MOUNTAIN BOY

These workings which are credited with a production of several thousand dollars, are on the west side of a small ridge and about three-quarters of a mile southwest of the Castle Creek camp. A part of the workings was not accessible at the time of visit and the following is quoted from a report made by Bancroft* which covers the full development of the property:

"Three adit tunnels with short drifts, inclines and other workings are located near one another on the Mountain Boy claim, about half a mile southwest of the camp. The rocks explored in all these workings are a part of the limestone and shale series which prevails over a large portion of Castle Mountain and the ridges projecting from it.

"Only two of the four tunnels represent development on ore bodies, Nos. 3 and 4 having been driven to open ground under the ore-shoots above. The No. 1 and 2 workings are within 75 to 100 feet of one another and practically on the same level.

"No. 1 tunnel is located at an elevation of 3,920 feet. A crosscut adit extends 30 feet, beyond which point a gentle incline 75 feet long and a steep pitch of 50 feet lead to a level known as No. 3. Short drifts have been run off from the main level in all directions, having resulted from gutting the small irregular ore-bearing quartz lenses that occur along the planes of schistosity of the sedimentary rocks. Underground development shows that these quartz lenses vary in width from half an inch to 18 inches and in length along the strike from two inches to 30 feet, and some may have greater dimensions. They contain irregularly scattered patches of galena, sphalerite, chalcopyrite, pyrite and tetrahedrite. The ores show some banding and are brecciated by post-mineral movements. Both the ore bodies and the sediments are traversed by innumerable veinlets of calcite."

Assays of a portion of the dump material are said to average 10 to 20 ounces of silver to the ton and during the winter of 1919 Mr. Cross was building a small 15-ton mill to treat a part of these dumps.

*Bancroft, Howland. The Ore Deposits of Northeastern Washington: U. S. Geol. Survey, Bull. 550, page 207.

SHERIDAN DISTRICT

GENERAL FEATURES

Ten miles by air line northwest of Republic are several properties which, after an idleness of 20 years, have been partly revived by the favorable market for silver. These are in the Sheridan (sometimes called the Cascade) District. Most of the holdings are in T. 38 N., R. 31 E., just across the Ferry County line into Okanogan County.

The first location was made during 1897 and a year later the Zalla M property made the first shipment of high-grade ore. All work was suspended during 1903 and aside from an occasional shipment from the Phil Sheridan and Toroda mines, the district was dormant until 1917. The total production has not been notably large, probably not over $100,000.

The values are principally in silver with minor amounts of copper and gold. The gangue minerals of quartz and calcite are but sparingly present in all except the Zalla M workings. Flourite is associated with the mineralization in the American Flag workings.

The country rock in the vicinity of deposits is a medium fine-grained igneous rock with a dark greenish cast. A thin-section causes it to be classified as phonolite. The section examined is composed of 45 per cent soda feldspar, 10 per cent nephellite, 25 per cent aegirite and augite, and the remainder serpentine, sericite and secondary pyrite.

This rock has developed a series of narrow shear zones along which the ore minerals have partly replaced the phonolite and deposited narrow zones and lenses of high-grade ore. The deposits are usually characterized by parallel false walls which in some instances mask mineable ore. They are not showy and constant sampling and assaying vigilance is a necessary aid to intelligent mining.

In the Zalla M Mine there is a quartz vein varying in width from one to six feet and traceable on the surface for several thousand feet. Since the greater portion of this vein is barren of values its successful development must come from locating the workable ore-shoots.

PHIL SHERIDAN

A company incorporated as the Carey Mining & Development Company, with head offices in Spokane, is working the Sheridan Mine under bond and lease. It has been carrying on development work with a small crew for several years and shipments of high-grade silver ore have been made at various intervals. During 1918 a 50-ton concentrator was erected and since that time intermittent mill runs have turned out several car loads of concentrates averaging 300 ounces of silver to the ton.

The property, which comprises 10 patented claims, is owned by P. J. McCormick of Republic. During the early history of the property, Mr. McCormick is reported to have mined a considerable tonnage of shipping ore; the records of these shipments are not now obtainable.

The mine openings are situated in a small gulch one mile north of the East Fork of Torodo Creek, in Okanogan County, one mile west of the Ferry County line, and the old Sheridan Camp. By air line the property is nine miles northwest of Republic but it can best be reached over the Wauconda road, which involves a trip of approximately 20 miles.

The property was visited in the absence of the operators. Both mine and mill were temporarily closed down. The present equipment cannot furnish sufficient power for both the mine and mill.

The country rock is a fine-grained phonolite. The vein fills a zone of shearing which cuts the phonolite with a strike of north 20° east and dips 50° northwest. The mineralized zone varies in width from one to seven feet. The hanging-wall is well defined and exhibits a painting of one inch of gouge. Intense shearing along the zone has developed a series of false walls, particularly noticeable along the foot-wall of the deposit. What appears to be cleanly defined foot-wall can often be broken through and back of it at a distance of a foot or more a second or third parallel wall found, identical in appearance with the first. Additional mineralization is sometimes found between these false walls. The brecciated country rock has been considerably altered and silicified by mineralized solutions which worked their way upward along

the shear zones. The feldspar in the brecciated rock is noticeably altered to kaolin and sericite while pyrite is strongly developed through the zone. The deposit appeared more in the form of a mineralized lode rather than a vein. It is not at all showy, in fact, very little rock was seen in place that gave the appearance of commercial ore, and it is necessary to closely sample and assay in order to determine the mineable shoots. In the upper levels appreciable quantities of quartz and calcite assist the ore minerals in cementing the brecciated country rock. A grab sample taken by the writer of one of the upper dumps gave an assay of 16 ounces of silver to the ton.

The deposit has been opened by a series of crosscut tunnels driven to the vein at intervals over a distance of 500 feet up the hillside. The lower crosscut is driven south 52° east to the mineralized zone. Drifts have been run along the zone and a limited amount of stoping done. An incline winze has been sunk on the vein from this level to a depth of 200 feet. This was apparently started on a well mineralized lens of ore but the mineralization does not appear to have extended all the way down the winze for little ore could be observed on the walls.

The upper levels are similar in plan to the adit level. They are connected by raises and several stopes have been broken. Judging from the appearance of the ground mined, the mineralized zone must have averaged three to four feet in thickness.

The property has a well equipped blacksmith shop and air for the drills is furnished by a three-drill steam-driven air compressor.

Description of the Concentrator.—The construction of the mill was begun during 1918 and completed early in 1919. Its average capacity per 24 hours is about 50 tons. The mill feed averages 15 ounces of silver to the ton and the concentrates 300 ounces. The machinery is operated by a Nagel steam engine which receives its power from a 60-horsepower boiler. Water for the mill comes from a storage reservoir 500 feet down the gulch. It is lifted back to the mill tanks by a Gould three-cylinder vertical pump, operated by a six-

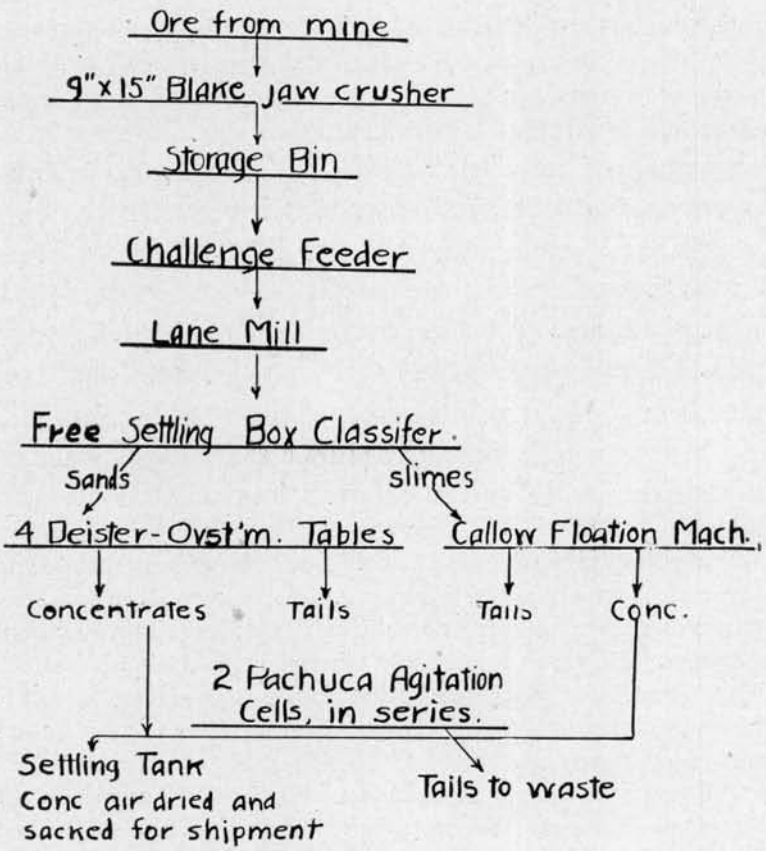


Fig. 17. Flow-sheet of the concentrator at the Phil Sheridan Mine.

horsepower distillate engine. During the summer months the water supply becomes low and has to be carefully husbanded.

AMERICAN FLAG

The American Flag holdings include one claim and a prospecting lease on several adjoining locations, situated in sec. 36, T. 38 N., R. 31 E., about eight miles by air line northwest of Republic or 13 miles by wagon road, and at an elevation of approximately 4,500 feet or 2,100 feet higher than Republic. The property is reached over an ordinary wagon road, the only objectionable feature being that the last mile of the trip is up a grade averaging ten per cent with many steep pitches that prohibit heavy hauling.

Some early discovery work was done on the property about 1898. The present company was organized during October, 1917, and carried on limited development work for a few months during 1918. Work was resumed May, 1919, with a crew of three men, but was again suspended during August of that year when a flow of water necessitating the installation of pumping equipment, was struck on the lower level.

The showings have been developed by a 97-foot drift driven north 45° east which gains a depth of 40 feet below the outcrop. A raise was opened on the vein to the surface and a small stope opened from which several shipments were made. At a distance of 49 feet from the portal an incline winze was sunk to a depth of 97 feet on the dip of the vein.

The ore occurs in a highly silicified zone two to eight feet wide, which strikes north 45° east and dips 50° northwest. The hanging-wall is well-defined while the foot-wall sides grades indistinctly out into the wall rocks. The ore minerals are chalcopyrite, bornite, sphalerite, pyrite and scattered minute specks of a sulphide, which is believed to be some silver mineral since the chief value of the ore is in silver. Purplish to bluish granular crystals of fluorite occur quite prominently in the vein and are closely associated with the ore minerals. Fluorite associated with ore-bearing minerals is believed to have the function of the so-called mineralizers. Its action is thought to make the vein-forming solutions less viscous thus promoting diffusion, and owing to the low critical temperature of many of the compounds that contain them, these compounds remain longer in the gaseous state.

The deposit is not at all showy and assays are necessary to determine workable ground. The ore occurs in localized shoots within the vein and it seems it is the tendency of these shoots to be short. In the upper drift two pay-shoots were encountered. The first was 16 feet long and is said to yield average assays of 13 ounces of silver to the ton, while the second is 23 feet long with an average of 27 ounces of silver. It is not known how far these shoots continue on the dip of the vein, because the lower workings are under water.

Post-mineral fractures were observed filled with growths of quartz crystals, some of the crystals being coated with a black skin of secondary deposited argentite. Near the surface the vein is leached and malachite stains of copper and vugs of quartz crystals are the predominating features.

Smelter certificates for two 30-ton shipments made from this property show an average of 16 ounces of silver, .10 ounces of gold, and 36 per cent copper to the ton.

On the surface the vein is traceable up the hillside for several hundred feet but here it appears quite barren of values. Several shallow pits have been opened showing it to have an average width of six to eight feet. Near the crest of the hill and about 450 feet from the main workings the vein intersects a north-south trending quartz vein known as the Uncle Sam. This second vein has a strike of south 15° west, stands nearly vertical, has an average width of four to five feet, and can be traced on the surface for over a thousand feet. It has been prospected by several shallow shafts and open cuts which are now filled with water. The dump material shows some mineralization in copper, iron and silver minerals.

Northwest of the American Flag Camp about 150 feet, there is still another well-defined quartz vein which averages three to four feet in width and runs parallel to the Uncle Sam vein. Where observed at several points along the surface it appeared practically barren of values.

ZALLA M

The principal workings of the Zalla M property are a few hundred yards west of the Ferry-Okanogan County border, in sec. 30, T. 38 N., R. 32 E., a half-mile northeast of the American Flag property and near the old Sheridan Camp. The mine openings are at elevations varying between 4,500 and 5,000 feet.

The first high-grade ore in the Sheridan Camp was discovered in the Zalla M workings June, 1898, and until 1903 this was mined and hauled in wagons to Midway, B. C., thence by railroad to the Trail Smelter. The total production was reported as about $40,000. The ore, however, was not rich

enough to withstand the high transportation costs, and the mine closed down during 1903, and there has been no new work since that time. The property is held by the Rossland, B. C., Branch of the Bank of Montreal.

H. M. Genin and Robert May, who own six adjoining claims, are now the only inhabitants of the old Sheridan Camp.

The road from Republic to the American Flag Mine continues northeast to connect with the Sheridan Camp, but on account of the steep grade this road is not used for heavy hauling. Ore is usually hauled down the Torodo Creek to Lynch Station on the Republic Branch of the Great Northern Railway, a distance of 22 miles.

Some of the old smelter certificates on 30-ton lots of hand-sorted ore show:

1.— 86 oz. of silver, .17 oz. of gold and 1.2% copper.

2.—118 oz. of silver, .25 oz. of gold and 1.0% copper.

The deposit is a well-defined quartz vein varying in width from one to six feet, striking south 25° west and dipping 45° northwest. By frequent outcrops and test pits the vein can be traced on the surface for several thousand feet, although large portions of the vein where observed were so sparsely mineralized that they could not be called ore. The vein fills an irregular fracture in the country rock. The wall rock in many places have been severely brecciated and the fractures are now cemented with lacings of crystalline quartz, calcite, and minute amounts of fluorite. The country rock is phonolite.

The deposit is developed by two levels which are connected by a raise approximately 200 feet in length, measured on the dip of the vein. As it has been idle for many years some of the workings are caved and the ladders in poor condition. Only the lower workings, reached through the lower crosscut, were visited. This crosscut is driven south 60° east a distance of 600 feet, where it encounters the vein about 300 feet below the outcrop. A drift was run northeast on the vein for a length of 60 feet and southwest for approximately 300 feet. The best ore was found in the southwest drift; two stopes were opened above the level and an incline winze sunk

on the vein to a depth of 100 feet. This winze is now under water. About 400 feet down the mountain side from the portal of the lower crosscut, a 1,000-foot adit tunnel was started to gain depth on the vein and provide drainage for the lower workings. This adit has been driven less than 100 feet.

The vein as exposed on the main or 300-foot level varies from two to six feet in width and is made up of crystalline quartz and some calcite. The silver values, associated with small amounts of chalcopyrite and pyrite, occur in localized shoots. An old assay map of the property was available and it shows the richest ore, which returned assays of 60 to 150 ounces of silver, to occur between the 150-foot level and the surface. This upper section of the vein probably represents a zone of secondary enrichment. On the lower levels the assays are of average lower grade and are not of workable value in the absence of concentrating facilities.

DANVILLE DISTRICT

COMSTOCK AND WALLA WALLA GROUPS

On Le Fleur Mountain, two miles by air line south 65 degrees west of, and 1,000 feet above the town of Danville, are located two groups of claims known as the Comstock and Walla Walla. These have recently been consolidated and are being worked under lease and bond by the Le Fleur Mountain Copper Co., with head offices at Colville. The holdings total four claims and six fractions. Work was started by the Le Fleur Co. late in 1918 and has continued since that time with a crew of four men.

To reach the property from Danville it is necessary to travel down the west side of Kettle River a distance of two miles, where a branch road turning off westward is constructed up the steep mountain-side by a series of switchbacks. Beyond the first half-mile, which is of steep grade, the road can be easily traveled by automobile.

The claims are located on an elevated bench which steadily increases in elevation toward the northwest. An interesting set of geologic conditions is exposed. This bench marks approximately the upward extent of a portion of a granitic

intrusion. The overlying older rocks as exposed near the workings are principally dense, dark-colored, fine-grained schistose rocks which have been metamorphosed and contorted in large part by the forces of the underlying intrusives. Erosion has made such heavy inroads into these overlying formations that in places they are sufficiently stripped-off to expose the upper limits of the underlying batholith. As would be expected, at the outer crust of the intrusive the rocks expose many local phases, but they appear to be of a composition varying between a monzonite porphyry and a diorite porphyry. Intruded into the schist are apophyses of the batholith in the form of granitic and lamprophyre dikes.

The ore minerals, bornite, chalcopyrite and pyrite, occur banded and peppered through a dike-like vein, better described as a ledge, which cuts south 85° west through the schist and stands nearly vertical. The gangue is made up largely of feldspars which have been, in part, altered to sericite. The best showing on the property is found on the Comstock claim, where the ledge is well mineralized and maintains a width of five feet for a length of 100 feet along the strike. Southwest of this it appears to pinch down. A few hundred feet further it appears again with a width of two feet and shows more or less mineralization scattered out in the wall rocks. At varying intervals over a length of half-mile along the general trend of the ledge between the Comstock and Walla Walla claims there appear several sporadic showings of mineralization. For the most part these shallow prospect pits are caved and no idea could be gained as to the size of the deposit. At the best exposure on the Comstock claim a shaft has been sunk to a depth of 35 feet. In this shaft the ledge continues strongly and a sample across the face would assay from 3 to 5 per cent copper; it is also said that the ore carries several ounces of silver to the ton. It would seem logical that the development work be centered on the further development of this exposure. The ledge can be traced only a short distance northeast of the shaft.

At the time of visit the company had a crew of three men sinking a prospect shaft on the Walla Walla claim to explore

some irregular croppings of chalcopyrite. This shaft at a depth of 35 feet exposes little ore. It has encountered a dike composed of plagioclase feldspar which possesses a peculiar dark-blue color. In this section, under the microscope this is found to be labradorite feldspar associated with minor amounts of calcite, albite, magnetite, and epidote. The company reports that several assayers have returned appreciable platinum assays from samples of this feldspathic material. The older schist roof-rocks are exposed a short distance north of this shaft.

CHATTERBOY MINING COMPANY

About August 1, 1919, the Chatterboy Mining Co. was organized with head offices at Dayton, Washington, to work the old Lucile Dreyfuss Mine under lease and bond. The holdings consist of two and one-half claims three miles south of Danville and 500 feet above Kettle River and the Great Northern right-of-way. The workings were not open at the time of visit and no examination was attempted. Development work with a small crew began about ten days later and according to reports was being continued into 1920. It is understood that outside of a few tons of ore already in the bins, all future production must come from ore yet to be developed. The main adit tunnel is 1,300 feet long and intersects the deposit at 1,200 feet from the portal. The ore is low-grade chalcopyrite, pyrrhotite, and pyrite, with the values chiefly in gold and silver with some copper.

NESPELEM (MOSES) DISTRICT

GENERAL FEATURES

The Nespelem District embraces an area of about 200 square miles in the southeastern corner of Okanogan County. It is legally bounded by Columbia River on the south, the Ferry County line on the east; on the north by an east-west line 12 miles north of Nespelem Village, and Okanogan River as the western extremity.

The district affords an exception to the usual association of the mines of Washington with pine-clad, mountainous slopes. Riding down out of the well-timbered range, which forms a

natural barrier between Ferry and Okanogan counties, the first view of the Nespelem country accentuates its rather barren semi-arid nature. The district stretches out in panorama as an elongated north-south* basin hemmed in on all sides but the south by walls which rise with gentle slope from the valley floor to culminate in ridges at elevations varying from 4,000 to 5,000 feet above sea level. In detail, the valley floor is composed of two flats at different levels. The higher, at an elevation of 2,600 feet, is a basalt table land, a northern segment of Columbia River basalt plain. The lower is an embayment of the 1,700-foot terrace of the Columbia Valley. South of the area is the deep-cut valley of Columbia River and beyond the flat-topped basalt plains of the Big Bend farming country.

To the north, the prominent, timbered hills stand out in marked contrast to the low, rolling sage-brush covered spurs that extend down into the southern end of the basin.

ACCESSIBILITY AND TRANSPORTATION

Hemmed in on three sides by steep mountain ranges and on the south by the deep, narrow valley of the Columbia, the Nespelem Basin offers no ready means of approach and its isolation from railroad transportation is a serious retardation. Of the four routes offered the one most generally used is from Almira, a station on the Washington Central Branch of the Northern Pacific Railway, 35 miles southeast of Nespelem. Okanogan, on the Wenatchee-Oroville Branch of the Great Northern Railway, is 25 miles northwest of Nespelem, but the road connecting the two towns was reported in very poor condition. Access may be gained from the east by traveling over the Keller-Republic road following Sanpoil River. At Cache Creek a branch road turns off to the west and ascends the summit of the range which forms the north-south boundary of Ferry and Okanogan counties. Within a distance of five miles this road ascends approximately 1,400 feet and the many sharp grades are not easily negotiated by automobile. The most natural means of access is by boat up Columbia River from the railroad at Pateros, but the rocky channel and a swift

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

current makes navigation hazardous during periods of either extreme high or low water.

Nespelem, with a population of about 500, is the only settlement of importance in the district. It is the trading settlement for this section of the Colville Indian Reservation and it is not uncommon to see more Indians than whites on the streets of the village. The United States Indian Agency is two miles south of Nespelem and most of the Nespelem Valley is occupied by Indian farmers.

GEOLOGY

The geology of the Nespelum and surrounding districts has been well interpreted by Pardee* and only the most salient features will be reviewed in this report.

The predominating formation of the Nespelem District is a rather coarse-textured, light-gray, soda-rich granite which has been named by Pardee, the Colville Batholith. It is characterized by large porphyritic crystals of pinkish orthoclase feldspar which were often observed to be an inch or more in length. The essential minerals of the granite are oligoclase, quartz, orthoclase and biotite, the necessary minerals apatite, zircon, titanite and iron minerals.

Many younger intrusive dikes of granodiorite porphyry cut the granite in the vicinity of Nespelem, and are particularly well exposed on Mineral and Multnomah hills west of Nespelem and along the low hills a mile east of the town.

The old Palezoic series of metamorphosed sediments have a few limited exposures in the area but generally they have been thoroughly removed by erosion. At the time the Colville granite was intruded into these sediments they posessed a thickness of several thousand feet thus forming an insulating cover under which the molten magma slowly cooled. Following the intrusion there existed a long erosive period during which the thick belts of sediments were in some places so deeply sculptured that the underlying granite was exposed. Later, in the Tertiary period, great outpourings of basaltic lava were busy inundating the old land surface of south central and southeastern Washington and building up the great

*Pardee, J. T. Geol. and Mineral Deposits of the Colville Indian Reservation: U. S. Geol. Survey, Bull. 677.

lava plateau. Tongues of this lava worked northward to reach into the Nespelem area, where segments of the flows may be found today. After sufficient time had elapsed for Columbia River to cut its channel 1,600 feet or more below the northern edge of the lava plain, the Nespelem area was overridden by a Pleistocene ice-sheet of such size that it moved at right angles across the deep-cut valley of the Columbia and invaded the Big Bend country to the south. On the plateau country of the Nespelem District there remain large hummocks of glacial debris and isolated basalt boulders weighing several thousand tons, which the glaciers dropped on their retreat northward. The present topography is largely influenced by the glacial erosion and no doubt the upper limits of many of the present ore deposits were planed off by ice action.

CONDITION OF MINING ACTIVITY

During August, 1919, six properties in the Nespelem District were actively engaged in exploration and mining. None of these properties, however, was carrying on extensive work and there were not over 40 men actively engaged in mining. All active properties are along a narrow strip of territory two miles long in a northwest direction and three-fourths of a mile wide, on the slopes of a low barren hill known as the southeast spur of Mineral Hill, and located one and one-half miles west of the town of Nespelem. The deposits visited are all of the same general type and carry their principal values in silver.

The costly transportation charges prohibit the shipment of ore that averages less than $35.00 to $40.00 per ton. During 1918 a company, organized as the Great Metals Mining and Milling Co., built a 60-ton concentrating mill near Nespelem Falls, about two miles southwest of town. Concentration facilities and the development of an excellent silver market resulted in a renewal of activity in the district during 1919. Ores averaging $12.00 to $15.00 per ton became of commercial importance. Work began on the re-sorting of old dumps and the mining of lower grade pay-shoots, the ores from the various properties being hauled to the mill by auto trucks.

With the advantages of milling facilities and a high silver market there is no good reason why several of the properties

cannot be profitably worked on a small scale. Mining must necessarily be confined to the better pay-shoots along the fracture zones, and since these are of limited extent they will not permit extensive operation.

COSTS

The following cost items were furnished by Beggs & Ostrowski, the principal shippers from the district:

Mining (crude	$ 4.00	per ton
Custom milling charge (crude)	4.00	" "
Transportation Conc. to R. R.	15.00	" "
Freight charges (Conc.)	17.00	" "
Smelting charge (Conc.)	20.00	" "

The crude ore sent to the custom mill averages from 14 to 25 ounces per ton in silver and a concentrate is made which averages from 300 to 500 ounces of silver to the ton.

The ore deposits visited are found along zones of fracture which trend in a northwesterly direction through the Colville granite. These fractures appear to have developed from contractions in the outer cooling shell of the intrusive granite, and the ore minerals collecting in the still molten interior of the magma were forced up in the form of hot solutions and gases which not only filled the fractures but partly altered and replaced the granite wall rocks. The result is that the veins are not cleancut but grade irregularly into the wall rocks. Along the fractures are found mineralized zones varying in width from a few inches to eight feet, the zone filling being shattered granite partly altered to sericite, kaolin and small irregular veinlets of calcite and quartz. Silver and small amounts of gold form the predominating values and are found associated with ores of lead, copper and iron. Only portions of the mineralized zones can be called ore. These pay-shoots occur as lenticular, enriched masses which thin out at the margins along both the strike and dip of the lodes. The largest pay-shoot so far developed has been in the Apache ground where the shoot averages about two feet in thickness, 100 feet along the strike of the vein, with the length along the dip not yet fully determined. Portions of this shoot were high-grade, averaging from 50 to 1,000 ounces of silver to the ton.

On account of recent glaciation and rapid natural erosion, the oxidized zones of the deposits vary between 10 and 30 feet in depth and are usually quite barren of values. The zones along the deposits have suffered sufficient post-mineral fractures to open numerous small channels and along these channels downward enrichment of silver values has proceeded until a lower enriched zone is formed. The depth to which this enrichment has reached cannot be determined until deeper mining has been attempted. It is hardly likely, however, that it will exceed 250 feet below the outcrops. The richest ore will be found in this zone of enrichment, but below this there is no reason why the primary silver minerals will not, in certain of the deposits, continue to good depth.

Named in order of their importance, the secondary silver minerals are argentite, proustite (ruby silver) and native silver. Proustite is the predominating ore mineral of the Double Header deposit, while in the Apache and Panama mines the secondary silver has been deposited as argentite and native silver.

APACHE

Location and General Features.—The Apache property is the best developed and most consistent producing property in the Nespelem District. The first shipments were made in 1911 and since that time it has been worked intermittently, making a total production of several thousand tons of excellent grade ore. During 1915 the property was leased to Beggs and Ostrowski and since that time work has been carried on with an average crew of five men. Until recently it has been necessary to carefully hand-sort all ore in order to keep the grade high enough to meet the heavy transportation costs. Since the completion of the Great Metals mill in 1918 the Apache ores have been the chief source of the mill supply. Ore that averages as low as $12.00 per ton became of commercial value and the Apache lessors began the mining of their lower-grade shoots and the re-sorting of their old dumps. This ore is hauled by auto trucks for a distance of two miles to the mill.

The property is in sec. 27, T. 31 N., R. 30 E., well up near the crest of the southeast spur of Mineral Hill, about two miles west of and one-quarter mile south of the town of Nespelem. The mine openings are at an elevation of approximately 2,100 feet or about 300 feet above Nespelem.

Description of the Deposit.—The ore is found along a replacement lode which occupies a sheared zone through the granite. The foot-wall of the lode is well-defined but the fractures trend out into the granite without finding any definite hanging-wall. The rich ore is found in narrow seams following close to the foot-wall. The statement is made that some of the carefully hand-sorted smelter shipments have carried as high as 1,000 ounces of silver to the ton. The strike of the lode is north 50° east and the dip 50° northeast. The major shear zone is cut and displaced a foot or more in several instances by cross-fractures which lead out erratically into the granite. The mine evidence strongly suggests that some of the best lenses of ore are found at the intersection of these fractures. This is a factor which should be well considered when directing future development work.

The upper 25 feet of the deposit is severely oxidized and leached of its values. Below the oxidized zone secondary argentite and flakes of native silver are deposited to sweeten the primary ores into rich shoots of limited size. The fractured condition of the lode has permitted enrichment to penetrate well blow the adit level.

About 60 feet below the surface a flatly-dipping fault truncates the vein and displaces the lower segment to the north. This fault is clearly marked by a four-inch streak of soft gouge.

Stephenite (brittle silver) is the most prominent primary silver mineral present, while argentite and native silver are the important secondary products. Outside of the high-grade shoots the unoxidized vein-filling consists of sericitized granite partly replaced by quartz, rhodochrosite, pyrite, tetrahedrite, galena, and sphalerite.

The principal shoot of high-grade ore can be well observed in the stopes below the adit level where it is found more

uniform than in the upper limits of the vein. It develops pinches and swells along both the strike and the dip of the lode. It has a stope length of 100 feet, a pitch length of 150 feet without bottoming the shoot and the thickness of profitable ore varies from one to two feet.

Development.—The property is opened by an adit tunnel driven 400 feet, with a general trend of north 55° west. From this level several small stopes are opened, one of which extends 100 feet through to the surface. Two hundred and seventy feet from the adit portal an incline winze has been sunk on the lead to a depth of 146 feet. The second level has been developed 96 feet below the collar of the winze by a drift 217 feet to the northwest and 138 feet to the southeast. The third level is 50 feet below No. 2 and from this drifts have been run 118 feet to the southeast and 40 feet to the northwest. The major portion of the ground southeast of the winze, between the third level and the main adit has been stoped out. In this same ore-shoot a prospect winze is being sunk from the third level. By August, 1919, it had reached a depth of 40 feet and good values were reported. The operators plan to deepen this winze and if the ore values warrant it, develop a fourth level and stope the intermediate ground. Another stope has been opened between the second level and the adit level, but it is of limited size because the ore shoot feathered out toward the northwest.

PANAMA

One of the later discovered properties in the district is the Panama, which is located about one-half mile west of the Apache Mine and on the opposite slope of the south spur of Mineral Hill. The deposit is on the southwest slope of the hill, 1,000 feet above and one-fourth mile north of Columbia River. The holdings, which consist of two claims and two fractions, were located during 1913. They are now being developed by H. P. Dickinson, a crew of three men being employed.

The deposit is quite similar to the Apache, being of the replacement type, located along a fracture zone running through the granite. The zone has the general northwest trend and the

steep dip toward the northeast that marks a great number of the active properties of the district.

The lode filling is made up of an altered zone of granite which varies in width from two to eight feet. The limits of the lode are not clean-cut and quite often alteration and replacement has extended out into the granite wall rocks in a manner strongly suggestive of sericitization along the fracture zone by the heated waters.

Stephanite, argentite, native silver, and pyrite are the predominating ore minerals. The argentite occurs as a secondary silver mineral forming a sooty, wax-like coating along the small fractures through the zone. The orthoclase feldspar and its alteration product, kaolin, which are prominent minerals in the granite, have apparently acted as agents to precipitate the downward percolating, silver-bearing solutions as argentite. Some thin flakes of native silver were also observed in specimens from this property.

Development is being carried on through two drifts opened on the hillside, one directly under the other, at a vertical difference in elevation of 43 feet. The upper tunnel is driven in a general southeast direction following the fractured zone. One hundred feet from the portal the zone swings toward the south, giving the deposit the strike of south 20° east and a dip of 50°-60° E. Near this bend a pay-shoot was encountered and drifted on for 20 feet. The face of the drift (August, 1919) showed a body six feet in width of altered granite cut by quartz stringers and carrying appreciable silver minerals. Channel samples across the zone would be necessary before attempting to estimate the silver content. Seventy-five tons of ore had been mined from this drift and was in the bunkers awaiting shipment to the Great Metals mill. The owners report that this averages 20 ounces of silver to the ton.

The lower crosscut was driven south 65° east for a distance of 120 feet, where it encountered the vein 45 feet below the upper level. The lead was then drifted on 50 feet toward the northwest and this work exposes two to three feet of crushed granite which has been invaded by siliceous solutions carrying the silver minerals. Near the face of the drift a winze has been

sunk on the vein. The walls of this winze, down to water standing 20 feet below the collar, expose ore of apparent milling grade.

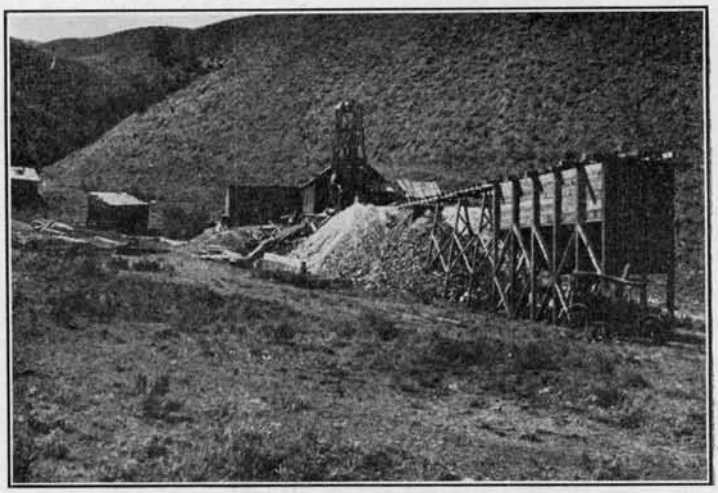
During November, 1919, a 12-ton shipment of hand-sorted ore was made to the Tacoma Smelter which averaged 56.8 ounces of silver and 9.32 ounces of gold to the ton.

One hundred feet northeast of the portal of the upper tunnel, a small open cut exposes a well-defined quartz vein three feet in width. This vein strikes south 50° east and dips nearly vertically. The limited work has exposed no mineralization other than stains of iron and manganese oxides. It is possible to explore this vein at depth by a cross-cut from either level.

GREAT METALS MINING & MILLING COMPANY

Cabin Claim.—The Great Metals Mining and Milling Company holds 46 claims which are scattered along the southeastern spur of Mineral Hill about two miles west of Nespelem. Their activity during 1919 was centered upon the operation of their custom mill and the development in a limited way of the Cabin property which they hold under lease and bond. During August, 1919, the two compartment shaft had been deepened to 200 feet and was being timbered for the installation of a hoist. The shaft had not been pumped out for some time and the water confined the examination to the upper level. This is 85 feet below the collar and consists of a 30-foot drift to the northwest which exposes quartz and calcite veinlets carrying limited mineralization of galena, pyrite, and sphalerite. These veinlets fill a zone of fracturing trending north 50° west through the granite and dipping to the northeast; a part of the northwest-southeast fracture system exposed in several of the other properties such as the Apache and Double Header. Kaolin and sericite are developed in the granite wall rocks along the zone, and the sulphide replacement in some cases extends out into the walls. The development on the 200-foot level is said to consist of a cross-cut from the bottom of the shaft to this fracture zone and a short exploratory drift.

It is the present plans of the company to explore the shear zone by drifts on the 200-foot level and if it does not develop



Head-frame and ore-bin, at Cabin shaft of Great Metals Mining & Milling Company.

ore, a cross-cut will be driven to the west to explore with depth a vein outcropping about 200 feet west of the shaft house.

A 20-horsepower distillate engine operates a 2-drill compressor and the hoist.

GREAT METALS MINING & MILLING COMPANY

During 1918 the Great Metals Mining and Milling Company completed a 60-ton concentrating mill near Nespelem Falls. Since its completion the mill has been working more or less steadily treating the silver ores from the nearby small properties, and ores sorted from the dumps left years ago by miners in search of only the high-grade ores. During August, 1919, the mill was running one shift treating ores from the Apache mine. The mill feed averaged 10 to 20 ounces of silver and was being made into a concentrate carrying 200 to 400 ounces of silver to the ton, for shipment to the Tacoma Smelter. About 90 per cent of these concentrates were being made on the flotation machine and the remaining 10 per cent on the tables. Later the tables were discarded.

The mill is favored with an excellent supply of water power. The water is picked up above Nespelem Falls, carried first to a wooden flume and then through a 28-inch wood-stave pipe to the mill, where, under an 80-foot head, it is delivered

to a four-foot Pelton wheel through two 3½-inch nozzles, 90 horsepower being developed on the wheel. Only a fraction of the potential power of Nespelem Falls is at present developed.

The ore is delivered to the mill by auto trucks which dump into a 75-ton storage bin. The ore is drawn from this bin over a grizzly set to 1½ inches; the oversize is crushed to one inch in a Dodge jaw-crusher and joins the grizzly undersize at the boot of a 50-foot bucket elevator. The elevator delivers to a small bin at the head of the mill proper. A Challenge feeder delivers to a 12-foot Lane mill which crushes to approximately four mesh. The ore is next crushed in a 4 x 4-foot ball mill which operates in closed circuit with a drag-belt classifier. Ninety per cent of the classifier overflow will pass a 60-mesh screen. This overflow goes direct to a standard K & K flotation machine. The concentrates from flotation are de-watered in a series of settling tanks and dried previous to shipment. The tailings are flumed direct to the waste dump.

DOUBLE HEADER MINING COMPANY

The Double Header Mining Company was organized to work the Little Chief property under lease and bond. During August, 1919, a crew of three men was employed on the property under the direction of B. S. Jenkins. The workings are at an elevation of 2,050 feet in the NW¼ of sec. 35, T. 31 N., R. 30 E., about two miles southwest of Nespelem village and three-quarters of a mile southeast of the Apache Mine.

The development work consists of an incline shaft sunk to a depth of 180 feet on the dip of the vein. On the first level drifts were run 275 feet to the northwest and 75 feet to the southeast. Just below the floor of the east drift several small stopes were opened and some high-grade ore mined. From the bottom of the shaft drifts have been run 75 feet both to the northwest and southeast, and two small stopes have been opened above the level. Down the hillside, several hundred feet northeast of the shaft collar, an adit tunnel has been driven 390 feet in a direction south 40° west to intersect the vein on its dip. This tunnel has not been completed.

