. 31 N., R. 18 E.

The Orphan Boy prospect in the Meadow Creek mining district was held by location in 1947 by George La Chapelle of Lakeside, Washington. It is most easily reached by taking the boat up the lake from the town of Chelan to the Meadow Creek Lodge, which is due east across the lake from the town of Lucerne and situated a little west of the mouth of Meadow Creek at the foot of a steep 7,000-foot ridge that rises directly from the lake. At the lodge one can procure a boat and either row or motor about a mile southeast to the mouth of Cascade Creek. Here there is a cabin. From the cabin a trail leads to the property, which is about 80 feet above the level of the lake. The workings are just below the trail as one approaches the first switch-back. This trail continues on up the slope about an eighth of a mile to the main lake-shore trail. The country rock throughout this area is granite gneiss.

The principal working is an adit just below a waterfall on the southeast bank of Cascade Creek, about 200 feet east of the point on the trail where the workings are first encountered. This adit follows for 50 feet along the eastward strike of a 7-foot-thick hydrothermally altered zone dipping 40° N. in granite gneiss. Samples were taken across this zone at a place 10 feet inside the portal, where the mineralization appeared to have been the strongest. Over a width of 6 feet 8 inches, silver assayed 26.2 ounces per ton and lead and zinc less than 0.2 percent. Across this same width from the hanging wall to the footwall, there are successively 1 inch of iron oxide-stained gouge; 3 inches of crustification banding composed of alternate bands of carbonate, quartz, and sulfides with minor pyrargyrite; 5 inches of silicified granite gneiss containing one-sixteenth-inch stringers of pyrrhotite; and in the remaining 6 feet of the zone limonite-stained sericitized, argillized, and silicified gneiss with stringers up to an inch thick filled with pyrite, sphalerite, pyrrhotite, galena, and some pyrargyrite. The footwall has a 1- to 2-inch gouge zone along it. This section just described appears to be quite representative of the entire zone along the length of the adit, except that in places there are horses of unaltered granite gneiss within the zone. One of these horses extends along the adit for 15 feet and across almost the entire width of the adit. In the face of the adit the alteration and mineralization had not been as intense as at the place where the sample was taken. It is impossible to trace the vein farther east on the surface without trenching.

One thin section and two polished sections of specimens from the crustified zone were made. The microscope showed the history of deposition in this 3-inch crustified zone to be quite complex and also very interesting, because the zone contains locally the chief ore mineral, pyrargyrite, in a relationship with pyrrhotite supposedly anomalous, as it is accepted by many geologists that pyrrhotite is diagnostic of high temperature (above 500° C.).[1] There appears to have been first a general brecciation of the wall rock followed by slight sericitization and silification and the development of comb quartz around the breccia fragments. Probably at this same time there was an introduction of euhedral pyrite (slightly anisotropic) and euhedral pyrrhotite, closely followed by anhedral sphalerite, containing pyrrohite blebs, most of which are irregularly distributed, but some of which show a pronounced alignment. This may have been caused by the unmixing of a solid solution during cooling. Apparently slightly later, but almost simultaneously with the deposition of the above sulfides, which are now found as irregularly distributed masses throughout the crustified zone, the brecciated fragments of wall rock and some fragments of the aforementioned sulfide masses were encrusted by several waves of a light-pink to tan carbonate, containing principally magnesium, iron, and manganese, and a minor amount of calcium. This carbonate has an index of refraction for the ordinary ray of 1.78 and an index of refraction for the extraordinary ray appreciably higher than quartz, approximately 1.59. The carbonate crustifications are coarser near the brecciated fragments, and each layer is about 1 millimeter in thickness. After this carbonatization there was a general introduction of subhedral to euhedral quartz, containing fine-grained subhedral arsenopyrite and anhedral pyrrhotite and sphalerite, in and around the pyrite pyrrhotite masses and along the fine concentric contraction fractures which roughly follow the curving boundaries of the individual encrusting carbonate layers. The quartz, arsenopyrite, pyrrhotite, and sphalerite replacements along the concentric fractures are quite discontinuous, the most favorable conditions for deposition naturally being where the concentric fractures were most open. But even where conditions were favorable for replacement, the quartz sulfide replacement bands are not more than 0.5 millimeter in thickness. Some of the quartz introduced at this time formed vugs about 0.5 millimeter and less in diameter which were later filled by pyrrhotite, sphalerite, and galena. A few specks of a mineral with the appearance of stannite was noticed in the quartz vugs with these later sulfides, but it was not positively identified. Sphalerite and galena introduced at the time of this latest sulfide surge replaced the carbonate along its cleavage fractures in an

[1] Edwards, A. B., Textures of the ore minerals: Australasian Inst. Min. Metallurgy, p. 127, 1947.

erratic manner. Apparently still later, pyrargyrite became distributed along carbonate cleavage fractures, likewise in a most irregular fashion, sometimes being deposited in the vicinity of the earlier sulfides and sometimes not.

A few additional items concerning the mineral associations are worth noting. Some of the galena contains irregularly distributed blebs of pyrrhotite. The galena in each instance has always replaced sphalerite, thus it may be that the pyrrhotite had originally come in with the sphalerite and not with the galena, the galena being able to replace only the sphalerite and not the pyrrhotite. Usually the galena replaced the sphalerite from its center outward. The manner in which this took place could be seen in polished section. One area cut at the appropriate angle showed only an island of galena in the sphalerite. Another area showed the galena entering the sphalerite along a narrow fracture to start the centrifugal replacement.

A particularly interesting bleb of quartz and sulfides which have replaced carbonate and pyrite was observed. The sulfides consist of sphalerite, pyrrhotite, and pyrargyrite showing mutual relationships; all three of these minerals are younger than the quartz. This close association of pyrrhotite and pyrargyrite is certainly most unusual, as is also the association of pyrrhotite with crustification banding. Nevertheless, this relationship has been observed before, as a similar association of sulfide has been described from the Providence mine near the international boundary midway across British Columbia.[1]

From the foregoing account of both the underground and microscopic observations it would seem that the temperatures of deposition of the deposit may have had an extremely wide range and therefore the deposit is of the xenothermal type (see p. 54) and is subject to the erratic behavior so common to this "telescopic" type of deposition, which has been caused by the abrupt cooling and precipitation of high-temperature solutions in areas of comparatively low hydrostatic pressure.

Just 85 feet west of and across Cascade Creek from the 50-foot adit just described is an inclined shaft 10 feet deep and having a 4- by 8-foot cross section. It has been sunk on a continuation of the altered zone, which shows the same characteristics in this locality as it did in the adit. The zone strikes N. 78° W., dips 55° N., and is 4 feet thick. There is an open cut on the same altered zone 75 feet farther west. Here it strikes N. 80° W. and has the same dip as in the inclined shaft. The thickness, however, is increased to 7 feet. Unfortunately, the intensity of alteration has decreased to the point where the feldspars have been argillized only partially, and the oxidation of a few scattered pyrite crystals give the zone a light

[1] Warren, H. V., and Watson, K. DeP., A pyrrhotite ruby silver occurrence in British Columbia: Econ. Geology, vol. 32, pp. 826-831, 1937.

limonite stain. On the hanging wall there is 1 inch of rusty gouge. The only sign of mineralization to be found in this part of the zone is a 3-inch silicified stringer about 1 foot from the footwall. It is heavily iron oxide stained and contains ⅛- to ½-inch quartz vugs. It was impossible to identify megascopically the few sulfides present. Likewise it was impossible to trace the zone any farther to the west.

In its entirety this mineralized and altered zone, containing a few thin stringers with scatterings of ruby silver which tease the prospector, has been traced along the strike for a known distance of 210 feet. It undoubtedly does extend somewhat farther both to the east and west, but before any further work is done a careful job of channel sampling the present workings should be initiated, care being taken to sample the thin stringers of ruby silver separately.

Under "Diaphorite" on page 26 in the section on antimony minerals, the Meadow Creek district is mentioned as being the most probable source of this rare mineral. It could have come from any one of the properties along the lake, such as the Sunday Morning, now under water, or the Orphan Boy, but the writer was able to see enough of the Sunday Morning vein to observe the similarity in its texture and mineralogy with that of the Orphan Boy. Thus, it is possibly not too much of an extrapolation to say that the geology of the unknown diaphorite occurrence was not dissimilar to that at the Orphan Boy.

Peshastin mine

SE¼ sec. 2, T. 22 N., R. 17 E.

The mine is located on the Peshastin claim in the Blewett mining district. The claim is held by assessment work by J. B. Woodworth of Vancouver, B. C. The tunnel may be reached by taking the road up Culver Gulch from the old town of Blewett, which is on the north side of Blewett Pass. The Peshastin tunnel is now caved and is identifiable by the fact that it has the third dump up the gulch.

According to Weaver,[1] stibnite is found associated with arsenopyrite in the workings of the tunnel, but it is not characteristic of the district. No stibnite was observed on the dump.

Snook and Ellen prospects

SW¼ sec. 4, T. 23 N., R. 15 E.

The Harrison property, comprising the Snook and Ellen prospects, is located at the head of Solomon Creek on the west end of Solomon Mountain, just below the divide separating Solomon Creek from Van Epps Creek, at an altitude of about 6,000 feet.

The prospects can best be reached by taking the road from Leavenworth up the north bank of Icicle Creek to the Chatter Creek

[1] Weaver, C. E., Geology and ore deposits of the Blewett mining district: Washington Geol. Survey Bull. 6, p. 77, 1911.

Forest Camp, a distance of approximately 17 miles. From there a good horse-trail goes south by bridge over Icicle Creek, and then west along its south bank 1¼ miles to Jack Creek. The trail on Jack Creek leads south along its east bank for 5½ miles, at which point a 3-mile branch trail leads up Solomon Creek, an eastward-flowing branch of Jack Creek, to the prospects.

The two prospects comprise a series of fifteen claims held by location and controlled by B. F. Harrison, 321 8th Avenue, Seattle, Washington. The western group of six claims is known as the Snook group, and the eastern group of nine claims is known as the Ellen group.

Briefly, the mineralization silicified and carbonatized a contact between diorite on the north and serpentine on the south. The contact strikes about N. 60° E. and dips 70°-85° NW. It crops out all the way across the steep narrow northward-trending ridge that forms the west end of Solomon Mountain. This contact zone has been followed for a strike length of 220 feet, and averages 15 feet in thickness, varying between 10 and 20 feet.

The Snook group is on the west side of this steep northward-trending ridge. The ridge rises about 100 feet above the Solomon-Van Epps pass and is about 200 feet through in an easterly direction at the pass elevation. There are two workings, an adit, now caved, and 35 feet above it an open cut. Mr. Harrison reports that the adit extends for 210 feet northeastward along the strike of the contact, and that at right angles to this adit there are five crosscuts that have exposed the full 15-foot thickness of the contact zone. According to Mr. Harrison, chip samples of this material ran $15.00 per ton in gold, and a few stringers ran as high as $1,100.00 per ton in gold.

In the open cut above the adit the nature of the contact zone is well shown. On the north side of the zone are two varieties of diorite: directly on the contact a biotite diorite which has been impregnated by ⅛- to ¼-inch quartz stringers and scattered blebs of arsenopyrite, and somewhat farther from the contact a hornblende diorite. Both rocks are reasonably fresh, the microscope revealing only minor amounts of chlorite and sericite, and in the case of the hornblende some alteration to brown iron oxide along fractures. On the south side of the zone the rock is serpentine, which was originally a fine-grained dunite. The olivine has now broken down to magnetite and antigorite. Accompanying this alteration there has been considerable development of chrysotile veinlets and talc.

The contact zone itself is about 10 feet thick where exposed in the open cut. The north contact is sharp, while the serpentine contact on the south is gradational. The north contact strikes N. 70° E. and dips 85° NW. The zone is typical of the so-called "nickel ledges" or "nickel dikes" that have been prospected in this area for many years. The outcrop is dark tan to buff and is spotted with dark

green. This appearance gave and still does give to the prospector an irresistible "come on." As yet none of these "nickel ledges" has been profitably mined. This one, as is typical of them all, is composed of chalcedonic quartz, high-iron dolomite, and a greenish material which may consist of any one of several minerals—in this occurrence it is talc. (See Denny prospect, page 89.) Considering the above description, it seems that the term silica-carbonate dike is more appropriate than "nickel ledge" for this rock type. Also visible in this outcrop is a highly siliceous phase that has replaced the more typical fine-grained material. A thin section and a polished section of this siliceous phase show it to be composed principally of euhedral quartz crystals, the interstices of which are filled with dolomite, which in turn has been partly replaced by the talc. The quartz crystals vary in size from 0.5 to 0.75 millimeter. Besides these nonopaque minerals, four sulfide minerals were identified in very minor quantities—arsenopyrite, millerite (nickel sulfide), chalcopyrite, and galena. Unfortunately their paragenetic relationships to each other and to the nonopaque minerals could not be determined. One portion of the outcrop showed an irregular quartz vein cutting across the silica-carbonate dike. It is about 3 feet thick, strikes N. 50° E., and has an almost vertical dip. It is apparent that this quartz vein is nothing more than an intensely silicified portion of the dike. The only sulfide mineral to be seen is galena. A grab sample assayed 0.12 ounce per ton in gold and 5.98 percent lead. In conjunction with this sample another was taken in order to determine the general character of the silica-carbonate dike; this assayed 0.22 ounce per ton in gold and 0.58 ounce per ton in silver. Thus, it might be worth while to open and sample the adit.

Around the ridge to the north, the Ellen group is located on the northeastward extension of this same silica-carbonate dike. There is only one working on this group, an adit from which a short crosscut has been driven south. The adit is about 10 feet lower than the adit on the Snook group. The Ellen adit was driven S. 40° W. in the diorite which forms the wall rock on the north side of the silica-carbonate dike. Because of the excessive steepness of the topography it was impossible to start the adit directly on the outcrop. Instead, it had to be begun in the diorite some 8 feet from the contact. For this same topographic reason the writer was not able to examine this outcrop, but from what could be seen the silica-carbonate dike here is about 14 feet thick and has 6 feet of well-defined quartz along its north side.

About 10 feet north of the Ellen portal is a dike of dark-gray to black dense hornblende lamprophyre, which on weathering has a pitted surface. This dike strikes N. 67° E., and dips 64° NW. The diorite, which is intruded, differs from that at the Snook. The Ellen diorite is more coarse grained and has a lower percentage of hornblende and biotite relative to the andesine.

The Ellen adit was driven 28 feet into the diorite and then a 10-foot crosscut was driven south to expose the quartz vein. Regrettably, this crosscut was not continued on through the main portion of the silica-carbonate dike. It is interesting to note that the 210-foot drift adit at the Snook, of which Mr. Harrison spoke, is probably some 10 feet directly above this point.

The quartz vein, as shown by the crosscut, is 6 feet thick and is divided into approximately equal parts by three parallel slips striking N. 50° E. and dipping 70° NW. The northernmost one is the hanging wall of the quartz vein, while the southernmost one is its footwall. Through a thickness of 10 inches in the footwall of the hanging wall slip, antimony has been deposited. Two polished sections and a thin section were made in order to determine the minerals present, and, if possible, something of the history of the deposition. This 10-inch hanging-wall zone is highly brecciated and some mylonite has been formed. The minerals indentified are quartz, dolomite, sericite, pyrite, arsenopyrite, sphalerite, stibnite, and berthierite. The quartz was evidently the first mineral to crystallize, as the loci of deposition of all the other minerals are confined to areas of fracturing in the quartz. The relationships between the post-quartz minerals are by no means entirely clear, but the following few observations seem to be quite certain: The stibnite definitely corroded the quartz and in places veined it, as the replacement process continued. Some of the stibnite bodies are of fair volume, individual masses up to half an inch in thickness and extending for several feet being common. These intersect and pinch and swell as they thread their way along the 10-inch zone in the hanging wall. This zone has been explored for only 10 feet along its strike. The stibnite also corrodes and veins the sphalerite and arsenopyrite. The sphalerite can be seen filling fractures and corroding the quartz along them. Fine-grained euhedral arsenopyrite and pyrite are deposited in fractures in the quartz and in places are themselves fractured and veined by dolomite and sericite, which are likewise filling fractures in the quartz and also interstices between euhedral quartz crystals. Admittedly, this is not a very detailed list of observations upon which to submit any paragenetic relations. However, it would appear from this that after the movement which brecciated and mylonitized the quartz, pyrite and arsenopyrite were deposited, and perhaps the sphalerite. Then after slight fracturing the dolomite and sericite were deposited. It is assumed that the stibnite may have been deposited at this stage, but nowhere were the relations between the dolomite, sericite, and stibnite actually observed.

The manner in which the berthierite occurs seemingly as a third depositional phase is most interesting. Everywhere the berthierite is to be found either as a thin border around the masses of stibnite,

and occasionally as thin veins through it, or as filling fine fractures in the quartz. Where observed in contact with dolomite and sericite, the berthierite seems to be replacing them, though the evidence is not clear-cut. As a possible explanation for these features, it may be that at stibnite's initial temperature of deposition it is capable of holding a small amount of iron in solid solution, but with slow cooling the iron migrates, in this case to the stibnite's borders and to favorable areas within the stibnite, thus causing the formation of the berthierite. If this explanation is correct, then of course the berthierite is not an additional depositional phase but rather a cooling phase of the stibnite period of deposition.

Aside from the 10-inch zone in the hanging wall, the remainder of the quartz vein is mineralized only slightly with pyrite, arsenopyrite, and chalcopyrite in a quartz-dolomite gangue. The depositional history of this larger part of the vein is essentially the same as that of the 10-inch hanging-wall zone, but conditions apparently were not structurally favorable for the deposition of the stibnite and berthierite at the time these solutions were introduced. A characteristic sample of this more barren part of the vein across a width of 5 feet assayed 0.04 ounce per ton in gold and nil in silver. In the crosscut the contact between the footwall of the quartz vein and the silica-carbonate dike is a well-defined slip plane. The dike is scarcely exposed, but appears typical in every way and has a scattering of pyrite through it.

From the foregoing discussion it is apparent that the possibilities of operating this property for antimony are poor, and it is extremely doubtful that any tonnage could be developed.

FERRY COUNTY

COVADA DISTRICT

General Description

The Covada mining district, mentioned also as the Meteor and in official county records as the Enterprise, lies 55 miles northwest of Spokane. It is described by Culver and Broughton:[1]

> The Covada district . . . occupies the northeastern part of the Colville Indian Reservation, having as its eastern boundary the Columbia between Harvey and Gerome, communities of western Stevens County. At its north edge the district extends westward to the San Poil divide, following Wilmont Creek southeastward to the Columbia. Topographically it includes part of the east slope of the San Poil divide with elevations ranging from 1,300 to 4,500 feet. Larger streams, Hall, Lynx, and Wilmont Creeks and their tributaries, are sharply incised so that the district is characterized by the mountain spurs trending east and southeast from the divide toward Columbia River.

[1] Culver, Harold E., and Broughton, W. A., Tungsten resources of Washington: Washington Div. Geology Bull. 34, p. 16, 1945.

More than half of the Covada district is underlain by rocks of the Covada group, which are tentatively placed in the late Paleozoic. To quote briefly from Pardee:[1]

> The rocks . . . range from shale, slate, and argillite to conglomerate, including limestone, greenstone, quartzite, and schist. In the Covada area a large proportion of the beds are blue-gray or black carbonaceous shale or slate, but their softness renders outcrops low and inconspicuous and likely to be concealed by surface mantle.

Pardee also states:

> The Covada group appears everywhere to have undergone severe deformation, the most conspicuous evidence of which is the steeply tilted attitude of the beds. As a rule the dips range from 45° to 90°, but the average is nearer the vertical, and the layers, which were originally horizontal, appear to have been compressed into a series of relatively small closed folds that strike on the average N. 15° W. As shown by the mine workings, faults of the same and of a northeast direction also are numerous, but the displacements they cause, although doubtless large in the aggregate, appear to be small individually.

This essentially sedimentary group was subjected to deformation and intruded, probably during the Mesozoic era, by the Colville batholith, mostly granodiorite in composition in this area. A few aureoles of weak contact metamorphism were formed, as is shown by the presence of epidote and garnet relatively close to some of the granodiorite porphyry. Lamprophyre and aplite dikes having a general northerly strike cut both the granodiorite and the Covada group.

The remainder of the area is underlain by glacial drift and below an elevation of 1,700 feet by fine light-colored Nespelem silt. It is well to keep in mind when prospecting in this area that ice moved essentially from north to south and that as a rule somewhat more than 50 percent of the drift fragments came from within a few miles of their present resting place.

The principle veins are quartz-filled fissures, though a few show evidence of associated brecciation and silicification of the wall rock. Those veins that are in the Covada group are apt to be more complex than those in the granodiorite. There are a few transverse faults, but in only a few places do the veins have an appreciable offset. The most prevalent strike is from north to N. 30° W., though all other points of the compass are represented. The prevailing dip is vertical. With the exception of thick brecciated and/or silicified zones a vein thickness of more than 3 feet is uncommon.

The economic minerals in the veins are silver-bearing galena and sphalerite in about equal abundance. It is interesting to note that it is the contact zone of the granodiorite and the Covada group that is the most richly mineralized. The galena in the metamorphosed sediments, however, is three times as rich in silver as that in the granodiorite. Other minerals are silver-bearing tennantite (chief

[1] Pardee, J. T., Geology and mineral deposits of the Colville Indian Reservation: U. S. Geol. Survey Bull. 677, pp. 140-155, 1918.

economic mineral at the Gwin mine), stibnite (Longstreet, Robert E. Lee, and Silver Leaf mines), chalcopyrite, pyrrhotite (at the New York mine intergrown with galena), tetrahedrite, cobaltite, jamesonite, arsenopyrite, molybdenite, scheelite, wolframite, and pyrite. Native silver, cerargyrite, argentite, and pyrargyrite have been identified in a few veins near the surface. Quartz is by far the principl gangue mineral, but there are also small amounts of fluorite, orthoclase, and late calcite. There is little doubt that the mineralization is associated with the granodiorite stocks.

Stibnite has been reported as being associated with ten different occurrences in the Covada district, but it is present in noticeable amount only at the Longstreet, Robert E. Lee, and Silver Leaf mines. Even at these properties it is of doubtful economic importance unless possibly as a byproduct mined with silver-bearing galena. The other seven properties were visited, but, as they have not been worked for 30 or more years, none of the workings were accessible, and in most cases one could hardly see where any work had been done.

Longstreet and Robert E. Lee mines

NE¼NE¼ sec. 36, T. 32 N., R. 36 E.

As the Robert E. Lee and Longstreet properties are adjoining and both owned by the same man, H. B. Rosenbaum of Inchelium, Washington, they will be discussed together. They consist of two patented claims, the Longstreet and the Fidalgo, and four that are unpatented.

The properties are located 5½ miles south of Inchelium at an altitude of about 2,000 feet. They are reached by going south from Inchelium for about 5½ miles to where, on the southwest side of the main road, there is a branch road to the portal of the Robert E. Lee claim.

The principal geologic feature in the area is an alaskite (quartz-feldspar) dike about 120 feet thick striking N. 15° W. and dipping approximately 60° W. cutting through a granodiorite stock. The dike has been traced on the surface for a little over a third of a mile and forms a particularly prominent ridge at the Longstreet and the northern end of the Robert E. Lee. On each side of the dike, the granodiorite has been mineralized and strongly altered.

At the Robert E. Lee these altered and mineralized zones can best be studied underground. On the east side of the dike the altered zone is 10 to 15 feet thick and consists of alternating bands showing the effects of kaolinization and silicification in about equal degrees of intensity. Some of the silicified bands are quite highly mineralized with scattered specks of pyrite, arsenopyrite, sphalerite, chalcopyrite, tetrahedrite, and galena.

According to Mr. Rosenbaum, the ore that runs the best in gold and silver is in those parts of the silicified bands not so well mineralized. He reported that this "high-grade" ore would run 15 to 16

ounces in silver per ton and $5.00 to $6.00 per ton in gold. The entire thickness of the altered zone has been mined to the surface in one place by means of a glory hole 40 feet wide, 100 feet long, and about 50 feet deep. In the ends of the glory hole are several post-alteration faults which strike parallel to the dike. Their dips are almost vertical. Just to the north of the glory hole is a shaft in the altered zone connected with the underground workings.

Underground on the west side of the alaskite the same general type of alteration prevails, but there has been less silicification and the zone is thicker, inasmuch as it extends for 60 to 70 feet west of the dike contact. However, there is a horse of granodiorite 30 to 40 feet thick in the altered zone, and the strongest kaolinization took place through a thickness of 25 feet on the west side of this feature. The Robert E. Lee portal is in this zone of intense alteration. Apparently the only sulfide mineral on the west side of the dike is stibnite, though no great quantity of this mineral was seen. Where observed it had been deposited along small discontinuous fractures; however, one vein in the horse of granodiorite is 3 inches thick. This vein has a strike of N. 45° E. and dips 60° W. At the portal small silicified lenses of stibnite occur in the highly kaolinized granodiorite. It has been mentioned that this altered zone carried scattered stibnite throughout to the amount of about 2 percent antimony. More often than not, 2 percent antimony would be plainly visible. Thus, were this a potential low-grade body, stibnite could be seen scattered through the zone, but such is not the case. The only stibnite seen was in thin fractures, as mentioned.

From the above discussion it is apparent that a chemical difference exists between the east and west sides of the dike—that is, on the west side of the dike principally antimony was deposited, while on the east side principally gold and silver were deposited.

Directly adjoining the Robert E. Lee claim on the north is the patented Longstreet claim. The portal to the principal Longstreet tunnel is located 180 feet south and 300 feet west of the northeast corner of sec. 36, and a few hundred feet north of the Robert E. Lee portal. The Longstreet tunnel runs from west to east directly through the ridge of alaskite. At the present time the east end, which holed through into an open cut, is caved. About 400 feet south of this open cut on the east side of the ridge and at a lower elevation, a crosscut adit has been driven west for a total of about 400 feet by means of several winding drifts. Unfortunately, these last-mentioned workings were caved at the time the property was visited, thus only part of the main Longstreet tunnel was available for inspection. To the west of the Longstreet portal there are several open cuts now mostly caved. According to Mr. Rosenbaum, these are all in the altered zone on the west side of the alaskite, and from them a car of hand-picked stibnite was shipped which assayed 25 percent antimony.

The tunnel itself seems to start out in partly altered alaskite, but the rock rapidly changes to a peculiar silicified and sparsely mineralized breccia. The only sulfide mineral seen was pyrite, though Pardee[1] reported stibnite, argentite, and galena in addition. The breccia is relatively fine, and few fragments are over an inch in diameter. The fragments appear to be quartz and highly silicified granodiorite, and the groundmass seems to be largely clay, in part silicified. All in all, this brecciated altered zone has the appearance that one would expect of the altered zone on the east side of the alaskite dike at the Robert E. Lee were it to be severely crushed and partially recemented. This brecciated zone at the Longstreet is 200 feet or more in thickness and is generally parallel to the trend of the dike. About 75 feet in from the portal of the Longstreet tunnel there is a prominent fault striking N. 15° W., dipping 75° W., and showing 20 feet of comminuted rock fragments and blue-black gouge. This is an indication of the tremendous crushing forces that were present. On the surface the brecciated zone forms a prominent ridge 40 or 50 feet wide and several hundred feet long on the eastern border of the alaskite dike, which has the appearance, in part at least, of being included in the brecciation.

From the foregoing descriptions it is readily apparent that at the Longstreet, too, the mineralization on the east side of the dike was confined principally to gold and silver and is of a different nature from that on the west, where antimony is the metallic constituent. It would appear that the kaolinization, silicification, and accompanying fractures and brecciation were associated with the intrusion of the alaskite, but it seems reasonable that the actual metallizing solutions came ultimately from the same source as the alaskite after the way had been prepared by the dike. Still remaining to be answered is the question: Why is the antimony on the hanging-wall side of the dike while the gold, silver, lead, and zinc are on the footwall side? Of course the obvious answer is that the temperature may have been different on the footwall side from that on the hanging wall and that therefore two separate physical chemical environments were available to mineralizing solutions. Whether or not this is the whole answer or what other factors play what part cannot be told until further work is done.

From the point of view of antimony production, it seems that the only hope for these properties would be the development of the west altered zone along the alaskite dike as a low-grade body that could be mined by low-cost methods. As described in the last paragraph of the section on the Robert E. Lee, this seems doubtful. However, at the Longstreet the open cuts were not sufficiently exposed to enable one to form an opinion, but as the type of mineralization appears to have been the same as at the Robert E. Lee, the writer is

[1] Pardee, J. T., op. cit., p. 168.

rather skeptical about the possible presence of a low-grade ore body that could be mined profitably. Nevertheless, if in time of emergency this country should be in short supply of antimony, these two properties should be thoroughly investigated.

Silver Leaf mine

SE¼SW¼ sec. 30, T. 32 N., R. 37 E.

This mine on the south slope of Rattlesnake Mountain is reached by taking the dirt road south out of Inchelium for about 5½ miles and then taking a branch road to the southeast for about ½ mile from whence a trail leads from the northeast side of the road to the mine. The property is owned by Hal Hightower and consists of two unpatented claims, Tungsten No. 1 and Tungsten No. 2. Mr. Hightower's home is just north of the old townsite of Covada, where at present there are no buildings. Culver and Broughton[1] give an excellent summary of the mine area, and the following two paragraphs are quoted from their report:

> Rattlesnake Mountain is the southernmost of the island-like masses of old metamorphic rocks projecting above the 1,800-foot surface of the Nespelem silt plain. Like the others it is elongate north-south in harmony with the structure of the beds composing it. A good growth of conifers will provide mine timbers. The mine workings lie above the present water table so that provision for an adequate water supply must be made.
>
> In the vicinity of the mine, Rattlesnake Mountain is made up of members of the Covada series which here are thin, interbedded quartzites, argillites, and marbles. The beds strike about N. 10° W. with practically vertical dips. Along the mineralized zone the beds are highly sheared and crenulated. This sheared zone, less resistant to erosion than adjacent beds, can be traced on the surface where it parallels the strike of the sedimentary rocks. On the southwest side of the mountain, extending up along its western slope from its base, a body of granodiorite has intruded the metamorphosed beds. Its contact, about 100 feet west of the mine workings, shows some development of garnet, epidote, and muscovite.

The major jointing of the area is parallel to the bedding and to the shear zone. Another somewhat subordinate, but well-developed set is nearly vertical and strikes N. 75° E. In and about the mineralized zone there are several quartz veins up to 1 foot in thickness parallel to the bedding. Numerous smaller quartz veins up to 1 inch in thickness parallel the set striking N. 75° E. Other quartz is erratically distributed throughout the shear zone as cement for the brecciated parts. These parts contain vugs up to 1½ inches in diameter lined with delicately set quartz crystals. It was in some of these vugs, according to Mr. Hightower, that wire silver was found.

The mine workings are all confined to the mineralized shear zone, which is about 50 feet in thickness. The principal working, an adit approximately 210 feet west of the south quarter corner of sec. 30, is driven 200 feet to the north in and along the shear zone at an altitude of about 1,800 feet. This adit was caved at the time of the writer's visit. Apparently it contains nothing of economic interest, as neither

[1] Culver, Harold E., and Broughton, W. A., op. cit., p. 19.

Bancroft[1] nor Pardee[2] mentions anything, even though at the time of their visits the adit was accessible.

To the north 150 feet, and 70 feet above the lower adit a 40-foot shaft was sunk on the shear zone. Extending northward from this old shaft for 30 feet was an open cut, from the end of which had been driven a 20-foot adit. All these workings are now caved and inaccessible, the shaft and open cut being filled with rubble. It was from these workings that the early production of silver and tungsten was taken. At the time of Pardee's visit in August 1912 these workings were accessible, and the following is quoted from his report:[3]

> The lode is irregular, about 8 feet in greatest width, strikes N. 30° W. dips steeply northeastward, and has rather indefinite boundaries. It is filled with argillite breccia cemented and partly replaced by quartz. The ore minerals are zinc blende, pyrite, and silver-bearing galena. Numerous drusy cavities are lined with quartz needles and crystals of the sulphide minerals, which are also intergrown with the quartz. The ore minerals are distributed irregularly through the lode, considerable portions of which appear barren. The ore shipped was sorted by hand from the material taken from the shaft and open cut. No well-defined ore shoot appears, but the best ore occurs in very irregular bunches. Some slip and fault planes cut the lode, and the zone of oxidation is very shallow.

He also mentioned that shipments to that date had aggregated 11 tons of hand-sorted ore having an average content of 3.6 percent lead, 2.2 percent zinc, and 180 ounces per ton in silver.

Pardee did not realize that scheelite was present, and as these same workings were still accessible in August 1941, when Broughton visited the property, the following paragraph on the occurrence of this mineral is quoted from Culver and Broughton:[4]

> Most of the scheelite occurs in the 20-foot adit at the end of the open cut just north of the old shaft. On the face of the adit there is a zone of brecciated, argillaceous quartzite that has been recemented with vein quartz. In an area about 2 feet square scheelite constitutes about 10 percent of the surface. It is in the vein quartz and particularly concentrated around the edges of the quartzite fragments. Small patches of scheelite are in the roof of the adit over an area 10 by 5 feet. Some of the scheelite crystals are as much as half an inch across, but the majority are smaller. In the east wall of the open cut just north of the old shaft there are several half-inch quartz veins carrying a high percentage of scheelite, but they pinch and swell from mere seams to the half-inch thickness. The entire zone would not run high in scheelite. Besides these veins there are several isolated patches of scheelite up to 1 inch across. The dump in front of this open cut and the 20-foot adit shows much scheelite.

The following note from the volume of Mineral Resources for 1915[5] is interesting in this connection: "The Silver Leaf property produced a small amount of scheelite, as well as a shipment of silver ore."

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[1] Bancroft, Howland, The ore deposits of northeastern Washington: U. S. Geol. Survey Bull. 550, p. 197, 1914.
[2] Pardee, J. T., op. cit., p. 171.
[3] Pardee, J. T., idem, p. 171.
[4] Culver, Harold E., and Broughton, W. A., op. cit., p. 20.
[5] Mineral Resources U. S., 1915, pt. 1, p. 569, 1917.

About 16 feet east of these caved workings is the adit in which Mr. Hightower is now doing his assessment work. This adit is likewise driven north along the shear zone and strikes N. 9° W. for the first 48 feet. Here a 23-foot crosscut was driven N. 78° W. which holed into the old workings lying just to the west and previously described. These no longer seemed safe. Apparently Mr. Hightower came back some 15 feet and drifted along the shear zone for 21 feet. Then he crosscut to the east and west, 6½ and 10 feet, respectively. In the back of the west crosscut 1 foot from the face is a spot of scheelite 2 inches in diameter. These workings appeared to be driven in a highly silicified argillite and limestone, striking N. 9° W. and dipping 75° E.

Only one spot of mineralization was observed in the adit: that was in the face at the starting point of the first crosscut 48 feet from the portal. A thin section and a polished section of a specimen from this area showed that pyrite, containing minute cobaltite inclusions, and sphalerite crystallized in a quartz gangue composed of inter-fingering coarse euhedral crystals with finer-grained anhedral quartz filling the interstices. These interstices acted as loci for replacement by an intergrowth of jamesonite needles and minor amounts of tetrahedrite.

Approximately 150 feet north and 40 feet above the portal of this adit is the only real showing of stibnite at the Silver Leaf. It occurs just south of a 50-foot eastward-trending open cut, as narrow ¼- to 2-inch stringers in pyritized and highly silicified argillite. The stibnite, in places partially oxidized to kermesite, both parallels and crosscuts the shearing and seems to be present for about 10 feet along the strike. No other stibnite was seen to the north or south of this area. In this zone, wherever the stibnite is not present as definite stringers, either with or without quartz, it seems to be disseminated throughout the rock. Because of the overburden the writer was not able to measure the thickness of the zone, but it is doubtful that it is more than a few feet. Scattered blades of stibnite were observed throughout this general area and 100 feet farther north and 90 feet higher in a small open cut about 10 feet in diameter.

Culver and Broughton mention a small quantity of scheelite in these upper trenches. In this connection it is interesting to note that in a specimen from the 10-foot stibnite zone a small crystal of scheelite appeared at first glance to be intergrown with stibnite. The stibnite is now altered to gray-white stibiconite. An occurrence of this type would be very rare indeed, but on further examination the stibnite could be seen to have replaced the scheelite, which had been deposited at an earlier time, probably in an environment of higher temperature and possibly higher pressure.

Culver and Broughton[1] summarized the history of mineralization in this area as follows:

> It appears probable that the sedimentary rocks were first metamorphosed and that subsequently, perhaps at the time of the granodiorite intrusion, the jointing parallel to the bedding was developed, together with local brecciation. Solutions, probably derived from the granodiorite, filled the fractures, producing quartz veins carrying sulfides and scheelite. The only mineral besides quartz that is closely associated with the scheelite is pyrite, and even that mineral is rare in the scheelite-bearing veins. Later stresses produced fractures cutting across the bedding and schistosity and striking about N. 75° E. Some of these fractures are filled with vein quartz. . . .

It was undoubtedly at the time of these later stresses, which made the rocks again susceptible to mineralization, that the stibnite was deposited in the resulting fractures along with the quartz. Some of the quartz may be even younger than the stibnite.

In retrospect, the sulfide mineralization at the Silver Leaf, when considered broadly, was extremely erratic and weak, even though the shear zone was strongly silicified over a thickness of 50 feet.

KING COUNTY

Gold Mountain prospect

NW¼SE¼ sec. 29, T. 26 N., R. 11 E.

The Gold Mountain prospect is an old property (ca. 1900) from which stibnite has been previously reported. Unfortunately, even after being given careful directions on the property itself, the writer was unable to find the long-abandoned upper workings. Apparently they are now caved and buried by wash in a narrow gully.

The dump of the Gold Mountain prospect is just below the northwest side of the Money Creek road 1.2 miles from its junction with the Skykomish road. The lower adit, from which this dump came, is now partly caved. Mr. R. L. Stitt of Seattle told the writer that he had been back in it for 30 or 40 feet in 1948, and that it was from there on that the adit was caved. The adit was driven in andesite. In 1939 the workings were examined by E. J. Dailey of Seattle who reported that the adit was 1,200 feet long and cut two well-defined veins, in one of which was silver-bearing stibnite, and in the other gold- and silver-bearing pyrite and minor quantities of chalcopyrite.

However, the adit which is supposed to carry the best stibnite is presumably about 250 feet vertically up the hill and approximately S. 30° E. from the opening reported on by Dailey. There a small draw trends along a joint plane, which strikes N. 60° W., dips 73° NE., and shows a slight horizontal movement. A 20-foot cut has been driven along this joint but gives no indication of stibnite. However, the country rock, andesite porphyry with feldspar phenocrysts, is pyritized and kaolinized for about 6 inches on each side of the joint. This is all that was found.

[1] Culver, Harold E., and Broughton, W. A., op. cit., pp. 20-21.

According to Mr. W. R. Anderson, of Baring, who accompanied the writer to the Gold Mountain property, the adit carrying the stibnite is said to have been driven on the vein for some distance and to have crosscuts in both directions at its face. It also contained a winze somewhere near the face. This adit should be found, according to Mr. Anderson, slightly below the point where the writer found the 20-foot cut described above. From the cut on down the draw, there now exists nothing but wash and there are no signs of any dump.

Great Republic mine

N½SW¼ sec. 33, T. 26 N., R. 11 E.

The Great Republic mine is located at an altitude of about 1,200 feet at the first falls on Happy Thought Creek, ½ mile above its junction with the Miller River to the east. It can be reached by an overgrown trail that takes off from the Miller River road 1½ miles from the Skykomish highway. This trail can be followed by car for a short distance to a cabin, from which it leads on to the mine.

The property is owned by Charles Wible, 909 Tacoma Avenue, Tacoma, Washington, who holds a group of five claims by location. He acquired the property in 1937. It was originally located in 1892 by L. M. Miller and R. L. Taylor. They abandoned their claims, which were relocated by John Terry for J. W. Cook. In 1900 the claims became the property of the Great Republic Mining Co., which did all the underground work and built a short cable tram and a 5-stamp mill in the old town of Berlin. This company ceased operations in 1905. From that date until 1937 the property was abandoned and relocated several different times.

The mine consists of two adit drifts which have been driven westward and connected by a raise. The upper adit is on the north bank of Happy Thought Creek, which flows from west to east. The lower adit is on the south bank, 20 feet lower and 240 feet to the east of the upper. The greater part of the work has been done on a flat-lying mineralized fault in andesite. The andesite is part of the Keechelus andesitic series of Miocene age.

The mineralization was far stronger in the upper adit, for here four rooms have been stoped out along its north wall. The adit was driven along the strike of the vein, which has a general westerly trend and a dip of 15°-20° S. At the portal is the best showing of stibnite on the property. It is exposed in the south wall and is about a 2½-foot thickness of almost solid stibnite that extends along its strike for about 4 feet. How far it extends down the dip could not be determined. It is not continuous up dip. The first stoped room is 35 feet from the portal; 60 feet farther on and for about 90 feet along the adit are the next three in quick succession. None

of these has been stoped north from the adit for more than 25 feet, and the average is about 15 feet. In all four of these rooms only three small patches of stibnite were seen remaining. The maximum thickness that the stibnite lenses possibly could have obtained is 3 feet, but the average was probably about 1 foot. The rooms themselves are about 4 feet high.

Beyond the stoped rooms the adit continues for another 35 feet. Starting at 20 feet from the face the vein splits, the main westward-striking branch dies out, and the split takes up along a N. 70° W. strike with a dip of 45° S. This split shows gouge and some alteration minerals, but no sulfides.

Directly south of the first room in the upper adit is a raise dipping 20° S. The vein is exposed throughout this raise, but unfortunately most of it as well as the lower adit is filled with sand and gravel. This occurred while the property was idle and was caused by a log jam which forced Happy Thought Creek to flow down through the mine workings and out the portal of the lower adit. That portion of the vein exposed in the raise shows an argillized zone 1½ to 2 feet thick and containing scattered stibnite.

The lower adit was driven south 55 feet along a southward-striking joint dipping 70° W. However, a vein with an approximate westerly strike and a 20° S. dip was soon intersected. This vein shows a mineralized zone about 3 inches thick which consists of pyrite, quartz, and stibnite. It is not displaced by the southward-striking joint. Whether or not this 3-inch vein is the same as the vein in the upper adit is not known. About 50 feet from the portal, where the small 3-inch vein appears to fade and dip into the sill, another similar small vein striking N. 63° E. and dipping 20° S. begins to show in the back. The adit turns to the west to follow it. About 45 feet from the turn a southward-striking joint dipping 30° E. cuts off this second small vein. From this place to the raise no more sulfides are seen. From 100 feet past this last north-south joint to 50 feet beyond the raise the adit is almost choked with sand and gravel. However, a reliable authority, who was in the workings previous to their filling, reported that no stibnite is to be seen in this vicinity. A crosscut driven from the adit 60 feet east of the raise in a northeasterly direction did not intersect stibnite. However, the rocks in the walls of the crosscut are kaolinized and sericitized and have small scatterings of pyrite, which occurs, as does all the pyrite in the mine, in tiny euhedral crystals. Thus, stibnite may not be too far away, but it appears very much as if this crosscut would have intersected the stibnite exposed in the raise, if the mineral had any continuity. Beyond the raise the adit continues west for about 100 feet and then turns north for 25 feet. According to Mr. Wible, the north face contains scatterings of stibnite. These were not seen by the writer because of the sand and gravel obstruction.

