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TURQUOISE DEPOSITS OF COURTLAND, ARIZONA.

WM. P. CRAWFORD AND FRANK JOHNSON.

D. H. Freas

B. L. White

J. B. Imswiler

January 26, 1970

Comment on Shannon Mine, Cochise County, Arizona and Alice Mine, Pinal County, Arizona.

SHANNON MINE

The Shannon Mine is located in the Turquoise Mining District, Cochise County, Arizona. The Turquoise District includes the towns of Courtland and Gleeson. The Charleston Group, which is situated northeast and east of Gleeson, contains nine patented claims and is owned by the Shannon Mining Company.

At the time of shutdown, September 1957, the Shannon mine was the third largest producer of copper in Cochise County, being preceeded only by the Phelps Dodge Bisbee operations and the Johnson Camp operation of Cyprus Mines. The total production from 1896 through 1957 was 494,256 tons of ore with an average value of 1.8% copper.

The Shannon Mine has been worked as a high grade copper mine throughout its history. The fact that it has not reopened, in spite of a doubling of the price of copper since 1957, indicates that it is probably finished as a high grade mine.

Ore in the Shannon Mine occurs as pyritic copper deposits in Carboniferous limestone. The limestone has been intruded by sills of quartz monzonite porphyry, and the copper mineralization is considered to be contact metamorphic in nature. The quartz monzonite porphyry has strong quartz-sericite alteration and contains dissaminated pyrite and chalcopyrite.

This mine is located in an area which I have always considered to be favorable for copper prospecting. It is an area of proven production, complex structure, strong alteration, and mineralized intrusive. I think it represents an area of "good hunting" for a porphyry copper deposit. In prospecting this district, however, an area much larger than that represented by the Shannon Mine must be considered. The feasibility of an exploration project in this area would largely depend on the property status of the district and what, if anything, has been done by other companies in the way of drilling in the district. I suspect that this area has been carefully scrutenized by other companies, but it has enough merit to warrant looking at and checking the land status and previous work.

To: B. L. White
From: J. B. Imswiler
Subject: Shannon and Alice Mines - Arizona

ALICE MINE

The information submitted by Universal Copper Company does not specifically locate the Alice Mine, but the general description would place it in Eastern Pinal County between the towns of Ray and Hayden. No literature references could be found pertaining to the Alice Mine.

The geological setting is certainly a familiar one in Arizona copper deposits, i.e., contact metamorphic and replacement deposits with mineralization associated with late porphyry intrusion. This area has been and is being heavily prospected. Mr. Gaylor's letter states, "Inspiration Copper Company recently spent a number of months doing geophysical work and drilling on their property north of and contiguous to my 14 claims....".

The Alice Mine obviously is not economical to operate today, but would have value only as part of a larger package if a porphyry copper should exist at depth. Since the surrounding ground is apparently taken up, and since the area has been heavily prospected, I can see nothing desirable about acquiring the Alice Mine.

Respectfully submitted,

J. B. Imswiler

JBI:jh
Cc D. H. Freas
Inc.

Weed, W. H., Geology and mining resources of the Judith Mountains of Montana: Eighteenth Ann. Rept., pt. 3, 1898, pp. 446-616. $2.15.

Weeks, F. B., Geology and mineral resources of the Osceola mining district, White Pine County, Nev.: Bull. 340, 1908, pp. 117-133. 30c.

Williams, Albert, jr., Popular fallacies regarding precious-metal ore deposits Fourth Ann. Rept., 1884, pp. 253-271. $1.65.

Woolsey, L. H., Lake Fork extension of the Silverton mining area, Colorado Bull. 315, 1907, pp. 26-30.

COPPER.

THE TURQUOISE COPPER-MINING DISTRICT, ARIZONA.

By F. L. Ransome.

INTRODUCTION.

The following notes are the record of a brief visit to the Turquoise district in October, 1911, when a little less than five days was spared from other work for an examination of the complex geologic relations of the copper deposits near Courtland and Gleeson. The results obtainable in so short a time are necessarily incomplete and are presented with the full realization that they are likely to be modified by later detailed study. They would be even more imperfect were it not for the facts that a topographic map by Mr. F. J. Gibbons, engineer of the Great Western Copper Co., was available for the part of the district adjacent to Courtland and that the geologic boundaries had been carefully traced for this area by Mr. W. G. McBride, general superintendent for the same company. The principal changes made in Mr. McBride's work, as presented in figure 17, are the interpretation of some of the boundaries as faults and the inclusion with the Cambrian dolomite and shale of some material originally mapped as quartzite. To both gentlemen I am much indebted for their courteous assistance.

SITUATION OF THE DISTRICT.

The Turquoise mining district is situated on the east flank of the Dragoon Mountains, in Cochise County, Ariz., about 14 miles due east of Tombstone and about 18 miles north-northeast of Bisbee. It lies for the most part in a small group of hills that separate the south end of the main range from the broad expanse of Sulphur Springs Valley. The district is reached from the north by a branch of the Southern Pacific Railroad by way of Pearce and from the south by a branch of the El Paso & Southwestern Railroad from Douglas.

It contains two small settlements—Courtland, shown in figure 17, and the older town of Gleeson, about 1½ miles to the south.

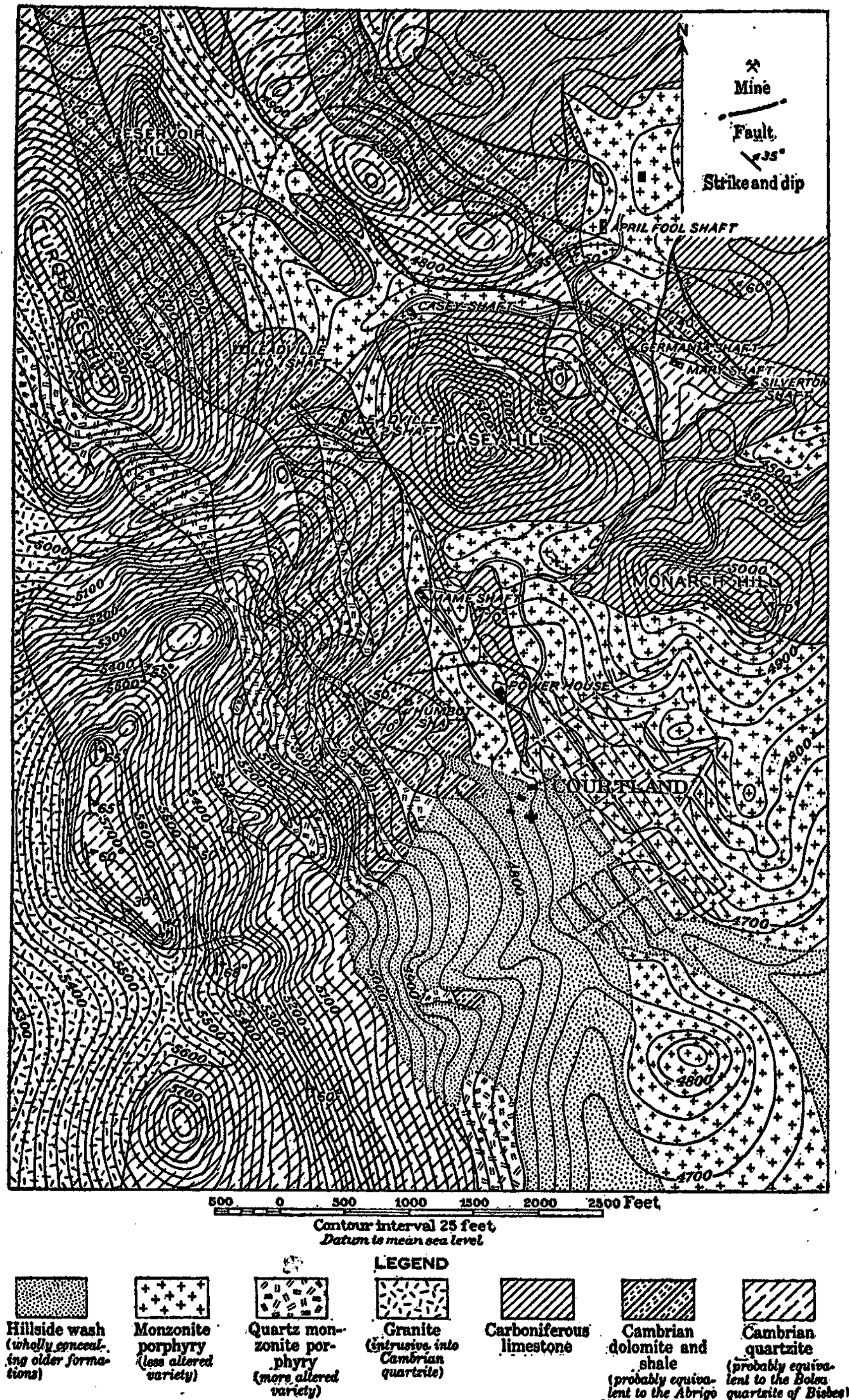

FIGURE 17.—Geologic reconnaissance map of a part of the Turquoise mining district, Arizona. Topography by F. J. Gibbons, engineer, and geologic boundaries by W. G. McBride, general superintendent, of the Great Western Copper Co.; with slight changes by F. L. Ransome.

Northeast of the limestone hills just mentioned lies another area of Cambrian rocks in which are the Mary and Germania mines. These rocks, as is clearly shown by the mine workings, rest on Carboniferous limestone and undoubtedly owe their present position to overthrust faulting. There are many puzzling features, however, in the structural relations of this part of the district and explanation of the overthrust in all its details would require much more than a hasty reconnaissance visit. A careful study of the workings connected with the Mary, Germania, Silverton, April Fool, and Casey shafts would probably clear up many obscurities; but unfortunately the Mary mine and a very small part of the Germania mine were the only openings that were readily accessible in 1911. The quartzite of this area is all much fractured, especially northeast of Casey Hill, and along the railroad north of that hill the principal fractures dip steeply to the northwest, suggesting that the mass may have been thrust from that direction. At the Mary shaft the shattered overthrust quartzite is 115 feet thick and caps the ore body.