The ore is found as replacement deposits along a fracture zone in the granite. The zone strikes north 60° west and dips 38° northeast, thus placing it along the northwest fracture system occupied by the Apache and other adjacent deposits. The vein material varies in width from two to ten feet between the walls of granite. The silver minerals are found in small stringers of quartz and calcite which cut irregularly through badly altered granite which makes up a part of the vein-filling. Considerable sericite and kaolin is developed in this granite, and it is in part replaced by pyrite.

The primary silver minerals occur associated with quartz and calcite as pin-point bunches of some silver sulphide believed to be stephanite. The primary minerals are, however, altered and enriched by pyrargyrite(ruby silver) and lesser amounts of argentite. Pyrargyrite is the important ore mineral and work is usually confined to searching for high-grade shoots of the enriched ore. The best ore has been found to the east of the shaft. On the first level, about 50 feet east of the shaft, one lense-like shoot of ruby silver ore was found which had a stope length of 30 feet and an average thickness of two feet or more. This lens is reported to have yielded approximately $10,000 in silver. No other lenses that would approach this in size or richness have been found. The present workings expose other shoots along the vein carrying some mineralization but systematic channel sampling would be necessary to determine if they could be called ore.

ANDY O'NEIL

The property known as the Andy O'Neil is in sec. 27, T. 31 N., R. 30 E., about one-quarter mile northwest of the Cabin Shaft, or two and one-half miles west of Nespelem. It is under lease to Frank Hammond and Roy Smith, who, during 1919, were carrying on development work and re-sorting the old dump, a crew of five men being employed in this work.

The property is opened at two levels connected by a 60-foot raise. The upper level is driven north 70° west for a length of 70 feet. The predominating country rock is granite, but about 30 feet from the portal quartzite appears and the drift is extended along the contact of the two formations where a small

vein carrying appreciable values is found. The strike of the vein is north 55° west and the dip averages 50° southwest. The ore minerals are galena, tetrahedrite, chalcopyrite, bornite, pyrite, and marcasite and the ore is worked principally for its silver values. Along broken surfaces the oxidation product from the pyrite coats the surfaces with a thin brown oxide skin. The sulphides make up about 25 per cent of the vein filling, the remainder being quartz and calcite. In the lower levels the ore minerals exhibit a rough banding parallel with the walls. Near the raise connection from the lower tunnel the ore is faulted off by a dike of Tertiary granite porphyry.

The lower level is driven north 35° east for a length of 135 feet. About 70 feet from the portal a second vein striking north 70° west and averaging 14 inches in width, was cut; although it carries appreciable mineralization it has not been followed. Near the bottom of the raise to the upper level the main vein is encountered. It has been explored for a short distance by drifting and a limitd amount of stoping has been accomplished. The vein has been faulted until it has the appearance of a series of lenses. These faults have fortunately not been large. One of which was measurable, exhibits a throw of 20 inches. In the lower level the vein as exposed has an average width of two feet. The foot-wall is well defined but the hanging-wall is obscured by irregular replacements reaching out into the granite.

TIP TOP

Near the crest of the southeastern spur of Mineral Hill, about one-quarter mile northwest of the Cabin workings, is the Tip Top property. This property had been active early in 1919 but at the time it was visited it was closed down temporarily and was visited in the absence of the operators.

The principal development work is a vertical shaft 150 feet deep from the bottom of which a short cross-cut has been run to the vein. From the side hill a drift is driven due west 80 feet to tap the shaft 40 feet below its collar. Near the portal, the drift cuts beds of black argillaceous shale, which strike south 70° west, and dips 50° south. Fifty feet from the portal the shales give way to grayish, impure quartzite. There are

numerous small fractures through the quartzite which have been cemented with marcasite, pyrite and chalcopyrite. The shales and quartzite are an isolated remnant of a vast belt of Paleozoic sediments which formerly covered the Nespelem area. About 50 feet down the shaft the underlying granite appears.

The lower part of the shaft was under water when visited. It is understood that the shaft cuts a small vein which is enclosed in granite and trends across the shaft. This vein is said to be 30 inches in width and well mineralized where cut by a 10-foot crosscut from the bottom of the shaft.

REBECCA MINING COMPANY

This property is situated along the south line of T. 30 N, R. 3 E., near the southeast corner of section 32 and about 10 miles southeast of Nespelem and two miles northeast of Stevenson's Ferry.

A hurried visit was made into the Nespelem District and lack of time prevented an examination of the property. The following description is taken from the report of Pardee*:

"The rock formations are interbedded argillite and impure limestone that strike north 10° east, and together form an inclusion half a mile long by 500 feet or more wide in the Colville granite. To the east basalt overlies the granite and the argillite in part. Glacial drift conceals the bedrock over considerable areas to the north and northeast.

"Open cuts along a course of about 400 feet expose a bed of impure limestone 20 feet or more in width in contact with the granite to the west. A large proportion of limonite is associated with the limestone, and the green stain of malachite is present. The deeper workings mentioned are situated within this belt, and the material of their dumps consists largely of aggregates of lime-iron silicates, chiefly, epidote and vesuvianite, together with magnetite, which may form 50 per cent of the mass. The sulphides, pyrrhotite, chalcopyrite, and sphalerite, are inter-grown with the minerals mentioned and locally form as much as 20 per cent of the whole. All the dumps show chalcopyrite and sphalerite in variable but appreciable percentages and the mineralized zone is evidently

*Pardee, J. T., op. cit. page 204.

of good size. A fairly representative sample from the surface of one of the richest looking dumps yielded by assay at the rate of 2.68 ounces of silver to the ton, a trace of gold, and 5.15 per cent of copper. No test was made for zinc, which is commonly present but in less quantity than the copper."

Since this report there was but little development work until May, 1919, when a contract for diamond drilling the property was let by the company to Boyles Brothers of Spokane. One of the owners of the property states that by August, 1919, a total of 800 feet of drilling, divided among six holes, had been accomplished and at that time the seventh hole had just been started.

KELLER DISTRICT

GREAT WESTERN

The Great Western property is a recent discovery, having been located early in 1920. The holdings are 500 feet above and one-quarter mile west of San Poil River, at a point four miles north of Keller.

The discovery was on the outcrop of the vein near the contact between the quartzite and an intrusion of granite. The vein averages 12 to 18 inches in width, strikes east-west and dips 25° north. The first 20 feet of the exposure is badly altered and stained, but where explored deeper by a shallow winze, the partially altered sulphides were beginning to appear. Samples taken across the vein in the shallow upper workings are reported to assay 50 ounces of silver to the ton. Thirty feet further down the hillside another small vein, exposed in an open cut, is said to assay quite well in silver.

The ore minerals have evidently been derived from the granite and then deposited in small marginal fissures developed along the quartzite contact.

To gain depth on the deposit a crosscut is being driven north 70° east from a point 100 feet down the hillside from the croppings. The crosscut has been driven 80 feet through coarse-grained granite which exhibits occasional splotches of molybdenite as an accessory mineral in the granite. One hundred feet south of the crosscut a small exposure of andesite over-

lays the granite. This exposure is related to the andesite of Tertiary age so well exposed northward along San Poil Valley.

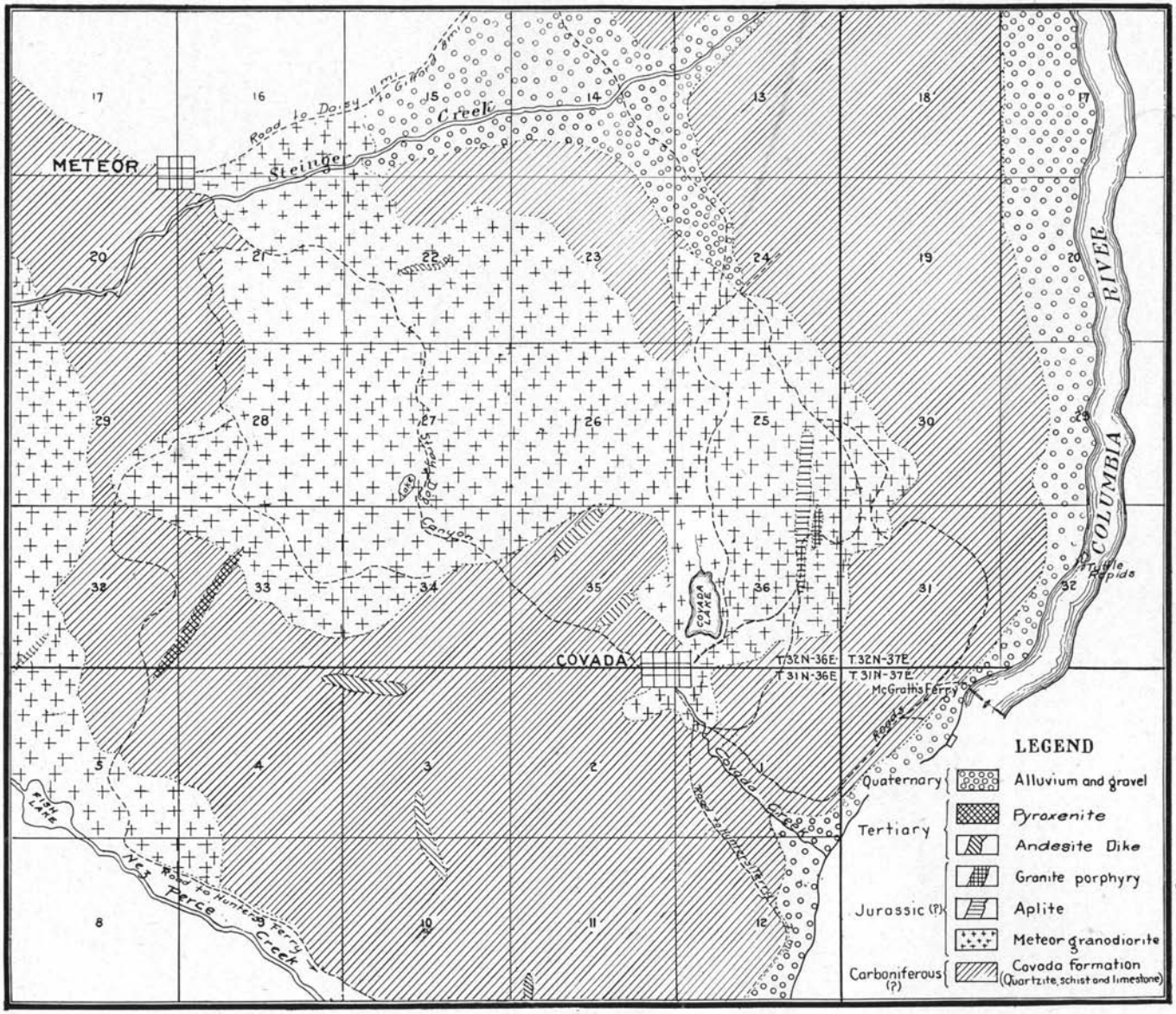
IRON CREEK

At a distance of seven miles up San Poil River from Keller a branch road leads off up Iron Creek five miles to the Iron Creek Mine. There has been intermittent prospecting on this property for a number of years and several small shipments of sorted ore have been made, which are reported to average between 50 and 75 ounces of silver. Operations have been continuous for the past year; several hundred feet of underground work has been done, a well equipped camp constructed and a 20-ton experimental mill is now under construction.

The formation in the vicinity of the mine is a highly metamorphosed, dark, argillaceous limestone, which is directly related to the Paleozoic series so well exposed in nearby areas and eastward in Stevens County. The exposure in the vicinity of the mine is but an isolated remnant of the series; it outcrops over an area of one square mile and is enclosed on all sides by granite porphyry.

The limestone has developed an irregular fracture pattern with the major fractures showing a prevailing northeasterly trend. From the major zones, minor fractures trend off into the limestone. The ore solutions have used the fractures for conduits and the best ore is found as irregular replacements near the fracture intersections. The upper portion of the deposit is badly weathered and iron-stained. The ore is partly altered to the carbonate and oxide forms with some galena yet unaltered and silver values present. Copper in the form of malachite has a limited occurrence.

The deposit has been disturbed by intrusive dikes of granite porphyry which are later than the ore bodies and have displaced them irregularly. Two hundred feet east of the mill the outcrop of a vein 30 inches in width fills a fracture which strikes north 70° east and dips 40° southeast. This vein is reported to average 20 ounces of silver to the ton. It was explored by a lower drift but a short distance in from the portal is cut off by a fault.



GEOLOGIC MAP OF COVADA DISTRICT

The experimental mill which was under construction August, 1920, is provided with a Blake jaw-crusher, two batteries of five stamps each, one Wilfley table, and one Standard table. The mill will be operated by steam power; wood for fuel is secured locally.

Anderson Claim.—One-fourth mile up Iron Creek, west of camp, the company has opened a vein which averages one foot in width and fills a nearly horizontal fracture through the limestone. The strike of the vein is east-west and the dip 15° south. It has been opened for a distance of 150 feet and the statement was made that it averages 15 ounces in silver and four per cent lead to the ton.

COVADA DISTRICT

The Covada mining district comprises an area of approximately 40 square miles adjacent to Columbia River in southeastern Ferry County. The district is retarded by its isolation from railway transportation. It is most easily reached over 30 miles of ordinary road from the town of Addy on the Great Northern Railway. It is also accessible from the highway up Columbia River. A ferry operates across Columbia River between Gifford and Inchelium. The latter town is the headquarters for the Indian Agent over that section of the Colville Reservation. Meteor and Covada, the two principal towns of the district, are connected with Inchelium by roads suitable for automobile travel.

The district was dormant during the summer of 1919 but when an adjoining area was visited during 1920, a shipment of high-grade silver ore was being hauled out from the Stray Dog property. The time remaining for field work was so limited that the district was not visited by the writer. It was fully described by Weaver* during 1912 and by Pardee† during 1913. Since that time only a scant amount of new work has been accomplished and accordingly these reports are still practically up to date.

*Weaver, C. E. Geology and Ore Deposits of the Covada Mining District: Wash. Geol. Survey, Bull. 16, 1913.

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

They indicate that the principal deposits occur as fissure veins enclosed in Meteor granodiorite and the older metamorphosed sedimentaries. As a rule the veins are narrow, seldom averaging over two feet in width of mineable ore. They contain some narrow pay-shoots of rich silver ores. In other instances the mineralization is found impregnated in the country rock along a series of fracture planes. A number of carloads of high-grade ore have been shipped from the district at various times. These shipments came principally from the Stray Dog, Meteor, Silver Crown, Silver Leaf, and Longstreet properties, and averaged $50 to $100 to the ton. Since freight and treatment charges total $30 to $35 to the ton, the mining of these narrow ore bodies and the rejection of the medium-grade ore discourages continued operations. If a sufficient tonnage of profitable ore can be definitely developed in the various properties, then a small but well-designed, centrally located custom mill would cut down the transportation costs and permit profitable operations on a limited scale. The descriptions of the various properties do not, however, indicate that a sufficient tonnage of ore to insure such a venture has yet been developed.

OROVILLE-NIGHTHAWK DISTRICT

GENERAL FEATURES

The Oroville-Nighthawk District, as designated in this report, includes an area of 150 square miles in the northeast section of the Chopaka quadrangle and a small adjoining fraction of the northwest section of the Osoyoos quadrangle as mapped by the U. S. Geological Survey in northern Okanogan County. The town of Oroville, situated in the Okanogan Valley six miles south of the international boundary, is the commercial center of an area devoted to farming, horticulture, and mining.

The area is well opened to transportation by the Wenatchee-Oroville Branch of the Great Northern Railway and also the Spokane-Oroville Branch of the same railway. From Oroville the Princeton Branch of the Great Northern follows up the Similkameen River into British Columbia. The properties in the vicinity of Nighthawk are all situated within a

few miles of this railway. Fairly good automobile roads traverse the area and the new road now being constructed between Oroville and Nighthawk will be a decided help to several of the mines.

TOPOGRAPHY

The district is a part of the broad, physiographic division of the State known as the Okanogan Highlands and is characterized by land forms varying from an elevation 922 feet above sea level at Oroville to the summit of Mt. Chopaka with a maximum elevation of 7,829 feet. Large portions of the area resemble an upland plateau with rolling surfaces surmounted with dome-shaped mountains which attain elevations of 3,000 to 4,000 feet above sea level. In the vicinity of Nighthawk is found the steep-walled rugged mountain topography so characteristic of that further north across the line into British Columbia.

Glaciation during Quaternary time by the Cordilleran ice sheet radiating southward from the mountains of British Columbia, has played an important role in developing the topography. Pre-glacial drainage systems had apparently incised "V" shaped valleys across the old land surface and these valleys influenced to a degree the subsequent southward journey of the ice sheets. Two of the major avenues of invasion are marked today by the two broad "U" shaped glacial trenches known as the Similkameen and Okanogan valleys. These trend southward keeping a parallel course with the separating distance about 12 miles. Where crossed by the international boundary the floors of these two trenches are each over a mile in width, but continuing southward they gradually taper down, thus suggesting the diminishing sturdiness of the glaciers as they gouged their way southward. Some idea of the size of these ice sheets can be surmised by observing bed rock striations on the mountain slopes 3,000 feet or more above the floor of the trench.

Damming along the floor of the trenches has developed several extensive glacial lakes, whose waters are utilized by irrigation projects. Glacial choking of the Similkameen trench caused Similkameen River, at a point five miles

south of the international boundary, to be deflected from the Similkameen trench eastward through a branch river valley to join the Okanogan River near Oroville. Willis* made a reconnaissance through the area in the later eighties and in the resulting publication suggested that Similkameen River formerly flowed south through the Similkameen Valley, joining Columbia River at some point south of Conconully.

POWER

The Okanogan Valley Power Company now supplies the district with electric power from its plant on the Similkameen River three and one-half miles above Oroville. The old plant diverts but a small portion of the flow and develops only 400 horsepower at low water. The district has outgrown this plant and a new dam and large power plant are now under construction and will be finished early in 1921. The dam is 50 feet above the bed of the river and gives an effective head of 75 feet and will make available 2,500 horsepower. The power costs on mining contracts will be approximately $40.00 to $50.00 per horsepower year.

GEOLOGY

Broadly interpreted, the older rocks of the area are made up of a series of slates, schist, quartzite and limestone, which are the metamorphic equivalents of the sedimentary and intrusive series of Paleozoic age. These were intruded and uplifted by granite intrusions during late Mesozoic or early Tertiary times. Later, lake bed deposits were built up over a part of the area and then andesite flows spread out over the eastern section. During Quaternary time monster ice sheets planed off large portions of the land surface with such success that portions of the underlying igneous batholith were exposed.

Umpleby interprets these series of events clearly in his report† to which reference should be made for more detailed discussion.

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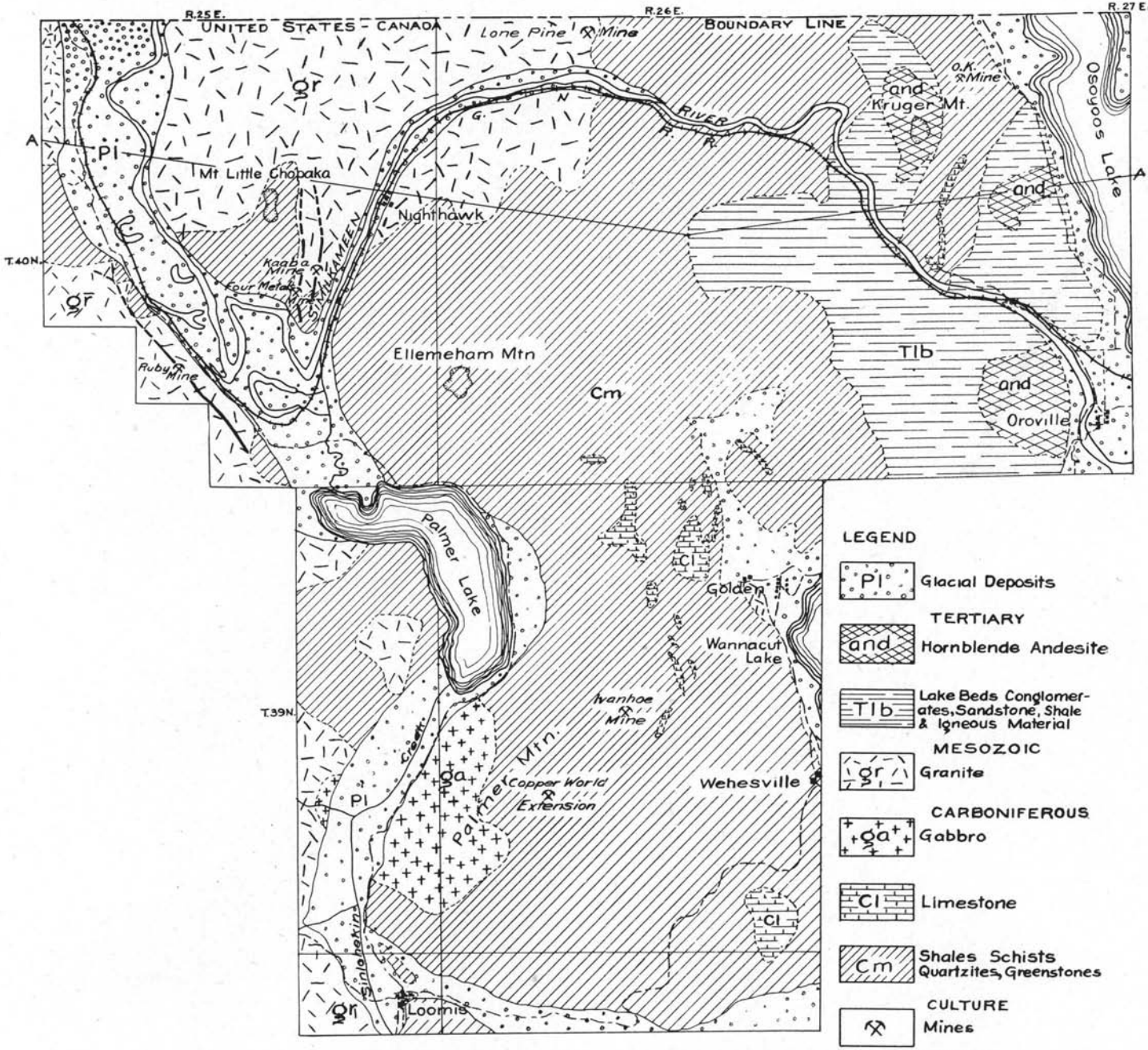
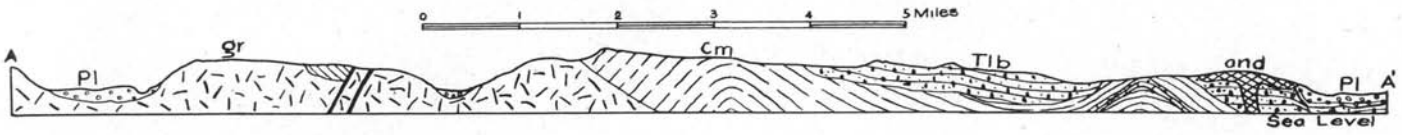
*Willis, Bailey. Changes in River Cources in Washington Territory Due to Glaciation: U. S. Geol. Survey, Bull. No. 40, 1887.

†Umpleby, J. B. Geology and Ore Deposits of the Oroville-Nighthawk District: Wash. Geol. Survey, Bull. No. 5, part 2.



GEOLOGICAL MAP OF OROVILLE-NIGHTHAWK DISTRICT

Recopied from Wash Geol. Survey Bulletine Nº 6



The mountain structure of the Okanogan Highlands as exposed in the Oroville-Nighthawk District, has been well interpreted in the masterful report of Daly in his Forty-ninth Parallel Report for the Canadian Government.†

In the area adjoining the international border from Osoyoos Lake westward to Pasayten River, a distance of 60 miles, Daly designates the mountain structure as the Okanogan Composite Batholith. By this is meant that this section of the mountain range is composed of material demonstrably intruded in two or more distinct stages of one eruptive period, the magmas of the different intrusions having different composition.

Similkameen Batholith.—Practically all of the productive mines in the district were found to be directly related to the Similkameen batholith and for this reason the general features of the batholith will be included in this report. It is well exposed to the north and west of Nighthawk, particularly on Little Chopaka Mountain and across the Similkameen Valley on the slopes of Mt. Chopaka. The rock is a medium to coarse-grained, light-gray, soda granite or granodiorite which is made up chiefly of basic oligoclase, alkaline feldspars, orthoclase, quartz, hornblende and biotite. The composition is quite variable, many marginal basic phases being observed near the outer crust of the intrusion, thus causing the rock to approach a monzonite or diorite in composition. Since the phases of the Similkameen batholith observed near the mines are nearer the composition of a granodiorite than a true granite, the rock will be referred to in this report as a granodiorite.

Roof Pendant.—The relations between the Similkameen batholith and the older Paleozoic series of roof rocks are well exposed in the vicinity of Nighthawk. A plunging, nearly vertical contact between the two formations was found 500 feet south of the Kaaba Mine openings, and from the roadside was traced in a westerly direction up the slopes of Little Chopaka Mountain. The development along the contact of well-shaped crystals of epidote and garnet with occa-

†Daly, Reginald A. The Okanogan Composite Batholith of the Cascade Mountain System. G. S. C. Memoir 38, 1906, p. 425.

sional sporadic bunches of chalcopyrite and pyrite tell the story of pneumatolitic contact reactions.

Daly* describes several large irregular blocks of schist roof rocks projecting downwardly into the Similkameen batholith, and designates them as roof pendants. If erosion had not removed the upward extension of the contact just mentioned, it would undoubtedly be found to flatten out and approach the horizontal with the schist forming a roof over the granodiorite. In other words, a block of the schist roof rock is suspended downward 1,500 feet or more into the batholith to form a roof pendant. The downward projection of this pendant is surrounded by the granodiorite and is analogous to the pendant of Gothic architecture. Its form originated from irregular stoping of the batholith into the overlying roof.

A small roof pendant is well exposed on the southwest slopes of Little Chopaka Mountain adjoining the Four Metals and Kaaba Mines where it extends across the Similkameen trench and is exposed on the slopes of Mt. Chopaka. This phenomenon is discussed here because its existence is believed by the writer to play an important part in controlling the formations of several of the most noteworthy veins in the district.

GENESIS OF THE ORE DEPOSITS

The ore deposits of the district were no doubt introduced as a part of the Similkameen intrusive batholith. During the extended cooling of the magma from a liquid state the mineral-bearing constituents tended to segregate within the magma and during the closing stages of crystallization were forced up in a mixed molten and gaseous state to fill fissures which had developed in the outer crust of the batholith.

Some of the most active mines of the district are centered in a very restricted area on the southwest slope of Little Chopaka Mountain and across the Similkameen trench near the base of the northeast valley wall of Mt. Chopaka. These veins are mostly in the granodiorite but near the margin of its contact with the roof pendant of schist. It would seem that the roof pendant chilled the marginal crust of the gran-

*Idem. p. 429.

Looking down the tramway of the Copper World Extension Mine, from point near tension station. Palmer Lake below.

odiorite and aided by the recurrent heavings of the still molten interior, crustal tensions were set up that influenced the development of fissures. These soon offered avenues for ascending mineralized solutions and gases originating deeper in the cooling magma. On Little Chopaka Mountain there are a series of north-south trending, close-set veins such as the Kaaba and Four Metals deposits, which trend off into the granodiorite at varying angles from the plane of contact.

The limited development of the veins points toward the suggestion that they are stronger and better mineralized within approximately the first 1,200 feet of the contact. Beyond that they narrow down and the mineralization as exposed by the limited exploration work, has weakened considerably. The veins have not yet been followed any distance into the schist. If the writer's hypothesis is correct the veins should be expected to continue strongly several hundred feet after crossing the contact into the schist pendant and then gradually die out.

The occurrence of the veins near the roof of the batholith, regularity of strike and dip, smoothed walls and other miscellaneous evidence suggests that the deposits were formed at depths of probably 3,000 to 8,000 feet below the surface.

TYPES OF ORE DEPOSITS

There exists an interesting diversity of ore deposits in the area which warrants a discussion that should lead to a clearer understanding of their controlling factors.

The first is the simple, marginal fissure in granodiorite filled by a quartz vein carrying its mineralization in values of silver, lead and copper, named in order of their ranking importance. This type is well exemplified by the Kaaba and Four Metals veins. The mine evidence suggests that practically barren quartz veins were first deposited. The quartz was subsequently fractured and mineralized by the sulphides.

The Ruby deposit, a mile and one-half southwest of the Four Metals, also occurs as a quartz vein inclosed in granodiorite but the fissure appears to have been originally opened by shearing movements trending north 45° west along what is now the base of Chopaka Mountain. The vein which is characterized by pinches and swells, has filled this shear zone and is found associated with considerable quantities of gouge-matter, which has been added to by post-mineral movements.

The Copper World Extension deposit on Palmer Mountain offers for variation, chalcopyrite, marcasite and pyrite occurring as an intergrown sulphide matte, which is found in a series of overlapping tabular lenses of varying dimensions.

The fourth type of deposit is represented by mineralization along an undulating shear zone through granite rocks. At the O. K. Mine on Kruger Mountain this shearing action has been so intense that the granitic rocks for a width of five feet along the zone have been directly transformed into quartz-mica schist. Movements along the undulating zone have thrown the walls into juxtaposition thus forming pinches and swells, both along the strike and dip of the vein. Chalcopyrite and pyrite in a matrix of quartz have been deposited in these cavities with the result that the ore lies in wedge shaped lenses. The O. K. Company mined its ore from one of the large bulged lenses. The Golden Chariot and 49th Parallel workings could not be examined but the surface showings indicate that they are located along the same zone of shearing and their production has likely been derived from similar lenticular masses.

Umpleby* describes a large body of low-grade, disseminated copper ore, which occurs on Kruger Mountain immediately west of Osoyoos Lake. Deposits of similar nature are known to occur at the Lakeview and Gold Dust properties about two miles further north and across the international boundary. Only scant development work has been done but judging from the reports of several competent investigators who have visited these deposits, the showings merit more extensive development work.

VEIN DEPOSITS OF GOLD ORE

When Umpleby visited the Oroville-Nighthawk District (1909) the principal mining activity was confined to gold veins, certain of these having their values entirely in gold and others carrying associated values in silver, lead and copper. When, after a period of 10 years the district was revisited, a decided change had ensued; not a single gold property was under development and all activity was confined to lead-silver and copper ores. The mining men of the district state that the lethargy in gold mining is not due to the fact that the properties are without merit but that the conditions are due to the present day status of gold mining.

*Wash. Geol. Survey, Bull. No. 5, p. 85.

An interesting question of relation is opened by the occurrence in this area of quartz veins carrying their chief values in silver, lead and copper and only subordinate values in gold, while closely associated are other similar quartz veins carrying gold as their chief value. These various veins are thought to have formed at about the same time and from the same parent source and their occurrence suggests that previous to their injection into the fissures the mineral-bearing agents were given the opportunity to segregate into respective types. The fissures in the vicinity of Nighthawk received ores principally of lead and silver, while several of those near the old town of Golden received gold ores with lesser values in lead and silver.

KAABA

General Features.—The Kaaba Mine is in secs. 14 and 23, T. 40 N., R. 25 E., near the base of the southwest slope of Little Chopaka Mountain, one mile southwest of the town of Nighthawk, and four miles south of the international boundary. The branch railroad to Princeton, B. C., passes within 100 yards of the workings.

The deposit has been developed intermittently for many years but the fact that the ore is not of shipping grade discouraged extensive development. During 1918 the Benders Milling Company erected a 75-ton custom mill at Nighthawk. The Kaaba Company mined and shipped 1,800 tons of ore said to average $8.00 per ton to this mill, but the mill recovery was not satisfactory and shipments were suspended. Since then development work has been carried on more or less irregularly and it is the present plan of the company to install a larger surface plant and carry development work ahead to develop a tonnage sufficient to insure the erection of the first unit of a large-capacity, modern concentrator. The present surface equipment consists of a two-drill air compressor operated by a 30-horsepower motor, while a 20-horsepower motor furnishes power to a small hoist. The customary mine buildings and auxiliary mining equipment make up the balance.

Head bin and hoist room for inclined shaft on Kaaba vein. The vein outcrops along the base of the mountain.

Description of the Deposit.—The Kaaba deposit is a large, normal quartz vein filling a fissure in granodiorite, which strikes north 3° west and dips 43° to 55° west. The vein outcrops boldly along the base of the mountain slope 100 feet from the county road. It has been explored for 600 feet on the strike and 240 feet on the dip and all the headings at the time of examination were in ore of apparently milling grade. The width varies from 6 to 20 feet with 11 feet as an average, thus stamping it as one of the large low-grade veins of the State.

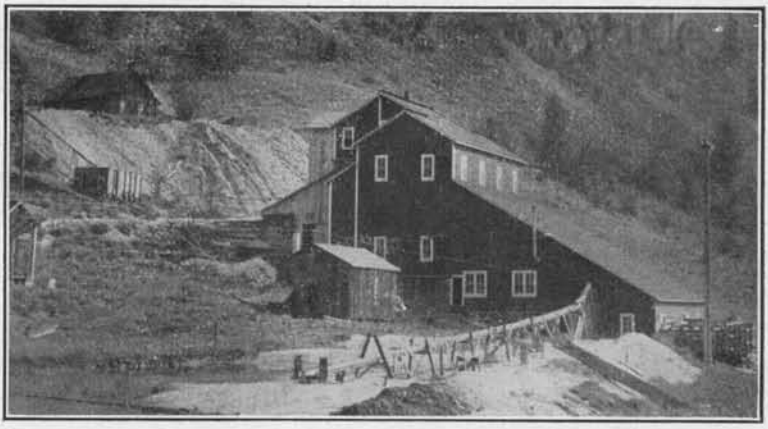
The deposit is a typical example of a marginal vein, formed near the contact of intrusive granitic formation and the older intruded roof rocks. The south shaft of the vein is 500 feet north of the plunging contact between the intruded hornblende-mica schist and the granodiorite, and the strike of the vein will carry it across the contact into the schist. The body of schist is mentioned earlier in the report (page 223) and is designated as a roof pendant. Its relations to the ore bodies are discussed on page 45.

The granitoid wall rocks in the vicinity of the vein have suffered hydrothermal alterations, the basic minerals being

partly converted into chlorite and in places slightly serpentinized while the feldspars are altered to kaolin. The quartz vein filling has been shattered parallel to the walls by movements along the plane of the vein. The ore minerals of argentiferous galena (both "cube" and "steel" variety), chalcopyrite, pyrite, and marcasite, tend to arrange themselves in irregular bands parallel to the walls while smaller bunches and specks are scattered irregularly through the quartz. The tendency toward sulphide banding indicates that the quartz was injected first, then soon after shattered and impregnated with the sulphides. All the development so far has found no part of the vein barren of values, but there is a tendency for the values to be concentrated in pay-shoots, and in mining it may be found necessary to leave blocks of ground too low-grade to pay.

The vein is invaded by two very fine-grained diabase dikes. In the bottom of the shaft these dikes form respectively a false foot-wall and hanging-wall. Near the 200-foot level the large dike leaves the foot-wall and breaks up through the vein to continue near the hanging wall, finally 50 feet below the collar of the shaft it leaves the vein, breaks nearly vertically up through the granodiorite and outcrops on the hillside above the shaft. The large dike is three feet in thickness at the 200-foot level and narrows down to one foot at the 50-foot level. These dikes are evidently post-mineral since they apparently have not influenced mineralization but in places cut through bands of ore; the force of the dike intrusion has caused some of the sulphides to develop flow-structure. In places, these dikes form false walls and in mining should be broken through, for in several places in the mine good ore was found between the dike and the true walls.

Development.—The vein is opened by a two-compartment inclined shaft sunk to a depth of 240 feet on the vein. From this shaft there exists 800 feet of drifting divided among three levels opened at 50, 100 and 200 feet respectively below the collar. On the surface south of the working shaft there are six shallow exploratory pits sunk at intervals along the out-



Bender Mill at Nighthawk.

crop over a length of 350 feet. The limited exploration work has not defined either the vertical or horizontal extent of the vein. It has, however, blocked out 100,000 tons of low-grade ore on two and three sides.

Summit Vein.—On the Summit claim, so named because of its location near the crest of Little Chopaka Mountain, one-quarter mile west of and some 600 feet above the Kaaba outcrop, there is a second quartz vein which trends parallel to the Kaaba vein. It is three and one-half feet in width and its general features form a miniature replica of the Kaaba vein. Open cuts have been employed to expose the vein for a length of 500 feet along its trend, and at one point an inclined shaft has been sunk to a depth of 80 feet. Samples from this shaft assay five to seven ounces of silver, with minor values in lead and gold.

BENDER MILL

During 1918 a company organized as the Bender Metals Milling Company erected a 75-ton custom mill at Nighthawk, utilizing a part of a mill building which formerly housed the stamp mill of the Nighthawk Mine. The plant was designed to treat ores from the Gold Bar, Kaaba and surrounding mines, but due to several local interfering factors, the mill has op-

erated only a few months since its installation. For the most part, the equipment is modern and by making several changes in the flow-sheet it should be capable of making a good recovery.