From underground observations it is possible to reconstruct the mineralization process that formed this deposit: Apparently the stibnite occurred in lenses, each room in the upper adit having contained an individual lens-shaped mineralized zone. The zones were formed where the faulting had brecciated the andesite, thus allowing the mineralizing solutions loci of deposition. Along the fault and particularly in areas of stibnite deposition the andesite has been argillized, sericitized, and pyritized. This alteration formed zones which averaged 7 or 8 feet in thickness and possibly as much as 10 feet in some places. The wall-rock alteration was probably concurrent with the metallization, for the concentration of the alteration products increases as the vein is approached, the products being more concentrated in the vicinity of the stoped rooms. These products close to the vein are largely sericite and pyrite. The pyrite is present in small amounts along the outer perimeter of the stibnite lenses, occurring as bunches of tiny (5 millimeter) euhedral crystals. The stibnite shows two modes of occurrence, both of which are associated with quartz, and, as near as can be determined, both were deposited at about the same time. The commoner variety is a fine intergrowth of stibnite blades and quartz, which has a gray fine-grained massive appearance. This crystallized in the vicinity of brecciated fragments of andesite. These fragments are largely replaced by sericite, quartz, and pyrite. In the other variety the stibnite occurs in bunches or clusters of radiating acicular crystals, some of which are as much as an inch in diameter, though the average is perhaps only half of that. These seem to characterize the more open portions of the vein where there was greater ease of growth. In one specimen there were several corroded crystals of pyrite within the stibnite blades. All the specimens clearly show pyrite, quartz, and stibnite being cut and corroded by late sugary calcite and quartz. The calcite and quartz were able to replace most easily the stibnite clusters, the fine massive stibnite quartz intergrowth being hardly touched. This may have been because the clusters were in the more open parts of the vein.

From this evidence the following possible process of vein formation appears reasonable: First, there must have been faulting and brecciation of the andesite, followed by the introduction of vein-forming solutions probably containing potash, silica, sulfur, and antimony. As well as depositing the vein quartz and stibnite at favorable points, these solutions probably made over the wall rock, rearranging its chemistry and mineralogy as indicated above. The iron for the small amount of pyrite present undoubtedly came from the ferromagnesians in the andesite. At least some of the stibnite must have crystallized after the quartz, as stibnite can be seen filling minute drusy quartz vugs. As a dying phase of the mineraliza-

tion, calcite and quartz no doubt crystallized from the solution, replacing parts of the stibnite clusters and other older minerals. Some of the calcium may have been introduced from below and some may have been taken from the andesine in the wall rocks, as they were altered to kaolin and sericite.

On the basis of the above observations the stibnite lenses would be expected to have an extremely erratic distribution, for even the discontinuous fractures themselves within which the individual lenses are scattered, have an irregular en échelon arrangement. Thus it would appear that prospecting between lenses would consume any profits made from an individual lens.

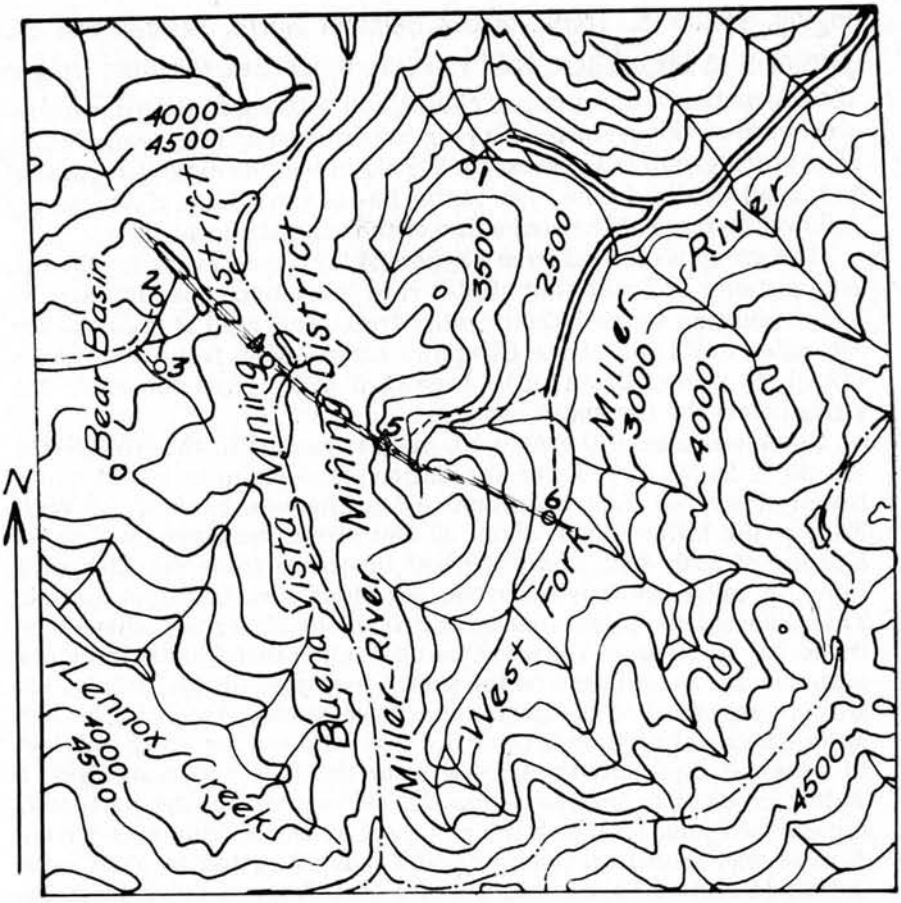
Buena Vista and Miller River Districts

The parts of the Buena Vista and Miller River mining districts shown on the sketch map, figure 5, are topographically and geologically a unit. Topographically the area is extremely rugged, with a relief of 3,000 to 3,500 feet. It is, except above altitudes of about 4,000 feet, heavily timbered with Douglas fir, hemlock, and Alaska cedar. Above 4,000 feet the timber is small and sparse, consisting for the most part of noble fir, jack pine, and some Alaska cedar.

The West Fork of the Miller River occupies a typical U-shaped valley so common in areas of alpine glaciation. Above this valley are cirques such as Coney Basin and the Cleopatra mine basin, and tarns, such as Francis Lake and Bear Lakes. The cirque walls reach an altitude between 4,500 and 5,000 feet. Above these altitudes are the last remaining remnants of the mature topography that was subjected to glaciation, a physiographic feature recognized by Smith.[1] These remnants are in a few places characterized by relatively gentle slopes such as those in the vicinity of Coney Lake, but the greater part of the higher area consists of small matterhorns and arêtes, such as are found between Lennox Creek and the headwaters of the West Fork of the Miller River. These last are caused by the individual glaciers in opposing valleys eating headward into the mountains until their headwalls meet, resulting in the present crenelated crestline.

The bedrock of this area consists principally of biotite granodiorite and scattered small intrusions of aplite and alaskite. A shear zone (see fig. 5) containing a series of northwestward, steep-dipping, intermittently mineralized planes is particularly prominent. It is along this zone that three of the mining properties under discussion are located. The commonest antimony-bearing mineral is jamesonite, together with subordinate amounts of stibnite and, in one property, freibergite and the rare silver-lead-antimony sulfide, andorite.

[1] Smith, Warren S., Physiography of the Skykomish Basin, Washington: New York Acad. Sci. Annals, vol. 27, p. 212, 1917.



Scale—Approximately 1 inch equals 1 mile
Contour interval 500 feet

EXPLANATION

Snoqualmie granodiorite

Intermittently mineralized shear zone

Mine workings

List of mining properties

1. Coney Basin mine
2. Bear Basin mine, Adit Nos. 6 and 7
3. Bear Basin mine, Adit No. 3
4. Dawson prospect
5. Cleopatra mine
6. Aces Up mine

FIGURE 5.—Map showing parts of the Buena Vista and Miller River mining districts. Topography by U. S. Geological Survey.

Cleopatra group

The Cleopatra group of 23 claims on the West Fork of the Miller River is held by location. In 1948 it was being leased by its owner, Edward Maloney of Skykomish, to the Cascade Mining Co. of Wash-

ington. Henry E. Trenk, of 512 Belmont North, Seattle, was the president in 1948. There are two silver properties, the Aces Up and the Cleopatra, in this group of claims, and both are in the same northwestward-striking, steeply-dipping mineralized zone in granodiorite. Part of the group is 3 abreast for 6½ claim lengths extended parallel to this mineralized zone. The center line of the middle claim closely follows the trace of the strike line of the zone at the surface.

The group is reached from Skykomish by a road to the northwest. At a distance of 2 miles out on this road is a branch road marked by a sign pointing to the Lake Dorothy trail. This road is followed for 7½ miles to its end at the Cleopatra camp. Also, from this road a branch to Coney Basin turns westward away from the river 1¼ miles below the Cleopatra camp.

The lower adit of the Aces Up mine is located in the SW¼SW¼ sec. 30, T. 25 N., R. 11 E., on the Eastern Star claim at the foot of a heavily timbered steep mountain side on the west bank of the West Fork of the Miller River, about 30 feet above the river level at an altitude of 2,300 feet, and 3,600 feet upstream from the Cleopatra camp. A good trail has been laid out along this 3,600-foot stretch. This property comprises four adits driven one above the other along the N. 50° W. strike of the set of parallel mineralized joints in biotite granodiorite, as indicated on the sketch map (see fig. 5). The lowest adit is now caved at the portal and inaccessible. According to Mr. Mike Kinney of Skykomish, the ore was followed for about 300 feet to where it died out; then, back from the face about 200 feet, a 90-foot crosscut to the north was driven to intersect the particular mineralized joint on which the next adit up the hillside was driven. A raise was driven up this joint, and it is estimated to have come within 14 feet of holing into a winze that dropped down from the adit immediately above. No accurate information could be obtained as to the quantity or grade of ore present in the lowest adit.

The next adit, 70 feet higher up the hill, strikes N. 50° W. and follows a vein or mineralized joint for 415 feet. At 192 feet from the portal is the winze just referred to, which has been sunk along the vein, which dips 70°-75° S. It is reported that very high grade ore has come from this winze, now filled with water. The vein averages about 9 inches in thickness for the length of the tunnel, and from about 50 feet beyond the portal to the winze it averages about 2 feet in thickness. At 20 feet back from the face the vein branches and becomes barren. This adit appears to be the one having the most merit, but even here only occasional streaks of sulfides 6 inches thick are to be seen. The mineralizing activity in this adit was very typical of that throughout the property. The wall-rock alteration was very weak, having consisted for the most part of chloritization of the biotite. However, at scattered points along the vein a small amount of kaolin and sericite extend a few inches out from the vein into the granodiorite. The sulfide mineralization of these

joints appears to have been mostly a replacement process along the joints in the granite with a small amount of actual filling of open spaces. Apparently, little or no movement took place along these joints. The minerals are quartz, pyrite, arsenopyrite, sphalerite, chalcopyrite, silver-bearing galena, and jamesonite. The sulfides have formed in a series of small lenses along the footwall in a gangue of quartz and highly silicified granodiorite. In this adit a late band of coarsely crystalline calcite is very prominent from the winze to within 50 feet of the face. It is usually found on the footwall, where it forms a 2-inch band between ½-inch bands of mixed sulfides.

The next adit, 150 feet farther up the hill, extends N. 55° W. along a vein for 175 feet. At 25 feet from the portal of the adit there is a winze dipping 65°-70° S. following down the vein. It was full of water at the time of the writer's visit. From the portal to this winze there is about a 2-foot thickness of heavy sulfides. The evidence of field relations and polished-section study indicates the general history of deposition. First, as shown by their usual mutual boundaries with one another, pyrite, arsenopyrite, and sphalerite have been almost simultaneously deposited along the joint, replacing the granodiorite. In two places the sphalerite appears to be eating into the pyrite, as evidenced by a long narrow embayment bordered with many minute islands of pyrite. The sphalerite shows scattered blebs of chalcopyrite, some of which have a linear arrangement. Second, and clearly later than the first stage of deposition, was an introduction of quartz. Apparently there had been minor movement preceding the introduction of the quartz, as it fills fractures in the pyrite, arsenopyrite, and sphalerite. At the close of the quartz deposition there were some open spaces, as evidenced by many euhedral quartz crystals. Closely following this quartz deposition, and perhaps in part simultaneous with it, silver-bearing galena and jamesonite were deposited in that order. Both of these minerals fill fractures in the quartz, and the jamesonite surrounds islands of the galena. This second period of mineralization may have taken place at a somewhat lower temperature than the first. Throughout the adit the vein averages about 4 inches in thickness; however, in the middle of the adit it is 1½ feet thick for about 10 feet along the strike. The vein fades out in the face of the adit. A few places along the vein show some kaolin and sericite extending a matter of inches into the granodiorite. The mineralization was of the same type as described for the 415-foot adit except that no calcite band was deposited.

According to Mr. Trenk, 60 feet higher on the hill is another adit directly above the one last mentioned. This adit is reported to have been driven along a vein for 20 feet, at which point the vein died out. Supposedly, this is the same vein on which the adit immediately below was driven. Mr. Trenk said that the vein in this uppermost adit consists of a few inches of high-grade sulfides (silver-bearing

galena) close to the portal, and that his company had shipped 500 pounds to the Tacoma Smelter, but that it had been too high in antimony to be acceptable. More than likely, the mineral jamesonite is responsible for the antimony, as it is in the lower adits. Unfortunately, the quantity of jamesonite and galena is too limited to make a commercial antimonial-lead concentrate. Thus any future the property may have will necessarily be based upon the silver content of its ores.

The Cleopatra mine is located in the NW¼SE¼ sec. 24, T. 25 N., R. 10 E., on the Silver Star and Silver Star No. 1 claims and is reached from the Cleopatra camp by a 1½-mile trail. The mine is about 1,600 feet above the level of the West Fork of the Miller River. Formerly a tram line 4,100 feet long connected the mine with the camp. This, along with all the mining and milling equipment, was sold in 1946 by the owner of the property, Edward Maloney.

The Cleopatra mine is 4,200 feet northwest of the Aces Up and in the same zone of mineralized joints. Here the mineralization has been considerably more intense, but of the same general type. The workings are in the southwest wall of a glacial cirque at an altitude of 3,850 feet. The west wall of this cirque is extremely precipitous, rising almost vertically from an altitude of 3,000 feet to 4,500 feet before sloping off to the crest line at 5,500 feet. The workings are about 2,100 feet in extent and consist of two adits, several short winzes, drifts, crosscuts, and a raise.

A small amount of water power could be obtained from a stream near by. The trees are scrubby and could hardly be used as a permanent source of mine timber.

The lower adit, striking S. 47° W., is a 305-foot crosscut in granodiorite through two steep southward-dipping, highly altered joints. The first is cut at 210 feet and the second at 300 feet. Both strike N. 45° W. and average about 5 feet in thickness. They show silicified and sericitized granodiorite plus a few scattered sulfides that consist mostly of pyrite and chalcopyrite. No commercial ore is present. At 125 feet from the portal a series of almost vertical unmineralized joints striking N. 68° W. has been followed for 290 feet to where a strongly altered zone was encountered. A crosscut was driven S. 23° W. for 120 feet from this zone. From 40 feet to 77 feet along this crosscut is a strongly kaolinized zone showing minor sericite and scattered sulfides. This zone strikes N. 60° W. and apparently dips about 75° S. A drift has been driven northwest along the zone for a distance of about 700 feet from the crosscut. Unfortunately, at the time of the writer's visit only the first 50 feet of this distance was open; beyond that there was badly caved ground. Through the courtesy of Mr. Trenk the writer was able to see an assay map of this caved area. At Mr. Trenk's request no information regarding ore reserves and assays is given, but the map indicated that at 435 feet

northwest of the crosscut and drift intersection is the beginning of an ore shoot that is 100 feet long and has an average thickness of 2½ feet. About 35 feet north of this shoot another parallel shoot is shown on the assay map. It has been opened up for only 150 feet along the strike.

A distance of 23 feet northwest of the afore-mentioned drift and crosscut intersection is a 220-foot raise to the upper adit. This raise follows a series of en échelon mineralized joints, which dip to the south at 75° and strike about N. 60° W. From the raise, four short drifts extend east and west for about 20 feet in each direction. They are equally spaced from the lower to the upper adit. As this raise and the upper adit were not particularly safe, little or no time was spent examining the type of mineralization there. However, it was observed that sulfides are reasonably plentiful over a thickness of about 3 feet in the faces of these short drifts. The upper adit itself is about 100 feet long and shows no ore. However, there is a strong alteration zone with scattered sulfides. At the portal the strike of the zone is N. 50° W., its dip is 64° SW., and its thickness is 3 feet.

As it was impossible to examine thoroughly the underground workings, what little information was obtained concerning the mineralogy had to be gotten from the dumps. Several specimens containing jamesonite were observed, indicating that the ore is contaminated by antimony. Also, Warren S. Smith[1] reported dyscrasite and several specimens of stibnite from the Cleopatra mine. Other specimens showed the vein minerals to be the same as those at the Aces Up. Likewise, the conclusions as to the possibility of producing an antimony-lead concentrate are the same—too limited a quantity of jamesonite and galena to be profitable; thus here, too, any future that the property may have will of necessity be based on the silver content of its ores.

Dawson prospect

NW¼ sec. 24, T. 25 N., R. 10 E.

At a distance of about 3,600 feet northwest along the strike of the Cleopatra vein from the upper adit is the Dawson prospect in the Buena Vista mining district. (See fig. 5.) This property is in the block of 25 claims held by the Bear Basin Mining Co., as described on page 85. The Dawson is most easily reached—unless of course one is staying at the Bear Basin camp—by going up the Miller River road to the Cleopatra camp, and then taking a trail into the head of Cleopatra Basin. Here is a long steep narrow talus slope running up the west wall. By climbing this slope as far as possible and then continuing up the steep timbered slope on the south side of the talus, one eventually comes to a basin at the foot of a small talus draw striking

[1] Smith, Warren S., Petrology and economic geology of the Skykomish Basin, Washington: Columbia School of Mines Quart., vol. 36, pp. 154-185, 1915.

N. 50° W. This draw is then followed to the divide. On the other (northwest) side of this divide is another talus-filled draw; about 500 feet down and on its southwest side, under an overhanging cliff of biotite granodiorite, is the main open cut, designated by the writer as Trench No. 1.

This trench is located at an altitude of about 5,350 feet. The altered zone in the granodiorite strikes N. 55° W. and dips 70° SW. In places it is extremely weak, but it seems probable that the draw up to the divide and the one down to the Dawson and beyond to Bear Lakes follow this zone of weakness in the granodiorite.

A zone of relatively intense alteration can be traced northwest from Trench No. 1 for about 100 feet. Slide rock from the overhanging cliff prevents the zone from being followed to the southeast. A distance of 25 feet northwest of Trench No. 1 is Trench No. 2, three-quarters of which was covered by the previous winter's snow at the time of the writer's visit on September 2, 1948. In these two trenches the hydrothermally altered zone is 11 feet thick, but the mineralization appears to have been stronger in Trench No. 1. The principal mineralization was within 1½ feet of the hanging wall and consisted of silicification, carbonatization, and pyritization accompanied by the deposition of small amounts of stibnite in the form of radiating bladed clusters up to about half an inch in diameter.

As glacial erosion has not been particularly effective here, considerable weathering has taken place. Most prominent is the transformation of the manganese carbonate to black manganese oxide and/or wad with the elimination of carbon dioxide. The stibnite has been oxidized to yellow stibiconite. There is also a small amount of limonite present. Numerous other thin parallel altered limonite-stained fractures occur in the immediate area, but they are all relatively inconsequential.

Bear Basin mine, Adit No. 3

NE¼ sec. 23, T. 25 N., R. 10 E.

The Bear Basin mine is reached from Snoqualmie by a gravel road running north up the North Fork of the Snoqualmie River for 18 miles to sec. 20, T. 25 N., R. 9 E., where it crosses the Snoqualmie River and continues on for 6 miles up the North Fork to Lennox camp. From Lennox camp 6 miles of good Forest Service trail follows up Lennox Creek and then up Bear Creek to the camp located in a glacial cirque known as Bear Basin. The camp is located at an altitude of about 4,300 feet approximately in the center of the glacial cirque, which is about 4,000 feet in diameter. Steep walls of granodiorite rise about 500 feet to the first rim on the north, east, and south. It is in these walls that the mine workings are located. Above this rim the slope is gentler, rising up to 5,800 to 6,000 feet above sea level at the crest. From here one can look east down into the valley of the West Fork of the Miller River and more specifically

into the cirque in whose west wall the Cleopatra mine is located. On the northeast rim of Bear Basin, 600 feet above the camp, is a smaller and still higher cirque containing two glacial tarns known as Bear Lakes. Streams run down the walls of the main cirque, providing some water. The timber is small and scattered, but large enough for some mine timbers. It consists for the most part of Alaska cedar and noble fir.

The Bear Basin mine is owned by the Bear Basin Mining Co., which holds 25 claims by possessory title. James R. Crippen, 1522 Lafayette N., Bremerton, Washington, is president. There is a total of about 1,900 feet of drifts and crosscuts on this property, but as only Adit No. 3 contains antimony, this discussion will be confined to that working.

Adit No. 3, at an altitude of 4,600 feet, is about a third of a mile S. 36° E. from the Bear Basin camp. The 4-foot fault zone along which this adit has been driven for 454 feet is in biotite-hornblende granodiorite and has a general strike of S. 75° E. and a dip of 75°-80° S. at the place where the adit was started. Both the hanging wall and footwall show horizontal grooving on their slickensides, indicating horizontal movement. The several inches of fault gouge and strongly sericitized granodiorite immediately adjacent to the vein walls contain stringers of various sulfide minerals and a pink and gray carbonate gangue. This carbonate contains substantial amounts of manganese, calcium, and magnesium, and about 2 percent iron; and has an index of refraction for the ordinary ray of about 1.76-7. It is identified as mangandolomite. The pink carbonate is altered to psilomelane on the surface. The central 2 to 2½ feet of the fault zone is composed of less strongly sericitized and kaolinized granodiorite. This condition continues for the first 40 feet of the adit, then the footwall slip changes its dip to 48°, and a horse of very slightly altered rock comes in between the two slips. The horse continues for 50 feet, to where, at a distance of 90 feet from the portal, the two slips come together. Here the dip is 80° to the south, and a general absence of the effects of mineralization and hydrothermal alteration is apparent. Beyond, the altered part of the granodiorite increases in thickness to about 3 feet for another 20 feet before narrowing again at 110 feet from the portal. Here a zone about 1 foot thick has a fine, thin gouge seam and practically no sulfides. This seam continues for 65 feet to where, for a further distance of 50 feet, the back has been mined out for a height of 15 feet above sill level. At this place the fault splits and widens, hydrothermally altered granodiorite again occurs over a thickness of 4 feet, and some sulfides are present. Beyond this, the zone thins again to a gauge seam showing about 6 inches of altered granodiorite on either side. This condition continues for a distance of 175 feet, or 408 feet from the portal, where the gouge seam is joined by a 3-inch mineralized veinlet striking

N. 45° W. and dipping 42° S. From this junction the mineralization was much more intense for a distance of 10 feet along the strike. Here the vein dips 70° to the south. Within this 10-foot distance the following characteristics across the vein were observed from hanging wall to footwall: 3 inches of gouge, 6 inches of sulfides (pyrite, arsenopyrite, sphalerite, freibergite, and jamesonite, all in mangandolomite and quartz gangue), 7 inches of sericitized and kaolinized granodiorite, and again 1 inch of sulfides. Beyond this place, the altered zone thickens to about 5 feet at a point 23 feet from the face, and then thins to a foot of gouge in the face, which is practically barren. The gouge zone in the face dips 90°.

In from the portal 40 feet on the south side of the adit a winze 20 feet deep has been sunk; at the time of the writer's visit this was full of water, but Mr. Sauers, former president of the company, reported that the fault zone is 8 feet thick in the bottom of the winze.

Very little stibnite was seen in the vein, it being identified only from one specimen from near the shaft. It proved to be a silver-bearing stibnite and occurred as filling in a drusy quartz veinlet which cut the crustified mangandolomite. Also present in the same specimen were blebs of andorite and stannite. From this and other specimens taken along the vein a general idea of its depositional history was obtained, even though this history in its entirety was nowhere demonstrated in any one cross section of the vein.

First, there appears to have been an introduction into the vein fissure of quartz, pyrite, arsenopyrite, and sphalerite which contains chalcopyrite blebs. Probably during this early sulfide stage the walls adjacent to the fracture were silicified and sericitized and partially replaced by fine scattered specks of pyrite and arsenopyrite. This wall-rock alteration effect extends for a fraction of an inch to as much as a foot out from the fissure. The quartz, continuing to deposit after this early sulfide stage, developed drusy vugs that are filled with jamesonite, freibergite, and minor amounts of galena. This filling may have taken place during the second stage of vein formation. The second stage started with slight brecciation allowing the introduction of mangandolomite along with andorite, stannite, and sphalerite. Local mangandolomite crustification bands on the vein walls were formed at this time. Mineralization of this mangandolomite stage can be seen quite clearly to have cut through and to have replaced that of the first stage. A still later and more gentle brecciation permitted an introduction of quartz with fine-grained pyrite and arsenopyrite. Some of this generation of quartz shows fine colloform banding, and drusy quartz vugs and veinlets are common. This late introduction of quartz and sulfides presumably replaced all preceding minerals. Lastly, small amounts of silver-bearing stibnite were deposited in some of the drusy

veinlets of this latest generation of quartz. Thus, a steady decrease of temperature during the formation of the vein appears to be indicated.

Nowhere in the vein were the antimony-bearing minerals, stibnite, jamesonite, freibergite, and the rare mineral andorite plentiful enough to be of more than mineralogic interest.

Coney Basin mine

NW¼ sec. 19, T. 25 N., R. 11 E.

The Coney Basin mine, whose location is shown on figure 5, was not known to contain an antimony-bearing mineral and so was not visited in connection with this investigation. Later, an assay of a specimen became available and showed:

Specimen assay from Coney Basin mine

Gold (ounces per ton)	0.64	
Siver (ounces per ton)	20.20	
Copper (percent)		0.5
Lead (percent)		6.9
Zinc (percent)		4.6
Iron (percent)		11.8
Antimony (percent)		0.6
Arsenic (percent)		2.03
Bismuth (percent)		0.074
Sulfur (percent)		14.9
Insolubles (percent)		55.4
Total		96.804

The minerals reported present were pyrite, arsenopyrite, sphalerite, chalcopyrite, silver-bearing galena, and another mineral assumed to be tetrahedrite. It is obvious from the assay that this assumption must be in error, since if both chalcopyrite and tetrahedrite were present the copper content would have to be higher than the antimony content. It is more likely that a small quantity of the mineral jamesonite is present, as is characteristic of other properties of this area.

KITTITAS COUNTY

Denny prospect

NE¼ sec. 10, T. 23 N., R. 14 E.

The Denny stibnite prospect, formerly owned by Fred Denny of Seattle, is located on the west bank of the Cle Elum River, 1.6 miles above Fortune Creek. The property is at the foot of Goat Mountain on its northeast slope at an altitude of about 3,700 feet, which at this place is about 300 feet above the Cle Elum River. This prospect has been opened up by a 178-foot adit and three open cuts. The adit dump is visible from the Cle Elum River road. All of the workings are on the north bank of a small creek that flows N. 80° E. into the Cle Elum River, and at present, in order

to reach the workings, the Cle Elum River must be forded and a trail made.

The uppermost open cut, arbitrarily designated as A, is about 110 feet vertically above the adit. Cut A is in white massive medium-grained sandstone of the Swauk formation of Eocene age and exposes a vein 6 inches thick which contains widely scattered stibnite in a quartz gangue. The vein can be traced for about 15 feet up the creek beyond the open cut A to where it seems to die out. The footwall of the vein is a fault surface that strikes N. 80° E. and dips 35° N. Grooves in the slickensided surface indicate some movement along the dip. Cut B is below A, 35 feet down the slope of the creek. Here the vein is in a bedded sandstone striking N. 15° W. and dipping vertically, and the vein has the same characteristics and attitude as at cut A. At 50 feet farther down along the creek is cut C. Here is exposed a fault contact between serpentine and a sedimentary breccia into which the overlying sandstone has graded; the stibnite vein is in the breccia. This breccia is composed of light-colored angular, subangular, and rounded fragments up to ½ inch in diameter, which consist largely of quartzite, silty argillite, and a few fragments of granite and graphitic schist. The groundmass is dark gray, and under the microscope can be seen to be composed of an exceedingly fine quartz mosaic which has calcite and shreds of sericite scattered through it. It apparently was this breccia that was considered to be part of the Keechelus lava by Smith and Calkins.[1] The writer considers it to be a basal phase of the Swauk formation.

In the breccia the stibnite vein, though it still maintains its same strike and dip, has changed to a mineralized fracture zone that varies all the way from 4 to 12 inches in thickness and averages about 6 inches. Within this zone the breccia has been fractured, allowing the deposition of thin stringers of drusy quartz containing scattered stibnite as felted masses and individual blades. The stibnite commonly fills vugs in the quartz, so it was the later of the two to crystallize. However, as none of these individual stringers are more than an inch in thickness, as the vein shown in cuts A, B, and C can be traced only for about 100 feet along its strike, and as even in this relatively short distance there are many stretches where the quartz carries no stibnite, any great quantity of stibnite can hardly be expected.

In cut C the fault contact between the breccia and the main mass of serpentine, which is so widely present to the east of Goat Mountain, is well exposed and occupies a zone some 2 feet thick. The fault which forms the west wall of the contact zone strikes N. 35° W., and close to the surface in cut C it has a vertical dip, but about 15 feet below the surface it dips 75° NE. The stibnite

[1] Smith, G. O., and Calkins, F. C., Description of the Snoqualmie quadrangle: U. S. Geol. Survey Geol. Atlas, Snoqualmie folio, (no. 139), p. 14, 1906.

vein steepens its dip to 40° N. as it approaches this fault, and either ends at the fault or has been displaced by the fault. If the former conclusion is correct, the stibnite can be considered to have been deposited in a gash vein. The gash-vein interpretation appears to be the most reasonable because of the greater competence of the Swauk breccia as compared to the serpentine.

The contact zone between the breccia and the serpentine exhibits the type of mineralization referred to locally as a "nickel ledge" or "nickel dike" (see p. 64), even though it may contain only a negligible percentage of nickel. This zone, as stated previously, is about 2 feet thick, and its west side makes a fault contact with the Swauk breccia. Fracturing indicates that the breccia moved down relative to the mineralized contact zone. The east side of the zone grades imperceptibly into the serpentine. As is typical, this zone is a gray, to buff, to red-brown dense silicified and carbonatized rock which contains disseminated pyrite, magnetite, and chromite as well as scattered specks of a green mineral which has not been positively identified. A piece containing a considerable amount of this green mineral gave a strong positive test for nickel. Hobbs and Pecora[1] found the nickel associated with a similar kind of rock occurring in marcasite, bravoite, and a greenish ankerite. This last mineral might be the source in this instance, as considerable carbonate is present, some of which has an index of refraction too high for dolomite. Undoubtedly the original source of the nickel is the serpentine, as it is characteristic of the serpentine in the western Cascade Mountains to carry approximately 0.2 percent nickel.

A microscopic examination of a thin section from the contact zone shows it to be composed largely of the fine cryptocrystalline mosaic that is characteristic of chalcedonic quartz; but also present are dolomite, another unidentified carbonate of higher index, and, locally, considerable talc. Because of the high percentage of silica and carbonate in this variety of rock, it has become known as "silica-carbonate rock." Besides the nonopaque minerals, it contains the pyrite, magnetite, and chromite mentioned above, as well as fine specks of arsenopyrite containing minute inclusions of cobaltite. All these opaque minerals can be seen to be corroded and replaced by the nonopaque minerals. As chromite and magnetite are very common in the serpentine, they are more than likely remnants of it. Also, in two instances the chromite was seen to be replaced along fractures by pyrite. Thus it is more logical to assume the chromite to be a hold-over from the serpentine environment where it is common, than to have been introduced with the sulfide minerals. Crisscrossing the thin section are fine thin stringers of dolomite and quartz, representing the youngest activity.

[1] Hobbs, S. W., and Pecora, W. T., Nickel-gold deposit near Mount Vernon, Skagit County, Washington: U. S. Geol. Survey Bull. 931-D, pp. 67-68, 1941.

The foregoing observations seem to indicate that there was faulting along the contact of the serpentine and the breccia which severely crushed the serpentine in the vicinity of the faulting and left it most susceptible to replacement by incoming hydrothermal solutions. Sufficient iron, nickel, magnesia, and silica were probably present in the serpentine for the roles they played in the transformation of the serpentine to silica-carbonate rock, but arsenic, cobalt, sulfur, calcium, carbon dioxide, and perhaps additional silica must have been added to them by the hydrothermal solutions. As mentioned previously, the sulfides evidently were the first to crystallize, and were followed by the chalcedony, carbonates, and, locally, a talc mixture. Later there was fracturing and deposition of quartz and dolomite in the fractures. The serpentine was entirely replaced except for the chromite and magnetite, as already mentioned. A late phase of this mineralizing activity probably was responsible also for the stibnite vein in the Swauk.

The original serpentine rock was evidently saxonite, as a thin section shows olivine and enstatite remnants. Shortly after the crystallization of these two minerals rather extensive hydration must have taken place, for the microscope reveals that the olivine crystals are surrounded by large halos of antigorite and the enstatite is altering to bastite. Also shown is a small amount of serpophite, a massive amorphous, almost structureless mineraloid associated with antigorite and composing part of serpentine. It occupies the same position with respect to the antigorite as the olivine remnants. Also veinlets of chrysotile crisscross the slide. Two other minerals were noticed in the slide, chromite and magnetite. Only a few grains of the former are to be seen, and its paragenetic relations to the other minerals could not be accurately determined. The magnetite occurs as narrow veinlets and ribbons of tiny individual octahedral crystals forming a polygonal pattern about the olivine-antigorite crystals only. Evidently the magnetite came into existence as an alteration product from the olivine as the antigorite was formed.

The 178-foot adit was driven S. 82° W., starting in serpentine. The elevation of its portal is approximately 70 feet below the point at which the fault changes its dip from 90° to 75° NE. in cut C. The fault was intersected in the adit 125 feet from the portal, where it has a strike of N. 30° W. and a dip of 75° NE. The remaining 53 feet of the adit is in the Swauk formation. It is quite apparent that the reason the adit did not intersect the stibnite is because the adit was driven too far to the south and therefore runs in under the stibnite vein.

From the foregoing observations it is evident that the deposit holds little promise as a stibnite producer.

LEWIS COUNTY

Reeves prospect

Center NE¼ sec. 29, T. 15 N., R. 11 E.

The Reeves property is at an altitude of 5,300 feet on the crestline of the Cascade Mountains. It is reached by the Frying Pan Lake trail from the highway 3 miles south of Ohanapecosh Hot Springs. From Frying Pan Lake no trail leads to the property, but it is ½ to ¾ mile up the hill to the northwest of the lake. The country to the east and southeast is extremely beautiful, being a marshy timbered (jack pine) upland having many small lakes; above these rise mature rounded hills and the steep-sided recent volcanic cone of Tumac Mountain. The upland has an average altitude of about 5,000 feet, rising gently to the east from the headwaters of Summit Creek to the crestline at about 5,300 feet in altitude.

The property was located in 1933 by W. R. Reeves for the Universal Alaska Mining Corporation. The single claim staked, known as the High Jack No. 2, was open for staking in 1947.

The working consists of a trench leading into a caved adit driven in greenstone and is located about 450 feet below the summit of the prominent timbered hill northwest of Frying Pan Lake. It exposes a hydrothermally altered zone about 10 feet thick, containing at its center a 6- to 8-inch stringer of vuggy quartz-cemented greenstone breccia. This altered zone strikes N. 35° W. and dips 70° NE. It can not be traced on the surface in either direction. If it were a strong feature, it could have been observed in the excellent exposures up the hill from the workings. The stibnite occurs with the quartz, which can be seen to have penetrated and to be disseminated through clusters of stibnite. From this it would appear that, as is taking place at Steamboat Springs, Nevada, the stibnite crystallized while being carried by the silica-rich solutions; that is, while the quartz was crystallizing from these solutions it penetrated through and in part replaced the clusters of stibnite. A small portion of the stibnite has oxidized to grayish-white stibiconite.

About 100 feet below the working is the contact of the greenstone and underlying graywacke. The attitude of the contact could not be determined, but it is quite probable that it is between the Miocene Keechelus andesite and the underlying Eocene Puget series.

OKANOGAN COUNTY

Carlquist prospect

SE¼NW¼ sec. 30, T. 40 N., R. 29 E.

Some doubt exists as to the exact location of the Carlquist prospect, but it is approximately ½ mile east of Mud Lake and 10 miles east of Oroville, in the rich wheat land of the high rolling plateau country just east of the Okanogan Valley and about 2,000 feet above it. As near as the writer could learn, the land was owned by John Widell in 1947.

The writer visited the property with Mr. Dunn of Oroville, and it is suggested that anyone wishing to find the one open cut obtain the guidance of someone very familiar with this area, because the working is overgrown with grass and surrounded by wheat fields. The pit, dug in quartzite, is about 5 feet square and 4 feet deep, the best exposure being in the east wall. At the north end is a steeply dipping sheared contact between a carbonaceous schist on the north and a quartzite on the south. The schistosity strikes N. 88° E. and is parallel to the quartzite contact. The carbonaceous schist is laced with limonite-stained quartz stringers about 2 inches thick and 2 to 2½ feet apart. About 2 feet south of the schist-quartzite contact is a fault in the quartzite now mineralized with quartz about 4 inches thick. This fault strikes N. 75° E. and dips 73° S. A polished section of this quartz shows that it and scattered subhedral crystals of arsenopyrite were deposited first; later, boulangerite was introduced, replacing the earlier minerals along fractures.

Mr. Dunn related that the original owner, Mr. Carlquist, thought he had found stibnite. Apparently, Mr. Carlquist discovered a very high-grade lens at the surface and started a shaft on it. All that is now left of this lens and shaft is the small pit containing the 4-inch quartz vein. Mr. Dunn said that according to some of the old-timers this high-grade lens had been faulted off at depth. Because of the caved and overgrown conditions of the pit, there was no way for the writer to either confirm or deny these statements. Likewise. it was impossible to trace the fault on the surface.

Lucky Knock mine

SW¼ sec. 19, T. 38 N., R. 27 E.