The under surface of the overthrust mass is apparently irregular. It is probable that after the overthrust was accomplished the rocks were further dislocated by normal faulting and were deformed by the intrusion of the porphyry. These, however, are merely suggestions and considerable detailed work will be necessary to ascertain definitely the relations of the overthrust to other faulting and to the epoch of intrusion. Southeast of the Mary shaft the layer of brecciated material produced by the overthrust is steeply upturned and outcrops southwest of the Silverton shaft as masses of ferruginous gossan associated with brecciated quartzite and some oxidized copper ore. How far this local steepness of the thrust plane may be original and how far it may be due to later deformation are questions as yet unanswered.

Two varieties of porphyry are recognized near Courtland. One, which is possibly the older, is intrusive, in the form of irregular dikes, into the Cambrian beds in the western part of the area mapped in figure 17. This rock is everywhere much altered and decomposed so that its original character is not closely determinable. It is for the most part nearly white, although in surface exposures it may be stained with rust, and in many places it is not readily distinguishable from some of the altered Cambrian beds. Little can be seen of its original texture, and the microscope shows that the rock is largely a secondary aggregate of quartz and sericite with finely disseminated pyrite. Most specimens show faint outlines of feldspar phenocrysts and a few small corroded crystals of primary quartz. Provisionally the rock will be referred to as quartz monzonite porphyry. One large dike of this rock is represented in figure 17 as extending into the granite west of Turquoise Hill, but no close examination was made of the relations of the two rocks, which here weather much alike and are deeply decomposed.

The second variety of porphyry, which occupies considerable areas east and north of Courtland, is intrusive mainly into the Carboniferous limestone but is in igneous contact with the Cambrian beds also. Although nowhere fresh, this porphyry as a rule is darker in color and much less altered than the other variety. Where comparatively fresh this rock shows abundant phenocrysts of reddish feldspar which are mostly plagioclase, although some of the larger crystals are orthoclase. There are visible also a few small irregular grains of quartz and fairly abundant chloritic pseudomorphs after biotite. The microscope shows that this rock also is a quartz monzonite porphyry, although apparently it is less silicic than the variety first described. Even the freshest specimens are more decomposed than mere inspection of hand specimens suggests and the rock of the low rounded hill just south of Courtland, supposed from its texture to belong to the second variety, is altered and bleached to a product closely resembling the porphyry west of the Mame shaft.

It appears that the two varieties of porphyry here described belong to the same rock type—quartz monzonite porphyry—and it is possible that they represent contemporaneous intrusions of the same magma; but their general appearance is sufficiently different to justify their provisional distinction in a preliminary examination of the field.

The cause of the metamorphism of the dolomitic Cambrian beds is not entirely clear. The alteration is probably connected with the intrusion of the porphyries, but as the visible portions of these igneous masses have themselves undergone metamorphic changes it appears that the transformation must be due principally to some underlying body of eruptive rock.

West of the Copper Belle mine, near Gleeson, there is a decomposed rock with contorted flow banding and a dark color due to very abundant dendritic films of manganese oxide. This is apparently a rhyolite. The only other igneous rock noted in the district is a gray tuff-breccia that was cut in the workings of the Casey shaft. This rock is altered and contains finely disseminated pyrite but is clearly of andesitic or latitic character and perhaps records volcanic activity at the time of the porphyry intrusions. Its geologic relations could not be ascertained in 1911, but as it is abundant on the dump of the shaft it possibly has considerable extent underneath the overthrust mass of Cambrian quartzite.

COPPER DEPOSITS.

The copper deposits of the Turquoise district may be grouped as follows: (1) Oxidized blanket deposits connected with thrust faulting, exemplified by the ore bodies of the Germania and Mary mines.

(2) Pyritic deposits with some associated bodies of oxidized ore in the Cambrian dolomitic limestone and shale, exemplified by the Mame and Leadville mines. (3) Pyritic deposits with associated bodies of oxidized or enriched ore in Carboniferous limestone, exemplified by the Copper Belle and other mines near Gleeson.

The general plan of the Mary-Germania ore body is shown in figure 18, the outline for the portion of the body within the Mary claim corresponding approximately to what is known of the extent of the ore, while the boundaries of that portion within the Germania claim are surmised from an inspection of the map of the

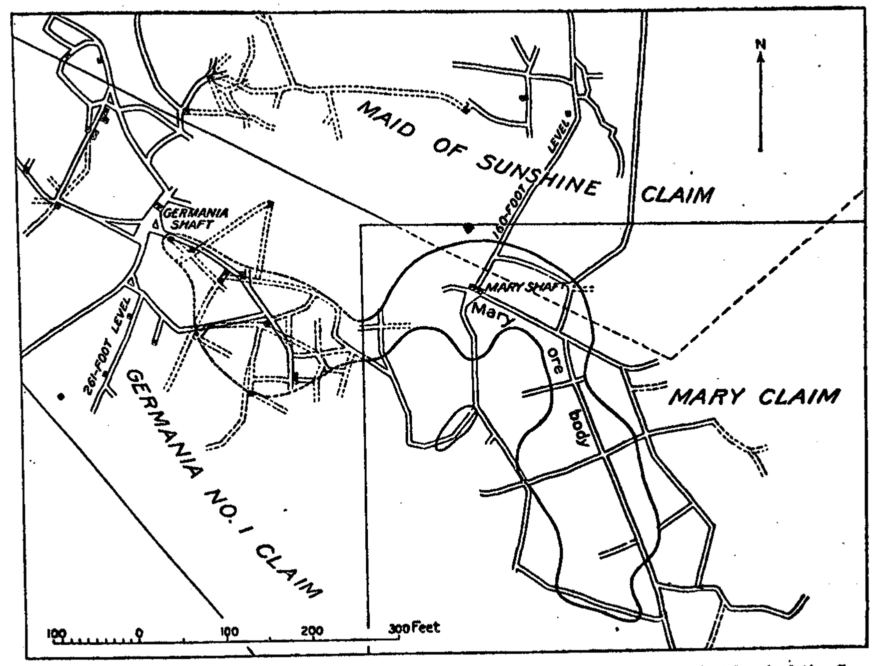

FIGURE 18.—Plan of parts of the 160-foot level of the Mary mine and of the 261-foot level of the Germania mine, Turquoise mining district, Arizona, showing the approximate outline of the main ore body.

underground workings of the Germania mine, the presence of sublevels and ore chutes being taken as indicative of stoping. Whether or not considerable ore occurs north of the Germania shaft was not ascertained. The ore is as irregular in thickness as in plan, the maximum being 50 feet and the average probably about 15 feet. The ore body is accompanied by much soft limonitic and clayey material, the whole closely resembling the oxidized ore and so-called "ledge matter" of some of the Bisbee mines. Definite boundaries are lacking, but the ore body as a whole rests on Carboniferous limestone and is overlain by shattered quartzite, which at the Mary shaft is 115 feet thick. Decomposed porphyry occurs with the quartzite above the ore, with the underlying limestone, and to some extent mingled with the ore, which in the main, however, is a replacement of the limestone.

The ore itself is as a rule a soft mass of earthy oxides of iron and copper, flecked and streaked with malachite and mingled with clay-like decomposition products of varied color and constitution. Here and there are irregular crevices or cavities lined with crusts of chrysocolla, malachite, and azurite. No sulphides have been found either in the ore or in the porphyry and limestone immediately under the ore, and the limestone is not metamorphosed.

The ore-bearing solutions evidently gained access to the broken ground along the thrust plane and replaced the shattered limestone by ore. The ore during deposition apparently was not limited in its downward extent by the zone of brecciation but replaced irregularly part of the underlying limestone, especially in the vicinity of fissures. Whether it was originally deposited as sulphides or was carried down from some overlying formation through the shattered quartzite and deposited directly in oxidized condition in the fault breccia and on top of the limestone is an open question. The view that the ore was deposited as sulphide and has been completely oxidized, essentially in place, by water that has percolated down through the porous quartzite capping is regarded as the more probable.

Northwest of the Mary and Germania mines and north of the Casey shaft there is a ridge of quartzite that apparently is part of the overthrust mass. Although it would be unsafe from a reconnaissance examination to predict the occurrence of ore bodies under this quartzite, it may be pointed out that there is a bare possibility of their existence. The exploratory drifts from the April Fool shaft do not extend far enough west to test this possibility thoroughly. Whether there are any drifts extending north from the Casey shaft and exploring the base of the quartzite in this ridge could not be learned in 1911. The Miami shaft, which is just north of the area covered by figure 17, was sunk by the Calumet & Arizona Co. through the small mass of quartzite that is shown about 2,000 feet northwest of the April Fool shaft, and extensive exploratory work was carried on in the underlying limestone, but without success.

Of the mines in the Cambrian dolomite and shale (Abrigo formation?) the Mame alone was open for examination in 1911. The Mame has reached a depth of 300 feet, but only the 100-foot level was examined in 1911, as time was short and according to Mr. MacBride the conditions on the lower levels are substantially the same as on the first level.

The general country rock of the Mame, Humbot, and Leadville mines is a series of shales and thin-bedded dolomitic limestones cut irregularly by many dikes and sheets of quartz monzonite porphyry. The beds have prevailingly steep dips to the east. The entire belt

of these rocks from Courtland northward shows decided metamorphism. The calcareous beds have been transformed to hard fine-grained aggregates consisting largely of garnet, with perhaps other silicates, quartz, calcite, and pyrite. The porphyry has been altered to fine-granular aggregates of quartz, sericite, and pyrite. The pyrite, though widely disseminated through the rocks, is more abundant at some places than at others. The superficial weathering of this formation is accompanied by further changes. The oxidation of the pyrite, with the production of sulphuric acid and sulphates, bleaches portions of the rocks and leads to the accumulation of iron oxides in other portions. In connection with this weathering there has been some concentration of oxidized ore near the surface, especially at the Humbot mine, but such concentration is local and superficial.

