QUICKSILVER
(Mercury)
RESOURCES OF ARIZONA

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PREFACE

In 1923 the attention of engineers was first directed to the Emmet Mercury Boiler, and much interest was aroused by the statement that tests conducted at Hartford, Conn., had demonstrated that the substitution of mercury for water resulted in a saving of nearly 50 per cent in fuel. Since the Hartford installation required 30,000 pounds of mercury and the production of the entire world for the preceding fifteen years had hardly been sufficient to supply half of the high pressure boilers in the United States alone, it seemed possible that the demand for mercury might be suddenly increased and that the price might advance. Consequently, officials of the United States Bureau of Mines endeavored to collect data relating to potential undeveloped sources of mercury in this country, and the Director of the Bureau attempted to obtain, through E. D. Gardner, Superintendent of the Southwestern Experiment Station of the Bureau, information concerning the mercury resources of Arizona. A consultation with the writer brought out the fact that, although mercury ore was known to exist at several places in the State, and a small quantity of the metal had been produced, reliable data bearing on the extent and commercial value of the deposits were not available.

After some correspondence, it was arranged that a cooperative investigation of the mercury resources of Arizona should be made by the United States Bureau of Mines, represented by E. D. Gardner, and the Arizona Bureau of Mines, represented by its Chief Geologist, Carl Lausen. Consequently, field work was begun in the summer of 1924, and was continued intermittently until the summer of 1926. This report embodies the facts then collected, but it is not strictly up-to-date even at the time of going to press since continual development of some of the deposits has been under way for the last year or two, and it has been thought best to include no data not actually checked by the writers. It is believed, however, that it will serve to convey a fairly reliable idea of the potential mercury resources of Arizona.

Not only did the two gentlemen mentioned work together in the field, but they jointly wrote the report. It is impracticable to attempt to state just which part of the report each of the joint authors prepared, but it may be said that, in general, Mr. Lausen is responsible for those portions dealing with mineralogy and geology, while Mr. Gardner wrote the descriptions of prospects and mines and the section dealing with the metallurgy of the metal.

G. M. BUTLER.

April 1, 1927.
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QUICKSILVER RESOURCES OF ARIZONA

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DISTRIBUTION OF QUICKSILVER IN ARIZONA

Quicksilver deposits have been worked in the Dome Rock Mountains, near the western boundary of Arizona; in Copper Basin, southwest of Prescott; in the Phoenix Mountains; and in the Mazatzal Mountains, north of the Roosevelt Dam. The relative positions of these deposits to important cities in Arizona is shown on the index map, Fig. 1, and will be described in detail on succeeding pages of this report. These are the more important deposits in Arizona, but the occurrence of cinnabar in small quantities has been reported from other parts of the State. The writers saw a specimen of quartz impregnated with minute specks of cinnabar at the Roadside Mine, and ore from the old Heintzelman Mine, now closed down for many years, carried quicksilver.

Undoubtedly, as prospectors become more familiar with quicksilver minerals and the occurrence of the ore, additional deposits will be found in Arizona.

HISTORY

In the month of January, 1862, Captain Pauline Weaver, while trapping along the Colorado River, discovered the famous La Paz placers. Returning to Fort Yuma, Captain Weaver exhibited the precious metal and soon there occurred a gold rush for the new “diggings.” As these placers began to show signs of apparent exhaustion, a search was made in the surrounding mountains for the lodes from which this placer gold was derived. It was probably during this search that the quicksilver deposit in the Dome Rock Mountains was discovered. Turner¹ states that: “The deposit is not a new one, for it was well known to J. W. C. Maxwell thirty or more years ago.” This would place date of discovery

¹Turner, H. W., Quicksilver: Mineral Industry During 1908, p. 743.
at least as early as the year 1878. The original locator or the date of location of this deposit is unknown. The only production of quicksilver from this district was reported in the Mineral Resources of the United States for the year 1908, but, unfortunately, the production from Oregon is included with that from Arizona.

Fig. 1.—Index map showing the distribution of quicksilver deposits in Arizona.

The quicksilver veins in Copper Basin, between Prescott and Skull Valley, have also been known for a number of years. During the late eighties and early nineties this metal is reported to have been produced to supply the local demand of gold mines for quicksilver needed for amalgamation. The production apparently was small and no record was kept of the amount produced.

Cinnabar was first discovered in the Mazatzal Mountains in 1911 by E. H. Bowman, on the west side of Alder Creek. Since then other occurrences of this metal have been found on Sycamore and Slate creeks, the latter in Gila County and on the east side of the range. There has been a small production of quicksilver from these ores, seldom over a few flasks per year and during some years no production.

Quicksilver was discovered in the Phoenix Mountains in 1916 by J. A. and Henry Porterie, father and son; and during the latter part

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of the same year cinnabar was found by Sam Hughes and associates, and the Rico group located. A few flasks of quicksilver were produced in a small retort built by Mr. Hughes.

ACKNOWLEDGMENTS

Many courtesies were extended and considerable help was given to the writers by mine operators and prospectors alike. The assistance of Colonel Baker, of Prescott, and Mr. Robert Donald, of Roosevelt, was particularly helpful in carrying out the work of this investigation. Mr. E. W. Bedford, manager of the Arizona Quicksilver Corporation, generously furnished maps and information regarding the operations of his company, and Chris Martin showed the writers over the ground. B. F. Baker and W. A. Malone of the Red Bird group, Wesley Goswick of the Ord group, A. M. Packard of the Rattlesnake group, Wm. Reynolds of the Northern Light and Mercuria groups, and Charles MacFarland of the Pine Mountain groups were generous with their time and hospitality while the examinations were being made.

The samples collected were assayed by Wm. A. Sloan, assistant chemist at the Southwest Experiment Station of the U. S. Bureau of Mines, Tucson.

Tracings of part of the sketches were made under the direction of R. A. Wood at the Pittsburgh Station of the U. S. Bureau of Mines.

General data in this report have been freely abstracted from the publications of the U. S. Geological Survey, from California Mining Bureau Bulletin No. 78, “Quicksilver Resources of California,” and from Bureau of Mines Bulletin 222, “The Metallurgy of Quicksilver.”

USES OF QUICKSILVER

Quicksilver or mercury is the only metal that is liquid at ordinary temperatures. Because of this and other physical and chemical properties it is an indispensable metal. Almost every branch of industry makes use of it or its compounds. For some of its applications no substitute is available, and for others the substitutes would be unsatisfactory or extremely expensive. A moderate but adequate supply is essential in case of war, and quicksilver has been classed as a war mineral by the War Minerals Board.

Quicksilver enters largely into the manufacture of drugs and chemicals. Mercury compounds are also used in the preparation of other chemicals in which the metal itself does not enter. Mercury fulminate is used as a detonator for high explosives and, to a lesser extent than
formerly, in small arms ammunition. Mercury, as mercury sulphide, constitutes the brilliant red pigment vermilion, and in the oxide form it is an ingredient of antifouling paints. The metal is employed extensively in electrical apparatus and storage batteries. In the manufacture of felt from rabbit fur, mercuric nitrate is used to roughen the hairs so they will adhere together. Metallic quicksilver is employed in the amalgamation of gold and silver ores. The metal is also utilized in the metallic state in the manufacture of various instruments such as gas governors, thermostats, and other appliances. A prospective use is as a second heat carrier in binary fluid turbine engines. Smaller quantities of quicksilver are also used in various other ways.

In 1917 the supplies required annually for the chief non-military uses of quicksilver were estimated as follows:  

Flasks of 75 lbs.  
Drugs and chemicals ........................................... 8,500  
Fulminate .......................................................... 4,850  
Vermilion .......................................................... 3,130  
Oxide (for antifouling marine paint) ......................... 3,000  
Electrical apparatus (batteries, electrolyzers, rectifiers, lamps, etc.) .................................................. 2,700  
Felt manufacture (especially hats) ........................... 1,700  
Gold and silver amalgamating mills .......................... 850  
Instruments, thermostats, gas governors, automatic sprinklers, etc. .................................................. 630  
Miscellaneous, including boiler compounds and cosmetics .......................................................... 1,000  

26,360

PRODUCTION IN THE UNITED STATES

Most of the quicksilver produced in the United States comes from California.

In 1924, the latest year reported by the Geological Survey, the production in the United States was as follows:  

State Flasks of 75 lbs. each Value
California 7,966 $347,185
Oregon, Texas, Idaho, and Nevada 2,095 143,905

From 1850 to 1923, 2,426,600 flasks of quicksilver having a value of $120,500,000 were produced in the United States. Of this amount California yielded 2,195,000 flasks; the remainder came from Texas, Oregon, Nevada, and Arizona.

Quicksilver production in 1920 was about one-sixth that of 1917 or 1918, the war period. During recent years about one-ninth of the world's production has come from the United States.

The average price for 1920 was $79.66 per flask. Subsequently the price steadily decreased until it was below $50 per flask. However, during 1924 and 1925 there has been a steady improvement in price. The quotation in the Engineering and Mining Journal-Press for Oct. 16, 1926, was $94.33 at San Francisco. There is a duty of $18.75 per flask on quicksilver, which should be advantageous to domestic producers.

In case the Emmett Boiler comes into wide use, there should be a substantial increase in the demand for quicksilver, which should be reflected in still higher prices. The expiration early in 1924 of the British contract for the sale of Spanish quicksilver is probably a factor behind the increased price.

MINERALOGY

Mercury is found in only a few minerals; the one which furnishes most of the metal of commerce is cinnabar. Commonly associated with cinnabar is the black modification, metacinnabarite. Calomel and native mercury are also fairly common, but all other minerals containing quicksilver are relatively rare.

COMMON QUICKSILVER MINERALS

CINNABAR

Mercuric sulphide (HgS) occurs as crystals, prismatic needles, crystalline masses with granular texture, and as an earthy variety which is massive. Color is vermilion-red, often inclining to brownish-red and lead-gray. Powder scarlet. The earthy variety contains iron oxides and clay as impurities, and usually gives a brownish-red powder when crushed. The mineral is transparent in crystals and opaque in the earthy
variety. Luster brilliant in crystalline varieties. Perfect prismatic cleavage. Hardness 2 to 2.5. Specific gravity 8. Because of the high gravity, the crushed mineral can easily be tested by washing in a miner's pan; the cinnabar present will be shown by a string of scarlet particles. Cinnabar is found at all quicksilver mines.

**METACINNABARITE**

Mercuric sulphide (HgS); color black; rarely as crystals, usually earthy, or as thin films coating cinnabar from which it was derived. Specific gravity 7.7. Some specimens from Guadalcazar, Mexico, contain a small amount of zinc (up to 4 per cent).

**CALOMEL**

Mercurous chloride (HgCl). Color white or yellow, rarely gray or brown. Commonly as crystals or crystalline masses. Transparent to sub-translucent, and with adamantine luster. Specific gravity 6.5. Hardness 1 to 2. An oxidation product of cinnabar.

**MERCURY**


**MERCURIAL TETRAHEDRITE**

Sulphantimonite of copper (Cu₄Sb₂S₇), mercury isomorphous with copper. Some varieties have been found to contain up to 17 per cent mercury. Color dark gray to iron-black; opaque. Hardness 3 to 4. Specific gravity 5.1. Most common in some copper-lead deposits.

**RARE QUICKSILVER MINERALS**

**AMALGAM**


**COLORADOITE**


**TIEMANITE**

Mercuric selenide, (HgSe). Color steel-gray to blackish lead-gray. Luster metallic; commonly massive. Specific gravity 8.2. Occurs at Clear Lake, California, and Marysvale, Utah.
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ONOFRITE
Mercuric sulpho-selenide, (Hg [S, Se]). Color blackish gray. Usually massive. Hardness 2.5. Has been found only at San Onofre, Mexico, and with tiermonite in the Lucky Boy Mine, Marysvale, Utah.

LIVINGSTONITE

The following rare oxidation products of cinnabar have been found only at Terlingua, Texas.

KLEINITE
A mercury ammonium chloride. Composition uncertain. As small crystals. Color yellow to orange, darkening on exposure to light. Hardness 3.5.

EGLESTONITE
Oxychloride of mercury, (Hg₄Cl₂O). As small crystals. Color brownish-yellow darkening on exposure to black. Hardness 2 to 3.

TERLINGUAITE

MONTROYDITE
HgO. Small prismatic crystals. Color and streak orange-red. Hardness 1.5 to 2.

MOSESITE

TENOR OF ORES
The quicksilver content of the ores now being mined differs widely. Ransome¹ says:

“The richest quicksilver ores worked on a large scale are those of Almaden, Spain, where the average content won from the ore in 1917 was nearly 7 per cent and where the average of some ore bodies is stated to be as high as 25 per cent. Probably the lowest tenor in ores that are successfully worked is found on the Pacific coast of the United States. The average content won from the California ores during the last two years is 0.38 per cent and the range, in furnace operations, in

1917 was from 0.17 per cent to 1.08 per cent. In Texas, in 1917, the average was 1.42 per cent and the range from 0.55 to 3.88 per cent. The ore at Idria, Austria, according to the latest information available, averages about 0.65 per cent. In the Monte Amiata district, Italy, the ores are reported to range in tenor from 0.25 to 30 per cent, the average for the district in 1913 being 0.89 per cent."

Quicksilver ore deposits are, on the whole, extremely erratic in occurrence, and there is no assurance in unproved territory that ore will extend any distance beyond the face where it is actually exposed. The estimation of the amount and grade of ore in a new district, therefore, is extremely difficult. Samples must be taken with care and assays must be interpreted with caution. Even if a body of quicksilver ore were exposed on three sides it would not be safe definitely to assume its value from the results of sampling.

In making an estimate of the possible ore, geological conditions, the persistence of the ore shoots in the district, and other data are taken into consideration. Any estimates of possible ore in an unproved property would, therefore, be of doubtful value.

TREATMENT OF ORES

Quicksilver ores are treated at the mines, and the liquid metal is marketed in 75-pound flasks. Of all the metals, quicksilver is probably the most easily recovered from its ores, as it can be volatilized at a comparatively low temperature (about 680°F), and thus separated as a vapor from nearly all other substances that might be present in the ore. Metallic quicksilver is readily obtained by condensation. Although in outline the process is exceedingly simple, the control of operations to obtain maximum production with a minimum cost presents difficulties and requires experience.

The metallurgy of quicksilver is described by L. H. Duschak and C. N. Schuette in U. S. Bureau of Mines Bulletin 222. Information relating to the metallurgy of the metal is also found in Bradley’s “Quicksilver Resources of California,” and in “Mineral Resources of the United States,” 1917, Part I, U. S. Geological Survey.

Because of its relatively small commercial importance, and the lack

1Note—Estimation of Quicksilver Ore Bodies.

In conventional reports on mining properties ore reserves are generally placed in three classes:
1. Ore in sight, exposed on three sides.
2. Probable ore, exposed on two sides.
3. Possible ore, exposed on one side.
of a stable market and price for the metal, quicksilver has not had the benefit of the same metallurgical and business direction that has been given the winning of the major metals. However, some operations are highly successful.

According to Duschak and Schuette:

"In the direct-furnace treatment of quicksilver ores the major problem in the extraction of quicksilver has been solved. Methods are available whereby low-grade ore can be treated with a remarkably high recovery and at low cost in view of the small scale of operations at most plants. It does not follow that present practice at all or even at the majority of the quicksilver reduction works in this country has reached the highest possible point of efficiency. Improvements can be made at many plants mainly by correcting minor defects rather than by making fundamental changes in the process used.

"In the past the quicksilver industry has suffered from lack of competent technical supervision, and some time and effort have been wasted through attempts to devise improvements in process and equipment without adequate regard for developments in other branches of metallurgy. Now knowledge of the metallurgy of quicksilver has advanced so far that adequate information is available for the design, construction, and operation of a plant for the treatment of any ordinary mercury-bearing ore. A few unusual cases which require further investigation are mentioned in this bulletin, but generally speaking there is no difficulty in recovering the metal from its ores effectively, and improvements in practice will consist mainly in applying available information more efficiently."

TREATMENT PLANTS

In general, two main types of plants—furnaces and retorts—have been used in the United States to recover the metal from the ore. Mechanical rotary furnaces are a recent development and give promise of wider adoption. In the furnace in general use the ore is exposed to the direct action of the flames, and the volatile products of combustion, together with the mercury vapor, dust, and soot are drawn into condensing chambers.

In retorts the ore is heated out of contact with the flames and only those volatile constituents that are driven from the charge pass into the condensers, which generally consist of water-cooled iron pipes.

The standard furnace in use in the United States is the Scott, which is built in sizes to handle from 10 to 80 tons of ore in 24 hours. This

furnace is a masonry structure requiring special skill to build. Wood, coal, or oil is burned as fuel in fire boxes, and is not mixed with the ore.

SCOTT FURNACE

According to the bulletin by Duschak and Schuette, before quoted:

"The Scott furnace consists essentially of one or more pairs of narrow, vertical shafts containing shelves of fire-clay tile set at an angle of 45° and placed alternately against the walls of the shafts. These form a series of inclined hearths down which the ore moves by gravity. The ends of the shafts are closed by perforated walls, these perforations communicating with the fire box and the dust chambers. The ore is heated by the hot gases from the fire box, which pass through the flues formed by the inclined tile. A single shaft usually contains about 26 tiers of tile, making the vertical dimensions of the shaft itself about 30 feet. The length of the furnace is determined by the number of tile used in each tier, usually from two to five; the width of the furnace is determined mainly by the number of shafts. Small furnaces are built with one pair of shafts; the usual furnace has four shafts, but a few furnaces have been made with six shafts.

"The outer walls, and sometimes the upper part of the inner walls as well, are built of ordinary red brick. When transportation is difficult or expensive, this brick is usually made near the furnace site. Fire brick is used for the interior walls of the furnace, including the pigeon wall, and also the lining of the combustion chamber and the lower rear dust chamber. Only standard fire brick and a few regular shapes are used. The tile are made of a good grade of fire clay, and are 36 by 15 by 3 inches. In some of the early Scott furnaces, special shapes of tile and fire-clay supports were used; but this has long been abandoned in favor of the standard materials.

"Operating Practice.—In starting up a furnace from two to three weeks are usually taken to bring it up to working temperature. During the early stages the furnace is left empty, but as the temperature rises old roasted ore or barren rock is fed through slowly. When the desired working temperature has been reached, ore is charged, and the regular routine of drawing and charging is begun. During the heating-up process the nuts on the tie-rods or staybolts must be eased off from time to time to take care of the expansion of the furnace. If this whole cycle of 'breaking in' a furnace is done carefully, little cracking of the brickwork will occur.

"The common practice is to charge ore to the Scott furnace every half hour. The first step is to discharge a suitable amount of roasted ore, which, with the ordinary hand-worked furnace, is done with large iron hoes or rakes. A skilled 'draw man' is able to judge by the appearance of the roasted
ore when a proper amount has been taken from each draw opening. Normally, the last of the ore descending into the draw is at a dull-red heat. The drawing is usually somewhat heavier from the end of the furnace next to the main fire box. Instead of discharging the roasted ore directly into the waste or draw cars, it is usually left to cool on the forward part of the draw plates.

"Some dust is always formed during drawing, the amount varying widely with the character of the furnace feed. For this reason, and because of the possibility that a little mercury vapor may sometimes escape from imperfectly roasted ore, the space about the furnace draws should be well ventilated."

Cost of Operation.—At the Oceanic Mine, in California, in 1917, ore containing 3.7 pounds of quicksilver to the ton was successfully treated in the Scott furnace, with a wood consumption of .031 cords per ton.

The cost of operating a Scott furnace will vary, of course, with local conditions and with the size of the plant. Figures of 50 to 75 cents per ton have been given for plants of 50-ton capacity when working under favorable conditions and under careful management. Reduction cost at the Oceanic Mine in 1917 was 57 cents per ton. Actual cost figures from ten different plants in California range from 60 cents to $1.10 per ton.

Tests show that an extraction of 75 to 92 per cent of the metal is made from the ore.

The disadvantages of the Scott or other masonry furnaces are the losses caused by absorption of the metal by the brick, and the high first cost per daily ton capacity. The first cost of the Scott is between $500 and $1,000 per daily ton capacity, which would make a 30-ton furnace cost between $15,000 and $30,000, without freight charges.

Effect of Sulphur in the Ore.—In their report before quoted, Duschak and Schuette say:

"When the ore contains more than enough sulphur, either elemental or as pyrite, to furnish the fuel for roasting the ore, the problem of regulating the temperature in a Scott furnace becomes particularly difficult. If air is admitted freely to such an ore, the temperature is likely to rise to a point where the ore
will slag and attack the furnace structure. The only means available for controlling the temperature is to run the furnace slowly, and to reduce the amount of air admitted until only a part of the sulphur is burned. Reducing the air has the obvious disadvantage of forming much mercurial soot. When heavy sulphide ores are roasted in mechanical furnaces of the McDougal type, excess heat can be prevented by passing through the furnace considerable excess air. This practice, however, is not applicable to the Scott furnace. One possible method of overcoming the difficulty would be to mix limestone with the ore; the decomposition of the limestone absorbs heat and prevents the excessive rise of temperature. This absorption of heat would, however, be offset to some extent by the heat liberated in forming calcium sulphate. This idea has been applied at the Big Bend mine in Brewster County, Texas, where a rhyolitic ore, containing considerable pyrite, was mixed with an approximately equal quantity of ore carrying a limestone gangue. In general, however, the use of barren limerock for this purpose would probably be too expensive.”

RE TOR T FURNACE

The most popular retort furnace is the Johnson-McKay made by the Joshua Henry Iron Works, of San Francisco. This retort consists of a bank or series of 10- or 12-inch cast iron pipes 6 or 7 feet long, set up in brickwork, with 4-inch iron pipes on the outside acting as condensers.

In a furnace with 12-inch pipes the duration of the heat required to volatilize all the quicksilver is about 12 hours. The capacity varies and is rated for a furnace with a bank of twelve retorts of this size, being from 3 to 5 tons per 24 hours. When using wood for fuel, the consumption is from 1 1/4 to 1 1/2 cords per day. The first cost of twelve, 12-inch retorts in San Francisco, in 1916, was $840, which would make the cost of such a furnace $2,500 to $3,000 under normal conditions, not including the freight.1

Although the retort furnace has the advantage of low first cost, its capacity is small and the labor cost in operation is higher. For example, a bank of 12 retorts requires one man on a shift or three men per 24 hours, and burns 1 1/2 cords of wood.

Allowing $5 per shift, the labor cost would be $15.00

Wood at $6 per cord ........................................... 9.00

or a daily cost of ........................................... $24.00

for an average of say, 4 tons of ore, or $6 per ton treatment charges. Also there appears to be more danger of men being salivated with this type of furnace.

MECHANICAL FURNACE

Other types of furnaces which take advantage of the revolving or cement-mill tube have been tried, but have not proved universally successful. However, a recent type called the Gould uses the cement-mill principle, and is reported to be efficient.

Duschak and Schuette in their report before quoted, say:

"Mechanical furnaces have not been used nearly as much in roasting quicksilver ores as in other branches of metallurgy. One of the reasons for this is the small tonnage of ore handled at quicksilver reduction works as compared with the tonnage treated in an average copper, lead, or zinc smelter, where much of the operating cost can be saved with mechanical furnaces. Certain requirements peculiar to the roasting of quicksilver ores developed difficult problems in adapting mechanical furnaces for this work. This circumstance, the isolation of many quicksilver deposits, and the lack of machine shop and other facilities for maintaining a mechanical furnace plant, have no doubt retarded development of mechanical furnaces for quicksilver.

"In 1918, the first rotary kiln was erected at the New Idria mine, San Benito County, Calif.; it was followed by additional furnaces at this and at other mines."