The present arrangement of the mill is as follows:

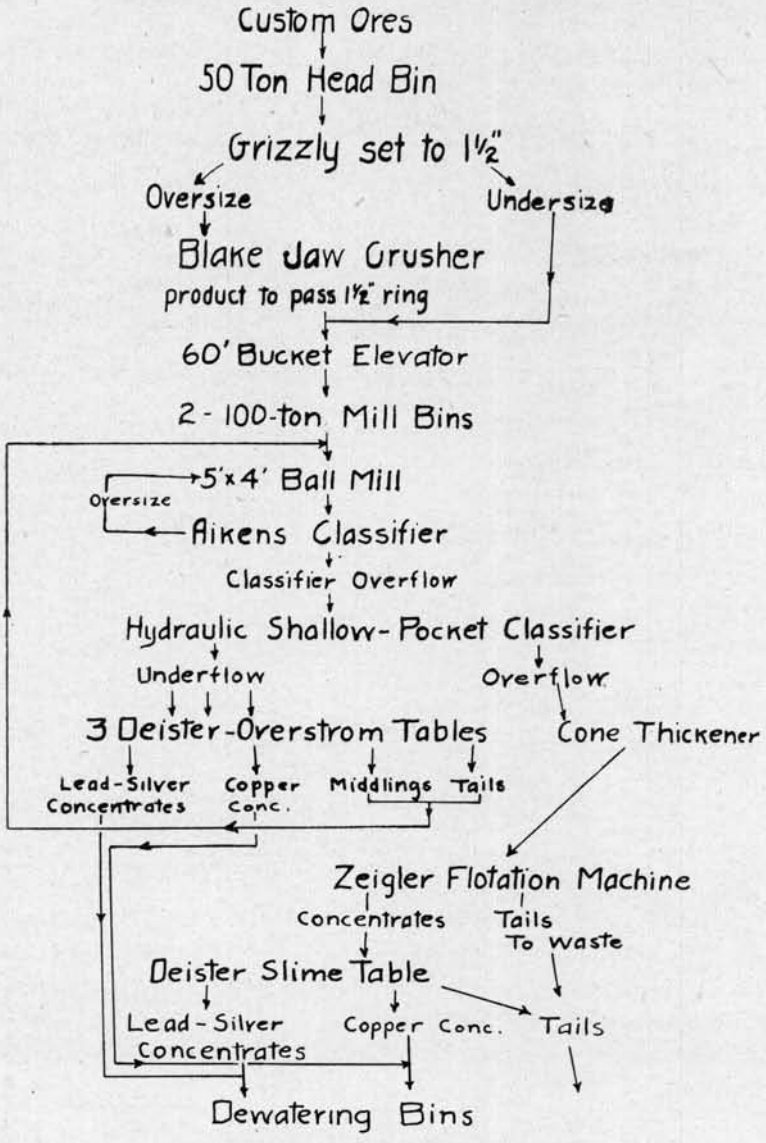


Fig. 18. Flow-sheet of the Bender Mill.

FOUR METALS

General Features.—For two years the Four Metals Mining Company has been actively developing its property which is in secs. 14 and 23, T. 40 N., R. 25 E., on the south slope of Little Chopaka Mountain, one and one-half miles southwest of Nighthawk, and three and one-half miles south of the international boundary.

The principal development work has been confined to a normal quartz vein filling a fissure in granodiorite, which strikes north 7° west and dips 32° to 37° west. The vein is about 4,000 feet by air line west of the Kaaba vein and trends practically parallel to it. Like the Kaaba vein it occurs in the granodiorite near the marginal contact of the granodiorite and the same roof pendant of hornblende-mica schist and associated metamorphic rocks. The south extension of the vein carries it into the schist and several surface cuts show it to be quite well mineralized there. The width varies from two to twelve feet with six feet as an average. The ore minerals of argentiferous galena, chalcopyrite and pyrite are concentrated in ribbon-like bands parallel to the walls with minor values in erratic specks and bunches scattered through the quartz.

Shamrock Claim.—About 100 feet back of the experimental mill, at an elevation of 300 feet above the Similkameen River, a 70-foot crosscut has been driven to a vein known as the Shamrock. The crosscut encounters this vein on an excellent pay-shoot and gives a depth of 100 feet below the outcrop. This pay-shoot measures approximately 60 feet along the strike of the vein and is said to average four per cent lead, one to two ounces of silver for each per cent of lead, one per cent copper and fifty cents per ton in gold. The sulphides are quite free from alterations and the galena for the most part is well crystallized into cubic form. From the crosscut a drift has been carried 57 feet to the north with the vein continuing strong in the face of the drift but mineralization weakened. South of the crosscut a short distance, the vein pinches down but surface cuts show that it will again widen. Other pay-shoots may exist either to the north or south and the mining chance warrants more extensive

drifting on the vein, for in a deposit of this type it is often found that pay-shoots are separated by zones that are nearly barren of mineralization. Where the surface wash is not too deep, test pits along the vein would serve to locate the shoots.

One hundred feet southeast of the portal of the Shamrock Tunnel a vertical shaft has been sunk to a depth of 110 feet, and from the bottom of this shaft a 30-foot crosscut was made to the Shamrock vein. This new work had been completed three weeks prior to the examination and the vein at this depth had been explored only by a 50-foot drift toward the north. All of this work exposes ore of apparent milling grade. This new exposure has not yet been systematically sampled. Pyrite is the predominating sulphide and associated with it are galena, chalcopyrite and minor amounts of sphalerite. The quartz vein exhibits a considerable variance in width with five feet as an average so far exposed. The shaft was sunk through the pendant of hornblende-mica but the crosscut from the bottom of the shaft soon enters granodiorite. The vein is enclosed in granodiorite but is trending close to the contact between the granodiorite and the roof pendant of schist.

Alice Claim.—On the Alice Claim about 1,500 feet north of the Shamrock openings, development work was in prog-

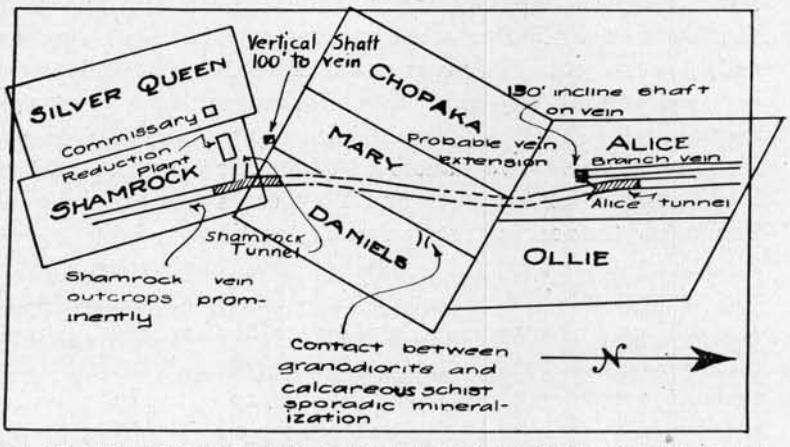


Fig. 19. Map showing claims and location of principal workings of the Four Metals Mine.

ress on what is evidently the northward extension of the vein exposed in the Shamrock workings. The vein here splits and the parallel branches are separated by 25 feet of conglomerate material. The east branch is opened by a 500-foot drift which exposes a two to five-foot vein which is badly crushed and lined with gouge matter. Considerable mineralization in dark argentiferous galena, chalcopyrite and pyrite is evident and the shoot as exposed by the drift is reported to average 10 to 15 ounces of silver to the ton. The sulphides have suffered somewhat from superficial alteration. This vein can be traced several hundred feet further northward on the surface.

Near the portal of the Alice tunnel an inclined shaft has been sunk on the vein to a depth of 135 feet. At the bottom of the shaft drifts have been carried 50 feet north and 60 feet south of the shaft. This work shows the vein to average five feet in width and to carry mineralization in the form of argentiferous galena, chalcopyrite, pyrite and a little sphalerite. The sulphides exposed in the Alice workings are as a rule much finer grained than those from the Shamrock workings. The gangue is crushed quartz which has been partly recemented by calcite. Fresh faces of the vein are quite hard but after several weeks' exposure to the air they become soft and friable. This section of the vein has been traversed by a fault which acted along the plane of the vein and severely crushed the filling. The principal mineralization entered the vein after the crushing and was deposited roughly in bands along the fracture planes and in bunches through the brecciated gangue. The calcite accompanied this mineralization. The horizontal extent of the pay-shoot on the lower level has not been determined.

From the lower level a 25-foot raise into the hanging-wall would intersect the parallel branch vein previously mentioned and such work offers a ready and economical opportunity to explore the parallel vein at this depth.

Mary Claim.—On the Mary Claim, 100 feet above and 500 feet north of the Shamrock openings, an open cut along the contact of the granodiorite and the old roof rocks, which

at this particular locality are calcareous schist, exposes irregular bunches of chalcopyrite, bornite, and pyrite occurring in a gangue of garnet and epidote. This mineralization is the result of contact metamorphic actions set up by the intrusion of molten granitic magma into the older schistose rocks and the minerals were formed by magmatic gases acting chemically upon the older rocks. This contact was followed for a considerable distance and other bunchy mineralization found but the sporadic character of the mineralization militates against the development of a large ore body, and it seems logical that work should be confined to the development of the excellent exposures in the Shamrock and Alice workings.

Mill and Surface Equipment.—A 25-ton experimental mill was completed on the property June, 1919. The ore is crushed by a jaw-crusher followed by a set of rolls, then elevated to a trommel and impact screens which size it for jig and table feed. The table tailings are retreated on a slime table. No attempt is made to separate the galena and chalcopyrite. Since the friable ores of the deposit slime badly when crushed, a high recovery of values cannot be expected from the present mill. By certain changes in the design of the mill and the addition of a flotation machine, there is no reason why an efficient recovery cannot be made. Power is furnished by a 25-horsepower gasoline engine but electric power from the Okanogan Valley Power & Light Company will be available as quickly as the new power plant is completed.

When the property was revisited during 1920 the mill was closed down because it had not made a satisfactory recovery of the values, and all work was centered on mine development. Systematic sampling of the mine exposures should prove a substantial tonnage of milling ore. If these conditions prove out, several months of vigorous development work should secure a tonnage that would warrant the erection of a modern concentrator of 100-ton daily capacity. It is highly desirable that the exposures be carefully sampled that their grade may be accurately determined.

RUBY

General Features.—The Pyrargyrite Mining Company, which owns the Ruby Mine, was organized during 1915 and has been operating intermittently since that time. Monroe Harmon, president of the company, reports a production of 31 cars of ore which showed a gross value of approximately $25,000. During 1919 and 1920 the property was put in shape for steady operation. A 75-ton modern concentrator was completed August, 1920. A well constructed bunkhouse, boarding house, and an administration building also have been erected. New mining equipment includes a three-drill Worthington compressor operated by a 50-horsepower motor, a modern blacksmith shop, and three new rock drills. During 1920 operations were delayed until the Okanogan Valley Light & Power Company could complete a larger power unit for its plant on Similkameen River.

The mine is near the level of Similkameen Valley but near the base of the east slope of Mount Chopaka and about one and one-half miles north of the head of Palmer Lake. The Oroville-Princeton Branch of the Great Northern Railway passes within a few hundred feet of the mine openings.

Description of the Deposit.—The country rock is granodiorite which shows many marginal basification phases; samples taken from different parts of the workings vary considerably in texture and composition. The granodiorite makes up the core of Mount Chopaka. The deposit outcrops poorly on the steep hillside 400 feet above the railroad right-of-way The vein occurs as a partial filling of a gouge-lined fault plane which strikes north 45° west and dips 42° southwest. The fissure varies irregularly in width from 2 to 12 feet and often carries a foot or more of gouge on both walls. The vein material occurs as stringers, lenses, and brecciated bunches of milky quartz running irregularly through the zone, with a variance in width from a few inches to six feet; three feet being an approximate average. Silver is the predominating value of the ore, but scattered irregularly through the quartz is found, chalcopyrite, pyrite, arsenopyrite, sphalerite, galena, pyrargyrite, proustite and argentite. The ore minerals sometimes

show polished slickensided faces, indicating post-mineral movements. The commercial ore lies in two or possibly three localized pay-shoots, the value of which are said to consistently average $10.00 to $15.00 per ton.

Development.—The deposit is well developed and the ore blocked for mining. Most of the development work was done several years ago and consequently the ladders, chutes, etc., will have to be renewed and several small caves caught up before actually starting to break ore. At the camp level an adit tunnel has been driven south 55° west a distance of 950

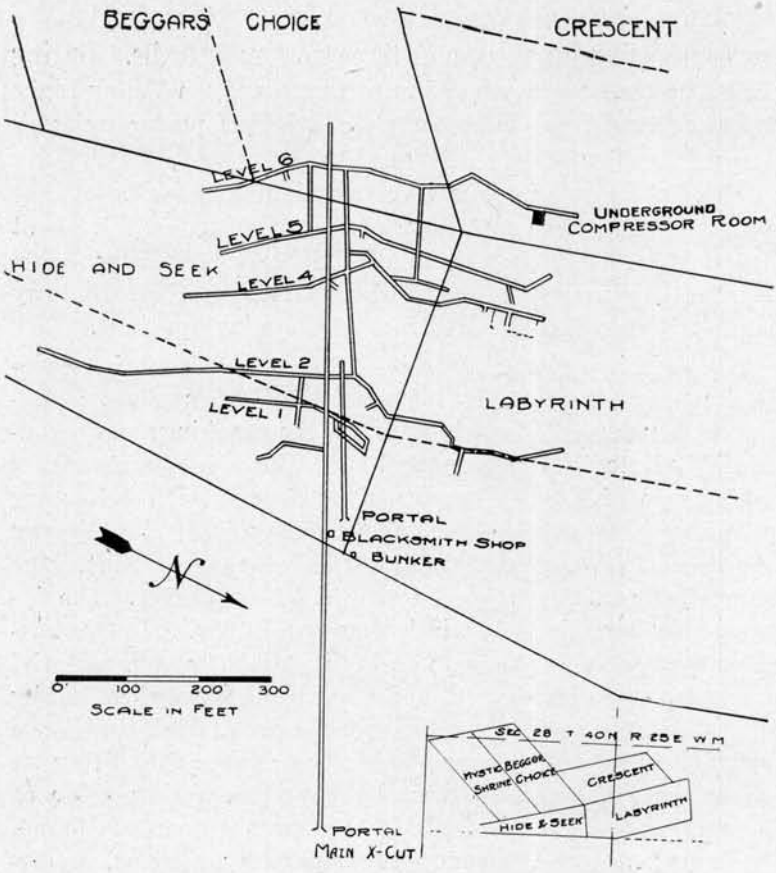


Fig. 20. Plan view of mine workings, Ruby Mine of Pyrargyrite Mining Company.

New camp buildings and concentrator at Ruby Mine.

feet to the vein, which it intersects at a depth of 550 feet below the outcrop, measured on the dip of the vein. From the adit level drifts have been run both to the northwest and southeast. Two hundred feet to the northwest an incline winze has been sunk on the vein to a depth of 210 feet. This winze was under water at the time of examination, but it is stated that a 25-foot drift 100 feet below the collar and a 10-foot drift at the bottom of the winze, expose good milling ore. The adit level is connected by a system of raises with the upper intermediate levels and in all the underground development totals 5,000 feet. This affords a horizontal development of 800 feet on the vein and vertical exploration to a depth of 770 feet.

Description of Concentrator.—This mill was completed during the summer of 1920 and will be put into operation as quickly as electric power can be secured from the local power company. The mill is expected to develop a capacity of 75 tons per 24 hours.

The ore from the mine is trammed to a 120-ton head-bin from which it is drawn over a grizzly set to one inch, the oversize being broken in a 7 by 10-inch Blake jaw-crusher. A 50-foot inclined belt-conveyor elevates the broken ore to a

120-ton mill bin. A Hardinge mill, grinding in closed circuit with a drag-belt classifier, takes the material from the bin and grinds it to pass a 15-mesh screen. The pulp as discharged from the ball mill is screened by passing over a shaking screen. The oversize is returned to the mill by the belt classifier and the undersize drops to the boot of a bucket elevator which lifts it to a Zeigler five-cell flotation machine. The flow-sheet is unique in that flotation precedes and also follows table concentration. The first Zeigler acts as a rougher cell and the concentrates are recleaned in a second machine of the same type, then sent direct to the concentrate bins. The rougher tailings are sent to four Deister-Overstrom tables which make a shipping concentrate. The table tailings are reground in a second Hardinge mill working in closed circuit with a drag-belt classifier. The classifier overflow is elevated by a bucket elevator to a settling tank and thickened before retreatment by flotation. Mine water is used for the mill, and to conserve the supply the water recovered at the lower end of the mill is lifted to a settling tank on the upper deck, where it is clarified and returned to the mill circuit. Air is furnished the flotation machines by a 6 by 8-inch Worthington compressor. All machines are electrically driven.

COPPER WORLD EXTENSION

General Feature.—The Copper World Extension Mine is on Palmer Mountain, two miles east of and 2,600 feet above Palmer Lake and at an elevation of 3,800 feet. It is connected by wagon road with Loomis 10 miles and Oroville 18 miles distant.

The property is held under lease by the Dempster Mines Company which for two years has been carrying on progressive development work. This company has also recently taken a lease and bond on the adjoining Copper World property and plans to prospect it with diamond drills. A considerable production was made during 1917-1918, and 1919, but the closing down of certain British Columbia smelters which desired this heavy sulphide ore for a flux has caused the property to suspend shipments until favorable smelter contracts can be made for its sulphide ores. A small crew is

employed doing improvement work. A new 5,000-foot Riblet aerial tramway with a maximum capacity of 400 tons per day was completed during 1919. The lower tram terminal is at the wagon road near the east shore of Palmer Lake and four miles from the railroad. Other surface equipment includes the customary camp buildings, a 40-horsepower hoist, 80-horsepower boiler, 40-horsepower auxiliary boiler, four-drill air compressor, pumps, blower, etc. Wood is used as a fuel; it is cut under contract near the mine and costs $3.75 per cord laid down at the mine.

Description of the Deposit.—The ore is a fine-grained mass of an intergrown natural sulphide matte of marcasite, pyrite, pyrrhotite, chalcopyrite and a little bornite, which is found in a series of overlapping tabular lenses; the larger lenses

Fig. 21. Sketch showing occurrence of ore lenses between first and second levels, Copper World Extension Mine.

measure several hundred tons of ore each. The sulphides occur massive and quite free from appreciable quantities of siliceous gangue. The ore as mined averages between 2.5 per cent and 4 per cent copper.

The association of the wall rocks with the ore lenses is peculiar and has led to considerable confusion of ideas. The foot-wall is a medium fine-grained igneous rock that is classified as an altered andesite. Under the microscope a thin section of the rock shows remnants of plagioclase and augite severely replaced by secondary epidote, calcite, quartz and chlorite. Titanite is present as a primary mineral. The rock which might be called the hanging wall of the deposit is milky-colored, dense-grained, and in the field was classified as a silicified limestone. The microscope reveals that originally it was andesite, the same as the foot-wall material, but that it has been highly silicified by solutions accompanying the mineralization. The section shows skeletons of plagioclase and augite largely replaced by calcite and quartz. The paragenesis of these minerals is quite clear. The secondary veinlets of calcite cutting the altered mass are in turn cut by later veinlets of quartz.

Near the ore this formation is badly metamorphosed by intense shearing action that has developed serpentine and talc and in places converted the rock directly into a schist. This altered andesite often occurs as a horse two to five feet thick separating two overlapping parallel lenses of ore.

Development.—The deposit is worked through a vertical shaft 300 feet in depth. Levels are opened at 100-foot intervals. A lens of ore cuts across the shaft between the collar and 100-foot level. A crosscut from the 100-foot station picks up the ore 18 feet from the shaft and an exploratory drift is carried on 60 feet further. Practically all the production has come from between the 200 and 100-foot levels, where there still exists a considerable developed tonnage of ore awaiting favorable smelting conditions. On the 200 level the ore was picked up 135 feet southwest of the shaft, and followed by inclined raises to the 100-foot level. In all, there are about

700 feet of drifting and crosscutting on the 200 level. The 300-foot level was under water at the time of examination. It is said that from the shaft a crosscut was run 574 feet to the southwest without encountering the ore. Since the lens dips away from the shaft it would take a long crosscut to reach it on the 300-foot level. This work was done by the old company; a part of their development work on the upper levels was poorly directed, and the fact that the ore has not yet been picked up on the lower level should not discourage a more systematic attempt to locate it at that depth.

LONE PINE

This property, also known as the Submarine, is now being developed by the Southern Minnesota and Washington Mining Co., with head offices at Oroville. The new company took up development work March, 1918, and has continued more or less regularly since that date with a crew of two or three men.

The property is in sec. 3, T. 40 N., R. 26 E., a few hundred yards south of the international boundary and at an elevation of approximately 2,600 feet. It is one mile north of and 1,300 feet above Similkameen River. From Oroville it is reached over 10 miles of poor wagon road. The new county road up Similkameen River from Oroville to Nighthawk is under construction and by building a mile and one-half of switch-back road the property can be connected with this road and the transportation problem be simplified.

The deposit occurs near the crest of a rounded hill, as a blanket-like quartz vein which strikes north 50° east and has an irregular flat dip with a maximum of 10 degrees from the horizontal. This causes the vein to lie with the hillside slope and where observed it at no time gained an appreciable depth below the surface. About 300 feet down the hillside from the main workings a small ravine cuts across the vein at right angles to its dip. On the opposite wall of the ravine the outcrop of the vein extension has not been found.

The country rock is a greenish-black, holocrystalline rock which in the vicinity of the mine is made up largely of hornblende and plagioclase feldspar and approaches a gabbro in composition. It is believed to be a marginal basification phase of the Similkameen Batholith. Near the vein, thin skins of serpentine have been developed by shearing movements.

The main tunnel is driven 300 feet north 50° west following the vein toward the crest of the hill. These workings expose the vein with a thickness varying from 1 to 10 feet with six feet as an approximate average. The ore minerals of argentiferous galena, chacopyrite, pyrite, a litte covellite and bornite occur scattered through the vein and in some places localized into shoots. The vein is shattered by post-mineral movements. At the tunnel level it can be traced northeastward along its strike for a length of 1,000 feet. Sufficient work has not been done on this extension to determine the extent of the mineralization.

A lower tunnel, 110 feet vertically below the upper workings, was driven some years ago for a total length of 1,000 feet in an effort to crosscut the ore body. Apparently the operators did not understand the attitude of the vein or were driving to crosscut some other exposure, for, near the portal of the tunnel a 25-foot raise would have entered the blanket vein. As the tunnel continues the intervening distance increases rapidly. Near the face of the old tunnel a raise was attempted to catch the blanket vein but the work was not carried far enough.

The grade of the deposit does not yield an appreciable tonnage of shipping ore and its successful operation must come from sufficient well-directed development work in an effort to block out a tonnage of milling ore that would safely insure the erection of a small concentrator. The primary sulphides have suffered but little from alteration and would concentrate readily.

O. K. COPPER

A company organized as the Oroville Copper Company has been spasmodically operating the O. K. Mine for the past several years. They report that since 1917 shipments of 19 cars of ore have been made, which averaged 7 per cent copper, 6 oz. of silver and $2.00 in gold per ton.

The holdings, which consist of two and a fraction claims, are located on the east slope of Kruger Mountain, four and one-half miles by road northwest of Oroville.

The deposit occurs in a shear zone which strikes north 10° west and dips 30° to 50° southwest. Along the zone, the movement has been so severe that the granitic country rock has been directly altered into crumpled, light-green quartz-mica and serpentine schist over a width of 6 to 10 feet along the plane of movement. The faulting movements have thrown the walls into juxtaposition with the result that pronounced pinches and swells have been developed along the strike and dip of the zone. The ore minerals of chalcopyrite, bornite, pyrite and a little tetrahedrite, have been injected into the broken ground to fill the receptacles and partly replace the schist along its planes of schistosity.

The production made by the property has come from one of these large bulged lenses which developed a length of 75 feet along the strike, 6 to 10 feet in average width and a reported depth of 70 feet on the dip. An incline shaft was su. k on the lens but this and the adjoining ground is now caved. The high-grade ore was sorted and shipped while 1,000 to 2,000 tons of probably one per cent to two per cent copper ore remains on the dump and in the workings.

About 400 feet north of the lens and at a lower elevation, a drift was run south 25° east along the zone of movement. The first part of this drift exposes two to four inches of quartz stringers carrying limited mineralization Two hundred and fifty feet from the portal a small lens of good ore was encountered but not explored. From this point to the face erratic stringers and bunches of quartz and ore have been found along the zone. The face of the draft is now approximately 50 to 100 feet from being under the shaft sunk on the large lens. Considering the excellent mining equipment already installed at the property, this drift should be continued several hundred feet further along this zone in an effort to pick up a possible extension of the productive lens or any new lenses that may occur further to the southeast.

The installation consists of a 4-drill air compressor operated by a 75-horsepower 2,200 volt motor, well equipped blacksmith shop, drills, ore bin, and accessory equipment.

GOLDEN CHARIOT

The Golden Chariot Mine, now idle, is situated a quarter-mile southeast of the O. K. and on the extension of the same shear zone. An inclined shaft has been sunk on the deposit to a reported depth of 320 feet and several carload shipments made. The ore is quite similar in appearance to the O. K., except that quartz is much more prominently associated with the ore than at the O. K. Mine. There are several hundred tons of milling ore on the dump.

FORTY-NINTH PARALLEL

Approximately 1,500 feet northwest of the O. K. Mine is another former producing property known as the Forty-Ninth Parallel. Because it has been idle for some time no examination was attempted. Standing on the O. K. workings and projecting a line northwestward along the strike of the shear zone, causes that line to pass near the workings of the Forty-Ninth Parallel, which suggests that the production from this property has come from another bulged lens along the same zone of movement.

RUBY-CONCONULLY DISTRICT

GENERAL FEATURES

The Ruby and Conconully mining districts are two adjoining areas in central Okanogan County. The Conconully District is directly adjacent to the town of the same name, and the Ruby District centers about Ruby Hill, five miles south of Conconully. Both areas are directly related geologically and for convenience are combined in this report.

The mines on Ruby Hill are best reached by a good automobile road which extends up Salmon Creek from the town of Okanogan, on the Wenatchee-Oroville Branch of the Great Northern Railway, to the town of Conconully. Twelve miles from Okanogan a branch road turns off, and by a series of switch-backs gains the crest of Ruby Hill, where all the present active mines are located. From Okanogan these mines can also be reached by the Loup Loup road, which involves a trip of 18 miles. This road avoids the steep switch-back grade of Ruby Hill. However, the northern half of the road has re-

ceived little attention and is reported to be in poor condition. An automobile mail stage operates between the town of Riverside, on the Oroville-Wenatchee Branch of the Great Northern Railway, and Conconully, a distance of 12 miles.

HISTORY

Between the years of 1887 and 1893 the Ruby and Conconully districts formed the most active center of mining in Washington. At that time they were far removed from transportation and supplies were brought by boats up Columbia River to Brewster and then transported overland a distance of 35 miles. The shipping properties developed were located chiefly on Ruby Hill. Jonathan Bourne, Jr., was actively operating the Arlington, First Thought and Last Chance mines, and the Fourth of July Mine had made several shipments of rich ore, when, during 1893, the silver market collapsed and forced every mine in the district to close down. Aside from occasional prospecting and development operations on a small scale, the district was dormant from 1893 until 1905. Since this latter date a number of properties have received more vigorous development and a few thousand tons of good-grade ore shipped each year. The Arlington Mine, which has shown the most activity, has completed about three thousand feet of development work and shipped several thousand tons of hand-sorted ore assaying from 35 to 70 ounces of silver to the ton and carrying minor values in lead and copper. None of the properties immediately adjacent to Conconully were active at the time the district was visited by the writer.

TOPOGRAPHY

The area is on the western border of the Okanogan Mountains and presents a rolling, fairly rugged mountainous topography. The relief has been sculptured by southward-moving ice-sheets, the paths of which are chosen by the present-day drainage system. These ice-sheets left near the margins of the Okanogan Valley large morainal hills of glacial debris. The stream valleys vary from 800 to 1,500 feet in elevation and the crests of the surrounding hills have an average elevation of 4,000 feet. The mines on Ruby Hill are at elevations varying

from 3,000 to 4,000 feet. The first mountain chain to the westward attains a maximum elevation of 8,275 feet on Mount Tiffany, while farther westward across the Methow Valley the eastern flank of the rugged Cascade Range forms a striking contrast with the more moderate topography of the Okanogan Highlands.

GEOLOGY

The ore deposits of the area are derived from an extensive granitic invasion which is directly related to the Similkameen batholith, so well exposed farther northward, near the town of Nighthawk, where it crosses the international boundary and is prominent in British Columbia.

Evidence has not yet been found to definitely fix the age of this intrusion. It is definitely older than the Miocene lake-bed formations near Oroville* and the physiographic evidence has caused most investigators to assign the intrusion to late Mesozoic. Daly,† on the other hand, considers that the Similkameen batholith was introduced during early Tertiary time.

The intrusive exhibits various phases but is essentially a biotite granite which is composed chiefly of quartz, feldspar, biotite, and minor amounts of hornblende.

Extensive exposures of hornblende-mica schist, limestone and quartzite occur in the area. These formations antedate the granitic intrusion and were the older rocks which received the magmatic invasion and assisted in forming a cover under which the magma slowly cooled and crystallized. All contacts observed between the granite and the older metamorphosed rocks, were of the plunging type (steeply dipping). Near these contact are found numerous inclusions of the metamorphic rocks frozen within the granite.

*Umpleby, J. B. Geology and Ore Deposits of the Oroville-Nighthawk Mining District: Wash. Geol. Survey, Bull. 5, p. 69, 1911.

†Daly, R. A. The Okanogan Composite Batholith of the Cascade Mountain System: Geol. Soc. America, Vol. 17, p. 334, 1906.

ORE DEPOSITS

The veins examined on Ruby Hill were all found to follow closely the margins of the plunging contact between the granite and the older schistose rocks. Thus, there is a pronounced tendency for the best veins to be localized near the margins of the batholith. (See page 45 for further discussion). Generally the veins are enclosed in granite and are 10 to 100 feet from the plane of contact and roughly parallel to it. In other instances they cross over into the schist, or they may lie directly along the steeply dipping contact between the two formations.

The veins are of the normal quartz type, varying in width from a narrow stringer up to a maximum of 40 feet. They are strongly continuous both along the strike and the dip.

The localization of the major veins is believed to be the combined results of the following factors:

1. The adjustments and contractions near the margin, as the magma cooled down, caused the development of well-defined and continuous fissures, which conformed roughly parallel to the plane of contact with the older schistose rocks.

2. The cluster of veins in a constricted area on Ruby Hil', and a similar cluster eight miles north of Ruby Hill, or one mile north of Conconully, suggests that these two areas represent local cupolas into which the mineral constituents from an extensive magma were collected and concentrated. (The time available for field work did not permit geologic mapping and the theory is advanced only as a suggestion until it can be investigated by detailed field work.)

3. As the outer crust of the intrusive magma crystallized, residual silica segregated and was injected into the marginal fissures. This siliceous segregation was but weakly mineralized with sulphides.

4. Further adjustments in the contracting and cooling magma fractured the quartz filling and these latter fractures were cemented with sulphides of lead, copper, silver, and zinc.

As an apparent result of the above reactions the veins are not regularly mineralized. Instead, the values occur as rich streaks of sulphides 6 to 40 inches in width trending through the quartz parallel to the walls. In the Arlington and Last

Chance mines these shoots assay 30 to 70 ounces of silver, 5 to 20 per cent lead, 1 to 4 per cent copper, and 1 to 5 per cent zinc. Along the strike of the vein they vary in length from 100 to 600 feet. Certain of the stronger shoots have been developed to a depth of 600 feet without bottoming the ore. Several of the shoots, however, are more erratic. It is not uncommon to find ore streaks dissipating at various horizons, while "per contra" deeper exploration has disclosed ore shoots not present in the upper segments of the veins. The veins can be expected to extend several thousand feet below the present workings on Ruby Hill, but development work has not yet been prosecuted through a sufficient vertical range to permit an intelligent prediction as to the depth to which mineable ore-shoots will extend. The Last Chance workings are approximately 1,200 feet lower in elevation than the Arlington, yet they show excellent ore in their deepest workings. It is unsafe to attempt definite predictions on the basis of datum horizons from surrounding mines, yet this offers evidence in favor of a much deeper extension of the Arlington ore-shoot and there is no opposing evidence to suggest an early disappearance of the Last Chance ore-shoots below the present workings.

The ore minerals are galena, chalcopyrite, pyrite, tetrahedrite, and sphalerite, all of which occur as primary sulphides. Oxidation is unimportant and extensive downward enrichment cannot be expected.

The Last Chance vein exhibits a series of faults which shift segments of the vein laterally 4 to 15 feet in each instance. The northwest vein segments are generally displaced toward the southwest. No serious displacements were found.

ARLINGTON

General Features.—A company organized as the Arlington Mining Company purchased this mine from Jonathan Bourne, Jr., during 1905. Since that date they have at various intervals carried through a total of approximately three thousand feet of development work and sorted and shipped several thousand tons of excellent ore. During 1918 the company was re-incorporated as the Arlington Silver Mining Company, with head offices at Spokane.

The mine is on the western slope of Ruby Hill, seven miles south of Conconully and two miles by air line south of the old mining camp of Ruby. From the Salmon Creek road at Ruby, a branch road is built a distance of four miles to the mine; in this distance the road ascends 2,400 feet. The mine workings are in sec. 5, T. 34 N., R. 25 E., at an elevation of approximately 4,400 feet. The holdings consist of 10 patented and several unpatented claims.

The property is well equipped for mining operations. A pole line was built from Okanogan and electric power is supplied by the Okanogan Light & Power Company. This power is received at 23,000 volts and transformed to 2,200 volts for mine use. Surface equipment consists of a 4-drill Ingersoll-Rand compressor operated by a 50-horsepower motor, well equipped blacksmith and machine shops, customary camp quarters and a large quantity of accessory mining equipment.

Production.—Prior to 1901 the returns on 1,000 tons of ore are reported at $25,000. During the period of October, 1914, to June, 1916, shipment of 15 cars of sorted ore contained 583.44 tons of ore yielding net returns of $17,021.71. The average content of metals in this shipment paid for by the smelter was as follows: Gold, 0.025 ounces to the ton, silver 75.96 ounces to the ton, and copper 1.3 per cent. Since 1916, 24 cars have been shipped which totaled 986 tons and averaged 66.6 ounces of silver, 1.15 per cent copper, and .02 ounces of gold to the ton, and yielded net returns of $31,145.38.

Development.—The vein outcrops near the crest of Ruby Hill and the early work consisted of shallow shafts and short crosscuts to the upper section of the vein. Mining is now confined to the lower levels and the upper level was not examined. The following information on this upper level is quoted from the report of Jones:*

"In the upper tunnel two parallel northerly veins about 30 feet apart have been cut. The eastern vein has been explored for 350 feet along its strike and dips 60—75° east. The vein is from six inches to five feet wide, but contains little

*Jones, E. L. Reconnaissance of the Conconully and Ruby Mining Districts, Washington: U. S. Geol. Survey, Bull. 640-B, p. 32, 1916.

ore. The western vein encountered by the upper tunnel is that on which the shaft is sunk. This vein is explored for 700 feet, but differs greatly in character at different points. Its maximum width is 10 feet, but it pinches out in the fissure near the north and south ends of the drifts."

During 1910 the workable vein was cut 440 feet below the outcrop by an adit driven south 80° east a distance of 990 feet to the vein. At the intersection a large station has been cut and a winze sunk in the foot-wall to a depth of 100 feet. Short drifts have been run on the vein from the 50 and 100 levels of this winze. On the main adit level drifts have been opened on the vein 250 feet to the north and 300 feet toward the south, several large stopes have been broken, and a raise connects with the upper level. The possibilities of the vein have not been exhausted and there is a considerable tonnage of milling ore left when mining the higher-grade shoots.

Description of the Ore Body and Associated Formations.— The vein is of the marginal type, running practically parallel to a plunging contact between hornblende-mica schist and an intrusive body of granite. It is enclosed chiefly in granite and generally maintains a distance of 50 to 100 feet from the plane of contact, although at certain points the schist forms one of the vein walls. The granite is coarse-grained and composed chiefly of quartz and orthoclase so that certain phases of it might well be classed as alaskite. Near the contact of the two formations angular fragments of the older schistose rocks are found as inclusions in the granite.

The ore minerals of tetrahedrite, argentiferous galena, chalcopyrite, pyrite, and a little sphalerite occur, with a strong tendency toward banding, in a vein of milky quartz which strikes north 15° west and dips 70° west. Silver is the principal value; a little copper and lead are present and the ore averages about $1.00 in gold. The vein varies in width from 2 to 12 feet, while the average is from four to five feet. The walls show evidence of considerable post-mineral adjustments along the plane of the vein. Fifty feet north of the station a pre-mineral fault offsets the north segment of the fissure 10 feet toward the west.

The mineralization is segregated through the vein in the form of pay-shoots and the sections of the vein intervening between these shoots show in some places zones of barren quartz and in others sporadic mineralization of possible milling grade. On the main adit level the vein has been explored along the strike for 550 feet. An excellent pay-shoot is exposed for a distance of 200 feet north of the station and it is from stopes opened on this shoot that many of the shipments have been made. South of the station the vein narrows down to three feet but exposes a short shoot of ore that is well mineralized with tetrahedrite. One hundred and thirty feet south of the station the vein disappears and the drift is continued 100 feet farther without encountering the ore. Examining the walls of the drift closely it seems apparent that the vein swings out of the drift and should be picked up again by a short crosscut to the west.

From the station the main crosscut is continued eastward 200 feet. One hundred feet east of the station a second quartz vein three feet in width was cut and drifted on 100 feet toward the south. This vein strikes south 20° east, dips 75° east, and carries but sparse mineralization. This vein apparently attempts to follow the plunging contact between the schist and granite.

Genesis.—The veins were derived from the granite shortly after its intrusion into the schist. Undulating fractures developed along the plunging contact between the two formations and these fractures were filled with quartz. The principal bands of sulphides were introduced slightly later than the quartz, although the entire vein filling was injected during the crystallization of the magma.

Conclusion.—The property is capable of yielding a good tonnage of ore that will permit hand-sorting into a shipping product. There is, however, a large tonnage of medium-grade ore that must be concentrated previous to shipment. While the ore is composed of mixed sulphides, there is no reason why it cannot be made amenable to present-day concentration practice. Table concentration, followed by flotation, would naturally suggest itself. Preliminary mill tests on the ores have proven very promising.*

*U. S. Geol. Survey, Bull. 640-B., p. 23.

LAST CHANCE

After an idleness of many years duration, the Last Chance Mine was re-opened during the summer of 1920. It is owned by Jonathan Bourne, Jr., formerly United States Senator from Oregon, and during the early nineties the several properties on Ruby Hill owned by Mr. Bourne were the chief producers of the district. C. S. Jackson, of Conconully, has now leased the property and at the time of visit the tunnel had been reopened for a distance of 500 feet by catching up several small caves. A pump was installed to unwater the shaft, and a boiler and small air compressor were being placed in operating condition.

The mine is situated in sec. 31, T. 34 N., R. 25 E., at the north end of Ruby Hill and at an elevation of 3,100 feet. The mine openings are passed by the Arlington Mine road at a point one and one-half miles northwest of the Arlington Mine.