At the Mame mine the oxidized ore is wholly inconsiderable and the work in progress during 1911 was directed to the exploration of the metamorphosed beds and the altered porphyry for bodies of pyritic ore. These are generally of lenticular form and lie with their greater dimensions approximately in the planes of bedding. They are said to be most abundant and largest close to the porphyry intrusions, which in their altered condition are difficult to distinguish underground from some of the metamorphosed sedimentary beds. These ore bodies have no sharp boundaries but are merely those portions of the formation where the pyrite is more thickly disseminated than elsewhere or where it has formed in solid masses by metasomatic replacement of the calcareous strata and probably, to some extent, of the porphyry also. Not all of the pyritic material contains enough copper to be classed as ore and numerous assays are necessary to determine the limits of each ore body. The deposition of the ore has no obvious relation to fissuring. The pyrite, together with the small proportion of chalcopyrite that gives the whole its value as a low-grade copper ore, was apparently formed during the general metamorphism of the formation by hot mobile solutions under such pressure that they were capable of moving along bedding planes and of penetrating the mass of the rock through minute openings and by molecular replacement.

At a few places in the Mame mine there has been a little chalcocitic enrichment, but the greater part of the ore has undergone no modification since it was first deposited.

In 1911 there had been shipped from the Mame mine about 1,500 tons of ore from development work, but stoping had not been begun.

The dump of the Leadville No. 1 shaft, about half a mile northwest of the Mame, shows considerable low-grade pyritic ore. The geologic conditions at the two mines are similar and if the Mame develops into a profitable mine this will probably lead to a resumption of work at the Leadville.

The Humbot shaft is situated about 800 feet south of the Mame and belongs to the same company. Although the rocks are identical with those of the Mame and although oxidized ore to the value of $100,000 is said to have been mined from open cuts near the shaft, considerable exploratory work on two levels has failed to show any sulphide ore bodies of workable size.

No special examination was made of the mines in Carboniferous limestone near Gleeson. The Copper Belle is opened by a 300-foot shaft with three levels. The country rock is gray limestone, which dips 30°–50° E. and contains a number of intrusive sheets of altered monzonitic or dioritic porphyry. The ore bodies of the Copper Belle occur along the contacts of this porphyry with two beds or slablike masses of limestone and have a total length from north to south of about 500 feet. The ore is mainly granular pyrite with a little chalcopyrite and scattered bunches of bornite, sphalerite, or galena. It has been deposited by irregular metasomatic replacement of the limestone, which shows no general metamorphism. The porphyry also is full of finely disseminated pyrite and carries small stringers of the same sulphide. The ore is graded into two classes and is shipped to the Clifton district, where its high percentage of sulphur and freedom from gangue make it valuable for smelting with other ores.

TURQUOISE DEPOSITS.

The turquoise occurs in joints and small irregular fractures in a bed of Cambrian quartzite that dips 65° E. and outcrops along the west side of Turquoise Hill a few feet above the contact with the decomposed granitic rock previously referred to. At the opening examined the bed has been stoped to a width of 4 feet and a depth of 75 feet or more, the bottom of the shaft being now filled with water. A short distance north of this opening and near the western boundary of the area mapped other workings, perhaps a little more extensive than those visited, have been opened on the same bed of quartzite.

SURVEY PUBLICATIONS ON COPPER.

The following list includes the principal publications on copper by the United States Geological Survey or by members of its staff. In addition to the publications cited below, certain of the folios of the Geologic Atlas of the United States contain discussions of the copper resources of the districts of which they treat. This list does not include publications on Alaska, a list of which is given in Bulletin 520, the annual report on progress of the Survey's investigations in Alaska for 1911.

The Government publications, except those to which a price is affixed, can be obtained free by applying to the Director, U. S. Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. The publications marked "Exhausted" are not available for distribution but may be seen at the larger libraries of the country.

Bain, H. F., and Ulrich, E. O., The copper deposits of Missouri: Bull. 260, 1905, pp. 233–235. 40c.

Ball, S. H., Copper deposits of the Hartville uplift, Wyoming: Bull. 315, 1907, pp. 93–107.

Bancroft, Howland, Reconnaissance of the ore deposits in northern Yuma County, Ariz.: Bull. 451, 1911, 130 pp.

Boutwell, J. M., Ore deposits of Bingham, Utah: Bull. 213, 1903, pp. 105–122. 25c.

——— Economic geology of the Bingham mining district, Utah: Prof. Paper 38, 1905, 413 pp.

——— Ore deposits of Bingham, Utah: Bull. 260, 1905, pp. 236–241. 40c.

Butler, B. S., Copper: Mineral Resources U. S. for 1911, pt. 1, 1912, pp. 255–313.

Collier, A. J., Ore deposits of the St. Joe River basin, Idaho: Bull. 285, 1906, pp. 129–139. Exhausted.

Diller, J. S., Copper deposits of the Redding region, California: Bull. 213, 1903, pp. 123–132. 25c.

——— Mining and mineral resources in the Redding district in 1903: Bull. 225, 1904, pp. 169–179. 35c.

Emmons, S. F., Geological distribution of the useful metals in the United States—Copper: Trans. Am. Inst. Min. Eng., vol. 22, 1894, p. 73.

——— Economic geology of the Butte (copper) district, Montana: Geol. Atlas U. S., folio 38, 1897. 25c.

——— Copper in the red beds of the Colorado Plateau region: Bull. 260, 1905, pp. 221–232. 40c.

——— The Cactus copper mine, Utah: Bull. 260, 1905, pp. 242–248. 40c.

Emmons, W. H., The Cashin mine, Montrose County, Colo.: Bull. 285, 1906, pp. 125–128. Exhausted.

——— Some ore deposits of Maine and the Milan mine, New Hampshire: Bull. 432, 1910, 62 pp.

INTER-OFFICE CORRESPONDENCE

IMC

COPIES TO: D. H. Freas

TO B. L. White

FROM J. B. Imswiler

DATE January 26, 1970

SUBJECT Comment on Shannon Mine, Cochise County, Arizona and Alice Mine, Pinal County, Arizona.

SHANNON MINE

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This mine is located in an area which I have always considered to be favorable for copper prospecting. It is an area of proven production, complex structure, strong alteration, and mineralized intrusive. I think it represents an area of "good hunting" for a porphyry copper deposit. In prospecting this district, however, an area much larger than that represented by the Shannon Mine must be considered. The feasibility of an exploration project in this area would largely depend on the property status of the district and what, if anything, has been done by other companies in the way of drilling in the district. I suspect that this area has been carefully scrutinized by other companies, but it has enough merit to warrant looking at and checking the land status and previous work.

The Milan G. Weber Associates Inc.

MANAGEMENT CONSULTING

P.O. Box 81 • Deerfield, Illinois 60015 • Area Code 312/945-3673

8 December 1969

Mr. D. H. Freas
Manager of Exploration
Western U. S. A.
International Minerals & Chemical Corporation
5401 Old Orchard Road
Skokie, Illinois 60076

Dear Mr. Freas:

Thank you for your letter of October 15th, expressing interest in the copper mine properties mentioned in my letter of September 23rd. I regret the long delay in responding, but I am pleased to send further details.

We are enclosing additional information about the company. For your very confidential information it is the Shannon Mine near Gleason, Arizona. It is owned by Hydrometals, Incorporated, of Dallas, Texas. Hydrometals, Incorporated, is in the process of divesting themselves of this copper property and would be pleased to discuss either an outright sale or an option arrangement.

Please do not hesitate to call on us for any further information you may now require for your evaluation of this mine as an acquisition prospect. Also, we will be very glad to arrange a visit at your convenience to inspect the properties.

With warm regards,

Sincerely,

Milan G. Weber
President

MGW:mj
Encl.

November 23, 1962

Re: Shannon Mining Company

Mr. J. W. Faust, Vice President
Peru Mining Company
Hanover, New Mexico

Dear Mr. Faust:

Attached Exhibit JCB is the basis of my findings herein:

1. 50,000,000 tons of favorable ground which has enough scattered mineral through it, enough to justify a few well selected pilot churn drill holes. Like raisins in a cake.

2. Assume:

   30,000 tons of 2% copper or 40 pounds at 20¢ copper gives $8.00 a ton
   5,000 tons of 3% copper or 60 pounds at 20¢ copper gives $12.00 a ton

30,000 x $8.00 =	$240,000
5,000 x $12.00 =	60,000
	$300,000
Plus $1.00 gold & silver	35,000
Total	$335,000

   A. Plus lead and zinc.
   B. Plus all copper milling ore (The above is shipping ore).
   C. Plus any value for iron, sulphur or silica.
   D. Plus exploration new findings.
   E. Less loss in mining and milling unless Mr. Conley's reserves are in recoverable figures.

3. Development, I feel, is the first step and the demand for copper (price) would add the controlling importance and value to this reserve. We have used here a net of 20¢ a pound value for copper with a 31 cent a pound market.

Respectfully,

Please return to:

Joseph C. Barton

The Milan G. Weber Associates
P. O. Box 81
Deerfield, Illinois 60015

JCB:f

EXHIBIT A-LJC

November 22, 1962

Re: Shannon Mining Company

To:
Mr. J. W. Faust, Vice President
Peru Mining Company
Hanover, New Mexico

The enclosed ore reserves report on the Shannon Mine was made by me in September 1957, at the time of shutdown. All information was current using information obrained by drifting, raising, diamond drilling, prospect drilling, and sampling. Mapping was complete and up-to-date.

The calculations were made by me. Tonnages were estimated using factors obtained by operational and geological observations in the period from November 1954 to September 1957.

The above estimate was made in 1957 to the best of my ability on information available.

L. J. Conley
Mine Superintendent

LJC:f

Enc.

EXHIBIT J. C. B.