THE ROTARY FURNACE PLANT AT NEW IDRIA

Duschak and Schuette in the report cited, say of the New Idria plant:

"This plant is described by Bradley in 'Quicksilver Resources of California,' California State Mining Bureau Bulletin 78, 1918, p. 248. The furnace shells are 56 feet long and 5 feet external diameter, and are lined with 6 inches of fire brick. The last section of the kiln at the feed end is tapering, and the opening is reduced to 22 inches in diameter. This serves the double purpose of checking excessive draft through the kiln and preventing the ore from feeding backward into the dust chamber. The slope is 1 foot in 25 feet, as in the experimental kiln. Each pair of kilns is driven by a 15-horsepower motor. The normal speed is one revolution a minute. The fire boxes are stationary, the construction being similar to that of the experimental kiln. The bottom of each fire box opens into a large inclined chute formed in the concrete foundation. These chutes have a capacity of about 20 tons of ore, so that considerable time is allowed for the cooling of the ore, with
the incidental escape of any residual mercury and the pre-
heating of air for combustion.

"Contrary to the practice with the first kiln, the fuel oil is
now atomized with compressed air at 80-pound pressure. This
air was preheated to a temperature of about 70° C., in a coil
of pipe which encircled the lower end of the kiln, and the oil
is preheated to about 80° in a set of flat coils placed on the top
of the inclined discharge chutes. The roasted ore is removed
from the bottom of the chute by a cable tramway. * * *

"The time is hardly ripe to make any positive statement as
to the advance which has been made in quicksilver metallurgy
through the application of the rotary kiln. Generally speak-
ing, this type of furnace seems particularly well suited for
ore treatment at the larger mines where the ore mined amounts
to 100 tons or more a day, and where power, mechanical fa-
cilities, and expert attendance are readily available."

Small quantities of ore can be treated daily in the Scott furnace at
lower operating costs than in the rotary furnace. No power is re-
quired and wood or even brush can be used for fuel, which gives the
Scott furnace an advantage over the rotary type where fuel oil and
power are not available. Also there are a few types of ore that have
not been successfully treated in the rotary furnace. The rotary has
a higher abandonment value, has greater flexibility in the quantity and
character of the ore that can be treated, and can be shut down and
started with little loss of time.

The choice of the type of quicksilver furnace for a new plant where
any appreciable tonnage is to be treated apparently lies between the
Scott and the rotary kiln.

RECOVERY OF QUICKSILVER FROM FURNACE GASES

As to the recovery of quicksilver from the furnace gases, Duschak
and Schuette¹ state:

"The problem of recovering quicksilver from the furnace
gas stream may be considered as a separate subject; the gen-
eral requirements of a condenser system are the same, regard-
less of the type of furnace used to roast the ore. The gas
stream passing to the condenser system should be reasonably
free from dust from the furnace, as the presence of dust
promotes the formation of mercurial soot and complicates
the problem of quicksilver recovery. The Scott furnace gives
rise to little dust, but mechanical furnaces handling certain
types of ore generate so much dust that special provision must

be made for removing it from the hot furnace gas before the latter passes to the condenser system. Methods of freeing of the gas stream from the suspended ore particles is not properly a part of the function of the condenser system. When carbonaceous soot forms in the furnace, most of it, because it is light and fluffy, is unavoidably carried into the condenser; but in general the condenser system is required only to cool the gas stream and to collect the condensed mercury. * * *

"The condenser system receives the gas stream from the furnace at a temperature that may at times rise to 300° C., cools the gas stream to a temperature that should not in general exceed 30 or 40° C., and at the same time collects the condensed mercury. As the concentration of mercury vapor in the gas stream is often as low as 0.1 per cent by volume, and less than 1 per cent by weight, the recovery of a large percentage of the mercury seems at first glance to be a rather formidable problem. Besides the gaseous constituents of the gas stream, a certain amount of dust and soot also enters the condenser system and must be collected with the mercury. In a quicksilver condenser two fundamental operations take place—the cooling of the gas stream and the collection of the condensed mercury. The former is ordinarily accomplished by bringing the gas in contact with the cooled surface of the condenser, from which the heat is removed in turn by the atmospheric air, or in some plants by water. The rate of the heat transfer depends on the thermal conductivity of the condenser material, the difference in temperature between the gas and the cooling medium, and the velocity of the gas next to the condenser surface; in other words, it is a function of both the form of the condenser system and the material of which it is constructed.

"The recovery of the condensed mercury and the precipitation of mercurial soot is essentially a mechanical problem of separating suspended particles from a truly gaseous medium. Apart from the use of electrostatic precipitation, this separation is accomplished by reducing the velocity of the gas until the particles settle by gravity, or by the use of baffles to throw the particles against the walls of the condenser. The efficiency of a condenser system in collecting these suspended particles is, therefore, essentially a matter of design, and involves only in a secondary way the material used in building the condenser. Although the two processes of cooling and collecting are considered separately, in the actual operation of a condenser they are largely simultaneous. * * *

"During the last few years several different forms of condenser systems have been constructed, which differ from the older type chiefly in the use of wooden chambers and glazed tile instead of massive brickwork."
The condensers of the plant near Quartzsite, Arizona, shown in Plate I-A are of brick, lined with pitch.

During the war some flotation plants were built in California, but were shut down after the price of quicksilver dropped.

Apparently, all the ore from a mine can be treated in furnaces more cheaply than it can be concentrated and the concentrates retorted.

**PRELIMINARY TREATMENT OF QUICKSILVER ORES**

Duschak and Schuette¹ make these comments on the treatment of quicksilver ore:

"The usual method of treating quicksilver is by roasting in either a direct-fired furnace or retorts, and is so simple that comparatively little preliminary treatment is needed.

"Ore is seldom hand sorted unless it breaks largely into lumps more than 3 inches in diameter. Generally, quicksilver ore is easy to sort owing to the bright red color of the cinnabar. Some impure cinnabar has a brownish color, almost identical with that of certain forms of iron oxide, also in the ore. If the surface is wetted the cinnabar at once shows bright red and can be readily distinguished. That class of ore in which the cinnabar has been deposited in cracks and fissures lends itself most readily to hand sorting, whereas, with certain types of disseminated ore, selection is difficult. Sorting is done underground sometimes, but usually it is done at the surface either in specially equipped rock houses or on sorting platforms.

"The amount of crushing required by quicksilver ore varies considerably. For ordinary furnace treatment, 1 or 2-inch ore is needed. For an ore that breaks readily in mining, only hand spalling of the larger pieces is necessary. Ore is crushed extremely fine at the Goldbanks mine near Winnemucca, Nev. Here the ore is unusually hard and fine grained. The cinnabar is disseminated throughout the silica which cements the original breccia. Crushing to one-fourth inch was necessary in order to roast the ore within a reasonable time.

"In general, particularly where a mechanical furnace is used, it is desirable to produce a minimum of fine material. * * *

"Except by the use of grizzlies, quicksilver ore is seldom screened. * * *

"The drying of the quicksilver ore prior to furnace treatment is not ordinarily regarded as essential in furnace practice and has not received the consideration that it deserves. Usually drying is done, because the physical characteristics

Plate I-A. Thirty-ton Scott tile furnace and dumps of treated ore, Cinnabar group.

Plate I-B. Three-ton Johnson-McKay retort, Cinnabar group.
Plate II. View of the schist topography near the quicksilver deposit in the Dome Rock Mountains.
of the wet ore require it, not because of effort to increase the efficiency of the furnace and the condenser."

Drying may be accomplished by spreading on drying floors or by utilizing waste heat from furnaces or boilers. Tunnel and rotary driers are used at some places.

HEALTH HAZARDS IN THE EXTRACTION OF QUICKSILVER

Sayers\(^1\) who has investigated the danger of mercury poisoning among furnace workmen says:

"There is probably no industry, trade, or art in which quicksilver is used but has produced some cases of mercurial poisoning. This is true of the mining and reduction of quicksilver ores, where the hazard has long been recognized. Cases occur when the ore contains free mercury or the more soluble salts and when the workings are underground and are poorly ventilated; but there are far more cases among the men employed about the reduction works.

"Very little free quicksilver has been found in recent years in the ores mined in the United States, so that the mercurial poisoning of miners is of subordinate importance. The chief danger is in connection with the reduction of ore in retorts and furnaces. The hazard at retort operations is the greater, because the mercury is evolved in the retort in the form of a concentrated vapor, and a small leak may permit the escape of a large amount of mercury. When the retort is opened for recharging, it may still contain a certain amount of mercury vapor, and some may still be escaping from the charge. Unless the operator thoroughly understands this condition and takes proper precautions, he may easily receive enough mercury to cause poisoning.

"In brief, the avoidance of mercurial poisoning depends upon proper control of the workmen. The conditions leading to this poisoning are well understood, and there is no inherent difficulty in rendering the reduction of quicksilver ores an entirely safe operation. From a practical standpoint the operator is frequently confronted by the serious difficulty of obtaining a class of labor intelligent and cleanly enough to observe the necessary precautions. The small size of the majority of quicksilver plants in the United States also presents economic difficulties in providing change rooms, wash rooms, lunch rooms, etc., such as one finds in other metallurgical plants, lead smelters, for example, where a similar health hazard exists. The intermittent character of quicksilver mining in the past

and the small margin of profit on which plants are compelled to run during periods of low prices—if they run at all—also make it difficult for the operator to obtain a desirable class of workmen. The reputed danger in quicksilver operations is also a factor to be considered, and a plant that gave adequate attention to the health hazards of the industry would no doubt find it easier to obtain the right kind of workmen.”

**DOME ROCK MOUNTAINS**

**LOCATION**

The Dome Rock Mountains are in northern Yuma County and about 10 miles east of the Colorado River. Quartzsite, the only town in the immediate vicinity, is situated on the detrital slopes flanking the east side of the range. This town is approximately 25 miles by highway from Bouse, and 35 miles from Vicksburg; two stations on the Parker Branch of the Atchison, Topeka, and Santa Fe Railway. The quicksilver deposit is in the heart of the range about 8 miles in an airline southwest of Quartzsite; and the distance by road to the deposit is about 24 miles. The mine may be reached by traveling south along the Yuma highway 12 miles to where a branch road leads to Cibola. The Cibola Branch is followed for 4 miles, and there a right-hand branch leads towards the mountains. This branch crosses numerous dry washes, and finally follows the dry, but rocky, stream bed of an arroya to the mine. Thus about two-thirds of the distance between Quartzsite and the mine is over fairly good road, but the remaining stretch of 8 miles is at present nearly impassable. Should this mine again become active, the management will undoubtedly build a new road across the low pass separating the deposit from the valley in which Quartzsite is located, and thus shorten the distance to the deposit by at least 12 miles. This undertaking would not be expensive, especially as fuel for the furnaces must be hauled from the railway.

**CLIMATE AND VEGETATION**

The belt of country on both sides of the Colorado River from Needles, California, southward to Yuma, Arizona, is one of the most arid portions of the Southwest. At Parker, about 35 miles north of Quartzsite, a maximum temperature of 127° F. has been recorded; and the summer months, from June to August, inclusive, are intensely hot. As the summer rains begin shortly after the first of July, the intense heat is temporarily moderated. The winter months, however, are mild; and the occasional light snowfall is usually confined to the higher
mountains. The average mean annual rainfall at Parker over a period of 12 years is somewhat less than 5 inches. Most of this rain falls during the summer when thunder showers prevail, but some precipitation occurs during the winter, especially in the month of February.

The vegetation in this region is highly characteristic of the desert, and consists chiefly of thorny varieties of shrubs or trees. Many different varieties of cacti may be found here; and cholla and prickly pear are the most abundant, but the sahuaro, or giant cactus, with its massive, branching arms, forms the most imposing feature of this otherwise desolate region. Ocotillo, which in the late spring is covered with most brilliant red flowers, and greasewood are two common shrubs. Along the washes may be found small trees such as palo verde, mesquite, and ironwood; they do not, however, grow large enough for mine timbers and are valuable only for fuel. Cottonwoods are usually to be found near water, and are a welcome sign to the prospector.

TOPOGRAPHY

The Dome Rock Mountains are an isolated range with a north-south trend, and the crest is approximately 12 miles east of the Colorado River. On the west is the valley occupied by the Colorado River, and on the east, at a somewhat higher elevation, is the valley in which the town of Quartzsite is situated. From the center of these valleys the surface slopes up, with increasing grade, to the foot of the mountains. Although the general direction of the mountain-mass is north-south, the spurs usually trend northwest-southeast, parallel to the schistosity. These spurs are highly serrated and are separated by deep canyons—a feature characteristic of the pre-Cambrian schist terrain of southwestern Arizona. No living streams occur in the mountains, and, with the exception of the Colorado River, none occur in the valleys. The precipitation, chiefly as torrential showers during the summer months, is carried off by the otherwise dry washes. During times of flood these streams are overloaded with debris which is deposited at the mouths of the canyons as well-developed fans.

At Quartzsite the elevation is approximately 1,000 feet above sea level, and the highest point in the range, Farrar Peak, is slightly over 2,900 feet. At the cinnabar deposit the elevation is about 500 feet above the base of the mountain or about 1,500 feet above sea level.

GEOLOGY

The main mass of the mountain, especially in the vicinity of the cinnabar deposit, consists of schist; but the southern end of the mountain
is composed of a coarse-grained granite. Between the granite and schist is a series of rhyolite flows and tuffs. The relations of these different formations to each other are shown in Fig. 2.

Fig. 2.—Geologic map of the central portion of the Dome Rock Mountains.
METAMORPHIC ROCKS

The metamorphic rocks in the Dome Rock Mountains consist of a series of sericitic, quartzitic, and conglomeratic schists of sedimentary origin, and chloritic schists probably derived from basic igneous rocks. The prevailing direction of schistosity is northwest-southeast with dips at steep angles. In the immediate vicinity of the mine the strike is N. 53° W. and the planes of schistosity dip 40° to the northeast.

Quartz-sericite schists are the most common variety, and show considerable variation both in texture and composition. Usually these schists are of a light gray color, but where chlorite or green biotite becomes abundant, the rock shows a decidedly greenish color. Some bands consist of dark brown slate. The parting planes of these schists are generally well developed, and the satiny sheen is due to the abundance of sericite. However, some varieties do not cleave readily, and consist almost entirely of quartz grains. They may be classed as quartzites; but as they part more readily in one direction under a blow of the hammer than in others, and as these parting faces show that some mica has been developed along them, they are here classed as quartzitic schists. They are not abundant, and form but a few beds in the metamorphic sedimentary series.

One phase of the schist has a strikingly mottled appearance, and close inspection shows it to contain numerous minute octahedra of magnetite. This type of schist might easily be confused with another mottled variety containing small flakes of dark brown, nearly black, biotite.

On the trail leading to the Scott furnace is an interesting exposure of conglomerate in the schist series. This rock has been cut by a vein of pegmatitic quartz containing some black tourmaline. The pebbles in this conglomerate, which are seldom over 2 inches in diameter, are well rounded, and consist chiefly of biotite gneiss, quartzite, vein quartz, and devitrified rhyolite. The matrix consists of quartz, sericite, and some feldspathic material. A few hundred yards northeast of the shaft is a similar conglomerate in the schist series. Here, however, the pebbles are generally over 6 inches in diameter. An interesting feature of this unusual phase of the schist is the fact that, although the matrix between the pebbles has been recrystallized, the pebbles show no apparent deformation.

A microscopic examination of these schists shows that they are composed largely of quartz and sericite in varying amounts. One slide, however, contained in addition some grains of acid plagioclase, ortho-
clase, and zircon, and showed small needles of apatite in the quartz grains. Another phase of the schist contains, in addition to quartz and sericite, flakes of deep brown, strongly pleochroic biotite; and the variety containing crystals of magnetite has been described above. In a thin section of phyllite the rock was found to be composed chiefly of sericite in some portions and of quartz in others, giving it under the microscope a streaky or banded appearance. Slides of the chloritic schist show that this rock consists chiefly of about equal amounts of chlorite and green hornblende, and, in addition, some epidote and deep greenish-brown, strongly pleochroic biotite. Quartz occurs as small interstitial grains. The mottled appearance of this rock in the hand specimen was found to be due to a segregation of large flakes of biotite.

The occurrence of conglomerates and quartzites in the sericite schists together with evidence of bedding in the phyllites, points definitely to a sedimentary origin of the materials from which the schists have been derived. One type of schist was derived from an arkosic sandstone, which originally contained numerous rounded grains of feldspar and some zircon. The chloritic schist is composed largely of mineral containing ferrous iron and magnesia, such as chlorite, hornblende, and biotite. As sedimentary rocks, other than dolomites or dolomitic limestones, rarely contain over 5 per cent of magnesia, it is unlikely that this type of schist was derived from some pre-existing sediment; and it most likely represents a re-crystallized igneous rock approaching basalt in composition.

Throughout southern and southwestern Arizona are isolated exposures of metamorphic rocks, chiefly schists and gneiss, invaded by batholithic masses of granite. To the east of Tucson these metamorphic rocks are unconformably overlain by fossiliferous Cambrian formation; but in the Dome Rock Mountains all the Paleozoic formations have been removed by erosion. Definite evidence of the age of these schists is therefore not available, and they are here tentatively assigned to the pre-Cambrian.

**IGNEOUS ROCKS**

**Granite.**—The southern end of the Dome Rock Mountains consists of a coarse-grained granite of uniform texture. This rock is composed chiefly of quartz, potash feldspar, and biotite. It invades and is therefore younger than the schist. About a mile south of Quartzsite are a few low hills of disintegrated granite that resembles the granite in the southern end of the range. Pegmatitic dikes and quartz-tourma-
line veins in the schists are probably offshoots from the granitic mass. Like the schist, this granite is believed to be of pre-Cambrian age, and in the absence of evidence to the contrary is assigned to that division of geologic time.

Andesite.—Approximately one mile south of Quartzsite is a small area of igneous rock which has been described by Bancroft as an augite andesite porphyry.

Rhyolite.—Between the granite and schist, near the southern end of the range, are several flows of rhyolite and associated beds of tuff. These flows range in color from pale yellow, often with a greenish tint, to light brown. They are dense, felsitic rocks, but usually phenocrysts of orthoclase or quartz may be seen. The total thickness of these flows and tuffs could not be determined as they are partly covered by the later gravels.

The rhyolitic flows as well as the andesites described above are of Tertiary age; and from the relative positions of similar flows in the surrounding mountains, the rhyolites are believed to be younger than the augite andesite near Quartzsite.

SEDIMENTARY ROCKS

Gravels and Sands.—Flanking the range on both sides are gravels and sands grading into fine silts in the central portions of the valleys. These gravels, especially near the foot of the mountain, often contain unusually large boulders, but generally the pebbles are only a few inches in diameter. The gravels contain pebbles of the various kinds of rocks occurring in the surrounding mountains. Mixed with the gravel is considerable sand with flakes of mica that were derived from the sericite schists.

Near the central portion of the valley south of Quartzsite, the exposures in the walls of the dry washes were found to consist of fine silts with occasional layers of sand and a few scattered pebbles; but the surface of the valley, in the flatter portions, is often a pebble-covered plain extending for hundreds of yards in all directions, and interrupted here and there by occasional dry washes.

ORE DEPOSITS

QUICKSILVER

The vein worked by the Colonial Mining Company occupies a fault fracture in the schists. Near the shaft this fracture strikes N. 53° W.,

but the strike varies somewhat to the southeast. Near the shaft, where the vein has been followed to the surface, the dip was found to be approximately vertical. It consists chiefly of vein quartz that has been thoroughly brecciated, probably by renewed movement along the fault plane after the deposition of the ore. The vein, as well as the fractures in the schist walls, are heavily stained with limonite and hematite. Small veinlets of calcite and siderite traverse the quartz gangue, and some of the oxidized iron minerals, so abundant at the surface, may have been derived from the breaking down of siderite. Outcrops of the vein are usually covered by surface detritus, but it has been exposed in a number of places by trenching.

The ore mined by this company occurred as a definite shoot that pitched to the southeast. The width of the vein ranged up to 5 or 6 feet, and a thick, iron-stained gouge separated the ore from the southwest wall. Ore occurred for 35 feet along the drift, but, as the pitch is unknown, the size of the ore shoot could not be determined. The central portion of the vein contained the best ore and had a maximum width of 2 feet; and, on each side of this richer streak some disseminated cinnabar occurred in the crushed vein material. This information was obtained from a miner who worked for the company before operations were discontinued, but, as the shaft is now in a bad condition, his statements could not be confirmed by direct observation.

Cinnabar is the chief sulphide of mercury in the ore, but some of the black variety, metacinnabarite, was also found; and Turner states that the ore contains sulphides of copper and mercury, as well as some gold and silver. No sulphides of copper were found by the writers in specimens collected from the ore bin and from the dump. Malachite and chrysocolla are intimately associated with the cinnabar, and one specimen contained small tabular crystals of wulfenite. The storekeeper at Quartzsite has a specimen of cinnabar, said to have come from this deposit, in which a visible flake of gold is embedded. Such association is not surprising, as the ore is reported to carry gold and silver. Native quicksilver and the chloride, calomel, were not seen in the samples of ore obtained from this property, but may be present in small quantities. The gangue minerals consist of quartz, hematite, limonite, and kaolin, the latter probably derived from sericite.

The occurrence of oxidized copper minerals in the ore suggests that sulphide of copper, either bornite or chalcopyrite, may be found below the oxidized zone. In this connection it is interesting to note that Ban-

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1 Turner, H. W., Mineral Industry During 1908, p. 743.
croft suggests that the cinnabar may have been derived from mercurial tetrahedrite. If so, this would account for the copper in this ore.

Where metacinnabarite and cinnabar were found in association the latter was invariably coated with thin films of the former. This relation is illustrated diagrammatically in Fig. 3. The cinnabar is usually pitted, suggesting that the metacinnabarite was formed at the expense of the cinnabar. In specimens without cinnabar, and consisting entirely of quartz and metacinnabarite, the ore is so porous as to indicate that considerable leaching has taken place.

![Diagram](image)

Fig. 3.—Diagrammatic section showing a lump of cinnabar partly embedded in quartz and surrounded by metacinnabarite.

**ANTIMONY**

Approximately a mile slightly west of south of the cinnabar deposit described above is a vein containing stibnite. The relative position of these two deposits is shown in Fig. 2. This vein strikes N. 70° W., dips 80° to the north, and occupies a shear zone in sericitic schist. The crushed zone in which the vein occurs does not have well-defined walls, but grades off into unaltered schist.

The ore consists of radiating blades of stibnite with the characteristic, highly perfect, pinacoidal cleavage. This stibnite is clearly residual, and is altering to a white mineral that gives a good reaction for antimony, which is probably the oxide of antimony, cervantite. An earthy mineral varying in color from straw-yellow to sulphur-yellow, and appearing amorphous in grain under the microscope may be the mineral stibiconite. These two alteration products of stibnite are intimately

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mixed and it is difficult to separate them for more detailed examination. The gangue minerals consist chiefly of quartz and limonite.

Careful panning of this antimony ore, crushed and sized, failed to show a trace of cinnabar, nor was stibnite found in the cinnabar ore described above.

PROPERTIES

Quicksilver has been mined from the Cinnabar group of claims, and a few specimens of the mineral have been found on the French-American group in the northern part of the Dome Rock Mountains in Yuma County, near Quartzsite, Arizona.

CINNABAR GROUP

The Cinnabar group consists of five claims, which were patented in 1904. The Colonial Mining Co. operated the property up to 1908, after which it was taken over by the Cinnabar Development Co., which kept a force of men at work up to 1914, when the mine was shut down. The ground now belongs to C. H. Coleman, an attorney at Yuma. Within the last few years lessees made an unsuccessful attempt to unwater the mine and repair the shaft.

Workings.—The U. S. Mineral Surveyor's notes show that when the claims were surveyed in 1904 two shafts, one 178 and the other 148 feet deep, with 145 feet of drifts, were on the Cinnabar No. 1, and a number of open-cuts on the other claims.

The main shaft is now reported to be around 640 feet deep, from which seven levels have been run. The lowest is reported to have extended 400 feet to the west. An oreshoot which outcropped at the surface between the two shafts is reported to have been 35 feet long and 2 feet wide, and to have raked strongly to the west. The drift on the lowest level did not reach the ore shoot and a raise was put up to it.

