

WALLOWA
RANGE
CORNUCOPIA
DISTRICT

EAST OF CORNUCOPIA

Opposite Pine creek from the town of Cornucopia the rock is largely greenstone. Prospecting on this side of town is only half-heartedly continued. No veins of large promise were observed.

SOUTHWEST OF TOWN

The pine-covered hills to the south, between the "Granites" and Pine creek, and below Cornucopia, are made up of a series of flows which were probably trachytes. They are now badly altered, in some places showing extreme silicification and in others impregnations of pyrite. The remains of the flow structure and an occasional rock crystal makes clear their original character. Little development of value was observed in these hills.

The veins which have been exposed in the past by shallow workings have since been caved, but veins up to four feet in width are said to exist here. Pieces found on the old dumps consist chiefly of massive quartz, with a few well-formed quartz crystals. These quartz veins in the greenstone, a considerable distance away from the "granite," contain chiefly copper sulphide minerals, chalcocite and chalcopyrite, while the veins in or close to the granodiorite contain chiefly iron sulphide minerals.

It is possible that the hot silica solutions, ascending for long periods of time through greenstones of considerable depth, may have had a leaching effect upon this rock, which usually contains copper, and carrying it upward has precipitated it to form quartz-copper veins. The quantity of copper contained, however, is insufficient to make ore in a vein of fair width unless considerable gold is also present.

The prospectors here, because values in the Cornucopia mine are roughly proportional to the amount of sulphides present, rely too much on the presence of sulphides and too little upon assays. To retain possession of a prospect and do the annual assessment work year after year and maintain hope upon the slender thread of one or two assays from samples poorly taken is not good business.

DECEMBER, 1914

THE MINERAL RESOURCES OF OREGON

*A Periodical Devoted to the Development
of all her Minerals*

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H. M. PARKS, Director

ORE DEPOSITS OF NORTHEASTERN OREGON

By ARTHUR M. SWARTLEY.

INTRODUCTION

NATURE OF THE REPORT

The ore deposits of northeastern Oregon, like those of most of the principal mining regions of the western United States, and much of the mining world as well, are the product of a granitic intrusion into the older rocks. Without such intrusions arts and industries would lack in metals, and civilization as we understand it, would not exist. It should go without argument that a fair understanding of the dominant factor in ore deposition should be had by all those who mine in that region. A knowledge of the source of the metals, the nature of the channel, and the agencies which precipitated them in those channels is of great practical importance to mine operator and prospector alike. Without such knowledge and the ability to make broad comparisons of one region with other regions, each is at the mercy of his necessarily limited actual experiences, or the frequently arbitrary conclusions of others.

Realizing that mining consists of two parts, the exploration and development of the ore body, in which geologic principles are dominant, and the extraction and bringing of the ore to the surface in which mechanical principles are dominant, we feel that a proper

108 at Baker City, to 44 in portions of Crook and Gilliam counties. The precipitation is heaviest during the winter months, but there is a secondary maximum during May and June which is plainly noticeable on the diagram showing the monthly distribution at representative stations. This secondary maximum during May and June is an important feature, as it is the time of the year when vegetation is making its early growth and requires more moisture than is the case later in the season. Only 6 per cent of the annual amount falls during July and August, and these months constitute the driest season of the year. The greatest monthly amount covered by the observations is 8.02 inches, recorded at Weston, Umatilla county, and nearly every year there are some stations where no rain falls for a month, and sometimes for two months at a stretch.

"The prevailing winds are westerly, with a shifting of a few points to the south in the winter and to the north in the summer. Fog is of rare occurrence, and the relative humidity is seldom high."

LITERATURE

Previous to 1900 R. W. Raymond's statistical reports upon mines and mining were about the only available sources of information concerning Oregon. In 1900 Waldemar Lindgren's report upon "The Gold Belt of the Blue Mountains of Oregon" was issued by the United States Geological Survey.

In 1909 the United States Geological Survey published "Faulting and Vein Structure in the Cracker Creek Gold District," by J. T. Pardee, and a year later his "Placer Gravels of Sumpter and Granite Districts." Besides these reports and the annual "Mineral Resources," published by the United States Geological Survey, there has been but little upon this region until the Oregon Bureau of Mines and Geology in 1914 began the publication of their monthly magazine, "The Mineral Resources of Oregon," in which there is published from time to time information concerning these districts.

One of these will contain a preliminary report upon the geology and mineral resources of the Sumpter quadrangle, by J. T. Pardee and D. F. Hewett, prepared in co-operation with the United States Geological Survey, and another will contain a paper by U. S. Grant upon a part of the Baker quadrangle.

"Cold waves are infrequent, but when they are experienced the cold spell may last a week or slightly longer. They are usually caused by northeast winds drawing cold air from the north and east into the valleys, where it remains until the warm winds from a southerly quadrant become sufficiently strong to mix with and impart their warmth to this cool lower air in the valleys. In many places during the cold season the Foehn or 'chinook' winds not infrequently descend along the mountain slopes and cause short spells of abnormally high temperatures. These winds rapidly melt the snow and the air feels mild and spring-like when they blow.

"The observations made at twenty-six stations are used in this discussion, and the average length of the rainfall record is about fifteen years. Short records are used only where there are no others to represent the locality.

TEMPERATURE

"The mean temperatures range between 43° and 56°, being highest in the bottom lands along the Columbia river and lowest in the high lands and mountains. The highest temperature that has ever been recorded is 119° at Pendleton, Umatilla county, on August 10, 1898, and the lowest is 34° below zero, at La Grande, Union county, on January 14, 1888. The average absolute annual range in temperature is 124°, and it is greatest in the south and least in the north. The warmest month as a rule is July, and the coldest is January. The average annual range in mean temperature is 39°; it is least, 31°, at Prineville, in Crook county, and greatest in the northern portion of Malheur county, where at both Beulah and Vale it amounts to 44°.

"The growing season varies greatly, being over 200 days in some favored localities, while in others freezing temperatures may occur every month in the year. Owing to the dryness of the air, frost does not always form with temperatures as low as the freezing point, or even four or five degrees below that mark, and hardy varieties of vegetation are seldom seriously injured by low summer temperatures.

PRECIPITATION

"The annual rainfall ranges between 8 and 25 inches at the observing stations, but greater amounts occur in the higher portions of the mountains, where it is estimated that on the windward slopes as much as 50 or 60 inches falls every year. The minimum of 8 inches, however, is probably within 2 or 3 inches of the lowest amount in any locality.