November 22, 1962

Re: Shannon Mining Company

Mr. J. W. Faust, Vice President
Peru Mining Company
Hanover, N. M.

I find the following:

1. L. J. Conley's ORE RESERVES and a statement covering his process of obtaining them. (Exhibits A and Exhibits B.
2. Tabulation of production figures, available since beginning.
3. Shipments to International Smelting & Refining Company, Miami Plant. (Settlement Sheets)

J. C. B. OPINION ON ABOVE:

1. Mr. Conley's figures cannot be verified because of the inability of going underground due to the shaft damage. As Mr. Conley was Mine Superintendent and Engineer on the job when it closed, he should have a good picture of it. Mr. Conley shows an estimate of 344,150 tons of 1.13% copper, of which 35,650 tons of 2.26% copper is shown. .
2. 1896 to 1957 - 494,256 tons of 1.81% copper. (Gold and silver not shown). This seems reasonable.
3. Settlement Sheets:
   October 28, 1955 to September 6, 1956 about 3,000 tons of 4.47% copper, 1.70 oz. silver and .020 oz. gold.
   March 28, 1957 to September 1957 about 2,000 tons of 4.94% copper, 1.44 oz. silver and .072 oz. gold.
   Settlement sheets shows for price of copper:

October 28, 1955	$.4300 a pound
September 6, 1956	.3967 a pound
March 28, 1957	.3140 a pound
September 18, 1957	.2780 a pound (Closed down)

The heavy production and lower copper was mined for the most part during high copper prices. The low copper price at September 18, 1957 would be a handicap for any production.

GENERAL:

This particular area has good possibilities which could be developed by surface drilling for the extensions of the known ore bodies as well as block drilling. The formations are broken up so that underground development may not be the answer because it probably would be costly to try to expand the present ore faces as the ore may cut in and out too fast. I would suggest it be recalculated as a possible open pit operation. Unlike the porphyries you may have a very large area of many small hot spots which could possibly be mined and selected much better in a pit than underground due to unusual post-mineral faulting.

There may be 50,000,000 tons of favorable mineral ground worth a few well placed pilot surface drill holes. Then to proceed as economics would justify.

EXHIBIT B — [illegible]

[illegible] MINING COMPANY

ORE RESERVES — COPPER

% GRADE	TONNAGE			
	PROVED	PROBABLE	PROSPECTIVE	TOTAL
1/2 - 1½	12,300	36,200	260,000	308,500
1½ - 2½	7,450	10,400	4,500	30,350
2½ - 3½	500	1,000	500	2,000
3½ - 4½	1,100	500	-0-	1,600
+4½	500	200	1,000	1,700
	21,850	56,300	266,000	344,150

ORE RESERVES - ZN. CU. PB COMBINED

% GRADE	TONNAGE			
	PROVED	PROBABLE	PROSPECTIVE	TOTAL
5 - 10	1,200	4,300	2,000	7,500
10 - 20	-0-	600	500	1,100
20 - 30	2,000	-0-	-0-	2,000
	3,200	4,900	2,500	10,600

✓ WILSON, E. D. (1927) GEOLOGY AND ORE DEPOSITS OF THE COURTLAND-GLEESON REGION, ARIZONA: UNIV. ARIZ., ARIZ BUR MINES BULL 123, 79 p map

WILSON, E. D. (1927). GEOLOGY AND ORE DEPOSITS OF THE COURTLAND-GLEESON REGION, ARIZONA: UNIV ARIZ. ARIZ. BUR MINES BULL. 123, 79 p. map.

p. 68 THE CHARLESTON GROUP, WHICH IS SITUATED NORTHEAST AND EAST OF GLEESON, CONTAINS NINE PATENTED CLAIMS — AND IS OWNED BY THE SHANNON COPPER CO.

CLAIMS:
- EMPIRE
- * COPPER BELLE
- CHARLESTON
- ELIZABETH
- DURAND
- DANDY
- OAKGROVE
- JOE
- KATHERINE

SEE PLATE III opp. p. 68

(2)

WILSON, E.D. (1927)

SHANNON ~~MINE~~ COPPER CO.

CHARLESTON GROUP

DEVELOPMENT OF THE GROUP HAS BEEN MAINLY IN THE COPPER BELLE MINE, WHICH INCLUDES ALSO THE PEMBERTHY WORKINGS.

COPPER BELLE OR LEONARD MINE

MINERALS YEARBOOK

~~[illegible]~~ 1963

NEW DEVELOPMENTS IN THE COUNTY INCLUDED THE START OF LEACH OPERATIONS AT THE [illegible] MINE IN THE TURQUOISE MINING DISTRICT BY THE INTERSTATE ACCOUNTING AND OFFICE SERVICE OF PHOENIX.

As late as 1958 SHANNON MINE was largest independent producer of copper in Cochise county except P.D. @ Bisbee and CYPRUS MINES @ Johnson Camp.

WEED, W. H., Geology and mining resources of the Judith Mountains of Montana: Eighteenth Ann. Rept., pt. 3, 1898, pp. 446-616. $2.15.

WEEKS, F. B., Geology and mineral resources of the Osceola mining district, White Pine County, Nev.: Bull. 340, 1908, pp. 117-133. 30c.

WILLIAMS, ALBERT, JR., Popular fallacies regarding precious-metal ore deposits Fourth Ann. Rept., 1884, pp. 253-271. $1.65.

WOOLSEY, L. H., Lake Fork extension of the Silverton mining area, Colorado Bull. 315, 1907, pp. 26-30.

COPPER.

THE TURQUOISE COPPER-MINING DISTRICT, ARIZONA.

By F. L. RANSOME.

INTRODUCTION.

The following notes are the record of a brief visit to the Turquoise district in October, 1911, when a little less than five days was spared from other work for an examination of the complex geologic relations of the copper deposits near Courtland and Gleeson. The results obtainable in so short a time are necessarily incomplete and are presented with the full realization that they are likely to be modified by later detailed study. They would be even more imperfect were it not for the facts that a topographic map by Mr. F. J. Gibbons, engineer of the Great Western Copper Co., was available for the part of the district adjacent to Courtland and that the geologic boundaries had been carefully traced for this area by Mr. W. G. McBride, general superintendent for the same company. The principal changes made in Mr. McBride's work, as presented in figure 17, are the interpretation of some of the boundaries as faults and the inclusion with the Cambrian dolomite and shale of some material originally mapped as quartzite. To both gentlemen I am much indebted for their courteous assistance.

SITUATION OF THE DISTRICT.

The Turquoise mining district is situated on the east flank of the Dragoon Mountains, in Cochise County, Ariz., about 14 miles due east of Tombstone and about 18 miles north-northeast of Bisbee. It lies for the most part in a small group of hills that separate the south end of the main range from the broad expanse of Sulphur Springs Valley. The district is reached from the north by a branch of the Southern Pacific Railroad by way of Pearce and from the south by a branch of the El Paso & Southwestern Railroad from Douglas.

It contains two small settlements—Courtland, shown in figure 17, and the older town of Gleeson, about 1½ miles to the south.

MINING DEVELOPMENT AND PRODUCTION.

During the eighties the Gleeson, Tejon, and a few other mines near Gleeson produced considerable quantities of oxidized ore, carrying gold, silver, lead, and copper, from deposits in a ridge of Carboniferous limestone east of town, but by 1902 these ore bodies had ceased to be profitable. The extension of the railroads into the district a few years ago made possible the utilization of lower-grade ores and at present the Copper Belle mine, near Gleeson, under lease to the Shannon Copper Co., is producing a low-grade pyritic ore.

The turquoise mines, from which the district gets its name, are on the west side of Turquoise Hill, northwest of Courtland (fig. 17). They are said to have been fairly productive, but they are now idle and very little could be learned of their history. Copper mining on an important scale began near Courtland on the Humbot claim about the year 1901, and it is reported that this mine yielded about $100,000 from a body of oxidized ore stoped near the surface. In 1907 and 1908 there was much activity in the vicinity of Courtland and extensive prospecting was carried on at several places by Phelps, Dodge & Co., the Calumet & Arizona Co., and the Great Western Copper Co. The work as a whole was rather disappointing, but the Calumet & Arizona Co. shipped 15,000 to 20,000 tons of 7 per cent oxidized copper ore from the Germania mine, and the Great Western Copper Co. had produced at the time of visit about 30,000 tons of ore from the Mary mine, which is on the same ore body as the Germania. About $250,000 was expended by the Calumet & Arizona Co. on the Leadville claims and some low-grade sulphide ore was found, but work was finally abandoned. Although there is known to be still some good ore in the Germania mine, the only mines in operation in 1911 were the Mary and Mame, both owned by the Great Western Copper Co. At the time of visit this company was shipping from all workings, but mainly from the Mary mine, at the rate of nine 50-ton cars a week.

GENERAL GEOLOGY.

The Dragoon Range, which trends generally north-northwest, with a length of about 25 miles, is composed chiefly of Paleozoic rocks, ranging from the middle Cambrian to the Carboniferous (Pennsylvanian). These are cut by various igneous rocks, especially by a large mass of rather coarse textured granite, which makes up much of the northern part of the range.

The hills of the Turquoise district rise 1,000 to 1,500 feet above the adjacent Sulphur Springs Valley, the highest line of summits being composed of hard quartzite which is probably the equivalent of the middle Cambrian Bolsa quartzite of the Bisbee district. The original base of this quartzite was not seen in this reconnaissance, although

F. T. Dumble[1] has reported the occurrence of mica schist, presumably pre-Cambrian, in South Pass, 7 or 8 miles northwest of Courtland. In the vicinity of Courtland the quartzite rests upon a rather fine grained, very much decomposed granitic rock which apparently occupies much of the relatively low ground between the Turquoise Hills and the main Dragoon Range and forms some of the low hills into which that range subsides toward the south. This rock is too much decomposed for complete identification, but apparently it is a quartzose granite in which the feldspar has been wholly altered to sericite. The microscope shows that most of the quartz grains are minutely fissured, the fissures being filled with sericite. The contacts of this rock with the sedimentary rocks are generally covered by loose detritus, but some exposures in the saddle about half a mile southwest of Courtland (see fig. 17) show that the granite rock is intrusive into the quartzite, which has been rendered schistose at the contact. Farther south, between Courtland and Gleeson, it probably is intrusive into the Carboniferous limestone also, although no exposures of this contact were seen.