The ground is reported to be hard to hold and the ventilation was bad in the lower levels. The water in the mine now stands at about the second level.

Surface Equipment.—The surface equipment consists of:

- Headframe
- 25 h.p. Henrie and Boltoff gasoline hoist
- 12 h.p. New Era gas engine for running compressor and crushe
- 10x12 Chicago pneumatic air compressor
- Gates jaw crusher
- 30-ton Scott tile furnace
- 3-ton Johnson-McKay retort
Plate III. Shaft and headframe, Cinnabar group.
Plate IV. Outcrop of vein and top of stope at surface, Cinnabar group.
Blacksmith shop
Timber framing shed
Cook house

The Scott furnace with six condensers, and the Johnson-McKay retort appear to have been built in a very workmanlike manner. The shaft and headframe is shown in Plate III.

Operations.—The ore was hoisted in 1,000-pound capacity buckets and dumped in an ore bin, from which it was trammed to the furnace or the retorts. Ore fragments up to 4 inches in size were noted in the dump from the Scott furnace. The last ore was put through a jaw crusher at the head frame, which crushed the material to go through a 1-inch grizzly.

Production.—According to the Geological Survey in "Mineral Resources of the United States," for 1908 and 1914, some quicksilver was produced from this group of claims during these two years. The productions for Arizona and Oregon were given together for 1908 and amounted to 386 flasks of 75 pounds each, worth $17,170. The Arizona production for 1914 lumped with "Other States." The only quicksilver produced during this period in Arizona was from the Cinnabar Group.

According to W. E. Scott, of Quartzsite, between 100 and 140 flasks were obtained from the Cinnabar Group during 1908. During December, 1913, and the early part of 1914, the mine produced ore a part of which at least was apparently put through the 3-ton Johnson-McKay retort. According to Will Anderick, of Salome, Arizona, 16 flasks were shipped from this run.

A rough estimate of the tonnage put through the Scott tile furnace is 2,000 tons, and through the retort, 50 tons. Allowing a production of 100 flasks from 2,000 tons of the ore, the amount of quicksilver recovered, not considering losses, would equal around 5 pounds to the ton.

A sample taken from the bin containing ore left after the last run was assayed and showed .06 per cent mercury. It is doubtful if the ore treated contained as high as 0.5 per cent mercury. It is said that the ore treated in 1914 contained 0.36 per cent, or 7.2 pounds, of quicksilver per ton.

The apparent difference between the percentage of quicksilver recovered and the claimed assay value is probably due to the fact that the Scott furnace was constructed from brick made locally on the Colorado River, and that an insufficient amount of ore had been run through this furnace to supply the amount of quicksilver which is invariably tied up by brick absorption in furnaces of this type. It is also reasonable to
suppose, owing to the difficulties in sampling ores as spotty as these in value, that the assays given do not represent the actual value.

_Ore Resources and Future Production._—The vein on the Cinnabar Group strikes with the claims and could be traced over the surface for about 4,000 feet. Isolated specimens of cinnabar were found at widely separated points on the surface for the full length of the outcrop. About 3,000 feet from the main shaft a parallel vein was noted for a few hundred feet. The vein outcrop and the surface occurrences of cinnabar are shown in Fig. 4.

![Diagram of ore resources and future production]

Apparently cinnabar ore outcropped in the Cinnabar No. 1 claim, as the vein has been stope to the surface. The photograph, Plate IV, shows where the stope has broken through to daylight. The stoping width at the surface apparently was about 3 feet, but the walls have sloughed off, and a wider opening is now shown.

Mr. Coleman, the present owner of the group, is reported to have acquired the ground through a tax sale, and can give no information as to the amount or value of any ore in the mine. It is the impression of the men who worked in the property that the ore shoot is nearly worked out, at least above the sixth level.
If the ore shoot persists to a greater depth and continues downward at the same cross-section as reported in the worked-out portion of the mine, only a small daily production could be expected because of its small size. Apparently, this ore shoot was larger at the surface than on the 600-foot level. For each 100 feet in depth a production of about 500 tons could be expected.

As the vein appears strong on the surface and contains evidence of cinnabar for a considerable distance from the shaft, there is a possibility that other ore shoots could be opened up. Apparently, well over $150,000 has been expended on the property with about a $6,000 return.

COPPER BASIN DEPOSIT

LOCATION

The quicksilver deposits in Yavapai County occur in Copper Basin, about 10 miles southwest of Prescott and approximately 7 miles by road, from Skull Valley, a station on the Phoenix Branch of the Santa Fe Railroad. A branch road from the main highway turns south and west, and follows a dry wash to within one-half mile of the deposit. The position of this deposit relative to Prescott and Skull Valley is shown on the index map, Fig. 5.

![Index map of the Copper Basin district.](image)

CLIMATE AND VEGETATION

As this deposit occurs at an elevation of over 5,000 feet the climate throughout the year is likely to be mild with occasional
more or less severe snow storms during the winter. The rainfall during the summer occurs usually as torrential downpours and thunderstorms, and the precipitation during the winter is largely as snow. As the deposit is on the southwest side of the mountains, the snow is not likely to remain on the ground long, and should not interfere seriously with mining operations.

The vegetation in the immediate vicinity of the deposit is rather sparse, and consists entirely of grasses, a few bushes, and an occasional stunted juniper. A few miles to the north, however, a good stand of timber occurs on the slopes of the Sierra Prieta. This timber consists of pine, juniper, and oak; and in the past much of it has been used in the mines of this region.

**TOPOGRAPHY**

The quicksilver deposit occurs in a semi-circular basin formed by the junction of several streams, and is partly surrounded on the north and east by higher ridges. These higher ridges form a part of the foothill belt flanking the high Sierra Prieta on the southwest. The isolated hills and ridges of this foothill belt consist of mature topographic forms on which the drainage is well established, and the smooth, grassy slopes are interrupted here and there by dikes of rhyolite or siliceous veins that stand out in relief. The various prospects in this district occur at elevations between 5,300 and 5,600 feet above sea level.

No living streams are to be found in the immediate vicinity of the deposits, and the prospectors must depend for their supply of water on temporary springs that issue from fractures in the granite.

**GEOLOGY**

The quicksilver deposits occur as siliceous veins in a batholithic mass of granite which has been intruded by an irregular mass of diabase and by dikes of andesite and rhyolite.

*Granite.*—Between Prescott and Skull Valley the Sierra Prieta consist almost entirely of a medium-grained, light gray granite. Porphyritic phases of the rock occur in which fairly large, well-developed phenocrysts of orthoclase are common, but they are merely a local modification of the main granitic mass and occupy only small areas. Near the quicksilver claims this granite has a decidedly gneissic texture, and everywhere is traversed by numerous joint planes trending northeast-southwest.

Examined megascopically with the aid of a small lens, quartz, orthoclase, striated plagioclase, and biotite were found to be the important
constituents of the rock, but small prisms of dark green hornblende are also present. Magnetite and titanite were observed as accessory constituents.

Microscopically the rock consists of quartz with minute inclusions arranged in bead-like strings, orthoclase slightly altered along cleavage cracks to kaolin, acid plagioclase near oligoclase, and microcline. The ferromagnesian minerals consist of green hornblende and strongly pleochroic, brown biotite. As accessory minerals, crystals of apatite and titanite are present, and grains of zircon and magnetite were noted.

The feldspars are partly altered to sericite and kaolin, and the hornblende is usually surrounded and sometimes penetrated by shreds of chlorite. The presence of epidote and sericite suggests that the rock has suffered some hydrothermal alteration.

The rock is medium-grained and holocrystalline, with well-developed crystals of biotite and hornblende. The plagioclase feldspars are subhedral, but the grains of quartz, orthoclase, and microcline are anhedral.

This rock shows a close resemblance, both in mineral composition and texture, to the main granitic mass of the Bradshaw Mountain, which Jaggar and Palache believe to be of pre-Cambrian age.

HORNBLENDE GABBRO

Occurring as a small intrusive mass cutting the granite described above is a greenish-black hornblende gabbro. On a fresh fracture the rock is found to be composed almost entirely of hornblende and stout laths of feldspar.

A thin section of this rock consists principally of hornblende and plagioclase feldspar together with ilmenite and a few slender prisms of apatite. The hornblende in this rock is the pale green, fibrous variety, uralite, and is an alteration product of pyroxene; it constitutes about one-half the area of the slide. Along the edges it is often altered to chlorite with the characteristic "ultra blue" interference colors. The feldspar is labradorite, and occurs as broad, simple twins, sometimes poikilitically enclosed by the hornblende. The feldspar often contains numerous thin shreds of a micaceous mineral which may be sericite, and an opaque substance, probably kaolin. The ilmenite occurs as irregular branching forms, and is altering to leucoxene. A small amount of calcite and secondary quartz are also present in the slide.

ANDESITE AND RHYOLITE DIKES

Dikes of these two varieties of intrusive rock cut both the granite and the gabbro. The andesite dikes are practically confined to the northern part of the area shown in Fig. 6, and a single dike of andesite cuts the intrusive mass of gabbro. There are numerous narrow dikes of andesite generally less than a foot thick on the Mercury Fraction No. 2 claim, but as they are more or less discontinuous they have not been mapped. The individual dikes vary in width from a few inches up to 30 feet or more, and the rhyolite dike that cuts the northeast side line of the Mercury No. 1 claim has a width of more than 50 feet. At this point it forms a prominent hill locally known as Elephant Butte.

Generally the dikes are under 10 feet in width. As shown in Fig. 6, these dikes may be divided into two groups: one with a north-south trend, and the other more nearly northwest-southeast. The crushed wall rock suggests that, in some cases, the dikes occupy pre-existing fault fissures in the granite. The relative age of the two types of rock is not positively known as they are nowhere in close contact. They are both believed to have been intruded near the close of the Tertiary period.

The andesite porphyry is a nearly black rock that weathers greenish-gray or brown. On the weathered surface one may readily see crystals of hornblende and sometimes feldspar. The mineral composition of these dikes is fairly constant, but in texture they show considerable variation. Some contain long slender crystals of hornblende, or occasional crystals of feldspar in a rather dense groundmass, while others are so fine-grained as to defy recognition of the constituent minerals even with the aid of a hand lens.

Examined microscopically, the rock is found to consist almost entirely of hornblende and feldspar. The hornblende is of the dark greenish-brown variety, is strongly pleochroic, and is often twinned. The feldspar consists chiefly of plagioclase, but some orthoclase was observed. The plagioclase was determined as andesine and is only slightly altered. The orthoclase occurs as phenocrysts and is almost entirely altered to sericite and kaolin. Magnetite and slender needles of apatite occur as accessory minerals. The alteration products are secondary quartz, sericite, kaolin, chlorite, and a little epidote.

The texture, although variable, is usually porphyritic, and crystals of hornblende and orthoclase occur as phenocrysts. The groundmass consists of a fine, felted mat of plagioclase and a second generation of hornblende with numerous, scattered grains of magnetite.
The rhyolite porphyry is a pink to brownish rock with numerous white crystals of kaolinized orthoclase and shiny flakes of biotite. On a weathered surface the rock is rather porous, due to the leaching out of the feldspar and mica. Flow lines are also rather pronounced on a weathered surface, and a specimen of the rock resembles a volcanic flow rather than an intrusive rock. However, as prospect pits have been sunk on these dikes, there is no doubt as to their intrusive origin. Quartz, orthoclase, and biotite occur in a felsitic groundmass.

In a thin section the phenocrysts of feldspar observed were so thoroughly altered to kaolin as to make positive identification impossible, but the original mineral was probably orthoclase. Phenocrysts of rounded and embayed crystals of quartz, always surrounded by a resorption border, are common in the slide. This border consists of a microcrystalline intergrowth of several minerals that could not be determined specifically. Biotite is also present, and is somewhat altered.
Grains of magnetite and stout crystals of apatite and zircon occur as accessory minerals. The groundmass is microcrystalline and consists of orthoclase and quartz with occasional minute needles of apatite.

ORE DEPOSITS

The quicksilver ores in this district occur as siliceous veins generally along dikes of andesite or rhyolite porphyry, although some veins are entirely in granite and others are in gabbro. The veins occupy fault fissures filled with crushed fragments of the wall rock. This is especially true where the vein occurs in granite, gabbro, or andesite; but those occurring in rhyolite show little or no crushing, and often only slight brecciation. In some of the rhyolite dikes the mineralization consists of narrow, anastomosing veinlets which on a weathered surface often resemble the flow lines occurring in this rock. The siliceous vein material cementing the brecciated fragment of the dikes is very resistant to erosion; and, because of their greater durability, these dikes stand out in relief above the surrounding wall rock.

From the map shown in Fig. 6, one can readily see that these veins, like the porphyry dikes, have a north or northwest trend. Very little prospecting has been done on these veins, and where shafts have been put down on them, they were found to be either vertical or to dip at steep angles to the northeast.

![Fig. 7.—Cinnabar surrounding a grain of pyrite.](image)

The valuable mineral in these veins is cinnabar, the sulphide of mercury; and closely associated with it is pyrite. Cinnabar partly surrounding pyrite is shown in Fig. 7, a drawing made from a polished surface of ore. In another specimen a cube of pyrite has been oxidized to limonite and removed by solutions, and a thin film of cinnabar now lines the walls of the cavity originally occupied by the pyrite. The film
of cinnabar faithfully depicts the original crystal faces of the pyrite. The oxidation of the pyrite, with the consequent production of free sulphuric acid, has had no apparent effect on the cinnabar, the mineral retaining its brilliant luster and the original striations on the surface of the pyrite. The two cases cited above suggest that pyrite was the earlier sulphide deposited and was followed by the deposition of the quicksilver mineral, often as a thin coating on the pyrite. Cinnabar also occurs as minute grains or tiny veinlets traversing chalcedonic quartz. This is rather characteristic of the ore from the Mercury No. 7 claim. The oxidation products of cinnabar, such as the chloride calomel, or the native metal, are apparently absent at this deposit; and only a single sheaf of radiating crystals of malachite was found.

Pyrite occurs as irregular grains and often as well-developed crystals. The cube, pyritahedron, and octohedron were the forms observed on these crystals. Where the mineral is surrounded by dense, chalcedonic quartz it resists oxidation very effectively, and specimens of ore with pyrite were found within a few feet of the surface.

Chalcedonic quartz, often beautifully banded, is the principal gangue mineral in these veins. This vein-filling contains more or less limonite and kaolin. When studied in thin sections, two periods of quartz deposition were found in the ore; an earlier one of slightly coarser texture was fractured after deposition, and in these fractures, the later, fine-grained quartz was deposited. Microscopic crystals of barite with a tabular outline were also found in some of the slides, and although sericite is present, it seems to have formed only in the enclosed rock fragments.

Pseudomorphs of limonite after pyrite are common, but much of the limonite is massive, and where the mineral fills cavities in the ore it is more or less cellular. All of the limonite in the ore was not necessarily derived from the oxidation of pyrite; it is especially abundant where the veins occur in andesite porphyry or gabbro, and may in part be due to the alteration of the ferromagnesian silicates in the wall rock.

The alteration of the rhyolite porphyry by the mineralizing solutions has not been intense, but where gabbro is found in contact with this rock the gabbro has been entirely altered to kaolin and quartz. Veinlets of hematite and limonite are common in this altered material. The andesite porphyry was also thoroughly altered by the mineralizing solutions, and considerable sericite was formed by the alteration of the feldspar.

These veins are not mineralized with cinnabar along their entire length since some portions contain only the barren chalcedonic quartz;
but the solutions that gave rise to the cinnabar also deposited the siliceous gangue material. The occurrence of quartz vein-material, therefore, does not necessarily indicate the presence of economically important minerals. Observation has shown that those portions of the vein where visible cinnabar is present, or where it has been found by assays, are usually stained by limonite and are more or less porous. These more important portions of the veins may appropriately be termed ore shoots. They are not confined entirely to the wider or more prominent outcrops, particularly those highly silicified portions, but may be rather inconspicuous and in part covered by the products of disintegration. However, the presence of chalcedonic quartz is suggestive of mineralization, and these veins should be followed along their entire length until the more favorable outcrops are found.

PROPERTIES

Cinnabar has been found in the Copper Basin district on the Mercury Group of claims. Other claims in the district consist of the Cinnabar Queen, Cinnabar King, and Zero Hour claims which were located February 18, 1924 by L. O. Becker and Ed Smith, for quicksilver. It is said some cinnabar has been found on the Zero Hour.

MERCURY GROUP

The group is owned by Col. Chas. N. Baker, of Prescott, but in April, 1924. Theo. Davis, a mining promoter, had an option on the ground. Seven claims of the group, Mercury Nos. 1 to 7, inclusive, were located March 27, 1922. Three claims, Mercury Nos. 8, 9, and 10, are a part of the group, but the locations were not recorded at the time of the writers' visit in April, 1924.

At the time of the investigation, Col. Baker, and J. J. Jackson, a miner, were sinking a shaft shown in Plate V near the south end of Mercury No. 5 claim on a quicksilver vein. The vein was in gabbro at the contact with the granite country rock. The shaft was 12 feet deep and 5 feet wide, and was in brecciated silicified gabbro containing vertical, narrow stringers of the gangue minerals and some cinnabar. The cinnabar occurred as patches and isolated crystals in several of the narrow seams.

Two samples, designated Nos. 1 and 2, were taken in the shaft on this claim and were assayed. No. 1 was across 4 feet 7 inches of the vein on the north side of the shaft and contained .04 per cent mercury. No. 2 was across 3 feet on the south side and contained .06 per cent mercury. Samples taken across 1- or 2-inch stringers would probably
show 2 or 3 per cent of the metal. A few pieces, the size of a man’s head, that contained more than 5 per cent quicksilver, have been taken out.

The samples were taken across the vein to include all the supposed quicksilver-bearing material, as pointed out by Col. Baker and Mr. Jackson. A portion of the vein was decomposed gabbro that gave a red streak when struck with a pick. It was said to contain quicksilver and was therefore included in the sample.

It is probable that a minimum stoping width of half the distance over which the samples were taken would contain double the amount of quicksilver shown by the assays. However, 18 inches of vein-matter containing 0.12 per cent of quicksilver could not be considered commercial ore. By hand-sorting out the stringers containing the most cinnabar, a very limited amount of ore containing 1 per cent or more of quicksilver could be mined at this place, but it would not appear that the operations could be made profitable.

The material from the shaft was being separated in two piles; one was called the “high-grade” and the other the “low-grade” dump. However, iron oxides were being mistaken for cinnabar in the greater part of the material.

There is a possibility that further development work at this point would open up a body of cinnabar-bearing rock in sufficient quantity and of high enough grade to be handled profitably. However, as cinnabar is not readily subject to weathering, and quicksilver veins do not have secondary enrichment, it can not be assumed that the grade of quicksilver ores at this point would improve with depth.

An old shaft said to be 60 feet deep is located on a vein at the southern end of Mercury No. 1. It is reported that about the year 1904 a 1- to 2-inch streak of cinnabar in the vein was stope at the place by E. C. McNary. The Mint Mine in the same district was being operated at that time, and quicksilver for the amalgamation plates at the Mint mill was obtained from this place. As the Mint Mine did not operate very long, it is probable that the consumption of quicksilver did not amount to over two or three flasks. The cinnabar was treated in a homemade retort near the mine. The vein matter and associated mineral at the shaft appears to be similar to the occurrence on No. 4 claim.

Some cinnabar was noted on Mercury No. 2 in a small patch in a seam in the vein at an old cut.

Mercury No. 7 is detached from the rest of the group and is on an independent vein. The discovery cut of this claim is in an outcrop of the vein. The face of the cut is 24 feet wide and is in dike material
ARIZONA BUREAU OF MINES

with frequent vertical planes. A 4-foot section of the rock in the face is highly brecciated. Chalcedonic quartz, in which were a few crystals of cinnabar, was noted in the bottom of the cut at one point.

Samples were taken from various other points on the claim and panned, but no cinnabar was found except in the places noted above and shown on the sketch. Nothing was seen on the group to indicate that there is a probability of an early production of quicksilver from this district. Judging from the surface indication, the best that could be expected would be the discovery of very narrow portions of the veins which would contain a low or medium grade of ore.

PHOENIX MOUNTAINS DEPOSIT

LOCATION

The Phoenix Mountains are a relatively small mountain mass of the Basin and Range type, and are typical of the desert region of southwestern Arizona. This range is about 8 miles long and is situated 11 miles north of Phoenix. It trends northwestward and gradually dies out in a group of low hills consisting of basaltic flows. The 1,250-foot contour line follows the base of the range on the southwest side. Squaw Peak, the highest point in the range, attains an elevation of approximately 1,500 feet above sea level. Radiating from this peak are long spurs whose topographic prominence is due to the more resistant nature of some members of the metamorphic series. The quicksilver deposits occur in a low pass which separates the main mass of the mountains from a northern spur. Plate VI is a panorama view of the mountains.

Close proximity to Phoenix, where mine supplies may be obtained, and the splendid system of highways in the Salt River Valley are of economic advantage to the mine operators in this district. The Arizona Canal flows within a mile of one of the deposits, and an adequate water supply could undoubtedly be obtained through arrangements with the Salt River Valley Water Users' Association. Power generated at the Roosevelt Dam or at the Horse Mesa Dam, now under construction, probably could also be obtained from this Association.

CLIMATE AND VEGETATION

The arid climate of this region is rather typical of the southwestern portion of Arizona. During the summer months the temperature is often over 100° F., but the winter months are unusually mild. The average annual precipitation at Phoenix is 7.87 inches, and more than 60
Plate V. Prospect shaft on the Mercury No. 5 claim.
per cent falls during the months of July, August, and September, chiefly as torrential downpours accompanying thunderstorms.

The vegetation on the slopes of the Phoenix Mountains and in those portions of the valley not under irrigation is rather sparse. Only a few scattered palo verde and mesquite trees remain; most of them have long since been cut for fuel. Several varieties of cacti are plentiful, especially the cholla; and the creosote bush or greasewood is the most common shrub. A supply of wood for operating a retort or furnace is not available, and some other fuel must be used.

GENERAL GEOLOGY

Most of the Phoenix Mountains consist of metamorphic rocks, largely of sedimentary origin, which have been invaded by dikes of olivine diabase and veins of pegmatitic quartz. Camelback Mountain, an isolated hill southeast of the main range, consists of pre-Cambrian granite. The northwestern portion of the range is composed of Tertiary and Quaternary volcanic rocks. The mountains are surrounded and partly buried in detritus derived from the higher slopes of the range.

METAMORPHIC ROCKS

The metamorphic rocks of this range consist of quartzite, sericite and chlorite schists, and marbles. These highly schistose rocks have been intensely compressed by regional metamorphism with the production of abundant mica. Wherever evidence of the original bedding planes was observed it was found to be parallel to the schistosity. This evidence was seen best in the slates and quartzites where distinct changes in sedimentation were most noticeable. The schistosity trends northeastward, and the dip is to the southeast, becoming steeper near the summit of Squaw Peak. The total thickness of the original sediments from which these schists were derived is unknown as there may be some duplication by folding and faulting, but it was certainly several thousands of feet, and may even be one or more miles.

The quartzites consist of massive beds from 1 to 10 feet thick. These massive beds are composed of rather clear, well-rounded grains of quartz that often show distinct angular cross-bedding. Sometimes thin layers of magnetite occur parallel to the bedding planes. No pebbly layers were observed and the texture is rather uniform, changing only slightly from bed to bed. Between the massive beds were deposited finer-grained sediments containing more argillaceous material which was later recrystallized by contact metamorphism to cyanite. This mineral has developed as radiating groups of crystals forming rosettes parallel
to the schistosity. Some of these rosettes are as much as 2 inches in diameter, and are more prominent on a weathered surface where the mica between the blades of cyanite has been removed by atmospheric action. Examined microscopically, the rock was found to consist of interlocking grains of quartz traversed by large blades of cyanite. Magnetite is very abundant in some portions of the section, and sericite is always present as small shreds. Scales of dark red hematite and a little tourmaline, bluish-gray in thin section, were identified.