"A large portion of the precipitation falls as snow, the annual amount of which varies from 122 inches at Sparta, in Baker county, to only 2 inches at Umatilla, in the county of the same name. The number of days with 0.01 inch or more of precipitation ranges from

Oregon comprises the counties of Baker, Crook, Harney, Malheur, Umatilla, Union, Wallowa and Wheeler. In 1913 the counties of Harney, Umatilla, Union and Wallowa returned no production. The combined gold output of the five producing counties of this region—Baker, Grant, Malheur and Wheeler—in 1913, was \$1,525,182, of which Baker county contributed \$1,373,480, or 90 per cent. This is an increase for 1913 of these counties, as compared with 1912, of \$972,706. The placer gold yield in 1913 was \$378,912, an increase of \$316,199, or 491.04 per cent. The lode mines produced in gold \$1,146,270 in 1913, as compared with \$489,763 in 1912, an increase of \$656,507 for 1913 or 134 per cent."

This production comes from 55 placer mines and 20 quartz mines. Of the placer mines 3 are yielding more than \$10,000 each, and 5 quartz mines produced more than \$100,000 each.

TOPOGRAPHIC FEATURES

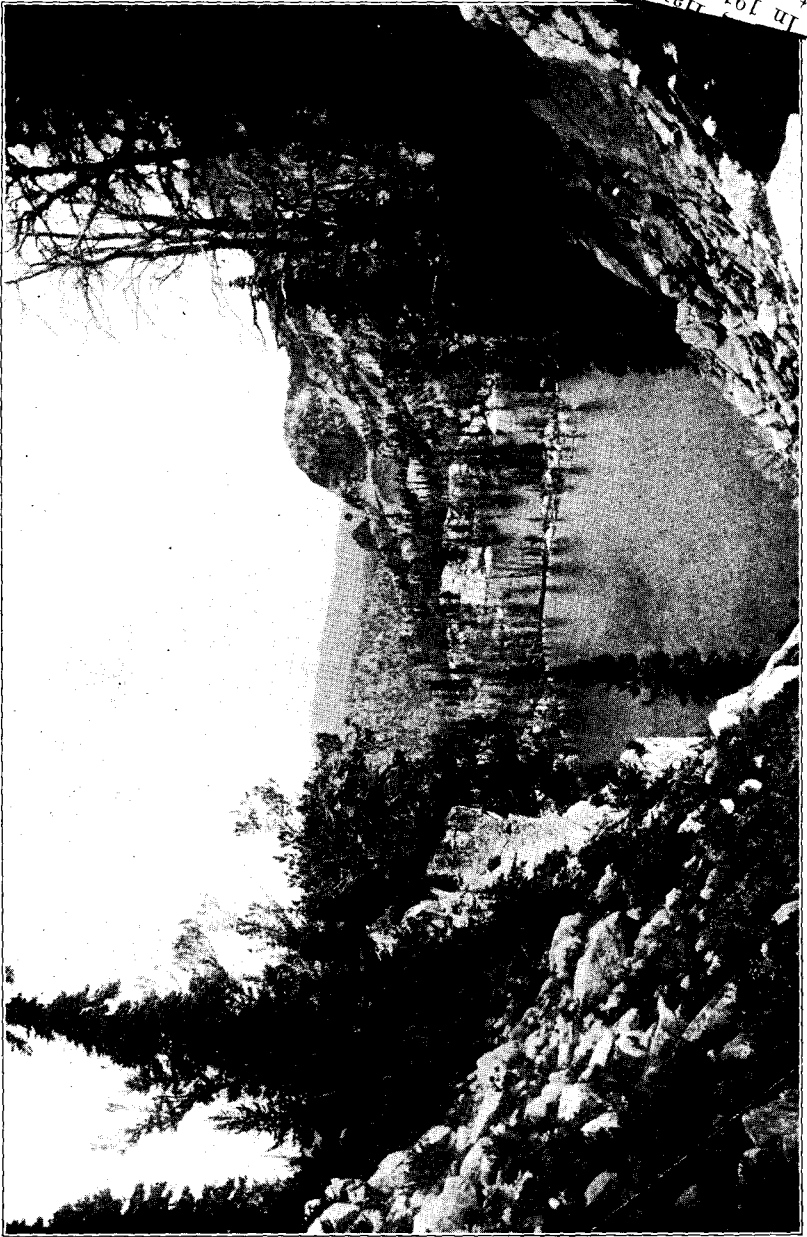
An understanding of the topographic features of northeastern Oregon can best be secured by a careful inspection of the relief map reproduced herewith.

CLIMATIC CONDITIONS

The climatic features of the eastern half of Oregon, comprising nearly 50,000 square miles of territory, are well stated by Edward A. Beals, district forecaster of the United States Weather Bureau, Portland, Oregon:

"In its essential features the climate is much the same in all parts of the section, and its chief characteristics are a scanty rainfall, large ranges in temperature, low absolute humidity, rapid evaporation and an abundance of sunshine. The variations which take place are due to topography, and marked differences in rainfall and temperature often prevail in places relatively near each other. The air from a hygienic standpoint is stimulating and healthful, and although summer temperatures of 100° are common, sunstrokes are practically unknown on account of the dryness of the air, which permits evaporation to take place freely, thereby lowering the surface temperature of perspiring humanity by several degrees.

"The strong insolation in the plateau sections promotes active convectional currents and these in turn increase the velocity of the wind, which in the daytime is apt to be disagreeably strong; these conditions are reversed at night, when the air is usually calm and cool. Except in winter the rainfall is nearly always associated with thunderstorms and occasionally heavy downpours happen that are popularly known as cloudbursts. Mountain and valley winds are common, but tornadoes with funnel-shaped clouds and destructive winds seldom, if ever, occur.



In 1913 the county, Malheur, Oregon, during no pre-

Quartz mine was discovered soon after the discovery of gold. Quartz mines were worked at Susanville and at Mormon Basin as early as 1865 and 1868. One of the first mills was built at Susanville in 1869. Connor creek and Cable Cove were worked, but the shipment of ore on horseback for several hundred miles caused the development to be slow. Real activity in quartz mining followed the construction of a transcontinental railroad in 1885, and the development of the many camps was thereafter placed on a more permanent and productive basis.

Speculation was rife from 1899 to 1903, and much money was unwisely spent. Eastern Oregon is just now recovering from the injurious effects of this "boom," and since the greater number of producing properties are in good hands, we have a steady production from most of them, which is being increased by the addition of other producers to the list.

PRODUCTION

The production of this region previous to 1880 is very imperfectly known. Since that time the total annual production has been compiled by the federal government. Taking into account the best information obtainable, the total production for this area from 1861 to the end of 1914 is estimated at \$95,000,000. This estimate is based on that of Waldemar Lindgren up to 1899, to which has been added the production since that time as found in governmental reports.

Production previous to 1904 was for some years above the million-dollar mark, but beginning with that year there was a decreasing annual production to 1911, the low-water mark, when \$460,248 was produced. Since 1911 there has been a marked increase in production, so that in 1913, the last year for which figures are available, the production from the three counties, Baker, Grant and Malheur, for all metals, was \$1,625,761. Since the phenomenal production of the earlier placer days this amount has been exceeded but once when in the year 1891, the gold and silver production was \$1,849,131.