The quartzite, which forms the steep hills along the western edge of the area mapped in figure 17, strikes on the whole nearly north and south and dips generally eastward at angles ranging from 40° to 80°. It is overlain to the east by a formation of thin-bedded dolomite or dolomitic limestone and shale within which are the Leadville, Mame, and Humbot mines. These rocks, which are probably the stratigraphic equivalent of what was named the Abrigo limestone at Bisbee,[2] have been strongly metamorphosed through the formation of garnet and other silicates with sulphides, chiefly pyrite. Such resemblance as the rocks may once have had to the Abrigo as developed near Bisbee has been obscured by this metamorphism and still more by the oxidation of the pyrite and by the action on the rock of the sulphuric acid thus formed.

Northeast of the Cambrian dolomite and shale is a belt of gray limestone forming Monarch, Casey, and Reservoir hills. This limestone is sparingly fossiliferous and is undoubtedly of Carboniferous age, probably Mississippian. No Devonian rocks were recognized near Courtland, although Dumble[3] has noted the presence of rocks of this age elsewhere in the Dragoon Mountains. The Carboniferous limestone near Courtland has been irregularly invaded by monzonite porphyry and no longer has its original stratigraphic position with reference to the Cambrian beds. In some places it is faulted against these beds and in others it is separated from them by intrusive masses of porphyry.

[1] Notes on the geology of southeastern Arizona: Trans. Am. Inst. Min. Eng., vol. 31, 1902, p. 713.
[2] Ransome, F. L., The geology and ore deposits of the Bisbee quadrangle, Arizona: Prof. Paper U. S. Geol. Survey No. 21, 1904.
[3] Op. cit., p. 711.

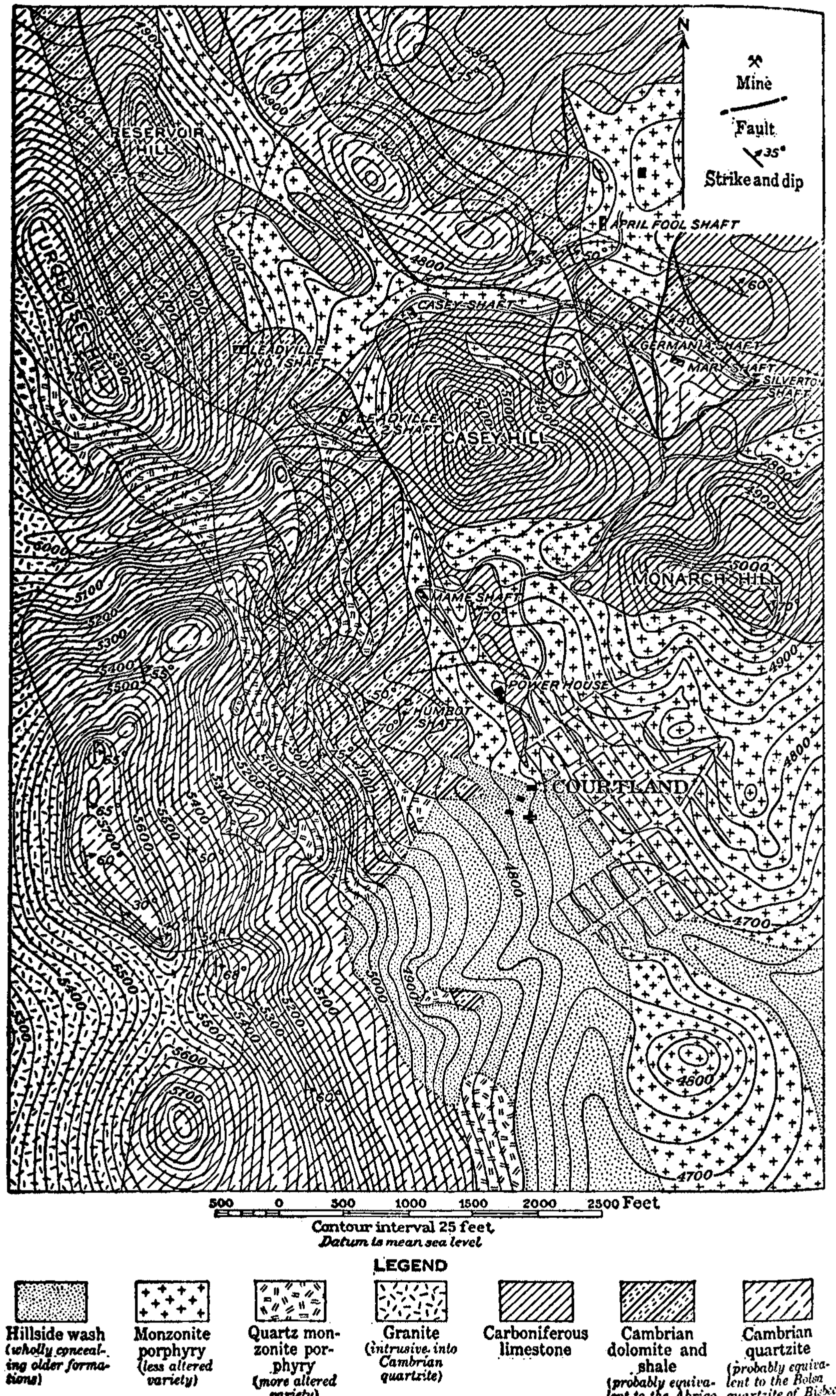


FIGURE 17.—Geologic reconnaissance map of a part of the Turquoise mining district, Arizona. Topography by F. J. Gibbons, engineer, and geologic boundaries by W. G. McBride, general superintendent, of the Great Western Copper Co.; with slight changes by F. L. Ransome.

Northeast of the limestone hills just mentioned lies another area of Cambrian rocks in which are the Mary and Germania mines. These rocks, as is clearly shown by the mine workings, rest on Carboniferous limestone and undoubtedly owe their present position to overthrust faulting. There are many puzzling features, however, in the structural relations of this part of the district and explanation of the overthrust in all its details would require much more than a hasty reconnaissance visit. A careful study of the workings connected with the Mary, Germania, Silverton, April Fool, and Casey shafts would probably clear up many obscurities; but unfortunately the Mary mine and a very small part of the Germania mine were the only openings that were readily accessible in 1911. The quartzite of this area is all much fractured, especially northeast of Casey Hill, and along the railroad north of that hill the principal fractures dip steeply to the northwest, suggesting that the mass may have been thrust from that direction. At the Mary shaft the shattered overthrust quartzite is 115 feet thick and caps the ore body.

The under surface of the overthrust mass is apparently irregular. It is probable that after the overthrust was accomplished the rocks were further dislocated by normal faulting and were deformed by the intrusion of the porphyry. These, however, are merely suggestions and considerable detailed work will be necessary to ascertain definitely the relations of the overthrust to other faulting and to the epoch of intrusion. Southeast of the Mary shaft the layer of brecciated material produced by the overthrust is steeply upturned and outcrops southwest of the Silverton shaft as masses of ferruginous gossan associated with brecciated quartzite and some oxidized copper ore. How far this local steepness of the thrust plane may be original and how far it may be due to later deformation are questions as yet unanswered.

Two varieties of porphyry are recognized near Courtland. One, which is possibly the older, is intrusive, in the form of irregular dikes, into the Cambrian beds in the western part of the area mapped in figure 17. This rock is everywhere much altered and decomposed so that its original character is not closely determinable. It is for the most part nearly white, although in surface exposures it may be stained with rust, and in many places it is not readily distinguishable from some of the altered Cambrian beds. Little can be seen of its original texture, and the microscope shows that the rock is largely a secondary aggregate of quartz and sericite with finely disseminated pyrite. Most specimens show faint outlines of feldspar phenocrysts and a few small corroded crystals of primary quartz. Provisionally the rock will be referred to as quartz monzonite porphyry. One large dike of this rock is represented in figure 17 as extending into the granite west of Turquoise Hill, but no close examination was made of the relations of the two rocks, which here weather much alike and are deeply decomposed.

The second variety of porphyry, which occupies considerable area east and north of Courtland, is intrusive mainly into the Carboniferous limestone but is in igneous contact with the Cambrian beds also. Although nowhere fresh, this porphyry as a rule is darker in color and much less altered than the other variety. Where comparatively fresh this rock shows abundant phenocrysts of reddish feldspar which are mostly plagioclase, although some of the larger crystals are orthoclase. There are visible also a few small irregular grains of quartz and fairly abundant chloritic pseudomorphs after biotite. The microscope shows that this rock also is a quartz monzonite porphyry, although apparently it is less silicic than the variety first described. Even the freshest specimens are more decomposed than mere inspection of hand specimens suggests and the rock of the low rounded hill just south of Courtland, supposed from its texture to belong to the second variety, is altered and bleached to a product closely resembling the porphyry west of the Mame shaft.

It appears that the two varieties of porphyry here described belong to the same rock type—quartz monzonite porphyry—and it is possible that they represent contemporaneous intrusions of the same magma; but their general appearance is sufficiently different to justify their provisional distinction in a preliminary examination of the field.

The cause of the metamorphism of the dolomitic Cambrian beds is not entirely clear. The alteration is probably connected with the intrusion of the porphyries, but as the visible portions of these igneous masses have themselves undergone metamorphic changes it appears that the transformation must be due principally to some underlying body of eruptive rock.