Quartz-sericite schist grades from quartzite to fine-grained, very fissile slates. The quartz-sericite schist is of gray color, sometimes with a decided greenish cast, and shows considerable variation in the size of the constituent grains. On a parting plane of the coarser-grained varieties the surface has a mottled appearance due to the larger grains of quartz around which mica foils have developed. With a decrease in the size and abundance of the quartz grains, and with an increase in the amount of mica, these rocks grade into phyllite or slate.

The slate is of a bluish-gray color and satiny luster due to the presence of abundant small scales of mica on the parting planes. The rock, although fissile, can not be used as commercial slate because of a false cleavage which has been developed and causes the rock to break across the main direction of schistosity. In mineral composition the slates are similar to the quartz-sericite schist. They differ chiefly in texture and in the relative proportion of quartz and sericite, and an examination of thin sections shows the mica to be relatively more abundant in the slates.

Limestones that originally occur here have been changed to marbles by the dynamic metamorphism that produced the schists. These marbles sometimes cleave readily into plates less than a quarter inch in thickness. An examination of the parting planes with a hand lens shows that considerable mica has been developed probably from impurities existing in the limestone. A partial analysis given below shows the marble to contain considerable impurities chiefly silica or silicates.

Partial Analysis of Marble from Phoenix Mountains:

<table>
<thead>
<tr>
<th></th>
<th>Per Cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insol</td>
<td>16.69</td>
</tr>
<tr>
<td>CaO</td>
<td>44.00</td>
</tr>
<tr>
<td>MgO</td>
<td>4.09</td>
</tr>
</tbody>
</table>

The chlorite schists are adjacent to the belt of marble. The rock is of a dark greenish color when fresh and weathers to a rusty brown. Examined in thin sections it was found to consist essentially of green chlorite, calcite, and quartz. A few grains of magnetite and a little hematite are also present. The alteration products consist of limonite
and a white, opaque substance probably kaolin. The calcite occurs in lenticular areas surrounded by shreds of chlorite.

An unusual phase of the chlorite schist contains numerous small black flakes on a parting plane. In thin section this mineral is of a bluish-green color and the optical properties correspond to the mineral ottelite. This unusual phase consists almost entirely of chlorite, ottellite, and magnetite; and, unlike the normal chlorite schist, calcite and quartz are present in only small amounts.

A schistified rhyolite of a pinkish-brown color is also present in this series of metamorphic rocks. On a weathered surface original phenocrysts of quartz and feldspar may readily be identified, and the flow structure of the rock is also distinct. The rock cleaves readily, however, due to the development of sericite along more or less parallel planes. When examined in thin section the grains of quartz were found to be clear, more or less round, and somewhat fractured. The wavy or irregular extinction shown by this quartz is due to the dynamic metamorphism to which it has been subjected. Orthoclase is also present as clear crystal grains. Some of the feldspar shows complex twinning, was determined as microcline, and was probably derived from orthoclase. No ferromagnesian minerals were observed, but the numerous minute particles of magnetite occurring throughout the slide may have been formed from the alteration of biotite, although no positive evidence on this point is available. The groundmass is microcrystalline and seems to be composed largely of quartz. Some sericite as small shreds is also present in the slide.

The presence of thick beds of quartzite in which cross-bedding is distinct, the occurrence of beds of marble, and the rhythmic banding in the slates strongly suggest that these schists were derived from sediments. Even the chloritic schists, because of the abundance of calcite, could hardly have been derived from igneous rocks, and most likely were originally calcareous shales containing some iron and magnesia. Deep burial and the accompanying great pressure, together with the intrusion of granitic magmas in the surrounding mountains, has changed these sediments into highly plicated and schistose rocks.

No Paleozoic sediments occur in the Phoenix Mountains and the age of the schists can not be positively determined. What appears to be the same belt of schist can be traced northeastward to where the pre-Cambrian age of these schistose rocks can be positively demonstrated. These metamorphic rocks are therefore correlated with the Pinal schist described by Ransome.1

IGNEOUS ROCKS

Camelback Mountain, an isolated hill a few miles southeast of the Phoenix Mountains, consists largely of coarse-grained granite. This granite is the oldest igneous rock in the district, and was probably responsible for the development of the cyanite in the quartzites. The veins of pegmatitic quartz cutting the schists are probably siliceous residues from the granitic magma.

The granite is of a light-gray color, medium grain, and a holocrystalline texture. It consists essentially of quartz, alkali feldspar, and biotite. No microscopic examination was made of the granite as it probably has no connection with the origin of the quicksilver ores. The rock is a part of the large pre-Cambrian batholithic mass that occurs in nearly all the surrounding mountains.

Dikes of olivine diabase cutting the schists were observed in the Phoenix Mountains. The rock is dark colored and of a medium to fine-grained texture. In a thin section it is found to consist essentially of plagioclase feldspar, augite, and olivine. Maximum extinction in the symmetrical zone proves the feldspar to be labradorite. As accessory minerals apatite, magnetite, and deep brown biotite were identified. The rock is remarkably fresh, but the biotite sometimes shows a slight alteration to chlorite, and the feldspar contains some cloudy material, probably kaolin. Laths of feldspar or grains of olivine are often enclosed in large crystals of augite, producing an ophitic texture.

The magma which gave rise to the flows of olivine basalt, so common in the northwestern part of the range, may have come up along the channels now occupied by these dikes.

Approximately 4 miles north of the quicksilver deposits are Tertiary flows and tuffs of olivine basalt. These flows are dense and of a fine-grained texture, and some are vesicular. They are gray to reddish-brown in color. The weathered surface is often covered with a thin film of black desert varnish that consists of oxides of iron and manganese. In a thin section the rock was found to be a normal alivine basalt, somewhat altered, and consisting of olivine, augite, and basic plagioclase feldspar. Magnetite and small needles of apatite occur as accessory minerals. The plagioclase feldspar is usually fresh and is near medium labrodarite in composition. Two generations of this mineral occur in the rock—the larger ones as phenocrysts and the smaller as minute untwinned laths in the groundmass. The augite is usually fresh, but the olivine is quite often altered to serpentine. A red micaceous mineral that seems to be a pseudomorph after olivine may be iddingsite.
Basalts of Quaternary age rest on the eroded surface of the Tertiary volcanic rocks. They are of a dark color, dense texture, and are remarkably fresh. No microscopic examination was made of them.

ORE DEPOSITS

The quicksilver deposits in this district occur along fault fractures which parallel in strike and dip the schistosity of the inclosing wall rock. As the rocks on both sides of the fault plane are very similar in composition and texture, it is impossible to make even an approximate estimate of the displacement on these faults. The rock in both walls has been crushed and a clay gouge developed by the fault movements. Some cross-faulting, later than the mineralization, was observed, the trend of which is northwest. This cross-faulting, however, has offset the veins only a few feet.

At least two directions of pronounced sheeting have been developed; one with a northwest trend and a steep dip; and the other with a northeast trend and a flat dip to the north. These two directions of sheeting together with the schistosity give the rock a blocky structure which is quite an aid in mining.

Prospects in this district in which cinnabar is definitely known to occur are confined to two varieties of schist. On the Mercury claim of the Porterie Group and on the Rico and Dolores claims of the Rico Group the cinnabar occurs in a quartz-sericite schist, while on the Jupiter claim of the Porterie Group the chlorite schist contains this mineral. It must not be inferred from these two occurrences of the mineral that cinnabar is not likely to be found in slate or limestone. In the Sunflower district, for example, quicksilver ores have been found in slates and limestone that are an integral part of the pre-Cambrian, metamorphic complex.

Outcrops of quicksilver ores in the Phoenix Mountains are rather inconspicuous. Small veinlets, usually not over 2 inches, and more often less than 1 inch in width, traverse the schists, generally paralleling the schistosity. They are sometimes so closely spaced as to form a mineralized zone several feet wide. These veinlets consist of dark brown limonite with more or less quartz. On the Jupiter claim are veinlets of a carbonate, apparently ankerite, which on weathering give rise to considerable limonite. Cinnabar was found by Mr. Sam Hughes where the outcrop of a vein on the Rico claim crossed the bed of a small stream. The mineral was slightly tarnished and of dull luster due to weathering processes, but on a fresh fracture the cinnabar showed a bright red color and a brilliant luster. Both on
the Mercury and Jupiter claims unaltered cinnabar was found within a few feet of the surface.

The ore occurs as well-defined shoots consisting of narrow veinlets and disseminated cinnabar in the fault gouge along shear zones or fractures. It has also been observed as disseminated cinnabar in the body of the schist, and as thin films on joint planes of the rock. These occurrences of the ore will be described more fully below in a discussion of the individual mines and prospects.

The most important quicksilver mineral is cinnabar, the red sulphide of mercury. This is sometimes coated with a black film which may be the secondary black sulphide, metacinnabarite. Native mercury has been reported, but was not found by the writers in this district. Gangue minerals occurring with the cinnabar are limonite, hematite, quartz, and calcite. In the fault gouge considerable kaolin was found with the limonite and hematite. A little pyrite was found on the Dolores claim, and the general absence of this mineral is due to oxidation rather than non-deposition. All of the prospect shafts are less than 100 feet deep and are in the oxidized zone, but when mining operations have been carried to greater depth more pyrite is likely to be encountered. The oxidized copper minerals, malachite, azurite, and chrysocolla are sparingly present, and were observed on fracture planes in the schist and associated with quicksilver ores. Other mineralized veins in the district carry copper sulphides as chalcopyrite and chalcocite, but apparently do not contain quicksilver minerals.

Rock alteration, except in the gouge along faults, is slight. Microscopic examinations of the wall rocks that contain disseminated cinnabar show little or no alteration that can be attributed positively to the mineralizing solutions. In the quartz-sercite variety of schist these two minerals are largely, if not entirely, primary constituents of the rock. The bleached condition of the chlorite schist at the surface is due to ordinary weathering processes, and is just as evident at a distance from the veins as near them.

PROPERTIES

This district was visited in April, 1924, and five groups of claims examined. Of this number, two groups, the Rico and Mercury, showed economic possibilities for the production of quicksilver, and on a third, the Eureka, cinnabar was noted at several places. No quicksilver minerals were noted on the other two groups, the Boulder and Sealrock, although they are reported to have been found there. Fig. 8 is an index map showing the location of the quicksilver deposits with respect to Phoenix.
Fig. 8.—Index map showing location of quicksilver deposits with respect to Phoenix.

**RICO GROUP**

The most promising prospect in the district is owned by Sam Hughes, who lives on the ground, and is known as the Rico Group. More consistent effort to develop a mine has been made on this group than elsewhere in the district.

Fig. 9 shows the relative positions of the claims and the location of the groups. The Rico Group consists of nine claims and a 20-foot strip across the south end of the Dolores. The Rico and Mary Ann claims, and seven claims of what is now known as the Eureka Group, were held originally as one group by Hughes, Louis Larsen, and F. E. Jetter. On dissolving the partnership, the original group was split up into two groups, and new locations made. As Hughes' original discovery and shaft was on the end of the Dolores, he was given the south 20 feet of this claim. In October, 1925, an option was held on the Rico Group by the Arizona Quicksilver Corporation.

Hughes, through misapprehension, allowed part of his ground, which is included in a homestead entry, to go to patent without protest. A
Fig. 9.—Claim map of the Rico, Eureka, and Mercury groups, Phoenix Mountains.
QUICKSILVER RESOURCES OF ARIZONA

patent cancellation suit instigated by the General Land Office was unsuccessful in the United States District Court for Arizona.

The Rico Group is in the open and does not reach the mountains. This group of claims is situated at the extreme southwest end of the mineralized belt. Development of the cinnabar found at the surface has opened up a small ore shoot.

The wall rock on the Rico claim is a quartz-sericite schist with a satiny sheen and a mottled appearance on parting planes. This mottled appearance is due to the larger grains of quartz, some of which are as much as a millimeter in diameter, and around which wind foils of mica. Some varieties of this rock contain cyanite while others have tourmaline as an accessory mineral. The strike of the schistosity is N. 25° E. and it dips to the southeast at an angle of 65°. There seems to be a slight decrease in dip with increasing depth.

The ore bodies occur in a fault zone of crushed schist, and there has been little mineralization of the wall rock. The ore shoots lie in the plane of the vein, have a rake to the southwest, and vary in width from about 14 inches to 5 feet. They consist of narrow, parallel veinlets of cinnabar from less than an inch to 4 inches in width. A close examination shows, however, that these veinlets which on casual inspection seem to be pure cinnabar, are largely quartz. The reason for this is because a specimen broken from the vein tends to fracture along the smaller veinlets of the quicksilver mineral traversing the quartz.

Cinnabar is the one important quicksilver mineral, and although a little metacinnabarite was found, the chloride and native metal were not observed. The gangue minerals are chiefly quartz and limonite. No copper minerals were seen on ore taken from the Rico claim, and, if pyrite was originally present, it has been entirely changed to limonite and hematite.

Specimens of the schists which have been impregnated with disseminated cinnabar were studied in thin sections, and were found to resemble similar mineralized schist from the Mercury claim. Tourmaline was found in one slide and with it some cinnabar. The two minerals, however, are probably not genetically related.

Equipment.—The surface equipment consists of a headframe and a hand windlass. Mr. Hughes' cabin and a 5-pipe Johnson-McKay retort are also on the ground. The retort seems to be crudely constructed and evidently was not very efficient.

Development Work.—All work on the property has been done by
hand. In April, 1924, the main shaft on the Rico Group was 112 feet deep. A 100-foot crosscut to the west and 59-foot drift to the south had been extended from the bottom of the shaft. The other work on the group consists of the regulation discovery shafts. Most of the work in the main shaft has been done by Hughes working alone. It has been necessary for him, after filling the bucket, to climb the 100 feet of ladder each time and hoist the ore bucket by means of a hand windlass.

The bottom of the mine is damp, the temperature in the face of the drift is high, and the ventilation is poor.

The rock in which the development work has been done is easy to drill and relatively easy to blast; nevertheless, it is firm enough to stand without supports. The shaft and levels have been standing for some time without the use of timber.

Ore.—The shaft is sunk on the vein, the drift is along the vein, but the crosscut is in unmineralized schist. Stringers of cinnabar were found to be more or less continuous all the way down the shaft. The seams of ore appeared to dip into the hanging wall. No ore, however, was found in the 100-foot crosscut except near the shaft. At 70 feet from the surface the highest grade streak of ore left the shaft on the south side and apparently had been again picked up in the drift.

Cinnabar was encountered in the drift 34 feet from the shaft and continued for 25 feet to the face, which still is in ore. In the first 12 feet the cinnabar was scattered, but it is probable that some of this part of the vein could be stoped. Nineteen feet from the face, the vein is cut by a cross stringer of quartz, which also faults the vein for 2 or 3 feet. The occurrence of cinnabar in the vein past the quartz was more regular than on the other side.

A sample was cut on the vein in the back of drift at the face over a distance 12.6 feet long, 3.6 feet wide at the face, and 4.6 feet wide at the other end. This sample, by assay, showed 1.29 per cent mercury. The vein at the point where sampled also contained two bunches of high-grade ore, each about one-half foot wide by 2 feet long, that were not included in the sample.

Assuming that the ore that left the shaft 70 feet from the surface and the ore exposed in the drift is the same shoot, the amount of probable ore in the 30 feet of backs would be about 1,725 cu. ft. or say, 160 tons. If all this contained 1.29 per cent mercury, the total amount of quicksilver would be about 4,100 pounds. To this amount should be added a quantity of metal that could not be estimated, and which would come from the bunches of high-grade ore. The high grade in the ore might be easily double the above estimate of the expected quick-
silver in this ore shoot. The vein appears to contain as much quicksilver in the face of the drift as in the back, although it is narrower. Hughes reports that cinnabar is also found in the bottom of the shaft.

A second ore shoot developed by the shaft did not extend into the drift. On account of shaft timbering, it was not practical to sample or measure this second shoot, but it did not appear to be as large as or contain as rich ore as the one sampled.

Rock containing cinnabar taken out in development work had been saved and stock-piled. A dump of this material, which is estimated by Hughes to contain 40 tons, was sampled, and the assay showed 0.72 per cent mercury. Even at $75 per flask the value of this ore would be $14.40 per ton, which would leave a good profit after treatment in any standard furnace or retort. A few hundred pounds of high-grade ore in the dump was not included in the sample. In addition, nearly 1,000 pounds of high-grade ore has been saved and sacked. Some ore has been treated in the retort and two flasks of quicksilver produced.

Judging from the experience of the writers elsewhere in mining similar deposits of other metals, ore should be mined from the shoot in the drift for around $5 per ton, if a power hoist were installed. This estimate does not include overhead or development charges.

Assuming a value of $25 per ton for the ore, a treatment charge in a retort of $7, and mining cost of $5 per ton, the profit on mining 230 tons of ore, with quicksilver at $75 per flask, would pay for the installation of a $3,000 retort. Assuming the same mining cost, and a $1.50 per ton treatment charge, about 810 tons would be required to pay for a 10-ton Scott furnace costing $15,000.

While an estimate of the possible ore in this property can not be made, the conditions on the ground give encouragement for further development in the hope of opening up sufficient tonnage to justify installation of, say, a 5-ton retort or 10-ton furnace. It is quite possible that with deeper and wider development several thousand tons of ore may be found.

**EUREKA GROUP**

The Eureka Group is owned by Louis Larsen and F. E. Jetter. It adjoins the Rico on the north, is on the same vein, and was at one time part of the same group. Cinnabar has been found at various points along the vein, but only in small quantities.

One hundred and fifty feet north of the Hughes shaft on the same vein a 50-foot shaft with 60 feet of crosscut and 90 feet of drifts has been sunk on the Dolores claim. In the face of the north drift
from the shaft a one-half inch seam of cinnabar about 6 inches long was noted in a 2½-inch soft streak of fractured green schist. No other cinnabar was noted in the shaft or underground. About 1,000 feet north of the shaft a surface cut across the strike of the vein disclosed some isolated crystals of cinnabar. A little cinnabar has also been found in soft green schist on the Eureka claim. A 30-foot crosscut tunnel, which has been driven in this schist, shows a 9-foot stratum similar to the ore-bearing formation on the Jupiter claim of the adjoining Porterie Group. This stratum was said to assay 0.61 per cent quicksilver, but careful panning failed to show any quicksilver minerals, except a few small, widely separated crystals of cinnabar in a one-half inch gouge on the footwall of the stratum. A 185-foot tunnel on the Eureka No. 1 failed to open up anything of value.

The occurrences of cinnabar on the group should encourage further development work. However, quicksilver minerals have not yet been found on the group in sufficient quantities to be of economic importance.

MERCURY GROUP

The Mercury Group adjoins the Eureka Group on the north and is on the wagon road from Paradise Valley to Phoenix. The claims lie in a broad pass in the Phoenix Mountains and extend into Paradise Valley. The group consists of about eleven claims, and is owned by the Porterie Mining Co. The claims were located by Henry and J. A. Porterie. Fig. 9 shows the general location and the relative positions of the claims. The principal development is on the Mercury and Jupiter claims; on the other claims of this group only location and assessment work has been done.

The schist on the Mercury claims is largely of the quartz-sericite variety, although some chlorite schist and a few thin beds of marble are exposed at the surface. The strike of the schistosity is N. 50° E. and the dip is 70° to the southeast.

A fault which parallels in dip and strike the schistosity of the wall rock was followed with an inclined shaft. Along this fault are a few inches of gouge in which no cinnabar was observed. The best ore found in the shaft was in the upper or hanging wall side in a belt of soft sericitic schist from 16 to 18 inches wide. Here the ore occurred as lenses in which small grains and veinlets of cinnabar were disseminated. These lenses are seldom over a few inches wide and overlap each other. A little cinnabar was also observed in the harder, quartz-sericite variety of schist, but the ore is much lower grade. A
few thin films of the green oxidized copper minerals were found in this harder schist.

A microscopic examination of thin sections of the ore shows that the cinnabar is most abundant around the larger grains of quartz which have been granulated and drawn out during metamorphism and recrystallization. Cinnabar occurs also as thin threads parallel to the lamination of the schists and between grains of quartz, suggesting that shreds of sericite were replaced by this quicksilver mineral. Although cyanite and cinnabar occur in contact with each other, the cyanite does not appear to have been replaced to the slightest degree.

The prevailing rock on the Jupiter claims is a dark green chlorite schist. The strike of the schistosity is N. 22° E., and the dip is somewhat less than 45° to the southeast. No definite faults appear to cut the schists near the ore body, but, instead, there is a zone of intense brecciation where the schist has been mineralized. Generally, no cinnabar is visible on the laminations of the schist, and only occasionally can thin films be seen on sheeting planes; on a cross fracture, however, minute specks of cinnabar may be seen with the aid of a hand lens in the body of the schist.

In a thin section this chlorite schist was found to consist essentially of calcite, quartz, and chlorite, listed in the order of abundance. The rock is made up of overlapping lenses a few millimeters in length and one or two millimeters in thickness, separated from each other by a thin winding layer of chlorite. The cinnabar occurs in these small lenses as irregular grains, and has replaced both the calcite and the quartz. Chlorite apparently has not been replaced by cinnabar although the two are often in contact with each other. Unmineralized chlorite schist was examined in thin section and found to be devoid of cavities, which supports the replacement idea advanced above.

Surface Equipment.—The buildings on the group consist of five 10- by 12-foot frame cabins and a 24- by 36-foot corrugated iron compressor building. In the compressor building is installed a 10- by 12-inch Sullivan air compressor, a Fairbanks-Morse 25-h.p. hoist, and a 40-h.p. gasoline engine for running the compressor. The machinery is in place, but has not been connected up. The forms are set for pouring concrete for the piers of a head-frame at the main shaft. All work so far done on the group has been performed by hand labor.

Development Work.—Most of the development work on the group has been done at two localities on the Mercury and Jupiter claims and on separate veins. Attention is called to Fig. 9. The work on the Mercury consists of:
Shaft, 4 x 6, x 65 feet deep
Shaft, 4 x 6, x 12 feet deep
Open-cut, 4 x 20, x 15 feet deep.

On the Jupiter:
Shaft, 3 compartment, timbered, 6 x 20, x 18 feet deep
Tunnels, 4 x 6, x 35, 42, and 20-foot long, respectively
Winze, 4 x 5, x 6 feet deep
Open-cut, 6 x 15, x 10 feet face
Open-cut, 4 x 40, x 12 feet face.

The regulation location holes and a few scattering cuts have been made on the other claims of the group. No work was being done at the time of the examination. Plate VIII shows the compressor building and shaft.

A sample was collected over a vertical distance of 6 feet at the bottom of the shaft on the Mercury claims across 2 feet of the vein which appeared to carry the highest values, and was assayed. The assay showed 1.47 per cent mercury. The ore did not extend across the shaft to the south. The sample can not be considered as indicating the value of the ore which could be mined from the shaft, but only shows the value at the particular face where taken. Ore assaying 1.47 per cent mercury contains 29.40 pounds to the ton, which, at $75 per flask, would have a value of $29.40 per ton.

The material excavated from the shaft has been piled for possible future treatment. A grab sample taken of this dump assayed 0.11 per cent mercury or 2.2 pounds per ton. This assay would indicate that all the rock taken from the shaft could not be mined or treated at a profit.

The showing of cinnabar in the shaft and the mineral occurring in the vein at the surface for 300 feet to the north would justify further development work, particularly drifting on the vein under the surface showings. The installation of machinery at the main shaft indicates that the company intended to do further work at this place.

The workings on the Jupiter claim are on a separate vein in a different rock that does not have the same strike or dip as that on the Mercury claim. A 14-inch stratum of green schist contains thin blades of cinnabar and siderite in the planes of schistosity. Some faulting or fissuring has occurred along the planes of schistosity near to the stratum which carries the cinnabar. The Jupiter is on the same belt as the upper end of the Eureka Group where the two tunnels were driven. A tunnel has been driven on the 14-inch stratum containing cinnabar,
Plate VII-A. Photomicrograph of a thin section of chlorite schist.