Every one of the producing counties in this region enlarged their output in 1913, both placer and quartz mines increasing their production. The only falling off in metal output was in the amount of copper and lead.

The following is taken from a chapter in "Mineral Resources" of the United States for 1913, written by Charles G. Yale:

It should be borne in mind that in the descriptions of districts the space devoted to any district is not necessarily the measure of its importance. Travel over wide areas and the service of uncertain transportation have caused a disproportionate amount of time to be spent in the investigation of the various camps. The geology and other features of some districts are comparatively simple and can be described more briefly than others of less commercial importance which, because of their complexity, may demand a more extended description.

It should also be remembered that the general and mining geology was secured at first hand, while much of the information dealing with development, assay values and production has been supplied by the owners or residents of the locality in question. It was not possible to visit all the mines and prospects in the region, and it should be emphasized that failure to mention any particular deposit is no indication whatever that it lacks merit.

This report deals with an immense area, which was examined in a short time. The examination must be considered, therefore, as being more in the nature of a scouting expedition, the report of which is only to be used until more useful information is made available as the result of detailed field work.

HISTORY

The first gold discovery in eastern Oregon was at Griffin gulch, a few miles southeast of Baker, in the fall of 1861. In 1862 the large placer mines of Auburn, nearby, were discovered, and the following year Auburn camp had a population of 5,000. By 1864 nearly all of the mining districts of eastern Oregon were known. Supplies were brought in from The Dalles, 300 miles away. Because of the difficulty of access and cost of transportation of supplies, gravels which did not yield \$8 per day for each man were not considered.

In 1863 the Auburn canal was completed. The next year the Rye valley ditch was constructed, and 9 years later Sparta ditch was completed, as was the Eldorado ditch with its total length of over 100 miles to supply water to the Malheur diggings. But by this time the principal placer deposits were largely exhausted and a gradual decline in production began which has continued nearly to the present day. The introduction of standard gold dredges has caused an increase in placer production in the last two years which is apt to be further increased by the same cause.

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...ure of the rocks except to state that the older rocks consist of considerable areas of argillites, limestones, old volcanic flows and breccias, and that the intrusive rock is a granodiorite with the exception that near its borders the incorporation of the older rocks into the intruded mass has changed it to tonalite, diorite or other phases. Where erosion has scored its way even a short distance into the intrusive mass normal granodiorite is always found.

For detailed statements the reader is referred especially to the main sub-divisions of this report, and especially to that treating of the Cornucopia district. Little attention has been paid to county lines, mining districts or the mining territory tributary to towns or valleys, in making these sub-divisions. All the mining territory on or bordering upon each separate dominant exposure of the intrusive are grouped together, since the ore deposits are all created there as the result of one cause.

The report begins with the Wallowa region, which comprises the ore deposits found on the slopes of the Wallowa mountains, the most rugged range of eastern Oregon. This region includes the contact-metamorphic copper deposits of the several branches of the Wallowa river adjacent to Wallowa valley. It includes the Cornucopia gold mining district, with its steady and increasing annual production. It includes the disseminated chalcocite and chalcopyrite deposits near the Snake river, and upon the mountains' lower southern slopes in the vicinity of Goose and Balm creeks.

Sparta, Virtue and Quartzburg, separately treated, are smaller exposures of the great Blue Mountain batholith, and each includes but one district.

Canyon mountain has but one mining district described, although there is much other territory that may be mining ground, and of which little is now known.

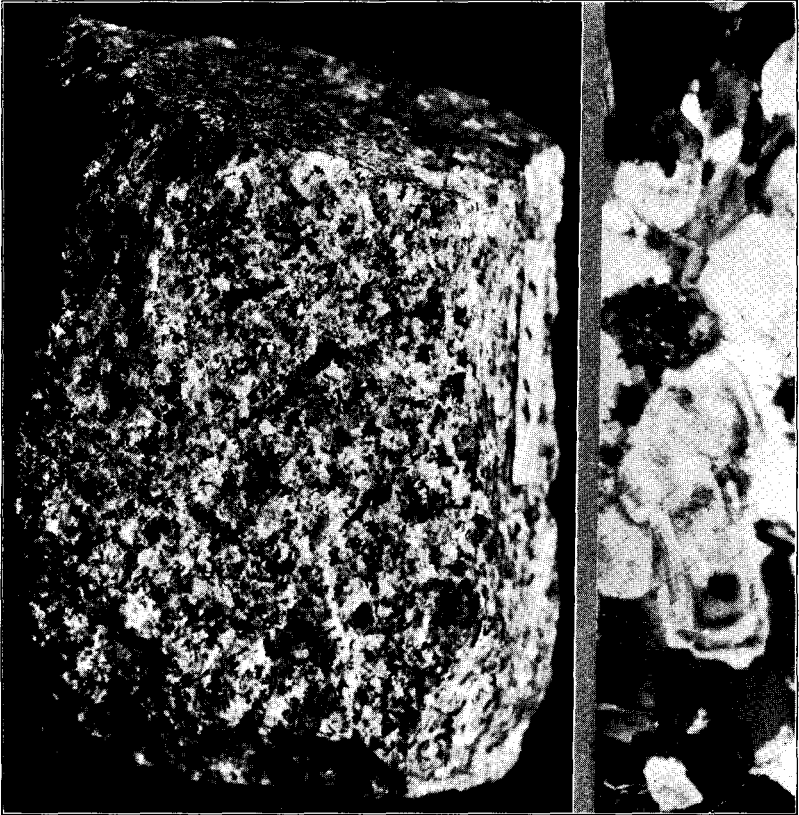
The Bald Mountain-Elkhorn region includes the districts of Granite, Camp Carson, Cable Cove, Cracker Creek and the various old camps of southeastern Elkhorn ridge, which are a part of Baker district.

The Greenhorn Mountain region includes Susanville, New Eldorado, South Side and North Side Silver districts, Greenhorn, Bonanza and Red Boy districts.

The Lookout-Pedro Mountain region includes Connor Creek, Gold Hill, Rye valley, Mormon Basin and Malheur city areas.

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considerable

As a result of the granodiorite intrusion a series of breccias were formed in its margin and in the overlying and surrounding older rocks. Where the intrusion is too far below the surface ore deposition is scanty or absent, and where erosion has cut deep into the intrusive mass, the ore deposits are seen but sparingly. Other things being equal, they are found in greatest abundance where there are projections of the older rocks into the granodiorite, and also where there are local invasions of granodiorite into the older rocks. In other words, they are found in greatest profusion in the vicinity of the re-entrant angles of both the older and newer rocks.