The quartz outcrops on the hillside above the road and is opened by a drift on the vein for a length of 650 feet. This drift is caved 500 feet from the portal. The vein is variable from 8 to 20 feet in width and 12 feet as a general average where observed. It strikes south 50° east and dips 70° southwest. The vein is enclosed chiefly in granite but has formed near the marginal contact between the granite and the intruded hornblende-mica schist. Limited mineralization is exposed in the vein at the portal, but 50 feet from this a pay-shoot was encountered which is made up of steel-galena, chalcopyrite, pyrite, tetrahedrite (silver-bearing), and sphalerite. The pay-shoot has a width of two to four feet of good ore and trends through the quartz vein for a distance of 200 feet. Beyond this point where the shoot pinches out the vein for the remaining distance to the cave is made up of normal white quartz. The quartz at the borders of the pay-shoot contains mineralization that in places is of probable milling grade. The stoping-back between this level and the surface varies from 50 to 100 feet. Mr. Jackson, the lessee, has opened a small stope above the level and is hand-sorting and shipping the ore. He reports the shipments to average about 30 ounces of silver, 17 per cent lead and four per cent copper.

The vein is cut by a series of post-mineral faults with displacements of 6 to 10 feet each. The northwest segments of the vein are generally shifted toward the southwest.

Near the portal of the tunnel a shaft has been sunk to a depth of 300 feet. Water stood almost to the collar of this shaft, hence the vertical extent of the pay-shoot could not be determined. The old maps indicate that at distances of 100 and 200 feet below the collar of this shaft, short drifts were run on the vein. From the bottom of the shaft a crosscut was driven eastward approximately 800 feet toward the downward projection of the adjoining First Thought vein.

FIRST THOUGHT

This property could not be examined on account of the workings being closed by caves. It is mentioned here because it was one of the first properties discovered in the district, and in the boom days was the most active mine in the camp. It adjoins the Last Chance Mine on the east.

The old reports* state that an aerial tramway was built from the mine to the town of Ruby, an air-line distance of one and one-half miles. At Ruby a mill was built which in six months produced concentrates valued at $66,000. The collapse of the silver market then caused operations to be terminated.

The vein is developed by cross-cuts from three levels. The vertical distance between the upper and lower levels is 350 feet. The reports indicate that 4,000 feet of tunnel work was accomplished, but the extent of the pay-shoots developed is not specified. The vein in places attains a width of 40 feet. The trend is north 10° east and the dip 60° northeast.

FOURTH OF JULY

The early reports† indicate that the Fourth of July Mine was one of the most promising properties developed on Ruby Hill. During its short period of operation a number of rich shipments were made.

*Bethune, Geo. A. Mines and Minerals of Washington: First Ann. Rept. State Geologist, 1891-1892.

†Hodges, L. K. Mining in Pacific Northwest: Published by the Seattle Post-Intelligencer, 1897.

The mine is near the crest of Ruby Hill, one-half mile north of the Arlington. A shaft was sunk on the vein to a reported depth of 500 feet but is now inaccessible. This vein is said to average 10 feet in width and to contain a streak of sulphide ore 18 to 24 inches in average width.

CARL FREDERICK

The Carl Frederick is a small property located well up near the western crest of Clarke Peak, at an elevation of approximately 7,200 feet. The claims are 11 miles by air line northwest of Conconully and are reached by following up Salmon Creek to the headwaters of its tributary, Peak Creek, then crossing over to the western flank of the range through a mountain gap at an elevation of 7,600 feet between Mount Tiffany and Clarke Peak. A good wagon road constructed seven miles up Salmon Creek forms the first lap of the trip. The remaining nine miles are covered by a pack trail which leaves the creek bottom and trends well up on the north wall of Peak Creek Canyon. From the backbone of the range near Mount Tiffany the traveler commands an impressive view over a wide range of the surrounding territory. Particularly is the eye attracted to the well-forested water-shed of the Upper Methow, and still further west to the lofty, even-topped ridges of the Cascade Range.

The mining holdings, which consist of nine unpatented claims, were located during 1906 and development work has been carried on each summer under the direction of C. Bernhard. The first discovery was of rich oxidized croppings of silver ore. The outcrop of the small vein was found at an elevation of 150 lower than these croppings and a drift driven on the vein for a length of 400 feet. This drift follows one to four feet of crushed ledge-matter through which is found a quartz vein averaging from four inches to two feet in width, striking north 25° to 40° east and dipping 37° to 42° northwest. The country rock is a medium-grained granite which in places contains enough of the ferro-magnesium minerals and plagioclase feldspar to be classed as a granodiorite. Closely associated with the vein and often forming its hanging-wall, is a lamprophyre dike, one foot in average thickness. In the first part

of the drift the mineralization is scanty but at a distance of 350 feet from the portal an ore-shoot was encountered and drifted on for a distance of 50 feet. The vein in this shoot is quite well mineralized with argentiferous galena. An inclined winze sunk 38 feet below the level has not bottomed the ore. Short drifts have been run on two levels from this winze. The first level is 20 feet below the collar and here a stope has been broken which contains 200 to 300 tons of broken ore, said to average 20 ounces of silver to the ton. This intermediate level is about 130 feet below the outcrop and the sulphides show slight secondary alteration, black sulphurets of silver and silver bromide and chloride being developed.

Sixty feet northwest of 220 feet vertically below the main drift, a tunnel has been driven north 60° east for a distance of 268 feet in an effort to pick up the downward extension of the vein. Unfortunately the 40-degree dip of the vein to the northwest was not fully taken into account and it will be necessary to turn the tunnel at almost a right angle and drive toward the northwest at least 150 feet to reach the downward projection of the vein.

The richest ore in the mine will be found in the partially enriched zone of the pay-shoot between the main tunnel level and the surface croppings.

The cost of transportation mitigates against the profitable shipping of any but the very richest ore. The greater part of the values are in the sulphide form, which would yield readily to flotation concentration and giving a concentrate carrying 300 to 500 ounces of silver to the ton. If the ore-shoot can be picked up on the lower level and several thousand tons of good-grade ore blocked out, it might then be possible to profitably clean up the ore with a small temporary flotation plant.

OTHER DEPOSITS IN OKANOGAN COUNTY

TRINIDAD

A company organized as the Trinidad Mining & Smelting Co. has been developing, for the past several years, a group of 12 claims in sec. 10, T. 36 N., R. 25 E., 10 miles by road southwest of Tonasket, on the shore of Turtle Lake, and at an eleva-

tion of 2,000 feet. T. W. Brown and Jos. Coleman, the principal owners, carry on the development work themselves, all work being done by hand mining. One shipment has been made which total 30 tons of ore averaging $12.00 per ton in gold and silver.

On the property is exposed a set of geologic relations which differ radically from other deposits visited in Okanogan County. The ore occurs as an irregular body in a dike-like zone of aplite-porphyry. This zone is 300 feet wide and trends roughly north and south. The rock is a light green siliceous ground-mass through which are rounded grains of quartz.

The silicified zone is intrusive into a belt of black argillite which has been highly silicified by its association with the aplite-porphyry. Intrusive into the aplite-porphyry and cleanly associated with the ore, is a hornblende-porphyry dike trending south 10° east and having an average width of nine feet. This is made up of a light-greenish ground-mass studded with black slender crystals of hornblende.

A shaft has been sunk in the irregular mineralized mass occurring in the aplite-porphyry, and 32 feet below the collar a drift is driven a short distance into the mineralized zone. For the first 17 feet across the zone it is reported to carry six to eight ounces of silver to the ton. The ore minerals are galena, pyrite and a little chalcopyrite and sphalerite. At this level the 30-ton shipment was mined. The limits of the mineralization have not been defined. At the bottom of the 50-foot shaft a drift is run south 20° west for a length of 60 feet following the dike of hornblende-porphyry. It is likely that better ore will be found by crosscutting to the east to get under the ore exposed in the upper level.

The aplite-porphyry zone has been prospected at several points with short drifts and shafts and the owners state that assays ranging from $1.00 to $3.00 in gold and silver can be secured in many places along the belt. A crosscut was started through the silicified argillite to prospect the contact between the argillite and the aplite-porphyry but this work was not completed.

SILVER LEDGE

Since 1918 a small crew under the direction of L. H. Markham has been actively engaged in exploring this property. The holdings are four miles up Gold Creek, a small tributary which enters Methow River 20 miles above Pateros. The nearest railroad point is Pateros and an excellent automobile road leads up Methow River; at the mouth of Gold Creek a branch road turns westward up the creek to connect the property with the main highway.

Three parallel veins outcrop on the north valley wall of Gold Creek. Named in order of their occurrence they are the North Star, Truax and Seattle. Limited prospecting on the two last named veins has failed to show any commercial ore, and all work is confined to the North Star.

The North Star vein has a filling of milky and bluish quartz which has been brecciated and re-cemented. Except in one instance, noted later, finely divided pyrite is the only sulphide visible to the naked eye. The chief values are in gold and silver, which are erratically distributed at points in the vein. The vein strikes nearly east-west and dips 45° norht. It is entirely enclosed in greenstone, apparently the metamorphic equivalent of volcanic flow-breccia.

An inclined shaft was sunk on the North Star vein to a depth of 150 feet but this opening is now only accessible for the first 100 feet. The average width of the vein is from two to three feet, but 88 feet below the collar the vein widens to eight feet, only to maintain this width for a short distance along its dip, then pinches down again to three feet. It is from this lens-shaped part of the vein that the encouraging assays have been secured. This shoot has not been explored to determine the stope or pitch length of the mineable ore. Superintendent Markham reports that a test shipment of two tons of unsorted ore yielded $20.00 to the ton in gold and silver. The quartz of this lens is heavily stained with iron oxide and some samples also show the yellow and blue stains of silver chloride and bromide. In one of the vein specimens there were noted pin-point specks of a silver sulphide, too sparsely scattered through the rock to permit of an accurate mineralogic determination.

At a point 342 feet below the collar of this shaft, the Silver Ledge Company have driven a crosscut north 15° east a distance of 970 feet (August, 1920), in order to explore the vein at depth. This tunnel has been driven entirely through greenstone. At a distance of 870 feet from the portal a small silicified fracture zone was encountered and drifted on toward the east a distance of 125 feet. This strikes east-west and dips 70° toward the north. Believing that the vein exposed in the shaft above had been cut, and that it was developing a steeper dip with depth, a raise was driven to connect with the bottom of the shaft. This raise was driven on the vein for a distance of 250 feet and showed it to vary in width from one to five feet. Samples taken gave erratic returns of gold, but the raise exposes no mineable ore. When the raise and shaft failed to connect, a prospect upraise was driven 20 feet into the hanging-wall, where it broke into the shaft and thus developed the fact that the raise had been driven on an unknown, blind vein of parallel trend, but of steeper dip than the North Star vein. The lower crosscut is now being extended farther to the north to cut the North Star vein at that level.

The only commercial ore so far developed in the mine is that exposed in the shaft. This should be explored and its limits determined for the future of the deposit depends upon the extent to which this shoot can be developed.

DEPOSITS IN THE CASCADE RANGE

THE CASCADE RANGE

TOPOGRAPHY

The Cascade Range trends north-south through western Washington as a segment of a great mountain chain that roughly parallels the west coast of North America. Where the range crosses the international boundary it is 120 miles in width, but further south it narrows until it is but 70 miles when crossing into Oregon. The rugged scenic grandeur of the range with its serrate ridges flanking deep-cut glacial canyons, its rock-bound alpine lakes nestling in cirque basins often 5,000 feet or more above sea level, the heavy forest mantling the stream valleys and the more gentle slopes, form a country that will gladden the eye of the most seasoned mountaineer.

PHYSIOGRAPHY

From the summit of the range the panorama of the tumbling sea of ridges presents a striking uniformity of elevation. If the canyons and valleys which gash the mountain chain could be suddenly filled in the summit of the Cascades would form a gently-sloping, nearly flat-topped plateau. This phenomenon impressed even the first geologic investigators and gradually caused them to assume that the range represents a plateau which has been elevated 7,000 feet or more above sea level and then vigorously dissected by ice and water. The snow covered peaks: Mts. Rainier, Baker, Adams, St. Helens and Glacier Peak, represent volcanic cones which have been built up above the general level of the plateau. These cones now range in an elevation from Mt. Rainier at 14,408 feet to Mt. St. Helens at 9,671 feet.

The physiographic development of the Range has been ably interpreted by Russell,* Willis and Smith,† all three of whom are in general accordance. Those interested should refer to these reports.

On the other hand, Daly,‡ takes decided exception to

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*Russell, I. C. Twentieth Ann. Rept., U. S. Geol. Survey, part 2, 1900.

†Willis, Bailey, and Smith, G. O. Prof. Paper No. 19, U. S. Geol. Survey, 1903.

‡Daly, R. A. Forty-Ninth Parallel Report: Canadian Geol. Survey, memoir No. 38, part II, pp. 621-641, 1912.

View of Cascade Range from Mt. Rainier looking south toward Mt. Adams.
Note the striking accordance of summit levels.

their conclusions and enters into an extended discussion of the problem. Briefly stated, he attributes the accordance of summit altitudes to natural inheritance of alpine topography rather than to spontaneous erosion in the present environment. He states that the hypothesis of late-Tertiary peneplation of the range cannot be reconciled with the areas showing slow-speed of erosion in eastern America and Europe, nor with the physiographic history which is so firmly established in those large areas of the earth's surface. He explains the accordance of summit phenomenon as follows: "A review of the conditions of general degradation show clearly its differential character above and below tree-line. Summits already reduced to the tree-line are bound henceforth to be stubborn against further erosion. Summits without the treeless zone are as clearly bound to continue wasting rapidly so as to tend to approach an accordance of summit levels with their tree-covered neighbors."

GEOLOGY

The rugged topography of the Cascades affords excellent rock exposures from which record the geologic history of the range may be in part deciphered. The paucity of fossil remains in the older metamorphosed sediments makes it at present imposible to closely fix the age of these belts. Nor can the problem of age be effectively attacked from a stratigraphic standpoint for the complexity and interruptions of the structure offers barriers that will not soon be surmounted.

Since the mining men are not usually concerned with the intricate geologic factors, only a generalized synopsis will be attempted.

The oldest rocks in the Cascades are the highly buckled and metamorphosed belts of quartzite, argillite, schist, limestone, conglomerate, and intercalated volcanics. The basal members of the belts may be pre-Cambrian in age. The majority of these belts, however, are without question assigned to the Paleozoic era, with certain of the upper, younger beds as late in age as the Cretaceous period of the Mesozoic. Following deposition they suffered the ravages of metamorphism which severely folded and faulted them.

Near the close of the Mesozoic era, the metamorphics were invaded by a great granitic batholith and it was from this magma that the chief ore deposits were formed.

A pronounced unconformity separating the pre-Tertiary and the Tertiary formations evidently marks an extensive period of erosion. If we have interpreted the geologic conditions correctly, the present site of the Cascade Range was marked only by a low range of mountains during the Tertiary period, and in the vicinity of the present Cle Elum District, large lake basins flanked the hills. The material secured by erosion was partly accumulated in these lake basins and the resultant sandstones and shales to-day mark the first record of the Tertiary. The Miocene period was inaugurated with the most intense period of vulcanism recorded in geologic history. Flow upon flow of lava was poured out to cover the surface. It was during this period that Columbia River Basalt Plateau was constructed. In the Cascades the numerous flows of basalt, andesite and rhyolite still remain to record the period.

During the short lulls in volcanic activity, sedimentation was active and when finally vulcanism subsided, erosion and sedimentation became once more the dominant factors. The Tertiary formations have been but moderately deformed into gentle folds. They contain many leaf and plant impressions which give valuable aid toward the fixing of geologic age.

Toward the close of the Tertiary there came a smaller batholithic intrusion of granodiorite. This is represented by the Snoqualmie granodiorite described by Smith*. From detailed areal mapping he was able to make the very interesting statement that the intrusion of Snoqualmie granodiorite reached within 4,000 feet of the land surface existing at that time. This 4,000 feet of cover was sufficient to allow the slow cooling necessary for the coarse crystallization of a granitic rock.

It was during the opening of the Pliocene that the Cascades are considered to have been elevated some 7,000 feet or more above the level of the sea. This uplift was accomplished by the complex arching of the strata which now form the

*Smith, George Otis. Snoqualmie Folio, Washington, No. 139, U. S. Geol. Survey, 1906.

range. The steep escarpments on the west flank of the Cascades in the vicinity of Startup, North Bend, etc., suggests that the arching became so intense in certain areas that the strata collapsed and left great fault escarpments.

Following the uplift and until the present day, water and ice have been constantly at work slowly gouging and tearing down the range.

SUMMARY

Those interested in the ore deposits of the Cascades should appreciate that there have been two periods of metallization: One, directly associated with the granitic intrusion during the Mesozoic and the more recent metallization with a second granitic intrusion during late Tertiary time. The Sunset Copper deposit represents the older type while the younger bodies are represented by the Apex Mine, in the Miller River District, and the Mineral Creek copper deposit, near the head of Little Kachess Lake. In a few instances the other formations described have received mineralization given off by the underlying granitic batholiths. It is of value to understand the relations of these formations to the ore deposits and to the intruded granites.

ORE DEPOSITS

The metalliferous ore deposits of the Cascades yield principally copper and gold, with lesser amounts of silver, lead, and arsenic. The Sunset Copper Mine, in the Index District, has, in recent years, been the premier producer in western Washington. Other copper properties under development in the Sultan Basin area, and north of Lake Kachess, in Kittitas County, may later reinforce the Sunset's production, when their transportation and other basic development problems are economically solved. These copper properties occur as both lodes and veins irregularly replacing the granite and granodiorite along shear zones through these rocks.

The ore deposits of the Cascades are prevailingly found enclosed in the granitic batholith from which they were derived. The character of the overlying host rocks was often favorable for the deposition of the ore minerals but the granitic

rocks apparently were not able to reject their ores, as in northeastern Washington. The time elapsing between the batholithic intrusion and the subsequent injection of the ore-bearing constituents, was adequate to allow the outer crust of the batholith to cool sufficiently to thus chill and precipitate the metal carriers before they were able to reach the older host rocks.

It is noticeably true that while the majority of the veins in the Cascades are usually narrow, they are also remarkably persistent for veins of such limited width. There are instances where a vein which does not average over 12 inches in width is traceable for a half mile and often more along its strike and has been explored to a maximum depth of 700 feet below the outcrop without being bottomed. This is a phenomenon not common to most mining districts. Such veins evidently formed at a moderate depth where the pressure was not sufficient to close narrow, persistent fractures traversing the country rock. The widening of these narrow fissures was accomplished by the metasomatic replacement of the walls by the ore-bearing solutions and gases.

This type of persistent, narrow veins is not so common to the copper deposits as it is to veins carrying gold values intimately associated with arsenopyrite, pyrite, chalcopyrite and similar base sulphides. The Apex Mine, in the Miller River District, forms an excellent type example.

There are a number of other gold properties in the range which will re-open when the present discouraging gold situation is relieved. First to be mentioned is the Boundary Red Mountain Mine in the Mt. Baker District, also the Lone Jack Mine of the same area. These deposits are normal quartz veins carrying their values in free gold. The tenor of the pay-shoots averages around $15.00 in gold to the ton and the character of the gold permits its economic recovery by amalgamation. These mines are 20 to 35 miles from the railroad and lack of cheap transportation has always been a troublesome factor.

There has been a strong market demand for arsenic during 1920, and if this condition continues the arsenopyrite prominently associated with a number of the deposits will give an incentive for the resumption of operations.

Several small veins of realgar (arsenic monosulphide) occur in the Cascades and during 1920 a small mill was built to work a deposit in the Index District. This highly volatile sulphide is found filling narrow irregular fractures which occur near the roof of the granitic batholith.

BLEWETT DISTRICT

INTRODUCTION

The Blewett Mining District is located in the south central part of Chelan County, approximately in the center of the State. The nearest railway point, Peshastin, on the main line of the Great Northern Railway, is 18 miles from Blewett and the two are connected by excellent automobile road. The center of the district is the old town of Blewett, which is situated on the Blewett Pass automobile highway across the Cascade Range.

The Blewett District is one of the oldest mining areas in Washington. Many prospectors working southward from the Caribou and Fraser River District in British Columbia and the Similkameen in northern Washington, are believed to have used a trail over Blewett Pass in order to cross the Cascade Range into western Washington. It was in 1860 when the first gold placers on Peshastin Creek were discovered and they have been worked at innumerable intervals since that date. About 1874 the first quartz claim was located by John Shafer, at the head of Culver Gulch, and within the next few years all the promising ground had been staked. The first attempt at the milling of ore in the territory followed when several arrastres were built to treat the rich oxidized surface ores of the district. On the bank of Peshastin Creek, 100 yards south of Blewett Store, one of these old arrastres is still well preserved to-day. It is shaped from solid rock and the symmetrical smoothed surface of both the spindle and bowl witness the long continued use of this crude crushing device.

During the period from 1891 to 1907 there has been sporadic mining and stamp milling of the Blewett ores. The greater part of the work has been centered about Culver Gulch,

just west of the old town of Blewett. No official record has been kept of the gold production from the camp, but from the best available data it is estimated at $1,700,000

When the district was visited during the summer of 1920, there had been no new mining development since the very complete and excellent report on the district made by Weaver* during 1910.

A company organized as the Amalgamated Gold Mines Company, with head offices in Seattle, began work July, 1920, on the old workings along the Peshastin vein. This property has been in litigation for the past eight years and the title has but recently been cleared. A crew of 15 men were employed re-opening the old workings and remodelling the old Blewett Stamp Mill. This mill has been largely dismantled except for the old battery of 20 stamps, and it is the plan of the company to begin in an experimental way by first placing in operation five stamps in conjunction with amalgamation followed probably by tables and flotation concentration. In the meanwhile mining operations will be carried on in an effort to develop enough ore to warrant milling on a commercial scale.

Since there has been no new mining since the report by Weaver, the writer made only a brief stop in the district and examined the series of openings along Culver Gulch that the Amalgamated Company plan to re-open. The examination was limited by caves which in places blocked the tunnels and stopes. It was surprising, however, to find some of the old stopes, mined out 25 years ago, still in part accessible.

GEOLOGY

The following geological summary of the district is largely abstracts from the report of Weaver*

The geological history of the Blewett Mining District is a part of the geological history of the Cascade Mountains. The same disastrophic movements involved in the deformation of the Cascades during the various periods of its history, the changes in the relative positions of land and sea, the metamorphism produced by igneous intrusions, the deposition of sedi-

*Weaver, C. E. Geology and Ore Deposits of Blewett Mining District: Washington Geological Survey, Bull. 6, 1910.
Washington Geological Survey, Bull. 6.

mentary rocks in the large fresh water lake basins and the final modification of the topographic features by the action of stream erosion, which has operated upon so tremendous a scale in developing the Cascades as a whole, have been the factors involved in producing the geological and topographical features in the area under discusion.

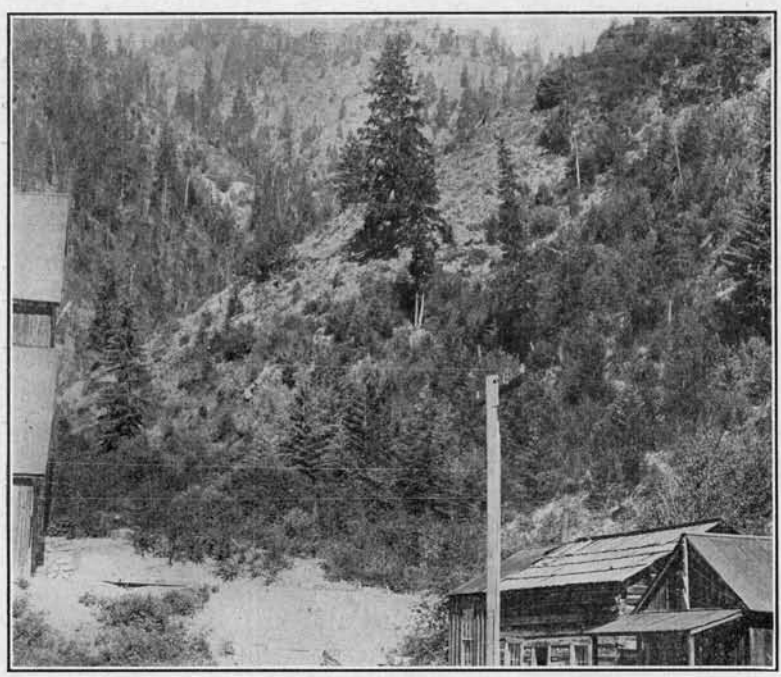
The formations in this region may be divided into two series which are separated by a pronounced unconformity. The older of these is represented by a bedrock complex, consisting of metamorphic and igneous rocks of pre-Tertiary age. The younger of the series is composed of non-metamorphosed sedimentary rocks together with igneous intrusive and extrusive rocks.

To convey an idea of the geological conditions, the various formations exposed in the area will be each briefly discussed in order of their age.

The oldest formation exposed is the Peshastin, which is prevailingly made up of black slates and fine-grained dark-colored quartzites. Extensive exposures of Paleozoic rocks are present in the northern part of the district and they are undoubtedly a part of the great series of metamorphosed Paleozoic sediments so well exposed in northern Washington, parts of Idaho and Oregon, and in British Columbia.

The rocks grouped under the general term of the Hawkins formation constitute the bolder crags and pinnacles such as Sheep Mountain, Iron Mountain and the high, ragged ridge between Culver Gulch and Negro Creek. They constitute a prominent feature of the areal geology within the district proper and are a part of a broad belt extending east and west from Mount Stuart. The rocks composing this formation are represented by volcanic breccias, tuffs and intercalated volcanic flows of probable Carboniferous age.

Three-fifths of the total area of the district is represented by ultra-basic intrusives, classed as perodotite. Where this formation was observed in the vicinity of the ore deposits along Culver Gulch, the perodotite had been converted into serpentine. Such a change was probably effected by the hydration of the perodotite by ascending hot waters, either latent waters from the perodotite intrusion or from later igneous activity.



View of Culver Gulch, Blewett District. Meteor and Pechastin tunnels are directly back of mill. The dumps of the Sandell and Humming Bird tunnels are visible farther up the gulch.

The formations of the Blewett area are underlain by an immense batholith of granodiorite of probable Jurassic age. Only dike-like apophyses of the granodiorite have reached the present land surface of the Blewett area, but the batholith is prominently exposed in the vicinity of Mount Stuart and is believed to be directly related to other large exposures of granodiorite through the Cascade Range, for example, the extensive exposures of granodiorite in the Index District. The ore deposits of the Blewett District are found chiefly in the serpentinized perodotite and are believed to have been derived from emanations from the underlying granodiorite batholith.

The Tertiary history of this region was inaugurated by intense deformation of the surface rocks, resulting in the formation of a great lake basin in which were subsequently formed beds of sandstone, shale, and carbonaceous material until a thickness of some 5,000 feet was obtained. These beds are now known as the Swauk formation. The remainder of the Tertiary period was marked by vulcanism with great out-

pouring of basic lavas and then long periods of erosion until the region was reduced to a peneplain. At the close of the Pliocene, or beginning of the Quaternary, the Cascades were again uplifted to at least 8,000 feet above sea level by a series of complex deformational movements. Since then the area has been vigorously attacked by the erosive actions of streams and glaciers with the result that the present physiographic mosaic has been sculptured from the uplifted plateau.

PESHASTIN VEIN

The Peshastin vein has been the major producer of the Blewett District. It outcrops on the south side of Culver Gulch a few hundred yards west of the Blewett Store and then follows roughly the westerly trend of the gulch up the mountainside. Culver Gulch has furnished the site for a series of drifts driven to the vein at various elevations. A large portion of the ground along the trend of the vein between these crosscuts has not been explored. This is largely due to the fact that the mining chance of finding new ore-shoots is not considered sufficient to warrant the cost of such extended exploration work.

The trend of the vein is north 65°-75° west and it dips 60°-75° toward the south. The vein occurs along an irregular shear zone through the serpentine and pronounced pinches and swells cause the width of the zone filling to vary from a tiny stringer to eight feet as a maximum. The ore lays in lenticular masses along the sheared serpentine; in some instances these lenses attain lengths of 100 feet or more and then pinch down until only the sheared serpentine marks the continuation of the fracture. Quartz and calcite are prominent as gangue minerals, and through the vein matter run ribbon-like inclusions of serpentine. Arsenopyrite and pyrite are the predominant sulphides and minor amounts of chalcopyrite and galena are present. Many rich samples of free gold have come from this vein and the tenor of the ore mined has varied from a few dollars a ton up to a maximum of $10,000 per ton form some of the rich pockets. In the Meteor tunnel dolomite was found as a prominent filling along the shear zone, also bright red streaks of iron oxide and associated with these the

writer found what appears to be garnierite, the hydrated silicate of magnesium and nickel. This was not observed in workable quantities but its occurrence is of interest and prospectors and operators in the district should note the extent of its occurrence in other workings. It was intimately mixed with green serpentine minerals which rendered its positive identification imposible.

Underground Workings.—The oldest workings occur near the head of Culver Gulch in what is known as the Summit Pocket. It was reported that these workings were largely inaccesible so examination was confined to the accessible workings on the Bobtail, Hummingbird, Sandell, Peshastin and Black Jack claims.

Wye Tunnel.—This tunnel, also known as the Bobtail, is the most westerly exposure visited. The workings are on the Bobtail claim at an elevation of 3,100 feet, or 700 feet above the town of Blewett. A 50-foot crosscut is driven to a lenticular quartz deposit which is probably the western extension of the Peshastin lead. A small stope has been opened on the lens. The amount of available ore appears limited and the assays are reported to be of medium grade.

Upper Humming Bird Tunnel.—The portal of this tunnel is also in Culver Gulch but at a point 75 feet lower in elevation. It has been driven 233 feet as a crosscut until a small slip was encountered and drifted upon 50 feet without exposing any ore. This slip has a well-defined wall of polished serpentine which strikes east to west and dips 70° south.

Lower Humming Bird Tunnel.—This is 100 feet lower in elevation , and, like the Upper Humming Bird tunnel, is driven 220 feet to a shear zone which strikes east and west and dips 70° south. A drift has explored the vein for 300 feet toward the west and a lens of ore encountered from which several hundred tons of ore have been stoped. The back of this stope shows a quartz vein one foot in average width, which fills the shear zone. Arsenopyrite, pyrite and chalcopyrite are present in moderate amounts. This showing is believed to be on the westward extension of the Peshastin fracture.

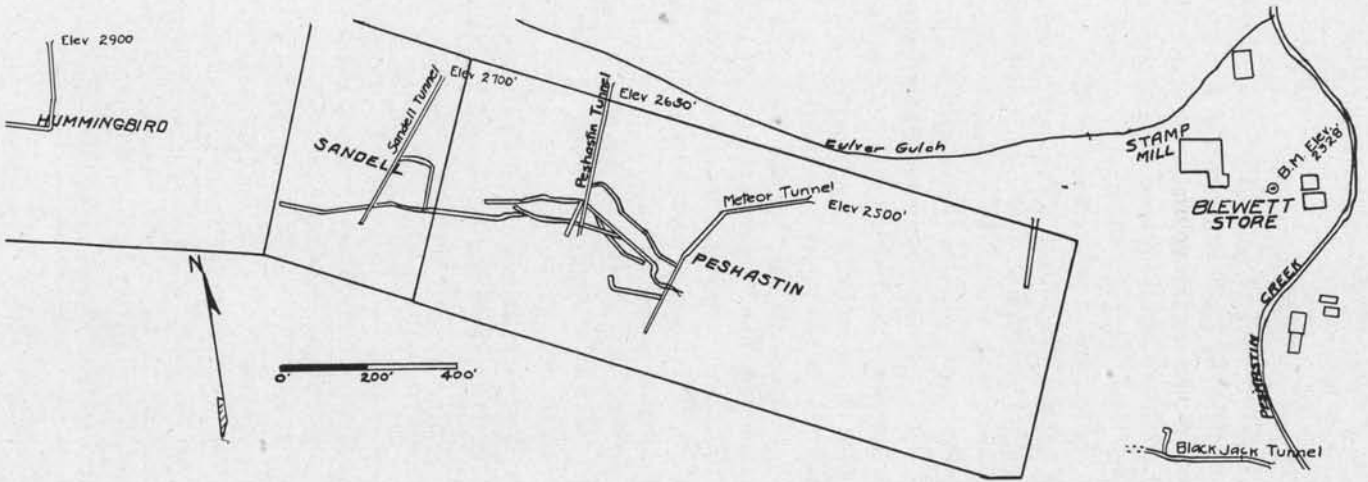


Fig. 22. Map showing mine workings on the east end of the Peshastin vein, near mouth of Culver Gulch, Blewett District.

Sandell Tunnel.—The portal of this tunnel is at an elevation of 2,700 feet, or 200 feet below the lower Humming Bird tunnel. It crosscuts the Peshastin vein 300 feet from the portal, and drifts are run on the vein several hundred feet both east and west of the crosscut. Stopes were opened both above and below this level; in part these are still accessible and judging from the pillars of ore remaining the ore-shoot averaged two to six feet in thickness. The quartz is streaked with pyrite and some arsenopyrite. Some very rich lenses of ore are known to have been mined from these stopes. The pay-shoot is apparently the same as that mined in the Peshastin workings, for the two tunnels are connected by stopes.

Peshastin Tunnel.—This tunnel was blocked by a cave near the portal and the workings could not be examined. It cuts the Peshastin vein 180 feet below the level of the Sandell tunnel. Weaver* mentions that on the Peshastin claim two ore-shoots were found, known as the "Parish" and "McCarthy" shoots. These were worked mainly from the Peshastin tunnel. They pinched down to a very narrow seam above the level of the Peshastin tunnel and also narrowed down to the east and west along the general strike of the vein. These shoots are credited with a large production of good-grade ore.

Meteor Tunnel.—The Meteor tunnel is about 80 feet below the level of the Peshastin and is driven as a diagonal crosscut a distance of 700 feet, where it encountered a shear zone cutting the serpentine. This was drifted upon for a distance of 1,000 feet or more without exposing any strong shoots of ore. This shear zone is supposed to be the downward projection of the Peshastin vein and Weaver* mentions that the two workings are connected by raises, but the writer was unable to find such connections. There is room for doubt as to whether the drift on the Meteor level is on the Peshastin vein. It follows more or less of an irregular shear zone, along which are occasional lenses of quartz, but such conditions could exist parallel to the main Peshastin shear zone. At one point a raise has been carried up 65 feet on some quartz stringers lying along a zone that trends north 65° east and dips 70°

*Idem. page 88.
Wash. Geol. Survey, Bull. 6, page 86.

south. It should only be necessary to continue this raise 20 feet to connect with the Peshastin workings and then this question could be definitely settled and development work from the Meteor tunnel could be planned in a more decisive manner.

BLACK JACK VEIN

The most easterly development on the Black Jack claim consists of a tunnel driven westerly from the level of Peshastin Creek for a distance of 1,300 feet, together with a shaft and several raises. Weaver* reports that 3,000 tons of ore averaging $10.00 to the ton, was mined from these workings. When visited during 1920 this tunnel was caved at a point 500 feet from the portal. Very little ore was observed, the best being from a narrow lens of quartz explored by a 75-foot raise above the level. Directly up the hillside, 100 feet from the portal of these workings, a second tunnel has been driven several hundred feet in a westerly direction. The work exposes several small lenses of ore which pinch out irregularly both along the strike and dip of the deposit.

CONCLUSIONS

In the workings visited on the Peshastin and Black Jack veins very little mineable ore has been left and future production must come from new exploration work. The deposit can ordinarily be expected to extend well below the level of Peshastin Creek. The pay-shoots were not studied in enough detail to warrant any definite conclusions regarding their downward extension. The most promising ground for exploration would be the systematic search for these shoots below the Peshastin level. The profitable development of the property will call for the most skillfully directed development work. As a preliminary it would be desirable to prepare a set of good working maps of the mine openings and when completed these could be compared with any other maps that may be available. There are a number of underground exposures that may be found to carry some ore of commercial grade; all these showings should be systematically channel-sampled. Since the old workings have been opened and extended at various times under different types of management, and in some cases by lessors, all unknown factors with respect to the workings should be systematically checked.

*Wash. Geol. Survey, Bull. 6, page 86.

KITTITAS COUNTY

CLE ELUM AND ADJOINING DISTRICTS

SWAUK MINING & DREDGING COMPANY

September 5, 1920, the Swauk Mining & Dredging Company put in operation a gold dredge near the junction of Williams and Swauk creeks. The dredge began work at a point only a few hundred yards from the postoffice of Liberty, Kittitas County, and if operations prove profitable the company plans to eventually work over the greater part of the Swauk Basin, which would offer them an extensive operating area.

The dredge was built by the American Dredge Building Company, of Seattle. It has a rated capacity of 1,000 cubic yards of gravel per day. The buckets are of two cubic yards capacity and are equipped with manganese-steel lips. Power is furnished by an 80-horsepower gas engine, kerosene being used as a fuel. It is planned to later install electric power. Water is handled by a 12-inch centrifugal pump.

The bucket-line of the dredge discharges over a grizzly spaced at two inches. The grizzly oversize passes to a cylindrical trommel 3′ x 14′. The trommel oversize is sent to the stacker belt and discharged from the dredge. The trommel and grizzly undersize is passed over riffles then flumed through tail sluices and discharged astern of the dredge.

The Swauk area has been the scene of placer mining activity since the coming of white men to the northwest, and its sporadic operations have produced the major portion of the State's placer gold. It is undoubtedly one of the most favorable areas in the State for dredging operations and the progress of the present company will be watched with interest. The ground has been tested a number of times and the erratic distribution of gold has caused a variance of opinion as to the success of such a venture.

The gold-bearing gravels of the district are well described by Smith,* who worked out the detailed geology of the area.

The following information is taken from his report: The gravel deposits vary from a few feet to 80 feet in thickness.

*Smith, G. O., Mt. Stuart Folio, Washington. U. S. Geol. Survey, Folio No. 106, 1904.

Colors of fine gold occur scattered through the gravel but most of the gold is found on the bed rock. The marked characteristic of the gold is its coarseness. The largest nugget found was valued at $1,100. The large nuggets are usually well-rounded, but in the tributary streams wire and leaf-gold are found. The source of the gold is from quartz veins known to occur in the immediate vicinity; indeed, the limited area of the Swauk drainage basin precludes any very distant source for the gold.