Plate VII-B. Photomicrograph of a thin section of cyanite schist.
Plate VIII. Compressor building and shaft, Mercury group.
for a distance of 20 feet, at which point the mercury values seemed to pinch out, although occurring in the vein outcrop farther up the hill. A 6-foot incline was sunk on the cinnabar-bearing schist near the face of the tunnel, after which work on the ore was discontinued.

Apparently the cinnabar-bearing schist, amounting to 20 or 25 tons, was sorted out and piled separately when the tunnel was driven. A grab sample taken of this pile assayed .22 per cent mercury or 4.4 pounds to the ton. The assay would indicate that all of the 14-inch stratum is of too low grade to be considered ore. The showing is sufficient, however, to warrant further development work.

After stopping work on the ore, the two cuts, together with the 35-foot and the 42-foot tunnels, were run for some other purpose which was not apparent. No cinnabar was developed in doing the work. The large shaft was apparently the last work done on the claim, and it probably was intended to cut the quicksilver-bearing stratum of schist at a depth of about 100 feet or so. This shaft was timbered with framed sets and was started as though 1,000 feet or more was to be sunk. It was large enough to have 3,000 tons per day hoisted through it. It is said to have cost $100 per foot.

No ore has been blocked out and no probable ore has been developed on the Mercury Group. Any estimate of ore tonnage would be necessarily of possible ore, and such an estimate, under the existing conditions, could not be intelligently made.

There are several promising showings of quicksilver mineral on the Mercury Group, and further expenditures would be justified in hope of finding a minable deposit of ore.

SEAL ROCK GROUP

Schrader\(^1\) reported finding cinnabar on the Seal Rock Group of claims on the east side of Squaw Peak, but careful panning of the vein-matter did not show any quicksilver minerals. A sample taken across the vein of the Discovery cut of the Seal Rock No. 1 was assayed, but it did not contain any mercury.

BOULDER GROUP

This group was examined, but no mercury minerals were noted.

ECONOMIC POSSIBILITIES OF THE PHOENIX MOUNTAINS DISTRICT

The showings of quicksilver in the Phoenix Mountains are sufficient to justify a belief that workable deposits may be developed. The

mining claims are held as locations by men of limited means who are financially unable to do much more than the required assessment work each year. However, if the ground were all under one management and development work were vigorously and intelligently performed, it appears probable that enough ore could be found and mined to keep a 10-ton furnace in operation for several years.

Fig. 10.—Index map of quicksilver deposits in the Mazatzal Mountains.

MAZATZAL MOUNTAINS DEPOSIT
LOCATION

The Mazatzal Mountains, of the Basin and Range type, lie in the central portion of the State. They trend slightly west of north, extend from the Salt River on the south to the East Verde River on the north, and have a total length of about 50 miles. On the east side of the range is Tonto Creek which discharges into the Roosevelt Reservoir, and on the west side is the Verde River, a branch of the Salt River.

Cinnabar was discovered in 1911 on the west slope of this range on Alder Creek, about 6 miles north of the Sunflower Ranch. (See Fig. 10.) Within the last few years several promising deposits have been found on Slate Creek, on the east slope of the range. This mineralized belt trends nearly east and west and is approximately midway
between the north and south ends of the range. As the summit of the range is the boundary between Maricopa and Gila counties, the deposits occur in both counties; those on the west side being located in Maricopa County.

The cinnabar deposits on Slate Creek are 4 miles from the Globe-Payson highway and about 70 miles from Globe. For a short time supplies were brought to the camp on Sycamore Creek from Globe. These supplies were hauled in motor trucks to Malone's camp on Slate Creek and then over the mountain on pack animals. During the past year supplies have been transported from Phoenix to Fort McDowell, thence across the Verde River and over a fair, but only locally improved, road to within less than 2 miles of the camp. The chief drawback to this route is that the Verde River can be crossed only at low-water stage. The distance from Phoenix to the camp is between 60 and 70 miles. In July, 1926, a wagon road had been completed 7½ miles up Slate Creek from the Globe-Payson highway and a survey was being made to extend the road all the way. Supplies were being taken into the Sunflower camp by pack animals from the end of the road.

**CLIMATE AND VEGETATION**

On both sides of the range the camps occur in deeply incised and steep-walled canyons and are surrounded by high peaks and ridges. The camp on Alder Creek is at an elevation slightly greater than 4,000 feet above sea level, while those on Slate Creek are somewhat under 3,000 feet. Even at the latter locality the summer heat is not excessive, and this is due largely to the greater elevation of the surrounding mountains which are an important factor in moderating the summer heat. During the winter months, however, snow falls frequently, but seldom remains on the ground more than a few days. The climatic conditions, therefore, are not likely to interfere with mine operations.

Rainfall, as in other parts of Arizona, is seasonal, and falls chiefly as torrential downpours during the summer months, and are usually accompanied by an intense electrical display. During the late autumn and winter the precipitation is chiefly as snow, and may be expected in the spring months even as late as the first of April. No records are available of the precipitation in this immediate vicinity, but it is probably greater than 15 inches per annum. In both Slate and Alder creeks water for domestic purposes is available throughout the year except following an exceptionally dry season, and even then some clear, cool water may be obtained from shallow wells sunk in the banks of the streams.
The vegetation in this vicinity is quite varied, and consists of a variety of trees, brush, and grasses. On Pine Mountain and on the upper slopes of Mount Ord is a good stand of yellow pine. At lower elevations and usually in sheltered ravines on the north sides of the higher points is an abundance of cypress. This occurs within easy reach of all the prospects and is the best wood available for mine timbers. A considerable stand of live oak and an occasional juniper are to be found at elevations around 4,000 feet. In the past oak wood has been used to fire the retorts. The slopes of the hills, especially at lower altitudes, are clothed with a dense growth of brush. Only a few of the species of brush occurring here are of value as feed for cattle, and as a whole they are a great hindrance to the prospector.

TOPOGRAPHY

The topography is rather rugged and consists of deeply incised, V-shaped canyons separated by high ridges. Both Alder and Sycamore creeks flow south across the schistose structure, while Slate Creek nearly parallels this structure. At the camp on Alder Creek the canyon is 1,000 feet deep and the slopes approach the critical angle for rock slides. The hardness of the rock has influenced the roughness of the topography; where slates outcrop, the hillsides are smooth and have rounded slopes, but, where rhyolite porphyry or jasper outcrop, cliffs predominate.

Nearly everywhere there is some evidence of recent uplift and rejuvenation of the streams. This uplift probably took place at the close of the Tertiary period.

GENERAL GEOLOGY

The quicksilver deposits in this region were examined by Dr. F. L. Ransome in the autumn of 1914 and his report was published by the United States Geological Survey. Since Ransome's report was issued considerable development work has been done and many additional claims located. The deposits on Slate Creek have been located in the last few years.

The southern half of the Mazatzal Mountains consists almost entirely of granitic rocks that locally may be somewhat gneissic, and are probably entirely pre-Cambrian in age. Near the extreme southern end of this range where the Roosevelt Dam was constructed across the Salt River is an excellent section of Paleozoic rocks. This section

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consists of quartzites and limestone of the Apache Group, and Devonian and Mississippian limestones. These Paleozoic rocks, however, are limited to a small area in these mountains, but originally extended many miles farther north.

On the north slopes of Mount Ord the granitic rocks have invaded pre-Cambrian crystalline schist, and from Slate Creek northward the basement of the range consists of these metamorphic rocks. From Mazatzal Peak to North Peak a massive-bedded and highly indurated quartzite rests unconformably on the upturned edges of the crystalline schists. This formation has been described by E. D. Wilson; and it was by him assigned to the pre-Cambrian and correlated with the Grand Canyon series.

At lower altitudes, on the west side of the range, the older rocks are locally covered by volcanic flows and associated tuffs. Volcanic rocks are rare on the east slopes of these mountains and only a single occurrence of lava was observed. This consisted of a flow of basalt intercalated in conglomerate on Slate Creek. On both sides of Tonto Creek, and extending nearly to the base of the Mazatzal Mountains, are numerous exposures of buff sandstone and red and green shales which in places are gypsiferous. These sediments and volcanic rocks are probably of late Tertiary age. The youngest formation in this vicinity consists of Quaternary gravels and sands, and caps the Tertiary sediments mentioned above.

METAMORPHIC ROCKS

In the immediate vicinity of the quicksilver prospects the prevailing rock is a crystalline schist that varies considerably both in mineral composition and texture. Quartz-sericite schist and brown slate predominate, but in addition chlorite schist, quartzite, and a dolomitic marble have been found. A massive vermilion-red jasper and a schistose rhyolite-porphyry form a part of this pre-Cambrian crystalline complex.

When Ransome examined the quicksilver prospects in this region he found that the schists could be subdivided into eight zones arranged symmetrically on each side of the jasper as a central axis. The relations of these zones to each other are shown diagrammatically in Fig. 11. He says: “It will thus be seen that in the southwestern part of the quicksilver belt the distribution of the rocks is such as to suggest that

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the jasper zone occupies the axis of a compressed syncline or anticline. Towards the northeast, on the east slope of the Mazatzal Range, the symmetrical arrangement of the rock zones is less evident.

The strike of the schistosity varies somewhat from place to place, and in Alder Creek is from 43° to 70° east of north, while on Slate Creek it is more nearly east and west. The dip of the schistosity is usually at steep angles to the northwest, but exceptions to this prevailing northwest dip were noted at several places. Surface creep is very pronounced on these steep slopes and often extends for a distance of 15 or 20 feet below the surface. This has sometimes misled prospectors, who do not know the cause of this phenomenon, and has led them to believe that their vein dips into the hillside at a low angle.

![Fig. 11.—Sketch showing relative positions of the schist zones, Mazatzal Mountains.](image)

Quartz-sericite schist is the most abundant type of metamorphic rock in the district. It varies in composition from a quartzite containing a little mica to a light-colored phyllite in which mica predominates. Other mineral constituents are present, but only in minute quantities, and are unimportant in the classification of these rocks. A notable exception is at Baker’s camp on Slate Creek where this variety of schist contains considerable calcite and a small amount of chlorite.

The brown slate is a fine-grained rock with a well-developed parting along which the rock cleaves readily. Although the mineral constituents are of small size, quartz and sericite were determined microscopically, and the brown color is due to a ferruginous pigment, probably the mineral hematite. Banding due to slight differences in composition may represent bedding planes, and near the Cornucopia claim this feature indicates that the schistosity makes an angle of approximately 45° with the original stratification.
Plate IX-A. View up Alder Creek, Mazatzal Mountains.

Plate IX-B. Specimen of schist-conglomerate from Alder Creek.
Plate X-A. Oxidized ore showing columnar structure.

Plate X-B. Veinlet of carbonate and quartz carrying cinnabar.
An area of chlorite schist is well exposed on the Packover and Go-By claims of the Sunflower Group. The rock is of a dark greenish color, and does not cleave as readily as the other mica schists or brown slates. The rock consists largely of chlorite and quartz, but small amounts of magnetite, sericite, and limonite are present. Some thin sections consist entirely of angular fragments of andesite and suggest that the rock was originally a volcanic tuff or breccia. A little red jasper was found associated with this variety of schist.

Bold outcrops of bright red jasper were seen north of the quicksilver deposits. The rock occurs as thin bands or layers in a pale yellow, dolomitic limestone. These bands are highly contorted and are often broken into angular fragments by the dynamic metamorphism that produced the schistosity. Occasionally the rock has a mottled appearance due to small white specks in a vermillion-red matrix, and is very striking in appearance, especially on a wetted surface. Small crystals of pyrite were found on a fresh fracture in some specimens.

A schistose conglomerate was observed on Alder and Sycamore creeks, and is a part of the quartz-sericite schist zone. The pebbles are all more or less angular, and comprise such rock types as rhyolite, andesite, banded quartzite, brown slate, and red jasper. The angularity of the fragments, which show no distortion due to deformation, suggests a local derivation and transportation for only a short distance. Microscopic examination showed the feldspars in the fragments of andesite to be remarkably fresh, although the ferro-magnesian constituents were entirely altered to chlorite.

Rhyolite-porphry occurs as two broad bands traversing this district in a northeast direction, and more or less paralleling the schistosity. The rock is of a creamy-yellow color and porphyritic texture with numerous phenocrysts of quartz and feldspar visible on a weathered surface. The central portion of this intrusion is rather massive and shows but slight schistosity, while the borders have been compressed and recrystallized to a quartz-sericite schist.

Microscopically, the less sheared rock consists of phenocrysts of quartz, orthoclase, and acid plagioclase. Much of the feldspar is altered to secondary quartz and sericite. No original ferro-magnesian minerals remain, but the form of the alteration products suggests that biotite was an original constituent. The groundmass is microcrystalline and consists of quartz and orthoclase, with sericite and kaolin as secondary minerals. The more sheared portions of the rhyolite-porphry consist of quartz and sericite, and the positive identification of
this highly compressed portion rests on the gradational intensity of the shearing from the center to the borders of the intrusive.

A specimen of rock collected near the trail along Alder Creek was found to be an amygdaloidal basalt. The rock breaks readily in one direction showing that a rude schistosity has been developed, but the general appearance in a hand specimen closely resembles an igneous rock. The amygdules, which consist of calcite, apparently have not been distorted by the metamorphism to which the rock has been subjected. Examined in thin sections the rock was found to consist largely of alteration products. No feldspar or original ferro-magnesian minerals remain. The alteration products are quartz as irregular grains and tiny veinlets, chlorite, serpentine, sericite, limonite, and kaolin. Nests of serpentine may have been formed from original olivine. Much of the magnetite present may be original.

Most of the schist exposed in this region was derived from sedimentary rocks. This conclusion is based on the finding of a conglomerate, original bedding planes in the slates and quartzite, and the presence of limestone. Very likely all the quartz-sericite schist was formed from sediments. The rhyolite-porphyry, chlorite schist, and amygdaloidal basalt are of igneous origin.

This belt of schist continues northeastward to the northern end of the Sierra Ancha where the metamorphic rocks are overlain by a member of the Apache group of supposedly Cambrian age. The schists are therefore pre-Cambrian.

VOLCANIC ROCKS

The effusive rocks are abundant on the west slope of the range and usually occur as lava mesas. Saddle Mountain, about 4 miles west of the camp on Alder Creek, is such a mesa. Here Ransome\textsuperscript{1} examined the various flows that make up this mountain and described them as follows:

"The volcanic rocks under which the schist passes at its southwest end have a thickness of about one thousand feet on Saddle Mountain. At the base is a soft-brown tuff, andesitic or basaltic, with many schist fragments. This appears to be fifty to sixty feet thick. It is overlain by light-gray fine-grained andesitic tuff of approximately the same thickness. Above this lies about 200 feet of coarse andesitic tuff-breccia, the fragments being mostly a light-gray hornblende-biotite andesite. This is succeeded by about 300 feet of andesitic flow breccia, which appears to pass upward without recogniz-

\textsuperscript{1}Op. cit., p. 117.
able plane of demarcation into a somewhat porous pink lava which, although resembling the dacite of the Globe-Ray region, proved on microscopic examination to be a fresh hornblende andesite with glassy groundmass. This flow or part of the flow is at least four hundred feet thick and forms the top of the mountain."

South of Red Rock Pass, between Sycamore and Slate creeks, the volcanic rocks have a total thickness of not over 700 feet. Here a well-stratified, brownish tuff, probably andesitic in composition, is the lowest member of the volcanic series observed in the vicinity of this pass; but, as the basement upon which it rests is not exposed, other flows may occur beneath it. This tuff is apparently present only on the west side of the pass, dips to the southwest at a low angle, and appears to fill a depression in an older topography. Above this tuff are flows of a light-colored biotite andesite with a thickness of at least 300 feet. On the east side of the pass a gravel rests on the eroded surface of these flows.

In the lower portion of Slate Creek is an exposure of olivine basalt intercalated in tilted conglomerate. The flow and conglomerate dip to the east at about 15°. Cliff sections along the stream show the basalt to have a thickness of between 80 and 100 feet. The rock is rather dark in color and very fine-grained, with olivine as the only macroscopic mineral. This basalt has been thoroughly shattered and the fractures filled with innumerable veinlets of calcite.

The volcanic rocks in this region are a part of the extensive lava field occurring to the northwest of the Mazatzal Mountains. In this region, as in many other parts of the State, the volcanic rocks are probably of Tertiary age; and the andesites are undoubtedly older than the basalts exposed in the banks of Slate Creek.

ORE DEPOSITS

At the time of Ransome's visit, in the autumn of 1914, very little development work had been done; and, although considerably more underground development work has been completed since then, the deposits are still to be considered as prospects rather than developed mines. Several new groups of claims have been located in the last few years, but only location and assessment work has been done on them.

The distribution of the groups of claims located for cinnabar is shown in Fig. 12. An inspection of this map shows that there are three distinct belts or zones of mineralization: The Alder Creek belt; Sycamore Creek-Pine Mountain belt; and the Slate Creek belt. In general, these groups of claims closely parallel the schistosity.
On the Sunflower Group Ransome\(^1\) recognized three approximately parallel lodes which are several hundred feet apart. The central or Packover lode is probably continuous with the ore found on the Cornucopia claim of the Robbins Group and may extend northward to Bow--

man's claims. Recent development work has shown that this lode consists of fairly well-defined ore shoots lenticular in plan, with a pitch to the southwest.

These lenses do not have clear-cut walls nor were they found to follow well-marked fissures except in a few instances. Where mineralization has occurred along faults, the cinnabar is often in one or both walls and decreases with increased distance from the fracture.

Faulting both earlier and later than the metallization was observed. The earlier faulting seems generally to have a northeast trend. The few lenses of ore found on the Cornucopia claim are along these northeast faults. A clear-cut example of later faulting was observed on the Go-By claim. Here the ore body was displaced by a northwest fault.

The ore consists of veinlets cutting the schists or as thin films on fracture planes. Some disseminated cinnabar in the body of the schist was also observed. The veinlets vary in width from a fraction of an inch to 6 inches or more, but a vein with a width of 2 inches or more is exceptional. Usually these small stringer veinlets are parallel, and when abundant enough the rock constitutes ore. Much of the mineralized schist observed carries so few of these small veins that careful sorting must be practiced to make a good grade of furnace ore. Tiny veinlets of cinnabar sometimes occur on fracture planes across the schistosity. Such specimens are very spectacular, as the cinnabar covers broad areas; and the tendency is to overestimate the grade of such ore.

Cinnabar is the only important quicksilver mineral in the ore, although small amounts of the chloride, calomel, and native quicksilver have been found. Metacinnabarite may be present in small amounts. An unknown gray mineral was found associated with cinnabar in polished surfaces of ore. This mineral is slightly harder than cinnabar and may be tetrahedrite, but this could not be determined positively as the amount of it found was too small to be tested separately. Pyrite is abundantly associated with cinnabar in ore from the lower tunnel on the Cornucopia claim. Cinnabar was found to fill fractures in the pyrite and has probably replaced this mineral to a slight extent. However, a crystal of pyrite surrounded by cinnabar was found in ore from the Sunnyside claim, and the pyritohedral faces on this crystal showed no evidence of replacement; and the pyrite is undoubtedly the earlier of the two minerals. Ransome reported some chalcopyrite from this district, and the writer found oxidized copper minerals associated with the cinnabar ore from Slate Creek and on Alder Creek.
Mr. Wesley Goswick, whose claims are on Slate Creek, gave the writers a specimen of stibnite and reported that it came from near his quicksilver claims. No stibnite was found associated with cinnabar in any of the specimens of ore collected from this district.

Gangue minerals consist chiefly of quartz, calcite, and a ferruginous carbonate. A small amount of serpentine was found in ore from the Red Bird Group on Slate Creek, and sericite occurs with quartz in ore from the Cornucopia claim. Tourmaline occurs as a gangue mineral in tiny veinlets closely associated with quartz and cutting the ferruginous carbonate. This black tourmaline is not abundant as a microscopic constituent of the ore, but is more widespread as microscopic needles. Quartz is by far the most important gangue mineral and occurs in two generations, both of which contain tourmaline. This quartz is always of a milky-white color and incloses numerous minute inclusions, circular in outline and arranged in rows like a string of beads. The ferruginous carbonate was tested chemically and found to contain considerable iron and lime and a small amount of magnesia. It probably contains both the ankerite and siderite molecules, and on weathering leaves a residue of limonite.

An intergrowth of this carbonate with quartz produces an interesting structure which, in many respects, resembles the columnar structure in lavas. This is shown in the illustrations on Plate X-A. The columns are often curved and extend across the vein from wall to wall. They do not consist of single crystals, but rather as interlocking grains of quartz that do not even have the same crystallographic orientation. This columnar structure is not to be confused with the typical comb structure so commonly associated with crustification. There is no banding due to crustification in the quicksilver veins of this district, and drusy cavities are rare. Some of these cavities are transverse to the walls of the vein and are lined with crystals of quartz; others are irregular in outline with sharp-pointed crystals of the carbonate on which cinnabar has been deposited.

The intimate intergrowth of quartz, carbonate, and tourmaline suggests that they were probably formed at about the same time, but this intergrowth is traversed by a second generation of quartz veins with tourmaline. Pyrite is later than the quartz-tourmaline veinlets and was probably formed at the same time as the sericite occurring in the ore from the Cornucopia claim. Cinnabar was the last mineral to be deposited, and replaces both the carbonate and quartz. It fills fractures in the tourmaline and pyrite, and may have replaced the latter mineral to some extent.
Outcrops are not conspicuous. Many of these lodes consist of small stringers or veinlets containing abundant carbonate; and, consequently, they weather more readily than the inclosing wall rock. Then, too, the rather dense growth of vegetation on the slopes of these hills rather effectively protects the thin mantle of soil covering the outcrops. Where quartz is abundant as a gangue mineral the course of the lode is more easily followed on the surface, as float is abundant on the lower slopes and can readily be traced to its source. Very often quartz and a ferruginous carbonate are intimately intergrown, and on weathering, this combination leaves an open-textured or spongy ore consisting of quartz and limonite with tiny veinlets of cinnabar. Outcrops of this porous ore are likely to be covered by soil.

Cinnabar is a rather stable mineral and does not alter readily under the influence of surface agencies. The adamantine luster is usually dulled by exposure to weathering, and the mineral may be covered by a thin film of a dark substance that may be the secondary sulphide, metacinnabarite. That some oxidation and reduction of the sulphide has taken place was definitely determined by the finding of calomel and metallic mercury. A bright yellow mineral found on the L and N group may be one of the rare oxychlorides of mercury, but the quantity of it found was too small to determine the mineral specifically.

PROPERTIES

The quicksilver ground is held under lode mining locations and none of it has been patented. Two groups of claims, the Robbins and L and N, have been surveyed for patent, but no applications have as yet been made. With the exception of the groups on Slate Creek, the claims are in the Sunflower mining district.

Fig. 13 shows the Robbins, L and N, Sunflower, Bowman, and Martin groups, which constitute the claims now being actively held in Maricopa County. The Sunflower, Robbins, and L and N groups are owned by the Arizona Quicksilver Corporation. In May, 1924, this corporation was prosecuting active development work on the Robbins Group. In 1924 the corporation acquired the Sunflower Group on which considerable work was done during the fall of 1925. Bowman was keeping alive six locations now known as the Bowman Group. The annual assessment work was done on the Martin Group for 1923. Reynolds has done the assessment work each year on his main or Northern Light Group, and recently has located a number of other claims.

The Red Bird Group on Slate Creek was located in 1922 by three Malones—W. A., Tom, and Otto. Wesley Goswick located the Ord
Fig. 13.—Claim map of the Sunflower, Robbins, Bowman, and L and N Groups.
Group adjoining the Malone claims in 1925, and the Rattlesnake Group adjoining the upper end of the Ord was located in 1925 by A. M., Robert B., and Gus Packard. In October, 1925, the Arizona Quicksilver Corporation had an option on the Goswick claims, and was putting up a camp; and in July, 1926, it was carrying on active development work. The Pine Mountain Group was located in September, 1925, by Wm. Reynolds, Charles MacFarland, and Wm. Boardman; and the Mercuria Group was located in June, 1926, by Wm. Reynolds.