Natural size

Magnified thin section

Fig. 3. Granodiorite. A medium-grained plutonic rock, which was formed by slow cooling of a molten magma at depth. As seen in the thin section the mineral composition is chiefly plagioclase feldspar, quartz, and biotite.



Fig. 2. Last Chance mine, Caracenic district.

understanding of both of these parts is essential to successful operations. The need of the first is never absent in the most highly developed mine, and the usefulness of the second begins with the mine opening. It was, however, deemed advisable, although this report is written by the mining engineer for the bureau, to dwell chiefly upon those geologic facts whose proper understanding is of use in exploration and development because there has been only one comprehensive report upon northeastern Oregon, that of Lindgren in 1900, and that report is now out of print.

That part of eastern Oregon which is best known as a metal mining region includes all of Baker county, much of Grant, the southern parts of Union and Wallowa and the northern part of Malheur. Although there are several mountain ranges within the area, they are generally grouped together and called the Blue Mountains of Oregon. This is the region of which this report treats.

The dominant geologic feature of this mining region is the granitic mass which is here called, for want of a better name, the "Blue Mountain Batholith." The word batholith is the geologist's name for a giant intrusion of a granitic rock reaching to unknown depths. This body of granitic rock which is, except locally, a granodiorite, represents an invasion from below by an enormous volume of molten rock. The cover, or roof, of older rocks under which the granodiorite cooled and solidified, has to a considerable degree been stripped off by the erosive action of atmosphere, running water, snow and ice, until now we have in a dozen or more places granodiorite exposed to view. These separate exposures vary from a few to as much as 250 square miles. It is believed that below the surface where the granodiorite is not now exposed, it nevertheless exists concealed at varying depths by the cover of older and newer rocks. The present exposures represent the higher altitudes of the invasion, or lower points where the forces of erosion have been especially active.

Long after the intrusion took place there was a large number of lava flows which, if they did not cover the entire region, surrounded it. All but the higher parts at least were submerged, as it were, in a wide exposure of lava. We thus have three main geologic subdivisions, the older, the intrusive, and the recent rocks. Those rocks which came since the time of the intrusion are too new and have been too little disturbed to have ore deposits in them. They are a hindrance to mining. They not only cover nearly half of the Blue Mountain region, but also vast adjoining areas under which doubtless many unknown ore deposits exist.

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Realizing that mining consists of two parts, the exploration and development of the ore body, in which geologic principles are dominant, and the extraction and bringing of the ore to the surface in which mechanical principles are dominant, we feel that a proper

THE WALLOWA RANGE DEPOSITS

The mining districts in this region are the Cornucopia, Wallowa, Homestead, and those on the southern slopes of the range, which include Eagle creek, Sanger and the Greenstone area in the vicinity of Balm and Goose creeks.

CORNUCOPIA MINING DISTRICT

The Cornucopia mining district in northeastern Oregon has been a steady and profitable producer of gold and silver since the completion of a well-devised cyanide plant at the Union-Companion mine the first of March, 1913.

The success of this company induced the Baker Mines company to build a somewhat similar plant to treat ore from the Last Chance vein, which began the operation of its 20 stamps and cyanide plant the latter part of October, 1914.

Gold was discovered about 1880. And soon afterwards production began in the intermittent way usual with new, isolated mountain mining camps.

According to Bernard MacDonald's report upon the property, the Union-Companion, Red Jacket and Last Chance claims produced \$1,008,000 previous to 1903.

Estimating the years 1906, 1908 and 1914, and taking the official figures of Charles G. Yale, of the United States Geological Survey for the other years since 1903, the entire production to January 1, 1915, for the district is in excess of \$2,500,000.

The production for 1914 is estimated at \$380,000 for three deep mines and one placer, which amount will be increased in 1915.

The deposits are normal white quartz veins in granodiorite, schist and greenstone.

The principal values are in gold which, except near the surface, is but little amenable to amalgamation.

Amalgamation and concentration recovered but 65 per cent of the gross value, which is largely locked up in iron and other sulphides occurring in irregular bunches within the white quartz body of the vein.

Fine grinding, 80 per cent through 200 mesh screen, and cyaniding recover 90 per cent.

The ores so far mined have a gross value well above \$10 per ton.

This region appeals to all because of its pine-clad lower slopes, rugged mountain tops, many fish-stocked streams, invigorating air and



Fig. 5. Cornucopia and the "Granites" in winter.

the additional interest due to its possessing many mineral-bearing veins. There are deep snows in winter and from many mountain slopes magnificent avalanches hurl themselves with resistless energy into the stream beds below.

The district appeals to the geologist because the processes of nature and their results are nearly all laid bare for his inspection.

Mining engineers will do well to become informed upon this district, and to follow this with an unhurried summer visit to it to examine its many undeveloped, though well-defined mineral-bearing veins.

GEOGRAPHY

The small incorporated town of Cornucopia situated on the upper reaches of Pine creek, in the Wallowa* range, is in the center of the district. It is 25 miles from the railroad town of Robinette, on the Snake river branch of the O.-W. R. & N., 33 miles north and down the river from the main line at Huntington. A good wagon road from Robinette to the camp leaves the Snake river at about 1,900 feet elevation at the mouth of Powder river which it also shortly leaves to mount on even grades to the divide between this stream and Pine creek at 3,060 feet.

From here one drops by easy grades 400 feet into the delightful Pine valley and the thriving town of Halfway. A 2 per cent grade carries us up beyond Carson, where begins a steady 1,200-foot rise along Pine creek to our destination, 6 miles beyond. This part of the journey is through a fairly dense forest and within sight and sound of a good-sized mountain stream. This passage from the hot sage-brush hills along the Snake, through a fertile agricultural valley dotted still with pines, into a region of deep canyons and precipitous slopes, is both impressive and refreshing. Except in winter, regular auto, as well as the daily wagon mail stages, take the traveler in by way of Robinette or directly in from Baker some 65 miles by road to the southwest.

ROCK EXPOSURES

From the time one leaves the watershed between Powder river and Pine creek, until well on his way from Carson to the camp, he passes over ordinary Columbia river basalt. One then begins to see

*Named by National Geographic Board. Often called Eagle Creek Range, Powder River Range, Granite Mountains, or Cornucopia Mountains.

greenstones and similar rocks, while in the stream beds boulders evidence the fact that Pine creek has its sources in granitic areas.

Many days of arduous climbing up steep slopes and oftentimes precipitous cliffs, are necessary to acquaint one in a general way with the rocks in the Wallowa range of mountains. He finds that the town of Cornucopia is situated at the eastern limit of a granitic outcrop approximately 250 square miles in extent. Its outline is quite irregular. Its greatest dimension is southeast to northwest, a distance of about 30 miles.