West of the Copper Belle mine, near Gleeson, there is a decomposed rock with contorted flow banding and a dark color due to very abundant dendritic films of manganese oxide. This is apparently a rhyolite. The only other igneous rock noted in the district is a gray tuff-breccia that was cut in the workings of the Casey shaft. This rock is altered and contains finely disseminated pyrite but is clearly of andesitic or latitic character and perhaps records volcanic activity at the time of the porphyry intrusions. Its geologic relations could not be ascertained in 1911, but as it is abundant on the dump of the shaft it possibly has considerable extent underneath the overthrust mass of Cambrian quartzite.

COPPER DEPOSITS.

The copper deposits of the Turquoise district may be grouped as follows: (1) Oxidized blanket deposits connected with thrust faulting, exemplified by the ore bodies of the Germania and Mary mines. (2) Pyritic deposits with some associated bodies of oxidized ore in the Cambrian dolomitic limestone and shale, exemplified by the Mame and Leadville mines. (3) Pyritic deposits with associated bodies of oxidized or enriched ore in Carboniferous limestone, exemplified by the Copper Belle and other mines near Gleeson.

The general plan of the Mary-Germania ore body is shown in figure 18, the outline for the portion of the body within the Mary claim corresponding approximately to what is known of the extent of the ore, while the boundaries of that portion within the Germania claim are surmised from an inspection of the map of the

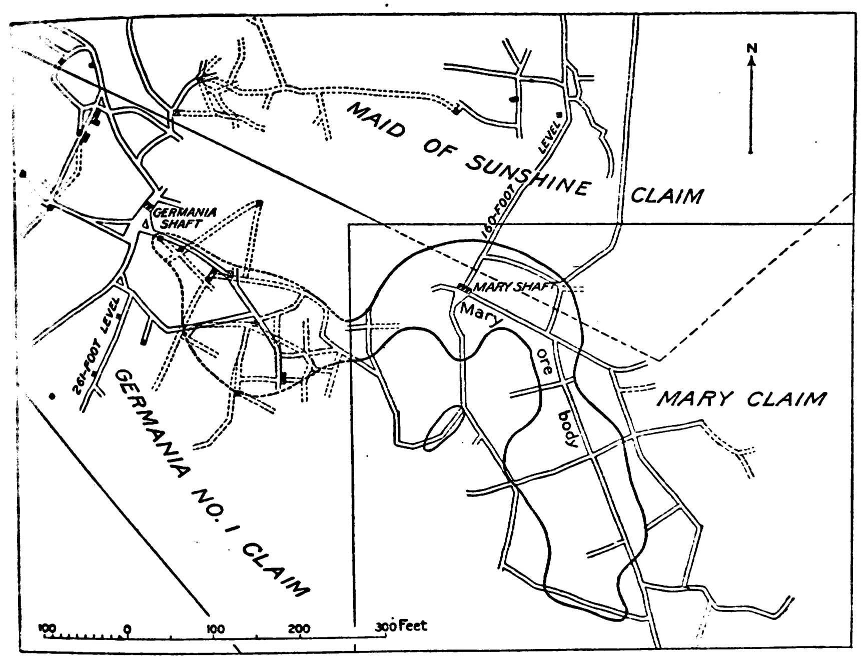


FIGURE 18.—Plan of parts of the 160-foot level of the Mary mine and of the 261-foot level of the Germania mine, Turquoise mining district, Arizona, showing the approximate outline of the main ore body.

underground workings of the Germania mine, the presence of sublevels and ore chutes being taken as indicative of stoping. Whether or not considerable ore occurs north of the Germania shaft was not ascertained. The ore is as irregular in thickness as in plan, the maximum being 50 feet and the average probably about 15 feet. The ore body is accompanied by much soft limonitic and clayey material, the whole closely resembling the oxidized ore and so-called "ledge matter" of some of the Bisbee mines. Definite boundaries are lacking, but the ore body as a whole rests on Carboniferous limestone and is overlain by shattered quartzite, which at the Mary shaft is 115 feet thick. Decomposed porphyry occurs with the quartzite above the ore, with the underlying limestone, and to some extent mingled with the ore, which in the main, however, is a replacement of the limestone.

The ore itself is as a rule a soft mass of earthy oxides of iron and copper, flecked and streaked with malachite and mingled with clay-like decomposition products of varied color and constitution. Here and there are irregular crevices or cavities lined with crusts of chrysocolla, malachite, and azurite. No sulphides have been found either in the ore or in the porphyry and limestone immediately under the ore, and the limestone is not metamorphosed.

The ore-bearing solutions evidently gained access to the broken ground along the thrust plane and replaced the shattered limestone by ore. The ore during deposition apparently was not limited in its downward extent by the zone of brecciation but replaced irregularly part of the underlying limestone, especially in the vicinity of fissures. Whether it was originally deposited as sulphides or was carried down from some overlying formation through the shattered quartzite and deposited directly in oxidized condition in the fault breccia and on top of the limestone is an open question. The view that the ore was deposited as sulphide and has been completely oxidized, essentially in place, by water that has percolated down through the porous quartzite capping is regarded as the more probable.

Northwest of the Mary and Germania mines and north of the Casey shaft there is a ridge of quartzite that apparently is part of the overthrust mass. Although it would be unsafe from a reconnaissance examination to predict the occurrence of ore bodies under this quartzite, it may be pointed out that there is a bare possibility of their existence. The exploratory drifts from the April Fool shaft do not extend far enough west to test this possibility thoroughly. Whether there are any drifts extending north from the Casey shaft and exploring the base of the quartzite in this ridge could not be learned in 1911. The Miami shaft, which is just north of the area covered by figure 17, was sunk by the Calumet & Arizona Co. through the small mass of quartzite that is shown about 2,000 feet northwest of the April Fool shaft, and extensive exploratory work was carried on in the underlying limestone, but without success.

Of the mines in the Cambrian dolomite and shale (Abrigo formation?) the Mame alone was open for examination in 1911. The Mame has reached a depth of 300 feet, but only the 100-foot level was examined in 1911, as time was short and according to Mr. MacBride the conditions on the lower levels are substantially the same as on the first level.

The general country rock of the Mame, Humbot, and Leadville mines is a series of shales and thin-bedded dolomitic limestones cut irregularly by many dikes and sheets of quartz monzonite porphyry. The beds have prevailingly steep dips to the east. The entire belt

of these rocks from Courtland northward shows decided metamorphism. The calcareous beds have been transformed to hard fine-grained aggregates consisting largely of garnet, with perhaps other silicates, quartz, calcite, and pyrite. The porphyry has been altered to fine-granular aggregates of quartz, sericite, and pyrite. The pyrite, though widely disseminated through the rocks, is more abundant at some places than at others. The superficial weathering of this formation is accompanied by further changes. The oxidation of the pyrite, with the production of sulphuric acid and sulphates, bleaches portions of the rocks and leads to the accumulation of iron oxides in other portions. In connection with this weathering there has been some concentration of oxidized ore near the surface, especially at the Humbot mine, but such concentration is local and superficial.

At the Mame mine the oxidized ore is wholly inconsiderable and the work in progress during 1911 was directed to the exploration of the metamorphosed beds and the altered porphyry for bodies of pyritic ore. These are generally of lenticular form and lie with their greater dimensions approximately in the planes of bedding. They are said to be most abundant and largest close to the porphyry intrusions, which in their altered condition are difficult to distinguish underground from some of the metamorphosed sedimentary beds. These ore bodies have no sharp boundaries but are merely those portions of the formation where the pyrite is more thickly disseminated than elsewhere or where it has formed in solid masses by metasomatic replacement of the calcareous strata and probably, to some extent, of the porphyry also. Not all of the pyritic material contains enough copper to be classed as ore and numerous assays are necessary to determine the limits of each ore body. The deposition of the ore has no obvious relation to fissuring. The pyrite, together with the small proportion of chalcopyrite that gives the whole its value as a low-grade copper ore, was apparently formed during the general metamorphism of the formation by hot mobile solutions under such pressure that they were capable of moving along bedding planes and of penetrating the mass of the rock through minute openings and by molecular replacement.

At a few places in the Mame mine there has been a little chalcocitic enrichment, but the greater part of the ore has undergone no modification since it was first deposited.

In 1911 there had been shipped from the Mame mine about 1,500 tons of ore from development work, but stoping had not been begun.

The dump of the Leadville No. 1 shaft, about half a mile northwest of the Mame, shows considerable low-grade pyritic ore. The geologic conditions at the two mines are similar and if the Mame develops into a profitable mine this will probably lead to a resumption of work at the Leadville.

The Humbot shaft is situated about 800 feet south of the Mame and belongs to the same company. Although the rocks are identical with those of the Mame and although oxidized ore to the value of $100,000 is said to have been mined from open cuts near the shaft, considerable exploratory work on two levels has failed to show any sulphide ore bodies of workable size.

No special examination was made of the mines in Carboniferous limestone near Gleeson. The Copper Belle is opened by a 300-foot shaft with three levels. The country-rock is gray limestone, which dips 30°–50° E. and contains a number of intrusive sheets of altered monzonitic or dioritic porphyry. The ore bodies of the Copper Belle occur along the contacts of this porphyry with two beds or slablike masses of limestone and have a total length from north to south of about 500 feet. The ore is mainly granular pyrite with a little chalcopyrite and scattered bunches of bornite, sphalerite, or galena. It has been deposited by irregular metasomatic replacement of the limestone, which shows no general metamorphism. The porphyry also is full of finely disseminated pyrite and carries small stringers of the same sulphide. The ore is graded into two classes and is shipped to the Clifton district, where its high percentage of sulphur and freedom from gangue make it valuable for smelting with other ores.

TURQUOISE DEPOSITS.

The turquoise occurs in joints and small irregular fractures in a bed of Cambrian quartzite that dips 65° E. and outcrops along the west side of Turquoise Hill a few feet above the contact with the decomposed granitic rock previously referred to. At the opening examined the bed has been stoped to a width of 4 feet and a depth of 75 feet or more, the bottom of the shaft being now filled with water. A short distance north of this opening and near the western boundary of the area mapped other workings, perhaps a little more extensive than those visited, have been opened on the same bed of quartzite.