The quicksilver deposits in this district were examined in April, 1924. The Slate Creek deposits were again visited in April, 1925, and the Sunflower Group and new discoveries on Slate Creek were inspected in October, 1925. The Ord and Northern Light groups were again visited and the Pine Mountain and Mercuria groups inspected in July, 1926.

**SUNFLOWER GROUP**

The original discovery of cinnabar in the district was made on the Sunflower Group by E. H. Bowman in 1911, who at that time located part of the claims. In 1913 Mr. Bowman sold his claims for $10,000 to the Sunflower Cinnabar Mining Company, which did most of the work on the ground. The property later was acquired by Judge Charles Ainsworth, of Phoenix, who sold it to the Arizona Quicksilver Corporation in 1924. The Arizona Quicksilver Corporation, which owns this group, is a subsidiary of the Great Lakes Security Company, of Toledo, Ohio. W. S. Stalker, of Toledo, is president of the corporation, and E. W. Bedford, of Phoenix, is local manager. The Arizona office is located at 326 Heard Building, Phoenix, Arizona.

The Sunflower Group consists of 17 unpatented claims on Alder Creek. The hillsides are very steep, which facilitates mining by tunnels. The surface is covered with scrub oak and manzanita, which makes progress over the surface difficult. Most of the ore on this group was found on the Packover, Go-By, and Sunnyside claims, on what is known locally as the Packover lode. Several hundred feet to the northwest is a parallel lode known as the Native or Jasper; similarly, southeast of the Packover is the Ione lode. These nearly parallel lodes or belts of mineralization trend northeastward with the strike of the schistosity. On both the Ione and Jasper lodes only location and assessment work has been done, and the main development has been confined to the Packover lode.

The ore shoot on the Go-By claim has a length of from 200 to 300 feet, and has been shown to be continuous over this distance by nu-
merous trenches or open-cuts across the lodes at close intervals. The width of the mineralized schist is quite variable. Development work done under Mr. Bedford’s direction suggests that the ore shoot pitches to the southwest, and the strike is approximately N. 45° E. The country rock is largely a dark green, chlorite schist containing some red jasper. The planes of schistosity have a nearly vertical dip. Cinnabar occurs in small veinlets up to an inch or more in width. Locally, these small veins may widen within a distance of only a few feet along the strike until the width is 10 or 12 inches. This lenticular shape is rather characteristic of these veins. Quartz, tourmaline, and carbonate are the gangue minerals, and pyrite is only sparingly present in ore from this claim. Near the southwest end of the Go-By claim the lode has been displaced by a fault which strikes N. 55° W, and dips 70° to the southwest. In an adit which cuts this fault is a zone of brecciation with the planes of schistosity in the footwall curved to the west. This suggests that the hanging wall has been displaced relatively to the northwest, but the amount of displacement could not be determined. Cinnabar was found in the crushed gouge and as a smear on the slickensided surfaces of the wall, showing that the movement was definitely later than the mineralization. These relations are shown in Fig. 14. A little cinnabar and pyrite was found in jasper near the end of this adit.

![Fig. 14.—Diagrammatic sketch showing faulted ore body, Sunflower group.](image)

Southwest of the Go-By some ore has been developed on the Packover claim by two short adits and several open-cuts on the surface. The inclosing rock as well as the nature and occurrence of the ore is so similar to that on the Go-By claim as to need no separate description.
Plate XI-A. Twelve-pipe retort on Alder Creek.

Plate XI-B. One-pipe retort on Sycamore Creek.
Plate XII-A. Part of Stalker village, Ord group.

Plate XII-B. Millsite, Ord group.
In a crosscut from the lower tunnel on the Sunnyside claim the ore occurs in a banded, gray and white lens of limestone in fine-grained, quartz-sericite schist. The schist strikes N. 45° E. and dips 70° to the northwest. The ore is localized at the intersection of several fractures with the lens of limestone. Quartz is apparently absent and the cinnabar replaces calcite. The ore body is rather small in size, and does not extend more than 20 feet above the level.

A little azurite and malachite together with quartz and limonite were found on the Silver Tip claim, but cinnabar, apparently, is absent. In a surface cut near the north end of the Sunnyside claim a little azurite is associated with cinnabar.

*Equipment.*—Since the group has been acquired by the Arizona Quicksilver Corporation a new camp has been built on the ground. The buildings consist of a bunk house, a mess house, store room, compressor house, and office. The machinery that was previously on the L and N and the Robbins groups is now installed on the Sunflower Group. A 12-pipe Johnson-McKay retort furnace (Plate XIA) has been built on the ground. The cylinders are 12 inches in diameter and 6 feet long, and are put up in crude rock masonry. The capacity is reported to be 2 tons per 24 hours. It is also reported that 13 hours were required to fully volatilize the quicksilver in each individual charge, and that 2 cords of wood were required for each ton of ore. As the wood cost $4 per cord at the retort, the fuel charge was $8 per ton of ore. A total of 75 flasks of quicksilver had been produced in this plant previous to 1925, and 24 flasks during 1925.

*Development Work.*—Considerable development work has been done on the group, and probably a total of $150,000 or $200,000 was expended by the old company. Most of this work was done on the Sunnyside, Go-By, and Packover claims. The development work completed by the old company consists of:

**Sunnyside:**

- No. 3 tunnel
- Drifts from No. 4 tunnel
- No. 2 tunnel and drift
- No. 4 tunnel
- No. 1 tunnel
- Open-cut

**Go-By:**

- Tunnel
- Open-cut
Packover:

Tunnel: 4 x 6 1/2, x 40 feet long
Tunnel: 4 x 6, x 60 feet long

The location cuts and a few prospecting pits have been sunk on other claims of the group.

The development work done on the group by the Arizona Quick-silver Corporation during the first six months of 1925 is as follows:

- 347 feet of drifts and crosscuts on Packover claim.
- 158 feet of drifts and crosscuts on Go-By claim.
- 27 feet of drifts and crosscuts on Sunnyside claim.
- 50-foot shaft on Packover.
- 660 feet of surface cuts on Packover and Go-by claims.

This new work, together with some done by the old company, is shown in Fig. 15.

In October, 1925, two tunnels were being extended on this ground. In addition, a force of men was extending the wagon road up Alder Creek toward the property, and others were doing some construction work on the claims.

Ore—

Sunnyside Claim.—No. 3 tunnel is a crosscut 345 feet to the lode, on which 80 feet of drifting has been done and a 10-foot raise put up. About 20 feet from the mouth of the southwest drift a bunch of cinnabar ore was disclosed. A raise was put up in the ore which pinched out 8 feet above the tunnel. The ore in the back of the drift is 4 feet long and about 2 1/2 feet wide, and would probably assay 2 per cent quicksilver. There is probably about 10 or 15 tons of ore opened on two sides at this place. Ransome examined this tunnel before the raise was put up and states:

"The lode as seen in the lower tunnel is of the same general character as in the upper tunnel. For a part of its course at least it follows a layer of squeezed limestone in the schist. This layer is cut by irregular stringers of quartz and white calcite carrying more or less cinnabar. In places also paper-thin seams of cinnabar without gangue are fairly abundant in the schist. In the schist exposed in the crosscut tunnel a little cinnabar was noted for at least 50 feet west of the main drift. Here as elsewhere the lateral limits of the lode are indefinite.

"A sample representing a width of 3 feet across the best part of the lode as exposed in the lower tunnel gave, accord-

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Fig. 15.—Section of hill and plan of haulage tunnel, Sunflower group.
ing to Mr. Hutchinson, a little less than 2 per cent of quicksilver.

No work has been done in No. 2 and No. 4 tunnels since Mr. Ransome's visit, and his description is as follows:¹

"The two tunnels of the Sunflower Cinnabar Mining Co. were both run so as to cut the Packover lode beneath a section of its outcrop where little or no cinnabar has been found. The lode where cut by the upper or No. 2 tunnel appears to have a width of about 12 inches, and the principal stringer, which is nearly 6 inches in maximum width, consists of buff ferruginous carbonate, white calcite, quartz, and cinnabar. An assay of a sample taken across a width of 7 inches of the lode at this point yielded Mr. Hutchinson 1.25 percent of quicksilver. Of three samples taken by him from this tunnel the richest, representing a width of 5 inches, gave 3 per cent of quicksilver, indicating roughly, at the present high prices (quotations in June, 1915, taken for convenience at $75 a flask of 75 pounds,) $80 ore.

"A few feet north of the crosscut the vein disappears. It is apparently cut off obliquely by a fault, but the displacement is probably not great. South of the crosscut the vein has been followed for about 100 feet to a point where the drift leaves the vein, which passes into the footwall."

A raise, put up to the surface on the best mineral showing on the upper tunnel level, showed that the ore did not extend far in any one direction, and that it occurred roughly in "pancake"-shaped bodies or bunches.

Ore has been mined from an open-cut about 1,000 feet northeast of the No. 2 tunnel. A 1-foot stringer of quartz 4 feet long which contains some cinnabar is now disclosed in the bottom of the cut. The ore was mined at this point on company account and packed down the hill on burros to the retorts. According to Mr. Donald, 39 flasks of quicksilver were recovered from this ore.

Mr. Ransome² described this cut, in 1914, as follows:

"On the Sunnyside claim, about a thousand feet north of the tunnels, the Sunflower Cinnabar Mining Co. was obtaining ore for its retorts at the time of visit from a small open cut. Here was exposed a veinlet, measuring 3 inches in its widest part, of cinnabar and limonite lying in the planes of lamination of the schist. The veinlet was exposed with nearly maximum width at the northeast end of the cut and had been followed to a point where it pinched out to the southwest, in a distance of 6 feet. This is probably the largest and richest

single veinlet seen. Mr. Hutchinson's report shows that it contains 38.2 per cent quicksilver, roughly $860 ore at present prices, but a 2-foot sample across the lode, with the stringer omitted, gave only 0.7 percent, corresponding to $14 ore.”

It is not known what percentage of quicksilver the ore from this place contained, but apparently it is now all mined out. During 1925 a drift from No. 1 tunnel was extended and cut a small ore body. An 18-inch streak in the face will run 3 or 4 per cent quicksilver. In the middle of the streak occurs 1 inch of solid cinnabar. The ore shoot is about 6 feet long to the face of the drift. A parallel drift was being extended to pick up the ore shoot beyond the present showing in the face. About 1 ton of ore that contains about 15 per cent quicksilver is piled on the dump.

Go-By Claim.—The best showing at present on the group is on the southwest end of the Go-By claim. On the west side of Bowman Creek a 250-foot tunnel and a large open-cut have been driven on the lode. A 50-foot shaft also has been sunk at this place. The cut was made by lessees in mining ore for retorting, from which 36 flasks of quicksilver were obtained. It is said that the men made good wages while the ore lasted. The ore was hand-sorted and was packed on burros to the retorts. According to Mr. Donald, the miners estimated that 20 pounds of quicksilver was recovered per ton of ore.

About 1 foot of quartz and cinnabar is next and parallel to a fault. Seams and veinlets of cinnabar occur in the schist throughout the bottom of the cut and in the back of the tunnel. The tunnel is about 5 feet below the cut and along the north side of it. In the back of the tunnel below the face of the cut and next to the fault is a little bunch of probable ore, 3 feet wide by 12 feet long by 12 feet high, not taken out. A sample, excluding the high-grade, taken across 3½ feet of the ore in the face of the cut in April, 1924, contained .09 per cent mercury. Including the high-grade, this ore left in the face should assay about 2 per cent.

During 1925, the Arizona Quicksilver Corporation sank the 50-foot shaft in the cut made by lesseors while taking out the ore. It is stated by Chris Martin, who was in charge of operations on the ground for the corporation, that the bottom of the shaft was in 1 per cent ore. The dump from the shaft shows considerable pyrite, and a little cinnabar. The tunnel alongside of the cut had been extended beyond the fault into the lode, but did not disclose any ore.

The tunnel on the other side of the gulch from the cut on October 22, 1925, was 235 feet long, and was being extended along the lode. Some cinnabar was found throughout the tunnel, but not in commer-
cial quantities, except possibly in one place. The first crosscut to the left, which was 35 feet long, was sampled by Mr. Bedford. Twenty-five feet of the distance assayed 0.38 per cent and 6 feet 1.0 per cent quicksilver. The next crosscut showed some cinnabar, but not in sufficient quantity to be mined. Attention is called to Fig. 15.

A series of cuts has been made by the present owners up the hill along the line of the tunnel. Cinnabar, as stated previously, was found in practically all of the cuts, and in many places apparently in commercial quantities, provided the oreshoots had any vertical dimensions. The tunnel is being extended to develop the showings made in the cuts at greater depth. About 45 tons of ore was packed from the surface cuts on the Go-By and treated at the retorts. About 1 ton was taken from the material removed from the shaft. This ore was mixed with 5 tons brought from the Cornucopia claim of the Robbins Group, and 24 flasks of quicksilver were obtained.

Mr. Ransome's description of the mineral at this place at the time of his visit is as follows:

"At one surface exposure of the Packover lode on the Go-By claim the schist for a width of at least 75 feet contains little veinlets of cinnabar and gangue, all less than 3 inches wide and most of them less than 1 inch wide. This zone of veinlets is not bounded by definite walls, and the schists probably contain some cinnabar outside of the 75-foot belt. At this locality Mr. Hutchinson, by careful prospecting and counting, established the existence of 17 veinlets in a width of 9 feet. The aggregate thickness of these veinlets was estimated by him at 15 inches. Another count 50 feet away on the same lode gave substantially the same result. Besides occurring in the veinlets the cinnabar, particularly near the veinlets, is disseminated as specks and small irregular blotches through the schist.

"A sample taken by Mr. Hutchinson at the locality just indicated, by making two cuts across the 9-foot zone and rejecting so far as possible the barren schist between the stringers, yielded on assay 3.60 per cent of quicksilver. That is, the result represents approximately the contents of an aggregate width of 15 inches of stringers out of a total width of 9 feet of lode. It may be estimated roughly from the foregoing data that a continuous sample across the 9 feet might assay from 0.5 to 1 per cent of quicksilver."

Ione claim.—Some cinnabar is exposed in a cut on what has been designated the Ione lode on the Ione claim on Bowman Creek. Associated with the small amount of cinnabar is considerable siderite and limonite in schist.

*Ransome, F. L., Quicksilver Deposits of the Mazatzal Range, Ariz.: U. S. Geol. Survey Bull. 620, p. 120.
A main haulage tunnel was started near Tunnel No. 4 on the Ione to mine ore to be developed by the upper workings on the Go-By and Packover claims. (See Fig. 15.) In October, 1925, the tunnel was about 300 feet in length and further progress was stopped for the time being. The compressor was being moved down the canyon to furnish air for power drills on the heavy rock work of the road extension.

Packover Claim.—Two tunnels have been run on the Packover lode on this claim. At the portal of the tunnel on the east side of the gulch occurs a 1-foot streak of schist, with veinlets of quartz containing a little cinnabar. The same lead is opened up in the tunnel across the gulch and shows a few scattering crystals of cinnabar at the face.

A few shots put in the lode at the portal of the west tunnel by the present owners of the claims opened up a showing of ore about 12 feet long and 6 feet wide. Streaks of pure cinnabar up to 1 inch thick occur in the lode at this place. Apparently ore containing about 3 per cent quicksilver could be sorted for treatment.

A number of surface cuts, most of which show some cinnabar, have been made on the ground, and show the continuity of the lode for a distance of about 1,200 feet on the Go-By and Packover claims.

Conclusions.—Considerable development work was done on the Sunflower Group by the old company, but the results were discouraging. Work done by the present owners has been performed to a better advantage, and considerable probable ore has been found. Further work will be required to prove definitely the extent of the ore bodies, before any given daily tonnage can be assured.

ROBBINS GROUP

The Robbins Group, consisting of 9 claims, is on Alder Creek in the Maricopa County belt and adjoins the Sunflower Group on the northeast.

This group was acquired from the locators by the Arizona Quicksilver Corporation, which has done the development work on the ground.

Active operations have been carried on in the district since 1921 by this corporation, and an intelligent effort has been made to develop producing quicksilver mines. In May, 1924, $2,500 per month was being expended in development work. Including purchase price of properties, between $100,000 and $150,000 has been spent up to this time in the district by this firm. In October, 1925, a total of 22 men was employed by the Corporation in the Sycamore and Slate Creek areas. Before starting development of the Robbins claims, considerable work was done by this corporation on the L & N Group.
The only ore found on this group occurs on the Cornucopia claim. The prevailing rock is a light gray phyllite, but some brown slate is also present. The schistosity strikes N. 50° E. and dips 75° to the southeast. The outcrop of the oreshoot as exposed in an open-cut consists of two strong veins of quartz and limonite with cinnabar. These two veins are separated by a few inches of schist, and on each side of these veins are small stringers of cinnabar. The total width of the ore is about 3 feet. Some of this ore is high-grade, and veinlets of pure cinnabar nearly an inch wide have been found. A sketch of the exposure in this cut is shown in Fig. 16. The ore is rather porous due to leaching out of the ferruginous carbonate and pyrite, and the cinnabar stands out as tiny veinlets surrounded by limonite. This same oreshoot was cut in the upper tunnel, 80 feet below the outcrop. A raise from the lower tunnel showed that the ore did not extend more than 20 feet below the level of the upper tunnel. At the portal of the lower tunnel is a 12-inch vein of quartz and limonite, but it apparently contains no cinnabar. In a crosscut, 114 feet from the portal, a 4-foot vein with an east-west strike was cut, but the ore was low-grade. A small stringer carrying some cinnabar was followed by the main tunnel. From 2 to 3 inches of ore was found in this vein 225 feet from the portal. All these veins occur along faults.
Equipment.—Machinery was installed and power drills used for underground drilling. Tracks were placed in the tunnels and the broken rock was removed in steel cars pushed by hand. The lower tunnel is ventilated through 600 feet of 7-inch galvanized iron pipe. The machinery on the property in May, 1924, consisted of a 32 h.p. Reliance gasoline engine using distillate for fuel; a Gardner No. 162 air compressor of 2-drill capacity; a mounted jackhammer; a stoper; a Denver rock drill sharpener; a Buffalo Forge Co. No. 3 blower; and a small gasoline engine for operating the blower. In October, 1925, the machinery had been removed down the canyon to the Sunflower Group.

The buildings on the property are of temporary character, and are as cheaply built as is consistent with the use required. They consist of a corrugated iron blacksmith shop, a corrugated iron compressor building, a cook and dining tent, a tent storeroom, and two tent bunk houses.

Development Work.—The development work on the group has been done on the vein on the Cornucopia claim and consists of:

- **Open-cut**.......................... 4 x 15, x 6 feet face
- **Upper tunnel**...................... 4½ x 6, x 370 feet long
- **Lower tunnel**...................... 5 x 6½, x 750 feet long
- **Raise**............................. 4 x 6, x 300 feet high
- **Stope**.............................. 4 x 5, x 26 feet high

Several crosscuts 10 to 25 feet long have been run from the tunnels. At the time of the writers' first visit preparations were being made to drive a 380-foot raise from the lower tunnel to the upper tunnel and thence to the surface, to develop an oreshoot exposed in the open-cut and upper tunnel. In October, 1925, this raise had been extended to the upper tunnel with discouraging results. A second raise or stope was put up above the upper tunnel for a distance of about 26 feet on a small oreshoot.

Work on the other claims of the Robbins group consists only of the location cuts.

Seven men were at work at the time of the writers' first visit. The force consisted of a superintendent, a compressor man and blacksmith, two shovellers, a man getting out timber, a roustabout, and a cook.

Supplies were brought from Globe to the claims at a cost of $50 per ton.

Mining timber may be obtained near by, but it is rather expensive on account of the steepness of the slopes, the thick underbrush, and
the absence of trails. Cord wood furnished to the Sunflower Group several years ago was cut and delivered at the retorts for $4 per cord.

**Ore.**—Cinnabar is found in small amounts at places on the surface over a distance of 900 feet. The open-cut on the lode on the Cornucopia claim was run on the best surface showing of quicksilver so far discovered in the Sycamore section of the district. A shoot of ore 3 feet across and 8½ feet long is opened up in the cut and the face is still in ore. At the surface a few feet above the face of the cut the ore appears to pinch out. With the exception of the cinnabar, the vein matter is oxidized at the surface. On the southeast wall of the vein and next to the ore is 4 inches of gouge. Ten feet to the northwest of the cut there are 2 feet of iron oxides and quartz containing a little cinnabar.

A sample across 3 feet of the face of the cut 1 foot below the surface was taken and assayed 3.46 per cent mercury. The vein also contains streaks and pieces of high-grade ore which were not included in the sample.

About 100 pounds of large pieces of ore containing about one-half cinnabar were sorted while excavating 10 or 12 tons of rock from the cut. The occurrence of this high-grade ore is very erratic. During 1925 about 5 tons of ore was gouged from the surface at this place and packed to the retort.

Eighty feet below the open-cut a tunnel has been driven on the vein. Directly under the mineral showing in the cut above, a body of ore 3 feet wide has been opened for a distance of 6 feet in a subdrift from a crosscut. This ore is shown in the back, bottom, and face of the subdrift, but a crosscut 18 feet ahead shows that the ore does not extend that far. The ore is wider at the bottom than at the top of the face of the subdrift.

A sample across 2 feet 7 inches in the middle of the face assayed 4.11 per cent mercury. Two assays made by Robt. T. Donald, formerly superintendent of the property, of grab samples of ore broken by blasting the last round back of the face assayed 18 and 20 per cent mercury. A load of 180 pounds of ore taken from 1 foot of the vein where the ore was first struck was retorted and yielded 39 pounds of quicksilver, which would indicate 21.8 per cent metal. Pyrite, iron oxide, and quartz are associated with cinnabar in the vein, and the walls on each side of the ore in the tunnels contain specks of pyrite and an occasional crystal of cinnabar.

A raise has been extended 26 feet above the tunnel level on the oreshoot, which averaged about 20 inches by 5 feet in cross-section.
About 15 tons of ore, which is estimated by Mr. Bedford to contain 4 per cent mercury, were taken from the raise or stope. Five tons of this ore have been packed on burros to the retort on the Sunflower Group, mixed with ore from the Go-By claim, and treated. Twenty-four flasks of quicksilver were produced during the run, which was stopped because the fire box of the retorts fell in.

The lower tunnel is driven on the same vein, 300 feet vertically below the upper tunnel, and is extended 100 feet further into the mountain. Patches of cinnabar in small seams and isolated crystals were noted in a number of places in the tunnel, and a 1-inch veinlet of pyrite and cinnabar was found directly under the ore showing in the tunnel above. Beginning on the 1-inch veinlet of cinnabar and quartz directly under the ore opened on the surface a 300-foot raise has been extended to the upper tunnel. At a point about 15 feet below the upper tunnel the oreshoot was encountered, which apparently had an outward rake. No ore was opened in the raise below the upper shoot and the 1-inch seam on which the raise started soon pinched out.

Insufficient work has been done in the district to show whether the ore occurs in “chimneys” with appreciable vertical dimensions, or is in the form of lenses. If the ore shown in the upper levels should extend downward to the lower tunnel, a small tonnage of better than 3 per cent ore, say 10 tons per day, could be expected from the property at this place. However, in order to have continuous production other ore bodies would have to be found.

The showing of cinnabar on the Cornucopia claim is sufficient to warrant thorough prospecting of the vein to either prove or disprove the existence of commercial ore bodies.

L & N GROUP

The L & N Group is on the east fork of the Sycamore Creek and adjoins the Robbins Group. It belongs to the Arizona Quicksilver Corporation, which obtained it by purchase from the locators. The surface equipment has been moved over the hill to the Robbins Group, work for the time being discontinued.