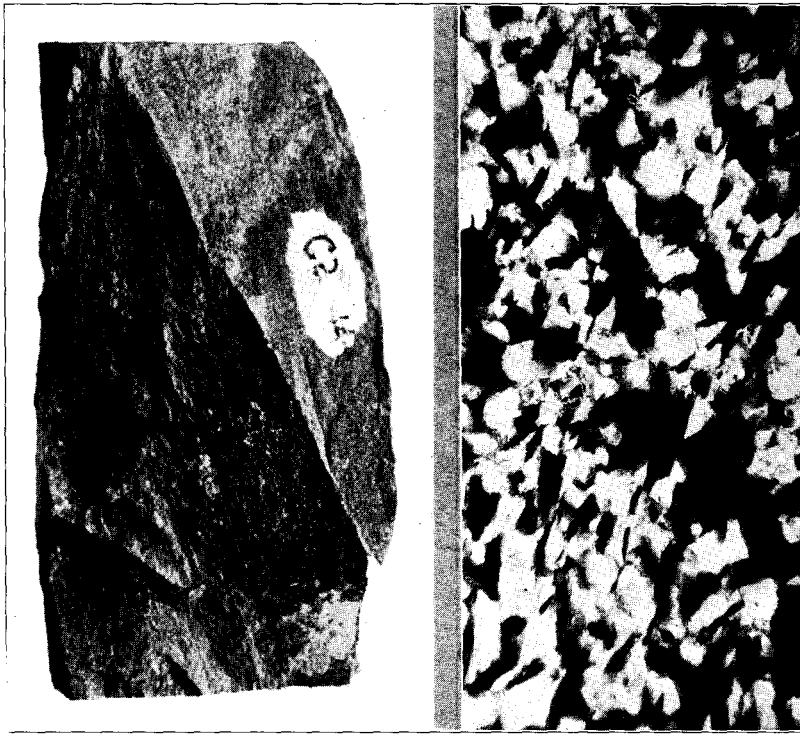
Eagle Cap mountain, elevation 9,860 feet, is the highest peak in all eastern Oregon, but the granodiorite which forms the watershed for the Imnaha river flowing northeast into the Snake river, the various branches of the Wallowa flowing northwest into the Grande Ronde, and Pine and Eagle creeks and Powder river which flow southwest into the Snake, has, in the main, elevations exceeding 8,000 feet. Surrounding this granitic area are found limestones, greenstones and schists. To the south and east these surrounding rocks are generally much lower in height. To the north and west many of their higher points rival the "granite" in the steepness of their slopes and in the loftiness of their elevations. Surrounding all is the Columbia river basalt, which covers so much of the area of Washington, Idaho and Oregon.

This is a country worthy of visitation by the most seasoned traveler in search of beauty and magnificence in nature. It is a region which would especially appeal to the geologist seeking to observe the way in which nature has built her mountains. Here much, if not all, of the records carved in stone are laid open and bare for him. However, to those of us who are more especially interested in interpreting that portion of the records which will assist in successfully exploiting the mineral resources, the following statement as to the forces which placed the granodiorite, the limestone, the schist, the dikes and the veins in the positions in which they are now found, is given.

INTERESTING GEOLOGY

The oldest rocks in the region are the greenstones and sediments. The youngest is the Columbia river basalt. After, and perhaps long after, the greenstones and sediments were placed in position, came the intrusion of the granitic mass. After, and perhaps long after, the solidification of the granitic mass, came the tremendous flow of basalt.

This oldest formation which we have heretofore called greenstones and sediments, is made up of a thick series of ancient lava flows interbedded with schists and limestone. Possibly at some points there may have been intrusions between the bedding planes. Of the sediments, limestones are found to the eastward along the Snake river, on the north side of the "granite" toward Joseph, and on its southwest side near the head-waters of Eagle creek. Most of these limestones have been so much metamorphosed that they are now marbles.



Natural size

Magnified thin section

Fig. 6. Fine-grained schist. A dark-colored, fine-grained rock with a slightly schistose or laminated texture. It consists chiefly of quartz with biotite and chlorite. In the microphotograph notice angular shaped fragments of quartz and the parallel attitude of the biotite and chlorite which are black in the photograph. This rock is of clastic origin, that is, it was deposited in an ancient sea from materials derived from the then existing land surface. On being subjected to pressure the secondary biotite developed and this mineral has since been partly altered to chlorite.

The other sediments of the series have been changed to schists, and because of their high content of chlorite and biotite, it is probable that the rock was once a basic sandstone, somewhat similar to the sand-

stones that now make up a large portion of the Coast range in Oregon.

The limestones and schists which make up the sediments are probably much less in quantity than the series of lava flows with which they are interbedded. These lava flows, or extrusives, vary in texture from dense to amygdaloidal. The latter texture resulted from the spongy condition due to gases in lava that left rounded openings which, after cooling and solidification, were filled with quartz or calcite through the medium of circulating waters. Their presence is in itself pretty certain evidence that the rock flowed out on what was then the surface of the earth.

All of these ancient lavas have, since their solidification, suffered from regional metamorphism. After their alteration as a result of these regional disturbances and pressure, they became meta-basalts, meta-andesites and silicified trachytes. In fact, an outcrop of the latter is so dense and so light in color that it was mistaken for a quartz vein. Besides these extrusive flows, there were probably some small intrusions in the form of dikes, sills or sheets.

No true volcanic sediments were found in the vicinity of the Cornucopia camp, although some of the most badly altered greenstones may have had that origin. On Eagle creek, however, fine-grained breccias composed chiefly of angular fragments of altered basic volcanics were found.

Some of the rocks of this series are so very dense in texture that it is almost impossible to gain an idea as to whether they were originally a sediment or a flow. The fact that they show slight indications of bedding will probably place them in the sedimentary class. The supposition is that they are mud sediments, the finer products of erosion from basic rocks deposited some little distance out from the shore of an ancient lake or sea.

The presence of the sediments interbedded with lavas, as above described, indicates that these flows took place near sea level, and that the shore line rose and fell so that at one time the streams carried sand and silt from the basic sandstone land areas and deposited them on the floor of the shallow ancient lake or sea. This shallow floor, due to movements of the earth's crust, rose out of the water and upon it the ancient lava may soon have flowed.

This portion of the earth may have oscillated several times to complete the series of sediments and lavas found here. That they were formed in some such way is further strengthened by the fact that in Wallowa county we find what was once limestone now a marble

interbedded with sediments which are now schists. This means that this region during the entire period may never have had land exposed above the surface of the water. Nevertheless, during the time the sediments which are now schists were being formed, it was much nearer to the surface of the water than it was during the time when the limestones, which are now marble, were deposited. The floor of the sea rose and fell.