MINERAL CREEK COPPER

The Mineral Creek Copper deposit is on a creek of the same name, two miles above Little Kachess Lake, northwestern Kittitas County. It is accessible only by boat up Kachess Lake to the head of Little Kachess Lake and from this point two miles of wagon road connects the deposit with water transportation. An attempt was made, during November, 1920, to examine the holdings but a severe storm interfered. The following information is abstracted from the notes of a responsible engineer who visited the property earlier in the season:

The holdings of the company comprise two adjacent deposits, known respectively as the Mineral Creek and the Copper Queen.

The first named property is on the north side of, and a few hundred feet above, Mineral Creek. The mineralization occurs as a replacement along an irregular shear zone pattern which traverses a large dike of granodiorite. This dike is apparently connected with a stock of Snoqualmie granodiorite (Tertiary) which outcrops a mile north of the workings.* The mineralization occurs along the narrow shear zones and joint planes but is not usually strong enough to link up the fracture pattern. The brecciated zone is 20 to 40 feet in width and the granodiorite is partly replaced by silica, pyrite, and lesser amounts of chalcopyrite.

The deposit is explored by a crosscut 248 feet in length and by a 50-foot shaft sunk on the mineralization at a point near the portal of the crosscut. These workings are connected

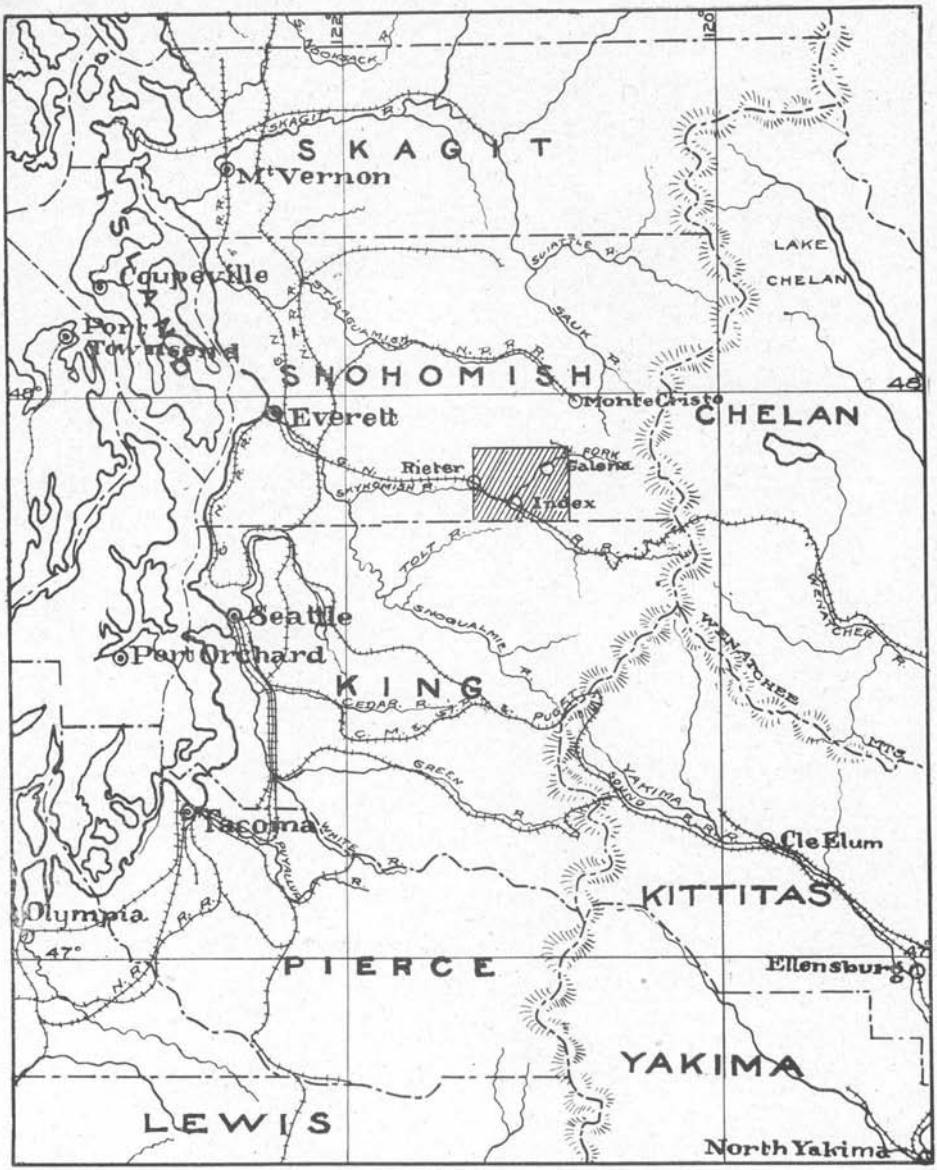
*Reference should be made to Snoqualmie Folio: Geologic Atlas No. 139, U. S. Geol. Survey, 1906.

by a short surface tram with a small mill situated near the creek level. This mill was built during 1920 and has a capacity of approximately 25 tons per day. The ore is first broken in a No. 2 Dodge crusher, then ground to flotation size in a Forrester rod mill. Two standard Ziegler flotation machines make a shipping concentrate and a tailing product which is re-treated on a Wifley table. The property is credited with several small shipments and E. J. Durrwachter, superintendent, reports that a carload shipment of crude ore averaged 6 per cent copper.

The Copper Queen deposit is one-half mile south of, and some 600 feet above, Mineral Creek. Here the mineralization occurs in a neck of oxidized rhyolite breccia. The largest lateral dimension of the mineralized zone is 40 feet. This area exhibits one strong fissure and many minor ones. The mineralization is chiefly pyrite with which is associated some chalcopyrite.

At the 3,500 elevation a crosscut has been driven through basalt and sandstone a distance of 550 feet to the rhyolite breccia. At the 3,660-foot elevation a second tunnel has been driven 230 feet; this work cuts basalt for the first 55 feet, and then rhyolite breccia for the remainder of the distance. Only 40 feet of the breccia shows evidence of mineralization. No. 5 tunnel is at an elevation of 3,820 feet and has a length of 65 feet; it is principally enclosed by basalt which exhibits no mineralization.

So far as is known, the deposits have not been systematically sampled. The copper content is relatively low, but no exact statement concerning the tenor of the mineralization can be made.



Scale

20 10 0 20

MAP OF PORTION OF CASCADE MOUNTAINS
SHOWING INDEX DISTRICT
WITH REFERENCE TO SURROUNDING COUNTRY.

Area Representing Index Mining District.
Areal Geology Mapped.

SNOHOMISH COUNTY

INDEX AND SULTAN DISTRICTS

GENERAL FEATURES

The Index and Sultan districts are two closely adjacent areas occupying an area of 400 square miles in southeastern Snohomish and northeastern King counties. Although the districts are separated from one another by rugged divides, they are intimately related geologically and to gain simplicity they will be grouped under one heading in this report.

The districts are in the heart of the Cascades and are served by the main line of the Great Northern Railway; the stations of Sultan and Index corresponding to the district names. All operating properties are from 5 to 18 miles from the railroad, but are assisted in part by logging railways built up the main river valleys to tap excellent stands of timber. The cost of transportation to the railroad has most often been a serious retarding factor.

GEOLOGY

The geologic conditions met with in this area do not materially differ from those encountered in many of the mining districts in north central and northeastern Washington The older rocks are represented by highly metamorphosed belts of quartzite, argillite, and schist. These are buckled into steeply-dipping folds and have been intruded by an extensive invasion of granodiorite. On the basis of correlation with similar identified strata occurring elsewhere in Washington and in British Columbia these metamorphics are classified as belonging to the Paleozoic era, with some of the upper belts possibly passing into the Mesozoic. The intrusion of granodiorite is definitely related to similar granitic invasions in western America during the Mesozoic.

The metamorphics, forming as they do, a sort of roof over the batholith, are usually found to make up the higher ridges and peaks over the area. In other instances roof-pendants of these older rocks measuring several square miles in extent, are found penetrating down into batholith to horizons below the level of stream valleys. Such pendants were noted near the mines in both the Sultan and Index districts and the

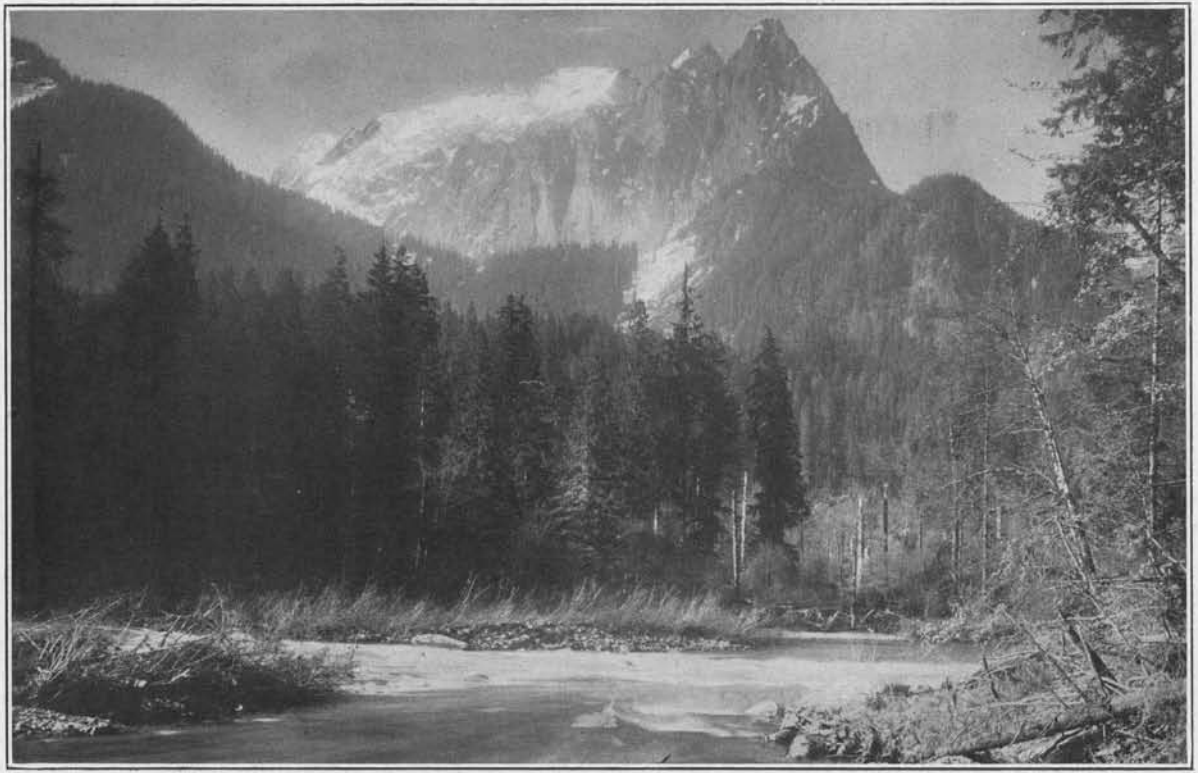
contacts between these pendants and the adjoining granodiorite are usually steep-dipping.

The ore deposits are believed to have formed soon after the intrusion of the granodiorite. They represent segregations from the cooling magma which were collected at deeper levels and injected along openings formed in the outer crust of the magma, and to a lesser extent in the overlying host rocks. Most of the deposits are found to be enclosed in the granodiorite but not at a great distance from pendants off the older rocks. They are of the type formed at intermediate depths below the surface.

Weaver* expresses doubt as to whether the ore-bodies of the Index District were derived directly from the Index Granodiorite or whether, like the ore bodies of the nearby Monte Cristo and Miller River districts, they represent mineralization from a later Tertiary intrusion. To the writer it seems simpler and more logical to regard the principal ore deposits of the Index District as the final segregations from the Jurrasic, Index granodiorite. The deposits are predominately enclosed in that rock and by reference to the geologic map of that area, it will be noted that the ore bodies are quite generally localized near the margins of the batholith, near the contact with the older intruded rocks. This phenomenon is characteristic of deposits filling marginal openings in their parent batholith. Arsenopyrite, galena, and stibnite, often carrying high gold values, are conspicuous in the Tertiary veins of the Monte Cristo and Miller River districts, but their occurrence in any horizons of the veins so far exposed is rare in the Index District. The Index granodiorite was mineralized with copper and iron sulphides, as evidenced by the minor inclusions of these sulphides occasionally found entrapped in the granodiorite. The existence of magnetite and tourmaline in the Copper Bell deposit stamps it as a high-temperature deposit, thus indicating an immediate cooling magma during the period of ore deposition.

The Monte Cristo and Silverton areas adjoin the Index and Sultan districts on the north. They have been relatively

*Weaver, C. E. Geology and Ore Deposits of the Index Mining District: Wash. Geol. Survey, Bull. 7, pp. 66-69, 1912.



Index Mountain, near Sunset Copper Mine.

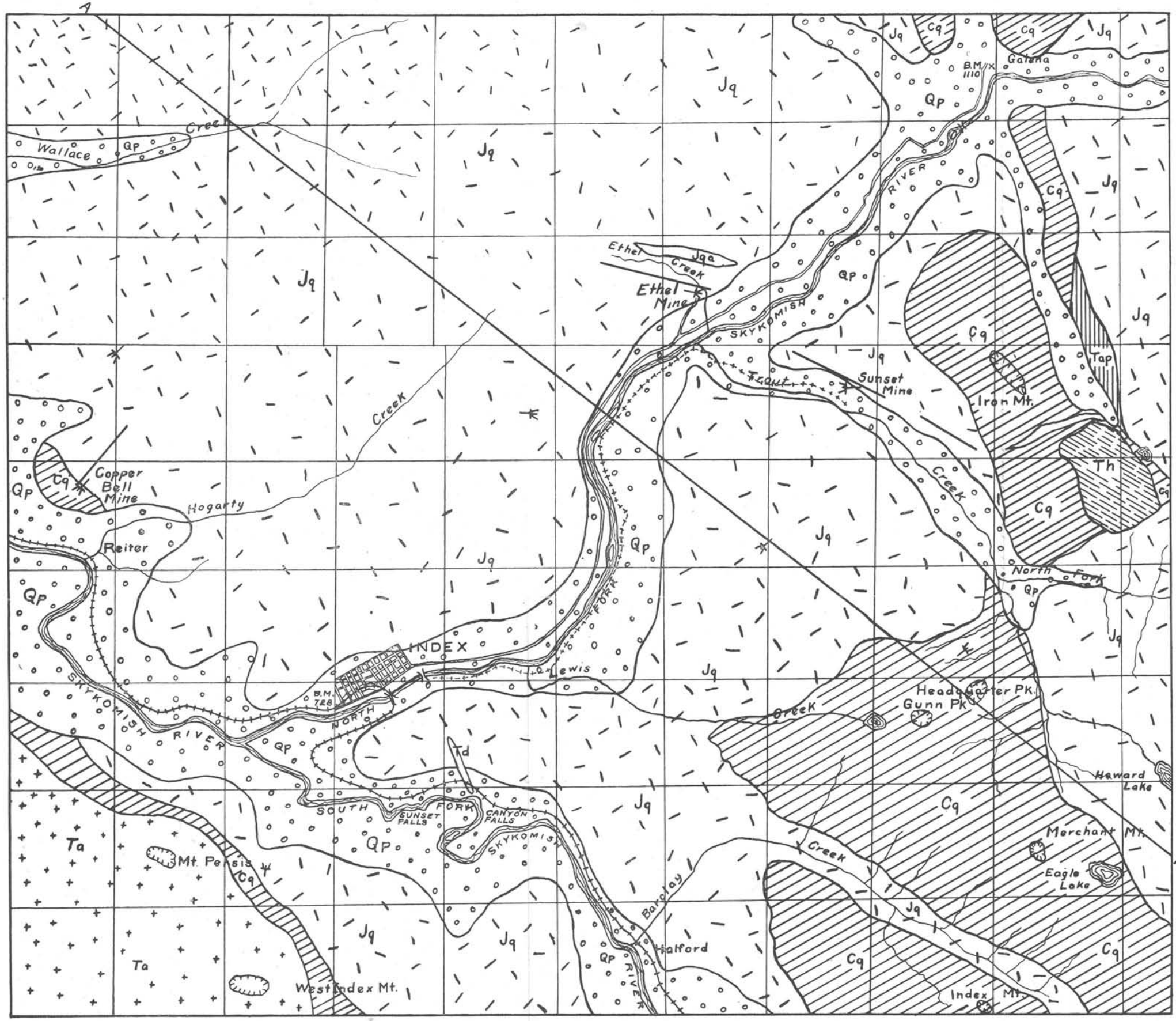
inactive for the past 20 years and were not visited. At one time they were the most active camps in the State and are credited with a production of $7,000,000, chiefly in gold, but have been held back by a number of adverse factors, which will not be detailed here. The gold ore occurs in a complex mixture of sulphides of copper, iron, arsenic, and antimony, which presents serious metallurgical problems. It is the belief of many who are familiar with local conditions, that several of the deposits in these idle districts will ultimately be worked at a good profit.

It was not found possible, before the close of the 1920 season, to visit several properties at the head of Sultan Basin. Of the mines in this section the Florence Rae, Sultan Group, Forty Five, and Mystery, have received sporadic development during the past 20 years. A crew of three men doing development work at the Sultan Group, represented the only activity during the summer of 1920. Later in the year the Florence Rae was taken under lease and bond by a group of Seattle men, and it is probable that this deposit will be further developed during the summer of 1921. Later mention is made in this report of the Forty Five, Sultan Group and Mystery properties.

SUNSET COPPER

General Features.—During recent years the Sunset Copper Mine has been the most consistent producing property in the Cascades. A 125-ton concentrating mill was completed on the property, August, 1918, and has been operating steadily up to December, 1920, with the exception of a period from February, 1919, to August, 1919, when a depressed copper market forced the closure of many copper mines. Previous to 1918 the mine was worked intermittently, and the high-grade ore was sorted and shipped without concentration.

The mine is on Trout Creek, six miles northeast of the town of Index, of the Index Mining District, Snohomish County. The main line of the Great Northern Railway passes through Index and the logging railroad of the Index-Galena Lumber Company is constructed from the town to the mine, thus furnishing favorable transportation facilities. The Lumber Company operates daily trains to its Camp No. 2 at the mouth of



LEGEND

QUATERNARY

Qpo — Pleistocene
Glacial drift, alluvium and stream gravels

TERTIARY

Td — Olivine Diabase

Th — Howard Arkose

Ta — West Index Andesite series

Tap — Andesite Porphyry

JURASSIC (?)

Jqa — Granodiorite Aplite

Jq — Granodiorite

CARBONIFEROUS (?)

Cq — Gunn Peak formation
Quartzite, slate and schist

Veins

SECTION ALONG A-A

GEOLOGIC MAP OF INDEX DISTRICT

Recopied from Washington Geological Survey Bulletin No. 7.

Camp of the Sunset Copper Company. (1) Portal of the main adit, (2) and (3) bunkhouses, (4) boarding house.

Trout Creek. A switch-back line continues up the mountain side to the mine, and the Lumber Company handle cars to and from the mine.

The Sunset Lode was first discovered by Arthur C. Egbert, June 18, 1897. The original Sunset Mining Company was organized July, 1897, with E. M. Egbert, President; John McManus, Secretary; and Nicholas Rudebeck, General Manager. Since that time the ownership of the company has changed many times. In recent years George Stevenson has been President of the Sunset Copper Company and it was under his direction that the concentrator was built and the mine put on a shipping basis. During 1919 he retired from the Company and E. A. Sims became President and General Manager. J. G. Sheppard is Superintendent.

Development.—The Sunset Mine has by 1920 been developed through a maximum horizontal range of 1,400 feet and a maximum vertical range of 490 feet. All ground within this area has, however, not yet been explored. (See Figure 24.)

The mine is worked through an adit crosscut driven northward 600 feet to intersect the Sunset lode 290 feet below the outcrop. On this level the lode has been explored 700 feet both

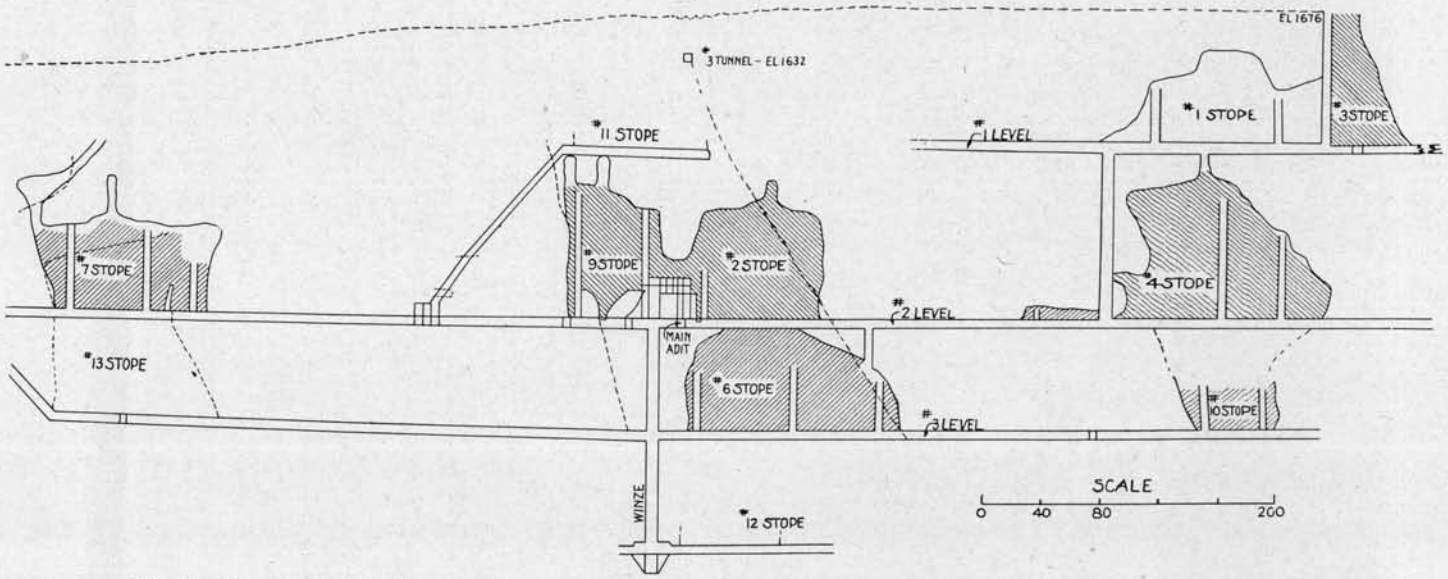


Fig. 24. Longitudinal section along plane of vein, to show development of Sunset Copper Mine, Index District.

east and west of the adit. Stopes and raises connect with an upper level which has its portal on the hillside above the camp.

Where the main adit encounters the lode a station has been cut and a winze sunk 200 feet below the level. At the first level in this winze 100 feet below the collar, 1,000 feet of drifting has been accomplished in order to get under the downward projection of the three ore-shoots exposed on the adit level. Large stopes are now opened above this level. At the bottom of the winze a new level was started during 1920 in order to develop additional stoping ground.

The Copper King lode is 475 feet north of, and practically parallel to the Sunset. The working adit is continued past the Sunset lode to reach the Copper King ore-body. This second lode has recently received several hundred feet of new development work from the main adit level.

Description of the Deposit.—The Sunset deposit might better be called a lode than a vein, for it consists of a series of large lenses of copper ore lying along a shear zone which traverses the granodiorite country rock. The strike of the zone is south 65° east and the dip averages 86° toward the north. The predominant characteristic of the lenses is that they pinch and swell both along the trend of the lode and along its downward projection. Connecting the ore lenses along the shear zone are narrow streaks of gouge and shattered altered granodiorite. In some instances these narrow streaks must be followed several hundred feet between lenses.

In tracing out the origin of the deposit it is found that the field evidence warrants the assumption that the original fracture plane through the granodiorite was undulating, rather than exactly true, and movements along the plane of the fracture threw the walls into such juxtaposition that at certain points bulged openings were created along the zone. Connecting these were constricted gouge-filled streaks. When the ore minerals were introduced from below they naturally filled these bulged openings and the adjacent fractured country rock, with chalcopyrite, pyrite, bornite, quartz, etc. Along the constricted sections of the zone the gouge matter dammed back the ore-carrying agents and they worked along

the fractures in the granodiorite and replaced it in part with the ore minerals and gangue. The shearing movements along the zone, that served to develop the receptacles for the ores, left behind as evidence of their forces, deep striations in the wall rock and streaks of serpentine and talc developed through the dynamo-metamorphism of the granodiorite. A thin-section of the altered granodiorite contained in the lode, shows the feldspars deeply altered to kaolin and the hornblende largely converted into chlorite.

The foot-wall of the lode is usually well developed while no definite hanging-wall exists. The width of the lode varies from a few inches to a maximum of 16 feet. Usually the best ore is found along the foot-wall and leading out into the granodiorite from this are numerous sympathetic fractures along which the ore solutions have worked to partly replace the country rock. The ore-shoots are naturally found in the open and fractured ground along the zone and the mineralization along these shoots is sufficient to permit opening stopes 5 to 10 feet wide, with the general run of the ore broken from these stopes averaging from two to six per cent copper.

The shear zone is remarkably persistent and should be expected to extend well below the present deepest workings. Considerable "dead work" is a necessary prerequisite to the development of new ore lenses, for, since diamond-drilling is seldom practicable for the exploration of an ore body of this nature, it is necessary to drift on the shear zone until new ore lenses are encountered. Three major ore-shoots have so far been developed, all of which have a pronounced rake toward the east. The ground to the east of the adit crosscut has been quite thoroughly explored and future development work should be directed west of the adit where it is reasonable to believe that new ore-shoots may be developed.

On the third level 300 feet east of the winze a six-foot diabase dike follows, for a short distance, the hanging-wall side of the lode, then leaves the ore body and trends southwest through the granodiorite. The dike shows in the stope above this level. The position of the dike with respect to the vein suggests that it is post-mineral.

Mineralogy.—Chalcopyrite and bornite are the principal ore minerals. Bornite is found mixed with the chalcopyrite from the surface down to the lowest level. Massive bodies of these sulphides are often encountered. In the upper workings the oxide and carbonates of copper have been developed in a limited way. The Copper King vein, however, has suffered more intense alteration. Where it is cut by the main adit, 400 feet below the outcrop, the foot-wall side of the vein is clayey and the sulphides are so severely altered to black copper oxide that they offer difficulties to a good mill recovery. This portion of the Copper King deposit is more open and the alteration has naturally been effected by downward percolating surface waters. Small amounts of molybdenite appear at various points associated with the ore and a small fracture, mineralized with this sulphide, is cut by the main adit at a point midway between the Sunset and Copper King lodes. Quartz is sparingly present in the lodes as a gangue mineral. Small quantities of native silver and copper have been found in the Copper King deposit.

It has been suggested that the massive bornite occurring in certain stopes of the Sunset Mine might be the product of secondary enrichment by downward percolating waters, and thus fade out in the lower horizons of the deposit. A study of the ores in polished section under the microscope reveals an intimate intergrowth of the chalcopyrite and bornite, which indicates that the bornite was deposited practically contemporaneous with the chalcopyrite by hypogene solutions (primary).

Copper King Lode

This deposit is 475 feet north of the Sunset lode and trends practically parallel to it. The main adit crosscut was extended to the Copper King vein several years ago but unfortunately it has not yet been well explored. At the time of examination (July, 1920) a stope was being broken above the point where the adit encountered the deposit. This stope was at that time up 90 feet above the sill-floor; the pay-shoot had been developed for a length of 80 feet along the strike and the average width of the stope was six feet. The characteristics of the vein

are simiar to the Sunset with the exception that it has been severely altered by infiltrating surface waters. Along the foot-wall there is a 12-inch streak of clayey ore well mineralized with black copper oxide. The remaining width of the lode has not suffered similar alteration and chalcopyrite and bornite predominate. When milling, an effective recovery cannot be made of the oxides. During mining they crumble and make up a portion of the fines; by passing the ore from this stope over a grizzly it is probable that the undersize will catch the major portion of the oxides and thus make a shipping product.

At a point on the hillside 400 feet above and approximately 1,000 feet west of the main adit, a crosscut has been driven 160 feet to the Copper King vein, which it intersects at a point 130 feet below the outcrop. The lode here shows a width of 10 feet of milling ore. The weathered streak of oxide is similarly present as in the lower workings. A 16-inch diabase dike follows the foot-wall of the lode at this particular exposure but is not exposed in the lower workings. The outcrop of the lode is easily traceable for several hundred feet on the hillside above the tunnel. At several points where it has been opened by shallow cuts the mineralization is decidedly encouraging for surface croppings. In these openings about 50 per cent of the values occur in the sulphide form as bornite and chalcopyrite, while the remainder are in the form of malchite and the black oxide of copper. It is probable that future exploration work will prove the Copper King lode to be as important as the Sunset. Certainly the surface exposures merit deeper exploration work toward the west on the Copper King. This can apparently best be accomplished by crosscutting to the Copper King vein from the extreme west workings on the Sunset vein.

Description of the Concentrator.—The Sunset concentrator was completed August, 1918, and has a capacity of 125 tons per 24 hours. It is well equipped and is making an extraction of 90 per cent of the values. E. C. Morse is superintendent.

The breaker house, which is separated from the mill proper, is 400 feet from the portal of the mine adit. The ore

Concentrator of Sunset Copper Mining Company.

is trammed to a 100-ton head bin from which it is drawn over a grizzly set to 1½ inches, and the oversize fed to a Blake jaw crusher. The grizzly undersize and crushed ore drops onto a 14-inch belt conveyor and is elevated to a 100-ton bin at the head of the mill.

The ore as drawn from the mill bin is conveyed to a set of 16″ x 24″ Traylor rolls, set to one-half inch. A 12-foot bucket elevator lifts the material to a 6′ x 5′ Allis-Chalmers ball mill. This mill uses hammered steel balls and a grate discharge. An experiment of using steel rails for ball mill liners has proven highly successful and has materially reduced the cost of liners. The ball consumption averages about two pounds per ton of ore.

The ball mill crushes to approximately 20-mesh for table feed and discharges to a bucket elevator which elevates to a cone thickener on the table floor. The thickened feed goes to a box classifier where it is divided between four Deister Simplex tables, and the slimes overflowing the classifier are sent to a double-deck Wilfley table. The table concentrates average 30 to 40 per cent copper. These are sent to a dewatering tan preparatory to shipping

The table middlings and tails go to a Dorr Simplex classifier. The classifier overflow is sent to a Dorr thickener, while

the sands are delivered to a 6′ x 5′ Colorado Iron Works ball mill. This mill is used for re-grinding preparatory to flotation. It works in closed circuit with a second Dorr drag-classifier and the overflow from this classifier and the thickened slimes from the thickener tank are elevated to the flotation cells. The overflow from the Dorr thickener is pumped back to the tables, where it is used as wash water.

A Zeigler and a K. & K. flotation machine are used as roughing cells. The tails from the roughers go direct to waste, while the concentrates are sent to a small Callow cell used as a cleaner. The tails from the Callow are returned to the flotation circuit while the concentrates are delivered to a small thickener. The thickened concentrates are elevated by a drag-classifier to a 6′ x 4′ Oliver filter. A compressor of 120 cubic feet capacity and a small blower furnishes air to the flotation machines and the Oliver filter. The dewatered concentrates, carrying about 12 per cent moisture, drop from the filter direct to the concentrate bins ready for shipment. The flotation concentrates assay 28 to 33 per cent copper.

A well-equipped assay office is maintained and a systematic check over the mine and mill products is kept daily. The total milling cost during 1920 was reported as $1.50 per ton milled.

COPPER BELL

This deposit (also known as the Bunker Hill) ranks second among the properties of the Index District, only to the Sunset, in point of development. During 1905 the company erected a 50-ton concentrator and also a well-designed copper reverberatory furnace. Much surface and mine development work has since been accomplished. No important development has been undertaken during the last ten years, due to the failure, so far, to develop sufficient ore for profitable mining. A watchman is kept at the property and the camp is still in fair repair.

The holdings are five miles northwest of Index, or one mile west of and 1,000 feet above the siding of Reiter, on the main line of the Great Northern Railway. The camp is connected with the railway by a narrow-guage surface tram.

The deposit is near a plunging contact between the older intruded schist and quartzite, with granodiorite. The plane of contact sets at a steep angle, and near the mine workings, trends north 40° west. The ore occurs as irregular replacement lenses along a shear zone in the granodiorite. Heated ore carriers ascending along this zone have sought out the best cavities and there partly replaced the granodiorite with chalcopyrite, bornite, pyrite, magnetite, quartz and calcite. Along the zone the femic minerals in the granodiorite are chloritized and the feldspars deeply altered to sericite and kaolin. A thin-section study of the material by Campbell* revealed the presence of well-shaped crystals of tourmaline. Since magnetite is prominently associated with the ores, the discovery of a second high-temperature mineral furnishes cogent evidence that the ore body should be classified as a high-temperature deposit, and that it is directly related to the granodiorite batholith which encloses it.

The deposit is explored by a long adit which follows the shear zone, 2,000 feet in a northeasterly direction. Six hundred feet from the portal a short crosscut to the northwest encountered an ore-shoot roughly cylindrical in outline. Stopes were driven up to daylight on this ore and a winze sunk below the adit level. This is now under water but it is reported that the ore lens pinches down to a small streak in the bottom of the winze. Above the present face of the long tunnel a short upper tunnel discloses a smaller lens of ore. Some years ago the deposit was prospected with diamond drills. The log of these holes is not available; however, it is known that some of the drill cores showed copper mineralization.

AMERICAN ARSENIC COMPANY

The high price existent for arsenic during 1920 encouraged the organization of the American Arsenic Company, for the purpose of developing a deposit of realgar (arsenic monosulphide) near Reiter, Snohomish County. The head office of the company is at Burlington, Washington. The mine is 2,000 feet above, and four miles by trail, north of Reiter, a station on the main line of the Great Northern Railway.

*Campbell, Roy A. Thesis Study, Univ. of Wash. College of Mines, 1920.

The arsenic occurs principally as realgar with subordinate amounts of orpiment; slight incrustations of the white arsenic oxide were noted in the oxidized portion of the deposit. The ores fill a small fracture plane in the granodiorite country rock. The main fracture has been developed by a drift 150 feet in length and this development shows the fracture to trend north 20° east and dip 70° southeast. The arsenic minerals from the entire filling for the fracture, which varies in width from 2 to 12 inches, with five inches as an average. There are also several minor veinlets of ore which fill fractures trending off at various angles from the drift. A small creek which cascades down the hillside, near the workings, has stripped away the surface material and exposed several other small veinlets of realgar averaging one to three inches in width and trending for several hundred feet up the mountainside. Evidently the granodiorite in this vicinity developed a number of small but fairly continuous fractures which were used as vents for gases of arsenical sulphide. Near the roof of the granodiorite these gases were chilled and the material deposited as a filling for the fractures.

The ore from the largest fracture developed is of sufficient width and quality that, while a favorable market exists, it could be sorted and shipped direct. It is the plan of the management to subject the lower grade material to concentration. During July, 1920, a 15-ton mill was completed at the property. The mill is 300 feet below the mine workings. Water is taken from a small creek at a point near the workings and delivered to the mill through a six-inch wood pipe, thus furnishing sufficient power to operate the mill. The crude construction of the mill is justified by the limited size of the deposit and the uncertainty of the arsenic market. In fact, under the existing conditions it would seem more desirable to take immediate advantage of the favorable market and center all efforts on the sorting and shipping of the high-grade ore.

The mill is arranged so that the ore is first broken to one-half inch in a 9″x5″ Dodge jaw-crusher and then passed to a 8″x36″ Hardinge ball mill where it is ground to 60 mesh

for flotation. In order to secure a high-grade concentrate the ore is sent to three rougher flotation cells and the concentrates thus made are successively cleaned in three cleaner cells. The final concentrates are then sent to settling tanks for dewatering.

KROMONA

In a glacial amphitheatre which form the basin at the head of the South Fork of the South Fork of Sultan River, are situated the nine claims of the Kromona Mining and Smelting Company. These are in the Sultan Mining District, ten miles by air line northeast of the town of Sultan, the exact location being sec. 13, T. 28 N., R. 9 E. The property is reached from Sultan by an 18-mile journey. The first six miles is over an excellent gravel road, the next seven miles are covered by the old Forty-Five Mine road. This is a corduroy road and is suitable only for pack animals or light wagons. At the summit a trail turns off from this road and trends five miles in a southeasterly direction to the mine camp.

The property was prospected some 20 years ago and was then known as the Scriber and Jones claims. It was re-located by the present company during 1916 and they have since carried on a limited amount of development work each summer. This work has so far been largely confined to building five miles of trail and the construction of good camp quarters. Several cuts have been opened on the deposit, and the company now plans to concentrate all work during the next few years on the actual exploration of the deposit.

Geology.—Along the trail leading to the camp were noted exposures of both light and dark-colored argillites, which have been highly metamorphosed and compressed into steeply dipping folds. Near the mine are exposures of impure quartzite, the beds exhibiting a strike of N. 25° W. and a nearly vertical dip. A contact between the quartzite and granodiorite was observed in Kromona Gulch, 500 feet below the workings. The plane of contact stands nearly vertical and shows no evidence of mineralization. The ore deposit is enclosed in granodiorite but is near the marginal contact with the impure quartzite. Southeast from Kromona Gulch, granodiorite outcrops

for a considerable distance. The granodiorite in the vicinity of the deposit exhibits many angular inclusions of the quartzite. During the intrusion of the granodiorite these were stoped off from the older adjacent rocks and only absorbed in part by the molten magma.

The geologic conditions in the area observed were found to be analogous with those of the Index District, six miles southward by air line, but separated from the Sultan District by high barrier mountains. The argillite and quartzite are believed to be of Paleozoic age and are the oldest formations in western Washington. They were intruded during the Mesozoic era by the granodiorite and it was from this intrusion that the ore-bearing solutions were derived.