Chris Martin located the group which consists of 17 claims, and made the discovery of quicksilver on the ground. Attention is called to Fig. 13.

Practically all the ore found on this group occurs on the L & N No. 1 claim. The inclosing rock is a belt of buff-colored quartzite, about 40 feet wide, on each side of which is a quartz-sericite schist. The quartzite is rather crumbly at the surface due to weathering. Veins of white quartz carrying limonite and cinnabar traverse this rock, and
small stringers of pure cinnabar extend from the main quartz vein into the wall rock in all directions. These small, ramifying veinlets contain very little gangue. Underground development failed to find an extension of this ore in depth, although a few small stringers were cut. Calomel and native mercury have been found on this claim.

**Equipment.**—A log cabin still stands on this ground. A one-pipe retort was built by Martin at the camp and a few flasks of quicksilver produced. The retort is crudely built and evidently is not very efficient. It is reported that Martin and his dog were salivated while he was treating the ore. Plate XI-B shows the retort.

**Development Work.**—A 1,100-foot tunnel with 500 feet of crosscuts has been driven on the L & N No. 1 by the present owners. Several open-cuts and two tunnels, one 40 and the other 26 feet long, were run by Martin on the same claim. The work on the other claims of this group consists only of the regulation discovery holes.

The best surface mineral showing on the group is near the middle of L & N No. 1, where the two tunnels were run by Martin. The tunnels were driven in a lode in gray quartz schist. A 2½-inch veinlet of quartz 6 feet high and 40 feet long was mined in the upper tunnel by Martin, and the ore retorted. A recovery of nine flasks of quicksilver is reported to have been made.

The second tunnel was driven on the same vein 18 feet below the first, but only a few isolated crystals of cinnabar were found.

Further east on the same lode some stringers of quartz contained cinnabar, metacinnabarite, calomel, and native quicksilver.

The tunnel run by the Arizona Quicksilver Corporation started at the level of the creek and extended along the lode to the west end line of the L & N No. 1, and thoroughly prospected the vein on this level. The end of the tunnel was about 750 feet below the surface. While some small patches of cinnabar were found in the tunnel, nothing was opened up to encourage any further development on the ground.

**BOWMAN GROUP**

This group, consisting of six claims, is owned by E. H. Bowman, and adjoins the Robbins Group of the Arizona Quicksilver Corporation on the northeast. It is also known as the Tatum Group, as a company of that name had an option on the ground and did some work. Fig. 13 shows the general location of the group.

The discovery cut of the Sugar Loaf No. 1 is in a lode in sericitic schist, which contains a few veinlets of quartz with a little cinnabar. The lode is about 150 feet from a large jasper stratum and there are
also streaks of jasper in the face of the cut. Some cinnabar was also found on the Lost Packer No. 1 in a lode in the schist. The two Tatum tunnels were driven simultaneously to cut this lode, which outcropped at the surface, but apparently the funds were exhausted before the contemplated objective was reached.

No ore has been discovered on this group and present conditions are not particularly encouraging for further work.

MARTIN GROUP

Chris Martin and three partners own four claims adjoining the Sunflower Group on the west. Thirty- and 35-foot tunnels have been run, and a number of surface cuts have been made on the ground. Some cinnabar has been found, but in no place in sufficient quantity to be commercial.

MARICOPA GROUP

This group consists of 14 claims and adjoins the Bowman Group on the northeast. A tunnel was started to cut the lode, but the ground was abandoned before the work was finished. The ground is now open to location.

The McDevitt and Quicksilver King groups are in the same belt northeast of the Maricopa Group, but no work has been done on most of the claims except the location cuts, and the ground is open to location.

PINE MOUNTAIN GROUP

This group consists of 10 claims in the Sunflower district in Maricopa county. It is situated about three-quarters of a mile southwesterly from Pine Mountain near the head of Sycamore Creek. The group is covered by brush. A stand of small cypress grows along the creek bottoms. A spring from which flows enough water for domestic purposes is situated on the No. 1 claim at the camp.

Cinnabar has been found in a belt of brown sericite schist. A red slate occurs on both sides of the schist. The lode has been traced over a distance of 7,500 feet along the strike, but has not been proved to be continuous. The general strike is N. 77° E. through three of the claims, as shown in Fig. 17. The schist is about 40 feet wide and is nearly vertical. The formation is cut by two rhyolite dykes, one on Pine Mountain No. 2 and the other through Nos. 1, 6, and 10 claims. The schist is considerably harder than the inclosing slate, and outcrops above the surface.

Cinnabar occurs in the schist in minute crystals that are seldom large enough to be seen by the naked eye. Considerable portions of the lode
are colored pink by the cinnabar. The schist contains a little quartz as narrow seams or flat kidneys at a number of places. The quartz is associated with iron oxide. It appears to be more plentiful in the discovery cut on No. 1 than in any of the other cuts on the group. Pink stains produced by cinnabar are shown in each of a series of cuts on Nos. 1 and 2 and in the outcrops between for a distance of about 1,000 feet. On No. 1 claim No. 2 cut, which is 4 feet wide by 16 feet long with a 10-foot face, has been run near the west end line and cuts across the stratum at an angle of about 45°. Four samples taken along the side and face of this cut for Mr. Reynolds assayed as follows: The first from the edge of the cut to 5 feet in, .04 per cent; the second from 5
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to 10 feet in, .08 per cent; the third from 10 feet in to the face, .16 per cent; the fourth across the face at the bottom, 0.26 per cent quicksilver. A sample taken by one of the authors across 5 feet of the face assayed .095 per cent quicksilver. The sampling previously done for Mr. Reynolds showed that the values in cinnabar increased from the surface to a depth of 10 feet at this particular place.

On No. 2 claim, cut No. 5, which is 4 by 21 feet long with a 7-foot face, cuts the strike of the lode at an angle of about 55°. A sample taken by one of the writers along one side of the cut for a distance of 11 feet assayed .24 per cent quicksilver. At $75 per flask this would indicate a value of $4.80 per ton. A sample taken previously for Mr. Reynolds along the side of the cut for the full distance of 21 feet assayed .41 per cent quicksilver. The lode at this cut appeared to have more pink stain than elsewhere on the claim. The cuts on No. 3 and No. 5 claims also developed pink-stained schist.

The quicksilver on this group appears to be disseminated through the rock rather than occurring in seams or as blades as on most of the properties elsewhere in the district. This characteristic of the quicksilver should be a favorable indication for the occurrence of low-grade bodies that could be mined on a large scale.

As the inclosing wall rock is soft, a portion of the schist adjoining the slate would probably have to be left in place in order to keep stopes open.

NORTHERN LIGHT GROUP

The Northern Light Group consists of 10 claims, end to end, and four side claims. The group extends from one-half mile below Pine Mountain at the head of Cane Creek, to the northeast across Gold Creek and its tributary, Box Spring Creek. Most of the group is in the Gold Creek drainage and all of it is in Gila County. Fig. 18 shows the general location and the relative positions of the claims. The group is reached by a trail, from Hardts' Ranch, which crosses over a local divide and then follows up Gold Creek and Box Spring Creek. The claims are covered with a growth of brush. There is some pine and oak timber on a part of the group. Gold Creek flows only a part of the year. A number of springs occur on the group which supply enough water for domestic purposes. This group is referred to by Ransome as the Bowman and Reynolds Gila County Group.

The claims were located by Mr. Reynolds and E. H. Bowman in April, 1914, and now belong to Reynolds and Raymond Lucy. Reynolds and Bowman located a number of groups together, but later on
dissolved partnership and divided their holdings, Reynolds taking the ground in Gila County, and Bowman that in Maricopa County.

The group is placed by Ransome in the Gila belt and the geology is described by him as follows:

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“On the Reynolds Gila County group the most southwest-erly opening at the time of visit was a small cut on the Bernice No 1 claim. The country rock here is a gray-brown granular schist which retains distinct indications of an original clastic structure and is apparently a metamorphosed sandstone or grit. The cinnabar occurs with quartz in small stringers, the widest measuring 1 inch, and in rather sparsely dispersed small specks through the adjacent rock. A sample taken by Mr. Hutchinson across 2 feet of what appeared to be the most promising part of the lode gave him 1.4 per cent of quicksilver, equivalent to $28 ore. A dark dike of altered basaltic rock runs parallel with the lode a few feet to the northwest, following the structure of the schist.

“About 800 feet northeast of the above cut, on the same lode and near the crest of the ridge between Cane and Gold creeks, a small shaft, 8 or 10 feet deep, has been sunk on the Sulphide No. 1 claim. The shaft disclosed some cinnabar, but none of the material can rank as ore.

“On the Northern Light No. 1 claim a prospect cut exposes a veinlet of quartz, limonite, and cinnabar, in places as much as 6 inches wide. Mr. Hutchinson’s sample of this stringer gave 1.1 per cent of quicksilver. Another sample from the same stringer, where from 1 to 3 inches wide, gave 2 per cent quicksilver, and a sample across 4 feet of schist adjacent to the stringer gave a trace.

“On Mercury Sulphide No 5 the lode shows the same general character as on the claims to the southwest. A sample taken by Mr. Hutchinson across a width of 11 inches of crop-pings just above the location cut gave 3.3 per cent quicksilver, corresponding to $66 ore.”

The annual assessment work required by law has been done each year on the ground since Mr. Ransome’s visit.

On the Bernice No. 1 the cinnabar sampled by Mr. Hutchinson is still exposed in the face and does not extend more than a few inches past the face sampled. A tunnel starting at the side of the mineral exposure has been extended from the face of the cut 10 feet along the lode. A seam of quartz cutting across the planes of schistosity at the face of this tunnel contains a patch of quartz and cinnabar about 1 inch thick and the size of a dinner plate.

A 60-foot crosscut tunnel and 20-foot drift have been driven into the hill and extend under the the discovery cut. Cinnabar in small iso-
lated patches and crystals was noted in the drift. A sample taken across 4 feet of the face by W. E. Defty, a mining engineer of Phoenix, Arizona, contained 2.95 per cent quicksilver. A sample taken by Mr. Reynolds across 5 feet of the vein at the surface of the tunnel assayed 1.45 per cent quicksilver.

A sample taken by Mr. Defty across 10 feet of the vein in a cut on Northern Light No. 2 contained 2.85 per cent quicksilver. This sample was probably from a selected portion of the cut and cannot be considered as showing the average value of the vein at this point.

Two samples were taken across the face of a 10-foot tunnel on the Mercury Sulphide No. 4, one across the top by one of the authors, and one across the bottom by Mr. Reynolds. The top sample showed .08 per cent and the bottom .045 per cent quicksilver. A number of open cuts have been run along the lode on this claim and some cinnabar is disclosed in all of them. The schist dips 70° to the east at this place. The cinnabar is associated with flat bunches of quartz containing limonite and siderite. Some quicksilver also occurs as fine seams in the cleavage planes in the schist.

A 30-foot crosscut tunnel has been run in the lead on Mercury Sulphide No. 5. Small flat kidneys of quartz containing iron oxide and iron carbonate with a little cinnabar are disclosed in the tunnel. A sample taken by Mr. Defty across the face of the tunnel showed .90 per cent quicksilver.

A sample taken by Mr. Defty across 4 feet in a face of an open-cut on Mercury Sulphide No. 6 contained 1.55 per cent quicksilver.

The cinnabar on the group occurs in a brown schist which averages about 60 feet wide. This lode can be traced clear through the group of claims a distance of 15,000 feet. Cinnabar has been found in the lead at numerous places. To date not enough work has been done on the group to prove the existence of ore bodies in sufficient size to justify the erection of a treatment plant. The cinnabar appears to be very "spotty" and considerable development work would be necessary actually to block out ore bodies. The persistence of quicksilver at the surface for such a great distance, both at the tops of the ridges and at the bottoms of the canyons, should encourage further work.

The schist carrying quicksilver is considerably softer than the adjoining rock which appears to be firm enough to stand well. The schistosity is nearly vertical. Due to the characteristics of the lead and of the wall rock, very low mining costs could be expected should ore bodies of an appreciable size be opened up. Due to the steepness of the
slopes, the lode could be developed and worked at depths by means of tunnels.

**MERCURIA GROUP**

The Mercuria Group consists of 10 claims and is situated at the head of Gardner Creek, a branch of Slate Creek. The group lies about a mile and a half southeasterly from Pine Mountain and about one-half mile from the divide between Maricopa and Gila counties on the Gila County side. Fig. 19 shows the ground covered by the group. A trail has been cut from the Gold Creek trail to within one-half mile of the group. A small spring that runs the year around is located on Mercuria No. 10. The group is covered with a thick growth of brush. The surface is steep. The claims run along the mountainside. The group was inspected on July 8, 1926, at which time Mr. Reynolds was actively engaged in developing the ground.

The upper line of claims is situated along a belt of white sericite schist, which strikes about N. 57° W., averages about 80 feet wide, and dips about 70° to the southeast. This belt has been traced for about 4,000 feet along the strike on the surface.
The lode occurs in brown schist. That on the northwest contains some feldspar and quartz phenocrysts, which would indicate that this rock was originally igneous. Rhyolite outcrops on the hillside on the northwest a short distance above the lode.

Mr. Reynolds found float, consisting of quartz fragments containing cinnabar crystals, along the hillside, which caused him to prospect the ground. The white schist is softer than the adjoining rocks and does not outcrop. The discovery cut, 4 feet wide and 12 feet long on Mercuria No. 1 was run across the strike in the white schist. A pit, the bottom of which reached about 12 feet below the surface, had been sunk at the face of the cut. When fresh the white schist has a pale yellow color which fades on exposure, which presumably indicates the presence of calomel. The yellow stain is associated with a pink stain. No crystals of cinnabar were visible to the naked eye, but on grinding and panning a string of minute crystals was noted. A sample was taken across 6½ feet of the lode in the cut, and on being assayed showed 0.175 per cent quicksilver. At $75 per flask this would indicate a value of $2.50 per ton. At $90 per flask the value would be $3.32 per ton.

The pink and yellow stain appeared to occur in all of the white sericite schist that had been opened up. A few quartz stringers up to 4 inches in thickness and 1 feet long occur in this schist in places. No quartz similar to the float with the cinnabar crystals has been found in place.

A tunnel 20 feet long had been started in a soft dike of basic igneous rock at the discovery cut on the Mercuria No. 10. It was intended to extend the tunnel through the dike to cut the white schist. No cinnabar in place has been found at this point.

The Mercuria Group appears to be between the Sunflower and Slate Creek belts and is probably on a separate zone of cinnabar-bearing rock. As far as could be seen by the limited development work there appeared to be a greater dissemination of cinnabar in the lode than is found at the older properties in the district. Not enough work has been done to prove the ground, but the discovery of what appears to be a wide zone containing disseminated mercury minerals offers encouragement for further development with the hope of finding a commercial deposit of low-grade quicksilver ore. As the wall rock is hard and firm and the vein matter soft, a system of mining could be adopted that would allow low mining costs should ore bodies of any appreciable size be developed.
The Red Bird group consists of 19 claims, and is situated on Slate Creek about 4 miles above Tonto Creek. The south side of the group extends over Malone Mountain. The Red Bird claims Nos. 1 to 9, 

RED BIRD GROUP
MINING CLAIMS
Arizona Cinnabar Co.
Gila Co., Arizona

Sketch shows relative position of claims, bearings approximate.

Fig. 20.—Claim map of the Red Bird Group, Slate Creek.
inclusive, were located February 25, 1922. The Bird Nos. 10, 11, and 12 and Native Metal Nos. 1 to 7 were located in March, 1925.

The relative positions of the claims, and their general location, are shown in Fig. 20.

The group is reached by an automobile wagon road, 3½ miles long, from the Globe-Payson Highway on Tonto Creek. Water runs in Slate Creek during most of the year, and can be obtained from pools during the dry season. Water could probably be developed in wells in sufficient quantity for a small treatment plant.

The upper claims are covered by a stand of small cypress and a few scattered oak, and sycamore trees grow on the lower ground. A thick growth of brush covers most of the ground. The surface is steep, which would permit mining by means of tunnels. The group is held by the Arizona Cinnabar Company whose post office address is Box 1927, Globe, Arizona.

The best showing of ore on this group is on the Red Bird No. 2 claim. The lode strikes nearly east and west and, apparently, dips nearly vertically. The rocks comprise a variety of quartz-sericite schists, and vary from rather pure quartzite to phyllite. In some of the phyllites chlorite and calcite are common. The ore occurs as veinlets of quartz and a ferruginus carbonate with cinnabar, and thin seams of fracture planes in the schist contain little or no gangue. The entire hillside is traversed by veinlets of white quartz with no cinnabar visible on weathered surfaces. On breaking a specimen of this white quartz, however, small specks and flakes of cinnabar were found to be common in many of the veins. Much of the rock is too low-grade to be considered ore. A parallel lode, at least 350 feet to the north, occurs on the Red Bird No. 7 claim. Here the wall rock and gangue minerals associated with cinnabar are the same as on the No. 2 claim. A sketch of these veinlets traversing schist is shown in Fig. 21. The parallel alignment of some of these veinlets, which cross the schistosity, suggests that the mineral was deposited in pre-existing fractures in the schist. Chlorite is very abundant in some of the ore, and some malachite and azurite were found.

Some green schist near Slate Creek on Red Bird No. 10 contains stringers of quartz, calcite and iron carbonate, with a little cinnabar. A sample across 2 feet of the schist contained 0.14 per cent quicksilver. An open-cut 8 feet wide with a 10-foot face showed the mass of green schist to be float and not in place. A similar showing of green schist with cinnabar occurs farther up the mountain side. A 200-foot
tunnel was driven into the hill apparently to the green schist stratum, but the showing of quicksilver at this depth was discouraging.

Cinnabar has been found in gray schist at the surface on the Red Bird No. 1 and Red Bird No. 8 claims. At the time of the writers' last visit two men were working on a showing of quicksilver along Slate Creek near the camp. No work had been done on the upper showing on Red Bird No. 8, and the value of the discoveries on either claim had not been demonstrated. A little cinnabar is also reported as having been found on Red Bird No. 9.

![Image of diagram showing cinnabar veinlets in schist]

Fig. 21.—Diagrammatic sketch showing cinnabar veinlets in schist.

The development work on the group consists of the 200-foot tunnel, and open-cuts which have been excavated for the location work and the 1923 and 1924 assessment requirements.

The discovery cut on Red Bird No. 2 is 5 by 13 feet, with a 10-foot face. The formation locally at this point presumably has flattened out, and dips about 20° to the south. At the top of the face of the cut a 1-foot stringer of quartz containing cinnabar and iron oxides is exposed. A sample of this quartz when assayed showed 0.23 per cent quicksilver.

If the quicksilver outcropping on the hill were in one place, there would appear to be enough to make a large mine. The veinlets as they occur are too widely separated to be of any economic importance and in addition the quartz, if the sample taken was representative, does not contain sufficient quicksilver to be profitably mined.

The discovery of cinnabar in the gray schist on the lower claims offers better possibilities, for the development of a producing mine, but up to the time of the writer's last visit not enough work had been done on these showings to determine their value.
ORD GROUP

The Ord Group consists of 20 claims on Slate Creek adjoining the Red Bird Group on the west. The ground is reached by a new wagon road about 7½ miles long, built by the Arizona Quicksilver Corporation from the Globe-Payson highway at Cooper's ranch. Slate Creek runs through the group lengthwise. Fig. 22 shows the ground covered by the group.

The upper claims contain a stand of small cypress, and the slope of Mount Ord above the group is timbered. The surface of the ground is steep and is mostly covered by brush. The claims were located by Wesley Goswick of Roosevelt, Arizona, in March and April, 1925. The ground was held under option by the Arizona Quicksilver Corporation in October, 1925, and was being actively developed in July, 1926.

On July 6, 30 men were employed on the group. The corporation has done a considerable amount of work on the ground. In addition to the 7½ mile road built from the Globe-Payson highway, a road had been built to a millsite on the top of a high ridge above the camp. The top of this ridge had been leveled off and foundations set for a 60-ton a day rotary furnace. (See Plate XII B). An oil tank and water tank were in place. Two 150-h.p. gasoline engines, a 27-kw. generator, and an air compressor were on the ground but were not set up at the time of the writers' last visit. Air for driving the tunnels was furnished by a 3-drill compressor set up at the bottom of the canyon. A 35-foot well, sunk in the creek bed, furnished water for the camp. Due to the lateness of the summer rains, the water in the well was failing. It was pumped by means of a 150-gallon per minute Gould pump, run with a 25-h.p. gasoline engine. The engine also operated an 11-kw. D.C. generator for lighting the camp.

A storehouse, office building, boarding house, guest house and eight dwellings had been erected up to July 6, 1926. The group of buildings was called Stalker Village, a part of which is shown in Plate XII A. The operations at the Ord Group were known as the Stalker division of the Arizona Quicksilver Corporation.

The prevailing types of schist on this group of claims are brown slate and cream-colored phyllite, with here and there ribs of hard quartzite. The schists strike nearly east and west, and dip at steep angles usually to the northwest. At least two, and possibly three, parallel lodes exist on this group of claims. These lodes have been shown to be continuous by numerous prospect pits and trenches. Two quite different
Fig. 22.—Claim map of the Ord Group, Slate Creek.
types of ore occur here, quartz veins carrying cinnabar, and finely disseminated cinnabar in puckered phyllite. In the quartz veins the quartz is intergrown with ferruginous carbonate producing the columnar structure described on the preceding pages of this report. The disseminated ore in phyllite consists of minute specks of cinnabar, visible only with a microscope yet abundant enough to impart a pinkish color to the rock. Occasionally tiny veinlets of pure cinnabar traverse the rock, but are seldom over an eighth of an inch in width. Mr. Wesley Goswick stated that he had found some native copper in the cinnabar veins, but this mineral was not seen by the writers, although the carbonates of copper, azurite and malachite, are present on the adjoining group of claims to the east.

Cinnabar occurs at the surface in a number of places south and west of the camp. Fig 22 shows approximately the location of the principal lodes and points where cinnabar was noted. At point marked S-1 a sample was taken across a 9-foot lode of pink sericite schist, which contained 1.04 per cent quicksilver, worth more than $20 per ton. The cinnabar occurs as fine veinlets, disseminated in a lode in the schist. The disseminated mineral gives the rock a distinct pink tint.

The lode from which sample ore was taken is opened up along the strike by a series of open-cuts for a distance of about 400 feet. The average width of the lode carrying cinnabar appears to be about 4 feet. Quicksilver is disclosed in each cut in apparently the same percentage as where the sample was taken. A profit could be made in mining a quicksilver ore shoot 400 feet long and 4 feet wide, which contained $20 ore. Although the surface showing indicates the possibility of such an ore shoot occurring at this place, only one face is exposed, and considerable work would be required to furnish definite proof of its existence.

During the first half of 1926 an adit was run from a gulch to the east and extended to a point 150 feet vertically under the west end of the outcrop of cinnabar-bearing rock. This adit failed to disclose ore of commercial grade. Also, there appeared to be a change of formation at this depth. On July 6, 1926, a crosscut was being extended northerly to cut the contact of the schist with a quartzite bed, and a raise was being put up in soft schist and gouge which contained a small amount of cinnabar. This raise, if extended to the surface, would come out at the extreme end of the outcrop containing cinnabar at the proposed millsite. The adit, which had a total length of 730 feet on July 6, 1926, is designated as Tunnel B on Fig. 22.

A crosscut was also extended to the lead under the west end of the
outcrop. Some cinnabar was found where the vein was cut, but it was not present in commercial quantities. A short winze was sunk in soft schist and gouge similar to that found in the raise in Tunnel B. The crosscut is shown on Fig. 22 as Tunnel A. It is about 150 feet long and 50 feet higher in elevation than Tunnel B. No drifting was done from the crosscut.