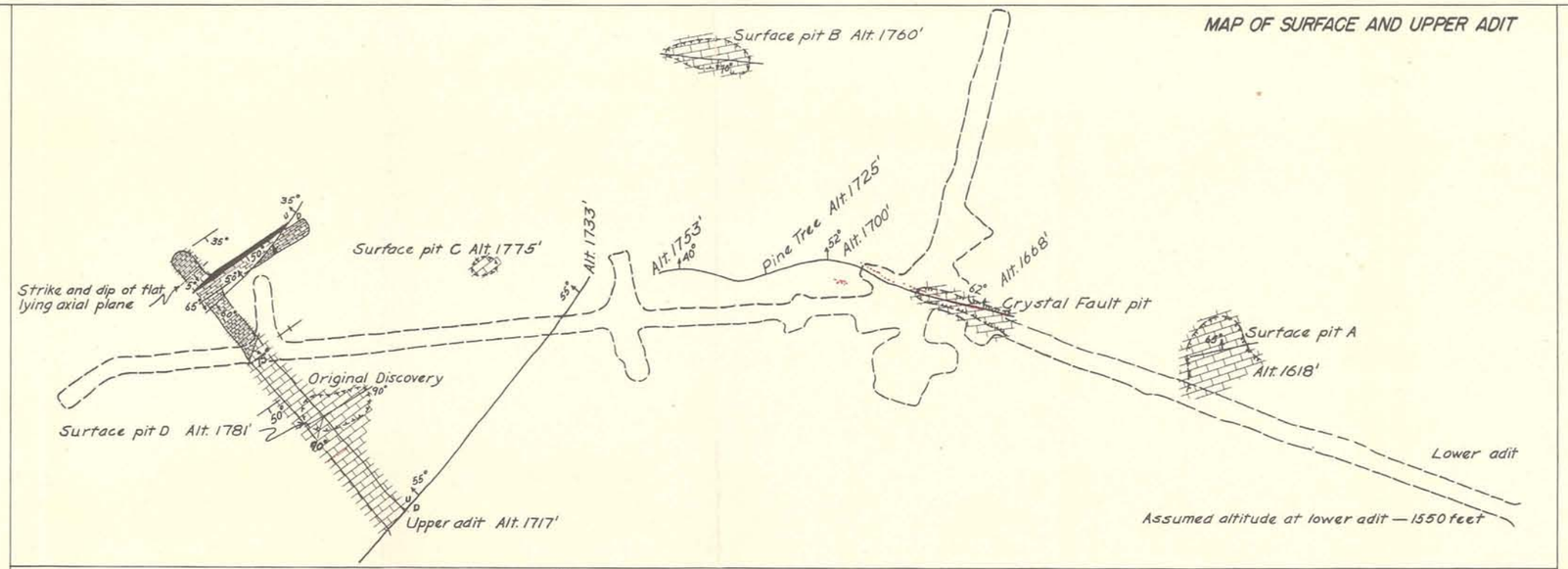
INTRODUCTION AND HISTORY

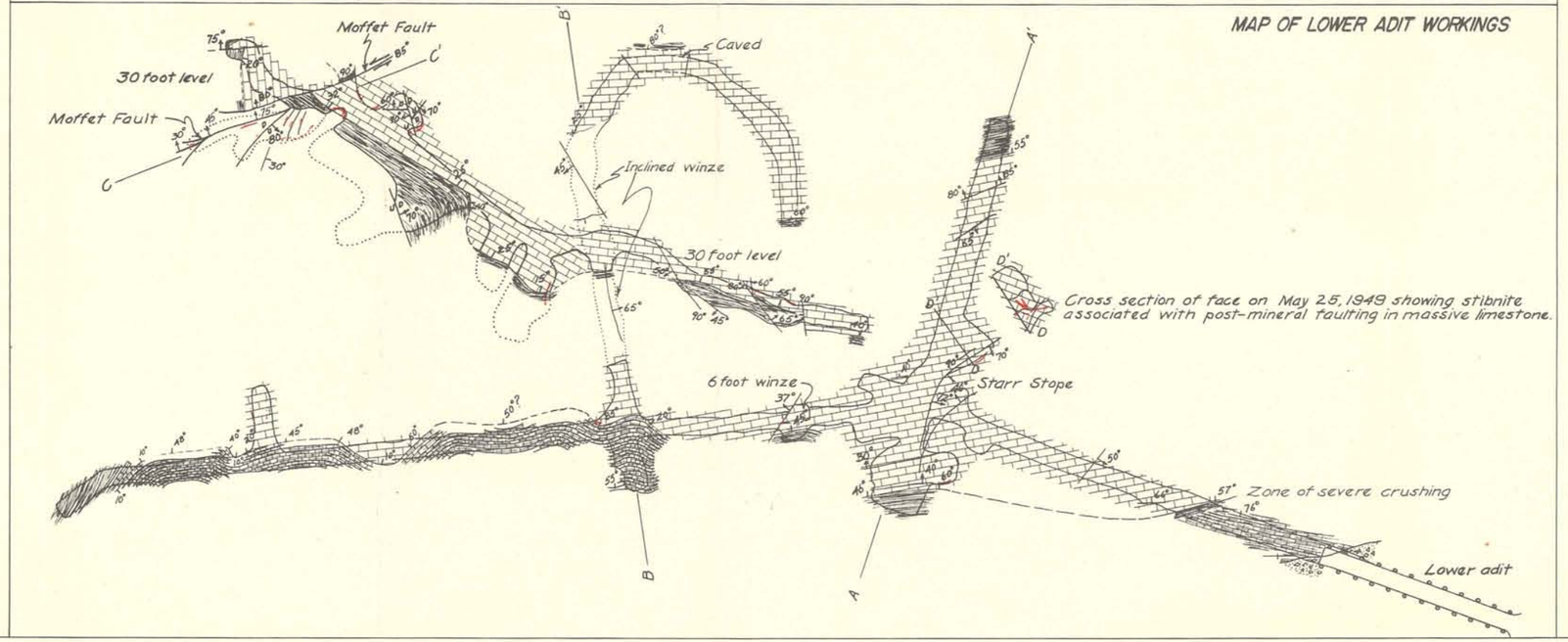
The Lucky Knock mine is located in the semi-arid Okanogan Valley 5 miles north of Tonasket opposite the foot of the extreme western slope of Whitestone Mountain and on the eastern edge of Cayuse Mountain. The property is reached by taking the road from Tonasket to the town airport, and then on past the airport to a low divide between the Whitestone Lake drainage on the north

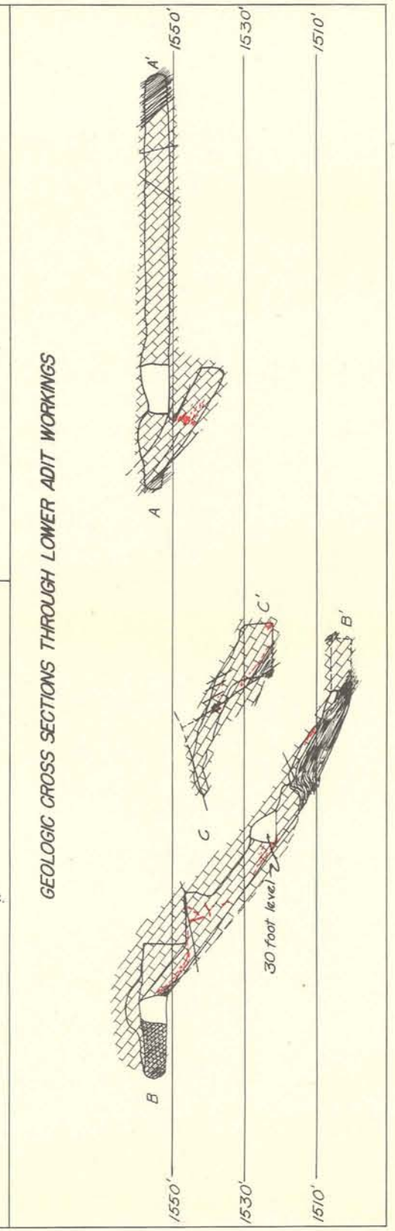
FIGURE 6 – GEOLOGIC PLAN OF LUCKY KNOCK MINE

EXPLANATION

- Glacial till
- Spessartite
- Limestone, massive with intermittent thin beds
- Phyllite
- Interbedded phyllite and thin bedded limestone
- Bedding, showing strike and dip
- Contact, showing dip
- Projected contact, showing dip
- Fault, showing dip
- Stibnite
- Lagging and cribbing







and the Okanogan River to the south. Just north of the divide a road leads off to the west up a low valley, in the middle north side of which are the mine dumps. Whitestone Mountain rises abruptly on the east for 1,300 feet above the divide, which is merely the high spot in the valley floor. The cliffs which make up Whitestone Mountain are composed of brilliant white beds of coarse sandstone containing abundant tuff fragments interbedded with coarse conglomerate. These beds are overlain by about 300 feet of andesite flows which cap the mountain. Across the valley on the west is Cayuse Mountain, which rises in gentle undulating slopes to a high point of 1,250 feet above the valley floor. This mountain is composed of metasediments, metavolcanics, limestone bodies, and alluvium. The bedrock is late Paleozoic and lies unconformably beneath the early Tertiary white beds of Whitestone Mountain. The northward-trending valley separating Whitestone and Cayuse Mountains is only an eighth of a mile wide at its narrowest point and widens rapidly to the north and south to as much as a mile in width. Its floor is perfectly flat and, like the surrounding country, covered with sagebrush. This valley was formed apparently as an old pre-glacial drainage channel and modified during the melting of the ice. The broad flat bottoms, characteristic of the north and south ends of this northward-trending valley between Whitestone and Cayuse Mountains, may have been constructed by the formation of two glacial lakes, one at the north end of the valley where it joins the Whitestone Lake valley and the other at the south end, where this northward-trending valley joins the Okanogan valley. The two glacial lakes probably were formed because the ice melted from the northward-trending valley before it left the valleys of Whitestone Lake and the Okanogan River. Consequently, melt water and general run-off were trapped in the two lower ends of the northward-trending valley, forming lakes. Fresh glacial erratics near the highest summits in the area show that the summits were completely covered by ice during the last Glacial period.

The Lucky Knock has had a long and varied history, the records of which have been assembled from different sources, principally from Mr. Wilbur Starr of Omak, and here are pieced together into as coherent an account as possible. In 1904 or 1907—there seems to be some confusion as to the exact date—the initial location was made by William Ingram, a homesteader. It seems that while staking out a fence line he stumbled over an outcrop, became angry and threw his hammer at it, breaking some of it loose. Much to his surprise, shiny and metallic surfaces were revealed on the interior of the broken fragments. Their exterior must have been a dull-white to gray antimony oxide, the same color as the surrounding limestone, and consequently until this incident had gone

unnoticed. He gathered up some of this material, had it assayed, and found that he had stibnite. He had indeed made a "Lucky Knock." This original outcrop is designated as Pit D on the map, figure 6. Mr. Ingram took out the high grade from this pit by sliding it down the hill in hides; as this was both expensive and tiresome, a wagon road was later built to reach the west side of the hill. The U. S. Geological Survey, in Mineral Resources for 1907 and 1908, mentions ore rich enough for a shipment being produced at the Lucky Knock, but very little being shipped. However, contrary to this, Dan Moffet reported that Mr. Ingram did ship from the original pit 40 tons assaying 62 percent antimony and that it brought $1,666.66 net. Further, corroborating Mr. Moffet's report, Wilbur Starr said that his father worked at the original discovery and that they shipped ore from the top of the hill to Brewster by team, thence by boat to Wenatchee, and by train to the East. Mr. Starr reported this activity to have taken place in 1908. After that activity the property was idle for a number of years, then about 1915 it was taken over and operated for a couple of years by the Standard Sanitary Manufacturing Co. of the American Radiator Corporation. During this time Wilbur Starr's father and Dan Moffet were in charge of the mining but working under the direction of a representative of the Standard Sanitary Manufacturing Co.

The greater part of the underground work was done between 1915 and 1917. The upper adit was driven first in an attempt to intersect the original high-grade pocket. When this failed, the company's attention was drawn to the crystal fault shown in figure 7 in the side of the hill. As stibnite occurs along this fault, it was concluded that an adit to cut the fault at depth would expose ore. Consequently, the lower adit, as shown in figures 6 and 7, was started. In the Starr stope, figure 6, a large body of high-grade stibnite was intersected. As can be seen from the geologic map, there is no relation between the fault on the surface and the fractures in and around the Starr stope, but nevertheless the ore was found. With this encouragement, a plant was built on the property for the purpose of transforming the stibnite into white antimony oxide to be used in the manufacture of bathtub enamels. In addition to the manufacturing of oxide, some shipping of high-grade stibnite also took place. According to Mr. Moffet, in order to obtain water for the oxide plant a well was put down to a depth of 321 feet. No stibnite was found in the well. He also reported that, as he remembered it, about 10 cars of ore (500 tons) was shipped and that a lot of trouble was had in maintaining grade. Aside from the Starr stope, most of the stibnite was obtained just south of the Moffet fault on the "30-foot level." Along about 1917 or 1918 the property was shut down. However, in 1920 six claims

PHOTO, COURTESY OF E. A. MAGILL

FIGURE 8.—View of the Moffet fault at the northwest end of the 30-foot level in the Lucky Knock mine.

PHOTO, COURTESY OF E. A. MAGILL

FIGURE 7.—View of surface workings and portal of lower adit at the Lucky Knock mine.

covering the property were brought to patent, even though all the workings and the mineralized area are on one claim, the Lucky Knock. After 1921 the workings caved and the property lay dormant for 20 years. In 1941 Whitestone Mines, Inc. bought the property and obtained a quitclaim deed. R. A. Clark, President, now deceased, and J. H. Engleman of Seattle had the old workings cleaned out and then shipped a car of ore, most of which was obtained just south of the Moffet fault on the 30-foot level; 2 or 3 tons came from the Starr stope. This car of ore (43 tons) was shipped in 1941 to the

Harshaw Chemical Co. in Los Angeles; it was hand-sorted, ran 30.47 percent antimony, and brought a net return of $1,873.00.

From 1941 to 1948 the property again lay dormant. In the spring of 1948 Mr. E. A. Magill of Seattle obtained a lease from the Whitestone Mines, Inc., and in the fall of that year he commenced to clean up the old workings. Mr. Magill began production in the spring of 1949, and he continued to operate for 9 months. During this time he made 7 truck shipments of high-grade lump stibnite to the Portland, Oregon, battery-plate plant of Morris P. Kirk and Sons, a subsidiary of the National Lead Company. These shipments totaled 47.83 tons and averaged 55.9 percent antimony. The grade was maintained through careful hand-sorting, the bulk of the ore being obtained from the 30-foot level, and about 2 truck loads from the area of the Starr stope. During September 1950 Mr. Magill acquired title to the Lucky Knock property from the Whitestone Mines, Inc.

DESCRIPTION OF THE LUCKY KNOCK STIBNITE DEPOSIT

The rocks in the vicinity of the Lucky Knock mine are, apparently, upper Paleozoic, and have been designated as belonging to the Middle and Lower Anarchist series by Waters and Krauskopf.[1] They consist largely of chlorite schists, phyllites, quartzites, and metamorphosed conglomerates, limestones, and lavas. The stibnite is entirely enclosed within a bedded metamorphosed limestone body, or pod as it is called by Waters and Krauskopf, from whom the following description and discussion is quoted:

> A large pod of white limestone near the base of the Middle Anarchist crosses the mountain [Cayuse Mountain] near its north end. [The pod just mentioned strikes N. 60° E., is 2½ miles long, and varies in width from ½ mile at its northeast end to 1 mile at its southwest end.] Though locally contorted and variable, the layers forming this pod have an average strike of about N. 50° E. and dip northwest at angles of 20 degrees to 50 degrees. A short distance south of the limestone, chlorite schists and phyllites of the Lower Anarchist are extensively exposed. They are highly crumpled, but in the central part of Cayuse Mountain their prevailing strike is about north-south with steep dips to the east; the strike even turns to the northwest in the southern and western parts of the mountain. These rocks therefore appear to strike into and beneath the limestone pod almost at right angles. However, in a narrow zone immediately beneath the limestone pod the underlying phyllites are highly contorted. At the contact with the limestone they have usually swung around to approximate parallelism with the overlying bed. It appears that during deformation the highly incompetent phyllites and chlorite schists were minutely folded along planes roughly at right angles to the regional strike. However, the overlying strong limestone did not yield to these minor contortions, and has sheared more or less bodily over the weak rocks. Significantly, the axes of plications in these incompetent materials practically always maintain the same pitch as the dip of the massive limestone above.

[1] Waters, A. C., and Krauskopf, K., Protoclastic border of the Colville batholith: Geol. Soc. America Bull., vol. 52, pp. 1355-1418, 1941.

From the above discussion it is evident that the limestone in all probability is conformable with the underlying Lower Anarchist chlorite schists and phyllites. North, west, and east of the limestone, exposures showing its contact with the adjacent rocks are lacking, unfortunately; thus the actual relationships are unknown. The ridge just to the north of the Lucky Knock mine is composed of slates, coarse cherty sandstone, and metamorphosed andesitic lavas. The contacts between these are obscured. However, on the north side of the Spectacle-Whitestone Lake Valley about 4 miles north-northwest of the Lucky Knock and 1 mile west of Wannacut Lake, a group of northward-trending limestone bodies extend for 6 miles. These bodies are smaller, but generally similar to the body in which the Lucky Knock mine occurs. Also, they are better exposed. They were studied in detail in 1948 by Crosby,[1] who came to the conclusion that "the origin of the limestones in the Lake Wannacut area and perhaps elsewhere in the Okanogan Valley Paleozoic exposures is not to be attributed to reef formation but to normal processes of sedimentation. The present areal distribution of the limestone is largely to be accounted for by the fact that much of it has been replaced by other rocks."

In other words, the limestone was laid down as part of the normal process of sedimentation in a continuous horizontal bed, underlain and overlain by other sediments and lava flows. Later these rocks were buried within the earth's crust, folded, and attacked by solutions probably consisting primarily of water, potassium, sodium, and silica. The end result of this activity is the present erratic distribution of limestone, the intervening sections having been absorbed and replaced by the solutions.

Whether or not these conclusions are applicable to the Lucky Knock limestone body is completely open to debate. No large masses of silicified limestone or migmatite rocks, both types having been described by Crosby as extensively replacing the limestone in the Wannacut area, were seen in the area of the mine. Crosby describes the migmatites as fine- to medium-grained, brown to dark-green rocks composed largely of sericite, albite, and 0-30 percent quartz, with almost no ferromagnesian minerals, except in rocks which may have an intrusive origin.

Thus, nothing definite can be said about the formation of the Lucky Knock limestone body except that the limestone is apparently the result of the normal processes of sedimentation and is not of the reef type, mentioned as a possibility by Waters and Krauskopf.[2]

In the mine area, which is at the very northeastward limit of the limestone body, two rock varieties are in evidence, limestone and

[1] Crosby, James W., Limestones in the Anarchist series. Okanogan County, Washington, Master's Thesis, State Coll. of Washington, 1949.
[2] Waters, A. C., and Krauskopf, K., idem, p. 1360.

black phyllite. The limestone is dark to light gray, fine grained, and for the most part massive, though there are some sections containing thin beds. The black phyllite, which was not seen cropping out on the surface, is largely composed of extremely thin (0.5 millimeter) laminated layers of alternating black flaky material, which was originally an organic mud, and a mixture of white dolomite and quartz. The thin flaky material is extremely characteristic, and underground gives to the phyllite a very black coaly appearance. Exposed in the mine are the upper and lower parts of two members of the phyllite which are separated by the limestone that carries the stibnite. As can be seen on the map, the lower phyllite member strikes approximately westward along the upper workings of the lower adit and maintains a dip between 40° and 60° N. West of the inclined winze on the 30-foot level the strike of the phyllite swings to the northwest and the dip lessens to between 20° and 30° N. The uppermost part of the lower phyllite member, immediately underlying the main limestone bed, quite commonly contains interbeds of highly contorted and thin-bedded dark-gray limestones. These may be seen in numerous places along the upper workings of the lower adit, but they are best exhibited in the first 40 feet of the lower adit beyond the timbered portion of the portal. The upper phyllite member, of which only the lower part is exposed and that in just three places, differs very slightly from the upper portion of the lower phyllite. This upper member contains silt lenses and lacks thinly bedded limestone. These characteristics can be seen at the end of the north crosscut from the Starr stope and on the north side of the Moffet fault on the 30-foot level. The stratigraphic distance between the two phyllite members varies from east to west, measuring about 85 feet in the vicinity of the Starr stope and narrowing to 20 feet or less at the bottom of the inclined winze. As can be seen from the map, the contacts of the phyllite members with the intervening limestone are highly irregular. As mentioned before, no outcrops of phyllite can be seen on the surface. However, Mr. Magill reported that in the saddle southwest of the mine some argillaceous rock crops out in a small cut. This may or may not be one of the two phyllite members.

From the discussion so far, it is apparent that the principal stratigraphic relationships underground are quite simple, merely a main limestone member between two phyllite members. On the surface the situation is equally simple—just limestone. However, the relationship between the underground stratigraphy and the surface is completely unknown. It would seem logical, because of the general excellence of surface exposures, that the phyllites are lenses within the limestone and do not crop out. Equally perplexing is the complete lack of correlation between the fracturing and faulting mapped on the surface and the fracturing and fault-

ing mapped underground. The geologic maps of the surface and of the underground workings demonstrate this lack. For instance, there are three principal faults in the mine area, the Crystal fault, the fault at the entrance to the upper adit, and the Moffet fault, none of which seems to bear any relation to any other. The Moffet fault appears to be the strongest. Because of grooves and plucking on the slickensided surface, it appears that the principal movement has been horizontal, causing a displacement of 20 feet in the map area. A photograph of this fault is shown in figure 8, the slickensided surface appearing at the very right of the picture. Along with these principal faults are numerous minor fractures, such as those in the eastward part of the 30-foot level.

The geologic map shows the stibnite mineralization to have been extremely erratic. Nevertheless there was some semblance of control, which apparently was largely pre-mineral fracturing. On the surface this control is evident at the Crystal fault, shown on the map, and at the spots designated by pits A, B, C, and D. In the vicinity of the Crystal fault there are several patches of stibnite scattered at places where slight silicification and brecciation occurred. The most noteworthy feature along the fault is the vug in the immediate footwall of the fault from which Mr. Magill obtained excellent specimens of partly oxidized interfingering acicular crystals of stibnite as much as 6 inches long and ¼ inch in diameter. As far as is known, this is the only location in the state from which clusters of stibnite crystals have been taken. Pits A, B, C, and D all have in common the factor that the stibnite is associated with minor fracturing in the limestone. At none of these places is silicified limestone particularly evident. At pit B the stibnite occurs as a filling in gently dipping fractures about ½ inch thick and as a breccia filling. A polished section of the breccia filling shows small grains of quartz and yellow sphalerite corroded by the stibnite. The veinlets of stibnite that comprise the breccia filling are rarely more than 1 or 2 millimeters in thickness, and the breccia fragments are seldom more than 1 or 2 centimeters in diameter. The polished section reveals that thin films of antimony oxide have begun to form along the contacts between the limestone fragments and the stibnite.

Since pit D is the pit at which the original discovery was made and the one from which the first ore was removed, little stibnite is left for examination. The few scattered pieces in the area seem to indicate that the surface of the stibnite was completely oxidized to gray stibiconite and cervantite and that good crystals were common. The stibnite evidently occurred as individual bladed crystals growing in the limestone and as crystal clusters, perhaps similar to those found along the Crystal fault. It was only natural that as this surface showing was excellent it would be thought to extend to some depth; so the upper adit was driven directly under the ex-

posure and proved that it was only a shallow pocket. The adit was started in a 2-foot brecciated fault zone striking directly across the portal, and, strangely enough, no stibnite has been found associated with this fault. At 25 feet from the portal a few scattered specks of stibnite are to be seen in the back of the upper adit. The rest of these upper workings are barren of stibnite. However, in the walls 8 feet back from the face there is some extremely intricate folding in the bedded limestone. In the northeast wall, which is about 6 feet high, three sharp folds lie one above the other. Their flat-lying axial planes strike across the adit and dip 5° toward the portal. At 13 feet back from the face a drift was run toward the northeast; in this drift are a small dike and a thin sill. The rocks of both of these features are now hydrothermally altered and almost unrecognizable. After studying them with the microscope the most logical conclusion is that they were originally spessartite, which is the intrusive equivalent of andesite. The relationship between the sill and the dike is obscured by the thrust fault that cuts off the sill and probably the dike as well.

In the lower adit stibnite occurred principally in the Starr stope, down the inclined winze, and more-or-less throughout the length of the 30-foot level. Almost no stibnite is now visible in the Starr stope, as is indicated on the map. However, some conception of the manner in which the stibnite occurs was gained through visits to the property while it was being operated by Mr. Magill. According to Mr. Magill, he obtained particularly high-quality massive stibnite in two spots in the Starr stope; one, along the fault striking toward the northeast at the start of the north crosscut as shown on the map, and the other, in the eastward bulge at the south end of the stope. In both instances, as is characteristic for the occurrence of good-grade ore on the property, the stibnite occurs in silicified and fractured areas not far removed from the underlying phyllite contact and apparently overlying only that part of the phyllite which is lacking in thin beds of limestone. Presumably, silicification was necessary for the development of pre-mineral fracturing, for if there had been no silicification, the limestone probably would have deformed plastically instead of fracturing. These generalizations seem to be consistent throughout the lower adit wherever good stibnite ore did occur. The individual masses of stibnite varied greatly in size, but none probably contained much more than 30 cubic feet, or roughly 4¼ tons, i. e., a block 5 by 3 by 2 feet in size. Many of the stibnite masses had been subjected to post-mineral faulting of small displacement. In fact, all of the faulting shown on the map appears to be post-mineral, and thus one would normally consider it to have little to do with ore location. On the contrary, in the Lucky Knock it appears to be very important, as in this occurrence ore is almost never present where there are no faults. Thus, as indi-

cated above, it would seem that the areas of post-mineral faulting were also areas of the pre-mineral fracturing, which allowed the mineralizing solutions to enter. After the deposition of the stibnite, a brittle mineral, these areas probably were even more susceptible to fracturing than before.

Mr. Magill obtained the bulk of his ore from along the 30-foot level. At a distance of about 25 feet east from the inclined winze, stibnite was encountered and it continued for another 25 feet. This ore was associated with small post-mineral cross faults and was immediately overlying phyllite. However, in the face the rocks are very tight and the facies of the upper part of the phyllite member has changed to dark-gray thin-bedded limestones. No sign of mineralization can be detected. On the west side of the inclined winze the phyllite contact was again followed. All along the contact where there is fracturing, stibnite was found replacing the limestone in a highly erratic and discontinuous fashion immediately above the phyllite—sometimes along the limestone bedding and sometimes at right angles to it—but nowhere has the mineralization taken place more than a few feet above the contact. In some places the stibnite has even replaced the uppermost part of the phyllite along its laminae.

As an excellent stibnite mass was just south of the Moffet fault, Mr. Magill cut through it in order to pick up the phyllite contact, and he hoped to find more stibnite on the other side. Unfortunately, little or no stibnite occurred there, but heavy ground and phyllite were in abundance. Thus work at this heading was stopped at once.

The horseshoe-shaped working below the 30-foot level was made by the Standard Sanitary Manufacturing Co. Immediately below the 30-foot level and directly above the phyllite, as shown in the cross section through the inclined winze, there is a little stibnite in silicified limestone. Also, at this location a common and important feature of the geology shows clearly. The fault below the 30-foot level, indicated on the map as striking N. 30° W. and dipping 45° W., is visible only in the limestone, for the phyllite absorbed the strain without faulting or fracturing. This relationship of phyllite to faulting is prevalent throughout the mine. The phyllite member shows fracturing only where it contains limestone. It is probably because of this relative incompetence that the phyllite is so seldom mineralized.

A few polished sections and a thin section from the area south of the Moffet fault were studied. The thin section is particularly revealing. It shows calcite (limestone) recrystallized and impregnated by quartz, fractures filled with stibnite crisscrossing this calcite-quartz ground-mass, and a late introduction of calcite cutting across stibnite blades. One of the polished sections reveals the presence of a few grains of light-yellow sphalerite in the silicified limestone. One of these grains is cut by two bands of stibnite.

Another of the polished sections shows alternate bands, 2 to 4 millimeters thick, of gray limestone, which contains minute specks of pyrite, and white coarsely crystalline calcite. The manner in which the calcite crisscrosses the limestone bands plainly indicates that the calcite has replaced the limestone, perhaps after a series of essentially parallel fractures were developed in it. Minor faults of small displacement pass across the alternate limestone-calcite bands. In and along these faults are small euhedral bladed crystals of stibnite which occur separately and in clusters. The stibnite crystals are located almost entirely in the white calcite bands. The manner in which these otherwise euhedral crystals of stibnite are very markedly embayed indicates strongly that they have been replaced by the coarsely crystalline calcite. It is apparent that in this rock a very odd relationship is found, i. e., stibnite is replacing the obviously older white calcite band, which in turn is apparently replacing stibnite. A possible explanation is that there were two intervals of calcite introduction separated by minor faulting and deposition of stibnite. Because the same type of calcite was introduced at each interval, there is no way to distinguish between the calcite of the different intervals. The other polished sections merely seem to support the above observations.

According to the entire preceding discussion of the deposit, the sequence of the Lucky Knock deposition took place in three steps about as follows:

1. Deformation of the limestone, followed by its silicification
2. (a) Fracturing, faulting, and intrusion of spessartite
   (b) Hydrothermal alteration of spessartite and deposition of minor amounts of pyrite and sphalerite in the limestone
   (c) Deposition of the major part of the stibnite
   (d) Introduction of calcite
3. (a) Fracturing and faulting
   (b) Deposition of fine stibnite crystals along fractures
   (c) Introduction of small amounts of calcite

(Steps 2 and 3 actually may have been one continuous chain of events, with no appreciable time interval between.)

It is possible to draw certain inferences as to the source of the stibnite and the origin of the structures controlling its deposition. The origin of the latter seems to be rather consistently related to areas of silicification with very few exceptions, the anomalous area coming most immediately to mind being pit D, where brecciation and deposition of stibnite took place apparently with almost no preceding silicification. Generally, in the lower adit workings silica appears to be scattered through the limestone, with perhaps a preference for the limestone immediately overlying that part of the lower phyllite in which thin beds of limestone are lacking. This may be caused by two rocks of greatly different competency being

adjacent to one another. As deformation took place, the phyllite yielded by flowage and the limestone fractured ever so slightly, allowing the preferential replacement by silica in the prepared areas above the phyllite contact. After the silicification three rock varieties of different degrees of competency were present; in increasing order these were phyllite, limestone, and silicified limestone. The silicified limestone was the most susceptible to the stibnite mineralization. Actually, stibnite is found in all three rocks, and by no means do all areas of silicified limestone and fracturing contain stibnite. Also, it should be pointed out that the area around the Crystal fault and the area of pit D were quite susceptible to mineralization and that these areas are in no way associated with the phyllite. From this discussion it seems as though there is no regularity to the deposit whatsoever. In detail, this may be true. However, considering the deposit in a broad sense, a certain regularity does become evident. It is readily apparent that a definite vertical block of ground has been mineralized, for the mineralized area at the surface directly overlies the mineralized area underground. Furthermore, the stibnite underground, where present, overlies the lower phyllite member, while the stibnite on the surface is not associated with phyllite. The above facts would seem to indicate that the antimony-bearing solutions traveled upward along the fracturing immediately overlying the lower phyllite member until it pinched out, at which place the solutions ascended vertically through whatever fractures were available in the limestone. Thus, future development work above the lower adit probably should be done directly between it and the surface exposures, and the development work below the lower adit should be done down along the dip of the lower phyllite member.

The source of the stibnite is not readily apparent, but some thoughts on the subject may be worth recording. To go back again to the subject of silicification, this phase of activity possibly can be correlated with the silicification of the limestones in the Wannacut Lake areas as described by Crosby[1] and is, therefore, related to the late Mesozoic granite intrusives, i. e., the Similkameen and Whiskey Mountain granodiorites. It is also to these intrusions that most of the metallic mineral deposits in the general Tonasket area probably are related. True as the preceding statement may be, the stibnite mineralization at the Lucky Knock probably is not related to the Mesozoic granite intrusives, but rather to the Tertiary andesite flows. This is because the mineral deposition in the area, with the exception of the Lucky Knock, can be classified as either hypothermal or mesothermal; because intrusions of probable spessartite, hydrothermally altered, are to be seen in the upper adit; and because stibnite deposition is rather definitely limited to the low

[1] Crosby, James W., op. cit., 1949.

temperatures and low pressures of the epithermal class. Therefore, it seems only logical that the deposit at the Lucky Knock is quite unrelated to the other deposits in the area in time as well as source.

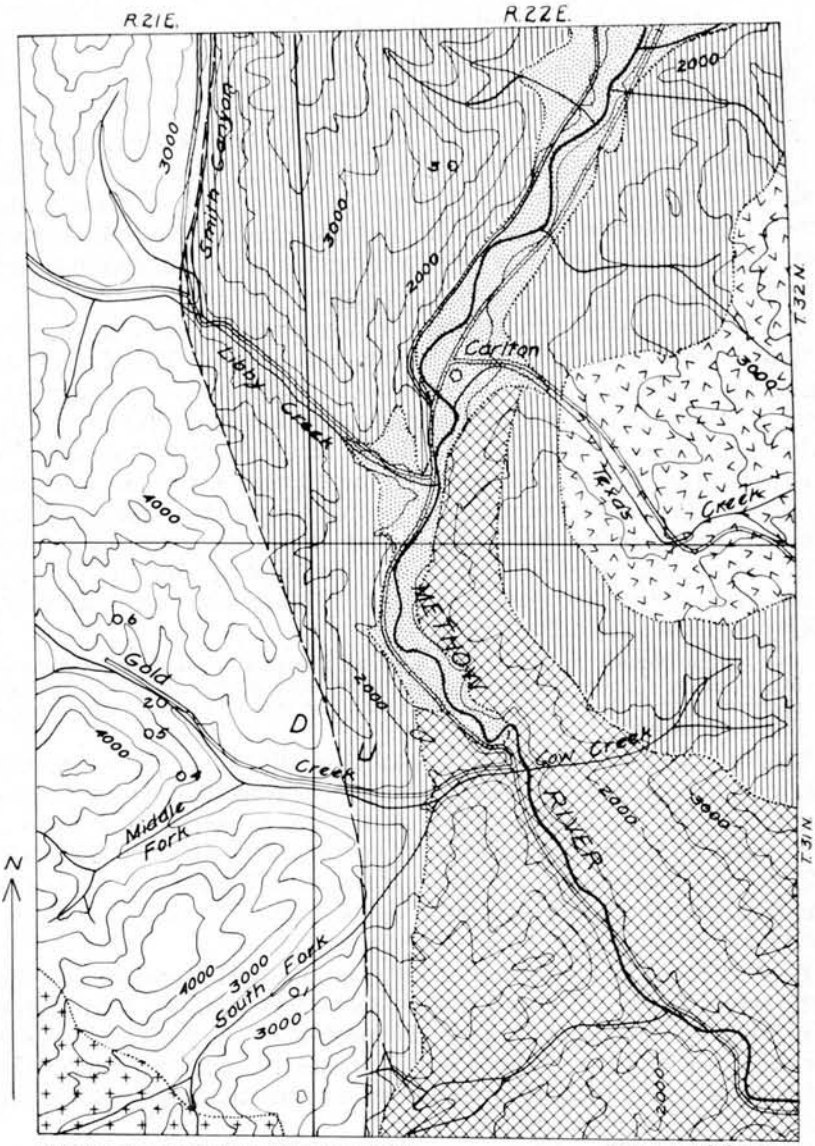
The future possibilities of the Lucky Knock are extremely difficult to evaluate. The extreme spottiness of the deposition makes it impossible to block out ore reserves by diamond drilling with any degree of confidence. This limits mining to the search for high-grade lump stibnite, wherever it may occur, and in turn the production of this material necessitates hand-sorting. Thus, costs are high. These factors combine to make a profitable operation next to impossible, except with a particularly favorable metal and labor market. Nevertheless, should all foreign sources of antimony be cut off, there is little question that a high-cost, high-grade product could be produced from the Lucky Knock. At present, as can be observed from the map, little or no stibnite ore is in sight. According to Mr. Magill, considerable drilling with long steel both above and below the Starr stope and in other favorable locations in the mine failed to reveal any stibnite.

Carlton-Gold Creek Area

The area shown in figure 9 is unique in that, up to the present time, it is the only area in the state where several stibnite deposits occur in a cluster. For that reason it is probably the most promising region for further prospecting and possible commercial production. The individual deposits are indicated by numbers in figure 9 as follows: 1. Antimony Bell, 2. Antimony Queen, 3. Bales prospect, 4. Coyote prospect, 5. Jumbo prospect, and 6. Stibnite prospect.

The entire map area has a general relief of about 2,500 feet, though the highest altitude is 5,400 feet and the lowest is 1,200 feet. The area contains portions of two physiographic provinces, the Okanogan Highland province to the east of the Methow River and the Cascade province to the west of it. The provinces in the map area are distinctive because of difference in angle of slope rather than relief. To the west of the Methow River the slopes rise steeply from the creeks for 1,500 to 2,000 feet and then become more gentle, giving a rounded appearance to the ridge tops. To the east of the Methow River the slopes are entirely of the more gentle and well-rounded type found only on the ridge tops west of the river. This difference is very striking when viewed from some of the prominent ridges.

The streams of the area are all consequent and youthful except Smith Canyon Creek, which is a youthful subsequent stream following a fault. The drainage pattern of the area is dendritic, as would be expected in a complex area of metamorphic and igneous rocks.



Base and topography from Methow quadrangle

Geology by J. D. Barksdale

Scale — Approximately 1 inch equals 2 miles

Contour interval 500 feet

EXPLANATION

- Alluvium
- Texas Creek quartz diorite
- Chelan batholith, granodiorite
- Newby formation
- Methow gneiss
- Leecher metamorphics
- Fault, approximate location
- Antimony occurrence

FIGURE 9.—Geologic map of the Carlton area showing the location of antimony occurrences.

General geology

The rocks of the area have been described by Barksdale,[1] and the following descriptions are taken entirely from his work.

In the very southwest corner of the map area are exposures of the Chelan batholithic complex, which in this area is a medium-grained biotite granodiorite. Its age is not definitely known, but some of the granitic rocks in the Methow quadrangle, which have been classified by Barksdale as belonging to the Chelan complex, apparently cut formations as young as Upper Cretaceous.

Just to the east of the Chelan complex is the Newby formation, in which most of the stibnite deposits are located. This formation is a series of black argillites, graywackes, tuffs, breccias, and metalavas of andesitic and possibly basaltic composition, which are estimated to be about 14,000 feet thick. A small stock of hornblende-quartz diorite, probably related to the Chelan complex, intrudes the Newby formation forming the country rock at a small stibnite prospect (no. 6 in fig. 9). Other small stocks showing similar relations were also noted by Barksdale in the Newby. He did not map these small stocks, because of their size relative to the map scale. Briefly to quote from Barksdale:

> . . . the Newby formation is a predominantly non-quartzose sedimentary section derived from volcanic rocks and interbedded with minor amounts of true flow rocks, sharply folded and faulted but only moderately metamorphosed.

The formation makes a fault contact (see fig. 9) with the Leecher metamorphics on the east, and on the west is intruded by the Chelan complex which has indurated the shales and breccias for at least a mile from the contact. The Newby formation has been tentatively assigned by Barksdale to a Triassic-Jurassic (?) age on the basis of lithologic character and its relation to the unconformably overlying Cretaceous rocks.

East of the Newby formation and on the upthrown side of the north-south fault are the Leecher metamorphics. It is in these rocks that the Bales antimony prospect is located. These metamorphics are a series consisting of distinctly banded hornblende schist, quartz-oligoclase-hornblende gneiss, biotite-quartz-oligoclase gneiss, and calc-silicate rocks.

Quoting from Barksdale:

> West of the Methow River the outcrops are poor, but there is evidence of intense shearing and the production of mylonites and phyllitic-appearing rocks derived from the medium-rank gneisses and schists. The strike of the foliation east of the Methow changes south of Carlton from nearly east-west to N. 45° E. northeast of the town. The predominant easterly dip varies from 25° to vertical. There is a macroscopically visible preferred orientation of the hornblende and mica within the gneissic banding, but statistical studies have not been attempted.

[1] Barksdale, J. D., Stratigraphy in the Methow quadrangle, Washington: Northwest Sci., vol. 22, pp. 164-176, 1948.

> The pronounced banding and the rapid alternation of rocks of diverse mineral and chemical compositions suggest that these are paragneisses derived from a series of impure arkosic sandstones and shales, basic lava flows, and, more rarely, limy sediments. Thin section study reveals evidence of both pre- and post-crystalline deformation of the gneisses.

On the east the Leecher metamorphics have been intruded by the Texas Creek biotite-quartz diorite, a phase of the Okanogan complex which shows very slight contact effects on the metamorphics. On the south they were invaded by the Methow gniess, an older intrusive than the Texas Creek diorite. The Leecher metamorphics are the oldest rocks of the map area, but no definite age can be assigned to them.

The Methow gneiss is a remarkably uniform granite now cataclastically metamorphosed to a distinctive biotite-granite gneiss. According to Barksdale,

> The gneiss has a marked foliation emphasized in outcrop and hand specimen by clots of biotite some of which are as large as a half dollar. The clots may be irregularly drawn-out ovoid areas of paper thinness or single ragged books of black biotite up to 2 mm in thickness. Outcrops paralleling the schistosity have a leopard-spot appearance.
>
> The gneiss is remarkably uniform in mineral composition when viewed in thin section. The feldspar is notably untwinned, clear and fresh, and within the oligoclase range. No potash feldspar has been found. The quartz is of consistently smaller grain size than the feldspar and appears in floods along the planes of shear. Some grains are unstained but others show strain shadows. Associated with the quartz is epidote and brown biotite. Much of the epidote is in prismatic euhedral form and has grown simultaneously with the biotite. Both minerals are for the most part post-shearing in age. Apatite and magnetite are the common accessory minerals.
>
> The Methow gneiss shows a concordance in structure with the overlying Leecher metamorphics north and east of the Methow River. Development of the gneissic structure in both formations was apparently accomplished at the same time, but there are details in the relationship of the remarkably uniform Methow gneiss with the heterogenous Leecher metamorphics not understood.

Conclusions

From the above discussion two ideas relating to the mineralization of the area appear plausible. The first is the preparation of the ground for deposition through fracturing, probably associated with the period of deformation which was responsible for the prominent north-south fault. The second is that the mineralization was an end phase of the intrusion and formation of the Chelan complex. Unfortunately, the relationship between the north-south fault and the Chelan complex is unknown. Too little investigation of the general geology has as yet been carried on to allow any more precise statements as to the fundamental origin of the mineral deposits.

Antimony Bell mine

NE¼SE¼ sec. 25, T. 31 N., R. 21 E.

The Antimony Bell mine is located at an altitude of about 2,300 feet on the southeast side 2 miles up along the South Fork of Gold Creek, which flows into the Methow River about 7 miles upstream

from the town of Methow. Here the mine workings are on a well-timbered northwest slope about 150 feet above stream level.

These workings are on the Antimony Bell claim held by location in 1948 by Charles Williams of Carlton, Washington. They are distributed for 270 feet along an almost eastward-striking thin, steeply dipping vein which shows evidence of very weak mineralization.

The westernmost working is a 5- by 5-foot shaft sunk 32 feet beside a shear in greenstone. A thin section of this greenstone, which is the country rock adjacent to all the mine workings, shows it to be a metamorphosed basalt composed of subhedral labradorite phenocrysts in a fine-grained groundmass of plagioclase and antigorite. Subhedral pyrrhotite is scattered throughout the thin section. Some of the plagioclase phenocrysts have been zonally replaced by sericite. Younger calcite stringers cut across the section at several places, and calcite specks are well scattered throughout the thin section. The antigorite may well have resulted from the alteration and hydration of augite. The shear, striking S. 66° E. and dipping 90°, is about 5 inches thick and contains a 1-inch seam of calcite. The calcite seam contains tabular vugs and acts as the cementing medium for locally brecciated greenstone. Red and white antimony oxides can be seen, but no stibnite is visible.

From the shaft the hill slopes upward at an angle of about 32°. Up this slope 75 feet east of the shaft is a 25-foot adit driven on the same shear as the shaft. Here the shear strikes S. 76° E. and dips 73° N., and is 10 inches thick where it occurs along the south wall of the adit. Slickensided surfaces show grooves pitching 30° to the east, and shear fractures indicate that the north wall moved up relative to the south wall. This zone is well brecciated and stained with limonite, but no indication of stibnite was seen. However, Mr. Williams said he had taken a quantity from a small lens.

About 125 feet farther up the hill on the same strike is an open cut driven to the south which shows at its face stibnite plastered along the walls of the shear zone. The zone dips vertically and has maintained its 10-inch thickness. About 15 feet above this cut and 10 feet farther along, the shear rolls to a 67° northerly dip. This rolling is well exposed on the north wall of a 20-foot adit. Shear fractures in this adit show that the south wall moved west relative to the north wall. No stibnite was seen, but it was from here that, according to Mr. Williams, 3 tons of stibnite was shipped from a lens about 2 feet thick. This does not seem unreasonable. Also, as the north wall apparently moved up relative to the south, it would be in areas of flatter dip that lenses of ore would be expected.

Around the hill from the 20-foot adit is another one about 25 feet in a straight line from the face of the second adit. This third adit is driven S. 15° E. for 25 feet along an unmineralized cross

fracture about 1 foot in thickness, dipping 70° W. However, this cross fracture does contain gouge and is stained with limonite. The main shear, still maintaining the same strike and 67° northerly dip, was intersected at 22 feet from the portal. It is not offset by the cross fracture. From the point of intersection of the cross fracture and main shear a 20-foot drift has been driven S. 58° E. In the back of the drift is a lens of stibnite 2 inches thick which extends along the strike for 8 inches. In the face, however, there has been no mineralization, although the shear zone is present.

According to Mr. Williams, he has not been able to trace this weakly mineralized zone any farther east up the hill or west down the hill beyond the shaft.

Antimony Queen mine

SW¼NW¼ sec. 11, T. 31 N., R. 21 E.

The Antimony Queen mine is 4¼ miles up Gold Creek, a tributary of the Methow River, on the southwest bank of the creek at an altitude of about 2,100 feet. The workings are at the foot of a steep timber-covered slope, facing northeast, which rises abruptly for 2,000 feet above the creek.