The Deposit.—The ore body is exposed along the floor of a small gulch which drains that portion of the mountainside. The small stream which occupies the gulch has found that the sulphides yield more readily to erosion than the country rock and hence has cut its channel along the trend of the vein. The deposit is exposed at intervals along the creek bottom for a distance of 600 feet and no doubt if the wash and vegetation were removed it would be found to have a greater length. The deposit can better be called a lode than a vein, for it consists of a series of copper sulphide stringers laced through a shattered zone in the granodiorite. The mineable ore varies from a width of one foot to a maximum of ten feet exposed in one open cut; the average width of the deposit as now exposed is about 30 inches. Considerable quartz is associated with the sulphides, yet the granodiorite country rock intervening between the stringers forms the principal gangue. The ore minerals are chalcopyrite, bornite, pyrite, while specks and flakes of molybdenite are conspicuously associated with the deposit. The strike of the lode is north 60° east and the dip nearly vertical.

One thousand feet above camp, at an elevation of 3,500 feet, a 70-foot tunnel was driven years ago by the former locators. Through a failure to correctly interpret the deposit this tunnel follows a false wall which trends away from the deposit and the work is of no value. At the 3,900-foot elevation the present

Outcrop of Kromona copper vein along floor of small gulch.

company has opened a small cut which shows the mineralized zone with a width of ten feet. On the north side of the cut there is an 18-inch quartz vein, and roughly paralleling this are a series of good-grade sulphide stringers. The entire exposure should average between two and four per cent copper. The ore is reported to also carry one to two ounces of silver and one to four dollars in gold to the ton. This cut was the

best showing observed, and it should be prospected more extensively. A drift on the ore from this point would rapidly gain mining depth under the steep hillside, and such work would quickly determine the merits of the deposit. Above the cut the deposit leaves the gulch and is covered under heavy hillside wash.

In order to visit an exposure of ore in a natural cave situated in an adjoining glacial basin, the climb was continued up the hillside until a pass was reached at an elevation of 4,700 feet. From this point a descent was made 300 feet down the steep basin wall at the head of the South Fork of Sultan River until the cave was reached. The cave is 8 feet wide, 12 feet high and 25 feet long. It is enclosed by granodiorite and appears to be a natural opening except that it has been lengthened by some prospector exploring it mineral showings.

Along the roof trends a number of rich stringers of chalcopyrite and bornite partially altered to malachite and azurite. The mineralized zone is four feet wide and can be observed trending up the sheer wall of granodiorite above the cave. On the basin wall below the opening the downward trend of the mineralization was not located. The trend and position of the mineralization indicates that this is very probably an extension of the deposit exposed on the opposite side of the ridge.

FORTY-FIVE

Were it not for the serious transportation conditions that fetter this property, it would, according to authentic reports, be classed as one off the regularly producing mines of the State. The deposit is on Williamson Creek, about two miles by air line from Silverton. The rugged nature of the country permits only a trail from Silverton, which passes through Marble Pass at an elevation of 4,190 feet. During 1897 the company built an aerial tramway to Silverton but just about the time the tram was completed a washout occurred upon the branch railroad, and transportation was interrupted for several years. A puncheon wagon road was then built from the town of Sultan, on the Northern Pacific Railway, to the mine, a distance of some 30 miles. This road was completed

at a very heavy cost but, it rough corduroy nature permits its use only for light wagons or pack trains. The road now serves as the only means of transportation into the rugged Sultan Basin District, and the cost of the long haul prohibits the shipment of any but the richest ore.

The control of this property, sometimes spoken of as the Deu Pree Lode, is now reported to be in the hands of the Lydia E. Pinkham Estate. The following description of the property is abstracted from an older report.*

"The ore body is a fissure vein cutting through diorite, and strikes a few degrees to the north of west, dipping south at an average angle of 80 degrees. The average width of the ledge is not far from six feet and the mineralization is quite uniform, there being no distinct pay streaks; the gangue material is largely quartz, much of it somewhat decomposed. Although the chief values are in silver and gold the ore is very base, carrying an average of four per cent galena, and considerable amounts of zinc blende and iron pyrites, besides some chalcopyrite, arsenopyrite and tetrahedrite. The greatest values of both the precious metals are found in the galena, although some of the silver is associated with pyrite; near the surface considerable ruby silver and the antimonial variety (pyrargyrite) are encountered; often in large enough quantities to form handsome specimens."

In spite of its isolation, the mine is credited with shipments totalling several thousand tons. It has been worked at various times during the last 20 years under the direction Nate Jones. The mine is equipped with ordinary mining machinery which is operated by water power. Five thousand feet of development work has been accomplished.

Apparently profitable operations must be preceded by the installation of efficient transportation facilities. If the topographic conditions between the mine and Silverton are at all favorable for aerial tramway transportation, this would be decidedly more economical than the long wagon haul to Sultan.

*Landes, Henry. The Metalliferous Resources of Washington, except iron: Wash. Geol. Survey, Vol. 1, part 2, 1902.

MYSTERY

The Mystery is one of the several properties near the head of Sutan Basin which could not be visited. The following data are abstracted from information furnished by David Boyle, one of the owners:

The property is reached over the old Forty-Five Mine road, and is on the North Fork of the Sultan River, at a point 19 miles from Startup, the nearest railway station. Development consists of 350 feet of tunnel work and 250 feet of open cuts. Three distinct parallel copper veins are said to outcrop on the holdings. These average in width from 3 to 12 feet, with certain showings which average five per cent copper. Mr. Boyle further states that one of the open cuts exposes a 12-foot face of massive copper ore.

The report of the occurrence of lenses of chromite on the same group of claims is decidely interesting, for it suggests the existence of ultra-basic intrusives in this area.

SULTAN GROUP

This property was not visited, and the following information is furnished by Ira W. Hicks, manager of the Sultan Group:

The holdings of 10 claims have been developed intermittently for the past 20 years. During recent years a small crew has been employed each summer on development work. The isolation of this and several surrounding properties has seriously retarded mining progress.

The claims are at the head of Sultan Basin, at an elevation of 4,300 feet, on the west slope of the Crested Buttes, T. 28 N., R. 10 E. They are connected with Sultan, the nearest railroad point, by 27 miles of wagon road. Twenty miles of this is the Forty-Five Mine road of puncheon construction. In the event that sufficient ore is developed, the mine would find more efficient transportation by an aerial tramway eastward to Mineral City, on Silver Creek. From Mineral City a short wagon haul would deliver the ore to the logging railroad of the Index-Galena Lumber Company.

In a zone 1,000 feet wide there are seven practically parallel veins outcropping. These zones fill brecciated fractures

through granite. They have an east-west trend and dip 80° to 85° toward the south. Chalcopyrite and pyrite are the chief ore minerals and they carry minor values in silver and gold. Recent development work has been confined to one of the strongest veins, and this has been explored by a 100-foot drift on the vein a short distance under the croppings; also a crosscut tunnel which has been driven 465 feet to the vein at a point 418 feet below the upper tunnel. The upper tunnel exposes a streak of high-grade chalcopyrite, two to three feet wide, which averages 5 to 12 per cent copper and two to four ounces of silver; the remaining width of the drift exposes low-grade vein matter averaging one to two per cent copper. The lower tunnel intersected the vein November, 1920, just at the opening of the winter season, and this fact caused further exploration work to be postponed until the summer of 1921.

The property is equipped with a small Ingersoll-Rand compressor and good camp buildings. Water power is available near the workings and timber is plentiful.

KING COUNTY

MILLER RIVER DISTRICT

GENERAL FEATURES

The mining properties of this area are to the southward of the station of Miller River (formerly Berlin) on the main line of the Great Northern Railway, northeastern King County. The principal properties are reached by roads, trails and trams which extend up Money Creek and Miller River.

The first discoveries were made during 1892, when surveys were run to locate the route of the Great Northern Railway across the Cascade Range. No important shipments were made until 1897, and between the years of 1900 and 1905 the climax of mining activity was reached. Since that time operations have been intermittent.

During 1920 the Apex was the only mine in the district that was showing activity. Properties such as the Mono, Cleopatra, Coney, Dawson and Seattle-Cascade have each received considerable development work and several have made small shipments. Limitations on field work prevented an examination of these inactive properties.

When the Apex Mine was visited (May, 1920) there were five feet of snow remaining at the mine and two or three feet in the valley bottom, hence very little of the surface geology could be studied. Along Money Creek bold exposures of granodiorite persisted. This is noticeably finer-grained than the Index granodiorite and Smith,* who studied the petrology of the area corelates this intrusion with the Snoqualmie batholith of late Tertiary age, described by Smith and Calkins† in their report on the Snoqualmie quadrangle, 15 miles south of the Miller River District. The deposits in this district are related to this Tertiary batholith and are much later in age than the deposits of the Index District, which are but six miles by air-line north of Miller River. These two batholiths must merge into each other at some point between Miller River and Baring, and their relations would warrant more detailed study.

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*Smith, Warren S. Petrology and Economic Geology of the Skykomish Basin, Washington: Columbia School of Mines Quarterly, V. 36, No. 2, January, 1915, p. 154.

†Smith, G. O., and Calkins, F. C. Folio 139, U. S. Geol. Survey, 1906.

Several miles up Money Creek there are rock slides which originate from the higher ridges. These slides show float of limestone and quartzite identical in physical appearance with the older roof rocks of the Index District.

The ore minerals are chiefly chalcopyrite, arsenopyrite (gold-bearing), pyrite and galena, with minor ore minerals of argentiferous stibnite, arsenolite, sphalerite and molybdenite. The gangue is quartz, calcite, and the altered granodiorite.

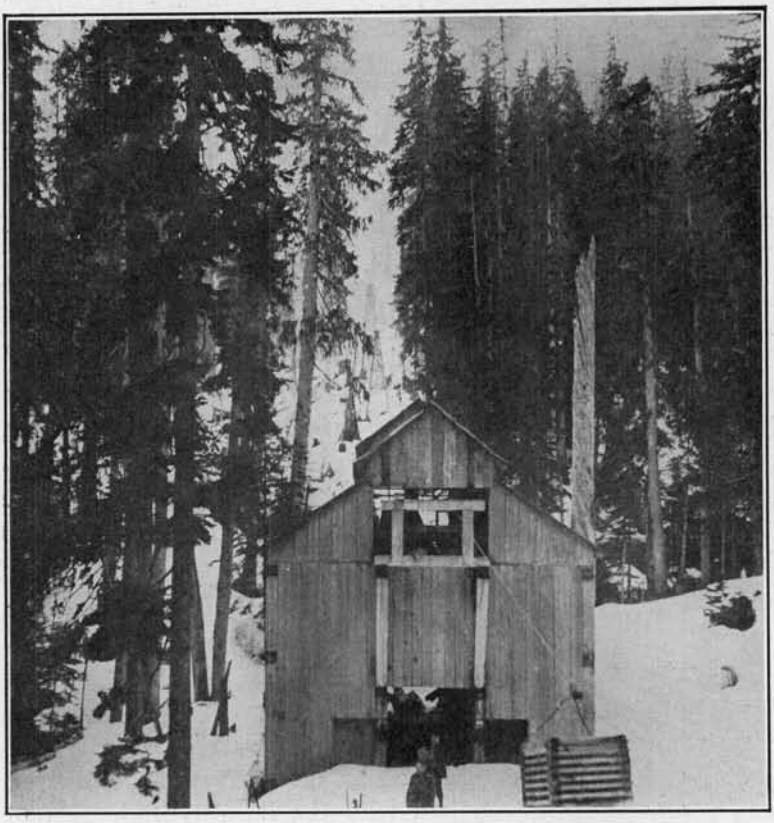
The deposits are replacement veins occurring along narnow fractures traversing the granodiorite. Smith‡ notes two systems of fracture, the major veins trending either approximately north 45° east or north 78° east. The mineable ore along the fracture is usually quite narrow in width but is persistent along the strike and downward projection of the vein.

The ores are refractory to early-day concentration methods but should be expected to yield to modern ore-dressing practice, provided thorough-going tests precede mill construction.

APEX

History.—The Apex deposit was discovered during 1892 by John Maloney, an engineer for the Great Northern Railway, who was engaged in surveying a route across the Cascade Range. It was one of the first discoveries in the district, and the property is credited with the largest production of any mine in the Miller River District. After the railroad was built as far as Berlin(now Miller River) shipments of ore were, for many years, brought to the railroad by pack-trains. Later the mine was sold to a company organized and managed by Abner Griffin, who expended well over $100,000 in developing the mine and equipping it with transportation facilities. After several years of operation, during which much sorted ore was shipped, the venture proved unsuccessful and operations were suspended. The mine was then dormant until 1917, when it was re-opened under lease and bond by William J. Priestly, who has since made several intermittent shipments. Smelter returns on a shipment of 237 tons of sorted ore gave a gross value of $9,734.00 or $41.07 a ton, the values chiefly in gold.

‡Smith, Warren S. Petrology and Economic Geology of the Skykomish Basin, Washington: Columbia School of Mines Quarterly, V. 36, No. 2, January, 1915, p. 154.



Lower tram terminal, on Money Creek, of Apex Gold Mines Company.

Location.—The mine is in the northeastern corner of King County, near the headwaters of Money Creek, T. 26 N., R. 10 E., six miles southwest of the Station of Miller River, on the main line of the Great Northern Railway. From Miller River a 36-inch guage railroad extends up Money Creek, six miles to the lower tram terminal. The upper terminal of the aerial tram is perched on the east valley wall at an an elevation of 3,150 feet, approximately 1,000 feet above the lower terminal.

Description of the Deposit.—The ore occurs in a narrow but exceptionally persistent fissure through the granodiorite. The strike of the vein is east-west and the dip 65° S. The vein filling varies in width from two to six feet, and consists of arsenopyrite, pyrite, galena, chalcopyrite, and quartz, replac-

ing the granodiorite, which along the fracture is soft and severely altered. Traversing this vein filling are narrow streaks of high-grade ore, not usually over 3 to 15 inches in width. Mr. Priestley reports these high-grade streaks to assay from $20.00 to $80.00 in gold. The gold is carried chiefly by the arsenopyrite. Near the east end of the pay-shoot, argentiferous galena is prominent, but farther westward it is quite thoroughly replaced by arsenopyrite. The foot-wall of the deposit is well-defined, while on the hanging-wall side, the ore grades out into the altered wall rocks and leaves no clearly marked wall.

All ore so far mined has come from one large ore-shoot which has a strike length of 500 feet and has been developed through a vertical range of 450 feet without showing any indications of nearing the bottom of the ore-shoot. On the main, or lower, level, this shoot is encountered at a point 700 feet from the portal. The ore-shoot is marked by many pinches and swells, and at points where the dip flattens out, rich lenses of ore usually occur.

There are several well-mineralized branch veins leading off from the main fissure, and when the mine is again in regular operation these should be explored for they offer an excellent chance of developing mineable ore. On the second level, in particular, there is a branch vein which carries a streak of high-grade ore, which would defray a good portion of the cost of exploration work.

Surface waters which percolate downward through the workings soon dissolve much arsenic which is later precipitated as a ripple-coating on the walls and floor of the lower tunnel as arsenolite. This material is soft when first deposited but hardens upon exposure to the air.

Development.—The deposit is developed by four levels driven at varying elevations on the steep hillside. The difference in elevation between the upper tunnel, near the outcrop, and the lower tunnel, at the tram terminal, is 400 feet. These four tunnels comprise a total lineal footage of 2,500 feet. All levels are connected by raises and chutes. The major portion of the pay-shoot above the lower tunnel has been stoped.

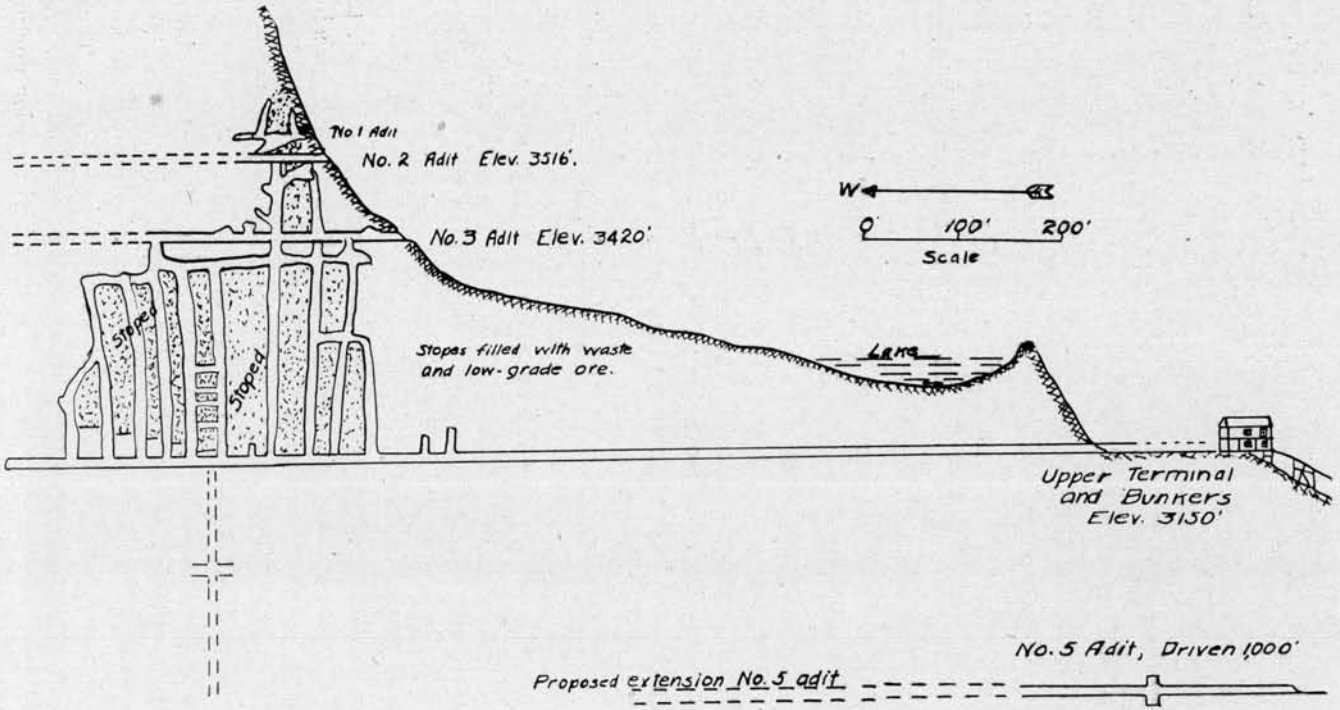


Fig. 25. Longitudinal section along plane of vein, to show development of Apex Gold Mine.

When stoping, only the high-grade ore was sorted out and the lower-grade vein material was used as stope filling. This filling has been sampled by Mr. Priestley, who reports the material to consistently average $5.00 to $7.00 per ton in gold.

To gain depth on the deposit, a lower tunnel was started at a point 300 feet below the upper tram terminal. This tunnel is now closed by a cave near the portal, but the mine maps indicate that it will have to be driven several hundred feet farther before the ore-shoot is encountered. There is every reason to believe that it will extend to this depth.

WHATCOM COUNTY

MT. BAKER DISTRICT

BOUNDARY RED MOUNTAIN*

The Boundary Red Mountain Mine is the most important gold property in western Washington at the present time. It is, however, little known, principally on account of its isolated location and the fact that the owners after two years of successful operations temporarily suspended work to await more favorable gold mining conditions.

The mine is in north-central Whatcom County, two miles south of the international boundary, and is best reached from the town of Chilliwack, British Columbia, a distance of 35 miles. The rugged nature of the country makes trail transportation necessary for the last few miles of the trip.

The property was taken under lease and bond early during 1916 by George Wingfield and other officials of the Goldfield Consolidated Mining Company of Nevada. From April 1st to December 31, 1916, they mined and milled 10,441 tons of ore having a gross value of $148,578. A similar tonnage of ore was handled during 1917 until the property closed down to await more favorable gold mining conditions. The mine and mill are in good physical condition and the properyt may well be regarded as a potential producer under normal conditions.

Development.—Mountainous topography permits the deposit to be opened on three levels by driving relatively short crosscuts from the steep hillside. No. 2 level is 140 feet lower than the upper level and is driven south 49° east a distance of 230 feet to the vein. The lower, or 500-foot level, is 300 feet below No. 2 level and is driven south 49° east 494 feet to the vein. No. 2 level is worked through a crosscut driven 230 feet to the vein. The deposit is developed by 3,000 feet of drifts equally divided among the three levels.

Deposit.—The values occur chiefly as free gold in a vein of quartz which averages from two to three feet in width, but varies from less than one foot up to seven feet. The ore-shoot

*The description of this property is compiled from notes taken by Joseph Daniels while employed by the Survey during 1917. These notes were brought up to date by E. A. Julian, consulting engineer for the company.

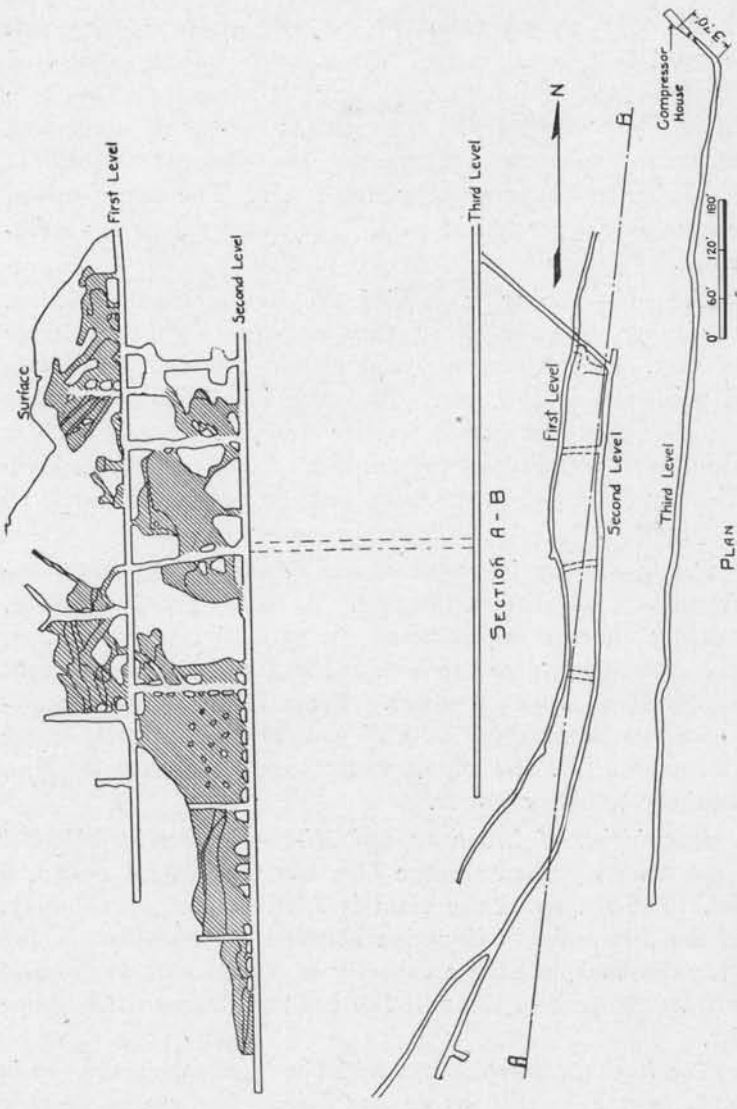


Fig. 26. Mine map of Boundary Red Mountain Mine showing longitudinal view and plan view of workings.

as developed on the 500-foot level, is 520 feet long, averages 26 inches in width and carries an average of 1.13 ounces of gold to the ton. When the vein narrows below one foot it is not mined but is left as pillars. The trend of the vein is irregular, varying from north 40° to north 13° east,

and the dip varies from 50° to 69° toward the east. The wall-rock is a dense, fine-grained diorite, separated from the vein by a thin parting of gouge. The free gold is finely divided and not usually visible to the naked eye; pyrite, chalcopyrite, pyrrhotite, and bismuth telluride(?) occur in minor amounts through the vein. The ore as mined averages $15.00 per ton in gold. The silver values are unimportant.

Methods.—Mining is carried on by overhand stoping. waste being used for filling, thus making very little timber necessary. Chutes are spaced at 25-foot intervals and raises and manways at 150 feet. The mine is comparatively wet during summer but dry in winter; during May and June it makes about 500 gallons per minute. A crew of 30 men are ordinarily employed in the mine and the normal output is 60 tons per day .

Power.—Power is generated on Silesia Creek, about one and one-half miles from the mill. A Hendy-Francis turbine, operating under a 30-foot head, drives a 25 KVA generator, which furnishes power for both the mill and mine. The mill requires about 70 horsepower. Three 25-horsepower, 2,300-volt motors drive three 9″ x 8″ compressors, furnishing air to the mine drills. An impact water-wheel, located at the mill, furnishes auxilliary power.

Description of Tramway and Mill.—The ore is delivered to the tramway from storage bins near the portal of No. 5 level. The length of the tram is 1,600 feet, approximately, and the difference in elevation between the terminals is 700 feet. The buckets have a capacity of 850 pounds of ore and the tram delivers to the mill 120 buckets during a nine-hour shift.

The buckets dump into a mill bin from which the ore is drawn over a grizzly set to one inch. The coarse rock is broken to one inch in a 7″x10″ Blake jaw-crusher, and then joiins the fines, which are by-passed to the stamp bins. Two Challenge feeders deliver the ore to a battery of 10 stamps weighing 1,000 pounds each. The height of drop varies between seven and eight inches; rate of drop, 101 times per

minute, and the height of discharge six inches, the ore being crushed to pass a 12-mesh battery screen. There are two outside amalgamation plates separated by a slight drop. The plates are both 5½′x10′ and are set with a slope of ¾ of an inch to the foot. The pulp next passes through a mercury trap delivering to a classifier. The classifier makes two products, sand and slime. The sands go to a small Marathon mill for re-grinding and are then returned to the plates. An amalgamating head is attached to the Marathon mill. The slimes are delivered to a Little Betty amalgamation barrel.

The mill treats about 60 tons of ore daily, with a recovery of 89 per cent. The mercury consumption averages two ounces for each ounce of gold. Cleanups are made approximately every 15 days. The total cost of milling for 1916 averaged $1.17 per ton. Mining for the same year cost $3.78, and the general expense totaled $1.15 per ton, which gave a total cost per ton of $6.10.

LONE JACK

This mine, which is also known as the Post-Lambert, is one of the best known properties in the Mt. Baker District and has made an important gold production. It was discover ed by Jack Post during 1897 and was one of the earliest locations in the district. During 1901 a 10-stamp mill was erected and a tramway built to connect the mine, at an elevation of 6,000 feet, with the mill 4,000 feet below. The venture met with success, but a few years later the mill was destroyed by fire and operations were not again actively resumed. It is owned by the Mt. Baker Mining Company of Portland, Oregon.

The holdings are near Twin Lakes, T. 40 N., R. 9 E., and can be reached by a trail up Nooksack River to Swamp Creek, or via Chiliwack, B. C., over 35 miles of road and trail.

Free gold with minor amounts of gold telluride, occur in a normal quartz vein which is traceable for some 2,500 feet. The average width of the vein is 30 inches, but the values are localized into pay-shoots and only portions of the vein carry commercial ore. The enclosing rock is schist. The gold is so finely divided that it is not ordinarily visible to the naked eye, and assays are necessary to approximate the grade. The average tenor of this ore is reported to vary from $15.00 to $35.00 to the ton.

PIERCE COUNTY

EAGLE PEAK COPPER

There were a number of groups of mining claims located in the near vicinity of Mount Rainier before that area was declared a National Park. Of these, the Eagle Peak Copper Mining Company is one of the few that have carried on sufficient development work to maintain its holdings. The present owners of the property located the claims during 1903 and during 1908 incorporated as the Eagle Peak Copper Mining Company. Intermittent development work has been carried on each year. The property is on the west slope of Eagle Peak, one of the prominent peaks of the Tatoosh Range. The camp is one and one-half miles above Longmire Springs and 300 yards off the Rainier Highway. The holdings consist of two unpatented claims with the north end lines near the junction of Paradise Creek and Nisqually River, and the side lines trend southward rudely parallel with Nisqually River.

One of the important features controlling ore deposition in this area is that the granite exhibits a series of distinct parallel joints or slip-planes which trend south 35° west across the granite and cut at steep angles down through it. Many of these planes have been mineralized with narrow streaks of ore. They are surprisingly persistent in length and depth for openings of such a type.

It is on one of the more favorable of the exposures that the company have opened their property. A drift 115 feet on the ore exposes a width between walls of six inches to five feet and through this runs a streak of high-grade ore which varies in width from 1 to 14 inches. The deposit exhibits several minor punches and swells; the strike is south 35° west and the dip 68° southeast. The ore is made up of chalcopyrite, bornite, pyrite and arsenopyrite. The chalcopyrite is effectively obscured by a skin-like coating of either covellite or chalcocite, this development being the result of secondary alteration. The arsenopyrite carries appreciable gold values. An 18-ton smelter shipment of ore yielded the following assays: Gold, .09 ounce, silver, 1.87 ounces,and copper, 8.05 per cent. By closer sorting of the ore it should be possible to make a higher grade shipping product. A single-rope aerial cableway has been installed to

Mt. Rainier, looking north from Tatoosh Range, view taken near Eagle Peak Copper Mine.

convey the ore to the river level, 400 feet below the workings just described.

Five hundred feet south of the upper workings and 250 feet lower in elevation a crosscut tunnel has been driven 600 feet south 50° east through the granite in an effort to crosscut the ore. This tunnel has encountered minor streaks and segregations of ore minerals. Several dikes were cut and 200 feet from the face a badly fractured zone 20 feet wide was encountered. This zone is unmineralized and yields a small flow of surface water. A careful survey should be made to determine the distance necessary to drive in order to reach the downward projection of the vein. These long crosscuts rapidly drain the resources of a small company and during the early stages of development it is far better to confine operations near the ore.

Water power developed from Paradise River is used to operate a small air compressor and accessory mining equipment.

PARADISE MINING COMPANY

The holdings of the Paradise Mining Company adjoin the south end lines of the Eagle Peak claims. Meager development work has been done on a vein that is either the southward extension of the Eagle Peak deposit or a closely allied parallel fissure. Its strike and dip are analogous to the Eagle Peak deposit and the only distinctive feature is that it is enclosed in andesite rather than granite. This raises an interesting point: The andesite formations of this area are obviously much younger than the granite. The fact that these mineralized slip-planes cross from the granite into the andesite stamps the ore as younger than the andesite and the deposits did not originate soon after the cooling of the granite.

The ore minerals are chalcopyrite, bornite, arsenopyrite and pyrite. The average width of the ore is 4 to 8 inches, but the main lead is often accompanied by minor parallel streaks of ore. It is reported that 40 tons have been sorted and shipped which assayed 10 per cent copper. A three-eigths inch aerial cable, 2,400 feet in length, connects the workings with the Rainier Highway.

OLYMPIC MOUNTAINS

The Olympic Mountain Range occupies the peninsula-like northwest corner of Washington. It rises sharply from the west shore of Hoods Canal to form the most rugged mountain fastness in the State. The sharp serrate ridges attain elevations of 5,000 to 7,000 feet above the level of the Canal and are separated by steep-sided glacier-carved valleys.

The rugged, inhospitable nature of the range, the difficulties of transportation, and the usual thick mantle of underbrush and wash below timber line has discouraged prospecting. It is only along the beaten trails that prospecting has been systematically attempted and the possibilities of finding unknown mineral resources are by no means exhausted.

No detailed attempt has yet been made to map and work out the geology of the Olympics. The predominant rocks are known to be quartzite, slate and limestone, presumably of Paleozoic and Mesozoic age. These formations are apparently directly related to similar rocks found in the Cascades, and even still further east near the Idaho Boundary. Associated with these steeply folded and metamorphosed sedimentaries are altered basic lava flows which for convenience are grouped under the general term of greenstones. No intrusive igneous rocks of the granite family are known to be exposed. Granite boulders are sometimes found in the stream valleys but they were transported there by glaciers moving down from the north.

MANGANESE DEPOSITS

It was not until the last few years that the existence of large bodies of manganese silicate in the Olympics was well appreciated. Transportation difficulties, lack of capital and the variances of the western ferro-manganese market have so far prevented any important production. The deposits, however, constitute important potential reserves of manganese ore which will ultimately be utilized.

Location

The manganese-bearing lodes have been found in a well-defined belt two or three miles wide, which lies on the south and east flanks of the Olympic Mountains, and extends from

a point south of Lake Quinalt to the head of the Dungeness River, a distance of 50 miles. Some of the better known outcrops in the Olympics are found along the north and south forks of the Skokomish River and on Copper Creek, a tributary to the Dungeness River*.

Mineralogy

The chief ore mineral is an uncommon brown, hydrous silicate of manganese which has been identified† as bementite, a manganese silicate which previously has been known only from rare occurrences. Detailed chemical and microscopic analyses by Geo. Steiger and E. S. Larsen, Jr., in the laboratories of the U. S. Geological Survey have served to definitely identify the mineral. Chemical analysis of a practically pure sample gave manganese oxide (MnO) 41.58 per cent, SiO_2 29.92, FeO 4.15, MgO 4.46, CaO 0.40, Al_2O_3 1.32, and water 8.39 per cent, thus giving a chemical formula (8 MnO.7 SiO_2. 5 H2O). Under the microscope the mineral appears as felted aggregates of fibres or plates associated with quartz, rhodonite, calcite and manganiferous calcite, these minerals being intergrown with the bementite and also deposited in veinlets that cut it. Some specimens of the bementite are cut by thin veinlets of dark brown to black amorphous neotocite (MnO. SiO_2. n H2O). Near the surface the silicate minerals have been partly altered to the amorphous black oxide, which fills the fractures and joint planes and paints the rock faces a showy black color.

Geologic Relations

The geologic relations of all the deposits are similar. The lodes occur in greenstones, argillites and limestone, all of which are regionally metmorphosed. In the limestone were found poorly preserved fossils of minute foraminifera determined by Dr. T. W. Stanton as most probably belonging to the genus Globerina, which may indicate the rock to be Mesozoic or younger. The limestone has a deep red color

*Pardee, J. T. Miscellaneous report for U. S. Geol. Survey, 1918.

†J. T. Pardee, E. S. Larsen, Jr., and Geo. Steiger. Hementite and Neocite from Western Washington: Journal of the Washington Academy of Sciences, Vol. 11, No. 2, January 19, 1921.

which is distinctive; it is very fine textured and exhibits a conchoidal fracture. Its red color should serve to make it a good marker for use when prospecting for new deposits.

APEX

The Apex Mine is near the North Fork of the Skokomish River, six miles above Lake Cushman. The mine camp is near the river and the deposit is 5,000 feet by air line up the mountainside and 1,500 feet vertically above the camp. It is reached by trail suitable only for men or pack animals.

The ore-body is cut by a small mountain stream and the solid ore is exposed on both sides and in the bottom of the creek. Beyond the stream the formations are covered with underbrush and 3 to 12 feet of hillside wash. Test pits through this have exposed the ore at a distance of 200 feet back from the creek—undoubtedly the ore extends still further.

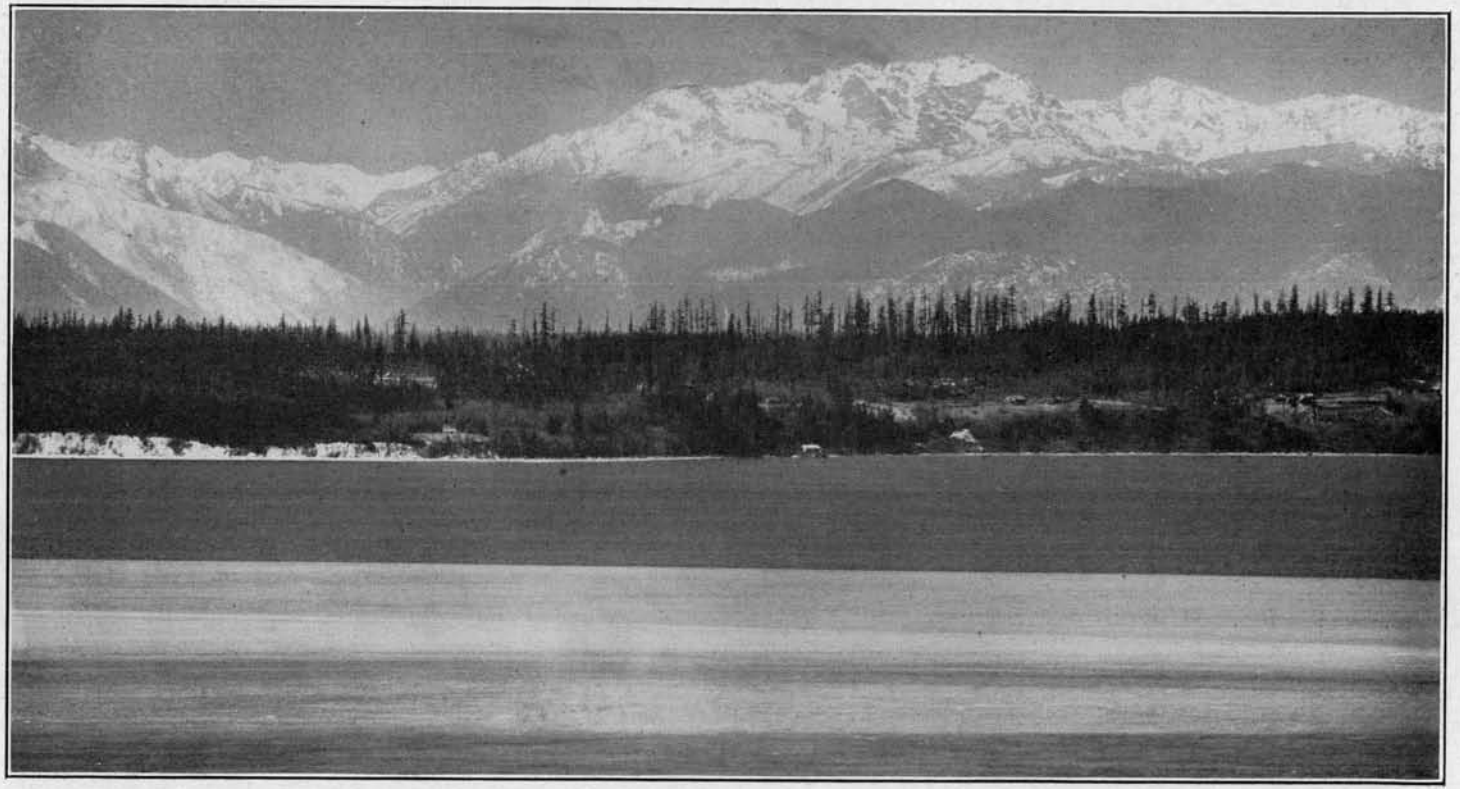
The ore-body as exposed by the water has a width of 15 feet and is opened to a depth of 30 feet. The crude ore averages 29 to 35 per cent metallic manganese, but by hand-sorting it should be possible to raise the grade. (See figure 27 for geologic associations). An important tonnage of ore could be cheaply mined at this deposit by open quarry methods. It would require a tramway one mile in length to deliver the ore at the foot of the mountain. Marketing conditions should be thoroughly studied before making such an installation.