A short distance up the hill to the eastward from the portal of Tunnel B a small cut has been run in a lode, at a point marked “S-3” on Fig. 22. A sample was taken across 1 foot of high-grade in the face of the cut, and it assayed 17.12 per cent quicksilver. A sample across 4 feet of the lode in this cut, taken by Mr. Bedford of the Arizona Quicksilver Corporation, assayed 5 per cent quicksilver. An assay of 5 per cent quicksilver would indicate a value of $100 per ton. A percentage of 17.12 quicksilver would have a value of $342 per ton. Ore from this latter place could probably be treated in a retort.

Tunnel C has been extended under this outcrop, and on July 6, 1926, was 130 feet long. The last 40 feet of the tunnel was in ore. The face of the tunnel was 60 feet below the surface. A sample taken across 4½ feet of the face on July 6, 1926, assayed .93 per cent quicksilver. The ore was apparently higher grade in the top of the drift back of the face.

Presumably it was planned to hoist the ore developed in Tunnels A and B through a shaft to the proposed treatment plant on the millsite. Tunnel C is on the same level as Tunnel B, and ore developed in this latter place could be hauled in through Tunnel B and hoisted at the same place.

The mineral at this place occurs mainly in a disseminated form all through the gray schist. Cleavage planes are not as well defined or as numerous as at the places where sample 1 was taken. Notwithstanding its high percentage of cinnabar, the ore has a distinctly earthy appearance and on weathering looks like the country rock.

The strike of the lodes on this part of the group vary locally, but average about N. 80° E. The dip is 60° to 75° to the north.

At the point market “S-2” on Fig. 22 a lode carrying cinnabar occurs in a soft, curly, gray sericite schist. The schistosity is well developed, and the rock contains numerous well-defined cleavage planes.

A sample across 20 feet taken by M. van Siclen, in April, 1925, ran 0.37 per cent quicksilver. A sample taken in the same cut by the writers in October, 1925, across 16 feet of the lode assayed 0.38 per cent quicksilver. The cinnabar occurs mainly as tiny seams and blades parallel to the planes of schistosity of the rock.
Sufficient work has not been done to show the length of the ore shoot. If the ore has any appreciable length and depth, a width of 20 feet would allow low mining costs, and apparently a profit could be obtained on mining and treating of ore of the grade indicated by the assays from this place. Ore containing 0.37 per cent quicksilver would have a value of $7,20 per ton with quicksilver at $75 per flask.

A belt of quartz schist outcrops in the west end of the group. At one place this belt contains quartz stringers with a little cinnabar. A tunnel was being run in October, 1925, to cut the ledge at a depth of about 40 feet.

The surface showings on the part of the group above the camp are excellent, and there appears to be a good chance of opening up a large tonnage of ore. The continuity of the quicksilver values along the strike of the lodes would indicate a probability of appreciable depths of the oreshoots on the dip of the vein. Although Tunnels A and B did not disclose any ore where the vein was cut under the west end of the main outcrop, development work would be required on the ore body by following the ore actually to prove or disprove the existence of a mineable ore body at this place.

Fig. 23.—Claim map of the Rattlesnake Group.

RATTLESNAKE GROUP

The Rattlesnake Group consists of eight claims that adjoin the Ord Group on the west, as shown by Fig. 23. The claims lie along the head of Slate Creek, and reach within about one-half mile of the divide between Slate and Sycamore creeks.
The group is reached by trail from the end of the wagon road on the Ord Group about 3½ miles distant.

The ground is owned by A. M. Packard, Robt. S. Packard, and Gus Packard, who located the claims in April, 1925.

The claims contain a negligible amount of timber, but are covered with thick brush. Slate Creek dries up during the dry seasons, but water probably could be developed in wells. The surface is steep, which permits mining development by means of tunnels.

A quartz schist stratum that strikes N. 65° E. and dips 60° to the north extends through Rattlesnake No. 1, No. 2 and No. 3 claims. This stratum is harder than the surrounding shales and outcrops several feet above the surface.

At one place on the Rattlesnake No. 2 the stratum stands up about 10 feet high for a distance of 30 feet. Three feet of the stratum, which is more silicious than the rest, contains narrow veinlets of cinnaabar. A cut 4x12 with a 10-foot face has been excavated in the outcrop, to the cinnaabar-bearing portion of the stratum. A sample taken across 2½ feet contained 1.42 per cent quicksilver. This would indicate a value of $24 per ton, with quicksilver at $75 per flask.

Several small cuts have shown that the stratum contains cinnabar for a distance of about 200 feet to the east, but there is nothing to indicate that the quicksilver-bearing portion is continuous. A few veinlets of cinnabar were found at the west end of the claim, but too isolated to be of any value.

A cut 25x6 feet with a 14-foot face exposes the stratum at the east end of Rattlesnake No. 3. A 1½ foot lode at the face and another parallel one 2½ feet wide, 11 feet back, both contained veinlets and disseminated cinnabar. The rock at this place has a slaty structure and broke in thin slabs. Some of the slabs of the rock in the cinnabar-bearing lode were barren and could be easily sorted out.

A pile containing about 20 tons had been made on the dump from the material taken from the two lodes. The flat slabs were built up vertically on the outside and the fine material thrown inside. A sample chipped from the outside of the slabs contained 0.44 per cent quicksilver, or $8.80 per ton. As cinnabar is very friable and readily breaks into fines, it is likely that the sample is too low to be representative of the pile.

The samples indicate that the cinnabar-bearing rock, if it occurs in sufficient quantity, is high enough in quicksilver to treat in a furnace. The lode is narrow and mining costs would be high. Not enough work has been done to indicate the existence of ore bodies, and no ore has
been developed. Further development work may demonstrate that ore bodies large and rich enough to work occur on the ground.

ECONOMIC POSSIBILITIES OF MAZATZAL DISTRICT

In discussing the economic possibilities of the district Ransome\(^1\) states:

"Not enough mining work has been done at the time of visit to determine whether the quicksilver deposits of the Sunflower district are susceptible of profitable exploitation. The geologic facts of occurrence and the sampling by Mr. Hutchinson indicate that the parts of the lodes of minable dimensions now exposed to view carry no more than 3 to 4 per cent of quicksilver at the most, although exceptional stringers here or there which might be sorted out from the broken ore are of much higher grade. To obtain a 3 or 4 per cent product—that is, $60 to $80 ore at present prices—considerable sorting would have to be done, with rejection of three-fourths or more of the rock broken. The chances for obtaining considerable quantities of 2 per cent or $40 ore with only moderate sorting appear to be good.

"Although costs are probably lower in California than in Arizona the situation of the New Idria mine is comparable with that of the Arizona deposits in that the mine has a 60-mile wagon haul to the nearest railway. Mr. Hutchinson’s sampling, while thoroughly reliable, was only preliminary to possible work and was rendered difficult by the lack of development. Before the deposits can be appraised at their probable value additional sampling will be necessary. This sampling should be directed particularly to the estimation of the probable available quantity of ore of the minimum grade that can be profitably worked without sorting. To what width, for example, can a lode be mined as a whole to get a 1 to 2 per cent ore and how much of such ore can reasonably be considered available?

"Facts that promise well for future exploitation are the undoubted persistence of the lodes for long distances over the surface and the lack of any evidence of decrease of tenor with increase in depth. Too little has been done to prove that the lodes continue downward without diminution in quicksilver

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content, and it is generally recognized that quicksilver ores, as a rule, are not deposited at as great depth as some other ores. Lindgren (Lindgren, Waldemar, Mineral Deposits, p. 472, 1913) states that no quicksilver deposit has been worked to a depth of 2,000 feet below its outcrop. On the other hand, the work already done on these deposits gives no foundation for a belief that the cinnabar is less abundant at moderate depth than near the surface.”

Since Mr. Ransome’s visit the ore has been opened up on the Robbins Group. The best exposures of ore that were exposed on the Sunflower Group at that time have either been mined out or further development work has proved the ore bodies to be of small size with no appreciable vertical dimensions. The mineral showings disclosed by recent work on the Sunflower Group by the Arizona Quicksilver Corporation appear more promising than previous discoveries, and there now appears to be a possibility of opening up ore bodies of larger size. The open-cuts and the tunnels being run on the Go-By claim in October, 1925, indicate the probability of finding a fair-sized ore body of medium grade. However, the work done to date has not actually blocked out any ore.

The discoveries of cinnabar made during 1925 in the Slate Creek part of the Mazatzal district look more encouraging than surface disclosures of ore elsewhere in the district. Cinnabar has been found over a distance of 4 miles along Slate Creek and it is quite likely that other discoveries will be made. Remarkable results have been obtained, considering the short time the ground has been prospected.

The discoveries of disseminated quicksilver ore on the Pine Mountain and Mercuria groups also add to the possibilities of the district. The pink color which indicates the values on the Pine Mountains and Mercuria groups had previously been mistaken for iron stain. It is possible that similar quicksilver outcrops elsewhere in the district have been overlooked and further developments are to be expected.

OTHER OCCURRENCES OF QUICKSILVER IN ARIZONA
ROADSIDE MINE

A specimen of quartz containing many small specks of cinnabar was shown the writers at the Roadside mine by Mr. Courtenay DeKalb. This is essentially a copper prospect, and is situated 35 miles west of
Tucson. The ore consists of pyrite, chalcopyrite, bornite, and chalcocite; the last probably supergene in origin. Andesitic flows, tuffs, and agglomerates are the prevailing rocks, and have been extensively faulted and tilted. According to Mr. DeKalb\textsuperscript{1} the cinnabar was probably derived from mercurial tetrahedrite, small quantities of which may be present in the ore. This occurrence is not of economic importance.

**CERRO COLORADO MOUNTAINS**

The Heitzelman or Cerro Colorado Mine, now closed down for many years, is situated on the south slope of a mountain known as the Cerro Colorado, and is 45 miles southwest of Tucson. In a report on this mine by Mr. F. Biertu and quoted by Mowry\textsuperscript{2} traces of quicksilver were reported to have been found in the ore. This ore consisted of stromeyerite, tetrahedrite, blende, galena, and native silver, and was mined for its silver and lead content. The quicksilver probably occurs in the tetrahedrite. Here the ore occurs in andesitic flows and tuffs, although some rhyolite and basalt are also present.

A few miles west of the old Heintzelman Mine is an occurrence of cinnabar on a group of claims located by Mr. James Guy of Tucson. The country rock consists of a series of rhyolitic flows traversed by dikes of rhyolite-porphyry and fine-grained monzonite. These flows appear to be earlier than the andesites and basalts of the Cerro Colorado and apparently pass beneath this mountain.

The cinnabar occurs in quartz stringers which occupy a fault fracture on the Lone Scot claim. This fracture strikes N. 45° E., the dip is vertical, and the vein is 6 feet wide. The quartz veins carry oxidized lead and copper minerals, and the small amount of chalcocite present is undoubtedly supergene in origin. Here and there, occasional, small, clear grains of cinnabar occur embedded in the quartz, but the mineral more often is found as bright red, pulverent masses that only partly fill the cavity they occupy. Cavities lined with quartz crystals are abundant in the vein, but here the cinnabar is rarely found; and the absence of quartz crystals in the cavities occupied by the quicksilver mineral suggests that the cinnabar may have been formed by the breaking down of some pre-existing sulphide-tetrahedrite for example.

Most of the quicksilver occurs in narrow streaks of quartz in the vein. A picked sample taken from about 500 pounds of material from a 3-inch streak from this vein piled on the dump of an old 35-foot shaft

\textsuperscript{1}Personal communication.
\textsuperscript{2}Mowry, Sylvester, Arizona and Sonora: The Geography, History, and Resources of the Silver Regions of North America, p. 83, 1864.
ran 0.82 per cent quicksilver. A sample from the vein matter outside of the streak showed 0.17 per cent quicksilver. The occurrence of quicksilver in the vicinity of Cerro Colorado is unimportant economically as the metal is present in the ores in only small amounts.

DEADMAN WASH

Cinnabar has been reported from Deadman Wash 12 miles above its junction with the Verde River. This locality is approximately 9 miles north of the Sunflower Camp on Alder Creek. A specimen of the ore was brought to Mr. Bedford, manager of the Arizona Quicksilver Corporation, who identified the ore as cinnabar-bearing schist. The deposit is reported to occur in a belt of northeastward trending schist. Elza Brown, a rancher whose address is Cactus, Arizona, and Ed. F. Foster, a miner, have located 8 claims called the Almaden Group which cover the reported discovery. According to Mr. Brown, the claims cover a belt of schist that strikes northeast and southwest.

ORIGIN OF THE QUICKSILVER DEPOSITS

Quicksilver occurs widely distributed throughout the world, but many of the deposits are small, and the production of this metal from the small mines is rather limited. A few of the mines have been worked for several centuries, and are still producers of quicksilver.

So many occurrences of quicksilver are in regions of late Tertiary and Quaternary volcanic activity that a genetic relationship between the deposition of quicksilver and vulcanism is considered as well established. Hot springs are the dying phases of vulcanism; and at Steamboat Springs, Nevada, and at Sulphur Bank, California, this metal is now being deposited. Quicksilver deposits are more closely associated with basalts and andesites than with the more acid volcanic rocks.

Becker\(^1\) has shown that an alkaline solution containing sodium sulphide will dissolve mercury sulphide as well as metallic gold and pyrite; and at both Steamboat Springs, Nevada, and Sulphur Bank, California, the hot waters are alkaline. At the latter locality Becker found this hot water to be rich in chlorides, borax, and sodium carbonate. The temperature of this water is 80° C. Thus we see that cinnabar can be transported by and deposited from hot or warm, alkaline solutions.

At Steamboat Springs, Nevada, careful analysis of the water failed to reveal a trace of cinnabar, but the action of the thermal springs has

deposited a sinter consisting largely of lime carbonate in which cinnabar was found together with other metallic compounds in small quantities.

Posepny\textsuperscript{4} states that one of the fissures, through which these hot solutions at one time passed, was opened by an adit 50 feet below the surface, and the vein-matter encountered was found to carry cinnabar, and was mined for a while as quicksilver ore.

Lindgren places quicksilver in the class of deposits formed near the surface, but notes that quicksilver also occurs in veins formed at moderate depths and temperatures. Regarding the deposition of ores containing quicksilver at high temperatures he states:\textsuperscript{2}

“High temperature is evidently unfavorable for their (quicksilver minerals) development. The most noteworthy occurrence is that of coloradoite in the gold telluride veins of western Australia, which contain, among other minerals, magnetite and tourmaline, indicating deposition at fairly high temperatures. In the gold-bearing quartz veins of the ordinary type, believed to have been formed at a considerable depth, but at considerably lower temperature and pressure than pegmatitic dikes, cinnabar is not an uncommon mineral.”

It is difficult to ascribe a common origin to the quicksilver deposits in Arizona. This is largely because of the diversity of the associated metals and gangue minerals.

The cinnabar at Copper Basin occurs largely in beautifully banded, chaledonic quartz with only a small amount of barite and sericite present. These veins occur in andesitic and rhyolitic dikes, and appear to be genetically related to Tertiary vulcanism. The single occurrence of malachite in these veins may have been derived from some foreign source, especially as no primary copper sulphides were found with the pyrite occurring in the cinnabar-bearing veins.

The quicksilver in the Dome Rock Mountains is in a vein that carries considerable oxidized copper and good values in gold and silver; and this fact, together with the absence of volcanic rocks in the immediate vicinity of the vein, lead Bancroft\textsuperscript{3} to suggest that the cinnabar was derived from mercurial tetrahedrite.


\textsuperscript{2}Lindgren, W., Mineral Deposits: 2nd edition, p. 488, 1919.

Plate XIII-A. Specimen of cinnabar ore, with quartz-carbonate gangue.

Plate XIII-B. Specimen of cinnabar ore, showing intergrowth of quartz, carbonate, and tourmaline.
Plate XIV-A. Photomicrograph of a veinlet of tourmaline.

Plate XIV-B. Photomicrograph of a veinlet of quartz.
Tetrahedrite carrying small quantities of mercury is not uncommon; and one specimen of this mineral was found to contain as much as 17 per cent quicksilver.

The occurrence of metallic gold with cinnabar in a specimen from the Dome Rock Mountains is not unusual. In northeastern Oregon Lindgren\(^1\) found secondary cinnabar formed from mercurial tetrahedrite in gold-bearing quartz veins.

Allen and Crenshaw\(^2\) have shown that of the two modifications of mercury sulphide, cinnabar and metacinnabarite, the former is the more stable form, and may be formed from acid solutions by hydrogen sulphide under certain conditions. Cinnabar may therefore be secondary (supergene) as well as primary (hypogene); and a derivation from tetrahedrite for the cinnabar in the Dome Rock Mountains is not impossible. A similar origin for the cinnabar at the Roadside Mine and in the Cerro Colorado seems most probable.

The occurrence of tourmaline with cinnabar in the veins of the Mazatzal Mountains is both interesting and unusual; and, so far as the writer knows, has not been noted elsewhere. As mentioned on a preceding page of this report, coloradoite, the telluride of mercury is associated with tourmaline in gold veins of western Australia. Tourmaline is a mineral typical of the pegmatite dikes, but also occurs in the deep-vein zone. In the Helena mining district of western Montana are silver-lead ores genetically associated with tourmaline. Here Knopf\(^3\) found tourmaline and sulphides intergrown, and between the black tourmalinic band, intense seritization of the granite. The sulphides in this deposit are arsenopyrite, pyrite, sphalerite, and galena. This is undoubtedly a high-temperature deposit and belongs in the deep-vein zone.

The evidence of a high-temperature origin for the quicksilver deposits in the Mazatzal Mountains, while not entirely conclusive, is certainly rather suggestive. Intergrowths of tourmaline, quartz, and the ferruginous carbonate ore are shown on Plate XIII B. The three minerals are practically contemporaneous. A later generation of quartz and tourmaline cuts the carbonates, and this is followed by cinnabar that cuts all pre-existing minerals, and replaces both quartz and carbonate.

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On Plate XIV A is shown a portion of a small vein consisting largely of ferruginous carbonate, a small amount of quartz, and cinnabar. Microscopic examination of the wall rock immediately adjacent to the vein shows that the cinnabar is confined to the vein. It is certainly reasonable to assume that the quartz and carbonate are gangue minerals associated with the cinnabar, especially as these gangue minerals are present in all the veins of the district. But the tourmaline is later than the carbonate which it cuts, and is in turn cut by cinnabar. The time elapsing between the formation of the tourmaline and the deposition of the cinnabar is, therefore, probably small.

No intrusive rocks of other than pre-Cambrian age occur in the near vicinity of these quicksilver deposits. Volcanic flows and tuffs, however, are fairly common, and have a total thickness of 1,000 feet or more. These may, at one time, have covered all the quicksilver veins. It is not impossible that this region was invaded during Tertiary time by a dioritic magma that gave rise to the andesitic flows and from which the solutions were derived that deposited the quicksilver.

PROBABLE AGE OF THE DEPOSITS

Very little information is available regarding the geologic age of these deposits. The cinnabar veins in Copper Basin are in dikes that are undoubtedly of Tertiary age, and the small amount of mercury in the ores at the Roadside Mine and at the Cerro Colorado is in Tertiary volcanic rocks.

Although Tertiary volcanic rocks occur at the south end of the Dome Rock Mountains and in the surrounding region, it is impossible to show positively that the deposits are definitely related to these flows. The time of formation of the quicksilver ores is, therefore, uncertain. A similar condition exists in the Phoenix Mountains.

In the Mazatzal Mountains the age of the deposit depends on the source of the quicksilver solutions; if it were derived from the same source as the volcanic rocks, then the veins were formed during Tertiary time. Here again uncertainty prevails.

ECONOMIC POSSIBILITIES OF THE QUICKSILVER DEPOSITS OF ARIZONA

No ore up to the time of the last visits to the various quicksilver properties had been actually blocked out—that is, opened on three sides; hence no estimate of definite available tonnage can be made.
Quite a number of faces of cinnabar ore have been developed by workings or appear in vein outcrops in the State, but due to lack of essential data, and to the known erratic occurrence of quicksilver ores, it was not considered practical to make any estimates of probable or possible ore. Not enough work has been done on the Arizona quicksilver properties to indicate the characteristics or to prove the persistence of the ore bodies, and until this work is done the information, which is essential in making an estimate of probable and possible ore, is not at hand.

The only deposit in the Dome Mountain district is apparently exhausted and any further production from that field is doubtful.

Enough probable ore is apparently developed in the Phoenix Mountains district to run a 10-ton furnace a few months, and it is possible that by further development, directed in a consistent and intelligent manner, enough additional ore could be discovered to keep such a furnace running for an indefinite period.

Developments on the Sunflower Group up to October, 1925, indicated a possibility of developing enough medium-grade ore to run a 10- or 20-ton furnace for a considerable period. It is stated by Mr. Bedford that since that date considerable probable ore has been developed and a much larger daily tonnage could be expected. The production from the Sunflower could be helped out by a small amount of high-grade from the Robbins Group.

The recent discoveries of quicksilver on the Ord Group are very promising, and the surface showings would indicate that there is a good chance of opening up enough ore to supply a 100-ton, or larger, furnace for an indefinite period.

It is possible that small bodies will be developed on the Northern Light Group of sufficient size to supply a small plant. Recent discoveries on the Pine Mountain and Mercuria groups increase the extent of the district and also offer further possibilities of production.

The Red Bird and Rattlesnake groups may also possibly produce quicksilver.

In the Copper Basin district some strong veins occur which contain a little scattering quicksilver in the outcrops. There is a possibility, although it does not seem very promising, that a producing quicksilver mine may be developed in that district. The tenor of the quicksilver-bearing rock so far uncovered is too low to make the material commercial.
In addition to the areas known to contain quicksilver, there is a possibility that by further prospecting other districts will be found to contain commercial deposits. The schist belt mentioned in this report is quite extensive, extending as it does nearly across the State. Prospecting for quicksilver in this formation would seem to offer a reasonable chance for success, especially so if in regions where volcanic activity prevailed, and andesitic and basaltic flows predominate.
Plate XV-A. Photomicrograph of cinnabar, replacing quartz and carbonate.

Plate XV-B. Photomicrograph of disseminated cinnabar in phyllite.
MAPS OF ARIZONA

The Arizona Bureau of Mines now has available for distribution four different maps of the State, as follows:

1. Base map of Arizona in two sheets on a scale of about eight miles to the inch. This map is strictly geographic, with the positions of all towns, railroads, rivers, surveyed lands, national forests, national parks and monuments, etc., indicated in black, and the location of mountains and other topographic features shown in brown. It also indicates where the various mining districts are situated, and is accompanied by a complete index. It was issued in 1919 and is sold, unmounted, for 35c, or mounted on cloth with rollers at top and bottom for $2.50.

2. A topographic map of Arizona in one sheet, on the same scale as the base map. It shows 100-meter contours, and there is a meter-foot conversion table on the map. It was issued in 1923, and is sold, unmounted, for 50c, or mounted on cloth with rollers at top and bottom for $2.50.

3. A geologic map of Arizona on the same scale as the base map, printed in many colors. It was issued in 1925, and is sold both mounted and unmounted for the same prices as the topographic map.

4. A relief map of Arizona on the same scale as the base map, printed in various shades of brown, black, and blue. It was issued in 1925, and looks exactly like a photograph of a relief model of the State. This map was prepared by the U. S. Geological Survey, and is sold by the Survey for $1.00. Unmounted copies may be obtained from the Arizona Bureau of Mines at the same price. The same map mounted on cloth with rollers at the top and bottom is sold by the Bureau for $3.00.

POSTAGE IS PREPAID ON ALL MAPS.

SERVICE OFFERED BY THE BUREAU

The Arizona Bureau of Mines will classify free of charge all rocks and minerals submitted to it, provided it can do so without making elaborate chemical tests. Assaying and analytical work is done at rates fixed by law, which may be secured on application.

The Bureau is always glad to answer to the best of its ability inquiries on mining, metallurgical, and geological subjects; and takes pride in the fact that its replies are always as complete and authoritative as it is possible to make them.

All communications should be addressed and remittances made payable to "The Arizona Bureau of Mines, University Station, Tucson, Arizona."