The Antimony Queen mine is owned by H. B. Johnsten, of 10741 Palatine Avenue, Seattle, Washington, who holds by location four claims: the Silver Seal No. 1, Silver Seal No. 2, Silver Seal No. 3, and Jumbo. All of the work connected with the mine has been done on Silver Seal No. 1. The Jumbo claim south of the Silver Seal No. 1 contains a working which has been described under the heading of the Jumbo prospect (see p. 124).

Very little is known definitely about the past history of the Antimony Queen, except that it has changed hands numerous times. The first record of any activity was in 1906, when a small amount of ore was extracted and perhaps shipped. About 10 years later the Gold Creek Antimony Mines and Smelting Co. is reported to have shipped about 1,000 tons of stibnite ore and several hundred tons of antimony oxide, which had been manufactured in a small plant near the mine. About ⅔ of a carload of ore was shipped in 1941. Since then the mine has been inactive, except for a small amount of assessment work.

The geology of the mine area is complex if studied in detail, but when considered in a broad sense, it is relatively simple. The country rock is composed of irregularly interbedded argillites and graywacke and is part of Barksdale's Newby formation,[1] which is tentatively dated as being Triassic-Jurassic (?). The formation in the vicinity of the mine has a general N. 30°-40° W. strike, and dips varying from 50°-80° W. Shear fractures with a lower angle of dip than the bedding in the south crosscut of Level No. 1 give a strong indication that the beds in this vicinity are overturned. As

[1] Barksdale, J. D., op. cit., p. 169.

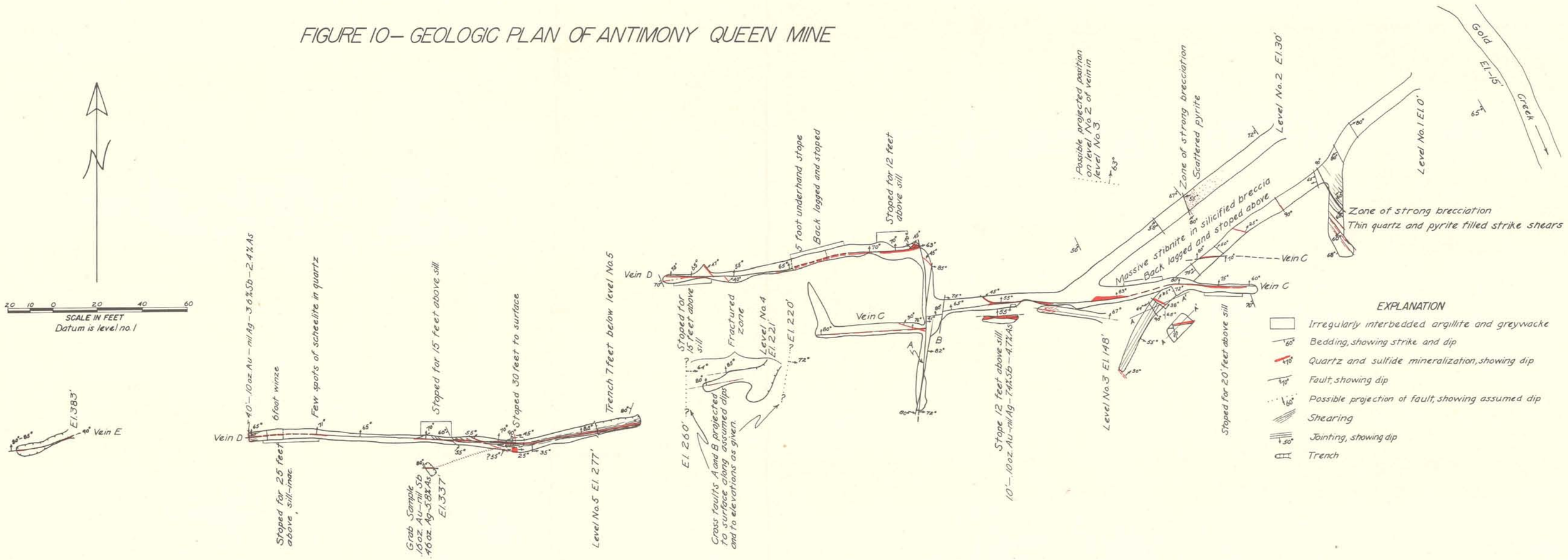
the Gold Creek area may be one of isoclinal folding, it would be presumptuous to say that this one piece of evidence indicates that all the beds in the mine vicinity are overturned.

Characteristic specimens of rock from the mine area were collected in the field, and thin sections were made. These show that the rocks are argillites and graywackes. As the rocks were all collected in the vicinity of hydrothermal action, they probably give a poor idea of the true nature of the original sediments as well as of the incipient regional metamorphism. However, significant wall-rock alteration was actually very limited, being confined to a small addition to the walls of calcite, pyrite, and some arsenopyrite and pyrrhotite. In local areas some silicification of the walls took place.

Three varieties of argillite may be distinguished in the vicinity of the mine. The most prominent type is the black argillite well exposed at the entrance to Level No. 2, and common in all the workings. Under the microscope it can be seen to be composed of lineated graphite shreds parallel to the bedding in a matrix of paste of exceedingly fine grained quartz and chlorite with a minor amount of sericite. The other two types of argillite, containing no graphite, are distinguished by color: one is white, and the other is gray inclining to a purplish hue in blotches. Both of these varieties may be seen on the surface or underground. Study of thin sections shows that these rocks are made up of a fine mat composed of quartz, chalcedony, chlorite, and sericite. Where a purplish hue is detected, a small amount of biotite is present. As previously mentioned, the specimens had been collected in the vicinity of areas subjected to hydrothermal alteration; thus much calcite and minor amounts of pyrite, arsenopyrite, and pyrrhotite are scattered throughout the thin sections. In places these minerals form thin veinlets averaging about 0.1 millimeter in thickness.

The graywacke is very difficult to identify with any degree of certainty in the field, because of its very fine grained and dense appearance, which at times makes it impossible to distinguish from argillite without the aid of a microscope. There are two principal kinds of graywacke that may be recognized both in the field and under the microscope. One crops out just southeast of the portal of Level No. 1 and at about 40 feet inside Level No. 2. This variety is gray to tan-gray with a medium grain. The thin sections show it to be composed of slightly rounded to angular quartz, orthoclase, and plagioclase (largely Ca-oligoclase) grains accompanied by rock fragments of both an igneous and an argillaceous nature. The mineral grains range in size from 0.1 to 1 millimeter, and the rock fragments, mostly from 2 to 3 millimeters. The groundmass is an argillaceous paste having the same mineral composition as the gray and white argillites. Scattered pyrite crystals, as well as liberal amounts of calcite, are not uncommon. The other type of graywacke has a decidedly purplish brown hue and is extremely dense in ap-

FIGURE 10— GEOLOGIC PLAN OF ANTIMONY QUEEN MINE



pearance. It crops out typically south of Level No. 5 and on the hillside just below Vein E. The microscope reveals slightly rounded to angular quartz, orthoclase, plagioclase grains, and rock fragments which are too fine grained to determine. Sizes range all the way from 0.3 millimeter to 2 millimeters. The argillaceous groundmass is made up of biotite, hornblende, chalcedonic quartz, and calcite. The biotite is particularly well developed in the rock just north of the cut at an elevation of 337 feet and seems to be definitely associated with those rocks that have a purplish hue. Pyrrhotite is also quite common in this kind of graywacke. In both varieties most of the feldspars show evidence of a small amount of alteration to sericite.

These different varieties of argillite and graywacke just described grade from one to the other both along and across their strike within distances of a few feet, which makes it impossible to map them satisfactorily. The contacts are both knife-edged and gradational. There are too few exposures on the surface to attempt to determine a sequence of deposition, and the dirtiness of the walls underground, combined with the close resemblance of some of the rock types, make it a practical impossibility to distinguish these different rocks in the mine. In the time available for the investigation no correlation could be made between rock types and quantity of sulfides, and the writer doubts very strongly that there is one. Also, with this type of sedimentation it is usually impossible to locate a key bed that will enable one to work out fault displacement accurately. However, further study might bring to light a depositional sequence that would be of some use in this connection.

Because of the presence of considerable black argillite and the high angularity and relative freshness of the grains and rock fragments in the graywacke, it is assumed that these beds were deposited rapidly in a relatively quiet marine basin under reducing conditions. This may have been responsible for some of the pyrite, though iron-bearing minerals, except for biotite from which the iron could have been derived, are indeed scarce. As yet no fossils have been observed in the mine area.

The mine workings trend along the eastward-striking vein system and extend from Gold Creek to an elevation of about 383 feet, as shown in figure 10. Level No. 1, driven entirely in gray and black argillite, has three principal points of interest. The first is the zone of strong brecciation in the south crosscut. Just south of it, black argillites dipping 68° SW. have their bedding intersected by minor strike shears dipping 60° SW. As mentioned above, this probably indicates overturning of the beds. Fine thin stringers of quartz and pyrite are present along these shears. The second point of interest is the place at which the main crosscut intersects Vein C. The vein is about 6 inches thick at this spot and contains quartz and stibnite in a ratio of about 5 to 1. The third point of interest

is the quartz vein dipping 35° NE. at a point 151 feet from the portal of the crosscut. The geologic relationship of this vein to the associated faults is shown by the small cross section. However, the connection between this vein and Vein C is not clear. Its history of deposition and its mineralogy are far more complex than that of Vein C. From this, one might think that the two had a different origin. Certainly, exploration along the complex vein to discover its true relation to Vein C is important.

The complex quartz vein contains pyrite, arsenopyrite, sphalerite, galena, jamesonite, stibnite, quartz, and calcite; and a spectrographic analysis of some of the pyrite and arsenopyrite crystals showed a content of 1 to 3 ounces of gold per ton. This vein has had an interesting and involved history. A polished section across the full thickness of the vein at a place where it is 6 inches thick indicates that quartz, pyrite, and arsenopyrite were deposited almost simultaneously. The sulfides probably crystallized the earlier, as there are some crystals that have fractures which are intermittently filled with quartz. Sphalerite, where it is deposited along fractures in the quartz, appears to be younger than the quartz, and this relationship is found in a few places. Also, in a few places sphalerite is found penetrating fractures in the pyrite. However, the general impression is that the sphalerite was deposited, in part at least, along with the quartz, pyrite, and arsenopyrite. The sphalerite contains well-aligned blebs of chalcopyrite. It was possibly during this first surge of mineralization that the argillaceous wall rocks were slightly pyritized.

At the close of the first surge of mineralization there was fracturing of the earlier sulfides and quartz, followed by the introduction of calcite, both into the vein and the wall rock. This apparently is the gangue mineral associated with the galena and jamesonite, which are clearly replacing all earlier minerals along fractures. The jamesonite invariably forms a rim around the galena and also is the metallic mineral of this depositional stage present in the thin fractures in the quartz. Some of these fractures extend out from blebs of galena and jamesonite. It seems probable that the jamesonite came in and replaced the galena along its borders.

The third period of vein formation was characterized by the brecciation of the argillaceous wall rock in the footwall, silicification, and the deposition of stibnite both as a replacement of quartz and as a filling in vugs of drusy quartz.

It might be concluded from this history of vein deposition that the temperature and pressure conditions became lower and lower as deposition progressed, changing perhaps from those of mesothermal to epithermal.

Two diamond drill holes are in the vicinity of this complex vein. One is horizontal, the other inclined upward. The horizontal hole is

located in the southeast wall of the crosscut about breast high, 155 feet from the portal. This hole trends S. 64° E. The inclined hole is directly opposite it, close to the back just above the gentle northeastward-dipping fault. The hole is inclined at about + 65° and trends N. 47° W. The results of this drilling are not known.

Just beyond these drill holes there is very prominent jointing in black argillite. On the map this jointing is shown dipping 55° SE. Along these joint planes, some six spots of scheelite less than ½ inch in diameter were seen by Mr. Marshall T. Huntting,[1] of the staff of the Division of Mines and Geology. Their relationship to the vein minerals is not known.

Level No. 2 is 30 feet above Level No. 1. As can be seen from figure 10, this level contains the principal workings of the property. With the exception of the first 53 feet, in which the country rock grades from black argillite to graywacke as described above, all the workings on this level seem to be in argillite, either of the gray, black, or white variety. The zone of strong brecciation 53 feet from the portal is reported by Mr. Johnsten, the owner, to carry $13.00 in gold and silver. This zone separates the graywacke on the east from black argillite on the west. Oddly enough, this zone of brecciation, almost a foot thick, is not to be found either in the drift on Vein C to the south or in Level No. 2. It seems almost incredible that the zone would die out in such a short distance, and it should be explored further.

At the intersection of the crosscut adit of Level No. 2 with the drift on Vein C is the best stibnite ore in sight on the property. The ore is well exposed in the bottom of the drift. Two polished sections and one thin section show clearly that it is composed of fragments of black and white argillite and quartz which are cemented by quartz, calcite, and stibnite. The fragments range in size from 0.1 millimeter up to 2.5 centimeters in diameter and are extremely angular. Though the mineralizing solutions do not appear to have been of the proper composition to modify the shape of the fragments by replacement, they were spotted by specks of sericite, calcite, pyrite, and arsenopyrite.

From this point east to the face along Vein C there has been a certain amount of stoping. According to the owner, the bulk of the last shipment made from the mine came from this area. However, there are no sulfides in the east face of this drift, although the fault along which Vein C formed is still strong.

Westward along the drift from its intersection with the crosscut adit, the vein is barren for a short distance, and then as the small stope shown on the map is approached the vein becomes quite strong and is as much as 2 feet thick, where a thin (2- to 3-inch) northwestward-striking quartz-pyrite vein merges into the main vein. This

[1] Personal communication.

thin quartz-pyrite vein is one of several subordinate fractures on this level developed by movement along the eastward-striking vein system. The results of sampling across the vein in the small stope are shown on the map. A polished specimen of ore from close to the place where this sample was cut is pictured in figure 11. Two prominent stages of vein formation are evident. The dividing line between these two stages of development can be covered by one thin section, as is clearly shown in figure 12. The polished section and thin section both show that the first stage was the formation of the quartz, pyrite, arsenopyrite vein, and that the second stage was a brecciation of this vein and the adjacent argillaceous wall rock to form a breccia ore precisely similar to that exposed in the bottom of the drift at its intersection with the crosscutting adit. In the thin section showing the contact of the quartz vein (lower right-hand corner) and brecciated ore (upper left-hand corner), the prominent undulatory extinction of the coarsely grained quartz vein and its incipient recrystallized fractures are conspicuous. The fracturing of the crystals of pyrite and arsenopyrite, now healed with quartz and calcite, took place during the formation of the quartz vein, as is shown in figure 12, where the quartz (white) can be seen in the lower left-hand corner to have maintained its optical continuity as it healed fractures in the pyrite (black). The calcite, present in some of these fractures, is probably the result of later replacement of the quartz by the calcite, because a fine-grained variety of the calcite occurs in the same manner, both in the brecciated and non-brecciated portion of the vein. In direct contrast to the coarse mosaic of the quartz vein is the fine mosaic formed by the brecciation of the quartz vein and the adjacent wall rock. Naturally, there are more and larger fragments of wall rock close to the wall, and more quartz fragments closer to the quartz vein. Both the thin section and polished section show that the zone of brecciation was later impregnated by the stibnite. The stibnite replaced the calcite along its cleavage surfaces, corroded the quartz breccia fragments, and filled fractures in the wall-rock breccia fragments.

The first cross fault to the west beyond the small stope is labeled B and shows that Vein C, which at this point is unmineralized, has been displaced to the left. This displaced segment has likewise been displaced to the left by cross fault A. As can be seen on the map, Vein C was slightly mineralized in the footwall of cross fault A. This mineralization consisted of the formation of a ½-inch-thick vein of quartz and stibnite, which is distinctly younger than the 2-inch-thick quartz-pyrite vein that dips 30° NE. This quartz-pyrite vein is displaced by Vein C about 4 inches, the north side of Vein C having moved up. In the west face of the drift along Vein C a barren gouge seam ¼ inch thick dipping 80° N. is visible.

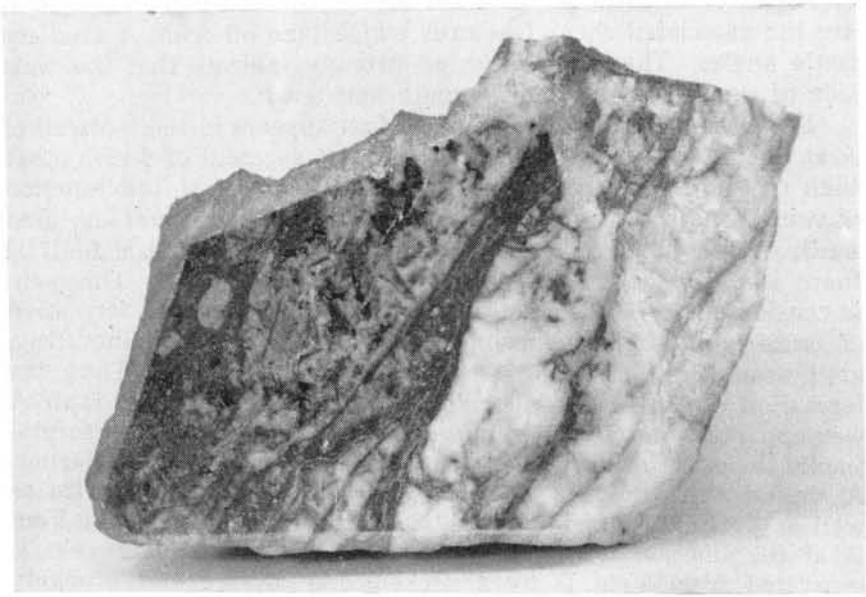


FIGURE 11.—Polished surface showing the two stages of vein formation at the Antimony Queen mine.

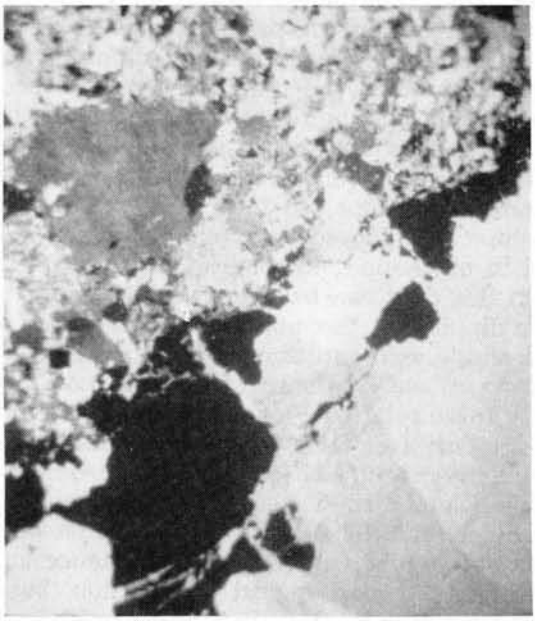


FIGURE 12.—Photomicrograph of thin section showing the contact between the two stages of vein formation at the Antimony Queen mine. X 17.

Along cross fault A the most significant features in the drift are the associated shear fractures which take off from A at sharp acute angles. These relationships strongly indicate that the west side of the cross fault moved south and down.

Thus, the strong quartz vein that first appears in the footwall of A at the north end of the drift along A is a segment of a vein other than C, and it has been designated as Vein D. At the junction of vein D and the cross fault A, the relationships are complex. Just south of the junction on the hanging-wall side of cross fault A there is a ½-inch quartz-pyrite vein dipping 45° NE. This vein is considered to be in a tension fracture caused by the formation of cross fault A. It seems most logical that it was mineralized at the same time as the other thin quartz-pyrite veins. Thus, the formation of the eastward-striking vein system and cross fault A was apparently an almost simultaneous operation, with the formation of the eastward-striking veins taking place only slightly earlier. A similar vein, dipping 45° NE., but containing arsenopyrite as well as pyrite, is immediately adjacent to the north wall of Vein D at its junction with cross fault A. This subordinate vein is separated from Vein D by a slickensided surface and probably formed at the time the eastward-striking vein system initially came into existence. Vein D at its junction with cross fault A contains shear fractures dipping 70° NW. in massive quartz, as shown on the map. This quartz rapidly thins out away from the cross fault; thus cross fault A probably acted as a dam. Stibnite is scattered through the quartz. The damming, combined with shearing adjacent to the earlier quartz, pyrite, arsenopyrite vein, afforded an excellent opening for mineral deposition in the footwall of the cross fault. A small amount of stoping was done here, but the principal stope on Level No. 2 is the inaccessible stope above the 5-foot underhand stope, 40 feet west of cross fault A. This inaccessible stope is supposed to extend for at least 40 feet above sill level and to have supplied some of the best ore. Farther still to the west on this drift can be seen two quartz-pyrite veins about ½ inch thick dipping to the northeast that appear to have been at one time a single vein and then later to have been displaced by Vein D. However, gash or shear fractures have been known to supply exactly these relationships to the principal vein when there has been movement after their formation, making it impossible to decipher their true origin. These subordinate quartz-pyrite veins, along both Vein D and Vein C, because of their mineralogy are considered to be older than the stibnite-bearing veins, but this assumption still does not supply any conclusive evidence as to their real nature. However, the most logical explanation, based largely on evidence to be presented later, is that these are gash veins and were formed independently but simultaneously with the formation of the east-west vein system.

The west face of the drift on Vein D is in argillite. The vein is still present as a quartz stringer about 1 inch thick carrying stibnite; just on its south is another 1-inch stringer of stibnite. According to Mr. V. LaMotte of Carlton, who formerly had an interest in the property, this face carries about $6.00 in gold.

On Level No. 2 where cross fault A intersects Veins C and D, it appears at first glance that the displacement was post-mineral, but because the mineralization was definitely stronger on the footwall side at both vein intersections, the writer prefers to think of it principally as a pre-mineral fault which has undergone slight post-mineral adjustment to give it its present deceptive appearance.

Level No. 3 is an adit driven along a thin fault seam in a zone of crushed limonitized fine-grained graywacke or argillite about 2 feet thick. About 2 feet from the face is an irregular network of quartz stringers ½ inch to 2 inches in thickness. Some crystals of stibnite in quartz were seen on the dump. If this crushed zone were projected to Level No. 2, it would intersect the crosscut adit just west of the strong zone of brecciation. As this does not happen, the dip reading was changed slightly, so that the position of the Level No. 3 crushed zone at Level No. 2 would be as shown on the map. The reason for taking this liberty is that there is a strong possibility that this crushed zone in Level No. 2 may be Vein D, and the writer feels that it is worthwhile to make this assumption in order to best evaluate the possibilities for further exploration.

Level No. 4 is a composite adit driven in badly crumpled and shattered fine-grained graywacke or argillite, all thoroughly stained with limonite. No stibnite was seen in the vicinity of these workings, and the shears shown on the map appeared to be completely barren, but Mr. M. T. Huntting[1] has reported that he saw blebs of stibnite up to 1½ inches in diameter along these shears.

The projected traces on the surface of cross faults A and B are indicated on the map. Though there is no direct evidence of these faults on the surface, it is felt that indirect evidence is sufficient to warrant placing their projected traces on the map. The indirect evidence consists of intense crushing around Level No. 4 and the abrupt change from this intense crushing and almost barren shears to the rather strong quartz-stibnite vein in the relatively undisturbed rocks present in the trench connected with Level No. 5.

The trench leading into Level No. 5 has purplish-gray argillite for a north wall and purplish-brown-gray mottled fine-grained graywacke on its south wall. Under the microscope the argillite is shown to be an exceedingly fine-grained matte of quartz, chalcedony, incipient biotite, kaolin, and calcite. Pyrite crystals are scattered throughout, and both calcite and quartz stringers about 0.5 millimeter in thickness cross the thin section. The graywacke

[1] Personal communication.

was described earlier, in the general discussion of rock types. This change of rock types from one side of the vein to the other is, of course, clear evidence that there has been movement along the vein. The direction of the movement is unknown. A detailed stratigraphic study might give the answer, depending on whether a suitable marker horizon or stratigraphic sequence could be found.

From the relations shown on the map it is felt safe to assume that the vein in Level No. 5 is the continuation of Vein D. From the eastern end of the trench to a few feet west of the stoped raise, the stibnite is present in a quartz vein varying from 2 to 6 inches in thickness in the trench and becoming as much as 1 foot thick and composed of almost solid stibnite in the east end of the stoped raise. In the west end of this raise the quartz vein is still about a foot thick, but contains only about 10 percent stibnite. This gives an excellent idea of the characteristic erratic nature of this deposit. Past this place a few feet is a silicified shear zone. This zone carries stibnite in quartz and has a small area at its west end where stibnite has impregnated crushed argillite. This zone extends to the west end of the area marked on the map, "stoped for 15 feet above sill." It averages about 1 foot thick. The mineralization of the accompanying subordinate or gash fractures that blend into the parallel shearing along this silicified portion of Vein D appears to have been earlier and to have taken place at a relatively high temperature, because it is confined to quartz, pyrite, and occasionally arsenopyrite, but no stibnite. Thus, these subordinate fractures have the same mineralogy as the subordinate fractures on Level No. 2, whose relationship to Vein D at that level, as was mentioned earlier, is not clear. It was because of these relationships which can be observed on Level No. 5 that earlier in this discussion the quartz, pyrite, arsenopyrite veins of Level No. 2 were assumed to have been gash veins. The fact that the two quartz-pyrite veins at the west end of the drift on Vein D on Level No. 2 appear to be displaced is attributed to the greater amount of movement along the vein at this point subsequent to the formation of the quartz-pyrite veins.

The vein increases in strength 35 feet from the face of Level No. 5, and apparently where stoping is indicated on the map some quite good ore was taken out. In 1948 the stope was inaccessible, and consequently the writer was not able to see much. Evidently the stibnite occurred in quartz, and at the east end of the stope a quartz vein about 3 inches thick containing stibnite can be seen. The face of Level No. 5 shows about 4 inches of heavily silicified argillite containing stibnite. Actually, the face is well mineralized all across its 4-foot width, as shown by the assay on the map. A thin section and a polished section show that the minerals consist of fine scattered specks of quartz, pyrite, arsenopyrite, and stibnite scattered through the gray argillite.

Ore from the 6-foot winze helped to make up the ⅔ of a carload shipped in 1941, according to Mr. Johnsten. As the winze was full of water, the writer was unable to examine the bottom of it.

Level No. 5 was examined by ultraviolet light for scheelite; a few specks were seen 35 feet from the face, associated with the stibnite vein. The nature of the relationship between the stibnite and the scheelite is not known.

On up the hill above Level No. 5, Vein D can be observed on the surface at two places. The first is where the stoped raise holes through. Here the vein is vertical, the same as below, but the quartz-stibnite portion is only 2 inches thick and is enclosed in a zone of altered and crushed graywacke about 4 feet thick. Farther up on the hill is a small open cut showing a limonitized and kaolinized zone about 2 feet thick with no visible sulfides. Consequently the assay shown at this location on the map was quite a surprise. The gold had probably been associated with arsenopyrite, as it is in this property, and because of weathering the arsenopyrite possibly oxidized, leaving the gold in scorodite or some similar alteration product of arsenopyrite. However, no definite arsenic-bearing mineral could be identified.

Still farther up the hill is the last cut that has been made on this set of stibnite veins. This cut is in interbedded fine-grained graywacke and black argillite. Unfortunately, it was not possible to determine the attitude of these beds. The work was done along a 2- to 4-inch shear enclosed in a dark brown altered crushed zone 2 feet thick that contains spots of stibnite. No stibnite was visible in the face. It was impossible to trace this shear up or down the hill. As can be seen from the map, it is quite obviously a different vein from Vein D and has therefore been designated as Vein E.

Now that the geology of the Antimony Queen mine has been discussed level by level, the question can be asked: Do these facts fit together to form a coordinated picture of the geology, a picture which may be used to assist in the development of the property? Unfortunately the answer to this question is not clear-cut, but if certain assumptions are made, a preliminary picture can be developed which should help future exploration work at the property. Also, it will help to bring out doubtful points in the present geologic evidence that should be clarified in order to arrive at the best possible conclusions.

From the evidence already discussed in connection with Level No. 5, the assumption has been made that the thin subordinate quartz-pyrite-arsenopyrite veins are the result of movement along the eastward-striking vein system at the time of its formation. Admittedly, more geologic work should be done to prove or disprove this idea and to determine accurately the relative displacement along these veins. A systematic search for marker horizons

or stratigraphic sequences would seem to be the surest way of obtaining accurate information. If the relative displacement could be determined, it could be seen whether or not the particular displacement involved was in keeping with the location of ore bodies and their relation to changing strikes and dips along the vein. This in turn would point the way for further search for more ore.

Based on the information available at present, the following outline gives a very generalized picture of the formation of this small vein system:

1. Almost simultaneous formation of the faults of which the eastward-striking vein system is composed, cross faults A and B, and all accompanying thin subordinate fractures, now filled with quartz, pyrite, and arsenopyrite. Naturally, the direction and nature of the stress that determined this entire complex system can only be worked out by making a study of the regional structural geology.
2. Mineralization of the subordinate fractures. This activity may have been concurrent with the initial mineralization of the vein system.
3. Further movement on the eastward-striking vein system, permitting introduction of the mineralizing solutions. This appears to have been in two stages: the first was principally the deposition of quartz, pyrite, and arsenopyrite accompanied by local silicification of the wall rocks; and the second stage, undoubtedly taking place under lower temperature conditions than the first, was the introduction of more quartz, calcite, and the stibnite. Also, as clearly shown in Vein C on Level No. 2, the second stage took place after movement causing local brecciation of the vein which was formed during the first stage. For this reason the movements along the eastward-striking vein system that localized the quartz, pyrite, arsenopyrite bodies may not have been in the same direction as those that localized the stibnite-breccia ore and the quartz-stibnite ore. This possibility should be considered when evaluating the relationship between the directions of movement and the localizing of ore. Damming against the footwall of cross fault A was important.
4. Probable post-mineral adjustment along the eastward-striking vein system and the cross faults to give the present appearance of post-mineral faulting.

As in all antimony deposits, the distribution of stibnite in the Antimony Queen is highly erratic, but there is a rather well defined vein system, and therefore further exploration should be carried out in a systematic manner. The following recommendations are offered as a possible beginning:

1. Geologic work.
    a. Clean out and map old stopes, as they may contain important information.
    b. Systematically channel sample the entire mine workings. Assay for gold, antimony, and arsenic. Take specimens for mineralogic study and describe all channels.
    c. Wash and clean down a strip along all walls so they may be carefully examined lithologically for stratigraphic study, and also note any wall rock alteration or ore that may have been missed.
    d. Extend trench at Level No. 5 east to see if assumed location of cross fault A is correct.
2. Development work. If the geologic work should result in favorable conclusions, the following development work appears justified to prove or disprove the property. It might also be done simultaneously with the geologic work.
    a. Work west on Vein C in Level No. 1 to get in under the high-grade ore in Level No. 2.
    b. Extend the south crosscut in Level No. 1 a short distance to intersect Vein C.
    c. Drift a few feet in both directions on the small complex quartz vein dipping 35° N., south of Vein C in Level No. 1, in order to determine its value and connection with Vein C.
    d. Drive a horizontal drill hole to the north in the northeast wall at the north end of the drift along cross fault A to try to intersect the east segment of Vein D.
    e. Extend Vein D out under Level No. 5 and explore to Level No. 5 with a raise, if this seems justified.

Stibnite ore is so erratic that it is almost impossible to try to prove its tonnage with a diamond drill. Ordinarily, it would appear that enough development work has been done on this property to make a tonnage estimate for possible ore, but estimates for even possible ore are not justified because of the very erratic nature of the shoots. Only where very detailed sampling and close development work have been carried out should such estimates be made.

However, there is no doubt that more stibnite ore is present in the Antimony Queen than is apparent. Also, there is probably a moderate tonnage of low-grade gold ore, as shown by assays of samples taken at various places throughout the workings and varying in grade from $3.00 to $5.00 per ton. Spectrographic work on arsenopyrite and pyrite indicated that the gold is associated with these minerals. Thus, besides the regular stibnite concentrates for antimony, an arsenopyrite concentrate for gold and arsenic might be possible. Some experiments should be carried out to make sure

that no appreciable gold would be lost in the pyrite and quartz tailings. Polished sections of rock that assayed about $3.50 per ton in gold were examined for possible signs of gold and, though magnified to 550 diameters, no gold was seen, which of course was not surprising, considering the low assay.

Therefore the question is: Is there enough ore of consistent tenor and volume to keep a small mill running? The answer to this question cannot be given on the basis of the present work, but after completion of the development program outlined above, one should be able to make a fair guess. As a last comment, it should be pointed out that a project at this mine based on direct shipping ore would be doomed to failure.

Bales prospect

SW¼NE¼ sec. 17, T. 32 N., R. 22 E.

The Bales antimony property is located at an altitude of about 3,200 feet, 2 miles northeast of the town of Carlton in the Methow Valley, Okanogan County, close to the top of a grass-covered southeast slope, which rises 1,800 feet directly from the river bottom in a horizontal distance of 0.6 of a mile. It is reached by a trail from the old Scott ranch, which is on the west bank of the river and about 3¼ miles north of Carlton.

This property, consisting only of the Bales claim, was discovered in the fall of 1947 and is owned jointly by Theo. Smith and Ollie Scott. Since then, work has been confined to bulldozing along the strike of the vein; however, at the discovery-post trench about 5 tons of lump stibnite has been removed.

The country rock at the property is a hornblende-quartz diorite that has been subjected to cataclasis and recrystallization; surprisingly, the rock does not seem to have any particularly strong linear features. In the vicinity of the vein the effects of hydrothermal alteration are readily apparent. The first noticeable effect is the coloring of the rock to a reddish purple by iron oxide staining along shreds of chlorite which under the microscope appear to be the remnants of hornblende. The quartz and plagioclase are much fractured and laced by veinlets of calcite and a reddish cloudy material. The alteration steadily intensifies as the vein proper is approached. Strangely enough, there does not appear to be any appreciable development of kaolin and sericite in the feldspars. None of this altered material contains antimony except in trace amounts.

The vein proper, or mineralized zone, is composed of three elements: intensely hydrothermally altered wall rock, quartz and lenticular masses of stibnite. The altered wall rock, which encloses the veinlets and lenticular masses of stibnite, is composed of erratically distributed and alternating iron oxide stained and bleached spots. Microscopic examination of a thin section of this altered material shows it to be composed of quartz, sericite, minor amounts

of kaolin, and scattered iron oxide. Crisscrossing through this material are tiny veinlets of stibiconite which have resulted from the alteration of stibnite. An assay of this altered material at the discovery post showed 10.9 percent antimony. This would indicate that the bleached and iron oxide stained zone would be well worth prospecting at depth, because below the zone of weathering these veinlets are probably composed of stibnite. The contact between the altered wall rock and the stibnite is usually characterized by the presence of quartz, which contains scattered areas of drusy vugs. Also, within the lenticular masses of stibnite are scattered blebs of this same type of quartz, which under the microscope appears to be older than the stibnite, as the quartz is cut by veinlets of stibnite. Thus, the processes of alteration and silicification were probably completed by the time the stibnite was precipitated.

The vein or mineralized zone strikes about N. 47° E. and dips 80° SE., showing local variations in both strike and dip. The thickness of the massive stibnite is as much as a foot in places, but the dimensions are highly irregular throughout the entire zone. At the discovery-post trench the entire bleached and iron oxide stained zone measures 5 feet in thickness and is bounded on both sides by shears. From the trench to the northeast along the vein the bulldozing uncovered stibnite at only one place, about 100 feet northeast of the trench. Here a small lens of stibnite about 4 inches thick is exposed for a strike length of about 20 feet. From the discovery post trench to the southwest, bulldozing has disclosed stibnite continuously for 200 feet. It averages about 4 inches in thickness throughout this distance.

Only surface work has been done, but it is sufficient to indicate that the prospect is very interesting and merits further exploration. The stibnite appears to be of good grade. Arsenic is the only impurity, and as this averaged about 0.2 percent in three reliable analyses, it would not be particularly detrimental.

Coyote prospect

Center sec. 14, T. 31 N., R. 21 E.

The Coyote property was unclaimed at the time of the writer's visit in 1948. It is located on the eastward-trending ridge near the junction of the Middle Fork with Gold Creek, a tributary of the Methow River, and is reached from the Middle Fork Gold Creek road by ascending the first timbered draw that intersects from the northwest about half a mile from the creek junction. The workings and discovery post are at an altitude of 2,800 feet on the northwest slope of the draw almost at its head and close to the crest of the ridge that rises about 900 feet above the valley floor.

At the discovery post of the old Coyote claim there is a 2-inch shear striking N. 20° E. and dipping 75° W., which shows no evidence of mineralization except for the 10 feet along the strike in

this immediate vicinity. This shear is in interbedded conglomerate, fine-grained graywacke, and black argillite, and appears to strike about north and dip vertically. Though no stibnite can be seen in place, an idea as to how it occurred can be obtained by examining dump samples. These samples indicate that apparently the first movement was along the main shear, causing brecciation. Then silica and stibnite were introduced into the brecciated zone and deposited in that order. Some of the stibnite was observed as a filling in quartz vugs.

A small (¼ to ½ inch thick) cross stringer to the main shear was observed close to the discovery post; it strikes N. 65° W. and dips 60° N., and has some limonite and pyrite along it. It appears to be older than the main shear, but it may be a tiny gash fracture. Apparently what stibnite deposition there was, took place in this immediate area.

Jumbo prospect

SW¼SW¼ sec. 11, T. 31 N., R. 21 E.

The Jumbo prospect is located at an altitude of 3,000 feet on a northeastward-trending ridge which is about a mile upstream from the junction of the Middle Fork with Gold Creek, a branch of the Methow River. The claim is held by location by H. B. Johnsten of Seattle and is one of the Antimony Queen group of four claims (see p. 109).

The property is reached by turning off the Methow Valley highway at Gold Creek and driving up Gold Creek about 4 miles to the old Smith ranch. Across Gold Creek from the ranch, a trail leads up the ridge to a trench which is about 1,000 feet above the valley floor.

The trench extends for 20 feet along a shear and brecciated zone striking N. 45° E. and dipping 65° NW. The rock on the northwest side of the shear is a gray to black argillite, while that on the southeast is a greenish-gray conglomerate containing quartz pebbles as much as ¼ inch in diameter and having a matrix of the composition and texture of a medium-grained graywacke. About 100 feet down the slope N. 70° E. from the trench, a gray to dark-gray fine-grained thinly banded graywacke strikes N. 35° E. and dips 75° NW.

Judging from the amount of high-grade stibnite ore that is piled alongside the trench, the original outcrop must have shown a lens of almost solid stibnite about 20 feet long and 2 feet thick. At the present time the exposures in the trench are not encouraging. A shear zone about 1 foot thick shows in the ends and along the bottom of the trench. Stibnite is very scarce. However, by studying that which has already been taken from the trench and what little actually could be seen in the trench, it is evident that the mineralization has been quite similar to that on the Coyote

claim just previously described. Apparently there was first the initiation of movement to form the shear; and perhaps the pyritization and silicification of the wall rock took place at this time. Later, more intense movement formed breccias at certain favorable places, depending on the physical conditions of the rock in the walls. In conjunction with this movement and probably continuing on afterwards, drusy quartz was introduced as a filling. The last activity seems to have been the deposition of the stibnite in these vugs and as a replacement of the quartz and brecciated host rock. The stibnite occurs in two distinct habits: one is the common bladed variety, the other a massive fine-grained granular aggregate of anhedral crystals. The relationship between the two became clear upon the study of two polished sections. The stibnite crystallized first in its common bladed habit. After this initial crystallization there was apparently further movement along the main shear, which caused deformation twin lamallae to be developed in the blades of stibnite; but locally where the stresses became too great, the blades of stibnite instead of deforming plastically were fractured, crushed, and then recrystallized to form the massive granular variety. In polished section under cross-polarized light these two habits of crystallization can be seen to grade from one to the other.

The shear zone along which this lens of stibnite occurred has not been traced in either direction on the surface. It seems strong and apparently shows a certain amount of actual displacement. As it is just about on the crest of the ridge surface, trenching would show the character of the deposit to good advantage. One discouraging factor was noted by the writer: directly in line with the strike of the trench and about 50 feet beyond its southwest end is an excellent graywacke exposure which shows no signs of mineralization. Graywacke, argillite, and conglomerate are so erratically interbedded in this area that it would be impossible to say whether the graywacke exposure is in the hanging wall or footwall of the shear, or whether the shear has died out.

Stibnite prospect

NE¼SE¼ sec. 3, T. 31 N., R. 21 E.

The stibnite prospect is located at an altitude of approximately 2,800 feet N. 12° E. from the old Foggy Dew C. C. C. camp. To the writer's knowledge, the prospect was unclaimed in 1948; and as there is no trail, the best way to reach it is to drive up Gold Creek to the C. C. C. camp, and then follow the compass bearing.

In 1947 only a few dump samples indicated the former presence of stibnite. A small trench 10 feet long exposed a weak shear, along which the small deposit must have occurred. The altered zone along this shear in quartz-hornblende diorite is 2 feet thick, strikes N. 85° E., and dips 85° S. The stibnite deposit may have been as much as a foot thick. Judging from an examination of the dump

samples, the stibnite replaced the hydrothermally altered quartz-hornblende diorite in the close proximity of the shear. About 2 feet south of the shear is an irregular body of hornblende-feldspar porphyry 1 foot to 3 feet thick intruding the quartz-hornblende diorite. Neither the porphyry nor the shear could be traced to the east or west because of overburden. It is very probable that neither is particularly extensive.

PEND OREILLE COUNTY

Lena Belle prospect

SE¼NE¼ sec. 6, T. 32 N., R. 45 E.

This prospect is situated near the foot of the southwest slope of No Name Peak at an altitude of about 3,000 feet. It is best reached by taking the Bead Lake road and traveling on past Bead Lake about 2½ miles to where the prospect is on the northeast side of the road.

The Lena Belle claim is owned by C. W. Carter and W. M. Miles of Newport, Washington. Unfortunately, the writer did not learn about this deposit in sufficient time before this report was sent to the printer to visit it. Thus, the following brief description was supplied by the owners. The deposit was uncovered by a bulldozer while a road was being built. A showing of massive stibnite 18 inches thick was exposed over a strike length of about 10 feet. The country rock is said to be dolomite. According to Schroeder[1] this dolomite is probably in the lower part of his Skookum formation, which is the youngest formation of his pre-Cambrian Newport group. In the vicinity of the prospect the formation probably strikes north and dips 55°-60° W.

Pinnel prospect

NW¼SE¼ sec. 12, T. 33 N., R. 44 E.