SURVEY PUBLICATIONS ON COPPER.

The following list includes the principal publications on copper by the United States Geological Survey or by members of its staff. In addition to the publications cited below, certain of the folios of the Geologic Atlas of the United States contain discussions of the copper resources of the districts of which they treat. This list does not include publications on Alaska, a list of which is given in Bulletin 520, the annual report on progress of the Survey's investigations in Alaska for 1911.

The Government publications, except those to which a price is affixed, can be obtained free by applying to the Director, U. S. Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. The publications marked "Exhausted" are not available for distribution but may be seen at the larger libraries of the country.

Bain, H. F., and Ulrich, E. O., The copper deposits of Missouri: Bull. 260, 1905, pp. 233–235. 40c.

Ball, S. H., Copper deposits of the Hartville uplift, Wyoming: Bull. 315, 1907, pp. 93–107.

Bancroft, Howland, Reconnaissance of the ore deposits in northern Yuma County, Ariz.: Bull. 451, 1911, 130 pp.

Boutwell, J. M., Ore deposits of Bingham, Utah: Bull. 213, 1903, pp. 105–122. 25c.

——— Economic geology of the Bingham mining district, Utah: Prof. Paper 38, 1905, 413 pp.

——— Ore deposits of Bingham, Utah: Bull. 260, 1905, pp. 236–241. 40c.

Butler, B. S., Copper: Mineral Resources U. S. for 1911, pt. 1, 1912, pp. 255–313.

Collier, A. J., Ore deposits of the St. Joe River basin, Idaho: Bull. 285, 1906, pp. 127–139. Exhausted.

Diller, J. S., Copper deposits of the Redding region, California: Bull. 213, 1903, pp. 123–132. 25c.

——— Mining and mineral resources in the Redding district in 1903: Bull. 225, 1904, pp. 169–179. 35c.

Emmons, S. F., Geological distribution of the useful metals in the United States—Copper: Trans. Am. Inst. Min. Eng., vol. 22, 1894, p. 73.

——— Economic geology of the Butte (copper) district, Montana: Geol. Atlas U. S., folio 38, 1897. 25c.

——— Copper in the red beds of the Colorado Plateau region: Bull. 260, 1905, pp. 221–232. 40c.

——— The Cactus copper mine, Utah: Bull. 260, 1905, pp. 242–248. 40c.

Emmons, W. H., The Cashin mine, Montrose County, Colo.: Bull. 285, 1906, pp. 125–128. Exhausted.

——— Some ore deposits of Maine and the Milan mine, New Hampshire: Bull. 432, 1910, 62 pp.

CONTENTS

ILLUSTRATIONS

PLATES

FIGURES

GEOLOGY AND ORE DEPOSITS OF THE COURTLAND-GLEESON REGION, ARIZONA

BY ELDRED D. WILSON

SITUATION AND ACCESS

The Courtland-Gleeson mining region, otherwise known as the Turquoise district, is situated in the south-central part of Cochise County, southeastern Arizona, about 15 miles east of Tombstone, 20 miles north of Bisbee, and 30 miles south of Cochise. It embraces a relatively small, but prominent, group of ridges and hills that stands out steeply upon the margin of a rock-cut plain on the west side of Sulphur Spring Valley at a distance of about 2½ to 3 miles east of the main southern ridge of the Dragoon Mountains. It is generally considered* as being distinctly separate from the Pearce district, which is about 8 miles farther north. Courtland and Gleeson, which lie about 3 miles apart, comprise the centers of activity of the Turquoise district. According to the 1910 United States Census, the population of Courtland was 914, and that of Gleeson was 600; in 1920, the combined population of the two towns was about 600; and in the last few years it has continued to decrease with the decline of mining activity of the region.

Railroad connections with Douglas are furnished by a branch of the former El Paso and Southwestern (now Southern Pacific), and with Cochise by a branch of the Arizona Eastern. Good highways extend from the district to Bisbee, Douglas, Tombstone, Cochise, Pearce, and the general Sulphur Spring Valley region.

PREVIOUS INVESTIGATIONS

A few investigators have published the results of limited studies of the Turquoise district. The most important of these contributions is that of Ransome,† which, although based upon a very brief visit, most

*Hill, J. M., Mining Districts of the Western United States: U. S. Geol. Survey, Bul. 507, p. 54. 1912.

†Ransome, F. L., The Turquoise Copper-Mining District, Arizona: U. S. Geol. Survey, Bul. 530, pp. 125-134. 1913.

clearly and accurately outlines the principal features of the geology a[illegible] ore deposits in the vicinity of Courtland, and includes a geologic m[illegible]

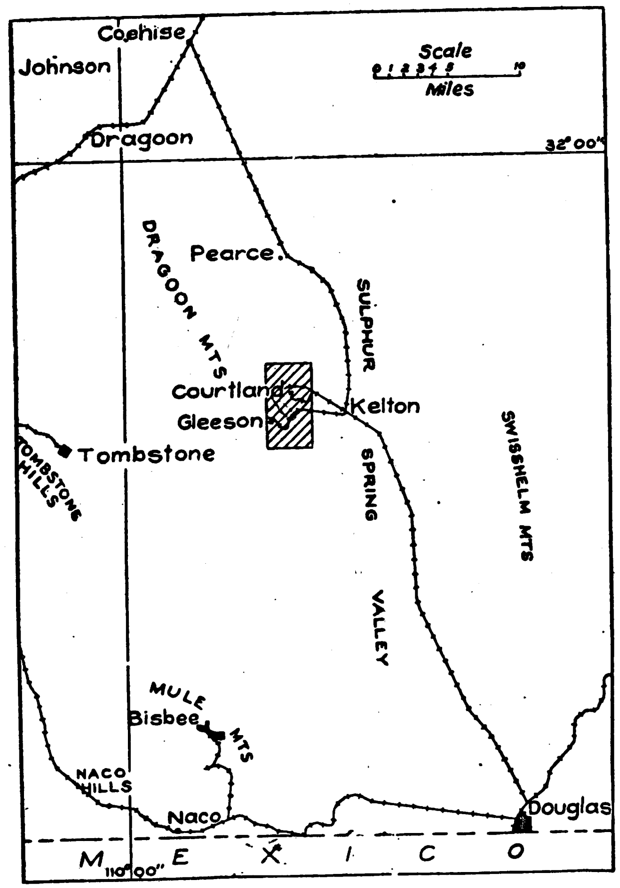


Fig. 1.—Index map showing area covered by this report.

of that part of the district by W. G. McBride. At an earlier da[illegible] Dumble* recorded briefly a few of the more salient geologic featu[illegible] of the general region. Others like Platt† and Pickard,‡ have writ[illegible] briefly about the mining activities of the district in 1909 and 191[illegible] Darton mapped the Dragoon Mountains for the Arizona Bureau [illegible] Mines Geologic Map of Arizona, and has described briefly* the general geology of the range. Mienzer and Kelton† have described the geology and water resources of Sulphur Spring Valley, but confined their geologic investigations mainly to the valley proper.

*Dumble, E. T., Notes on the Geology of Southeastern Arizona: Amer[illegible] Inst. of Min. Eng., Trans., Vol. 31, pp. 696-715. 1902.

†Platt, J. M., The Turquoise Mining District, Arizona: Eng. and Min. J[illegible] Vol. 87, p. 213. 1909.

‡Pickard, B. O., Mining in the Gleeson District of Arizona: Mining Sci[illegible] Vol. 67, No. 1722, pp. 52-53. 1913.

PURPOSE

Nothing covering the geologic details of the region about Gleeson has heretofore been published; and, since Ransome's brief study of the Courtland vicinity in 1911, many new workings have been opened. Although at present the larger mines of the district are no longer producing, there is still a fair amount of activity being evinced by lessees and prospectors, and consistent small shipments of ore have been going forth from the two camps. The purpose of investigating the geology and ore deposits of the district for the following report was, therefore, to obtain as much information of interest to mining men, prospectors, and investors as existing conditions and available time and means permitted.

FIELD WORK

The field work for the following report was done during a part of the summer of 1924, with the assistance of Mr. W. R. Hoffman, and during a few brief subsequent visits. Careful study was made of the accessible underground workings of all the producing mines and active prospects of the district. In studying surface relations, the areal geology of the district was mapped in such detail as exposures admitted. An enlargement of a portion of the United States Geological Survey Pearce Quadrangle topographic sheet was used as a base map, to furnish geographic locations and elevations. The geology of the region about Courtland, which had been mapped by McBride before 1911, was remapped in the light of new information and to fit the better base map. Certain stratigraphic, structural, and contact relations existing in the main Dragoon Range were examined to help throw light upon the more complicated conditions of the Turquoise region.

ACKNOWLEDGMENTS

Grateful acknowledgments are due all the various mining men of the region for their generous hospitality, courtesy, and information; to the officials of the Calumet and Arizona Mining Company for furnish-

*Darton, N. H., A Resumé of Arizona Geology: Ariz. Bureau of Mines Bul. [illegible] Geol. Series 3, pp. 293-296. 1925.

†Meinzer, O. E., and Kelton, F. C., Geology and Water Resources of Sulphur Spring Valley, Arizona: U. S. Geol. Survey, Water Supply Paper 320. 1913.

ing blueprints of the Maid of Sunshine Mine workings; and to Mr. W. Bennie, Manager of the Shannon Copper Company at Gleeson, for the privilege of viewing various records and private reports upon the Copper Belle Mine. The writer is indebted to Dr. A. A. Stoyanow, Professor of Paleontology at the University of Arizona, for identification of the fossils collected, and to Mr. Carl Lausen, Geologist of the Arizona Bureau of Mines, for much valuable advice, particularly upon the petrography of the igneous rocks.