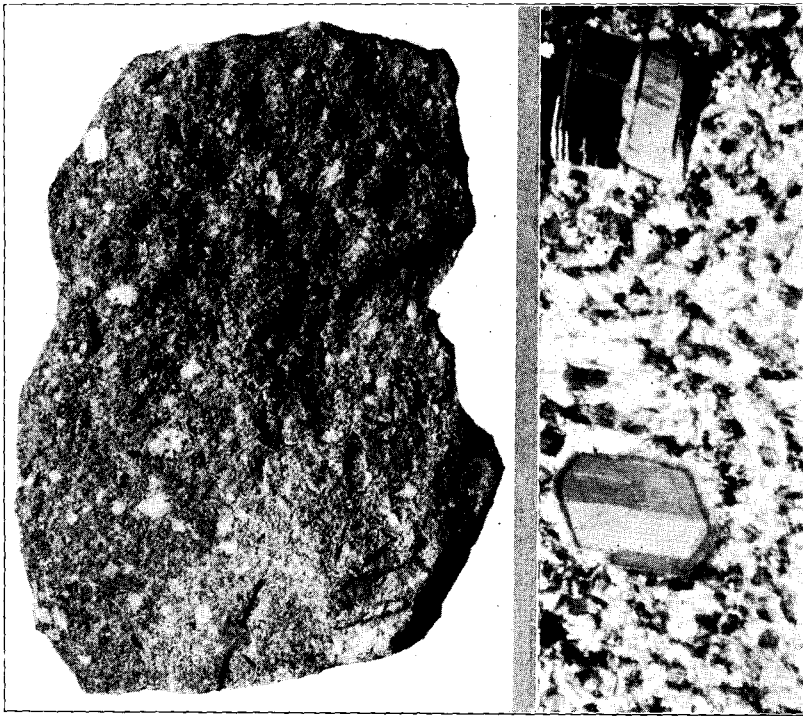
Natural size

Fig. 7. Amygdaloidal basalt. This specimen, taken from one of the recent lava flows, shows some of the gas-formed cavities filled with secondary minerals thus forming amygdules, while some are only partially filled. The elevation of this particular flow is now 9,500 feet.

Now, remember that we have in this series sediments altered to schists, flows of basalt, andesite and trachyte severely altered mostly into greenstones, and limestone largely changed to marble. How and when were these conditions brought about? These Triassic series have

activities, the pressure upon the viscous intrusive from below decreased, and the main mass of the intrusive became somewhat chilled due to the continued incorporation of blocks of cooler wall rock. The borders of the intrusive were in addition chilled by mere contact, so that they became so viscous that eventually pieces of the wall rock sank but little into the mass.

In the earlier stages of this intrusion the period of time was so long, the temperature so high and the mass so fluid, that the blocks which fell off and sank into the interior were completely dissolved. As time went on a continued decrease in temperature especially near the exterior, made action insufficient to dissolve completely the pieces of wall rock. They sank partly into the mass, and the action was suffi-



Natural size

Magnified thin section

Fig. 8. Granodiorite porphyry. One of the common dike rocks cutting the granodiorite. Has a similar appearance but is finer grained with a few larger crystals of feldspar (which are white in the photograph) and hornblende (which are black in the photograph). The larger crystals are called phenocrysts and the spotted appearance, a porphyritic texture. The thin section clearly shows the crystal outlines of the phenocrysts and the slightly darker band around the lighter colored one indicates a different composition from the central portion.

cient in the earlier part of this second stage to re-crystallize them to a large degree. Its power to do this lessened as time went on so that one finds particles of the wall rock within the granodiorite near the contact practically without alteration.

These inclusions of the wall rock found on the exposed contacts of the "granite" in the Cornucopia region or any other, especially the angular fragments, are proof in themselves that the included fragments are parts of the older rock. The enclosing rock must of necessity be younger than the enclosed fragment.

The chilling of the intruded rock progressed toward its center, the deep seated portion in all probability remaining in a molten condition for a long period of time. After this solidifying or freezing of the exterior, it is quite reasonable to expect that cracks would form in the newly solidified rock, due probably to strains set up by cooling.

Do not forget that there still remained a roof of the older rock covering the intrusion. The contraction of the latter, with perhaps a decrease of regional pressure and a continued enlargement of the cavity on some of its deeper levels, may have caused a subsidence of the roof due to these causes. In this way extensive fissures were created not only in the upper and outer part of the cooled intrusive but in its roof of older rock as well. It is to be expected also that regional disturbances did not abruptly disappear. These may have been an additional cause of fracturing.

Now if at this stage the interior portion is still in a liquid condition and under some pressure from below, it will force its way up into these freshly formed cracks or fissures and, after solidifying, become dikes. The lower part of this intrusive magna although molten, has already started to crystallize, the crystals, large because they formed at depth under slow cooling conditions, will be carried up into the fissures. Here on account of quick cooling conditions these larger crystals will be caught in a fine-grained groundmass. In this manner a porphyry dike is formed. The composition of the porphyry will indicate whether there is much difference in the composition of the still molten interior from that of the now solidified exterior. The granodiorite porphyry taken from the dikes of the Union-Companion property is not only of more basic composition than the enclosing granodiorite wall rocks, but the zonal growth of the large crystals shows a gradual change; the central or older portions are more acid than the outer or younger portion.

A recurrence of fracturing may follow from time to time, which

of the outer portions of the intrusion had gone deep, and a much more quiet condition of the earth's crust prevailed. It must be borne in mind, however, that this intrusion was well covered by the older rocks; that its mass is to be thought of in cubic miles; that its temperature although lowered to such a point that the mass had become solid, was still very hot.

It must further be remembered that the same causes which produced the fracturing before this time will create fractures again. These fractures may cut through both the intrusion and the older rock as well. They will not be filled by molten rock, either of porphyry or of aplite, but will be filled in the main by the precipitation of quartz and other vein minerals from ascending circulating waters. Now these circulating waters, because of the temperature of the region, will be hot because of the uncooled condition of the intrusion and the wall rocks as well, and since they are well below the surface of the earth, they will be under considerable pressure. With high temperature and pressure chemical activity is much more intense. This of course refers to the ability to take material into solution. Whether the ascending waters are a product of the intrusion or come from the older rocks, they will in the deep interior dissolve a great deal of quartz and lesser amounts of other rock and metallic minerals.

From whatever points or regions the solution of these substances may come, whether from the uncongealed remnants of the intrusion or from the adjoining older rock, either or both, it will be from a few thousand feet below the surface. As the hot water containing the dissolved quartz and metallic minerals ascends, pressure and temperature decrease. With decrease in pressure and temperature, following the chemical law above stated, the ability to hold in solution is lessened and precipitation begins. If, in the deep-seated region where the taking into solution is going on, there are little or no metallic minerals, the ascending hot water will of course not contain them. It will deposit in the fissures in the upper few thousand feet quartz upon the fissure walls, and a barren quartz vein, when the fissure has been completely filled, will have been created.