The Pinnel property is owned by Ed Maryland of Usk, Washington, and is on the east bank of the North Fork of Skookum Creek at an altitude of about 3,200 feet. It may be reached from Usk by the Kings Lake road and a branch road 6 miles long that turns off 2 miles east of Usk. Mr. Maryland owns the NW¼SE¼ sec. 12 and the adjacent N½NE¼SE¼ sec. 12. The land contains sufficient timber (ponderosa pine) for mining purposes.

The workings on this property are all in bedded quartzites of pre-Cambrian age that can probably be correlated with the Belt series 6 miles to the east in Idaho. They have a general strike of N. 12° W. and an average dip of 60° W.; local overturning is indicated at two small outcrops. Quartz monzonite[2] crops out 0.2 mile east of the workings.

[1] Schroeder, M. C., Geology of the Bead Lake District, Pend Oreille County, Washington. Unpublished manuscript.

[2] Schroeder, M. C., Personal communication.

Stibnite occurs at only two small cuts on the surface, and at only one of these is it in place. Consequently, little was learned about its mode of emplacement. However, at the one cut in which stibnite was observed in place, it is present in white to gray fine-grained quartzite as lenses in fractures dipping 60° W. These lenses average about ⅛ inch in thickness and about 4 inches or less in diameter. The bedding strikes N. 3° W. and dips 80° E. At first glance these relations appear to indicate that the beds are top side up, but the manner in which quartz and stibnite fill the fractures indicates that these were probably opened by tensile strain, and also indicates that the beds are locally overturned. Apparently some silica was first introduced into the fractures, forming vugs of drusy quartz which were later filled with the stibnite. The early introduction of quartz into fractures seems to have been quite widespread, whereas the deposition of the stibnite was extremely local. By no means are all the drusy quartz vugs in the vicinity of the stibnite occurrences filled with stibnite. Stibnite occurs as coarsely bladed crystals, and also as fine acicular crystals in radiating clusters about ¼ to ½ inch in diameter.

About 60 feet lower and 100 feet west of the two stibnite cuts, Mr. Maryland drove a crosscut adit to intersect the stibnite at depth. This crosscut trends S. 70° E. for 480 feet. The only evidence of mineralization seen by the writer throughout the length of the adit was a small north-striking shattered zone with scattered pyrite dipping 40° W. at 390 feet from the portal. Mr. Maryland reported he had seen stibnite along a slip striking N. 73° E. and dipping 23° S. at 340 feet. The only other points of interest in the adit are a small homocline (the dip changes from 60° W. to 5° W. to 50° W. within 20 feet) at 290 feet, and a highly irregular intrusion of biotite lamprophyre from 340 to 370 feet. A thin section shows the biotite lamprophyre to be minette.

SNOHOMISH COUNTY

John Feldt prospect

SE¼NE¼ sec. 30, T. 30 N., R. 9 E.

The John Feldt prospect is situated at an altitude of about 1,300 feet on the lower north slope of White Horse Mountain. It is 200 feet upstream from the intersection of two creeks, one flowing north, the other, northeast, which join to form one of the major branches of Ashton Creek, about 3½ miles west of Darrington. From the John Feldt place, a trail gaining 600 feet in elevation leads to the property about ¾ mile up the southeast bank of the Ashton Creek tributary.

The prospect, owned jointly by John Feldt and Axel Sjorgren, comprises seven claims, all held by location. The principal workings are two open cuts about 800 feet apart which have been made

along thin veins. The first of these workings is on the east side of the canyon cut by the northward-flowing creek. This is about 200 feet upstream from the junction of the northward- and the northeastward-flowing creeks. Here the bedrock is an augite andesite flow. Under the microscope this is shown to be metamorphosed to the degree that the plagioclase has become slightly sericitized and carbonatized, while the augite has become completely altered to a brown fine indeterminate mass that is highly birefringent. It is cloudy under reflected light. Some chlorite has also been developed. In this rock there is exposed a mineralized stringer 1 inch thick that strikes N. 30° E. and dips 70° SE. It was examined along the strike for 150 feet. Unfortunately, its northeasterly extension is covered by heavy overburden, and at the time of the examination its southwesterly extension was under snow, which filled the deep canyon. Mr. Sjorgren reported that the snow usually lies in this canyon until late August. He also said that the southwesterly extension of this stringer thickens to 25 feet in the canyon bottom and is there filled with rich silver-antimony ore. However, no trace of the stringer could be found across the canyon on the west bank, some 250 feet distant. Intersecting the west wall of the 1-inch stringer about 50 feet from the creek bank, is a vertical stringer some 3 inches thick and striking N. 65° E. This stringer could not be traced across the canyon either. The canyon may have been carved along the strike of a fracture which cuts off these stringers in the canyon bottom, and at this hypothetical junction an ore body may exist. Snow was too plentiful at the time of the examination for this theory to be proved or disproved.

The mineralogy of these two stringers is similar. They both consist of thin brecciated zones which have euhedral quartz crystals encrusted around breccia fragments and incompletely filling the available open spaces. The remaining vuggy areas are filled with stibnite and berthierite. The latter appears to be the more common. With the antimony-bearing minerals are pyrite, arsenopyrite, and chalcopyrite, erratically scattered through the brecciated fragments and quartz. Thus, these last-mentioned minerals appear to have been introduced with the quartz and earlier than the antimony minerals.

The second working, or cut, 800 feet southwest of the first, is in a quartz latite which is now partly altered. The feldspar phenocrysts are sericitized and in part resorbed; likewise the quartz phenocrysts show resorption along their borders. The plagioclase laths in the groundmass are unaltered and appear to vary between calcic-oligoclase and sodic-andesine. Their interstices are now filled with chlorite (variety prochlorite) which has probably been derived from hornblende. Calcite is scattered throughout in blotches and appears to be a hydrothermal introduction.

This rock is exposed in the bed of the northeastward-flowing creek, whose course is determined by a thin persistent vein as much as 7 inches thick in places. It is on this vein that the small cut has been made, 100 feet higher in elevation than the berthierite-stibnite stringers and about 200 feet above the junction of the north- and northeastward-flowing creeks. The vein occupies a fault zone striking N. 45° E. and dipping 80° NW., where the relative displacement is indicated by the grooved slickensides and the presence of shear fractures, now filled with calcite, within the vein itself. The grooves in the slickensides consistently pitch 25° NE., and the other evidence indicates that the northwest wall moved southwest and up relative to the southeast wall to form a high-angle thrust fault.

The vein has been mineralized with pyrite, sphalerite, galena, a tetrahedrite-chalcopyrite intergrowth, and arsenopyrite which encloses occasional minute cubes of cobaltite in a quartz-calcite gangue. A polished section study indicates a rather interesting vein history. First, there appears to have been a general brecciation followed by the introduction of pyrite and arsenopyrite-cobaltite. The cobaltite occurs only rarely as small pinkish cubes enclosed within the arsenopyrite. As these minerals contain quartz-filled fractures, a period of slight movement preceding the quartz deposition is indicated. The greater portion of the sericitization and silicification of the unreplaced breccia fragments and wall rock undoubtedly took place during this period of sulfide-quartz deposition, giving the wall rock its bleached appearance in the close vicinity of the vein. At the time of the next period of deposition the temperature and pressure in the vein were possibly lower, as sphalerite, galena, and tetrahedrite-chalcopyrite were deposited in sequence, as can be seen by their crosscutting relationships. Closely following this mineralization the entire vein appears to have been impregnated by calcite. Later, there were slight movements that minutely fractured the sulfides and gangue and allowed additional calcite to be introduced. Still later there must have been a further adjustment along the vein, as the shear fractures, now filled with calcite, cut all the earlier mineralogical features of the vein.

A channel sample across the vein at a point where it is 7 inches thick assayed as follows:

Assay of channel sample from 7-inch vein on Feldt property

Gold (ounces per ton)	0.07
Silver (ounces per ton)	8.20
Copper (percent)	0.09
Lead (percent)	2.79
Zinc (percent)	2.20
Antimony (percent)	0.18

Because of snow conditions the showings reported to be best were not examined, and therefore it is impossible to form an opinion as to the commercial possibilities of the property.

Monte Cristo district

Monte Cristo mine

S½ sec. 23, T. 29 N., R. 11 E.

The Monte Cristo mine is located at an altitude of about 4,200 feet in Glacier Creek Basin in the Monte Cristo mining district. The property comprises some six patented mining claims all owned by Harold S. Ofstie, Route 2, Monroe, Washington. The claims are: Mystery, Pride of the Woods, Pride of the Mountains, IXL lode, Side Line lode, and 89. The principal workings are on the first three claims mentioned.

The property is reached by taking the county road to the old town of Monte Cristo, at an altitude of about 2,800 feet, nestled at the foot of craggy peaks which rise to elevations of 3,000 to 3,500 feet above the town site. From old Monte Cristo one takes the trail up the south bank of Glacier Creek, following along the old wagon road. This trail maintains a gentle grade for the first half of a mile and then gradually begins to steepen. A road extending for this first half of a mile was completed in 1950. After the first three-quarters of a mile has been traveled, Glacier Creek Falls and the foot of Mystery Hill are reached. Due south from here, about 600 feet above the trail are three dumps that show the location of the mine portals on the Mystery claim. These three workings have been driven along the strike of three veins in an easterly direction into Mystery Hill at its junction with the large talus slope. As there is no trail to these workings, one must leave the main trail to Glacier Basin and climb the talus slope up to the dumps.

GLACIER BASIN CLAIMS

In order to enter Glacier Basin one continues on the trail as it climbs steeply over the 500-foot rise in elevation at Glacier Creek Falls and swings from east to north to enter the basin, which has a northerly trend. Once in the basin the trail maintains a gentle upgrade to the mine workings a distance of about half a mile.

In 1900 when the Monte Cristo mine, comprising the six claims mentioned above, was operated as a unit by the John D. Rockefeller interests, who incidentally sold out in 1904, there was an aerial tramway connecting the Mystery workings with the concentrator at Monte Cristo and another aerial tramway connecting a portal on the Pride of the Mountains claim, at an altitude of 4,700 feet on the east side of Glacier Basin, with the Monte Cristo concentrator. This latter tramway ran across the northern tip of Mystery Hill. The workings on the Mystery claim, the Pride of the Woods claim, and the Pride of the Mountains claim are all connected underground. William S. Thying, writing for the Washington Geological Survey's Annual Report for 1901, part II, pages 71-72, has the following to say about the Monte Cristo mine:

In the Monte Cristo mine about 12,000 feet of tunnel and cross-cut work have been done, besides a large amount of stoping. The principal vein, which has been formed in a fissure in diorite, strikes a little north of east with a dip ranging from 55 degrees to 70 degrees to the northwest. The values run chiefly in gold and silver, although some lead is saved in smelting. The milling ore extracted from the mine averages $6 per ton in value, of which about $4 is in gold. This ore is concentrated in the company's mill, located in the town of Monte Cristo. In the concentration the ore is brought down from 3 or 3½ tons to 1 ton. The mine is located due east of the town, all of the ore being transported to the mill by two wire rope trams, of the Bleichert patent, one 3,600 feet and the other 6,250 feet in length. The mine during the past summer (1901) was producing ore at the rate of 3,500 tons per month, so that about 1,000 tons of concentrates were shipped monthly. While working, with the exception of the first two years of its history, the mine has produced an average of 39,000 tons of milling ore yearly. All of the ore which is mined is crushed and washed, the product containing an average of but ten per cent. of gangue matter. The loss in concentrating is stated to vary from 18 to 30 per cent. according to the degree of mineralization of the ore treated. All of the concentrates are shipped to the smelter at Everett.

During the summer of 1901 the Monte Cristo was the only mine in the district that was shipping ore. Other properties were either lying idle or else undergoing little besides assessment work.

In addition to these remarks it would be well to note that the gold is considered to be enclosed within the arsenopyrite. In this area the arsenopyrite carries values as high as 2½ ounces of gold and 6 or 7 ounces of silver per ton.

Unfortunately, at the time this property was visited in August 1948 the weather was foggy and rainy, so the examination of the surface exposures was under adverse conditions and necessarily limited. In Glacier Basin four mine portals with their attending dumps were visited. All the workings were inaccessible. The two lowest adits on the Pride of the Mountains claim in the east side of Glacier Basin were partly filled with water, doubtless unsafe, and mostly inaccessible. The vein at the portal of one adit is 2 feet thick, and the vein at the other is 3 feet thick; they both strike about N. 70° E. and dip about 65° NW. In the west side of Glacier Basin two other adits driven west into the east side of Mystery Hill were visited. The adit having the larger dump had at its portal a large mass of loose boulders and timbers that appeared to be ready to bury the portal at any moment; aside from this it was accessible. However, the writer did not go in. The other adit was half-full of water, but, as could be seen from the small dump, was probably not very long. Veins were not cropping out at either of these places. Once when the fog lifted for a short period, prospect holes could be seen scattered all over the mountain walls surrounding Glacier Basin. Mr. Ofstie reported that the workings in Glacier basin, particularly those on the east side, contain considerable quantities of sphalerite.

MYSTERY CLAIM

The three portals and dumps at the Mystery workings on the west side of Mystery Hill were visited. The lower two are open, but half-filled with water and emit a very strong odor from the decaying

timber, so they were not examined. The lowest dump contained, associated with sulfide minerals, some excellent specimens of radiating acicular clusters of tourmaline ranging in diameter from ¼ to ½ inch. This may indicate a temperature of mineralization around 400°-450° C. and solutions that were weakly alkaline.[1] The upper portal proper is caved, but still it was possible to make some worth-while observations above the portal where a stope had holed through to the surface. Here there was a caved zone or gash in the hillside about 20 feet wide. At the head of this, two mineralized joints or veins about 3 feet thick intersect; one strikes eastward and dips 75° north, the other strikes N. 70° E. and dips 85° N. According to Spurr's study of the Monte Cristo district,[2] the vicinity of such intersections or zones of fracturing are most favorable to mineral deposition. At this particular intersection there has been almost no wall-rock alteration outside of the immediate mineralized zone, and the sulfides occur as thin veinlets parallel to the walls of this altered zone. The zones pinch and swell, sometimes containing lenticular horses of the quartz diorite or tonalite.

The country rock in and surrounding Glacier Basin and Mystery Hill is classified as a tonalite by Spurr[3] who gives the following description:

> In the field the tonalite strongly resembles granite, being composed chiefly of quartz, feldspar, and hornblende. The microscope brings out its true character. The essential minerals are found to be feldspar, hornblende, and biotite, with occasional augite and hypersthene, and an abundant gray metallic mineral which is probably magnetite. The feldspar varies between oligoclase and bytownite, in general indicating a rather basic dioritic rock. The secondary minerals are actinolite, chlorite, epidote, pyrite, calcite, kaolin, etc. The structure of the rock is ophitic to nearly hypidiomorphic granular, with a slight tendency to porphyritic. The feldspar is generally the oldest of all the minerals except the occasional pyroxene; the quartz is youngest.

From the above description it is clear that the terms tonalite and quartz diorite are synonymous. In this report the latter, more common name is used.

Specimens were collected from the dumps on both sides of Glacier Basin, and one polished section was made for the purpose of mineral identification. Judging from the examination of the surface exposures, the veins appear to be mineralized joints in the quartz diorite. The mineralizing solutions have come up from below along these joints, which possibly have originated in part through contractive stresses set up at the time of the cooling and solidifying of the quartz diorite mass. As was shown in the section on the origin of the antimony-bearing sulfides (p. 32), such solutions are considered to be the final product of the fractional crystallization of a

[1] Smith, F. Gordon, Transport and deposition of the non-sulfide vein minerals. IV Tourmaline: Econ. Geology, vol. 44, no. 3, p. 186, 1949.

[2] Spurr, J. E., The ore deposits of Monte Cristo, Washington: U. S. Geol. Survey 22d Ann. Rept., pt. 2, pp. 822-824, 1901.

[3] Spurr, J. E., idem, pp. 796-797.

silicate magma. They are thought to have been hot, aqueous, and in this instance, because of the presence of the tourmaline, weakly acidic to weakly alkaline. Of course the necessary chemical components must have been present to permit the deposition of the observed minerals. At Monte Cristo these components were probably boron, potash, silica, sulfur, iron, copper, lead, zinc, arsenic, antimony, and gold. The wall rock was attacked by the mineralizing solutions only to a very slight extent outside the vein boundary. Spurr[1] has the following to say concerning the wall rock alteration on the Mystery claim:

> Microscopic examination of the foot wall of the main vein in the Mystery mine shows an altered yet easily recognizable tonalite, distinguished by being traversed by numerous parallel cracks and seams, without crushing. The feldspars are partly altered to fine muscovitic aggregate, while of the original dark minerals only the pale-green hornblende persists, the others having been replaced by a fine mat of actinolite fibers. The magnetite has been almost entirely extracted. In other specimens of the tonalite wall rock there is an abundant development of blue amphibole. In this case the biotite has often not been attacked to so great an extent as have the other original ferromagnesian minerals, which have disappeared and are represented by a nearly isotropic greenish-brown mass of decomposition products. The secondary blue amphibole is in irregular plates and also more or less perfect crystals. In this case also the magnitite has been extracted from the rock.

The fine muscovitic aggregates of which he speaks are undoubtedly what is now recognized to be sericite, formed by ascending hydrothermal solutions. Judging from the slight amount of wall-rock alteration observed and from Spurr's microscopic examination, it would seem that the hot ore-bearing solutions had percolated up through the joints for only a relatively short period of time.

The specimens and polished section give at the best a most limited picture of the process of vein formation. They indicate that the main gangue is apparently quartz and silicified quartz diorite, and the sulfide minerals are pyrite, pyrrhotite, arsenopyrite, sphalerite, chalcopyrite, galena, and jamesonite. Evidently there were two stages of deposition. The first comprised a silicification of the quartz diorite and the deposition of pyrite, pyrrhotite, arsenopyrite, sphalerite, and chalcopyrite in about that order, but with considerable overlapping; the chalcopyrite is deposited along fractures in sphalerite and also occurs as blebs enclosed within the sphalerite. As quartz fills fractures in the earlier sulfides, it is assumed that the second stage opened with an introduction of quartz after a period of fracturing. Elsewhere this quartz is euhedral and commonly forms small vugs which are filled with galena, jamesonite, and still more quartz. The jamesonite also fills some of the vugs as fine wire needles. Spurr cited this same type of occurrence for stibnite in the Monte Cristo, and nowhere does he mention the presence of jamesonite. From this it would seem that it is not at all unlikely

[1] Spurr, J. E., op. cit., p. 863.

that Spurr mistook the jamesonite for stibnite, because they are rather similar physically, and in 1901 the metallographic technique for the study of ores was not in common use.

According to the above observations the chemistry of the solutions underwent a change and the temperature conditions in the veins probably underwent a reduction between the first and second periods of sulfide deposition. Possibly the temperature during the first period of deposition was about 400°-450° C., as evidenced by the presence of the tourmaline and pyrrhotite. A somewhat lower temperature is suggested for the second period of deposition because of the presence of drusy quartz, galena, and jamesonite, which seem to occur ordinarily in environments of lower intensity than do tourmaline and pyrrhotite.

From the general impression gained while in the area and in accordance with the above discussion, it seems resonable to classify these deposits as being essentially of the mesothermal type, though they do have certain anomalous relationships that suggest the xenothermal (see p. 54). It is extremely doubtful that any antimony ore of consequence could be developed in this property.

Foggy mine

SW¼SW¼ sec. 13, T. 29 N., R. 11 E.

This property is located 1½ miles northwest of Glacier Basin on the southeast slope of the northeast ridge of Cadet Peak at an altitude of 5,500 feet, some 2,000 feet directly above Goat Lake Basin.

The property comprises three patented claims, the Foggy lode, the New York, and the 95 mine, all owned by Dr. W. J. Collings of 705 3rd Street, Renton, Washington, and all aligned in a northeasterly direction along the ridge.

The property is reached by taking the Monte Cristo road as far as Barlow Pass. This is the low pass separating Palmer Creek, a branch of the South Fork of the Stillaguamish River, from the South Fork of the Sauk River. The South Fork of the Sauk River is followed for about 1¼ miles to Elliott Creek, where a good trail leads to Goat Lake, a distance of about 5 miles. From the head of Goat Lake a trail, now indiscernible, once lead to the Foggy property; it is still marked on the Glacier Peak and Skykomish quadrangle maps of the U. S. Geological Survey and is probably the best route. Because of the difficulty of access during the continual fog and rainy weather of the summer of 1948, the writer did not attempt to visit this property. The following discussion, therefore, has been taken from Spurr[1] and from a report by P. C. Stoess.[2]

The rocks in this area are quartz diorite, the tonalite of Spurr, and a quartz-garnet-staurolite-biotite schist. The schist is to a large

[1] Spurr, J. E., op. cit., pp. 794, 822, 836, 842-844.
[2] Stoess, P. C., Monte Cristo, Silverton Mining District. Unpublished report in Division of Mines and Geology files, prepared under auspices of the Federal Civil Works Administration and the Washington Emergency Relief Administration in 1934.

degree the result of the metamorphism of Spurr's lower andesite, probably correlative with the Keechelus andesite to the south. An hypothesis that may explain this border metamorphism is nicely described by Spurr, from whom the following paragraph is quoted:

> Summing up the metamorphism due to the Glacier Creek-Goat Lake tonalite, we find that the recrystallization of the rock into which it intruded has extended, roughly speaking, a thousand feet or more. On the outer portions of the metamorphic zone the result has been simple silicification and the development of biotite, . . . As the tonalite is approached the schist becomes coarser and often loses all trace of its original nature, and besides biotite, garnet, staurolite, and occasionally hornblende are developed. Sometimes the rock becomes gneissic in appearance, and contains interbanded quartz veinlets. In proportion as the recrystallization increases the schistosity does the same, being most pronounced near the tonalite contacts and disappearing entirely when the slightly altered or unaltered rock is reached. Microscopic study shows that the schistosity is due to pressure, which has produced shearing. It is plain, therefore, that the tonalite mass, on forcing its way up through the rocks of the volcanic series, has produced a shearing on both sides, and to this shearing the metamorphism is doubtless partly due. Therefore this case of contact metamorphism is one where the results are partly due to dynamic action produced by the tonalite intrusion, and partly to metachemic action produced by solutions from the tonalite.

The principal joint in which the Foggy vein has formed strikes approximately northeast, dips about 60° NW., and cuts through both the schist and the quartz diorite. This property differs from those in Glacier Basin chiefly in having numerous branch veins with an eastward strike and 70° southward dip extending from the main vein, and it is at these intersections that the best ore occurs. The veins are reported to vary in width from about 2 feet to 20 feet, with shipping ore thickness from 9 to 20 inches and a mining thickness of from 4 to 5 feet. About 2 miles of development work is reported to have been done. This work consists of adits, drifts, crosscuts, and raises. As far as is known, no ore was ever shipped from this property. The mineralogy is approximately similar to that in Glacier Basin, but differs in detail. Galena, sphalerite, pyrrhotite, chalcopyrite, and calcite are less common than at Glacier Basin, arsenopyrite and pyrite being more common. Realgar and stibnite are present in relatively large quantities and were evidently the last minerals to crystallize. Realgar is reported as far as 1,000 feet below the surface.

Stoess reported that over a period of years he took a large number of samples for the former owners of this property and averaged them to arrive at the following assay figures: 0.2 ounce per ton in gold, 8 ounces per ton in silver, 3-5 percent zinc, 3-4 percent lead, 3.15 percent arsenic, and 5.5 percent antimony.

Not having examined the property, it is impossible for the writer to give any opinions as to its economic possibilities from the standpoint of antimony ore. Antimony is evidently present; and if it is present as stibnite, as reported, and there is a large enough volume of this 5.5 percent antimony ore, a concentrate might be made. The inaccessibility of the property may be the feature most detrimental to a profitable operation.

STEVENS COUNTY

Acme mine

SE¼NW¼ sec. 27, T. 35 N., R. 37E.

The Acme property is located at an altitude of 2,400 feet on the western slope of the east bank of the Columbia River about 5 miles below its junction with the Colville River. It is best reached by a dirt road leading east from State Highway 22 about 4 miles south of the Colville River bridge. In about ½ mile a south branch of this road is taken and followed for 2½ miles. The property is opposite this place on a small knoll rising above the flat upland on the west side of the road.

The Acme property comprises two patented claims owned by Louis Strauss of Colville. On the knoll are several partly caved open cuts and a partly caved 80-foot shaft, all on small quartz veins in muscovite granite. Below these workings is a 250-foot adit driven to the east under the hill. The adit strikes S. 58° E., and at 180 feet from the portal a winze has been sunk to a depth of 180 feet on a sparsely mineralized quartz vein. Just before the winze a short drift extends out from the main adit in a northeasterly direction. At the junction of this short drift and the main adit is a thin 2- to 3-inch stringer striking north and dipping 60° W. This stringer, subordinate to the main northwestward-striking quartz vein, contains very small amounts of boulangerite, bournonite, and andorite. Other minerals present are quartz, pyrite, arsenopyrite, sphalerite, and a few remnants of chalcopyrite, most of the latter having been transformed into covellite. The antimony minerals were in such small quantities that they could be identified only under the metallographic microscope. The U. S. Geological Survey very kindly identified a small mineral specimen from the thin quartz stringer as follows:

> Optical study by reflected light and microchemical tests made by Charles Milton, and X-ray investigation by George Switzer indicate that the chief constituent of your sample is bournonite, $CuPbSbS_3$. Galena is also present, but in much lesser amount, and there is also a third mineral, which is probably boulangerite, but it is present in too small amounts to be identified positively.

Boulangerite was also identified from the dump of a shallow open cut about 150 feet east and up the hill from the portal of the upper adit, though it was not found in place. The three antimony minerals seemed to be about the same age, but younger than the quartz, pyrite, arsenopyrite, sphalerite, and chalcopyrite.

About 500 feet below this upper 250-foot adit is a long crosscut adit which runs S. 70° E. for 1,450 feet into the hill. At the time of the writer's visit it was inaccessible. The rock on the dump consisted almost entirely of muscovite granite, silicified argillite, and a few scatterings of quartz and sulfides.

Mr. Strauss showed the writer a complete chemical analysis of a large group of samples from the upper adit, its winze, and the lower adit. It showed 4.38 percent arsenic, but no antimony, thus providing a further indication that the property is of no practical interest as regards antimony, despite some interest that has been shown.

Cleveland mine

NE¼ sec. 9, T. 30 N., R. 38 E.

The Cleveland mine is located in the Huckleberry Mountains at an altitude of 3,400 feet at the head of Hunters Creek. It is 8 miles due east of the town of Hunters, or about 11 miles by automobile road. The property is reached by taking the Springdale-Hunters road for 6 miles to where a road branches off to the northeast and, after crossing Hunters Creek, eventually leads to the mine in about 5 miles.

In January 1950 the property was owned by Base Metals, Inc. C. L. Miles was manager at the time of the writer's visit in the summer of 1947. There are nine patented claims: the Cleveland, Olympia, Ona, Etta, Triangle Fraction, Lucky Boy, Stewart Fraction, Copper King, and Copper Queen. The greatest part of the work has been done on the Cleveland claim, where there are about 3,500 feet of drifts, crosscuts, and raises, exclusive of stoping and the very oldest workings, which were close to the surface. In 1946 and 1947 several cars of boulangerite concentrates were shipped to Midvale, Utah.

The rocks in the vicinity of the mine consist of a group of phyllites, quartzites, and dolomites that have been designated as the Deer Trail group of pre-Cambrian age.[1] This group has a northeast strike. In the vicinity of the mine the beds dip steeply to the east, but 200 feet south of the mine workings the dips are 55° W. What happens in between is unknown. According to Mr. Bennett,[2] a westerly dip is the more common throughout this belt of rocks. He also stated that just to the north of the Cleveland mine area the rocks dip toward the west. Thus the area in which the mineralization has taken place appears to be an anomalous one. Unfortunately, the structural relations between this area and the rocks to the north and south have not been worked out. A correct understanding of these relations is particularly important to anyone mining in this area, as the fault system controlling the ore deposition appears to have more than local significance. Only through careful geologic mapping of several square miles around the mine and further underground development will the structural geology and its relation to ore deposition be worked out. During the present study enough work was done by the writer to present a strong case against the

[1] Bennett, W. A. G., Preliminary report on magnesite deposits of Stevens County, Washington: Washington Div. Geology Rept. of Inv. 5, p. 8, 1941.
[2] Bennett, W. A. G., Personal communication.

existence of a major cross fault which Jenkins[3] described as follows:

> 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.

Careful examination of the surface and underground workings brought to light no evidence in support of the statements in the quoted paragraph. On the contrary, in the immediate vicinity of the mine an undisplaced quartzite bed can be followed directly across the trace of the supposed fault.

Figure 13 is a geologic section through the above-mentioned anomalous area which gives a general picture of the ore occurrence, its relation to the fault system, and the rocks in the immediate vicinity. These rocks are composed of phyllite, dolomite, and a relatively thin bed of quartzite, all of which have been intruded by dioritic dikes or sills. The phyllite is the most abundant. For the most part it is gray to green to tan in color and is composed almost entirely of fine recrystallized quartz grains with just enough biotite and chlorite to place it in the phyllite class. Dolomite is the next most plentiful rock type and is the host rock for the ore. Two kinds of dolomite are present. One, the most plentiful, is a gray to white massive equigranular rock containing about 90 percent dolomite and 10 percent quartz. In the vicinity of the ore it contains scattered flakes of sericite, though no particular increase in quartz was noted. The other variety is a thin-bedded reddish iron-stained equigranular rock containing about 85 percent dolomite and 15 percent quartz. It contains blebs of hematite scattered in fine, thin quartz veinlets. The thin bed of quartzite is stained reddish brown by iron oxide, contains lenses of white, milky quartz, and generally is thoroughly recrystallized. The iron staining seems to be caused by the alteration of introduced pyrite to either limonite or hematite, depending on the oxidation state.

The dikes or sills are composed of a dioritic rock. This rock, as can be seen from the structure section, is by no means uncommon. It is now highly altered, but evidently at one time it was essentially a hornblende-plagioclase rock with disseminated ilmenite. At present the hornblende has broken down to chlorite, the plagioclase is kaolinized and sericitized beyond recognition, and the ilmenite is partly altered to leucoxene. The rock has three modes of occurrence, the most prominent being as dikes in the phyllite. The other two occurrences are unusual. One of these is as dikes 6 to 8 inches thick along which some of the major fracturing controlling the ore deposition took place. The peculiarities of the other occurrence in the

[3] Jenkins, O. P., Lead deposits of Pend Oreille and Stevens Counties, Washington: Washington Div. Geol. Bull. 31, p. 130, 1924.

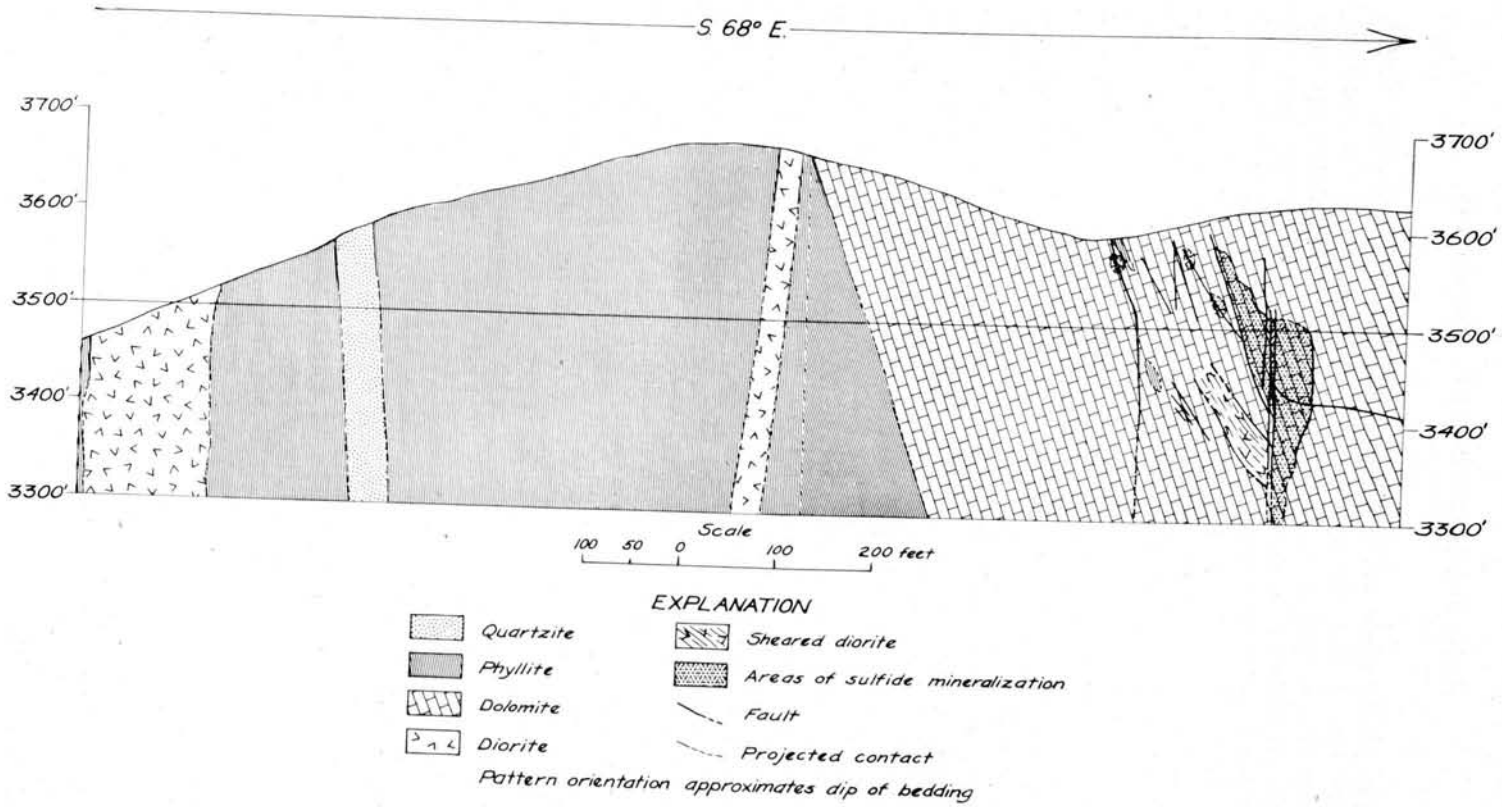


FIGURE 13.—Geologic cross section through the Cleveland mine area.

footwall of the main ore body (see fig. 13) are observable only in thin section. It has the texture of a micro-augen gneiss with the ilmenite and/or leucoxene forming the eyes. The chlorite and sericite are segregated in parallel bands, and the whole has been impregnated by calcite, indicating that this rock was present during the deformation of the sediments and subjected to the same stresses. Thus, these three different occurrences of diorite suggest that igneous intrusions took place in this area just before and during its deformation.

As can be seen in the cross section, the ore is associated with a fracture system in the dolomite. The system strikes N. 40° E., approximately parallel to the strike of the sediments. Some 200 feet south of the cross section, as mapped, the fracture system coalesces to form a well-defined fault, in the footwall of which is a sphalerite-boulangerite ore body that crops out at the surface and has been followed down its pitch to the south for 160 feet to where it may be fading out. This ore body is relatively shallow and not as high grade as the ones shown in the plane of the cross section, where small ore bodies are scattered through the fracture zone and the principal ore body is concentrated in the hanging wall of the zone. This body has been worked out down to 200 feet beneath the surface, below which point it has been explored for 55 feet and is still present. The body is roughly eliptical in plan, and at its widest point, 140 feet below the surface, measures about 70 feet in thickness and 100 feet along its strike. It becomes smaller toward the surface and also at depth.

A rough zoning of the sulfides has become evident at the Cleveland, while on the other hand, the same gangue minerals are present throughout the workings. As the ore is highly siliceous, the most important gangue mineral is quartz. However, there is also a minor amount of dolomite, and a rather rare carbonate which has been identified as mesitite. This mineral, not uncommon in the mine, is an intermediate compound of the isomorphous series magnesite-siderite and contains approximately 60 percent magnesite and 40 percent siderite.

The sulfides from the surface to 200 feet beneath the surface consist of pyrite, arsenopyrite, sphalerite with blebs of chalcopyrite, boulangerite, and minor amounts of galena. The boulangerite and sphalerite are the predominant ore minerals. Close to the surface there is a shallow zone of oxidation and the following minerals derived from the sulfides have been found: cerussite, anglesite, mimetite, bindheimite, valentinite, and scorodite. Below, 200 feet beneath the surface, there appears to be rather an abrupt change in the composition of the sulfide minerals, for below this point the boulangerite and arsenopyrite die out and galena takes the place of the boulangerite.

Therefore, it appears doubtful that any more boulangerite will be found below the present workings. If this assumption proves to be the case, any further antimonial-lead ore will have to come from newly discovered ore bodies. However, the Cleveland undoubtedly still has a good future as a producer of lead and zinc. Certainly, the the absence of boulangerite will simplify the milling and make the ore more easily marketable.

Easter Sunday mine

Center sec. 22, T. 40 N., R. 37 E.

The Easter Sunday property is located at an altitude of 3,550 feet, in northern Stevens County, 5½ miles east of the Kettle River and 3½ miles south of the Canadian boundary. It can be reached from U. S. Highway 395 by a dirt road leading northeast across the Kettle River at a place 3½ miles north of Orient. At 1½ miles beyond the Pierre Lake turnoff a steep rough road leads to the mine.

In 1949 the Easter Sunday property, including the Easter Sunday and Cairns patented claims, was owned by Delbert C. Ames, 534 Melrose Avenue, Kenilworth, Illinois. When visited in June 1949, all the workings were inaccessible and apparently there had been no activity for 20 years. Consequently the following account of the property is taken from Bancroft's report:[1]

> [In 1909] the deposit was being worked by the Forest Mining & Milling Co., which was carrying on experiments with the ore to determine its amenability to cyanidation. One shipment of a little less than 20 tons of ore is reported to have been made from a shallow shaft about 200 feet north of the main working shaft. A partial analysis of this ore is as follows:
>
> *Partial analysis of ore shipped from Easter Sunday mine*
>
> | | | |
> |---|---|---|
> | Fe | per cent | 6.5 |
> | SiO_2 | do | 68.9 |
> | CaO | do | 6 |
> | Cu | do | 1.21 |
> | Au | ounces to the ton | .44 |
> | Ag | do | 12.4 |
>
> . . . . The underground developments are a 130-foot inclined shaft pitching about 50°-55° N. 65° E., and two short levels run at 70 and 100 feet from the collar, making in all some 550 feet of workings. A diamond-drill hole, started 185 feet east of the collar of the shaft, has been sunk vertically to a depth of 480 feet.
>
> The rocks in the vicinity are dark, distinctly banded cherty argillites which are impregnated with pyrite. Intruded into this shale series is the monzonite porphyry commonly found throughout the Orient district.
>
> The ore body consists of a quartz vein parallel to the direction of schistosity of the shales, which strike N. 25° W. and dip 20°-60° N. 65° E. The vein ranges from 2 to 6 feet in width and appears to follow the curves of the inclosing strata, dipping about 50° N. 65° E. down to the 70-foot level, where it flattens out for a distance of 50 feet and then pitches northeast at a steep angle. An examination of the vein below the 70-foot level was impossible because of the presence of water in the shaft. Near the 70-foot level the main vein breaks up into several parallel

[1] Bancroft, Howland, The ore deposits of northeastern Washington: U. S. Geol. Survey Bull. 550, pp. 83-84, 1914.

stringers a few inches in width which traverse the shales. On the 70-foot level an intrusion of monzonite porphyry cuts off the vein. The ledge is reported to have been found again in the 100-foot level. In general the quartz appears to be rather barren, containing some pyrite, chalcopyrite, sphalerite, galena, and an indeterminable massive gray mineral containing lead, antimony, and sulphur.

Cyanide tests were discontinued during the summer of 1909, and presumably because of the scarcity of the ore no further shipments were made to smelters. According to the records the diamond drill penetrated a large ore body at a vertical depth of 146 feet. Assays of the contents of the ledge at this depth are not at hand. The company reports that the drill passed through 64 feet of vein material.

It was reported to the writer that the main inclined shaft had been continued on down to the 500-foot level, and judging from the size of the dump in 1949 this is probably correct. The "indeterminable massive gray mineral containing lead, antimony, and sulphur" has been determined to be boulangerite. An examination of specimens on the dump and a few pieces left in the old ore bin indicates that this mineral occurs only as a mineralogical curiosity at the property.

Mullen mine

W½NW¼ sec. 16, T. 32 N., R. 41 E.

The Mullen mine, under contract from the State to John Mullen of Chewelah, is located 3 miles due east of Chewelah and 1 mile due east of Quartzite Mountain at an altitude of 2,900 feet. It is situated in a saddle between two ridges; the lower one on the west is composed largely of hornblende granodiorite porphyry, probably an offshoot of the Loon Lake batholith, and the higher one to the east is composed of Addy quartzite of lower Cambrian age.

The property is easily accessible by a well-graded dirt road, but may be difficult to find without specific directions.

Geologically, the mine is on a mineralized quartz vein close to the contact between the granodiorite porphyry and the quartzite. In thin section the granodiorite can be seen to be composed of phenocrysts of plagioclase varying between calcic-albite and sodic-oligoclase, green hornblende, biotite, and a small amount of augite. The last three named minerals have partly altered to chlorite and minor amounts of epidote. The groundmass is composed of subhedral crystals of plagioclase and orthoclase with anhedral quartz filling their interstices. The plagioclase was too greatly kaolinized to be identified as to type. Small amounts of calcite as well as scattered specks of magnetite are visible. The quartzite in the vicinity of the property is quite arkosic, and where affected by the vein-forming solutions the feldspars have been largely changed to sericite.

At the time of the writer's visit to the property, in June 1949, a vertical shaft had been put down 17 feet on the quartz vein. The vein, striking about north, had been traced for 150 feet on the surface. It is about 150 feet east of the northwestward-trending granodiorite-quartzite contact. In the shaft the vein varies in thickness

from 0 to 6 feet between the irregular quartzite walls. The vein averages about 3 to 4 feet in thickness, and the sulfide minerals are confined to a fracture zone 1½ to 2 feet thick in the center of the vein. Apparently there has been a small amount of post-mineral faulting along flat-lying fractures. The displacement has been to the east, the underlying side being displaced about 2 feet in that direction at the one place where this faulting could be observed at the time of the writer's visit. This was at the south end of the shaft about 15 feet below the surface. Obviously, too little work has been done to enable conclusions to be drawn regarding the habit of post-mineral faulting.

Polished sections show that the sulfide minerals have replaced the quartz along fractures. The minerals are pyrite, sphalerite, tetrahedrite, zinkenite, meneghinite, and steel galena. The specimens examined show that the deposition was perhaps in that order. Polished sections examined show definitely the following relationships: galena crosscutting sphalerite and corroding pyrite and tetrahedrite, and meneghinite containing scattered fragments of zinkenite crosscutting sphalerite. Unfortunately, the relationship between the galena and the meneghinite and zinkenite could not be observed in any of the specimens collected. The following analysis, obtained through the courtesy of Mr. Mullen, is of an average sample of ore from the property.