The holdings are now under lease to the Mt. Elinor Manganese Mining & Smelting Company of Seattle, which has a small crew at the property.

TRIPLE TRIP

The Triple Trip deposit is approximately 200 feet above the river camp of the Apex Company. It is developed by 300 feet of tunnel work. Apparently, the failure to understand the position of the deposit caused much of the work to be valueless.

The manganese occurs as a vein-like body averaging 24 to 30 inches in width and is traceable along the strike for 600 feet. The trend is south 60° west and the dip nearly vertical.



Olympic Range as viewed from near Seattle. Note low glacial plain in foreground and Mt. Constance in background.

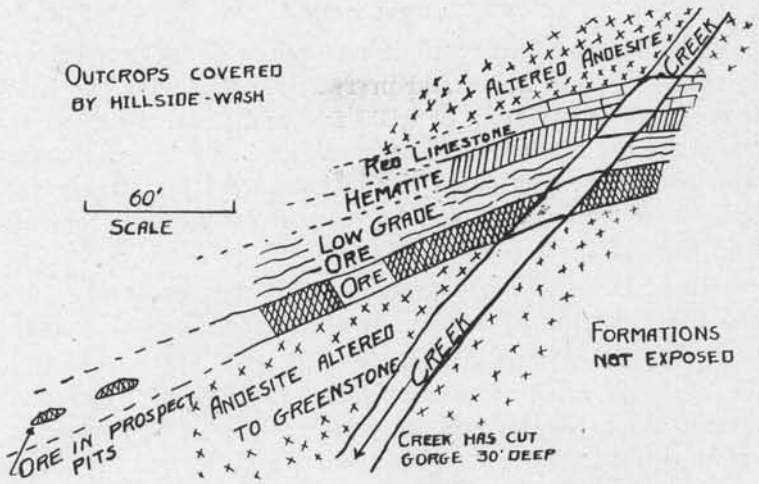


Fig. 27. Geologic sketch map of ore-body and associated formations at Apex Manganese Mine.

The ore is closely associated with the same belts of greenstone and red limestone found at the Apex property a mile distant.

An erosion remnant of the deposit is exposed at the portal of the lower tunnel. This, apparently encouraged the driving of 150 feet of tunnel which exposed no ore. Continuing up the creek the lode is exposed by a 50-foot trench along the outcrop. A short distance further up-stream it has been cut at a depth of 50 feet by a 35-foot crosscut. These showings were sampled and the ore not enriched by the black oxide averages 30 per cent metallic manganese.

McKEAN CLAIM

This deposit adjoins the Triple Trip. It is much similar in character. The ore exposed in several small pits shows a body of manganese associated with hematite. The total width is six feet but not all this is commercial ore. During the war small production was made from this property and taken out to Lake Cushman on pack horses.

TUBAL CAIN

The Tubal Cain deposit is on Copper Creek, a tributary to the Dungeness River, and in T. 27 E., R. 3 W. The holdings are at an elevation of 6,300 feet and to secure transportation for the ore it will be necessary to build an aerial tramway from the ridge down to the bottom of the stream valley, where water-grade can be secured for highway or railway construction.

Dean Henry Landes examined this deposit during 1918 and the following description is abstracted from his report:

"The Tubal Cain deposit is situated above timber line, the outcrops attaining a maximum elevation of 6,300 feet, so that the exposures are exceptionally good. The lenses of brown silicate are developed in a red limestone, and they form practically a continuous lode at least 1,500 feet long and six feet in average width. The natural cross-sections show that the lode persists to a depth of at least 500 feet. It is conservatively estimated that this body of ore contains 450,000 tons of ore. Adjoining the manganese lode is a bed of shale carrying impregnations of copper minerals. This copper was the object of considerable mining development and it was not until recent years that the true nature of the manganese was appreciated. The property is well equipped with mining and power machinery and has camp buildings suitable for the accommodations of 35 men.

COPPER DEPOSITS

At various times reports have come in of copper finds in the Olympics. Prospectors have returned with rich samples of native copper and of copper sulphides but so far no producing mine has been discovered. Several prospects have received considerable development work. One of the best known of these properties is the Tubal Cain, where beds of shale carrying impregnations of copper minerals are closely associated with the manganese lode just described. Several years ago a crosscut was driven 2,300 feet to cut this ore at the level of the creek but the venture has so far been unsuccessful. It is not known whether this crosscut has yet been

driven far enough to definitely expell any chance of encountering ore at depth.

During October, 1920, a company organized as the Big West Copper Syndicate, began development work on a group of claims on the South Fork of Quinault River, 20 miles above the lake, bearing the same name. Aside from the company's announcement that it has an extensive low-grade copper ore body, no data are available as to the character or possibilities of the deposit.

DESCRIPTION OF SMELTING PLANTS IN WASHINGTON

TACOMA SMELTER

The Tacoma Smelter, owned by the American Smelters Security Company, is located near Point Defiance and on the outskirts of the city of Tacoma. It is on the west side of Commencement Bay and offers wharfing facilities to any size vessel. It is also accessible to all the principal railroads, thus making it possible to handle ores shipped either by rail or boat.

The Smelter receives ores from the states of California, Oregon, Washington, Idaho, and Montana; from British Columbia, Alaska, West Coast of South America, and at times from Mexico and Korea. At one time Tacoma also operated lead stacks, but of recent years these have been done away with and all the plant devoted to the treatment of copper ores. From 1904 to 1907 some electrolytic refining of copper was done on a small scale, and in 1911 a large refinery was added to the plant which now makes it possible to turn out direct to the trade from Tacoma the purest refined copper. The smelter has a capacity of approximately 45,000 tons of ore per month, while the refinery at present turns out some 180,000,000 pounds of refined copper per year.

Being on tidewater the bulk of the ore naturally comes to the plant by boat. The dock is in the shape of a letter "L" and can accommodate at least four of the largest vessels at one time. Two lines of standard gauge railroad tracks run the full length of the dock and extend from it to all parts of the plant and also connect to the outside railroad spurs. The ores shipped by boat are shoveled by hand into large buckets which are hoisted to the traveling dock bunkers, where they are automatically tripped. From these dock bunkers the ore is loaded into steel railway cars and taken to the track scales where it is weighed and a moisture sample taken and then sent directly to the sampling mill, in the case of ore, and to concentrate storage bins in the case of concentrates.

The sample mill consists of two units which are duplicates of each other and a third mill of smaller capacity for handling high-grade shipments of small lots.

In the case of the big mills the entire lot is sampled

through automatic samplers of the Vezin bell-type. One-tenth of the entire lot is first cut and as this fraction is again reduced the ore is reground so that the bulk reduction bears an approximate ratio to the reduction in fineness. When the sample has diminished to about one-five hundredth of the original lot it is further ground to pass an eight-mesh screen and then sampled on down by hand until a 50 to 100-pound sample is secured.

This goes to the bucking room where it is further crushed and a 5 to 10-pound sample riffled out and dried for one or two hours at a temperature of 100° C. This is further ground to pass an 80 to 200-mesh screen and riffle cut to 20 or 30 ounces which is thoroughly mixed and cut into three samples, one for the smelter, one for the shipper and one for the umpire.

In sampling concentrates, which includes flotation concentrates, the first cuts are made by taking each 10th shovel as a car is unloaded. This lot is reduced in the sampling room by the ring and cone method and then sent to the bucking room where it receives the same treatment as the other ores.

In the treatment of small lots it is not necessary to make so many reductions and so the smaller sampling mill is used. This operates on the same principle described above.

Quite often it is impossible to take a lot directly to the storage bins after sampling and it is necessary to store it out in the yard. In order to handle this material a bypass is arranged on the main conveyor belt by which the ore is delivered into a loading station on a Bleichert aerial tramway. The towers of this tram are arranged over the storage yard in such a way that a bucket in making the complete circuit passes over all parts of the storage yard and hence materials can be piled in any place desired by first arranging an automatic skip dumping decise on the tramway.

For preparing the blast furnace charge there are 44 charging bins holding the ore, limestone and coke. They are hopper-bottomed and underneath each one is a separate hopper and scales.

*Abstracted from a report by Dale Pitt, formerly manager of the Tacoma Smelter.

Steel dump cars having a capacity of 4,000 pounds each and handled by electric locomotives pass under the bins and draw a calculated amount of certain ores and of limestone and coke to make up the calculated blast furnace charge. The car is then taken to the side of the blast furnace and dumped directly into it.

There are three blast furnaces 48x261 inches at the tuyeres and set with their long axes on the same line. The available column is 13 feet giving a daily capacity of 700 tons each. The tapping floor is some twelve feet above the main floor, giving room for a 17-foot settler three and a half feet deep in front of each furnace. These settlers are lined with refractory brick and have one slag tap over the top and two matte taps near the bottom.

The slag is taken in ten-ton slag pots by electric locomotives and automatically dumped into the bay. The slag keeps building up and gradually reclaims additional land surface for use of the smelter.

The matte taken from the settlers is run into 12-ton ladles and handled to the converters by traveling electric cranes.

The fine ores, such as flotation concentrates, are more troublesome to handle. When wet they tend to cake and clog up any machinery used and if dried dusting losses are excessive. This type of ore is first roasted in a Herreshoff roaster and then smelted in a reverbatory type furnace. The feed entering the top deck of the roaster carries about 25 per cent sulphur and is roasted to an 18 per cent product. Upon leaving the roaster it is taken, while still hot, in steel cars and dumped into hoppers above the reverbatory furnace.

The reverbatory furnace is 23½x130 feet and has a daily capacity of 600 tons. The heat is produced by five oil burners at the back end, pulverized coal is also used. The furnace bottom slopes slightly toward the back end of the furnace, permitting the matte to run that way as it is formed. It is tapped out on one side through a launder into the same type of ladle used at the blast furnaces. As the slag accumulates it rises to the top of the mass and is tapped off and sent to the slag dump.

The waste heat from this furnace goes to three Sterling boilers of 512 horsepower each, which furnishes steam used in the air compressors. The exhaust from these compressor engines is conveyed to the refinery where it is used to heat the electrolyte for the tanks.

The matte from both the blast furnaces and the reverberatory furnace is taken direct to three converters where it is blown to blister copper. The slag from the converters is poured onto a casting machine, cast into blocks and returned to the head of the blast furnace as part of its charge.

The blister, when properly blown, is taken in the large ladles and emptied into the anode furnaces. There are three of these furnaces, and two smaller furnaces held in reserve for emergency use. In front of each furnace is a standard Walker anode casting machine. These are 30 feet in diameter and carry 25 moulds, each of which will cast an anode weighing 485 pounds. The wheel slowly revolves in a horizontal plane and the copper which has been properly treated with air and green poles, is poured out into each mold as it passes the spout. This is accomplished by tilting the whole furnace slightly. As each mould passes from beneath the spout it is sprayed with cold water until it reaches the other side of the circle when it is sufficiently cooled that it may be mechanically handled to the refinery.

The gasses and fumes from all the different furnaces and converters are carried by a system of flues of the balloon type, into brick flues and to a Cottrell plant for further treatment before they are finally sent to the stack and out into the air. In the Cottrell plant the gas passes up through a vast series of 12-inch pipes set vertically, 15 feet in height. Within these pipes are set up a highly charged electrical field. The smoke particles being very fine take on either a positive or negative charge. Naturally they now seek the opposite pole of their charge which is either the casing or the electrical wire suspended through the center of the casing. In either case, when they touch it they are neutralized and either fall to the bottom or stick to the sides. By cutting off the smoke and electrical charge and tapping the pipes with hammers,

all the dust falls to the bottom, where it is gathered by drag conveyors, briquetted and fed back into the furnaces. After passing through the Cottrell plant the smoke is carried to a stack 572 feet 10 inches high. As far as is known, this is the highest stack in the world.

In connection with the smelter there is operated an arsenic plant which turns out some 150 tons of white arsenic per month.

Another very interesting by-product is the manufacture of liquid sulphur dioxide. This is made by taking fumes from the converters, washing out the dust, absorbing them in water, boiling out the water, drying, compressing and cooling them down until they liquify. This liquid SO_2 is put on the market in steel cylinders of various sizes and in tank car lots.

The last and probably most interesting process used at the smelter is the electrolytic refining of the copper. The blister as it comes from the converters is practically free from iron and sulphur but contains as impurities gold, silver, cobalt, antimony, etc., in varying amounts. By the electrolytic process the anodes cast at the anode furnace are eaten away in a copper sulphate solution through which a current is passing, using this anode as one pole and redepositing as pure copper on a thin sheet of refined copper used as the other pole. All the impurities fall to the bottom of the tanks and leave a finished product of copper of a fineness ranging from 99.90 to 99.98, containing as impurities As, Fe, Sb, and Ni, so small that they are beyond the limits of computation. This refined copper is again melted and cast into shapes as desired by the trade.

There are three large buildings housing the refinery. To give some idea of the size of these buildings, the small one has floor space enough to accommodate 466 tanks 8 feet 2 inches long by 33 inches wide by 44 inches deep. The next one 480 tanks 12 feet 4 inches long by 33 inches wide and 44 inches deep, and the third 240 tanks 14 feet 6 inches long by 33 inches wide by 44 inches deep. The smaller tanks hold 21 anodes of 485 pounds each and the larger 32 anodes of

the same weight. The entire number for each tank is handled at one time on a special frame, and the same is true of the cathodes. To do this 6½ and 10-ton electric cranes travel the entire length of the buildings and can reach every tank.

During the refining process the gold, silver and other impurities from the anodes fall to the bottom of the tanks as a black spongy mass. The solution from the tanks is syphoned off and the mass gathered and taken to bullion furnaces in the precious metals house where it is further treated and refined.

The refined copper is sent to melting furnaces where the temperature is gradually raised until the copper is again molten. A certain amount of air is introduced into the bath and the charge is skimmed and covered with coke. It is then polled with green poles to a proper set and is ready for casting, into ingots, wire bars, or the various kinds of cakes for the trade.

NORTHPORT SMELTER

The plant of the Northport Smelting & Refining Company at Northport, Washington, has been operated for the reduction of lead ore and concentrate from the Coeur d'Alene District to base bullion and copper matte since March 8, 1916. Previous to that date it had been used as a copper smelter by the LeRoi Mining Company. Some crude lead ore is received but most of the material is the product from jigs, tables and flotation machines. Receipts are classified and sampled as crude ore, coarse concentrates, fine concentrates and slime. Ore is received principally from the Hercules and the Tamarack & Custer mines of the Coeur d'Alene District. Some custom silver-lead ore from district tributary to Northport is treated. The company operates properties at Republic which produce the silicious ore required and it owns a quarry near the plant which supplies the necessary limestone.

Frozen ore is thawed in the cars in a steam-heated brick building in which the temperature can readily be held at 110° F. The building is equipped with a double track which will hold 16 railway cars.

Crude ore and coarse concentrate are unloaded on belt conveyors which deliver to the crushing plant. This is equipped with two 10 by 20-inch Blake crushers and two 18 by 42-inch sets of rolls, one trommel with three-eighths-inch round holes and two Vezin samplers. These samplers cut out one-tenth of the stream and are set in series. The reject is delivered to the charge bins of the sintering plant. The samples go to a plate room where they are ringed, coned and quartered to about 40 pounds, which goes to the Englebach mills. The product from the mills is quartered down to 32 ounces, which is bucked to pass a 100- 150 or 200-mesh screen and divided into samples for assaying. Fine concentrates and slime are unloaded on belt conveyors which deliver directly to the charge bins of the sintering plant. Every tenth shovelful is reserved for a sample and this is cut down in the plate room.

The sintering plant is equipped with seven Dwight-Lloyd machines with pallets 42 inches wide and suction boxes twenty-two feet long. Fuel oil is used for ignition. In order to control the production of matte, a large part of the lead ore treated is roasted twice. The charge for preroasting consists of about 80—85 per cent lead ore with limestone and silicious ore. The product forms 60—75 per cent of the charge for final roasting, the remainder being unroasted lead ore. To the final sinter, limestone and coke are added to make up the charge for the blast furnace.

There are three blast furnaces, each having a hearth area of 42 by 192 inches and twelve tuyeres on each side. The shafts are water-jacketed for fourteen feet above the crucible and have brick walls for five feet above the jackets. Two matte settlers are used and the slag is granulated. The matte and settler-barrings are handled by hoists and 15-ton bridge crane. The furnaces are run with a heavy bullion fall and a light matte fall.

The bullion is hauled in cast steel pots by storage battery locomotives to the drossing plant. This contains six 50-ton kettles commanded by a 10-ton bridge crane. A Howard

*Information furnished by E. H. Laws, manager, Northport Smelter.

press, operated by compressed air, is used for skimming. The dross is returned to the blast furnace charge. The bullion is sampled by dipping 80 "gum-drops" weighing approximately 0.5 assay ton each, and is pumped to a casting machine. The bars are transported by storage battery trucks to two scales for weighing and then to railway cars.

The small amount of copper which the ores contain is recovered in a leady matte carrying about 10 per cent copper. This is accumulated for ninety days, then crushed, sintered with limestone and silicious ore and smelted. Lead bullion and matte carrying 40 per cent copper are produced and shipped.

The combined gases are humidified by sprays set in the top of the flue and pass through a Cottrell treater. This has 832 steel pipes which are 12 inches in diameter and 16 feet long. The fume is precipitated by a high voltage electric current and falls into brick cellars. It burns or oxidizes to a gray product which is lumpy or granular and which can be readily handled. It is shoveled to flat railway cars, crushed and added to the sintering machine charge.

The plant is supplied with water from Deep Creek by means of two miles of box flume and wood pipe. Electric power is furnished from Canada over a double transmission line. The current is transformed from a voltage of 60,000 to 2,300 at power company's substation. The smelter is completely equipped with shops and laboratory.

BILROWE ALLOYS COMPANY

The use of the electric furnace for the smelting of certain types of ores seems destined to become a process of considerable importance here in the northwest where so abundant a supply of cheap water power awaits further development. As a trail-breaker the ferromanganese plant of the Bilrowe Alloys Company of Tacoma have been operating for several years a number of electric furnaces for the manufacture of ferromanganese.

The company has six resistance type electric furnaces. These are single-phase, open-top shaft furnaces and each has a capacity production of 1.5 to 2 tons of ferromanganese

per day. Only four of these furnaces were in operation during the summer of 1920. The four operating furnaces are enclosed in shells of three-sixteenths inch boiler plate, the outside diameter being 77 inches and the height 69 inches. The shells are water cooled by a spray from a perforated pipe which encircles the top of the shell. Ordinary fire bricks are now used for lining the sides of the crucible and the bottom lining is a rammed-in mixture of ground-up graphite carbon and coal tar.

A single amorphous carbon electrode 16 inches square is used for each furnace. These are supported by steel cables from a car track overhead. The electrodes have threaded recesses in each end and new electrodes are joined to the old by means of a threaded plug screwing into both pieces.

Power is purchased from the city of Tacoma under a favorable contract. The rates vary as the load factor and this is usually such as to earn a rate of from 3.31 to 3.52 mills per kilowatt hour. Under the power contract the plant is subject to shutdown in cases of low water. The power required for each furnace is approximately 375 kilowatts. The current supplied at the terminals carries about 50 volts and measures 7,500 amperes. The power factor is said to be about 90 per cent.

The two furnaces not now in operation are of reinforced concrete construction, seven and one-half feet square on the outside with a central circular shaft 79 inches in diameter. The essential operating principles of these furnaces are similar to the four just described.

The mixed charge of ore, limestone, and coke is regularly shoveled into the top of the furnace and are kept poked down at all times except 20 minutes before tapping. It is desirable to have the furnace crust over before tapping so that no imperfectly separated material will be tapped out. At regular intervals of two hours the ferromanganeses and slag are tapped into small cars and allowed to cool for several hours. The ferromanganese sinks to the bottom and forms a pig and the crust of slag is broken from the pig with sledge hammers and if the charge has been correctly proportioned the

line of separation between the slag and pig is clean cut. The following analyses of the ferromanganese and slag produced are reported:

Analysis of Ferromanganese		Analysis of Slag	
Manganese	80.03 %	Manganese	13.97%
Iron	11.5 %	Ferrous oxide	1.22 %
Silicon	0.6 %	Silica	34.7 %
Phosphorous	0.274%	Lime	35.8 %
		Alumina	4.6 %

The manganese ore used comes from Phillipsburg, Montana. This is partly in the form of table concentrates and the fineness of the material often gives some operating difficulties. The packing of the charge often prevents the gases working up through the charge until enough gas is present to force a passage. These "blows" materially increase the electrode consumption and make furnace losses. In other instances the fine ore is melted and entangled in the slag before coming in contact with the coke a sufficient length of time to be reduced. When the slag runs high in manganese it is crushed up and passed through a Faust jig where the ferromanganese is recovered as a jig concentrate.

The ferromanganese is sold to various foundries and iron works along the Pacific Coast. The market price for ferromanganese during 1920 averaged approximately $150 per ton.

DIRECTORY

AMALGAMATED GOLD MINES COMPANY ..... Chelan County

Blewett District

Local postoffice address: Blewett.
Head offices: Seattle.
Officers: President, C. R. Hesseltine; Secretary, J. E. Reynolds; Treasurer, G. W. Walker; Manager, C. R. Hesseltine, Seattle, Wash.
Number of men employed: 20.
Class of ore: Gold.
Miscellaneous information: Mine has reopened after an idleness of about 10 years. See page 268.

AMAZON MINE ..... Stevens County

Chewelah District

Local postoffice address: Chewelah.
Officers: Owned by J. Oppenheimer.
Class of ore: Copper.
Miscellaneous information: Property has been idle for several years. See page 132.

AMERICAN ARSENIC MINING COMPANY ..... Snohomish County

Index District

Local postoffice address: Index.
Head offices: Burlington, Wash.
Officers: President, A. F. Kirkpatrick; Secretary-Treasurer, Chas. Callahan; Superintendent, C. W. Hager.
Number of men employed: 5.
Class of ore: Arsenic.
Miscellaneous information: Mine recently opened and small mill built, to take advantage of favorable arsenic market. See page 291.

AMERICAN FLAG MINE ..... Ferry County

Sheridan District

Local postoffice address: Republic.
Head offices: Aberdeen, Washington.
Officers: President, M. V. Snider; Secretary-Treasurer, W. D. Hoover, Aberdeen, Wash.; Superintendent, J. S. Stevens.
Number of men employed: 4.
Class of ore: Silver.
Miscellaneous information: Operations suspended September, 1919. See page 196.

ANDY O'NEAL MINE ..... Okanogan County

Nespelem District

Local postoffice: Nespelem.
Number of men employed: 5.
Class of ore: Silver and copper.
Miscellaneous information: Under bond and lease to Frank Hammond and Roy Smith, operations suspended during 1919. See page 214.

APACHE MINING COMPANY ..... Okanogan County

Nespelem District

Local postoffice address: Nespelem.
Head offices: Pioneer Bldg., St. Paul, Minnesota.
Officers: President, F. A. Hoyt; Secretary-Treasurer, M. H. Evans.
Number of men employed: 7.
Type of ore: Silver.
Miscellaneous information: Most consistent producer of Nespelem District. Under bond and lease to Beggs & Ostrowski of Nespelem. See page 207.

APEX GOLD MINING COMPANY ..... King County

Miller River District

Local postoffice: Miller River.
Number of men employed: 5.
Type of ore: Gold-silver-arsenic.
Miscellaneous information: Worked by Wm. Priestly of Miller River under lease and bond. See page 301.

APEX MANGANESE MINE ..... Mason County

Manager: A. Kelly, Seattle.
Local postoffice: Lake Cushman.
Number of men employed: 3.
Type of ore: Manganese.
Miscellaneous information: Under lease to Mt. Elinor Manganese Mining & Smelting Company of Seattle. See page 315.

ARK MINES COMPANY..... Stevens County

Kettle River District.

Local postoffice: Kettle Falls.
Head offices: Spokane.
Officers: President, J. J. Budd; Secretary-Treasurer, O. L. Budd; Manager, J. J. Budd, Kettle Falls.
Number of men employed: 3.
Type of ore: Silver.
See page 143.

ARLINGTON SILVER MINING COMPANY.....Okanogan County

Ruby District

Local postoffice: Okanogan.
Head offices: Sherwood Building, Spokane.
Officers: President, H. E. Rhodenhamel; Secretary-Treasurer, H. S. Stoolfire; Superintendent, J. E. Stoolfire, Okanogan, Wash.
Number of men employed: 10.
Type of ore: Silver-lead-copper.
See page 250.

BEAD LAKE GOLD-COPPER MINING CO.....Pend Oreille County

Newport District

Local postoffice: Newport.
Head offices: Hyde Building, Spokane.
Officers: President, G. C. Geisler; Secretary-Treasurer, W. E. Allen; General Manager, W. E. Allen, Spokane, Wash.
Number of men employed: 15.
Type of ore: Copper-silver-lead.
Miscellaneous information: Building 100-ton concentrator during 1920. See page 75.

BELLA MAY MINE—See Diamond R. Mining Company.

BLEWETT MINE—See Amalgamated Gold Mines Company.

BONANZA MINE ..... Stevens County

Northport District

Local postoffice: Bossburg.
Head offices: Spokane.
Number of men employed: 8.
Type of ore: Silver-lead.
Miscellaneous information: Now being reopened by Spokane capital after an idleness of several years. J. Verwacke, superintendent, Bossburg, Wash. See page 117.

BONANZA COPPER MINE ..... Stevens County

Deer Trail District

Postoffice address: Spokane.
Type of ore: Copper.
Miscellaneous information: Idle during 1920. See page 151.

BOUNDARY RED MOUNTAIN MINING CO.....Whatcom County

Mt. Baker District

Local postoffice: Chiliwack, B. C.
Head office: Reno, Nevada.
Officers: President, Geo. Wingfield; Secretary, C. F. Burton; Manager, E. A. Julian, Reno, Nevada.
Number of men employed: 40.
Type of ore: Gold.
Miscellaneous information: Closed down temporarily to await more favorable gold mining conditions. See page 306.

CARL FREDERICK MINING COMPANY.....Okanogan County

Conconully District

Local postoffice: Conconully.
Head offices: Coeur d'Alene, Idaho.
Officers: President, C. Bernhard; Secretary-Treasurer, C. W. Quarrles; Manager, C. Bernhard, Conconully, Wash.
Number of men employed: 4.
Type of ore: Silver.

CASTLE CREEK MINE ..... Ferry County

Park City District

Postoffice address: Republic.
Number of men employed: 5.
Type of ore: Lead-silver.
Miscellaneous information: Operated under lease by C. E. Cross. Building small mill during 1919. See page.....

CAREY MINING & DEVELOPMENT COMPANY....Okanogan County

Sheridan District

Local postoffice: Republic.
Head offices: Spokane.
Number of men employed: 5.
Type of ore: Silver.
Miscellaneous information: Through mis-management a receivership was forced onto the company during 1920. See page 194.

CHATTERBOY MINING COMPANY.....Ferry County

Danville District

Local postoffice: Danville.
Head offices: Dayton, Wash.
Officers: President, A. Monett; Secretary-Treasurer, C. F. Melton; Superintendent, J. E. Leonard, Danville.
Number of men employed: 5.
Type of ore: Copper-gold.
Miscellaneous information: Formerly known as Lucile Dreyfus Mine Reopened during 1919, idle during 1920. See page 202.

COPPER BELL MINE (Western Copper Mining Co) Snohomish County

Index District

Local postoffice: Index.
Head office: 1123 Broadway, New York.
Officers: President, C. G. Reiter; Secretary, J. J. O'Brien; Treasurer, J. D. Campbell; Superintendent, C. Hendricks.
Type of ore: Copper.
Miscellaneous information: Property has been idle for 10 years. Reincorporated April, 1917, under laws of Maine. See page 290.

COPPER KING MINE ..... Stevens County

Chewelah District

Local postoffice: Chewelah.
Type of ore: Copper-silver.
Miscellaneous information. In receivership. Worked for time during 1918 and 1919, under lease and bond by United Silver-Copper Mining Company, who operate an adjoining property. See page 131.

COPPER WORLD EXTENSION MINING CO.....Okanogan County

Oroville-Nighthawk District

Local postoffice: Nighthawk.
Head offices: Columbus, Ohio.
Officers: President, W. A. Boyle; Secretary, Alfred F. Carman.
Number of men employed: 15.
Type of ore: Copper.
Miscellaneous information. Property under lease to Dempster Mines Company who have installed two miles of aerial tram, and equipped property for production. See page 240.

DAISY MINE—See Silver Mountain Mining Company.

DEER TRAIL CONSOLIDATED MINING COMPANY..Stevens County

Deer Trail District

Local postoffice: Springdale.
Head office: Spokane.
Number of men employed: 5.
Type of ore: Silver.
Miscellaneous information: The mine was extensively worked 20 years ago and made an impressive production of high-grade silver ore. It has been in litigation for years. Now being re-opened by Clarke Brothers of Spokane. Page 149.

DIAMOND R MINING COMPANY.....Pend Oreille County

Metaline Mining District

Local postoffice: Metaline.
Head offices: Spokane.
Officers: President, Wm. Kroll; Secretary-Treasurer, A. H. Kroll; Manager, C. L. Wickstrom, Metaline, Wash.
Number of men employed: 8.
Type of ore: Silver-lead-zinc.
Miscellaneous information: Erected small concentrator during 1919. See page 85.

DOUBLE HEADER MINE ..... Okanogan County

Nespelem District

Local postoffice: Nespelem.
Officers: President, G. M. Quinn; Secretary-Treasurer, L. C. Shuff.
Number of men employed: 4.
Type of ore: Silver.
Miscellaneous information: Exploration work during 1919, but idle during 1920. See page 213.

EAGLE PEAK COPPER MINING COMPANY.....Pierce County

Local postoffice: Longmire Springs.
Head offices: Tacoma.
Officers: President, R. H. Wheelock; Secretary-Treasurer, Mary Long; Manager, R. H. Wheelock, Longmire Springs, Wash.
Number of men employed: 3.
Type of ore: Copper-gold.
See page 310.

ELECTRIC POINT MINING COMPANY.....Stevens County

Northport District

Postoffice address: Northport.
Officers: President, Roy A. Young; Secretary, F. M. Turner; Treasurer, H. M. Waddell; Superintendent, C. D. Belser.
Number of men employed: 60.
Class of ore: Lead-silver.
Miscellaneous information: Contributes the major portion of Washington's lead production. See page 93.

FIRST THOUGHT GOLD MINING COMPANY.....Stevens County

Orient District

Local postoffice: Orient.
Head offices: Calgary, Alberta.
Officers: President, P. Burns; Secretary-Treasurer, W. J. C. Wakefield.
Type of ore: Gold.
Miscellaneous information: Property has been idle for several years but is credited with substantial production and is expected to reopen when gold mining conditions improve. See page 164.

FIRST THOUGHT SILVER MINING COMPANY...Okanogan County

Ruby District

Head offices: Portland, Oregon.
Officers: President, Jonathan Bourne, Jr.
Type of ore: Silver-copper-lead.
Miscellaneous information: Property idle. See page 255.

FOUR METALS MINING COMPANY **Okanogan County**

Oroville-Nighthawk District

Postoffice address: Nighthawk.
Officers: President, R. S. Grant; Secretary-Treasurer, C. Arkins; Manager, R. S. Grant, Nighthawk, Wash.
Number of men employed: 8.
Type of ore: Silver-lead-copper.
See page 233.

FRISCO-STANDARD MINING COMPANY.....Stevens County

Northport District

Local postoffice: New Boundary.
Head offices: Spokane.
Officers: President, G. H. Harrington; Secretary-Treasurer, James T. Burcham.
Number of men employed: 3.
Type of ore: Silver-lead-copper-gold.
Miscellaneous information: Under lease to J. Astloford and W. E. Hightower of Northport. See page 112.

GALENA HILL MINING COMPANY.....Stevens County

Orient District

Local postoffice: Orient.
Head offices: Reardon, Washington.
Officers: President, W. L. Shearer; Secretary-Treasurer, V. A. Finrow; Manager, W. S. Bliss, Orient, Wash.
Number of men employed: 8.
Type of ore: Lead-silver-zinc. See page 162.

GLADSTONE MOUNTAIN MINING COMPANY.....Stevens County

Northport District

Local postoffice: Leadpoint.
Head offices: Sherwood Building, Spokane.
Officers: President, Thaddeus Lane; Secretary-Treasurer, Walter J. Nicholls; Superintendent, Dan Dodd, Leadpoint, Wash.
Number of men employed: 12.
Type of ore: Lead.
See page 102.

GREAT METALS MINING & MILLING COMPANY..Okanogan County

Nespelem District

Local postoffice: Nespelem.
Head offices: Nespelem.
Officers: President, Willis Schrock; Secretary-Treasurer, Adam Rinehart; Manager, E. C. Williamson.
Number of men employed: 10.
Type of ore: Silver.
Miscellaneous information: Operated during 1919 but idle during summer of 1920, account shortage of water. See page 211.

GREAT WESTERN MINE ..... Ferry County

Keller District

Local postoffice: Keller.
Number of men employed: 3.
Type of ore: Silver.
Miscellaneous information: A recent location which is being prospected by W. H. Galloway and C. Koenig. See page 217.

GORIEN ZINC MINE ..... Stevens County

Northport District

Local postoffice: Northport.
Number of men employed: 10.
Type of ore: Zinc.
Miscellaneous information: A recent important discovery of zinc carbonates leased to John Gorien of Minneapolis, Minn. See page 111.

IRON CREEK MINING COMPANY ..... Stevens County

Keller District

Local postoffice Keller.
Head offices: Spokane.
Number of men employed: 10.
Type of ore: Silver-lead.
Officers: President, R. J. Clark; Secretary-Treasurer, J. E. Angle; Manager, R. J. Clark.
See page 218.

KAABA MINES COMPANY ..... Okanogan County

Oroville-Nighthawk District

Local postoffice: Oroville.
Head offices: Spokane.
Officers: President, J. W. Douglas; Secretary-Treasurer, S. Barghoorn; Manager, J. W. Douglas, Oroville, Wash.
Number of men employed: 8.
Type of ore: Silver-lead-copper.
See page 228.

KNOB HILL MINING COMPANY ..... Ferry County

Republic District

Local postoffice: Republic.
Head offices: Old National Bank Building, Spokane.
Officers: President, John Byrne; Secretary-Treasurer, O. A. Broyles; Superintendent, J. E. Daley; Mine Superintendent, Horace Mason.
Number of men employed: 10.
Type of ore: Gold-silver.
See page 175.

KROMONA MINING & SMELTING COMPANY....Snohomish County

Sultan District

Local postoffice: Sultan.
Head offices: Peyton Building, Spokane.
Officers: President, C. B. Krom; Secretary-Treasurer, C. B. Krom; Manager, J. F. Krom, Spokane, Wash.
Number of men employed: 3.
Type of ore: Copper.
See page 293.

LA FLEUR MT. COPPER COMPANY.....Ferry County

Danville District

Local postoffice: Danville.
Head offices: Colville.
Officers: President, W. A. Acorn; Secretary-Treasurer, I. J. Lasswell; Manager, I. J. Lasswell, Colville, Wash.
Number of men employed: 4.
Class of ore: Copper.
See page 200.

LAST CHANCE MINE .....Okanogan County

Ruby District

Local postoffice: Okanogan.
Head offices: Portland, Oregon.
Officers: Owned by Jonathan Bourne, Jr.
Number of men employed: 2.
Class of ore: Silver-lead-copper.
Miscellaneous information: Under lease to C. W. Jackson of Okanogan, who is sorting and shipping high-grade ore. See page 254.

LEAD KING MINE ..... Stevens County

Northport District

Address: Northport.
Officers: President, Roy Young.
Number of men employed: 2.
Type of ore: Lead.
Miscellaneous information: Idle since 1919. See page 106.

LEAD TRUST MINE ..... Stevens County

Northport District

Local postoffice: Leadpoint.
Head offices: Wenatchee, Wash.
Officers: President, J. A. Scaman; Secretary, D. A. Shiner; Treasurer, F. N. Mintzer; Manager, F. C. Scaman.
Number of men employed: 10.
Type of ore: Lead.
Miscellaneous information: Completed small concentrator during summer of 1920. See page 104.

LONE PINE-SURPRISE CONSOLIDATED MINING COMPANY
(Last Chance Mine) .....Ferry County

Republic District

Local postoffice: Republic.
Head offices: Hyde Block, Spokane.
Officers: President, C. P. Robbins; Secretary-Treasurer, C. Theis; Manager; C. P. Robbins, Republic, Wash.
Number of men employed: 15.
Type of ore: Gold-silver.
Miscellaneous information: Workings are confined to Last Chance Claim, and mine sometimes spoken of as Last Chance Mine. See page 185.

LOON LAKE-BLUE BIRD COPPER MINING CO.....Stevens County

Springdale District

Local postoffice: Loon Lake.
Head offices: Spokane.
Officers: President, H. D. Trunkey; Secretary-Treasurer, Jos. McCarthy; Manager, J. C. Haas, Spokane.
Number of men employed: 6.
Type of ore: Copper.
See page 158.

LOON LAKE COPPER COMPANY .....Stevens County

Springdale District

Local postoffice: Loon Lake.
Head offices: Spokane.
Officers: President, Mr. McCormick; Secretary-Treasurer, M. Brock; Manager, W. L. Zeigler.
Number of men employed: 25.
Type of ore: Copper.
Miscellaneous information: Company passed into receivership during the latter part of 1919. See page 153.

MELROSE MINING COMPANY ..... Stevens County

Northport District

Local postoffice: New Boundary.
Head offices: Spokane.
Officers: President, Jos. Cohn; Secretary-Treasurer, S. Edelstein; Manager, O. Matthews, New Boundary, Wash.
Type of ore: Lead-silver.
Miscellaneous information: Idle since 1919. See page 116.