It is plain to be seen then that the proportion of minerals deposited in the veins is largely dependent upon the proportions present in the deeper zones.

It is also seen that, although the interior may have contained plenty of metallic minerals which have been taken into solution and have ascended through the fissures made for them so that the

fissures have been completely filled with quartz and other minerals, still the finding of ore at or near the earth's surface will depend upon how much that surface has been lowered since the completion of the vein.

Also, when a primary ore is found at or near the surface whether ore will continue to a considerable depth will also depend upon the amount of erosion. In other words the vertical distance between the points where deposition begins and ceases is considerable. The latter point is usually well below the surface at the time of deposition. The distance between these two points under conditions similar to those found at Cornucopia is rarely as little as one thousand feet, and is



Natural size

Magnified thin section

Fig. 10. Basalt. The most common recent lava rock. Dark in color, fine-grained porphyritic in texture. Consists chiefly of basic plagioclase (labradorite) pyroxene and olivine. The microscopic thin section at the right shows the lath-shaped labradorite phenocrysts, and the olivine of high relief is slightly altered to serpentine.

usually much increased in length by the presence of certain wall rocks, such as found there. To what point has erosion progressed at Cornucopia? The erosion has progressed to the point where the roof of older rocks has been removed together with considerable of the intruded granodiorite itself over an area of something like 250 square miles.

Throughout the long period of time when the large quantity of ascending water was filling the fissures, the region affected was slowly cooling. Perhaps during much of this period the erosion of the then existing surface was progressing more or less rapidly. What the topographic forms were at the end of this period would be impossible to determine.

In our story we have arrived at the period of greatest quiet which was followed by another regional disturbance due to unbalanced forces within the earth, the effect of which was to make complex fractures out of which flowed enormous quantities of basaltic lava. How great a quantity may be imagined when one considers the great depths and the enormous areas of it now covering large parts of Idaho, eastern Oregon, and eastern Washington. According to Waldemar Lindgren the region under consideration was the principal source of Columbia river basalt.

This lava, welling up through the complex fractures in the granitic and older rocks of the region filled the then existing gulches and other depressions of the surface. Such overflowing may have continued to so great an elevation that when cooled the Cornucopias were a plain or else an island in a sea of basalt.

Following the final flow of lava, for there were many flows, erosion began again and has progressed to such a point that now, over most of this region, the lava has disappeared and only the basalt in the dikes is left. These dikes cutting the granitic and older rocks in all directions, crossing the quartz veins, breaking along their sides or else diagonally through them, are the most striking visible feature of the Wallowa range.

Above, in bare outline, is the geological history from the forming of the Triassic sediments before the coming of the granitic intrusion down to the present time. It is a necessary prerequisite to an understanding of the ore deposits of this region.

THE MINES AND PROSPECTS

The producing veins are all situated on "Granite" mountain two or three miles to the north and east of the town of Cornucopia, and at elevations of 1,000 to 3,000 feet above it.

There are many prospects on both slopes of this mountain as well as the ones on Red mountain, Simmons mountain, in Norway basin and those to the east and south of town. There are also the placers on Pine creek. There are several parallel veins on Granite mountain which strike a few degrees east of north and usually dip 45° westward.

UNION-COMPANION MINE

This mine is now the property of the Cornucopia Mines Company.

History.—The gold bearing veins of the Cornucopia district were discovered about 1880. The nearest railroad at that time was the main line at Baker. This distance to railroad transportation, together with the isolation of a snowy mountain camp, caused production to be intermittent for some little time. The strikingly favorable appearance of the veins attracted investors, and early in 1895, although but slightly developed, the Union-Companion claims were sold for \$60,000. The purchasers proceeded vigorously with development and installed a 20-stamp mill and chlorination plant to treat the ore. The latter proved to be unsuitable and was abandoned.

The method followed from this time on, was by* “the customary method of crushing with light stamps, amalgamating, and concentrating, with a canvas plant for the tailings. The mill was built in 1896 and succeeded in extracting only about 65 per cent of the values. Owing to the fact that the mine is situated 25 miles from a railroad, the hauling, together with smelting charges on the concentrates, combined with the low extraction, made it very difficult to keep the property on a paying basis. It was therefore decided that, if possible, the ore should be treated by cyanidation, thus eliminating outside charges on concentrates and at the same time making a better recovery of the metals contained in the ore. Tests showed that a satisfactory extraction could be obtained by grinding fine, and treating the product by agitation and filtration. Accordingly, in June, 1912, construction on the cyanide plant was started. The crusher, ore bins and stamps of the old mill were left intact, and only such changes were made to the mill buildings as were necessary to accommodate the new machinery.” Since the completion of this plant, March 1, 1913, the production has been steady and profitable.

Geology.—The outcrop of the Union-Companion vein is at an altitude of 6,100 feet, or 1,400 feet above the town of Cornucopia, one and one-half miles away down Fall creek. The outcrop of this vein is traceable, according to Bernard McDonald, for 6,800 feet throughout the

*Paul W. Gaebelein in the *Engineering and Mining Journal* of February 28, 1914.

epidote, are in evidence near the borders of the dike for the most part, but sometimes are seen in the adjacent limestone. The pyrite and pyrrhotite appear in greater percentages in the outer portions of the dike. This dike, a basic differentiate of the great intrusion injected in a molten condition into the fissure in the limestone, probably had sufficient heat with the assistance of mineralizers to form the small amount of garnet and epidote present.

Practically no mineralization is seen in the limestone adjoining the dike. In an examination of several open cuts scattered for a considerable distance along this dike the copper minerals appear to be too thinly scattered through the dike to call it ore. Without the presence of precious metals in fair amounts this primary deposit would not pay to work.

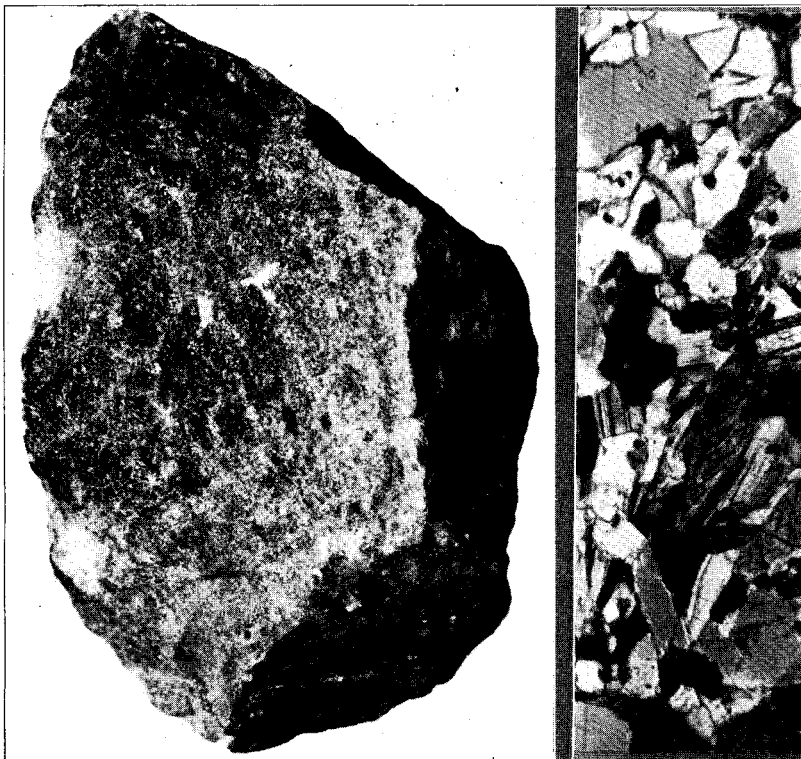
Returning to the stream again we start north for Lostine, 17 miles away. Most of the way granodiorite predominates on our left, while on the right besides granite much limestone and other sediments appear.