Analysis of average sample of ore from the Mullen mine

	Analysis from Bunker Hill Smelter	
Gold (ounces per ton)	.56	
Silver (ounces per ton)	21.60	
Copper (percent)		1.0
Lead (percent)		33.8
Zinc (percent)		9.7
Antimony (percent)		5.6
Arsenic (percent)		0.14
Bismuth (percent)		0.0
Iron (percent)		1.6
Sulfur (percent)		12.0
Calcium		Trace
Insolubles (percent) (quartz)		32.6
Total		96.44

As can be judged from the above comments, the property's principal interest as far as antimony is concerned is as a source of the rare mineral meneghinite.

Pomeroy prospect

SE¼ sec. 22, T. 40 N., R. 37. E.

The Pomeroy property is on the same road as the Easter Sunday and is ¼ mile to the south of it, the main shaft being a few feet to the west of the road. This property was owned in 1949 by W. M. Hendrickson of Orient, who held by location two claims, the Copper Mask and the Copper Glance. As the shaft was nearly full

of water when the property was visited, the true attitude of the vein could not be determined, but it appears to strike about N. 60° W. and be a branch off the Easter Sunday vein. Judging from specimens on the dump, the country rock is apparently a greenish argillite, while the vein is largely quartz which has been mineralized with pyrite, sphalerite, chalcopyrite, boulangerite, and galena. Sphalerite is the most abundant sulfide. As at the Easter Sunday, the boulangerite is only a mineralogical curiosity. This shaft is said to be 220 feet deep and to have a drift from the bottom leading toward the Easter Sunday vein. At the surface about 150 feet to the southeast of the main Pomeroy shaft, the southerly continuation of the Easter Sunday vein has been exposed by a shallow 27-foot shaft. Here the vein is about 8 feet thick and strikes N. 20° W. and dips 75° E. It is sparsely mineralized with pyrite, chalcopyrite, bornite, and a little galena.

Schrenberg prospect

SE¼SW¼ sec. 18, T. 32 N., R. 41 E.

The Schrenberg property is located 1 mile southeast of Chewelah. It is reached by traveling east out of town on the Usk road for about ¾ mile to the Walter Luttrell farm, which is on the south side of the road just west of a cemetery. J. J. Schrenberg, who originally owned this farm, has retained the southernmost 20 acres to include his antimony prospect. One may drive to within about ¼ mile of the deposit, but final directions should be obtained at the Luttrell farm, as the property is difficult to find, hidden as it is on the west side of a northward-trending ridge covered by scrub timber.

The amount of stibnite seen at the prospect was extremely meager, and it occurs at only one place. There, in an outcrop, are very small irregular segregations of stibnite with calcite in white medium-grained silicified dolomite. The largest calcite-stibnite body observed was 3 inches thick and 2 feet long. The deposits seem to be along joints dipping about 30° SW. in dolomite on the footwall side of a quartz vein. The latter is about 3 feet thick, strikes N. 35° W., and dips 60° SW. The quartz vein contains scattered showings of pyrite and chalcopyrite.

A little to the west and directly below the outcrop just described is a barren 20-foot shaft apparently sunk on the quartz vein. About 50 feet to the west of this shaft is another 165 feet deep. A little scattered pyrite is around the dump on this shaft, showing that the quartz vein had been intersected at depth. Both of these shafts are now partly caved.

Tile Creek Mining Co. prospect

SW¼ sec. 7, T. 38 N., R. 39 E.

The Tile Creek Mining Co. property is located on the north side of Swede Pass on the east bank of Ryan Creek at an altitude of

about 1,800 feet, approximately 500 feet above the Columbia River. It is extremely difficult to locate because of heavy brush.

The prospect consists of a 35-foot adit striking N. 25° E. along the contact of black medium-grained massive graphitic limestone and black graphitic thin-bedded limy argillite. The limestone is massive and breaks with a conchoidal fracture. In thin section it is seen to be composed of shreds of graphite, calcite, and about 5 percent original quartz. The contact dips about 75° SE., the limestone being on the footwall and the argillite on the hanging wall. The stibnite, partly altered to yellow and white stibiconite and cervantite, occurs along fractures and in vugs in a quartz lens that follows the limestone-argillite contact. It has been almost completely mined out. Judging from specimens on the dump, the lens had a maximum thickness of about 2 feet. A few specks of scheelite were noticed in the quartz.

Possibly other stibnite-bearing quartz lenses might be discovered along this contact, but it is doubtful that they would appear with sufficient frequency and be of sufficient size and tenor to make this prospect worthy of further effort.

Vanasse prospect

S½NE¼ sec. 10, T. 36 N., R. 38 E.

The Vanasse property, leased from the State by Luther Vanasse of Colville, is about 1.3 miles up the Mission Road, which branches from U. S. Highway 395 approximately 5½ miles northwest of Colville. A dump on the property may be seen from the road.

The Victory shaft is about 30 feet deep and was sunk on a 1- to 2-foot quartz vein in arkose. The vein strikes N. 30° E. and dips 75° E.; and it carries sparsely disseminated chalcopyrite, tetrahedrite, galena, and sphalerite. Mr. Vanasse reported that some of this quartz runs as high as $100.00 per ton in silver. About 300 feet N. 65° E. of the shaft are the former stibnite workings. No stibnite was seen in place, but a few specimens were gathered from rocks lying beside the scattered trenches. The trenches have been dug in iron-stained fine-grained silicified quartzite striking about N. 50° E. and dipping 35° NW. Small, thin quartz stringers follow the bedding, and apparently it is in these that the stibnite occurred. From studying specimens of stibnite-bearing rock it appears obvious that a solution carrying silica and iron was first introduced along the bedding planes; then after later fracturing, stibnite was introduced, filling the fractures and replacing some of the quartz. Several strong gossan zones occur east of these trenches, but insufficient development work has been done on them to permit their appraisal.

Wells Fargo mine

NW¼NE¼ sec. 36, T. 31 N., R. 38 E.

The Wells Fargo mine is located at an altitude of about 4,000 feet on the south side of the eastward-striking ridge separating the headwater drainage of the two northwest tributaries of Deer Creek. It is reached by taking the Waits Lake road out of Valley, passing around the north end of the lake and continuing west for 4 miles to a cross road. Just east of this intersection is the Carr place where it is suggested that further directions be obtained.

The property was originally located in 1890. The principal development work was done by the Wells Fargo Mining Co. between 1897 and 1917. In 1947 the property was owned jointly by C. R. Carr, J. M. Carr, and F. B. Carr. Their latest work there, in 1946, consisted of putting down a 17-foot drill hole.

The eastward-striking ridge, into which the two adits on the property have been driven, is covered with a light stand of pine. The uppermost working is about 150 feet below the crest of this ridge at an altitude of approximately 3,900 feet. The entire ridge is composed of alternate beds of gray slate and thin beds of quartzite, which according to Bennett[1] are of pre-Cambrian age. He places these rocks in the Deer Trail group. They have an average strike of a few degrees east of north and a dip of between 50° and 70° NW. The slaty cleavage in the mine workings generally seems to parallel the bedding. This would indicate that the property is on the western limb of a northeastward-striking anticline. Some cross-bedding was noticed in the quartzite, but its relations were not sufficiently clear to distinguish between top and bottom.

The general relationship between the mineral veins and this slate-quartzite sequence is shown in figure 14, which is a plan view of the upper adit. A barite vein, which is apparently older than the quartz, appears to parallel the attitude of the sediments. It contains 1/16-inch discontinuous streaks of siderite parallel to its walls, giving the barite a very undesirable impurity. At this level the siderite is almost entirely weathered to limonite. An outcrop of barite and crosscutting eastward-trending quartz veins, 1 to 2 feet thick, were seen on the surface 35 feet to the north of the exposure shown in the drift. The crosscutting quartz veins associated with the barite are almost completely devoid of sulfides, only a scattering of pyrite being present. Because of a thick coating of greasy mud and high backs in the barite portion of the workings, it was impossible to arrive at any satisfactory conclusions as to the exact relationship between barite, quartz, and the shearing.

The stibnite vein averages about 3 feet thick except at its northeast end, where it is split into small stringers and dies out. The

[1] Bennett, W. A. G., Preliminary report on magnesite deposits of Stevens County, Washington: Washington Div. Geology Rept. of Inv. 5, p. 8. 1941.

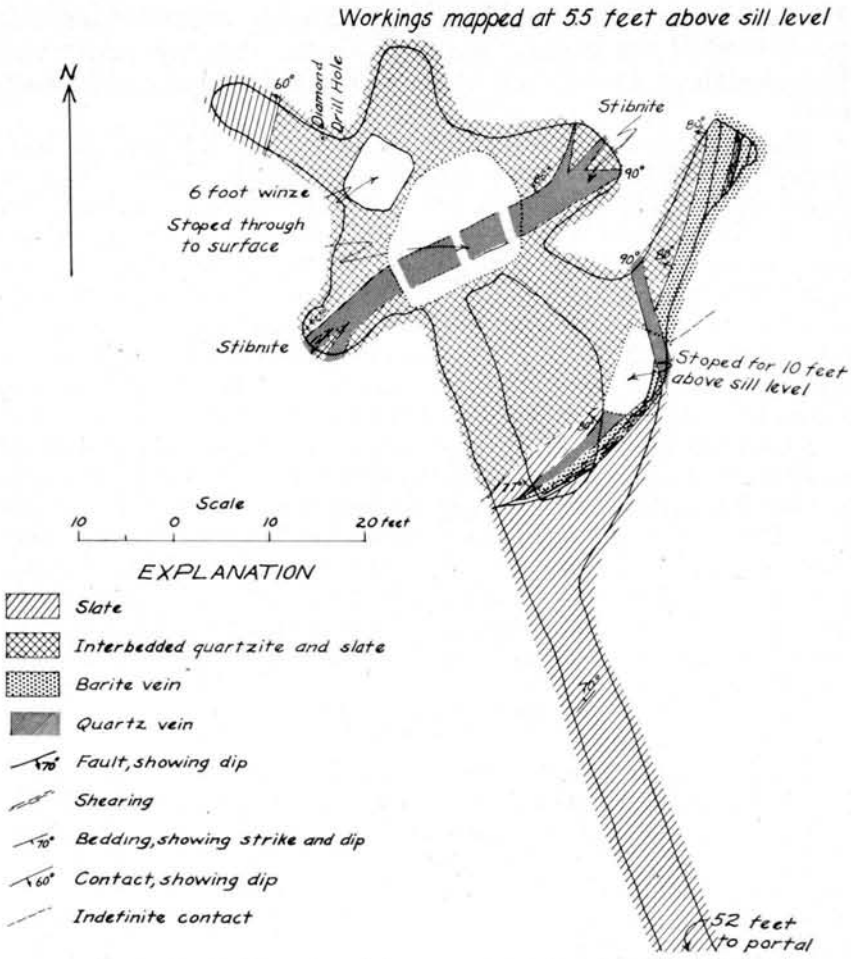


FIGURE 14.—Geologic plan of the upper adit at the Wells Fargo mine.

southwest end gives a similar impression by having a higher percentage of slaty streaks than the other portions of the vein. The slaty streaks are parallel to the vein walls, which locally are weakly sericitized. Pyrite cubes up to ⅛ inch in diameter are disseminated through the vein, as are occasional segregations and thin streaks of brown siderite. The stibnite occurs in scattered bunches of plumose aggregates averaging ½ to ¾ inch in diameter in quartz of both a milky and a sugary variety. Generally, the stibnite is filling vugs in the milky quartz, but in places the stibnite is replacing the sugary quartz. The stibnite has partly oxidized to gray and yellow stibiconite. At the time of the writer's visit very little stibnite was visible in place; only at the two points marked on the map was any appreciable amount seen. Mr. Clarence Carr reported that there was stibnite in the quartz taken from the last

9 feet of the drill hole, and quartz, presumably without stibnite, in the bottom of the shallow winze, indicating that the quartz vein has maintained its thickness at least for a short distance below sill level.

That portion of the vein directly above the timbers has been stoped through to the surface, which is about 50 feet above sill level. At the surface the vein is 7½ feet thick, strikes N. 15° E., and dips 60° W. This means a change in strike of about 45° in a vertical distance of some 35 feet. In general the vein usually follows the attitude of the cleavage in the sediments, with only local crosscutting. As it is impossible to descend from the surface through to the upper adit, the details of this abrupt change in strike of the vein could not be determined. At the surface the 1½ feet of vein on the hanging wall contains the greater percentage of the stibnite.

About 200 feet S. 25° E. from the portal of the upper adit, at an altitude of about 3,755 feet is the lower adit. It was inaccessible in 1947, but according to Weaver[1] it was driven N. 30° W. for 125 feet. The first 70 feet cut across calcareous argillite and schist, and the remaining 55 feet was in light cream-colored quartzite. A small shipment of stibnite ore averaging 7 percent antimony was made in 1937 by L. E. Carr. So far as the writer knows, this is the only shipment that has ever been made from the property.

Young America mine

NE¼NW¼ sec. 33, T. 38 N., R. 38 E.

The Young America mine is located at an altitude of about 1,700 feet in a dolomitic limestone bluff 500 feet above the Columbia River, or Roosevelt Lake. This bluff in the vicinity of the mine strikes N. 10° E. The workings are about a quarter of a mile northeast of the town of Bossburg, which is located on State Highway 22 and the branch line of the Great Northern Railway that extends between Spokane, Washington and Nelson, British Columbia. The mine is reached by a quarter of a mile of gravel road that turns east from the highway just north of Bossburg.

In 1950 this property, owned by Perry Leighton and associates, of Colville, Washington, comprised four claims: the Potomac, Silver Star, Mount Vernon, and Comet Silver, all held by location. It is interesting to note that this property was first discovered in 1885, making it, with the Old Dominion and the Bonanza Lead, one of the three oldest properties in the Colville district.

For two reasons the writer feels that the discussion of this property should be confined largely to the mineralogic occurrence of the rare mineral geocronite, which in turn limits the discussion to the old upper workings, as geocronite has not been found in the new ore

[1] Weaver, C. E., Mineral resources of Stevens County, Washington: Washington Geol. Survey Bull. 20, p. 212, 1920.

body developed in 1949. The first reason is that the general geology and mining possibilities of the property have been thoroughly examined with the aid of diamond drilling by the U. S. Bureau of Mines, and the results compiled by R. J. Hundhausen[1] into an excellent report to which the reader is referred for a detailed discussion. Most of the information and ideas concerning the general geology of the mine, which were used as a background for the writer's microscopic work on the mineralogy and ore deposition, were obtained from that report and from discussions in the field with its author. The second reason is the chemical composition of geocronite. The arsenic-free variety of geocronite (schulzite, $Pb_5Sb_2S_8$), which is the variety at the Young America, contains 67.58 percent lead, 15.67 percent antimony, and 16.73 percent sulfur; thus, because of its composition and rarity, it can never be considered as a source of antimony. For instance, when a stope largely composed of geocronite, but nevertheless containing minor galena and sphalerite was being mined, the concentrates ran only 3 percent antimony. Therefore the prime interest of this mineral in connection with a report on antimony occurrences is due to the facts that it is a mineralogic curiosity and that it does occur in such large quantities on this property.

The principal ore zone is just beneath a flat-lying shear in a gray to white massive fine-grained dolomitic limestone. The shear strikes into the bluff about N. 65° E. and dips between 15° and 25° N., averaging about 20° N. The attitude of this plane of thrusting is more or less controlled by the attitude of the dolomitic limestone. In the latter part of 1948 the ore had been mined along its strike for 300 feet and along the dip for 200 feet. The zone, containing numerous flexures, varies in thickness from a few inches to 10 feet. Hundhausen[2] gives a good description of the general features of the ore zone, from which the following is quoted:

> The ore shoots in the mine consist of replacement stringers, veins, and lenses along an irregular, gently dipping zone of movement. The ore is not confined within sharply defined walls. In some places the zone consists of a series of narrow bands of ore separated by unreplaced limestone. It ranges in width from a thin stringer to a massive lens nearly 5 feet thick.
>
> . . . . In the steeper parts of the vein the ore tends to pinch; in the flatter parts the ore generally is thicker. Small lenses of ore often exhibit a wavy modified "S" shape in sectional view. Furthermore, a sectional view of the mine workings exhibits the same "S"-shaped fracture pattern. The flexures creating ore shoots became more curvaceous and complex toward the northeast end of the mine.
>
> . . . . The ore shoots narrow and finally pinch out when followed up the dip. Locally, the ore may narrow or widen abruptly in the vicinity of minor faults.
>
> Another lens of ore, 25 feet vertically below the hanging wall ore zone, has been mined . . . Apparently this is a branch fracture diverging from the main fracture zone.

[1] Hundhausen, R. J., Investigation of the Young America lead-zinc deposit, Stevens County, Washington: U. S. Bur. Mines, Rept. Inv. 4556, November 1949.
[2] Hundhausen, R. J., op. cit., p. 8.

This tabular S-shaped ore zone is cut at a distance of 186 feet S. 70° E. from the main portal by a calcite vein 2 to 4 feet thick striking N. 20° E. and dipping 72° E. The vein is composed of exceedingly coarsely crystalline calcite containing scattered vugs lined with drusy quartz, the deposition of which was the most recent mineralizing activity. The contacts of the vein are irregular and clearly show the replacement nature of the calcite. Likewise, in places along its course it splits up, for short distances, into individual stringers. Within the vein several examples of drag ore breccia have been seen. The calcite vein is divided at its center by a fault plane paralleling the attitude of the vein. According to Mr. Sorensen, general manager at the mine during 1949, there has been some displacement along the calcite vein. The southernmost exposure underground shows almost no displacement, while 180 feet to the north the vertical displacement is 15 feet. The east side has moved down; no evidence was seen for a horizontal component, the movement being of the hinge type.

A crosscut extending out into the hanging wall or east side of the calcite vein intersects a hydrothermally altered and mineralized felsite dike. The dike carries, as films along fractures, pyrite and minor amounts of chalcopyrite. It has the same mineralogy as the "lamprophyre" dike exposed at the surface and described by Bancroft,[1] that is, much feldspar now almost completely altered to sericite, and a minor amount of a ferro-magnesian mineral now completely altered to chlorite.

The rock above the hanging wall of the vein is more fractured than that below the footwall. Consequently, the ore bodies are of greater size adjacent to the hanging wall, as this ground was the more receptive to the mineralizing solutions. Also, this would seem to indicate that even though the calcite vein is definitely post-ore and contains fragments of ore, this same plane may nevertheless have also been a plane of pre-ore movement. Thus in the vicinity of the calcite vein there are two factors controlling the loci of ore deposition, (1) the calcite vein, and (2) the flat-lying shear beneath which the ore occurs. The ore thins out more the farther away it is from the calcite vein. Also, a rough zoning is apparent around the calcite vein—lead close to the vein, zinc away from it—however, according to Mr. Sorensen, the recent (1947) smelter returns for the mine show a constant lead/zinc ratio of 1:2 throughout the mine, which indicates of course that the zoning is more apparent than real. Nevertheless, the fact that there is an apparent zoning does show that conditions for crystal growth were more favorable in one place than in another. In further support of this, Mr. Sorensen showed the writer a stope in the hanging wall of the

[1] Bancroft, Howland, The ore deposits of northeastern Washington: U. S. Geol. Survey Bull. 550, p. 62, 1914.

calcite vein in which the sphalerite is so finely divided in the gray dolomitic limestone that except for a check assay on a sample this ore would have been missed.

Originally the oxidized ores of lead and zinc, cerrusite and smithsonite, were mined. This was soon followed by the mining of the sulfide ores, the silver-bearing galena and sphalerite. At the present time only a small amount of oxidized ore is to be found underground, and that is adjacent to fractures, allowing groundwater circulation.

In 1947 a new stope was opened up on the main level just east of and adjacent to the calcite vein. At first this stope was thought to contain the usual galena and sphalerite. However, Hundhausen suspected the presence of a mineral other than galena and sent some specimens for identification to A. J. Kauffman, petrographer for the U. S. Bureau of Mines at the regional office in Albany, Oregon. By means of microscopic, spectrographic, and X-ray diffraction data Mr. Kauffman identified the mineral as geocronite. The smelter returns on the concentrates from this stope showed about 3 percent antimony. A spectrographic analysis of the geocronite made by Mr. Valentine, of the staff of the Division of Mines and Geology, shows, besides the predominant lead and antimony, 0.28 percent arsenic, 0.02 percent tin, and 0.002 percent silver or about 58 ounces per ton.

Although the geocronite had been fairly well mined out in the summer of 1948, a sufficient amount was left so that an idea of its mode of occurrence could be gained. The geocronite had been deposited in lenses parallel or nearly parallel to the bedding of the limestone. According to reports some of these lenses were as much as 5 feet thick. Immediately adjacent to the geocronite is an alteration halo averaging ¼ inch in thickness of dark-brown earthy anglesite, and scattered through it are minute specks of geocronite. Galena was also observed altering to similar anglesite in an identical manner. Surrounding and enclosing the anglesite halo is the quartz gangue. At the contact of the quartz gangue and the limestone is commonly a thin layer of yellow powdery cervantite. This indicates that in this early stage of geocronite oxidation the antimony had the ability to migrate short distances. Never is the cervantite powder observed to be more than an inch from the geocronite.

The polished-section study shows that the geocronite replaced the sphalerite, as can be discerned from crosscutting relationships and the corroded outlines of dark-brown sphalerite grains scattered through the geocronite. In one specimen a veinlet of galena was seen to cut across the geocronite. Otherwise the relationships between the geocronite and the galena are uncertain. Probably there was very little difference in their time of deposition; both, however, followed the sphalerite. Attention should be called to the fact

that in the immediate vicinity of strong geocronite, galena is present in only minute amounts, and vice versa.

Polished sections and thin sections from other parts of the mine, when studied in connection with those of the geocronite itself, give a good insight into the mineralization history of the principal ore bodies mined up to 1949. From one polished section which includes the calcite vein contact, the majority of the principal textural relationships can be observed and all of the minerals identified. These relationships are upheld by the other polished and thin sections. The greater part of this polished section shows quartz, containing euhedral pyrite grains with microscopic cobaltite inclusions, being replaced by massive dark-brown sphalerite containing minute inclusions of stannite. The habit of the dark sphalerite to contain inclusions of stannite seems to be common to all parts of the mine. The evidence for replacement of pyrite by sphalerite is based on the fact that the pyrite in the early quartz is euhedral and that the pyrite within the sphalerite always has a corroded periphery. Prominently crosscutting the massive sphalerite is a second generation of quartz which contains small drusy vugs in which are fillings of either galena or geocronite. These in turn were observed in one place to be cut by stringers of calcite. Similar stringers can be traced to the calcite vein. After the calcite period of deposition, drusy quartz, as mentioned above, was deposited as a vug lining on the calcite.

A polished and a thin section of ore were made from the lens of ore 25 feet vertically below the main ore zone. This lens of ore is predominantly sphalerite with minor amounts of galena. Dark-brown sphalerite containing minute stannite inclusions replaces and fills fractures in the limestone and quartz gangue. There are two varieties of sphalerite present, the dark-brown type and a light-brown to yellow type which does not have stannite inclusions. The darker, containing more iron, is enclosed by the lighter, showing that the latter is the younger and possibly was deposited at a lower temperature.

From the above observations it can be seen that the history of the lead-zinc mineralization took place in somewhat the following stages:

1. Pre-ore fracturing which prepared the dolomitic limestone for the introduction of mineralizing solutions. Fracturing probably continued into the early part of the next stage.
2. Introduction of quartz, and euhedral pyrite with minute cobaltite inclusions. Generally, the best ore bodies are found where the concentration of silica in the limestone is the highest. Hydrothermal alteration of the felsite dikes and deposition of pyrite and chalcopyrite along fractures in the dikes may have taken place at this stage.

3. Deposition of dark-brown sphalerite with stannite inclusions in silicified limestone, followed by depletion of copper, tin, and most of the iron from the mineralizing solutions (as evidenced by the deposition of light-brown to yellow sphalerite alone) as the final phase of the zinc mineralization.
4. Deposition of the second generation of quartz.
5. Deposition of geocronite and galena, perhaps in that order.
6. Formation of the calcite vein and subordinate stringers, preceded by some displacement. The calcium in the calcite vein may have been derived from that which was displaced from the dolomitic limestone at the time of its replacement by the mineralizing solutions.
7. Deposition of drusy quartz.
8. Post-mineral movement on calcite vein.

APPENDIX

As mentioned in the introduction to this report, it was impracticable to visit all the antimony occurrences known in the state. Only those deposits were visited that contained either stibnite or some unusual antimony-bearing mineral that might be of particular mineralogic interest. However, included in this appendix are all the reported and known occurrences of antimony, listed alphabetically by counties. This list of occurrences has been compiled by Mr. Grant M. Valentine on the staff of the Division of Mines and Geology after an exhaustive search through the geologic and mining literature of the state and the files of the Division.

The sources of all this information vary widely in reliability, all the way from explicit field notes of staff members of the Division to hearsay and rumors. In spite of the lack of authenticity of some of the reports, it is thought that they all should be listed for each individual to appraise as he may wish. In the bibliography, alphabetically arranged by authors, each reference has been assigned a number. These numbers are used at the end of each description to indicate the references pertaining to the particular property.

Two properties in this list deserve special mention, because it is very possible that antimony could be produced profitably from them as a byproduct. These two properties, the Chinto and the United Silver Copper, contain as the principal constituents of their ore a mixture of chalcopyrite and silver-bearing tetrahedrite. The Sunshine Mining Co., also a producer of silver-bearing tetrahedrite, has developed an electrolytic process for the production of antimony cathode metal. This process takes place in the manner described in the following excerpt:[1]

> The antimony contained in the tetrahedrite ore is put into solution by leaching 8 to 10 hours at 100° C. in a solution of Na_2S. After filtering, the pregnant solution is electrolyzed in diaphragm-type cells containing mild-steel anodes and cathodes. The resultant cathode metal contains about 96 or 97 percent antimony and is sold as such without further refining.

Consequently, it may be possible under favorable market conditions to produce byproduct antimony metal from the Chinto and the United Silver Copper.

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[1] Schaum, J. H., Antimony: Minerals Yearbook, 1943, p. 785, 1945.

ABBREVIATIONS

The following list of abbreviations is arranged alphabetically and contains all those used in the following inventory of antimony deposits.

Ag	silver	N.	north
As	arsenic	NE.	northeast
Au	gold	Ni	nickel
Bi	bismuth	NW.	northwest
Br	bromine	**Ore min**	ore mineral (s)
Cd	cadmium	oz.	ounces
Cl	chlorine	p., pp.	page, pages
Co	cobalt	Pb	lead
cor.	corner	%	percent
Cu	copper	**Prod**	production
Dev	development	**Prop**	property
E.	east	**Ref**	references
est.	estimated	S.	south
ft.	foot, feet	S	sulfur
Hg	mercury	Sb	antimony
Improv	improvements	Se	selenium
in.	inch, inches	SE.	southeast
lbs.	pounds	sec.	section
Loc	location	SW.	southwest
mi.	mile, miles	W.	west
Mo	molybdenum	Zn	zinc

Sec. 6, (23-15E). The parenthetical abbreviation indicates Township 23 North, Range 15 East, Willamette meridian.

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LIST OF WASHINGTON ANTIMONY OCCURRENCES

Chelan County

1. **Name:** Bald Eagle and Gray Eagle. **Loc:** On a fork of Jack Creek, a tributary of Icicle Creek. **Owner:** L. A. Parker and H. C. Castlebury (1897). **Ore:** Cu. **Ore min:** Tetrahedrite. **Dev:** 16-ft. drift. **Ref: 10,** p. 27.

2. **Name:** Caledonia. **Loc:** Sec. 1, (22-17E). **Prop:** 4 claims. **Ore:** Au, Ag, Cu. **Ore min:** Pyrite, free gold, tetrahedrite. **Gangue:** Quartz. **Deposit:** 3 parallel veins. **Dev:** 2 shafts and 2 tunnels. **Assays:** Some assays ran more than $100. **Ref: 10,** p. 15.

3. **Name:** Humbug. **Loc:** (23-15E), in Solomon Creek Gulch near Silver Fiend prospect. **Prop:** 1 claim. **Owner:** James Grieve, K. W. Dunlap, and August Sasse (1897). **Ore:** Pb, Ag, Au, Cu. **Ore min:** Galena, tetrahedrite. **Gangue:** Quartz. **Deposit:** Thick vein. **Ref: 10,** p. 28.

4. **Name:** Hunter. **Loc:** SW¼ sec. 12, (31-18E), on shore of Lake Chelan just N. of mouth of Cascade Creek. **Prop:** 1 claim. **Owner:** D. H. Lord and A. W. Chappell (1897). **Ore:** Ag, Au, Cu. **Ore min:** Pyrargyrite, tetrahedrite. **Deposit:** 4-in. pay streak. **Dev:** 15-ft. tunnel. **Assays:** 140 oz. Ag, $16 Au. **Ref: 10,** p. 32.

5. **Name:** Little Jap. **Loc:** NW¼SE¼ sec. 3, (31-18E), on shore of Lake Chelan about 500 ft. SW. of Sunday Morning. **Access:** Boat from town of Chelan. **Prop:** 4 claims. **Owner:** Crocker Perry (?) 1947. **Ore:** Ag, Cu, Au. **Ore min:** Pyrite, pyrrhotite, and, according to old reports, pyrargyrite and chalcopyrite. **Deposit:** 4-in. gouge seam in granite gneiss con-

taining a ½-in. seam of quartz in which is scattered pyrrhotite and pyrite. **Dev:** Main adit below lake level, 30-ft. adit about 200 ft. above the lake. **Ref: 10,** p. 33; **22.**

6. **Name:** Marcus Stein. **Loc:** NE¼ sec. 17, (31-17E), at mouth of Wilson Creek. **Access:** Road from Lucerne. **Prop:** 2 claims. **Owner:** Marcus Stein (1897). **Ore:** Hg, Au. **Ore min:** Pyrargyrite, pyrite. **Gangue:** Quartz. **Ref: 10,** p. 36.

7. **Name:** Orphan Boy. (See p. 59.)

8. **Name:** Peshastin (Blewett, La Rica). (See p. 62.)

9. **Name:** Silver Fiend. **Loc:** NW¼ sec. 10, (23-15E), in Solomon Creek Gulch. **Access:** 10-mi. trail from mouth of Jack Creek at end of Icicle Creek road. **Prop:** 1 claim. **Owner:** James Grieve (1897). **Ore:** Pb, Ag, Au, Cu. **Ore min:** Galena, tetrahedrite. **Gangue:** Quartz. **Deposit:** Thick vein. **Dev:** 15-ft. tunnel. **Ref: 10,** p. 29.

10. **Name:** Sunday Morning. **Loc:** NW¼SE¼ sec. 3, (31-18E), on E. shore of Lake Chelan. **Access:** Boat from the town of Chelan. **Prop:** 1 claim. **Owner:** Crooker Perry of Lakeside, Washington (1947). **Ore:** Ag, Pb, Au. **Ore min:** Galena, pyrite, pyrargyrite. **Gangue:** Quartz. **Deposit:** 4-ft. zone of hydrothermal alteration in granite gneiss containing a ½- to 2-in. stringer of sparsely mineralized quartz. **Dev:** 70-ft. adit, under water when the lake is high. **Assays:** A shipment returned $250 per ton gross. **Prod:** 4,600 lbs. shipped to a smelter. **Ref: 10,** p. 30; **22.**

11. **Name:** Van Epps (Snook and Ellen). (See p. 62.)

12. **Name:** Wenatchee Antimony. **Loc:** Wenatchee district. **Ore:** Sb. **Deposit:** Ore from Antimony Queen mine was shipped to Pateros and thence to Wenatchee during 1916. Probably this fact is responsible for reported antimony production in the Wenatchee area. **Prod:** Small production reported in 1916. **Ref: 10,** p. 46.

13. **Name:** White Star. **Loc:** T. 23 N., R. 15 E., near Silver Fiend in Solomon Creek Gulch. **Prop:** 1 claim. **Owner:** John Stewart (1897). **Ore:** Pb, Ag, Au, Cu. **Ore min:** Galena, tetrahedrite. **Gangue:** Quartz. **Dev:** 20-ft. tunnel. **Ref: 10,** p. 29.

Ferry County

14. **Name:** Advance (Cabin). **Loc:** Near center NW¼ sec. 35, (32-36E). **Access:** 1 mi. NW. of Covada. **Prop:** 9 claims: Rising Sun, Cora, Nellie, White Quartz, Saturday, Cabin, Tamarack, Sunbeam, Silver Spray. **Owner:** Advance Mining Co. (1924). **Ore:** Ag, Pb, Zn, Cu, Au. **Ore min:** Chalcopyrite, pyrite, galena, pyrargyrite, native silver, sphalerite, pyrrhotite. **Gangue:** Quartz. **Deposit:** 2- to 3-ft. shear zone in schist in which are mineralized lenticular masses of quartz 1 to 16 in. thick. **Dev:** 849-ft. crosscut, 350-ft. drift, and 37-ft. winze from lower level. 200-ft. drift, 40-ft. raise, 35-ft. winze, and 350-ft. crosscut from upper level. **Assays:** 8% Pb, 0.05 to 333 oz. Ag, and trace to 0.93 oz. Au. **Ref: 1,** pp. 193-195; **9,** pp. 145-147; **15,** pp. 163-164; **23,** pp. 44-47.

15. **Name:** Black Hawk. **Loc:** SW¼ sec. 26, (32-36E). **Access:** 1¼ mi. N. of Covada. **Prop:** 1 claim. **Owner:** Mr. Kelley (1912). **Ore:** Pb, Zn, Sb, Ag, Au. **Ore min:** Galena, sphalerite, stibnite, pyrite. **Gangue:** Quartz. **Deposit:** 3 quartz veins in granite from 8 to 12 in. thick. **Dev:** 60-ft. tunnel, 25-ft. open cut, 80-ft. tunnel. **Assays:** 12-in. vein assayed 0.03 oz. Au, 3.30 oz. Ag. **Ref: 23,** p. 64.

16. **Name:** Colorado. **Loc:** E½SE¼ sec. 2, (31-34E). 1,000 ft. W. of U. S. prospect. **Prop:** 2 claims, Colorado nos. 1, 2. **Owner:** M. H. McConnel

(1912). **Ore:** Pb, Ag, Au. **Ore min:** Galena, pyrite, arsenopyrite, limonite, stibnite. **Gangue:** Quartz. **Deposit:** Lens 5 ft. thick and 20 ft. in diameter enclosed in limestone, now mined out. Ore on dump is galena and limonite in quartz gangue. Also disseminated ore minerals in limestone drift and 12-ft. shaft. **Assays:** Average sample from tunnel assayed trace Au and 0.60 oz. Ag. **Ref: 15,** p. 138; **23,** pp. 63-64.

17. **Name:** Comstock (part of LeFleur group). **Loc:** Near SE. cor. sec. 7, (40-34E). **Access:** 2 mi. W. of Danville-Curlew highway from a place 2 mi. S. of Danville. **Prop:** 3 claims and 6 fractions. **Owner:** Morning Star Mining Co. (1943). **Ore:** Cu, Ag, Pb, Zn. **Ore min:** Chalcopyrite, bornite, galena, sphalerite, tetrahedrite, chalcocite, covellite, pyrite, magnetite, specularite. **Gangue:** Syenite. **Deposit:** Ore minerals occur as concentrations in 5-ft. syenite dike in metamorphic rocks. **Dev:** 35-ft. shaft, shallow prospect pits. **Assays:** 3 to 5% Cu across the face of the dike in the shaft. **Ref: 18,** pp. 200-201.

18. **Name:** Juliet (Little Tom). **Loc:** SE¼ sec. 28, (32-36E). **Prop:** 1 claim. **Owner:** George T. Eves and Arthur Slaton of Impach, Wash. (1949). **Ore:** Pb, Ag, Au. **Ore min:** Pyrite, galena, arsenopyrite, reportedly stibnite. **Gangue:** Quartz. **Deposit:** 2 intersecting quartz veins. **Dev:** 150-ft. crosscut, several old open cuts. **Assays:** 0.02 oz. Au and 3.40 oz. Ag. **Ref: 15,** pp. 157-158; **22; 23,** p. 78.

19. **Name:** Keystone. **Loc:** Near center E½ sec. 34, (32-36E). **Access:** 3 mi. from Covada up Stray Dog Canyon road. **Prop:** 1 claim of the 8-claim Keystone group. **Owner:** G. A. Mathews (1912). **Ore:** Pb, Ag, Au, Cu, Zn. **Ore min:** Galena, sphalerite, chalcopyrite, pyrite, native silver, pyrargyrite. **Gangue:** Quartz, calcite, gouge. **Deposit:** 2- to 6-ft. thick shear zone in schist and carbonaceous shale. Breccia mineralized with pyrite. Also mineralized quartz veinlets 1 to 4 in. thick. **Dev:** 550-ft. adit. **Assays:** Some veinlets said to carry as much as 4 oz. Au and 190 oz. Ag. **Ref: 15,** p. 158; **23,** p. 70.

20. **Name:** Kohler. **Loc:** NE¼NE¼ sec. 2, and NW¼NW¼ sec. 1, (34-36E). **Access:** Paved county road crosses the property. **Prop:** 80 acres of deeded land. **Owner:** Joseph A. Kohler. **Ore:** Cu, Sb, (Ag?). **Ore min:** Tetrahedrite, malachite, azurite, pyrite. **Gangue:** Quartz. **Deposit:** Quartz lenses and stringers with maximum thickness of 14 in. exposed for 200 ft. in a limestone bed in the Covada series. **Dev:** 3 small open cuts. **Ref: 22.**

21. **Name:** Last Chance. **Loc:** W½NW¼ sec. 35, (37-32E), on E. side of Eureka Gulch. **Access:** 1 mi. NW. of Republic by road. **Prop:** 1 claim, the Last Chance. **Owner:** Aurum Mining Co. (1949). **Ore:** Au, Ag. **Ore min:** Free gold, tetrahedrite, pyrite. **Gangue:** Quartz, calcite. **Deposit:** Vein in andesite flow breccia averages 8 ft. in thickness. Vein filling consists of chalcedonic banded quartz, calcite, and fragments of country rock. Ore is mostly removed above the 500-ft. level. **Dev:** 2-compartment vertical shaft 690 ft. deep from which 1,200 ft. of drifts and crosscuts have been driven. Also extensive stoping. **Assays:** 24,000 tons of ore averaged about $13.00 per ton. Ratio of precious metals averaged 7.85 oz. Ag to 1 oz. Au. **Prod:** $3,000,000 by the end of 1923. **Ref: 18,** pp. 182-184.

22. **Name:** Longstreet. (See p. 68.)

23. **Name:** Meteor. **Loc:** Near SW. cor. sec. 33, (32-36E). **Access:** 3 mi. S. of Meteor by road. **Prop:** 4 patented claims: Peoria, Ohio Fraction, Meteor, and Comet. **Owner:** W. D. Chamberlain of Spokane, Wash. (1949). **Ore:** Ag, Pb, Au, Cu, Zn. **Ore min:** Pyrite, galena, sphalerite, rhodochrosite, chalcopyrite, cerargyrite, pyrargyrite, arsenopyrite, argentite, tetrahedrite, native silver. **Gangue:** Quartz, gouge. **Deposit:** Quartz vein from 1 in. to 1½ ft. thick in a shear zone in metamorphic

rocks. **Dev:** 160-ft. inclined shaft, 700-ft. crosscut from which a 125-ft. drift has been driven. **Assays:** Smelter certificates on ore shipped show 0.6% Pb, 0.06 oz. Au, and 65.84 oz. Ag per ton on 17-ton lot. **Prod:** 20 tons of ore with total gross value of $1,000 by 1918. **Ref: 1,** pp. 191-193; **9,** pp. 139-141; **15,** pp. 155-156; **18,** p. 220; **22; 23,** p. 84.

24. **Name:** Montana. **Loc:** Near center sec. 28, (32-36E). **Access:** 3 mi. NW. Covada. **Prop:** 1 claim. **Owner:** Messrs. Fish and Pea (1912). **Ore:** Ag, Pb, Zn, Au. **Ore min:** Galena, sphalerite, pyrite, pyrargyrite. **Gangue:** Quartz, calcite. **Deposit:** Mineralized quartz vein at least 1 ft. thick in granodiorite. **Dev:** 3 shafts said to range from 20 to 90 ft. **Assays:** Samples said to assay as much as 0.16 oz. Au, 224.8 oz. Ag, and 47.6% Pb. **Prod:** Has produced. **Ref: 9** , p. 125; **15,** p. 157; **22; 23,** p. 76.

25. **Name:** New York: **Loc:** N. central part sec. 33, (32-36E). **Access:** 2½ mi. NW. of Covada. **Prop:** 1 claim. **Ore:** Pb, Ag, Au, Zn. **Ore min:** Pyrrhotite, pyrite, sphalerite, galena, arsenopyrite, pyrargyrite. **Gangue:** Quartz. **Deposit:** 12- to 16-in. quartz vein in granodiorite. **Dev:** 2 shafts, 40 ft. and 60 ft. deep. **Improv:** Steam hoist (1913). **Assays:** Selected samples assay 0.02 oz. Au and 4 oz. Ag where pyrrhotite predominates. Where galena predominates Au is same, but Ag only half. **Ref: 15,** p. 157; **23,** p. 78.

26. **Name:** Old Nell. **Loc:** Near center S½ sec. 36, (32-36E). **Access:** ¾ mi. NE. of Covada. **Prop:** 1 claim. **Ore:** Sb, Ag, Au. **Ore min:** Native antimony. **Gangue:** Quartz. **Deposit:** Quartz veinlets in granodiorite and quartzite. **Dev:** 7-ft. shaft; open cut 8 ft. long, 4 ft. deep; 25-ft. tunnel. **Assays:** Sample from open cut near center of the claim: trace Au, 0.20 oz. Ag. **Ref: 15,** p. 169; **23,** p. 54.

27. **Name:** Perry. **Loc:** Near center NE¼ sec. 36, (32-36E). **Access:** 1 mi. NE. of Covada. **Prop:** 1 claim. **Owner:** Joseph Hartwell (1912). **Ore:** Sb. **Ore min:** Stibnite (?). **Gangue:** Quartz. **Deposit:** 4-ft. quartz vein in quartzite carries Sb. Well mineralized, and resembles the Longstreet vein. **Dev:** 42-ft. slope, two 10-ft. tunnels, several open cuts. **Ref: 15,** p. 169.