METALINE ORIOLE MINING COMPANY.....Pend Oreille County

Metaline District

Address: Metaline.
Officers: President, Fred N. Davis; Secretary-Treasurer, Ella M. Davis; Manager, Fred N. Davis.
Number of men employed: 2.
Type of ore: Lead-silver-zinc.
See page 87.

MINERAL CREEK COPPER COMPANY.....Kittitas County

Cle Elum District

Local postoffice: Cle Elum.
Officers: President, Charles Durrwachter; Manager, E. J. Durrwachter, Cle Elum.
Number of men employed: 5.
Type of ore: Copper.
Miscellaneous information: Completed small concentrator during summer of 1920. See page 277.

MT. ELINOR MANGANESE MIN. & SMELTING CO—See Apex Manganese Mine.

MYSTERY MINE ..... Snohomish County

Sultan District

Address: Sultan.
Officers: David Boyle.
Type of ore: Copper.
See page 298.

NEW ENGLAND MINE ..... Stevens County

Northport District

Address: Northport.
Officers: Owned by Ben Stout and L. M. Cook.
Number of men employed: 2.
Type of ore: Zinc.
See page 110.

NORTHPORT MINING COMPANY ..... Stevens County

Northport District

Address: Northport.
Head offices: Minneapolis, Minn.
Officers: John Gorien, Secretary-Treasurer and Manager.
Number of men employed: 5.
Type of ore: Zinc.
Miscellaneous information: Idle since 1919. See page 107.

NORTHPORT SMELTING & REFINING COMPANY (Republic Mines Branch) ..... Ferry County

Republic District

Local postoffice: Republic.
Head offices: Wallace, Idaho.
Officers: President, Jerome Day; Manager, Frank Bailey.
Number of men employed: 8.
Type of ore: Gold-silver.
Miscellaneous information: Supplies siliceous gold ores to the Northport Smelter for use in fluxing heavy sulphide ores. See page 185.

O. K. MINE (Oroville Copper Company).....Okanogan County

Oroville-Nighthawk District

Address: Oroville.
Officers: President, Theo. Wondra; Secretary-Treasurer, H. D. James; Superintendent, J. P. Gormely.
Number of men employed: 3.
Type of ore: Copper.
Miscellaneous information: No shipments made since 1919. See page 244.

O-LO-LIM COPPER MINING COMPANY .....Stevens County

Local postoffice: Davenport.
Head offices: Hyde Block, Spokane.
Officers: President, James Keith; Secretary-Treasurer, B. R. Riegel; Manager, Jas. Keith, Spokane, Wash.
Number of men employed: 5.
Type of ore: Copper.
See page 160.

PANAMA SILVER MINING COMPANY .....Okanogan County
Nespelem District

Local postoffice: Nespelem.
Head offices: Seattle.
Officers: President, H. P. Dickinson; Manager, H. P. Dickinson, Seattle.
Number of men employed: 3.
Type of ore: Silver. See page 209.

PARADISE MINE ..... Pierce County

Address: Longmire Springs.
Miscellaneous information: A copper prospect owned by Sherman Evans and Ike Evans. See page 312.

PYRARGYRITE MINING COMPANY ..... Okanogan County
Oroville-Nighthawk District

Address: Oroville.
Officers: President, Monroe Harmon; Secretary, C. A. Andres; Treasurer, W. C. Jones; Manager, M. Harmon.
Number of men employed: 15.
Type of ore: Silver.
Miscellaneous information: Completed 75-ton concentrating mill during 1920. See page 287.

QUILP GOLD MINING COMPANY ..... Ferry County
Republic District

Local postoffice: Republic.
Head offices: Spokane.
Officers: President, J. Hutchinson; Secretary, G. R. Dodson; Treasurer, Thos. Hooker; Manager, W. G. C. Lanskail; Con. Engr., Sam Richardson.
Number of men employed: 10.
Type of ore: Gold-silver. See page 180.

REARDON COPPER COMPANY (High Grade Mine)..Stevens County
Deer Trail District

Local postoffice: Turk.
Head offices: Reardon.
Officers: A close corporation, Directors: Oscar Carstens, T. J. Carstens, Henry Carstens, and A. H. Kenyon.
Number of men employed: 2.
Type of ore: Copper.
See page 146.

REBECCA MINING COMPANY ..... Okanogan County
Nespelem District

Local postoffice: Nespelem.
Officers: President, H. J. Neely; Secretary-Treasurer, J. McCarthy; Manager, H. J. Neely.
Number of men employed: 5.
Class of ore: Copper.
Miscellaneous information: Idle since 1919. See page 216.

GIANT SILVER MINING COMPANY.....Stevens County
RED CLOUD MINING COMPANY ..... Stevens County

Deer Trail District

Local postoffice: Fruitland.
Head offices: Hatton, Washington.
Officers: President, J. K. Fields; Secretary-Treasurer, A. J. Railsback; Manager, A. H. Anderson, Fruitland, Wash.
Number of men employed: 5.
Class of ore: Copper-silver.
See page 150.

RIES MINING COMPANY ..... Pend Oreille County

Northport District

Address: Newport.
Officers: President, A. L. Ries; Secretary, E. E. Jones; Treasurer, F. Vawter; Manager, A. L. Ries.
Type of ore: Lead-silver-copper.
See page 80.

RUBY MINE—See Pyrargyrite Mining Company.

SAN POIL MINE ..... Ferry County

Republic District

Local postoffice: Republic.
Head offices: Trail, B. C.
Officers: Owned by Consolidated Smelting & Ref. Co. of Trail, B. C.
Type of ore: Gold-silver.
Miscellaneous information: Supplies siliceous fluxing ore to Trail Smelter. See page 188.

SILVER LEDGE MINING COMPANY ..... Chelan County

Methow District

Local address: Methow.
Head offices: Waterville, Washington.
Officers: President, William Dunn; Secretary-Treasurer, A. L. Maltby; Manager, L. H. Markham, Methow, Wash.
Number of men employed: 6.
Class of ore: Gold-silver. See page 259.

SILVER MOUNTAIN MINING COMPANY.....Stevens County

Kettle River District

Local address: Daisy.
Head offices: Spokane.
Officers: President, P. E. Seelye; Secretary-Treasurer, R. J. Nevers; Manager, P. E. Seelye.
Number of men employed: 5.
Class of ore: Silver.
See page 136.

SILVER QUEEN MINE—See Ark Mines Company.

SOUTHERN MINNESOTA & WASHINGTON MINES COMPANY (Lone Pine Mine) ..... Okanogan County

Oroville-Nighthawk District

Address: Oroville.
Officers: President, E. A. Williams; Secretary-Treasurer, F. B. Sangers; Manager, H. W. Holley.
Number of men employed: 4.
Class of ore: Silver-lead.
See page 243.

SUNSET COPPER COMPANY ..... Snohomish County

Index District

Local postoffice: Index.
Head offices: Seattle.
Officers: A close corporation; E. A. Sims, president and manager; J. G. Shepherd, Superintendent, and E. C. Morse, mill superintendent.
Number of men employed: 50.
Type of ore: Copper.
See page 282.

SWAUK MINING & DREDGING COMPANY.....Kittitas County

Swauk District

Local postoffice: Liberty.
Head offices: Yakima, Wash.
Officers: President, Mark Pennington; Secretary, D. J. Bryant; Treasurer, M. Bernard; Manager, Frank Bryant, Liberty, Wn.
Number of men employed: 12.
Type of ore: Gold.
Miscellaneous information: Began dredging operations during September, 1920.
See page 276.

TEMPEST MINING COMPANY ..... Stevens County

Kettle River District

Local postoffice: Daisy.
Head offices: Spokane.
Officers: President, F. H. Schindler; Secretary-Treasurer, C. W. Hill, and J. N. Horton.
Number of men employed: 2.
Type of ore: Silver.
See page 140.

TIP TOP MINE ..... Okanogan County

Nespelem District

Address: Nespelem.
Miscellaneous information: Idle since 1919.
See page 215.

TRINIDAD MINING & SMELTING COMPANY.....Okanogan County

Address: Tonasket.
Officers: President, J. Coleman; Secretary-Treasurer, T. W. Brown.
Number of men employed: 3.
Type of ore: Silver.
See page 257.

UNITED SILVER-COPPER MINING COMPANY.....Stevens County

Chewelah District

Local postoffice: Chewelah.
Head offices: Symons Building, Spokane.
Officers: President, Conrad Wolfle; Secretary-Treasurer, M. E. Poole; Manager, E. A. Wolfle, Chewelah, Wash.
Number of men employed: 50.
Type of ore: Copper-silver.
Miscellaneous information: One of most consistent producers in the State. See page 123.

YOUNG AMERICA MINE ..... Stevens County

Northport District

Address: Bossburg, Washington.
Number of men employed: 5.
Type of ore: Lead-silver-zinc.
Miscellaneous information: Owned by Mrs. C. W. Connell of Bossburg. Under lease to Cuprite Mining Company, who built 15-ton concentrator and did considerable development work during 1919. See page 119.

ZALLA M. MINE ..... Okanogan County

Sheridan District

Address: Republic.
Officers: Held by Rossland, B. C., branch of the Bank of Montreal.
Type of ore: Silver.
See page 198.

GLOSSARY

A

Amphibole, the generic name for the group of bisilicate minerals whose chief rock-making member is hornblende. It is often pre-fixed to those rocks which have hornblende as a prominent constituent.

Amygdaloid, a vesicular igneous rock whose cavities have become filled with secondary minerals. The fillings are called amygdules.

Aplite, an acidic phase of a granitic rock occurring as a dike.

Argentiferous, silver-bearing.

Argentite; Silver glance, a silver sulphide, Ag_2S. Contains 87 per cent silver.

Argillite, an argillaceous metamorphosed sedimentary rock, that may or may not possess a slaty clevage.

Arkose, a sedimentary rock composed of material derived from the disintegration of granite, transported and redeposited with little sorting.

Arrastre, apparatus for grinding ores by means of a heavy stone dragged around upon a circular bed. The arrastre is chiefly used for ores containing free gold, and amalgamation is combined with the grinding. Use now practically obsolete.

Arsenolite, a white arsenious oxide, As_2O_3.

Arsenopyrite; Mispickel, a sulpharsenide of iron; FeAsS. Contains 46 per cent arsenic.

Augite, the commonest rock-making pyroxene. Contains large amounts of alumina and iron.

Auriferous, containing gold.

Azurite, blue copper carbonate, $CuCO_3Cu\ (OH)_2$. Contains 46 per cent copper.

B

Back, that part of a lode which is nearest the surface in relation to any portions of the mine; thus the back of a level or a stope is that part of the unstoped lode which is above.

Barite, sulphate of barium $BaSO_4$; also called heavy spar, from its high specific gravity.

Basalt, in a broad sense basalt includes all the dark basic volcanic rocks. It is the most common extrusive rock.

Basic, a general descriptive term for those igneous rocks that are comparatively low in silica. About 50 to 55 per cent is the superior limit.

Batholith, a huge irregular mass of plutonic rock that has crystallized at depth, and has been exposed only by erosion, or subsequent uplift.

Bed Rock, the solid rock underlying soil, sand, clay, etc.

Biotite, a magnesium-iron mica. The common black mica.

Bornite, peacock copper. A sulphide of copper and iron. Also called horseflesh ore.

Breast, the face of a working.

Breccia, a fragmental rock whose components are angular and therefore, as distinguished from conglomerates, are not water worn. There are friction of fault breccias, talus breccias, and eruptive breccias.

Brittle Silver, a synonym for stephanite.

C

Calcareous, consisting of or containing carbonate of calcium.

Calcite, calcium carbonate, (rhombhedral). The more common form of $CaCO_3$. Contains 56 per cent lime, CaO.

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*The definitions for the most part are taken from U. S. Bureau of Mines Bulletin No. 95: A glossary of the mining and mineral industry, A. H. Fay, 1920.

Chalcedony, a transparent or more generally translucent crytocrystalline quartz. It often lines or fills cavities in rocks.

Chalcocite, a copper sulphide Cu_2S, containing 79.9 per cent copper.

Chalcopyrite, the most common sulphide of copper and iron, $CuFeS_2$. Contains 34.5 per cent copper.

Chert, a compact, siliceous rock formed of chalcedonic or opaline silica. Flint is a variety of chert.

Clastic, a descriptive term applied to rocks formed from the fragments of other rocks; fragmental.

Cleavage, a tendency to cleave or split along definite, parallel, closely spaced planes. It is a secondary structure commonly confined to bedded rocks, is developed by pressure and ordinarily is accompanied by at least some recrystallization of the rock.

Cobbing, breaking ore to sort out its better portions.

Collar of shaft, the first frame of timbers around the top of a shaft.

Conchoidal, shell shaped. The more compact rocks such as flint, basalt, etc., break with concave and convex surfaces and are therefore said to be conchoidal.

Conformable, when beds or strata lie upon one another in unbroken and parallel order, and this arrangement shows that no disturbance or denudation has taken place at the locality where their deposition was going on, they are said to be conformable. But if one set of beds rests upon the upturned edges of another, showing a change of conditions or a break between the formations, they are said to be unconformable.

Conglomerate, an aggregate of rounded boulders and pebbles cemented together into a coherent rock.

Contact deposit, a mineral deposit found between two unlike rocks, usually applied to an ore body at the contact between a sedimentary rock and an igneous rock.

Contact metamorphism, a general term applied to the changes which take place along a contact such as the recrystallization of limestone or the forming of the typical silicate minerals. Metamorphism produced by the heat of an igneous intrusion.

Cordillera, strictly a continuous chain of mountains. Generally a whole mountain province.

Country rock, the general mass of adjacent rock as distinguished from that of a dike, vein, or lode.

Croppings, portions of the vein as seen at the surface.

Crosscut, a level driven across the course of a vein.

Crystalline, of or pertaining to the nature of a crystal, having regular molecular structure.

Cupola, a domical-shaped projection of igneous material from a batholith. Many stocks are cupolas on batholiths.

Cuprite, red copper oxide, Cu_2O. Contains 88.8 per cent copper.

D

Dacite, a vitrophyric, generally volcanic, igneous rock, containing essentially plagioclase and quartz.

Diabase, a basic fine-grained igneous rock usually occurring in dikes or intrusive sheets, and composed chiefly of plagioclase feldspar. Distinguished from other dike rocks by its fine-grained and mottled texture.

Differentiation, the process or processes whereby cooling magmas separates into rocks of different kinds, usually connected by gradations.

Dike, a long and relatively thin body of igneous rock, which, while in a state of fusion has entered a fissure in older rocks and has there chilled and solidified.

Diorite, a granitoid rock composed essentially of hornblende and feldspar which is mostly or wholly plagioclase, with accessory biotite and augite. A basic member of the granite family.

Dip, the angle at which beds or strata are inclined from the horizontal.

Dolomite, the double salt of calcium and magnesium carbonate. Limestone often contains enough magnesium to be classed as a dolomite.

Drift, a horizontal passage underground. A drift follows the vein, as distinguished from a crosscut, which intersects it.

Dynamic metamorphism, metamorphism produced by earth movements in regions of great dislocations, shearing or crushing of rocks. Distinguished from chemical processes, but the former are seldom unattended by the latter.

E

Effervesce, to bubble and hiss as limestone on which acid is poured.

Enstatite, a magnesium silicate mineral, $MgSiO_3$. The variety of orthorombic pyroxene with less than five per cent FeO.

Epidote, a basic orthosilicate of calcium, alumium, and iron. Often found along contact zones as a product of contact metamorphism. Usually has a greenish cast.

Exposure, the condition or fact of being exposed to view, either natural or artificially; hence, also that part of a rock, bed or formation which is exposed; an outcrop.

Extralateral right, in the United State mining law, said of the right which one which locates on the public domain, a claim in which a vein comes to an apex, has to parts of the vein beyond the planes passed through the side lines of his claim, but lying within vertical cross planes passed through the end lines.

Extrusive, a term applied to those igneous rocks which have cooled after reaching the surface.

F

Face, in any adit, tunnel, or stope, the end at which work is progressing or was last done.

Fault, in geology, a break in the continuity of a body of rock, attended by a movement on one side or the other of the break so that what were once parts of one continuous rock stratum or vein are now separated. The amount of displacement of the parts may be a few inches or thousands of feet. Various descriptive names are used to designate the various types of faults.

Fault breccia, the breccia which is frequently found in a shear zone, more especially in the case of a thrust fault.

Fault escarpment; Scarp, an escarpment or cliff resulting from a fault, or a dislocation of the rocks adjacent.

Fault fissure, the fissure produced by a fault, even though it is afterwards filled by a deposit of minerals.

Feldspar, a general name for a group of abundant rock-forming minerals, which is further divided into two broad groups: Orthoclase feldspar, a potassium-alumina silicate, and plagioclase feldspars which are a subgroup of triclinic minerals at one end of which is albite, a sodium-aluminum silicate, and at the other end anorthite, a calcium aluminum silicate.

Femic, standard minerals of the second group, comprising minerals low in silica but high in iron, magnesium, or calcium.

Ferromagnesian, in petrology, containing iron and magnesium. Applied to certain dark silicate minerals, especially amphibole pyroxene, biotite, and olivine, and to igneous rocks containing them as dominant constituents.

Ferruginous, containing iron.

Fissure, an extensive crack, break, or fracture in the rocks. A mere joint or crack persisting only for a few inches or a few feet is not usually termed a fissure by geologists or miners, although in a strict physical sense it is one.

Fissure vein, a cleft or crack in the earth's crust, filled with mineral matter different from the walls and precipitated therein from aqueous solution, or introduced by sublimation or pneumatolysis.

Float, a term much used among miners and geologists for pieces of ore or rock which have fallen from veins or strata, or have been separated from the parent vein or strata by weathering agencies. Not usually applied to stream gravel. Used also as an adjective.

Fold, rocks or strata which have been bent into domes and basins, or rolls. This structure is observed mainly in mountainous regions, and is characteristic of both the altered and unaltered sedimentary rocks.

Free milling, applied to ores which contain free gold or silver, and can be reduced by crushing and amalgamation, without roasting or other chemical treatment.

G

Galena, lead sulphide PbS. Contains 86.6 per cent lead. The commonest lead mineral.

Gangue, the non-metalliferous or non-valuable metalliferous minerals in the ore; veinstone or lode-filling. The mineral associated with the ore in a vein.

Garnet, a group of silicate minerals including several species with related chemical structures. Garnet often occurs as a contact-metamorphic mineral in association with metallization.

Gash vein, a mineralized fissure that extends only a short distance vertically. It may be confined to a single stratum of rock, but is comparatively shallow type of vein.

Geosyncline, a great downward flexure of the earth's crust opposed to Geanticline.

Glacier, a stream or sheet of ice formed by the compacting and recrystallization of unmelted snow accumulated to a great thickness, flowing down a mountain valley or outward across country in all directions from a center of accumulation.

Gneiss, a layered crystalline rock with a more or less well-developed cleavage, but without the fissility of schist. A foliated granite.

Gouge, a layer of soft material along the wall of a vein favoring the miner, by enabling him after "gouging" it out with a pick, to attack the solid vein from the side. Gouge is rock flour and is usually produced by crushing and grinding actions.

Granite, a granular igneous rock composed essentially of quartz, orthoclase or microline. Commonly a part of the feldspar is plagioclase. The mica present may be either biotite or muscovite, or both. Hornblende is common augite an uncommon component. Commercially, almost all compact coarse grained igneous rocks are called granite as distinguished from slate, sandstone, and marble.

Granite-porphyry, practically a quartz-porphyry with a coarsely crystalline groundmass and preponderating phenocrysts. The chief phenocrysts are, however, feldspar.

Granodiorite, a term which is employed for the intermediate rocks between granites and quartz-diorites. It is a contraction for quartz-diorite and is a very useful name.

Grizzly, a grating of iron or steel bars for screening ore, etc.

Ground-water level, the level below which the rock and subsoil down to unknown depths, are full of water.

H

Hanging valley, a valley the floor of which is notably higher than the level of the valley or shore to which it leads.

Hanging wall, the upper wall of an inclined vein, or that which hangs over the miner at work.

Hematite, one of the commonest ores of iron, Fe_2O_3, which when pure contains about 70 per cent of iron and about 30 per cent of oxygen. The hydrated variety of this ore is called limonite.

Holocrystalline, a textural term applied to those rocks that consist entirely of crystallized minerals as distinguished from those with more or less glass.

Hornblende, a variety of the mineral amphibole. Color between black and white, through various shades of green, inclining to blackish green; also dark brown. The name of the minerals is prefixed to many rock names.

Horn silver, chloride of silver.

Horse, a mass of country rock lying within a vein.

Hydrous, containing water chemically combined as in hydrates.

Hypersthene, an orthorhombic pyroxene. $(FeMg)SiO_3$.

I

Igneous, in petrology, formed by solidification from a molten state: said of the rocks of one of the great classes into which all rocks are divided and contrasted with sedimentary. Rocks formed in this manner have also been called plutonic rocks, and are often divided for convenience into plutonic and volcanic rocks, but there is no clear line between the two.

Inclusion, in petrology, a crystal or fragment of another substance, or a minute cavity, filled with gas or liquid inclosed in a crystal. A fragment of whatever size, of another rock enclosed in an igneous rock; a xenolith.

Intrusion, in geology, a mass of igneous rock which, while molten, was forced into or between other rocks.

Intrusive, in petrology, having while molten, penetrated into or between other rocks, but solidifying before reaching the surface.

J

Jasper, red, brown, green, impure, slightly translucent cryptocrystalline quartz with a dull fracture.

Juvenile water, water from the interior of the earth which is new or has never been a part of the general system of groundwater circulation.

K

Kaolinite, A white soft earthy mineral consisting of a hydrous silicate of aluminum and one of the chief constituents of clay. A common product of rock decay and of oxidation in veins.

L

Labradorite, A lime-soda feldspar.

Laccolith, in geology, a mass of intrusive igneous rock, of approximately circular outline and lenticular cross-section with a flat base, which has been forced between strata so as to raise the overlying beds in the form of a dome.

Lamprophyre, a general term, now used in somewhat wider sense than originally proposed. Generally a fine-grained basic dike rock with a sugary texture. Associated with granite intrusions.

Latite, a name suggested by F. L. Ransome for the rocks that are between the trachytes and andesites. Latite is meant to be a broad family name and to include the effusive representative of the plutonic monzonites. The texture may be glassy, felsitic, or porphyritic.

Limonite, brown, hydrous oxide of iron containing, when pure, 85.6 per cent of iron oxide and 14.4 per cent of water. The mineral is earthy or of irregular form, never in distinct crystals. It is the usual product left behind in the oxidation of pyrite, chalcopyrite and other iron-bearing minerals.

Lode, strictly a fissure in the country rock filled with minerals; usually applied to metalliferous lodes. In general miners' usage, a lode, vein, or ledge is a tabular deposit of valuable minerals between definite boundaries. Whether it be a fissure formation or not is not always known, and does not affect the legal title under the United States Federal and local statutes and customs relative to lodes. It must not be a placer deposit, i. e., it must consist of quartz or other rock in place and bearing valuable mineral.

M

Macroscopic, in petrology, recognizable by the unaided eye; said of characters of rocks. Now replaced by Megascopic.

Magma, in petrology, liquid molten rock; the molten material from which igneous rocks are formed by solidification. An original, parent magma may break up into several derived ones.

Magmatic differentiation, in petrology, the process by which different types of igneous rocks are derived from a single parent magma, or by which different parts of a single molten mass assume different compositions and textures as it solidifies.

Magnetite, magnetic iron ore. The magnetic iron oxide, $FeO.Fe_2O_3$, contains 72.4 per cent iron.

Malachite, green basic copper carbonate, $2CuO.CO_2H_2O$. Contains 40.3 per cent copper.

Massive, in petrology, (a) of homogeneous structure, without stratification, flow-banding, foliation, schistocity, and the like; said of the structure of some rocks; often but incorrectly used as synonymous with igneous and eruptive.

(b) Occurring in thick beds, free from minor joints and laminations; said of some stratified rocks.

Matrix, the rock or earthy material containing a mineral or metallic ore; the gangue. Sometimes called Ground mass.

Megascopic, large enough to be distinguished with the naked eye; the antithesis of microscopic.

Melaconite, black copper oxide. CuO. Contains 79.8 per cent copper. The name given to an earthy, black massive variety of tenorite.

Metallization, the process, or group of processes, whereby valuable metals, or minerals containing such metals, are introduced into the rocks.

Metamorphism, in geology, any change in the texture or composition of a rock after its induration or solidification, produced by exterior agencies, especially by deformation and by rise of temperature. The processes and results of cementation and weathering are not ordinarily included. The most important agents are heat, moisture and pressure.

Metasomatic, in geology, characteristic of, pertaining to, produced by, or occurring during metasomatosis. The term is especially used in connection with the origin of ore deposits, to designate the replacement of the wall rocks by ore bearing agents.

Meteoric water, water that previously existed as atmospheric moisture, or surface water, and that entered from the surface into the voids of the lithosphere.

Mineralizers, the dissolved vapors in an igneous magma, such as steam, hydrofluoric acid, boracic acid and others, that exert a powerful influence in the development of some minerals and textures. The word is also technically used in some definitions of ore. Thus it is said that an ore is a compound of a metal and a mineralizer, such as copper and sulphur, iron and oxygen, etc.

Molybdenite, sulphide of molybdenum, MoS_2. Contains 60 per cent molybdenum.

Moraine, an accumulation of earth, stones, etc., carried and finally deposited by a glacier. A moraine formed at the extremity of a glacier, is called a terminal moraine; in the center and parallel with its sides, a medial moraine, and beneath the ice but back from its end or edge, a ground moraine.

Muscovite, potash-bearing white mica, $H_2KAl_3(SiO_4)_3$.

N

Nephelite, an orthosilicate of sodium, potassium and aluminum.

Normal fault, an inclined fault of which the down-thrown side is hanging-wall side. Also called a tension fault or gravity fault.

O

Olivine, an orthosilicate of iron, and magnesium. The name of the mineral is often prefixed to the rocks that contain it. Olivine is of especial importance in the respect that its presence marks a more basic development in the rocks that contain it, as contrasted with those which lack it.

Ore, a mineral or mineral aggregates containing precious or useful metals or metalloids, and which occurs in such quantity, grade and chemical combinations as to make extraction commercially profitable.

Ore body, generally a solid and fairly continuous mass of ore, which may include low-grade and waste as well as pay ore, but is individualized by form or character from adjoining country rock.

Ore-shoot, a large and usually rich aggregation of minerals in a vein. It is a more or less vertical zone or chimney or rich vein matter and has definite width laterally. Sometimes called pay-streak, although the latter applies more specifically to placers.

Orthoclase, the monoclinic potash feldspar. Contains 16.9 per cent potash.

Overthrust, the lateral thrusting of a mass of rock over or upon other rocks along a thrust fault.

P

Paleontology, the science that deals with the life of past geological ages. It is based on the study of fossil remains of organisms.

Paragenesis, a general term for the order of formation of associated minerals in time succession, one after another. To study the paragenesis is to trace out in a rock or vein the succession in which the minerals have deposited.

Pegmatite, an igneous rock, generally coarse-grained, but usually irregular in texture and composition, composed mainly of silicate minerals of large size, including quartz, feldspar, muscovite, biotite, tourmaline, beryl, lithia minerals, zircon, etc. Some pegmatites carry minerals containing rare earth metals, tin, tungsten, tantalum, uranium, and others.

Peneplain, a surface of slight relief and very gentle slopes, formed by the subaerial degradation of the land almost to base level.

Peridotite, a granular igneous rock composed essentially of olivine, generally with some form of pyroxene, and with or without hornblende, biotite, chromite, garnet, etc.

Phenocryst, a porphyritic crystal; one of the relatively large and ordinarily conspicuous crystals of the earliest generation in a porphyritic igneous rock.

Phonolite, a fine-grained or porphyritic igneous rock consisting of essentially orthoclase or anorthoclase and nephelite, and accessory amphibole, pyroxene, or mica.

Plagioclase, the triclinic feldspars are called collectively plagioclase. The principal triclinic feldspars are albite, anorthite, labradorite, and oligoclase. As constituents of rocks they occur generally in small crystalline grains and without a microscopic examination it is difficult to distinguish them in this form from one another.

Plutonic, of igneous origin. A general name for those rocks that have crystallized in the depths of the earth, and have therefor assumed, as a rule, the granitoid texture.

Pneumatolytic, a general name applied to those minerals that have been produced in connection with igneous rocks through the agency of the gases or vapors called mineralizers. They may be in the igneous mass itself or in cracks in the wall rocks.

Porphyritic. A textural term for those rocks which have larger crystals (phenocrysts) set in a finer-grained ground mass.

Porphyry, any igneous rock in which relatively large conspicuous crystals (phenycrysts) are set in a finer-grained groundmass.

Portal, the surface entrance to a drift, tunnel, adit or entry.

Propylitic, a term that may be applied to any kind of a vein, meaning that the ore solution which has furnished the vein filling has also effected a decomposition or alteration of the wall-rocks as well, so that the walls of the vein consist of clay, talc, or other altered rock.

Prospect, the name given to any mine workings the value of which have not get been made manifest. A prospect is to a mine, what mineral is to ore.

Proustite, a light-ruby silver-arsenic sulphide mineral, $2Ag_2S.As_2S_3$. Contains 65.4 per cent silver.

Pyrite, a hard, heavy, shiny, yellow mineral, FeS2, generally in cubic crystals. It may be distinguished from chalcopyrite by being of a paler yellow, harder, and giving a black powder, whereas chalcopyrite gives a yellow powder. Marcasite has the same composition, but is white and crystallizes differently.

Pyroclastic, of igneous origin and fragmental texture; said of some rocks, as tuff, agglomerate, volcanic breccia, etc.

Pyroxene, a metasilicate chiefly of calcium and magnesium, also iron.

Q

Quartzite, a metamorphosed quartz sandstone formed by the deposition of secondary silica between the original grains, so that the rock is more firmly cemented and less porous than before and tends to break across the grains.

Quartz monzonite, an igneous rock of granular texture containing quartz without orthoclase and plagioclase in equal proportions.

Quartzose, containing quartz as a principal ingredient.

R

Raise, an opening like a shaft made in the back of a level to reach a level above.

Rake, as applied to pay-shoots, etc., to designate their inclination from the vertical.

Realgar, arsenic monosulphide, AsS. Contains 70 per cent elemental arsenic.

Replacement vein, a vein in which certain minerals have passed into solution and have been carried away, while other minerals from the solution have deposited in the place of those removed. The process is called metasomatic replacement.

Rhyolite, a porphyritic to vitreous igneous rock composed assentially of quartz and alkalic feldspar, or of rock glass having substantially the same composition with or without biotite, hornblende, pyroxene, etc. It is also defined as a lava, usually of light color corresponding in chemical composition to a granite. The same molten liquid that at great depth within the earth solidifies as a granite, would, if it flowed out on the surface, cool more quickly and crystallize less completely as a rhyolite.

S

Scheelite, calcium tungstate, $CaWO_4$. Contains 80.6 per cent tungsten trioxide.

Schist, a crystalline rock that can be readily split or cleaved because of having a foliated or parallel structure, generally secondary and developed by shearing and recrystallization under pressure.

Secondary enrichment, an enrichment of a vein or an ore body by material of a later origin, often derived from the oxidation of decomposed overlying ore masses. Nature's process of making high-grade out of low-grade ores.

Sedimentary, formed by deposition or accretion of grains or fragments of rock-making material, commonly from suspension in or transportation by water or air, or by the precipitation of such material from solution, with or without the aid of living organisms; said of one of the two great classes or rocks and contrasted with igneous.

Sericite, a talc-like hydrous mica (a variety of muscovite) occurring in small scales and sometimes forming sericitic schists.

Serpentine, (a) in mineralogy a hydrous magnesium silicate, commonly green, greenish-yellow or greenish-gray, and massive, fibrous, lamellar. It is an important constituent of some metamorphic rocks and is everywhere secondary after olivine, amphibole, pyroxene, etc.

(b) In petrology, a metamorphic rock composed chiefly or wholly of the mineral serpentine.

Shaft, an excavation of limited area compared with its depth, made for finding or mining ore or coal raising water, ore, rock or coal, hoisting and lowering men and material or ventilating underground workings. The term is often applied to approximately vertical shafts, as distinguished from an inclined shaft.

Shale, a fine-grained, fissile, argillaceous, sedimentary rock characterized by rather fragile and uneven laminae and commonly a somewhat splintery fracture.

Shear zone, in geology, a zone in which shearing has occurred on a large scale, so that the rock is crushed and brecciated.

Siderite, spathic iron ore, iron carbonate, $FeCO_3$. Contains 48.2 per cent iron.

Silicate, A salt or ester of any of silicate acids. In mineralogical chemistry the silicates are of great importance forming by far the largest group of minerals.

Sill, an intrusive sheet of igneous rock, of approximately uniform thickness, which is slight compared with the lateral extent, forced between level or gently inclined beds.

Slate, a dense fine-grained metamorphic rock whose separate minerals are indistinguishable to the unaided eye, and which has an excellent parallel cleavage so that it breaks into thin plates or pencil-like shapes.

Slickenside, a polished and sometimes striated surface on the walls of a vein, or on interior joints of the vein material, or of rock masses. Produced by rubbing during faulting.

Slip, a fault. A smooth joint or crack where the strata have moved upon each other.

Smithsonite, dry bone ore. Carbonate of zinc, $ZnCO_3$ (Contains 52 per cent zinc.)

Step fault, a series of parallel faults forming steps.

Stephanite, brittle silver ore. Silver antimony sulphide, $5\ Ag_2S.\ Sb_2S_3$. Contains 68.5 per cent silver.

Stibnite, antimony glance; gray antimony; antimony sulphide Sb_2S_3. Contains 71.4 per cent antimony.

Stock, a body of igneous rock intruded upward into older formations. In ground plan a stock is circular or elliptical but in cross-section it may increase downward.

Stope, an excavation from which the ore has been extracted either above or below a level, in a series of steps. The term stoping is usually applied to any subterranean extraction of ore except that which is incidentally performed in sinking shafts, driving levels, etc., for the purpose of opening the mine.

Strike, the course or bearing of the outcrop of an inclined bed or structure on a level surface.

Supergene, applied to ores or ore minerals that have been formed by generally descending water. Ores or minerals formed by downward enrichment.

Syenite, any granular igneous rock composed essentially of orthoclase, with or without microline, albite, hornblende, biotite, augite, or corundum. If a small quantity of quartz is present it is called quartz syenite.

Syncline, a fold in rocks in which the strata dip inward from both sides. The opposite of anticline.

Syngenetic, in mineralogy, formed at the same time as the inclosing country rock; said of some ore deposits.

T

Talc, a hydrous magnesium silicate. Has a greasy or soapy feel and is soft and easily cut. Occurs in beds more or less impure and is then known as steatite or soapstone.

Talus, a heap of coarse rock-waste at the foot of a cliff, or a sheet of waste covering a slope below a cliff.

Tennantite, gray copper ore. Copper arsenic sulphide, $3Cu_2S.As_2S_3$. Contains 57.5 per cent copper. Composition varies as tetrahedrite, into which it grades.

Tenor, the percentage or average metallic content of an ore, matte, or impure metal.

Tenorite, black oxide of copper in minute black scales, CuO. Contains 79.8 per cent copper.

Tetrahedrite, gray copper ore. Copper antimony sulphide, essentially $3\ Cu_2S.Sb_2S_3$. Contains 52.1 per cent copper. In many tetrahedrites the copper is partly replaced by iron, lead, zinc, mercury, and silver, and the antimony by arsenic. Through the last replacement tetrahedrite grades into tennantite. Argentiferous tetrahedrite is correctly known as freibergite.

Throw, the amount of vertical displacement up (upthrow) or down (downthrow) produced by a fault; sometimes, loosely, a dislocation not vertical, the direction being specified.

Tonalite, a quartz-mica hornblende diorite.

Trachyte, a fine-grained igneous rock composed essentially of alkalic feldspars.

Tremolite, white fibrous amphibole.

Tuff, a sedimentary rock composed of fine material, volcanic dust, so called ash and cinder, and lapilli, explosively ejected from a volcano. Tuff may or may not be deposited in water. It may be incoherent or indurated.

Tunnel, a tunnel, strictly speaking, is a subterranean passage open at both ends. An adit, if continued through a hill would then be a tunnel. General usage: Any level or drift in a mine open at one end, or which may serve for an adit.

U

Unconformity; unconformable, discordant in attitude with the underlying rocks, due to overlap or to a lapse in deposition, during which the rocks beneath were deformed or partly eroded away or both.

Unctuous, having a greasy, oily or soap feel when rubbed or touched by the fingers, as talc, serpentine, etc.

Unit, a term used in smelter settlements for valuable contents of ores and is equivalent to one per cent of a short ton or 20 pounds.

Uplift, elevation of any extensive part of the earth's surface relatively to some other part, opposed to subsidence.

V

Vadose, extending only a short depth below the surface; said of the shallower portions of the ground water.

Vein, an occurrence of ore, usually disseminated through a gangue, or veinstone, and having a more or less regular development in length, width and depth. A vein and a lode are, in common usage, essentially the same thing, the former being rather the scientific, and the latter the miners' name for it. The courts have placed various interpretations on the numerous definitions provided to cover a vein or a lode.

Vein system, a term applied to the veins of a given area, district, or age, regarded as a whole.

W

Willemite, zinc silicate, $ZnSiO_4$. Contains 58.6 per cent zinc. The zinc is commonly replaced in part by manganese.

Witherite, native barium carbonate. $BaCO_3$.

Wolframite, a series of minerals composed of tungstate of iron and manganese. An important ore of tungsten.

Wollastonite, a white mineral of the proxene group consisting of silicate of calcium ($CaSiO_3$). A common product of the metamorphism of limestone by intrusive igneous rocks. Often in aggregates of flat prismatic crystals without district crystal planes or faces.

Z

Zeolite, a generic term for a group of minerals occurring in cracks and cavities of igneous rocks, especially the more basic lavas. Zeolites are hydrous silicates of aluminum with either sodium or calcium or both, and rarely barium or strontium. They have little economic importance.

Zone, in geology, used in the same sense as horizon to indicate a certain geological level or chronological position, without reference to the local attitude or dip of the rock.

(b) An area or region more or less set off as characteristic or distinct from surrounding parts, as in a metalliferous region, the mineral zone.

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