ECONOMIC GEOLOGY OF THE WALLOWA DISTRICT

The geology of this, the northern part of the Wallowa range, is similar to the Cornucopia or eastern portion. It is a part of the same granitic intrusion. The greater differences are in the sediments which made up the roof of the batholith of which much was absorbed by this intrusion, and the metamorphism at the contact with these sediments. The minor differences are a few occurrences of pegmatite and numerous occurrences of lamprophyres.

The roof of the batholith in the Cornucopia region was composed probably of altered basic volcanics, or greenstones and their volcanic breccias together with schists which were once basic sandstones. In the Wallowa country, however, we had for a roof a limestone, probably of considerable thickness, together with considerable calcareous and other schists and some greenstones. The area which the limestone originally covered has not been determined, but it is probable that a large part of the northwestern border of the intrusion was covered by it many hundreds of feet thick. The composition of the granodiorite shows the effect of the absorption of calcareous sediments. In every case the feldspars are more basic and in many places hornblende becomes a prominent accessory mineral.

Lamprophyres of various compositions, such as, quartz-kersantite, kersantite and pyroxenite were found to be more or less closely con-



Natural size

Magnified thin section

Fig. 60. Lamprophyre. A dark-colored dike rock consisting chiefly of biotite, hornblende, plagioclase feldspar and a small amount of quartz. The presence of quartz makes it a quartz-kersantite.

nected with ore deposits. The origin of these dikes is still a matter of hypothesis. It also appears that gases or vapors called mineralizers accompanied or immediately followed the intrusion of some of these dikes.

Contact-Metamorphism.—The ore deposits are chiefly those on the contact between granodiorite and limestone. By contact-metamorphism is here meant the change that takes place at the contact of a granitic intrusion with a calcareous or limy sediment. It is characterized by a replacement of some or all of the minerals of each rock by other minerals.

The limestone is replaced more or less completely by such lime-silicate minerals as garnet and epidote, and by other minerals, such

as, quartz, calcite, pyrite, chalcopyrite, magnetite, and molybdenite. The intrusion, in this case a granodiorite, is not altered to such distances from the contact as is the limestone. The replacement of the granodiorite when complete, results in it becoming almost completely siliceous. In some of these deposits considerable garnet and some epidote are found in the granodiorite.

Without stating the evidences found in this region or that derived from like deposits elsewhere, the conclusion is reached that the silicate minerals and the sulphides were derived in large part from emanations from the intrusion during the long period of its cooling. To a lesser degree the limestone contributed some of its lime and impurities; the immediate granodiorite furnished a little from its feldspar, hornblende, and biotite. The limestone and the intrusive emanations formed a chemical system in which reactions of great intensity proceeded. Sometimes the limestone and the intrusive show by the development of epidote and garnet in the latter that a vigorous interaction has taken place.

These deposits were formed beneath the surface, but in the absence of knowledge of the depth of the overlying sediments its depth cannot be stated. In other states similar deposits have been formed at a minimum of less than a thousand feet. Other things being equal, contact-metamorphism will continue downward to the lowest limits of the contact.

Mineralogists and physical chemists have agreed that these minerals are a product of high temperature only. The deposits are not continuous along contacts, but are massed in certain places dependent probably on the facilities for the escape of the gases. The size of these deposits seems to be influenced by several factors:

1. Whether the contact is flat lying or is at a high angle. Where it is at a high angle the deposit is not of great extent. This may seem to be contradictory to the field evidence at Fraser's property, but even there the main plane of contact is essentially flat lying. For the greatest possible amount of mineralization the plane of contact should have a low angle of dip with limestone for a hanging wall, so that the ascending emanations may penetrate more extensively the overlying sediments.

3. The effect of fissuring seems to be particularly important during the latter part of the formation of the contact zone. It is then that we have conditions similar to that of fissure veins. Fissuring in the plane of the contact, especially at the Fraser property, seems to

have occurred after the formation of this zone was well under way. In this fracturing the high-temperature aqueous solution of quartz and molybdenite and other minerals creates more or less vein-like deposits. This fracturing has tended to prolong the period of mineralization by re-opening the channel.

3. In many cases mineralization seems to be closely connected with both acidic and basic dikes, technically called "complementary dikes." At the Gem group we find aplite associated with ore minerals and at the Lostine contact and at the Walla Walla group at Aneroid lake we find lamprophyres closely connected with the ore-bearing minerals. The effect of these dikes on the size alone of contact deposits is probably similar to that of fissures. They furnish means for the distribution of mineralizers; they also probably contained mineralizers and maintained them at elevated temperatures.

4. The character of the overlying material is by far the most important factor in determining the size of the deposit. Limestones or a rock that contains lime are the only ones mineralized to any considerable extent. The degree of alteration probably depends more on the physical character of the rock than on its composition. The fact that the limestone is loose textured and granular makes it more easily affected than a dense hard rock. In any case alteration is somewhat capricious.

The point of most interest and worth is the probable value of these deposits. Can we reasonably hope that some of these contact-metamorphic copper deposits may become mines? The development is practically negligible so that we are forced to view these croppings, open cuts, and extremely shallow underground workings in the light of similar deposits in other parts of the world.

Those who are interested in comparing the conditions obtaining here with those deposits already developed elsewhere are referred to the considerable literature upon the subject. This can be found in technical periodicals and official publications.

In the southwest contact-metamorphism is the dominant factor in mineralization in such well known camps as Clifton and Bisbee in Arizona, Bingham in Utah, and some districts in New Mexico and Nevada. Contact-metamorphic deposits are also found in Montana, Idaho, and Alaska, but in the southwest this type of deposits is mined more extensively than elsewhere.

By comparing the conditions of these developed deposits with those found in the Wallowa region the interested person can form an idea as to the probabilities of developing considerable ore bodies.