28. **Name:** Pin Money. **Loc:** Near center E½ sec. 18, (37-34E). **Access:** 13 mi. by road NE. of Republic. **Prop:** 1 claim of the Oversight group. **Owner:** Oversight Mining & Milling Co. (1918). **Ore min:** Arsenopyrite, pyrrhotite, pyrite, tetrahedrite, (smaltite?). **Gangue:** Quartz. **Deposit:** Quartz vein with 6-in. average thickness has hanging wall of impure limestone and footwall of slate or phyllite. **Dev:** 80-ft. inclined shaft. **Assays:** Au, Ag, Ni, and Co reported. **Ref: 1,** p. 173; **19,** p. 62.

29. **Name:** Polepick. **Loc:** NW¼ sec. 5, (29-33E). **Access:** 1 mi. N. of Keller on E. side of the ridge W. of the Sanpoil River. **Ore:** Cu, Zn, Pb. **Ore min:** Chalcopyrite, sphalerite, galena, subordinate pyrite, and a little tetrahedrite. Molybdenite in some fractures of the granite. **Gangue:** Quartz: **Deposit:** Quartz veins along the contact of granite and porphyry. Veins have total thickness of several feet and are sparingly mineralized. **Dev:** 700 ft. of workings on one level, and some surface cuts. **Prod:** No large shipments reported. **Ref: 1,** pp. 186-187.

30. **Name:** Republic (Blaine Republic). **Loc:** NE¼ sec. 12, (36-32E). **Access:** ½ mi. SW. of Republic by road. **Prop:** 13 patented claims. **Owner:** Eureka Mining & Milling Co. (1940). **Ore:** Au, Ag, Se, Cu, Zn, Sb, As. **Ore min:** Pyrite, chalcopyrite, tetrahedrite, free gold. **Gangue:** Quartz, calcite. **Deposit:** Vein as much as 8 or 10 ft. thick but averages 2 or 3 ft. Vein is composed principally of chalcedonic quartz, concentrically crustified. Crustifications marked by thin dark crenulated bands. **Dev:** About 2 mi. of tunnels, drifts, winzes, raises, and crosscuts. **Assays:** Some hand-picked ore assays $100, but most averages 0.14 oz. Au and 0.56 oz.

Ag. **Prod:** Estimated at $1,400,000 up to 1910, in 1937 shipped 2,757 tons of ore to smelter, shipped 1938-40. **Ref: 1**, pp. 154-157; **5**, pp. 87-91; **13**; **14**, pp. 16-18; **19**, p. 22; **20**, pp. 44-50.

31. **Name:** Robert E. Lee. (See p. 68.)

32. **Name:** Rosario. **Loc:** Near NW cor. sec. 31, (32-37E). **Access:** 1 mi. NE. of Covada. **Prop:** 1 claim. **Owner:** George Terpening (1912). **Ore:** Cu. **Ore min:** Pyrite, tennantite or tetrahedrite, and molybdenite. **Gangue:** Quartz. **Deposit:** Small quartz veinlets in silicified granodiorite. Ore minerals sparingly distributed. **Dev:** 300-ft. tunnel, short tunnel, some open pits. **Ref: 15**, p. 169; **23**, p. 81.

33. **Name:** Silver Crown No. 1. **Loc:** NW¼ sec. 6, (31-37E). Just E. of Silver Crown No. 2. **Prop:** 1 claim. **Owner:** Mr. Howe (1912). **Ore:** Sb. **Ore min:** pyrite, (stibnite?). **Gangue:** Quartz. **Deposit:** Several quartz veins 4 to 16 in. thick in quartzite. One, 16 in. thick, consists of solid quartz with some pyrite and antimony. **Dev:** 12-ft. shaft, 125-ft. tunnel, several open cuts. **Ref: 23**, pp. 58-59.

34. **Name:** Silver Leaf. (See p. 71.)

35. **Name:** Stray Dog. **Loc:** SW¼NW¼ sec. 27, (32-36E). **Access:** 2 mi. NW. of Covada by road. **Prop:** 5 claims. **Owner:** Stray Dog Mining Co. (1909) (1912). **Ore:** Ag, Pb, Cu, Zn, Au. **Ore min:** Pyrite, chalcopyrite, sphalerite, galena, tetrahedrite, pyrargyrite, argentite, arsenopyrite, native silver. **Gangue:** Quartz, calcite, talc. **Deposit:** Sparingly mineralized quartz vein from ¼ inch to 2 ft. thick occupies a shear zone 18 inches to 4 feet thick in quartz monzonite porphyry. **Dev:** Lower level: 260-ft. crosscut, 300-ft. drift, 75-ft. winze, and 108-ft. raise. Middle: 100 ft. of work. Upper: 50 ft. of work. 100-ft. shaft on ridge top. **Assays:** One 20-ton lot assayed 0.3 oz. Au and 5 oz. Ag, the other 0.6 oz. Au and 66 oz. Ag per ton. **Prod:** Two shipments of 20 tons each reported prior to 1910. **Ref: 1**, p. 193; **9**, pp. 123-124; **15**, pp. 159-160; **18**, p. 220; **23**, pp. 34, 74.

36. **Name:** Summit. **Loc:** SE¼ sec. 36, (32-36E), E. of and parallel to Silver Dollar and Kentucky Bell claims. **Prop:** 1 claim. **Ore:** Pb, Sb. **Ore min:** Galena, (stibnite?), pyrite. **Gangue:** Quartz. **Deposit:** Several quartz veins, one 6 in. thick, in quartzite. **Dev:** 3 shafts, 15, 20, and 25 ft. deep. **Ref: 23**, pp. 56-57.

King County

37. **Name:** Aces Up. (See p. 80.)

38. **Name:** Bear Basin. (See p. 84.)

39. **Name:** Cleopatra. (See p. 82.)

40. **Name:** Coney Basin. (See p. 87.)

41. **Name:** Dawson. (See p. 83.)

42. **Name:** Dutch Miller. **Loc:** NE¼ sec. 20, (24-13E), at head of Middle Fork of Snoqualmie River. **Access:** 12 mi. by trail from Goldmeyer Hot Springs. **Prop:** 2 patented and 5 unpatented claims. **Owner:** A. B. Crain of the Cascade Development Co. (1942). **Ore:** Cu, Au. **Ore min:** Chalcopyrite, arsenopyrite, tetrahedrite, pyrite, secondary copper minerals, galena, sphalerite. **Gangue:** Quartz, tourmaline, siderite, pink chlorite. **Deposit:** 3 parallel en échelon veins along shear zones in granodiorite. Ore occurs as segregation 25 ft. long and 12 ft. thick on one of the veins. **Dev:** 65-ft. adit, 25-ft. adit, and two shafts. **Assays:** Smelter returns averaged $37.65 per ton after deduction of smelter charges. **Prod:** Several shipments prior to 1901. **Ref: 14**, p. 86; **22**.

43. **Name:** Gold Mountain. (See p. 74.)

44. **Name:** Great Republic (Happy Thought). (See p. 75.)

45. **Name:** Lennox. **Loc:** Secs. 7, 18, (25-10E) and sec. 13, (25-9E). **Access:** End of county road up the North Fork of Snoqualmie River. **Prop:** 45 claims held by possessory title. **Owner:** Priestley Mining & Milling Co. (1949) leasing from the Lennox Mining & Development Co. of Seattle, Wash. **Ore:** Au, Ag, Zn, Pb, Cu, As, Sb. **Ore min:** Sphalerite, chalcopyrite, pyrite, arsenopyrite, galena. **Gangue:** Quartz. **Deposit:** Shear zones in granodiorite are persistent to depths and lengths of several hundred feet, but sulfides are intermittently distributed. **Dev:** 6 tunnels and 2 open cuts. **Improv:** 4 bunkhouses, mess hall, sawmill, 2 machine shops, a Pelton wheel, and an 80-kw. generator. **Assays:** A 1-ton lot of picked ore (1938): 1.14 oz. Au, 10.42 oz. Ag, 1.5% Cu, 1.2% Pb, 8.3% Zn, 6.18% As, 0.67% Sb. 8 samples assayed in 1947 ranged from $7.51 to $63.91 per ton in Au, Ag, Pb, Zn, and Cu. **Ref: 22.**

46. **Name:** Salmon Creek. **Loc:** S½ sec. 10, (26-10E). **Access:** 1 mi. S. of Baring. **Prop:** 5 unpatented claims. **Owner:** W. R. Anderson of Baring, Wash. (1936). **Ore:** Reportedly Sb. (Doubtful occurrence.) **Ref: 22.**

Kittitas County

47. **Name:** Denny (Goat Mountain). (See p. 87.)

Lewis County

48. **Name:** Jug Lake. **Loc:** Reportedly on the W. shore of Jug Lake. **Access:** Trail up Summit Creek from Soda Springs camp ground. **Ore:** Sb. **Ore min:** Stibnite. **Deposit:** Said to be a 2-ft. vein of antimony sulfide exposed in the lake shore and extending into the lake. **Note:** Division of Mines and Geology investigation failed to locate.

49. **Name:** Reeves. (See p. 91.)

Okanogan County

50. **Name:** Andy O'Neil (Andy O.). **Loc:** NE¼SW¼ sec. 22, (31-30E), adjoining Anchor claim on NE. **Access:** 2½ mi. W. of Nespelem. **Prop:** 4 claims. **Owner:** Formerly owned by the late G. H. Beggs (1939). **Ore:** Pb, Ag, Cu. **Ore min:** Galena, pyrite, chalcopyrite, tetrahedrite, bornite. **Gangue:** Quartz, calcite. **Deposit:** Fissure veins in granite at and near its contact with quartzite. Ore minerals constitute 25% of the vein in places. Veins 1 to 4 ft. thick. **Dev:** 2 adits, 70 and 135 ft. long, with drifts and stopes. **Ref: 18,** pp. 214-215.

51. **Name:** Antimony. **Loc:** NW¼ sec. 30, (38-27E). **Ore:** Sb. **Ore min:** Stibnite. **Deposit:** Country rock is slate and quartzite. No vein was observed, but short irregular drifts in the tunnel probably represent places where the ore has been removed. **Dev:** 200-ft. tunnel. **Note:** Division of Mines and Geology investigation failed to locate. **Ref: 21,** p. 107.

52. **Name:** Antimony Bell (e). (See p. 107.)

53. **Name:** Antimony Queen. (See p. 109.)

54. **Name:** Apache. **Loc:** SE¼ sec. 27, (31-30E), near crest of SE. spur of Mineral Hill. **Access:** 2½ mi. SW. of Nespelem by dirt road. **Prod:** 3 unpatented claims. **Owner:** Apache Mining Co., Nespelem (1942). **Ore:** Ag, Au, Cu. **Ore min:** Argentite, galena, tetrahedrite, pyrite, native silver, sphalerite, pyrargyrite, stephanite, chalcopyrite. **Gangue:** Quartz, rhodochrosite. **Deposit:** Tabular lenses and veinlets of ore along an 8- to 10-ft. fracture zone in granite. Ore-bearing portion of the zone is 1 to 2 ft. thick. **Dev:** Main haulage tunnel 700 ft. long, 2,500 ft. of workings

on 3 levels, including 3 shafts and 3 adits. **Assays:** High-grade ore 300 oz. Ag, ¾ oz. Au, and 1.5% Cu. Mill-run ore reportedly about $12. **Prod:** 29 tons of ore with gross value of $10,170 in 1911-12. Also produced 1916-17, 1919-22, 1925-26, 1937. Est. prod. to 1940 is $250,000 Ag, $20,000 Au. **Ref: 14,** p. 34; **15,** pp. 72-74; **18,** pp. 207-209; **19,** p. 22.

55. **Name:** Arizona. **Loc:** Near Ruby. **Owner:** George Melvin (1892). **Ore:** Ag, Au. **Ore min:** Tetrahedrite. **Gangue:** Quartz. **Deposit:** 6-ft. quartz vein. An extension of the Buckeye. **Dev:** 70-ft. adit, 25-ft. shaft. **Assays:** Reportedly $100 to $260 in Au and Ag. **Ref: 2,** p. 52; **3,** p. 85.

56. **Name:** Arlington. **Loc:** SW¼SW¼ sec. 5, (34-25E), on W. slope of Ruby Hill. **Access:** 4 mi. by road from the Salmon Creek road at Ruby. **Prop:** 10 patented and several unpatented claims. **Owner:** Leased by Benton Bailey (1949). **Ore:** Ag, Cu, Pb, Au. **Ore min:** Argentiferous galena, chalcopyrite, tetrahedrite, sphalerite, pyrite, pyrargyrite. **Gangue:** Quartz. **Deposit:** Quartz vein mainly in granite near contact with schist. Main vein averages 4½ ft. in thickness and carries ore in banded segregations. Other similar but smaller parallel veins. **Dev:** About 3,000 ft. of underground workings on at least three levels. **Assays:** 24-car average in 1920: Ag 66 oz, Cu 1.15%. Reportedly 0.18 oz. Au in concentrate. **Prod:** 1,000 tons in 1901, shipped siliceous ore 1914-1921, shipped concentrates in 1937, produced 80,000 oz. Ag and 33,000 lbs. Cu in 1938, shipped in 1940. **Ref: 2,** pp. 47-48; **3,** p. 80; **12,** pp. 32-34; **14,** pp. 33-34; **17,** p. 87; **18,** pp. 250-253.

57. **Name:** Bales. (See p. 122.)

58. **Name:** Bellevue. **Loc:** NW¼ sec. 4, (39-26E). **Prop:** 5 claims. **Ore:** Au, Ag, Cu. **Ore min:** Arsenopyrite, pyrite, chalcopyrite, pyrargyrite, stephanite, a little native silver, free gold, and possibly gold-silver telluride. **Gangue:** Quartz. **Deposit:** Quartz vein from 10 in. to 3 ft. thick enclosed in slate. Vein averages 15 in. in thickness. **Dev:** Small shaft and several open cuts. **Assays:** A test shipment of 1,000 lbs. returned $75 per ton in Au and Ag, more than half of which was Au. **Prod:** Several tons. **Ref: 21,** p. 101.

59. **Name:** Billy Goat. **Loc:** Near SE cor. sec. 15, (38-20E), on S. slope of Billy Goat Mountain. **Access:** Road up Eightmile Creek. **Prop:** 4 claims: Billy Goat and Billy Goat Nos. 2, 3, and 4. **Owner:** W. F. Berge, R. E. Johnson, Clint Hanks, Fred Hasse, and Mrs. Charles (Della) Graff (1946). **Ore:** Cu, Au, Ag, Zn, Mo, Pb. **Ore min:** Molybdenite, pyrite, chalcopyrite, sphalerite, galena, tetrahedrite. **Gangue:** Quartz, ankerite. **Deposit:** Mineralized quartz veinlets ¼ in. to 2 in. thick lace through altered volcanic rock. A large area has been mineralized. **Dev:** Three shafts, 20, 40, and 60 ft. deep; three adits, 60 ft., 15 ft., and one of unknown length; and a 700-ft. drift. **Improv:** Cabin. **Assays:** Cu generally less than 1%, but in places as much as 2% over minable widths. Au also low, but as much as 0.5 oz. per ton in places. **Ref: 9,** p. 176; **22.**

60. **Name:** Buckeye. **Loc:** Near Ruby on Ruby Hill. **Prop:** 1 claim. **Owner:** George Melvin (1892). **Ore:** Ag, Au. **Ore min:** Tetrahedrite. **Gangue:** Quartz. **Deposit:** 7-ft. vein of quartz. **Dev:** 70-ft. adit. **Assays:** An old assay reports $100 in Au and Ag. **Ref: 2,** p. 52; **3,** p. 85.

61. **Name:** Buckeye. **Loc:** Sec. 26, (39-26E). **Prop:** 1 claim. **Owner:** A. M. Wehe, Wehesville, Wash. (1911). **Ore:** Cu, Pb, Au, Ag. **Ore min:** Pyrite, chalcopyrite, galena, some stephanite. **Deposit:** Vein about 1 ft. thick enclosed in quartzite and siliceous schist. **Dev:** Minor. **Assays:** Au said to predominate over Ag. **Ref: 21,** p. 102.

62. **Name:** Carlquist. (See p. 92.)

63. **Name:** Chief Sunshine. **Loc:** SW¼SE¼ sec. 35, (36-24E). **Access:** 2½ mi. from Conconully. **Prop:** 7 claims. **Owner:** Alfred Davidson of Conconully, Wash. (1941). **Ore:** Ag, Pb, Zn, Cu, Au. **Ore min:** Tetrahedrite, galena, pyrite. **Gangue:** Quartz. **Deposit:** Quartz vein near a lamprophyre dike in granite. Vein averages about 1 ft. in thickness. Short lengths of the vein have been heavily mineralized. **Dev:** 500-ft. adit and 360-ft. adit. **Improv:** 2 cabins and a road built in 1941. **Assays:** Ore said to average $20. One assay shows 94.90 oz. Ag, 15 to 16% Pb, 8.8% Zn, 3.5 to 4.5% Cu, and 0.035 oz. Au. **Prod:** Sporadic shipments in 1940 and 1941. **Ref: 9,** pp. 214-215; **22.**

64. **Name:** Chloride. **Loc:** Twisp district. **Prop:** 1 claim. **Owner:** Robert Allison, H. E. Davis, and John Mulholland (1892). **Ore:** Ag, Cu, Sb, Au. **Ore min:** Argentite, chalcocite, stephanite, malachite. **Gangue:** Quartz. **Deposit:** 4-ft. quartz vein. **Dev:** 100-ft. adit. **Assays:** 240 to 650 oz. Ag, 1.25 to 2.0% Cu, trace of Au. **Ref: 2,** p. 68; **3,** p. 112.

65. **Name:** Coyote. (See p. 123.)

66. **Name:** Crystalite. **Loc:** 5 mi. up Gold Creek from its mouth. **Prop:** 2 claims, Crystalite and Gold Creek. **Owner:** John Runnels and Thomas Deaver (1892). **Ore:** Au, Ag, Sb, Cu. **Deposit:** 2-ft. vein. **Dev:** Short crosscut. **Assays:** Said to assay "from 50 to 350 oz. per ton in Au and Ag." **Ref: 3,** p. 115.

67. **Name:** Fourth of July. **Loc:** SE¼NW¼ sec. 5, (34-25E), near crest of Ruby Hill ½ mi. N. of Arlington mine. **Owner:** Leased to Benton Bailey (1949). **Ore:** Ag, Cu, Au. **Ore min:** Tetrahedrite, argentite, native silver, stephanite, cerargyrite, ruby silver. **Gangue:** Quartz. **Deposit:** Vein said to average 10 ft. in thickness and to carry a streak of sulfide ore 18 to 24 in. in average thickness. **Dev:** 500-ft. shaft. **Assays:** Average assays said to be $100 per ton, mostly in Ag. Au is in trace amounts. **Prod:** $36,000 recorded. **Ref: 2,** pp. 48-49; **3,** pp. 80-81; **12,** p. 32; **18,** pp. 255-256.

68. **Name:** Hardscrabble. **Loc:** Sec. 30, (36-25E), NE. of the Mammoth claim. **Prop:** 1 claim. **Owner:** Hardscrabble Mining and Milling Co. (1892). **Ore:** Ag, Sb. **Ore min:** Stephanite. **Deposit:** 15-in. vein with an 11-in. paystreak. **Dev:** 30-ft. drift. **Assays:** Three old assays gave 178, 335, and 658 oz. Ag respectively. No Au. **Ref: 2,** p. 59; **3,** p. 95.

69. **Name:** Hercules. **Loc:** NE¼ sec. 14, (33-31E). **Prop:** 1 of 4 patented claims in the Ramore group: **Owner:** Ramore Mining Co. (1918). **Ore:** Pb, Ag, Cu, Zn. **Ore min:** Galena, sphalerite, chalcopyrite, pyrite, pyrrhotite, tetrahedrite. **Gangue:** Quartz, fluorite. **Deposit:** 5-ft. shear zone along contact of granite and metamorphic series. Ore minerals disseminated in the zone. **Dev:** 430-ft. adit, 180-ft. drift. **Prod:** No large shipments reported. **Ref: 1,** pp. 207-208.

70. **Name:** Horn Silver (Arizona). **Loc:** S½ sec. 21, (40-26E). **Prop:** 5 claims. **Owner:** Horn Silver Mining Co. (1915). **Ore:** Ag, Cu, Au. **Ore min:** Stephanite, cerargyrite, a little proustite, galena, sphalerite, pyrite, and chalcopyrite. **Gangue:** Quartz. **Deposit:** 3 veins. The one which has been most developed is 4 in. to 4 ft. thick and is composed of well-mineralized quartz. Country rock is argillite and granite. **Dev:** 750 ft. of tunnel, a raise of 100 ft., and a shaft 100 ft. deep. **Assays:** 2 carloads of ore averaged $62 per ton. $2.50 of this amount was in Cu and Au, the remainder in Ag. **Prod:** Several carloads of ore prior to and during 1909. **Ref: 21,** p. 100.

71. **Name:** Ivanhoe. **Loc:** SW¼ sec. 16, (39-26E). **Prop:** 4 claims. **Owner:** Ivanhoe Mining Co. (1926). **Ore:** Ag, Au. **Ore min:** Pyrite, stephanite, cerargyrite, ruby silver. **Gangue:** Quartz. **Deposit:** Fine-grained iron-stained quartz vein enclosed in calcareous slate. Vein 3½ to 4½ ft. thick

with a 2½-ft. paystreak. **Dev:** 65-ft. and 80-ft. inclines. **Assays:** Ore shipped said to have netted $272 to $636 per ton. **Prod:** Considerable ore shipped about 1900. **Ref: 2,** pp. 63-64; **3,** p. 99; **21,** p. 102.

72. **Name:** Jumbo. (See p. 124.)

73. **Name:** Leonora. **Loc:** Sec. 30, (35-25E), on S. slope of Peacock Hill. **Prop:** 1 claim. **Owner:** J. T. McDonald and J. C. Robinson of Ellensburg, Wash. (1892). **Ore:** Pb, Ag. **Ore min:** Galena, stephanite, pyrite. **Deposit:** 5-ft. vein with a 4-in. paystreak. **Dev:** 80-ft. shaft, surface trenching. **Assays:** Old assays show 17 to 25% Pb and as much as 350 oz. Ag. **Ref: 2,** p. 53; **3,** p. 82.

74. **Name:** Leuena (Laeuna, Launa). **Loc:** SW¼ sec. 35, (36-24E), near crest of S. spur of Mineral Hill. **Prop:** 1 claim. **Owner:** Thomas L. Nixon and Chester F. Griesemer of Tacoma, Wash. (1892). **Ore:** Ag, Cu, Au. **Ore min:** Tetrahedrite, stephanite, argentite. **Gangue:** Quartz. **Deposit:** Quartz vein 7 ft. thick. **Dev:** 50-ft. shaft, 75-ft. shaft, 60-ft. tunnel, 70-ft. crosscut. **Assays:** Assays as high as 200 to 860 oz. Ag, 1.13 to 2.12% Cu, and trace of Au reported. **Prod:** Reportedly, several carloads shipped to San Francisco prior to 1890. **Ref: 2,** p. 59; **3,** p. 96; **12,** pp. 28-29.

75. **Name:** Little Chief (also known as Double Header and Grand Coulee). **Loc:** NW¼ sec. 35, (31-30E). **Access:** 3 mi. SW. of Nespelem by good gravel road. **Prop:** 18 unpatented claims. **Owner:** Nespelem Consolidated Mines, Inc. (1940). **Ore:** Ag, Au, Cu. **Ore min:** Pyrargyrite, argentite, stephanite, pyrite, (antimony oxide?), chalcopyrite. **Gangue:** Quartz, sericite, calcite. **Deposit:** Ore shoots along a fracture zone in granite 2 to 10 ft. thick which is largely replaced by quartz. **Dev:** 3,000 ft. of workings on 3 levels includes 3 adits, 1 shaft, and 7 stopes. **Assays:** Assay value of different lots of ore shipped to smelter in 1911 and 1912 ranged from 0.09 to 0.31 oz. Au and from 77.7 to 590.59 oz. Ag. Another assay shows 4% Cu. **Prod:** More than $10,000 by 1921. Produced in 1937. **Ref: 15,** p. 74; **18,** pp. 213-214.

76. **Name:** Lone Star (Star). **Loc:** NE¼ sec. 36, (36-24E), on W. side of Salmon Creek. **Access:** 1½ mi. N. of Conconully by road. **Prod:** 1 patented claim. **Owner:** Lone Star Mining & Development Co. (1935). **Ore:** Cu, Pb, Ag. **Ore min:** Chalcopyrite, pyrite, galena, stephanite. **Gangue:** Quartz. **Deposit:** Vein 18 in. to 10 ft. thick in granite. **Dev:** Tunnel consisting of 125 ft. of crosscut and 290 ft. of drift. Also 185-ft. crosscut with 100 ft. of drifts, 375-ft. inclined shaft. **Assays:** 7 old assays show 30 to 65% Pb, 39.6 to 140 oz. Ag, and 0.1 to 1.6 oz. Au per ton. **Prod:** Reportedly shipped a carload of ore in 1913. **Ref: 2,** p. 55; **3,** p. 89; **12,** p. 27; **17,** p. 63.

77. **Name:** Lucky Knock. (See p. 92.)

78. **Name:** Mineral Hill (Washington Consolidated). **Loc:** Near SW. cor. sec. 31, (36-25E) and extending up Mineral Hill to N½ sec. 2, (35-24E). **Access:** Roads from Conconully. **Prop:** Numerous claims. **Owner:** Central Mining & Milling Co. of Seattle (1939). **Ore:** Cu, Ag, Pb, Zn. **Ore min:** Galena, sphalerite, pyrite, chalcopyrite, tetrahedrite, molybdenite. **Gangue:** Quartz, sericite. **Deposit:** Quartz veins in granite. 2 parallel veins cut by lower tunnel are each 11 ft. thick. Upper workings expose two veins, one 12 in. thick, the other 6 to 36 in. thick. **Dev:** 800-ft. lower tunnel and an upper tunnel with more than 2,000 ft. of development. **Prod:** Flotation concentrates in 1939. **Ref: 9,** pp. 211-212; **12,** pp. 27-28.

79. **Name:** Minnehaha. **Loc:** Sec. 31, (36-25E), an extension of the Homestake property. **Owner:** George Cooper and T. A. Wilson (1892). **Ore:** Ag, Pb, Au. **Ore min:** Galena, tetrahedrite, pyrite. **Gangue:** Quartz. **Deposit:** 17-ft. vein carrying several rich paystreaks. **Dev:** 200-ft. crosscut adit. **Assays:** 12.5 to 14% Pb, 98 to 113 oz. Ag, trace of Au. **Ref: 3,** p. 93.

80. **Name:** Mountain Boy. **Loc:** NW¼NW¼ sec. 12, (33-31E), on NW. slope of Old Glory Mountain. **Access:** 1 mi. NE. of Park City by road. **Prop:** 1 claim (Mountain Boy), one of the Mountain Boy group. **Owner:** Castle Creek Mining Co. (1922). **Ore:** Pb, Ag. **Ore min:** Galena, sphalerite, chalcopyrite, pyrite, tetrahedrite. **Gangue:** Quartz, calcite. **Deposit:** Mineralized quartz lenses ½ in. to 18 in. thick and 2 in. to 30 ft. long on planes of schistosity in shale and limestone. **Dev:** 4 adits, 2 on ore. One adit 155 ft. long. **Assays:** 4 or 5 carloads of ore shipped said to average $60 per ton, presumably in Ag and Pb. **Prod:** 4 or 5 carloads reported. **Ref: 1,** p. 207; **15,** pp. 94-95.

81. **Name:** Nevada. **Loc:** NE¼ sec. 30, (35-25E), W. of Reservoir Creek on SE. flank of Peacock Mountain. **Access:** 1 mi. NW. of town of Ruby. **Prop:** 1 claim of Peacock group. **Owner:** Peacock Mining and Milling Co. (1917). **Ore:** Ag, Pb, Cu. **Ore min:** Galena, tetrahedrite, pyrite, chalcopyrite, sphalerite, stromeyerite (AgCuS). **Gangue:** Quartz. **Deposit:** Vein about 8 ft. thick, with granite footwall and gneiss-schist hanging wall, contains paystreaks as much as 1 ft. thick. **Dev:** 216-ft. shaft, 1,300-ft. tunnel with drifts on the 40- and 100-ft. levels. **Assays:** Carload shipped averaged $27 per ton, $10 of which was in Ag and Pb. **Prod:** A carload of ore reportedly shipped about 1900. **Ref: 2,** pp. 61-62; **12,** p. 30.

82. **Name:** Olentangy. **Loc:** W. part of secs. 8 and 17, (40-30E). **Prop:** 4 patented claims. **Owner:** Olentangy Mining Co. (1915). **Ore:** Au, Cu, Pb, Zn. **Ore min:** Chalcopyrite, pyrite, traces of tetrahedrite, some arsenopyrite, sphalerite, and galena. **Gangue:** Quartz. **Deposit:** Fault zone in calcareous quartzite consists of breccia cemented by ore-bearing quartz stringers. **Dev:** 160-ft. shaft with drifts on 100- and 150-ft. levels. **Assays:** Au varies from traces to high value. **Ref: 9,** p. 174; **21,** pp. 51-52.

83. **Name:** Panama. **Loc:** Secs. 24 and 27, (31-30E). **Access:** 4 mi. W. of Nespelem. **Prop:** 5 unpatented claims: Foresight, Coulee Fraction, Jessie N., Panama, and Panama Fraction. **Owner:** Grand Coulee Mines, Inc., (1939). **Ore:** Ag, Au. **Ore min:** Stephanite, argentite, native silver, pyrite, a little chalcopyrite. **Gangue:** Quartz. **Deposit:** Quartz veins along fracture zones in altered granite. Main zone is about 4 ft. thick and carries an 8-in. quartz vein. **Dev:** 30-ft. crosscut, 30-ft. drift, and 35-ft. stope on upper level; 170-ft. crosscut and 100-ft. drift on middle level connected by raise and stope to upper level. Lower level, 155-ft. crosscut and 220 ft. of drifts. **Assays:** 12 tons of hand-picked ore returned 57 oz. Ag and 9.3 oz. Au; 13 tons in 1936 averaged $40 per ton. **Prod:** 12 tons in 1919, 1¼ tons in 1921, 13 tons in 1936. **Ref: 18,** pp. 209-211; **19,** p. 22.

84. **Name:** Par Value. **Loc:** NW¼ sec. 35, (31-30E). Adjoins Little Chief mine on SE. **Access:** 3 mi. by good gravel road SW. of Nespelem. **Prop:** May be included in the present Little Chief claims. **Ore:** Ag. **Ore min:** Pyrite, argentite, pyrargyrite, cerargyrite. **Deposit:** Believed to be an extension of the Little Chief lode though not so well mineralized. **Dev:** 68-ft. shaft. **Ref: 15,** p. 75.

85. **Name:** Peacock. **Loc:** Sec. 19, (35-25E), on summit of McDonald Peak. **Prop:** Nevada, Blue Grouse, Republic, Wyoming, and other claims. **Owner:** Peacock Mining Co. (1949). **Ore:** Au, Ag, Cu, Pb, Zn. **Ore min:** Galena, tetrahedrite, chalcopyrite, sphalerite, pyrrhotite, pyrite. **Gangue:** Quartz, sericite. **Deposit:** Quartz veins along contact between quartz diorite and metamorphics. **Dev:** 170-ft. crosscut. **Assays:** Cu. 0.05 and 0.8%; Pb, 2.2 and 18%; Ag, 10.4 and 19.2 oz. (2 samples from shaft). **Ref: 3,** pp. 82-83; **9,** pp. 204-206; **12,** pp. 29-31; **19,** p. 22.

86. **Name:** Plant-Callahan. **Loc:** Near NE. cor. sec. 32, (35-25E), on steep hillside E. of Ruby. **Access:** 1 mi. SE. of Ruby. **Prop:** Several claims. **Ore:** Ag, Cu. **Ore min:** Tetrahedrite. **Gangue:** Quartz. **Deposit:** Ore minerals occur in stringers and bunches of quartz in a shear zone in biotite schist. The stringers and bunches range from mere seams to masses several feet across. **Dev:** 65-ft. tunnel, 175-ft. tunnel, open cuts, shallow shaft. **Assays:** Selected samples assayed as high as $1,000 per ton in Ag. **Prod:** Reportedly a small shipment of rich silver ore in 1886 yielded $6,000. **Ref: 12,** p. 31.

87. **Name:** Ramore. **Loc:** Near center sec. 14, (33-31E), 1,600 ft. NE of Hercules mine. **Prop:** 1 patented claim of 4 in the Ramore group. **Owner:** Ramore Mining Co. (1918). **Ore:** Pb, Ag, Au. **Ore min:** Sphalerite, galena, pyrite, chalcopyrite, pyrrhotite, tetrahedrite. **Gangue:** Quartz, fluorite, calcite. **Deposit:** 10-ft. ore body along contact of granite and metamorphic rocks. Chiefly quartz in which sulfides are disseminated. **Dev:** 440-ft. adit from which have been driven a 600-ft. crosscut, several short crosscuts, a drift, and a 45-ft. winze. **Assays:** Four analyses show 2.7 to 9.6% Pb, 13 to 59 oz. Ag, and 0.05 to 0.07 oz. Au. **Prod:** No large shipments of ore reported. **Ref: 1,** pp. 207, 208-209; **9,** pp. 188-190; **15,** p. 99.

88. **Name:** Rich Bar. **Loc:** Approximately in W½ sec. 11, (40-26E). **Access:** On Similkameen River about 5 mi. E. of Nighthawk. **Prop:** 11 claims. **Owner:** Rich Bar Mining Co. (1911). **Ore:** Cu, Zn, Ag, Pb. **Ore min:** Chalcopyrite, sphalerite, pyrite, stephanite, galena, argentite in order of decreasing importance. **Gangue:** Quartz. **Deposit:** Lode varies from stringers to a 6-ft. vein of mineralized quartz enclosed in quartzitic slate. **Dev:** 2 shafts, deeper one 150 ft. deep with drifts from the 50- and 150-ft. levels. **Assays:** From trace to $40. Richer ore seems to occur in center of lode. **Ref: 9,** p. 223; **21,** pp. 95-96.

89. **Name:** Ruby. **Loc:** SE¼ sec. 28, (40-25E). On W. side of the valley. **Access:** 4 mi. by road N. of the N. end of Palmer Lake. **Prop:** 5 claims: Crescent, Beggars Choice, Labyrinth, Mystic Shrine, and Hide and Seek. **Owner:** Chloride Queen Mining Co. (1934). **Ore:** Ag, Pb, Au, Cu, Zn. **Ore min:** Pyrite, chalcopyrite, arsenopyrite, galena, sphalerite, proustite, pyrargyrite, argentite, free gold, malachite, azurite, limonite. **Gangue:** Quartz, calcite, gouge. **Deposit:** Vein from a few inches to 6 ft. thick in gabbro or granodiorite partially fills a gouge-lined fault zone. Veins tend to pinch and swell. **Dev:** 6,000 ft., 1,300 ft. of which is in tunnels and the remainder in drifts, raises, and crosscuts. **Assays:** Average of high-grade ore taken from dump, 0.01 oz. Au, 92.1 oz. Ag. Payshoot ore averages $10 to $15, high-grade averages $60. Main values in Ag. **Prod:** $25,000 in 1915-1920 inclusive, also produced in 1922-23 and 1939. **Ref: 9,** pp. 224-225; **17,** p. 87; **18,** pp. 237-240; **19,** pp. 20, 22, 51; **21,** pp. 94-95.

90. **Name:** Ruby. **Loc:** On Ruby Mountain. **Access:** Wagon road from main county road. **Owner:** Thomas Donan, John Clunan, William Milliken, and Jonathan Bourne (1890). **Ore:** Ag, Au, Cu. **Ore min:** Pyrargyrite, cuprite, native silver, malachite. **Gangue:** Quartz. **Deposit:** Quartz vein 6 to 18 ft. thick in which are high-grade shoots of ore. One shoot was 2 ft. thick. **Dev:** 60-ft. shaft with 30-ft. crosscut, 50-ft. tunnel. **Assays:** Assay on the 2-ft. shoot showed $320 in Au and Ag. **Ref: 2,** pp. 50-51.

91. **Name:** Salmon River. **Loc:** SW¼ sec. 31, (36-25E), on E. side of Salmon River ¼ mi. SE. of Tough Nut property. **Access:** North of Conconully by road. **Prop:** 5 claims: Salmon River Chief, Knickerbocker, Salmon Creek, Wellington, Manhattan. **Owner:** Henry Wellington (1892). **Ore:** Ag, Pb, Au, Cu, Zn. **Ore min:** Galena, argentite, tetrahedrite, arsenopyrite, sphalerite, chalcopyrite, pyrite. **Gangue:** Quartz. **Deposit:** Veins in sandy mica schist. A 3-ft. vein with a 12-in. paystreak,

a 1- to 4-ft. vein, a 3-ft. vein, a 5-ft. vein with 18-in. paystreak, and a 4-ft. vein. **Dev:** 150-ft. crosscut with 500 ft. of drifts, 20-ft. tunnel, 20-ft. crosscut, 30-ft. tunnel. **Assays:** Trace to 4 oz. Au, 36 to 83 oz. Ag, 6 to 20% Pb. **Ref:** **2**, pp. 56-58; **12**, p. 26.

92. **Name:** Sidewinder. **Loc:** On opposite side of Gold Creek from the Crystalite property. **Prop:** 1 claim. **Owner:** John Runnels and Thomas Deaver (1892). **Ore:** Au, Ag, Sb, Cu. **Deposit:** 4½-ft. vein said to be similar to the Crystalite but not as rich. **Ref:** **3**, p. 136.

93. **Name:** Sonny Boy. **Loc:** NE¼NE¼ sec. 6, (34-25E), about ¾ mi. N. of the Arlington mine. **Access:** Road from Conconully. **Prop:** Several unpatented claims. **Owner:** Ruby Mountain Mining Co. of Tacoma (1940). **Ore:** Ag, Pb, Cu. **Ore min:** Pyrite and minor amounts of galena, chalcopyrite, tetrahedrite, and sphalerite. **Gangue:** Quartz. **Deposit:** 2 mineralized quartz veins near the contact of granite with schist. One vein 6 to 8 in. thick, the other 6 in. to 6 ft. thick. Thick vein traceable for 70 ft. **Dev:** 600-ft. adit with some 300 ft. of drifts and raises, and a 100-ft. adit. **Prod:** 1939 and 1940. **Ref.** **22.**

94. **Name:** Stibnite. (See p. 125.)

95. **Name:** Summit. **Loc:** Sec. 11, (33-31E). **Access:** 1 mi. NE. of Park City by road. **Prop:** 1 claim (Summit), part of Mountain Boy group. **Owner:** Castle Creek Mining Co. (1922). **Ore:** Pb, Ag, Cu, Zn. **Ore min:** Galena, pyrite, chalcopyrite, sphalerite, tetrahedrite, malachite, azurite, anglesite. **Gangue:** Quartz, gouge. **Deposit:** Shear zone 18 in. thick in granite contains mineralized lenses of quartz along with much gouge. **Dev:** 350-ft. adit, 1,000 ft. adit, 100-ft. adit, 150-ft. adit, surface cuts. **Assays:** 50-ton shipment said to average 30% Pb and 20 oz. Ag. Ore from stope in adit said to assay 0.06 to 0.12 oz. Au, 35 to 90 oz. Ag, and 30 to 40% Pb. **Prod:** Reportedly 50 tons of galena. **Ref:** **1**, pp. 205-206; **9**, pp. 183-185; **15**, p. 94; **18**, pp. 190-191.

96. **Name:** Sunrise. **Loc.** On Mineral Hill. **Prop:** 1 claim. **Owner:** John C. Collins and Newton Campbell (1892). **Ore:** Ag, Cu, Sb. **Ore min:** Stephanite, tetrahedrite, argentite. **Gangue:** Quartz. **Deposit:** 4-ft. vein with a 14-inch paystreak. **Dev:** 75-ft. drift. **Assays:** Average samples from the paystreak said to assay 379 oz. Ag. Samples across the vein assayed 120 oz. Ag. **Ref:** **2**, p. 60; **3**, p. 97.

97. **Name:** Wasco. **Loc:** Near center S½ sec. 9, (33-31E). **Prop:** Several claims. **Owner:** May be property held by West King Mining Co. **Ore:** Ag, Cu, Au, Pb, Zn. **Ore min:** Galena, sphalerite, chalcopyrite, pyrite, tetrahedrite, molybdenite, molybdite, malachite, azurite. **Gangue:** Quartz, fluorite. **Deposit:** 3 veins in granite and along its contact with schist are sparsely mineralized: one 12 in., another 24 in., the third 36 in. thick. Molybdenite occurs in granite dikes. **Dev:** Shallow shaft, several small surface cuts, 400-ft. adit. **Assays:** Ores said to contain appreciable quantities of Ag and Cu and some Au. **Ref:** **1**, pp. 209-210; **9**, pp. 178-179; **15**, pp. 100-101.

98. **Name:** Windfall. **Loc:** Twisp district. **Owner:** Hill Thomas (1890). **Ore:** Ag, Au, Sb. **Ore min:** Stephanite, cerargyrite. **Gangue:** Quartz. **Deposit:** A 3-ft. vein carries 13 in. of ore. **Dev:** 60-ft. shaft. **Assays:** Assays show traces of Au and 118 to 325 oz. Ag. **Ref:** **2**, pp. 68-69.

Pend Oreille County

99. **Name:** Blue Jim. **Loc:** Center W½ sec. 17, (38-43E). **Access:** Road. **Prop:** 1 unpatented claim. **Owner:** C. N. West and associates of Metaline Falls, Wash. (1945). **Ore:** Ag, Cu, Au, Pb, Zn. **Ore min:** Tetrahedrite (?), malachite, siderite, chalcopyrite, galena, sphalerite, pyrite.

Gangue: Quartz. **Deposit:** Zone in limestone is laced with mineralized quartz veinlets over a thickness of 7 to 20 ft. for an exposed length of 200 ft. **Dev:** 40-ft. adit, 400-ft. adit, four open cuts. **Ref: 6**, p. 43.

100. **Name:** Isabelle. (See footnote on p. 20.)

101. **Name:** LaSota (Silver Crest). **Loc:** Secs. 3 and 10, (37-41E), on saddle and flanks of Aladdin Mountain. **Access:** 1 mi. by road and 1½ mi. by trail from the Meadow Creek road. **Prop:** 16 unpatented claims. **Owner:** F. P. LaSota of Metaline Falls, Wash. (1944). **Ore:** Pb, Ag, Zn, Cu, reportedly Co, Au. **Ore min:** Galena, sphalerite, tetrahedrite, azurite, malachite, (horn silver?), chalcopyrite, bornite, (embolite?). **Gangue:** Quartz, tourmaline. **Deposit:** Narrow mineralized quartz stringers and mineralized limy bands in argillite. One quartz vein is 2 to 4 ft. thick and traceable for 450 ft. **Dev:** 20-ft. winze, 95-ft. drift, 50-ft. winze, 100-ft. crosscut with drifts, 20-ft. drift, numerous open cuts. **Improv:** Cabin, hand-mining tools. **Assays:** One assay across 3 ft. of vein showed 11.50 oz. Ag and trace Au. A 4-ft. sample at another place showed 0.04 oz. Au and 0.14 oz. Ag. **Ref: 22.**

102. **Name:** Lena Belle. (See p. 126.)

103. **Name:** Pinnel (Maryland). (See p. 126.)

Skagit County

10'. **Name:** Lawrence (Higgins Mountain). **Loc:** SW¼ sec. 28, (33-8E), on N. slope of Higgins Mountain. **Access:** Trail from Darrington Highway 1 mi. W. of Hazel. **Prop:** 2 claims: Nugget nos. 1 and 2. **Owner:** W. J. Lee (1941). **Ore:** Cu. **Ore min:** Chalcopyrite, pyrite, bornite, arsenopyrite, (tetrahedrite?). **Gangue:** Quartz. **Deposit:** 3-ft. fracture zone in granodiorite contains 3 mineralized quartz stringers from ½ in. to 9 in. thick. Granodiorite is in the form of a 50-ft. dike cutting Chuckanut sediments. **Dev:** Reportedly a tunnel. **Ref: 22.**

Snohomish County

105. **Name:** Big Four. **Loc:** NW¼ sec. 33, (30-10E), on the N. slope of Big Four Mountain. **Prop:** 7 claims. **Ore:** Pb, Ag, Sb, As. **Ore min:** Galena, arsenopyrite, probably tetrahedrite. **Deposit:** 30 in. of sulfide ore between syenite hanging wall and granite footwall. **Dev:** 100-ft. adit. **Assays:** $50. **Ref: 4**, p. 41.

106. **Name:** Columbia Mountain. **Loc:** In Troublesome Creek mining district 15 mi. from Index. **Access:** Trail. **Prop:** 2 claims. **Ore:** Reportedly Cu, Sb, and Ag. **Ore min:** Said to be tetrahedrite. **Ref: 22.**

107. **Name:** Consolidated. **Loc:** At the head of Martin Creek adjacent to the New Seattle property. **Prop:** 4 claims. **Ore:** Au, Ag, Cu, As. **Ore min:** Arsenopyrite, tetrahedrite. **Deposit:** Extension of the New Seattle vein. **Ref: 4**, p. 42.

108. **Name:** Eureka. **Loc:** SE¼ sec. 14, (30-10E), on the divide between Perry and Falls Creeks. **Prop:** 15 claims. **Owner:** Ore Recoveries Corp. (1941). **Ore:** Cu, Ag, Au, Pb. **Ore min:** Chalcopyrite, galena, tetrahedrite. **Deposit:** 2 veins. **Dev:** 7 adits up to 75 ft. in length. **Assays:** 4 to 36 oz. Ag, $1 Au. **Ref: 4**, p. 43; **9**, pp. 164-165.

109. **Name:** Everett. **Loc:** NE¼ sec. 20, (30-10E). **Prop:** 3 claims. **Ore:** Cu, Au, Ag. **Ore min:** Chalcopyrite, pyrite, tetrahedrite. **Deposit:** Three veins, 6 to 14 in. thick. **Ref: 4**, p. 43.

110. **Name:** John Feldt. (See p. 127.)

111. **Name:** Foggy (Alleghany). (See p. 134.)

112. **Name:** Glengarry. **Loc:** NW of Silverton near the Three Sisters prospect. **Prop:** 9 claims. **Ore:** Ag, Au, Cu. **Ore min:** Tetrahedrite. **Deposit:** 45 in. of ore. **Assays:** $140.70 Ag, $4.20 Au. **Ref: 4**, p. 43.

113. **Name:** Gold Mountain (Darrington). **Loc:** Sec. 31, (32-10E), on Gold Mountain on N. side of the Sauk River opposite the mouth of Clear Creek. **Access:** Truck road. **Prop:** 8 claims. **Owner:** Mr. Cornelius and associates of Mount Vernon, Wash. (1942). **Ore:** Au, Ag, Cu. **Ore min:** Chalcopyrite, (tetrahedrite?), pyrrhotite, and minor amounts of sphalerite and galena. **Gangue:** Quartz. **Deposit:** Quartz veins in schist. One vein is traceable for 125 ft. and has a maximum thickness of 8 ft. It narrows to a thickness of 1 ft. in a short distance, however. Two other veins are about 1 ft. thick. **Dev:** Crosscut with 125 ft. of drift and another old adit in barren rock. **Assays:** $18 to $36 Au, trace to 18 oz. Ag, $18 to $32 Cu. **Ref: 4**, p. 8; **22.**

114. **Name:** Gray Mare. **Loc:** SE¼ sec. 29, (32-9E). **Access:** 9 mi. by road from Darrington. **Prop:** 3 claims: Snow Gulch, and Gray Mare nos. 1 and 2. **Owner:** W. J. Lee of Seattle and Mrs. Charles Lawson and Earl Bemen, both of Arlington, Wash. (1943). **Ore:** Ag, Pb, Zn, Sb, Au. **Ore min:** Galena, silver sulfides. **Deposit:** Mineralized breccia zones in cherty limestone and calcareous shale. There may be considerable low-grade ore. **Dev:** 50-ft. adit, another short adit, and some surface workings. **Improv:** Cabin. **Assays:** Assays, probably on hand-picked samples, show 15.8 to 245 oz. Ag, 20 to 70% Pb, 1 to 3% Zn, 0.3 to 9.8% Sb, 0.01 oz. Au, and 0.34% As. **Ref: 22.**

115. **Name:** Hard Pass. **Loc:** SE¼ sec. 36, (29-10E), on the W. side of Sheep Gap Mountain. **Prop:** 1 claim. **Ore:** Cu, Au, Ag. **Ore min:** Chalcopyrite, tetrahedrite. **Dev:** 10-ft. adit. **Ref: 4**, p. 48.

116. **Name:** Monitor and Sterling. **Loc:** Sec. 14, (30-9E), on Martin Creek. **Prop:** 2 claims. **Ore:** Cu, Au, Ag. **Ore min:** Chalcopyrite, tetrahedrite. **Deposit:** 30 in. of ore. **Dev:** 20-ft. adit. **Ref: 4**, p. 45.

117. **Name:** Monte Cristo. (See p. 130.)

118. **Name:** Myrtle C. **Loc:** NE¼ sec. 19, (32-10E), on Gold Mountain. **Prop:** 9 claims. **Ore:** Au, Ag, Cu, Hg. **Ore min:** Chalcopyrite, tetrahedrite, pyrite, cinnabar, native gold, native mercury. **Deposit:** 7 veins ranging from 9 in. to 6 ft. in thickness. **Assays:** $8 to $26 in Au, trace to 41 oz. Ag, 18 to 36% Cu. **Ref: 4**, p. 10.

119. **Name:** New Seattle. **Loc:** NW¼ sec. 2, (30-9E), near the head of Martin Creek. **Ore:** Ag, Au, Cu, Sb. **Ore min:** Tetrahedrite. **Deposit:** 5-ft. vein. **Dev:** Adit. **Assays:** 350 oz. Ag, $5.69 Au. **Ref: 4**, p. 45.

120. **Name:** Whistler. **Loc:** Sec. 23, (29-11E), on the N. slope of Cadet Peak. **Ore:** Au, Ag, Cu, Pb. **Ore min:** Pyrite, galena, tetrahedrite. **Deposit:** 4- to 20-ft. fracture zone that carries 1½ ft. of ore. **Dev:** 20-ft. adit, 30-ft. adit. **Ref: 4**, p. 26.

Stevens County

121. **Name:** Acme (Acme-Dora). (See p. 136.)

122. **Name:** Anaconda. **Loc:** NW. cor. sec. 30, (40-42E). **Access:** 2 mi. from Deep Creek road on Red Top Mountain road. **Prop:** 2 patented claims. **Owner:** Mr. Flugal (1913). **Ore:** Pb, Zn. **Ore min:** Galena, sphalerite, tetrahedrite. **Gangue:** Quartz, calcite. **Deposit:** 2- to 4-ft. vein between limestone and schist composed of partly replaced country rock and ore minerals in alternate bands. Solid band of galena 6 in. thick at one place. **Dev:** 40-ft. shaft with 30-ft. drift at bottom, 225-ft. tunnel. **Prod:** 30 tons in 1902. **Ref: 1**, p. 57; **9**, p. 76; **11**, p. 102; **24**, pp. 300-301.

123. **Name:** Ark (Silver Queen). **Loc:** Near center N½ sec. 11, (35-37E). **Access:** 1 mi. SE. of State Highway 22 from a place 6 mi. S. of Kettle Falls. **Prop:** 9 patented and 10 unpatented claims. **Owner:** D. Warfield (1949). **Ore:** Ag, Pb, Zn, Cu, Au. **Ore min:** Tetrahedrite, galena, sphalerite, chalcopyrite, pyrite. **Gangue:** Quartz, calcite. **Deposit:** Quartz lenses from a few inches to 3 or 4 ft. thick along lamination planes of argillite and limestone. Mineralized zone as much as 30 ft. thick. **Dev:** 100-ft. inclined shaft and 3 short drifts from the shaft, 150-ft. shaft, 1,600-ft. tunnel with a 130-ft. raise. **Improv:** 40-ton mill, compressor. **Assays:** One sample assayed 10 oz. Ag, 1% each of Cu, Pb, and Zn. Some samples said to run $5 Au. **Prod:** 14 tons in 1915, 1,700 tons of ore milled in 1938, 250 tons of ore in 1939, a few tons of concentrates in 1940. **Ref:** **1**, pp. 125-126; **7**, p. 58; **9**, pp. 105-107; **18**, pp. 143-144.

124. **Name:** Brooks. **Loc:** Near NE. cor. sec. 11, (29-37E). **Access:** 10 mi. by road SE. of Fruitland. **Prop:** 3 claims: Brooks, Success, First Adventure. **Owner:** Abandoned (1941). **Ore:** Ag, Pb, Zn, Cu, Au. **Ore min:** Stephanite, pyrite, galena, sphalerite, tetrahedrite. **Gangue:** Quartz. **Deposit:** Series of limestone and argillites intruded by lamprophyric dikes is cut by 5- to 7-ft. quartz veins. **Dev:** 50-ft. shaft, 80-ft. tunnel, another tunnel caved 100 ft. from portal, open cut. **Prod:** 2 carloads shipped prior to 1901. **Ref:** **1**, p. 116; **7**, p. 73; **14**, p. 11; **24**, pp. 192-193.

125. **Name:** Chinto (includes Amazon and Copper King) (also known as Banner). **Loc:** Near center N½ sec. 32, (33-41E). **Access:** 6 mi. by road from Chewelah. **Prop:** 3 patented, 11 unpatented claims, and 1 millsite. **Owner:** Eagle Mountain Mining Co. (1949). **Ore:** Cu, Ag, Au. **Ore min:** Chalcopyrite, tetrahedrite (var. freibergite), sphalerite, pyrite, arsenopyrite, malachite, azurite. **Gangue:** Quartz, calcite, siderite. **Deposit:** Several continuous quartz-calcite-siderite veins varying between 3 and 20 ft. in thickness along laminations in argillite. Ore occurs as lenses and also disseminated in the argillite. **Dev:** 1,500-ft. tunnel, 350-ft. shaft, total 7,000 ft. of workings. **Improv:** 25-ton flotation mill, several bunkhouses and cabins, hoist, compressor, and generator. **Assays:** Concentrates shipped in 1940 returned 0.16 to 0.38 oz. Au, 56.72 to 137.75 oz. Ag, and 21.86 to 30.50% Cu. Smelter returns of 1917 from Amazon vein showed Sb as high as 9%. **Prod:** Copper King 1904, 1909, 1912-13, 1915-17. Amazon 1910, 1915-17. Chinto 1938, 1939 (130 tons), 1940 (460 tons). **Ref:** **1**, pp. 102-104; **7**, p. 31; **18**, pp. 131-135; **24**, pp. 142-144, 150-151.

126. **Name:** Cleveland (Santa Rita). (See p. 137.)

127. **Name:** Columbia River. **Loc:** NE¼ sec. 7 or NW¼ sec. 8, (36-38E). **Access:** 3 mi. SE. of Marcus by road. **Prop:** 2 claims. **Owner:** Columbia River Gold Mining Co. (1914), abandoned 1941. **Ore:** Cu, Au, Ag. **Ore min:** Chalcopyrite, pyrite, tetrahedrite, molybdenite. **Gangue:** Quartz, calcite, siderite. **Deposit:** Vein 3 to 6 ft. thick in shale and limestone consists of brecciated country rock cemented by gangue minerals. Ore shoots as much as several inches thick and several feet long. **Dev:** 2,700-ft. tunnel and several laterals at 1,675 ft. Inclined shaft said to be 300 ft. deep at elevation of 2,525 ft. **Prod:** Small production in 1904 and 1910. **Ref:** **1**, pp. 124-125; **7**, pp. 56-57; **24**, pp. 233-234.

128. **Name:** Copper King. **Loc:** NE cor. sec. 25, (40-41E). **Access:** 1½ mi. from Deep Creek road on Red Top Mountain road. **Prop:** 2 claims, Copper King nos. 1 and 2. **Owner:** Red Top Mining Co. (1941). **Ore:** Pb, Zn, Ag. **Ore min:** Galena, sphalerite, tetrahedrite. **Gangue:** Quartz. **Deposit:** Ore occurs along contact of limestone and an intrusive dike. Also a 6- to 7-in. quartz vein in limestone. Bands of galena and sphalerite 4 to 10 in. thick. **Dev:** 285-ft. tunnel, 20-ft. shaft, 221-ft. tunnel. **Prod:** Has produced. **Ref:** **1**, pp. 57-58; **7**, p. 107; **9**, pp. 76-77; **11**, p. 102; **24**, pp. 299-300.

129. **Name:** Daisy-Tempest (Silver Mountain) (includes Daisy and Tempest mines). **Loc:** Secs. 6 and 7, (33-38E), on W. slope of Huckleberry Mountains. **Access:** 5 mi. E. of Daisy by good truck road. **Prop:** 16 claims and additional property total about 580 acres. **Owner:** Daisy Silver-Lead Mines, Inc. (1948). **Ore:** Ag, Pb, Cu, Au. **Ore min:** Galena, chalcopyrite, pyrite (nickeliferous), sphalerite, marcasite, scheelite, tetrahedrite, arsenopyrite. **Gangue:** Quartz, calcite. **Deposit:** At least 4 quartz veins from a few inches to 12 ft. thick cut a series of argillites and quartzites intruded by diorite. **Dev:** 4 tunnels and shaft on Daisy total 4,000 ft., and a tunnel and shaft on Tempest total 2,600 ft. **Improv:** 50-ton mill, shops, and 2 houses (1948). **Assays:** Ag 1 to 20 oz; Ni, Co, and Au reported. **Prod:** 2,000 tons prior to 1890; 1915, 1917, 1923, 1929; 50 tons of concentrates in 1934-35. **Ref:** **2**, pp. 26, 73-74, 79; **3**, p. 119; **7**, p. 65; **8**, pp. 65-67; **11**, pp. 124-126; **18**, pp. 136-143; **19**, p. 22; **24**, pp. 227-230.

130. **Name:** Copper Queen. **Loc:** Sec. 6, (33-41E). On Chewelah Creek. **Access:** 10 mi. N. of Chewelah by road. **Ore:** Cu. **Ore min:** Pyrite, chalcopyrite, tetrahedrite. **Gangue:** Quartz, calcite. **Deposit:** Small lenticular and irregularly spaced quartz veins in quartzite and conglomerate. Veins sparingly mineralized, as is the calcite cement in the conglomerate. **Dev:** Several short adits, drifts, and winzes aggregate about 600 ft. of underground development. **Ref:** **1**, pp. 108-109.

131. **Name:** Eagle (Blue Star, Redwood). **Loc:** Near center N½ sec. 5, (32-41E). **Access:** 4½ mi. by road NE. of Chewelah. **Prop:** 2 patented, 7 unpatented claims, and some deeded land. **Owner:** Chewelah Eagle Mining Co. (1949). **Ore:** Ag, Pb, Cu, Zn, Mo. **Ore min:** Galena, tetrahedrite, sphalerite, chalcopyrite, pyrite, pyrrhotite, cerrusite, anglesite, malachite, azurite, molybdenite. **Gangue:** Quartz. **Deposit:** Irregular lenses and replacements in dolomitic limestone near granite contact. Ore bodies from a few inches to 3 or 4 ft. thick and a few to 50 ft. or more long. **Dev:** Main level with more than 3,000 ft. of crosscuts and drifts. Shaft 217 ft. deep. **Prod:** Prior to and during 1890, 1911, 1925. Production to 1925 was $150,000. **Ref:** **1**, pp. 105-106; **2**, pp. 26, 75; **3**, p. 121; **7**, p. 32; **24**, pp. 148-149.

132. **Name:** Eagle Newport. **Loc:** SE¼ sec. 25, (35-37E), on N. side of gulch. **Access:** Near road. **Prop:** 160 acres of patented land. **Owner:** John Marty of Kettle Falls, Wash. (1942). **Ore:** Ag, Cu, Pb, Au. **Ore min:** Tetrahedrite, galena, malachite, azurite, pyrite. **Gangue:** Quartz. **Deposit:** Shear zone in argillite 25 ft. thick contains numerous mineralized quartz veins cut by post-mineral faults. **Dev:** 580-ft. adit with several short drifts and a winze, also a 40-ft. shaft. **Assays:** An 8-ft. channel sample along the tunnel assayed $6. A shipment of 28 sacks of ore ran $1.75 Au, 19 oz. Ag, 2.1% Cu, and 9.5% Pb. **Prod:** The 28 sacks shipped to Bunker Hill Smelter. **Ref:** **7**, p. 59; **22**.

133. **Name:** Easter Sunday. (See p. 141.)

134. **Name:** Edna (King). **Loc:** SE¼SE¼ sec. 9, (31-39E). **Access:** Road. **Prop:** 4 claims: Alpine, Log Cabin, Log Cabin Extension, and Mother Lode. **Owner:** Arthur L. Hooper of Spokane, Wash. (1941). **Ore:** Cu, Ag, Au. **Ore min:** Chalcopyrite, pyrite, arsenopyrite, tetrahedrite, bornite, malachite, azurite. **Gangue:** Quartz, siderite. **Deposit:** Old reports describe an 80-ft. mineralized zone with 4 ft. of shipping ore and 6 ft. of concentrating ore. Openings accessible in 1942 showed an 8-in. quartz vein along foliation of argillite. **Dev:** 370-ft. shaft with nearly 1,000 ft. of drifts and several caved open cuts. **Improv:** Cabin, several barns. **Assays:** 150 tons averaged 7% Cu, 4 oz. Ag, and $2.75 Au. **Prod:** In 1899, 1904, and 1917 total about $5,000. **Ref:** **7**, pp. 46-47; **22**; **24**, pp. 181-182.

135. **Name:** Frisco-Standard. **Loc:** S½NW¼ sec. 12, (40-42E). On Jubilee Creek. **Access:** 12 mi. E. of Boundary on Cedar Creek road. **Prop:** 9 claims, of which 7 are patented. **Owner:** John T. Raftus leasing to George Niemi (1950). **Ore:** Ag, Pb, Cu, Zn. **Ore min:** Galena, tetrahedrite, pyrite, chalcopyrite, sphalerite, stannite, pyrargyrite, azurite, malachite. **Gangue:** Quartz. **Deposit:** Quartz veins or lenses up to 7 ft. thick in sheared graphitic schist. Veins occur along the planes of schistosity. One vein varies from a few inches to 6 ft. in thickness. **Dev:** 1,000 ft. of accessible workings and several caved adits. **Assays:** 3 small shipments showed 49.2 to 72.8 oz. Ag, 7 to 16.8% Pb, 2.7 to 4.6% Cu, and a trace to 0.01 oz. Au. **Prod:** Small, intermittent. **Ref:** **1**, pp. 58-59; **7**, p. 95; **11**, p. 104; **16**, pp. 61-62; **18**, pp. 112-114; **24**, p. 304.

136. **Name:** Gold Bar. **Loc:** Secs. 15 and 22, (37-38E). **Access:** 1,000 ft. E. of State Highway 22 by road. **Prop:** 120 acres of deeded land in 8 patented claims: Mayflower nos. 1 to 6 and Contact nos. 1 and 2. **Owner:** Gold Bar Mining Co. (1949). **Ore:** Au, Ag, Cu, Pb, Zn. **Ore min:** Pyrite, tetrahedrite, sphalerite. **Gangue:** Quartz. **Deposit:** Quartz veins from ½ in. to 8 in. thick filling fractures in quartzite and argillite. Veins sparsely mineralized. Small tonnage of ore exposed. **Dev:** About 1,000 ft. of workings in 4 adits and 2 inclines. **Improv:** Cabin. **Assays:** 7 assays show from .005 to 0.15 oz. Au, 1.2 to 62.0 oz. Ag, 0 to 1.3% Pb, 0 to 1.7% Zn, 0 to 0.3% Cu, and 1.02 to 2.70% As. **Prod:** 400 lbs. shipped to Bunker Hill Smelter prior to 1945. **Ref:** **7**, pp. 80-81.

137. **Name:** Hoodoo. **Loc:** Sec. 12, (29-37E). **Access:** 10 mi. SE. of Fruitland by road. **Prop:** 1 claim of the Deer Trail mine. **Owner:** Paso Robles Mining Co. (1949). **Ore:** Ag, Pb, Zn, Cu. **Ore min:** Pyrite, chalcopyrite, sphalerite, galena, tetrahedrite, malachite, limonite. **Gangue:** Quartz. **Deposit:** Quartz veins 2 to 3 ft. thick in metamorphic rocks near intrusive camptonite dikes. Vein is sparingly mineralized. **Dev:** Tunnel at least 150 ft. long and said to be 400 ft. **Ref:** **1**, pp. 117-118.

138. **Name:** Jay Dee (Delmonico, Enterprise, High Grade). **Loc:** SW¼ sec. 31, (33-41E), ½ mi. SW. of the United Copper mine. **Access:** 4 mi. by road NE. of Chewelah. **Prop:** 6 claims. **Owner:** Jay Dee Mining Co. (1941). **Ore:** Ag, Pb, Cu, Zn. **Ore min:** Galena, tetrahedrite, sphalerite, chrysocolla, malachite, azurite, chalcocite. **Gangue:** Quartz. **Deposit:** Small quartz stringers from less than 1 in. to several inches thick in limestone. Ore minerals sparsely distributed in the quartz. **Dev:** 160-ft. shaft, 100-ft. adit with a 50-ft. winze. **Improv:** Steam hoist. **Assays:** Said to carry high values in Ag. Ore shipped said to have netted $800 per ton. **Prod:** Some hand-sorted ore shipped. **Ref:** **1**, p. 105; **7**, p. 31; **24**, pp. 144-145.

139. **Name:** Jay Gould. **Loc:** Near center E½ sec. 8, (32-41E). **Access:** 4 mi. by road E. of Chewelah. **Prop:** 3 claims and a fraction, and 20 acres of deeded land. **Owner:** O. C. Niles (1941). **Ore:** Ag, Pb, Zn, Au, Cu. **Ore min:** Galena, pyrite, sphalerite, chalcopyrite, some tetrahedrite, bornite, malachite. **Gangue:** Quartz. **Deposit:** Several large quartz veins and numerous small veinlets in argillite near contact with granite and basic dikes. **Dev:** 200-ft. inclined shaft, from which 2 levels several hundred feet long have been driven. **Improv:** Buildings (now collapsed). **Assays:** Dike reported to assay 60¢ or less in Au. Ore shipped in 1939 netted $50 per ton in Ag and Pb. **Prod:** Production to 1920 about 6,200 tons; shipped in 1939. **Ref:** **1**, pp. 106-107; **7**, p. 34; **24**, pp. 151-152.

140. **Name:** Joe Day. **Loc:** N½ sec. 9, (38-39E) (?). **Prop:** Said to consist of several unpatented claims. **Owner:** Joe Day of Colville, Wash. (1941). **Ore:** Sb. **Ore min:** Stibnite. Note: According to investigation by Washington State Division of Mines and Geology, the precise location is unknown to Mr. Day, and it was too arduous a trip for him to try to locate the outcrop again.

141. **Name:** Keough. **Loc:** NE¼ sec. 14, (40-42E). **Access:** 1 mi. S. of Frisco Standard. **Owner:** Mr. Keough (1913). **Ore:** Pb, Zn. **Ore min:** Galena, sphalerite, tetrahedrite, reportedly free gold. **Gangue:** Quartz. **Deposit:** Slightly mineralized quartz lenses in dolomite near its contact with shale. **Dev:** Open cuts. **Ref:** **1**, p. 59.

142. **Name:** Krug (Hartford). **Loc:** NE¼SE¼ sec. 26, (33-39E). **Access:** 1½ mi. NW. of Bluecreek by road. **Prop:** 9 claims and a fraction. **Owner:** Mrs. A. Krug of Bluecreek, Wash. (1941). **Ore:** Cu, Ag, Au. **Ore min:** Pyrite, chalcopyrite, tetrahedrite, galena, sphalerite, malachite, azurite, limonite, cuprite. **Gangue:** Quartz. **Deposit:** Several quartz veins in limestone and diabase. One vein 2 or 3 ft. thick is fairly well mineralized. Also, some pyrite and chalcopyrite is disseminated in diabase and metamorphics. **Dev:** 340-ft. adit tunnel, 35-ft. shaft and open cuts. **Assays:** A specimen from the 2- or 3-ft. vein assayed 0.49 oz. Au, 94.2 oz. Ag, and 4.8% Cu. **Prod:** Small. **Ref:** **1**, pp. 109-110; **7**, p. 43; **24**, pp. 167-169.

143. **Name:** Liberty Copper. **Loc:** N½NE¼ sec. 2, (32-39E). **Access:** 2½ mi. SW. of Bluecreek by road. **Prop:** 6 unpatented claims. **Owner:** Liberty Copper Co. (1941). **Ore:** Cu, Au. **Ore min:** Pyrite, chalcopyrite, tetrahedrite, bornite, chalcocite, cuprite, malachite, azurite. **Gangue:** Quartz, siderite. **Deposit:** Mostly small, barren to slightly mineralized quartz veins in metamorphics. One vein 6 ft. thick, another 4 ft. thick. **Dev:** More than 2,000 ft. of workings on lower level and a 300-ft. tunnel on upper level. **Assays:** In 1909 an average of 28 assays was $19.20 in Au, Ag, Cu. **Prod:** None reported. **Ref:** **1**, p. 110; **7**, p. 42; **24**, pp. 163-165.

144. **Name:** Little Frank. **Loc:** NW¼ sec. 1, (29-37E). **Access:** 9½ mi. SE. of Fruitland by road. **Prop:** Fractional claim. **Owner:** Mr. Stiles of Fruitland, Wash. (1941). **Ore:** Pb, Zn, Cu. **Ore min:** Galena, sphalerite, tetrahedrite, malachite, limonite. **Gangue:** Quartz. **Deposit:** 12-in. quartz vein cutting limestone shale series. **Dev:** 8- to 10-ft. crosscut and about 100 ft. of drifting. **Ref:** **1**, p. 117; **7**, p. 73.

145. **Name:** Loon Lake Copper (Kemp-Komar). **Loc:** Near center sec. 33, (31-41E). **Access:** 6 mi. N. of town of Loon Lake. **Prop:** 2 claims. **Owner:** John P. Oschgar of Loon Lake, Wash. (1941). **Ore:** Cu, Ag, Au. **Ore min:** Chalcopyrite, bornite, tetrahedrite, malachite, azurite, cuprite, atacamite, hematite, pyrite. **Gangue:** Quartz. **Deposit:** Quartz vein from 4 to 20 ft. thick in argillite. Known payshoot was 200 ft. long and 500 ft. deep. **Dev:** 480-ft. shaft from which about 700 ft. of drifts have been driven on 3 levels, 60-ft. shaft, and some drifts. Workings inaccessible in 1948. **Assays:** Mill feed averaged 2% Cu, a few oz. Ag, and a little Au. Highest Au value was $2. **Prod:** About $125,000 by 1918. **Ref:** **7**, p. 30; **14**, p. 8; **17**, p. 63; **18**, pp. 153-158; **24**, pp. 217-219.

146. **Name:** Lucile (Owen, Boundary Silver Lead). **Loc:** Near center S. line SW¼ sec. 19, (40-42E). **Access:** By road 1 mi. NE. of the Red Top mine and about 5 mi. from Leadpoint by road. **Prop:** 7 claims: Tip Top, Winner, Cabin, Lucile, Comet, Silver Tip, and Effie. **Owner:** Consolidated Speculator Corporation, Mr. and Mrs. S. W. Zoldok and Joseph Zoldok (1949). **Ore:** Pb, Ag, Zn, Cd. **Ore min:** Galena, tetrahedrite, sphalerite, pyrite, scheelite, cerussite. **Gangue:** Quartz, calcite. **Deposit:** Irregular mineralized zones in marble associated with quartz veins and lamprophyre dikes. Ore body developed in 1948, with thickness of 8 to 25 ft., estimated to contain 11,000 tons of ore valued at $727,000. **Dev:** 212-ft. adit, from which several winzes and drifts have been driven. **Improv:** New ore bins, compressor house, and cabin (1949). **Assays:** Zinc concentrates reportedly high enough in Cd to pay freight and smelter charges. **Prod:** Has produced Pb, Ag, and Zn; more than 300 tons of ore in 1948. **Ref:** **7**, pp. 89-90; **8**, pp. 61-62; **9**, pp. 66-68; **11**, pp. 100-102; **24**, pp. 298-299.

147. **Name:** Melrose. (Paragon, Maple Leaf). **Loc:** Sec. 28, (40-41E), 4 mi. S. of the town of Boundary. **Access:** 1½ mi. SE. of the Northport-Boundary highway by truck road. **Prop:** 3 unpatented claims. **Owner:** Ben Hofer of Northport, Wash. (1941). **Ore:** Ag, Pb, Zn, Cu. **Ore min:** Tetrahedrite, galena, sphalerite, pyrite. **Gangue:** Quartz. **Deposit:** 6-ft. vein in argillite contains irregularly scattered bunches of ore. **Dev:** 1,600 ft. of underground work on 2 levels. **Assays:** 75 tons shipped prior to 1921 returned a gross value of $8,000 in Ag. A 3-ton shipment returned 17.5% Zn, 8% Pb, 2.6% Cu, 1.01% Bi, 1.7% Sb, and 73.2 oz. Ag. **Prod:** 1937, 1938. **Ref:** **7**, p. 101; **18**, pp. 116-117; **19**, p. 22.

148. **Name:** Middleport (Rinchaw). **Loc:** SW¼ sec. 1, (36-41E). **Prop:** 2 patented and 6 unpatented claims. **Owner:** Ed Fisher of Addy, Wash. (1941). **Ore:** Zn, Pb, Cu, Ag, Au. **Ore min:** Sphalerite, galena, tetrahedrite, chalcopyrite, pyrite. **Gangue:** Quartz, dolomite, chlorite. **Deposit:** Mineralized quartz vein in granite averages 6 to 24 in. in thickness. Vein said to have a length of 6,000 feet. **Dev:** 800-ft. tunnel, 60-ft. tunnel, 60-ft. shaft. **Assays:** Ore said to run 8% Pb, 8 to 32% Zn, 11.80 oz. Ag, and 0.13 oz. Au. **Prod:** 1929, 1937, 1938; 50 tons mined and 35 tons milled in 1939. **Ref:** **7**, p. 51; **9**, pp. 112-113.

149. **Name:** Mountain View. **Loc:** Sec. 35, (40-39E). On N. side of Squaw Creek, NW. of the Providence property. **Access:** Road. **Prop:** 2 unpatented claims. **Owner:** T. T. Richardson, Ben Hofer, and John Colby (1941). **Ore:** Pb, Zn, Cu, Ag, Au. **Ore min:** Pyrite, chalcopyrite, sphalerite, galena, tetrahedrite. **Gangue:** Quartz and reportedly fluorite. **Deposit:** Interbedded limestone and argillite in which are a 1-ft. and a 9-ft. quartz vein. The 9-ft. vein has a 13-in. band of solid sulfides along the footwall. **Dev:** 350-ft. adit, 50-ft. shaft, 30-ft. shaft. **Assays:** 2½ tons averaged $80. **Prod:** 2½ tons of sorted ore prior to 1941. **Ref:** **7**, p. 91; **9**, p. 63; **24**, p. 314.

150. **Name:** Mullen. (See p. 142.)

151. **Name:** Myeerah (My Era). **Loc:** E. center sec. 11, (40-42E), across the gulch W. fo the Frisco Standard mine. **Access:** Road. **Prop:** 4 unpatented claims. **Owner:** Jury Robinson, lessee (1949). **Ore:** Pb, Ag, Zn. **Ore min:** Galena, tetrahedrite. **Gangue:** Quartz. **Deposit:** Vein 2 ft. thick, consisting of quartz and sheared slate, cuts black slate. Numerous lamprophyre dikes. Vein traceable for about 1,000 ft. **Dev:** 475 ft. of adits, numerous open cuts. **Assays:** Shipments returned 27% Pb and 13 oz. Ag per ton. **Prod:** 1926, Pb ore. **Ref:** **7**, p. 98; **16**, p. 62.

152. **Name:** Nevada. **Loc:** SW¼ sec. 23, (32-39E). **Access:** 5 mi. by road and 1 mi. by trail SW. of Bluecreek. **Prop:** 40 acres of deeded land. **Ore:** Pb, Zn, Ag. **Ore min:** Galena, sphalerite, tetrahedrite, chalcopyrite, pyrite. **Gangue:** Quartz, actinolite, epidote. **Deposit:** Ore minerals form pockets replacing limestone. The pockets range from a few inches to a foot or more in diameter. **Dev:** 30-ft. shaft and 2 other shallow ones. **Assays:** Ore reported to carry Ag. **Prod:** Carload of ore hauled to siding in 1903. **Ref:** **1**, p. 111; **7**, p. 37; **9**, pp. 97-98; **24**, pp. 169-170.

153. **Name:** Orazada (West King). **Loc:** SE¼NW¼ sec. 27, (29-37E). **Access:** Road. **Prop:** 40-acre Indian Agency lease. **Owner:** West King Mining Co., lessee (1941). **Ore:** Ag, Pb, Sb, Au, Zn, reportedly Cu. **Ore min:** Jamesonite, pyrite, arsenopyrite, galena, sphalerite. **Gangue:** Quartz, barite, calcite. **Deposit:** Narrow mineralized breccia zones in argillite and limestone. Heavy gossan on the surface. **Dev:** 2,400-ft. adit, another adit and open cuts. **Assays:** Said to average $8.00, mostly in Cu and Ag. **Ref:** **7**, p. 67; **9**, pp. 110-111.

154. **Name:** Pomeroy. (See p. 143.)

155. **Name:** Providence. **Loc:** Sec. 34, (40-39E). **Access:** 4 mi. SW of Northport. **Prop:** Several unpatented claims. **Owner:** Abandoned (1941). **Ore:** Pb, Ag, Cu, Zn. **Ore min:** Pyrite, galena, tetrahedrite, sphalerite, chalcopyrite. **Gangue:** Quartz. **Deposit:** Argillite cut by acidic dikes. 2 quartz veins contained in acidic dikes are exposed, one vein 12 in. thick. Also a mineralized dike 8 ft. thick. **Dev:** 100-ft. inclined shaft, 192-ft. tunnel, two other shafts. **Assays:** Ore said to carry Ag. **Ref:** **7**, p. 113; **24**, pp. 314-315.

156. **Name:** Saturday Night-Sunday Morning. **Loc:** Sec. 11, (29-37E). **Access:** Poor road. **Prop:** 1 claim. **Owner:** Mr. Stiles of Fruitland, Wash. (1941). **Ore:** Pb, Ag, Zn, Cu. **Ore min:** Galena, sphalerite, tetrahedrite, malachite, limonite. **Gangue:** Quartz, barite. **Deposit:** Ore minerals occur in small patches along fracture zones in limestone and argillite. Main vein is about 18 in. thick. **Dev:** About 800 ft. of workings in several tunnels and shafts, mostly caved. **Assays:** Said to assay high in Ag. **Prod:** Probably has produced. **Ref:** **1**, p. 116; **7**, p. 73; **24**, pp. 191-192.

157. **Name:** Schrenberg. (See p. 144.)

158. **Name:** Sunset. **Loc:** SW¼ sec. 30, (40-40E). **Access:** ½ mi. N. of Northport, 300 ft. W. of the Columbia River. **Prop:** 20 acres of deeded land. **Owner:** Mr. Gourley and associates of Wenatchee, Wash. (1941). **Ore:** Pb, Ag, Au, Zn, Cu. **Ore min:** Galena, sphalerite, pyrite, tetrahedrite, chalcopyrite, much pyrrhotite. **Gangue:** Quartz. **Deposit:** Mineralization occurred along contact of kersantite dikes with limestone and shale. Vein varies from a few inches to several feet in thickness. **Dev:** 400-ft. inclined shaft from which short drifts have been driven at 100-ft. intervals. **Assays:** Au, $2.40 to $17.20; Ag, 3 to 29.8 oz.; Pb, 9 to 75%. **Ref:** **1**, pp. 59-60; **24**, p. 316.

159. **Name:** Tile Creek Mining Co. prospect. (See p. 144.)

160. **Name:** United Silver Copper (United Copper). **Loc:** E½NW¼ sec. 32, and NE¼ sec. 31, (33-41E), on W. slope of Eagle Mountain. **Access:** 5 mi. NE. of Chewelah by good truck road. **Prop:** 7 claims, 5 fractions. **Owner:** Eagle Mountain Mining Co. (1949). **Ore:** Cu, Ag, Au. **Ore min:** Chalcopyrite, tetrahedrite, (freibergite), pyrite, arsenopyrite, malachite. **Gangue:** Quartz, calcite, siderite. **Deposit:** Mineralized zone in fractured argillite 5 to 20 ft. thick (average 8 ft.). Tetrahedrite forms a persistent streak 2 to 12 in. thick. **Dev:** Adit about 4,000 ft. long, 500-ft. adit, 300-ft. shaft, considerable drifting and stoping. **Assays:** High grade carries 75 to 300 oz. Ag. Mill feed averages 1.5% Cu and 3.5 oz. Ag, .01 to .02 oz. Au. **Prod:** 700 tons 1909, $2½ million up to 1934, reopened 1943. **Ref:** **1**, pp. 98-102; **7**, p. 33; **17**, pp. 63, 87; **18**, pp. 123-131; **19**, pp. 20, 22, 37; **24**, pp. 139-141.

161. **Name:** United Treasure. **Loc:** Near center sec. 11, (40-42E). On E. side of Fish Creek 1 mi. W. of Frisco Standard property. **Access:** 11 mi. E. of Boundary (town) on Cedar Creek road. **Prop:** 4 unpatented claims. **Owner:** H. P. Howard (1941). **Ore:** Ag, Pb, Zn, Cu, Au. **Ore min:** Tetrahedrite, galena, sphalerite, azurite, malachite, pyrite. **Gangue:** Quartz, carbonates. **Deposit:** Irregular vein zone of quartz having a maximum thickness of 4 ft. cuts slates. Thin lamprophyre dike above the vein zone. **Dev:** 1,000 ft. of shallow adits and cuts and one 800-ft. adit. **Assays:** Most returns derived from the Ag content. **Prod:** Small intermittent shipments. **Ref:** **7**, p. 114; **11**, pp. 104-105; **16**, pp. 60-61; **18**, pp. 114-116; **24**, pp. 303-304.

162. **Name:** Vanasse (Sugar Load, Victory). (See p. 145.)

163. **Name:** Wall Street. **Loc:** SE¼SW¼ sec. 35, (39-39E). **Access:** Logging road and trail from Onion Creek road. **Owner:** George Van Stone? (1943). **Ore:** Cu, (Zn?), reportedly Ni. **Ore min:** Pyrite, pyrrhotite, (tetrahedrite?), malachite, azurite, and either siderite or sphalerite. **Gangue:** Quartz. **Deposit:** A 2- to 4-ft. quartz vein along a shear zone in limy argillite is sparingly mineralized. Also a limy argillite near intrusive granite is heavily mineralized with iron sulfides. **Dev:** 30-ft. inclined shaft, caved shaft, and inaccessible adit. **Ref:** 22.

164. **Name:** Wells Fargo. (See p. 146.)

165. **Name:** Young America. (See p. 148.)

Whatcom County

166. **Name:** Gold Hill (Northern Cascade, Peterson). **Loc:** SW. cor. sec. 30, (37-17E), on tributary of Granite Creek. **Access:** From Gilbert on the Twisp River over Twisp Pass and Rainy Pass and down Granite Creek. **Prop:** 40 unpatented claims and 2 millsites. **Owner:** Northern Cascade Mines, Inc. (1949). **Ore:** Ag, Au, Pb, Zn, Cu, Sb. **Ore min:** Pyrrhotite, sphalerite, galena, pyrite, reportedly argentite. **Deposit:** Shear zones 2 to 8 ft. thick in black argillite are mineralized in places. **Dev:** 4 tunnels total about 1,800 ft. Also several open cuts. **Improv:** 165-cu. ft. compressor, 3 gasoline engines, cars, track, pipe, and complete mine and camp equipment. **Assays:** High Au, Ag, Pb, and Zn assays have been reported, but nothing in the two lower tunnels was seen to verify the reports. **Ref:** 9, pp. 232-233; 22.

Yakima County

167. **Name:** Richmond. **Loc:** NE¼ sec. 32, (16-13E), on Martha Creek near headwaters of the North Fork of Rattlesnake Creek. **Access:** 3 mi. by trail from Clover Spring. **Prop:** 26 unpatented claims. **Owner:** George V. Rankin, Frank Hardy, William Eamon, and Lin B. Bissell of Yakima, Wash. (1946). **Ore:** Pb, Ag, Zn, Cu. **Ore min:** Galena, tetrahedrite, sphalerite, pyrite, malachite, azurite, arsenopyrite, bornite. **Gangue:** Siderite, calcite. **Deposit:** 2-ft. shear zone in andesite. Brecciated rock has been cemented by calcite and ore minerals. Ore minerals occur in small local shoots. **Dev:** 3 adits: one 50-ft., another 10 ft. long, and a longer one caved. Also a shaft and an open cut. **Improv:** Cabin. **Assays:** 5 assays on picked samples show 22.5 to 248.0 oz. Ag, 0.02 to 5.02% Pb, 0.08 to 1.08% Zn, and 0.02 to 1.87% Cu. **Ref:** 22.

INDEX

Properties listed in the appendix are numbered consecutively. In the index these numbers appear within parentheses following the respective property names.

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