HISTORY OF MINING

Valuable mineralization of silver, lead, and copper is said to have been known to exist in the Turquoise district earlier than 1877, and it is quite probable that the deposits of turquoise had long been known to the Indians, who prize the semi-precious gem material as a medicine-stone. According to Mr. John Gleeson,* the first location in the district was made in 1877 by John Collins upon a claim a short distance east of the site of the Copper Belle shaft; and, in 1878, some four or five claims, including and adjacent to the Tom Scott, were located by Josiah Bryant. Other locations were probably made at about that same time, but the hostility of Indians and the general remote wildness of the country allowed comparatively little work to be done until 1883. The Silver Bill, Gleeson, Tom Scott, and a few other smaller mines then for a while actively produced, from near the surface, oxidized ore that contained high-grade values in silver and lead, with minor amounts of gold and copper. In 1887 or 1888, according to Mr. Thomas Cowan,* of Gleeson, the Charleston claim, and probably also most of the present Tejon claims were located by Kit Charleston; and at about that time several near-by claims were located by Alexander Casey.

An unfortunate amount of bitter misunderstanding and litigation arose in several parts of the district during the early days, and continued, with great ultimate loss to all concerned, through the most prosperous years.

The Silver Bill shaft is said to have been sunk in 1890, after which time both it and the Tom Scott produced considerable rich silver-lead ore. A depression in silver prices in the early nineties, however, somewhat discouraged silver-lead mining for several years, although it probably stimulated interest in the copper prospects of the region. A few claims in the vicinity of Courtland, which settlement was then known as North Turquoise, had been located in 1890, and in the decade following many others were added. Among these early claims were parts

*Oral communication.

of the present Great Western holdings, which were located by Messrs. McCormack, Hardy, and Warnekross and later purchased by the Young brothers. The Turquoise claims, on the west side of Turquoise Ridge, are said to have been located in the early days by Messrs. Raskum, Tannenbaum, and George, and for several years occasional shipments of high-grade turquoise were made from them. In 1896 Mr. John Gleeson discovered the Copper Belle, or Leonard, deposit upon the Charleston claim, which he obtained from Kit Charleston; and, as development proceeded in the few years following, it became a noteworthy copper producer. About 1900 the settlement known prior to that time as Turquoise moved to the southeast, and was thereafter called Gleeson, after Mr. John Gleeson. The Humbot claim near Courtland began to yield an important amount of copper ore about the year 1901.

In 1907 a boom started in the Courtland vicinity, due to the interest and active prospecting of the Calumet and Arizona, Phelps Dodge, and Great Western companies. To this boom is probably due the building of the railroads into the district in 1909, when the Arizona Eastern and the El Paso and Southwestern railroad companies are said to have raced each other with construction in order to be the first to reach both Courtland and Gleeson. In previous years mining efforts had been greatly hampered by the 30 miles of wagon-haul to Cochise, which was the nearest railroad shipping-point; so the advent of railroad transportation greatly facilitated output and brought the district to its zenith of copper production in 1912. The history of the district since 1909 is principally that of the individual mines, and will be considered in connection with them in another part of this report. Broadly speaking, however, the larger mines have been idle since 1920; but production by lessees and small operators continued, with the result that the district attained its maximum lead production in 1923.

PRODUCTION

Probably the first mineral production from the district consisted of small amounts of turquoise gathered by the Indians. In the late seventies a small quantity of rich silver and silver-lead ore was mined by the early locators. The value of such ore mined during the eighties was no doubt considerable, but no record of the amount is available. According to Mr. John Gleeson,* about $50,000 worth was taken from the Tom Scott tunnel, and several other diggings yielded rich returns. Likewise, it is not known how much turquoise was mined from Turquoise Ridge; but, according ot Mr. Lynn Shattuck,* of Courtland,

*Oral communication.

it totaled several thousand dollars worth. Mr. Gleeson* states that between 1896 and 1900 about $280,000 worth (gross), principally of copper ore, was shipped from the Copper Belle Mine. According to Mr. W. J. Young, Jr., President of the Great Western Copper Company, about $100,000 worth of copper ore was produced from the Humbot claim in 1901.

The "Mineral Resources of the United States"† have recorded the Turquoise district's production since 1906. Below are listed the figures given therein for copper and lead; but, unfortunately, no data upon the amounts of gold and silver are available, because the quantity of those metals produced from Pearce and Middlemarch was included with that of the Turquoise district. The values listed in the following table have been computed from the yearly metal prices quoted by the Mineral Resources.

Year	COPPER		LEAD	
	Pounds	Value	Pounds	Value
1907	64,982	$ 12,996	Not listed	$
1908	69,716	9,203	16	0.67
1909	1,206,312	156,821	Not listed	
1910	4,767,688	605,496	Not listed	
1911	3,395,446	424,431	12,391	558
1912	8,282,308	1,366,581	44,213	1,990
1913	6,227,897	965,324	30,032	1,321
1914	1,586,237	210,970	15,015	596
1915	2,048,016	358,403	55,065	2,588
1916	3,251,394	799,843	206,306	14,235
1917	3,526,880	962,838	127,887	10,998
1918	4,365,969	1,078,394	20,725	1,471
1919	2,549,373	474,183	18,009	954
1920	1,763,050	324,401	8,918	713
1921	36,767	4,743	490	22
1922	138,893	18,743	266,546	14,660
1923	1,139,644	167,528	695,048	48,653
1924	1,329,543	174,170	635,643	50,851
Total	45,750,115	$8,115,068	2,136,304	$149,610

CLIMATE AND VEGETATION

The Courtland-Gleeson region, like much of the Southwest, has a semi-arid climate with, usually, two very dry and two rather rainy seasons each year. No official climatological data are available for the immediate region; but its elevation, which ranges from about 4,600 to

*Oral communication.

†Published annually by the U. S. Geol. Survey up to and including the year 1923, and by the U. S. Bureau of Mines since 1923.

5,840 feet above sea level, means that the rainfall amounts to from 12 to over 16 inches per year and that occasional light falls of snow occur in winter. The summers are hot, with temperatures that often reach above 100° F. in the shade, and the daily range in temperature provided by the cool nights usually amounts to about 40°. Official United States Weather Bureau figures for Tombstone, which is 15 miles to the west at an elevation of 4,550 feet, show that the average yearly rainfall there is about 14 inches, including around 5 inches of snow; the driest months are May, June, December, and February, with practically no rainfall; the wettest months are July and August, with showers often torrential; the hottest month is June, with a maximum temperature of 105°; the coldest months are January and February, with a minimum of about 16° above zero; and the average temperature for a year is about 63°. In general, the climate of the region is not unfavorable to mining operations during any season.

Natural vegetation of the immediate region consists chiefly of desert-type shrubs, trees, and foothill grasses, with the addition, in the higher elevations, of occasional representative trees of the oak-juniper zone. Such shrubs and plants as mesquite, cat's claw, greasewood (creosote), ocotillo, yucca, sotol, gambulla (desert hackberry), cholla, prickly pear, sage brush, hymenclea, and salt bush are common upon the hillsides and flats; and along washes leading down from the mountains, the ash, hackberry, and wild cherry trees are numerous. Timber for mining needs is in part brought from the Chiricahua Mountains, which are about 30 miles east of the district.

PHYSICAL GEOGRAPHY

RELIEF

The Courtland-Gleeson group of hills consists of two major ridges of north-northwest trend, and some low, scattered foothills that fringe them on the east. This group stands out steeply on the eastern margin of a rock-cut plain, or pediment, that slopes eastward from the main southern Dragoon Mountains for about 2½ miles down to the western edge of the broad, intermont, detrital plain known as Sulphur Spring Valley. This pediment is for the most part floored with quartz-monzonite of medium granitic texture, and, except for shallow, branching arroyos, is almost unbroken in its regularity. The group of hills represents the work of long-continued, normal, sub-arid erosion upon a formerly much higher and larger disordered mass that was upheaved by block faulting and igneous intrusion, and slightly influenced by later, less intense faulting.

Of the two major ridges, the northern, or Turquoise Ridge, stands immediately west of Courtland; the southern, or Gleeson Ridge, rises just northeast of Gleeson; and only a short gap separates the southwest corner of the former ridge from the northeast corner of the latter.

Turquoise Ridge trends approximately N 10° W., is about 2½ miles long, and generally less than three-fourths of a mile wide. Its cap of steeply eastward-dipping, hard, weather-resisting Bolsa quartzite presents a crest of sharply-rounded peaks, separated by broad saddles; and its slopes, which consist mainly of fine-grained granite and quartz monzonite porphyry, are very steep. A canyon cuts through the ridge, at an elevation slightly less than 5,000 feet above sea level, in the vicinity of the Leadville property. Browns Peak, which is 5,840 feet above sea level, or about 1,200 feet above the adjacent plain to the east, is this ridge's highest point.

Gleeson Ridge trends approximately N. 35° W., is about 2 miles long, and one-half mile or less in width. Composed essentially of eastward-dipping limestone and coarse-grained quartz monzonite, it has eroded into a broader, lower, and less rugged or steep-sided form than Turquoise Ridge; but, fracturing and cross-faulting have tended to produce a somewhat irregular profile. Certain higher portions of the mass attain an elevation of 5,500 feet above sea level, or about 900 feet above the adjacent plain to the east. The western side of this ridge is shown in Fig. 2.

For a distance of about 1½ miles east of these two major ridges, are a few scattered, irregularly-rounded foothills that are made up chiefly of Carboniferous limestone. In the vicinity of Courtland, they constitute rather prominent features, such as Casey and Monarch hills, that rise a few hundred feet above the plain; but toward the southeastern portion of the region mapped, they become smaller and finally merge into a mere pediment that dips under the filling of Sulphur Spring Valley.

DRAINAGE

No perennial streams exist in the region; but numerous, minutely-branching arroyos that are dry during most of the year drain the run-off of the wet seasons eastward into Sulphur Spring Valley. Of the major drainage-channels, one passes through Gleeson, another between Gleeson and Turquoise ridges, and a third through Turquoise Ridge past the Leadville and Maid of Sunshine mines. Since these

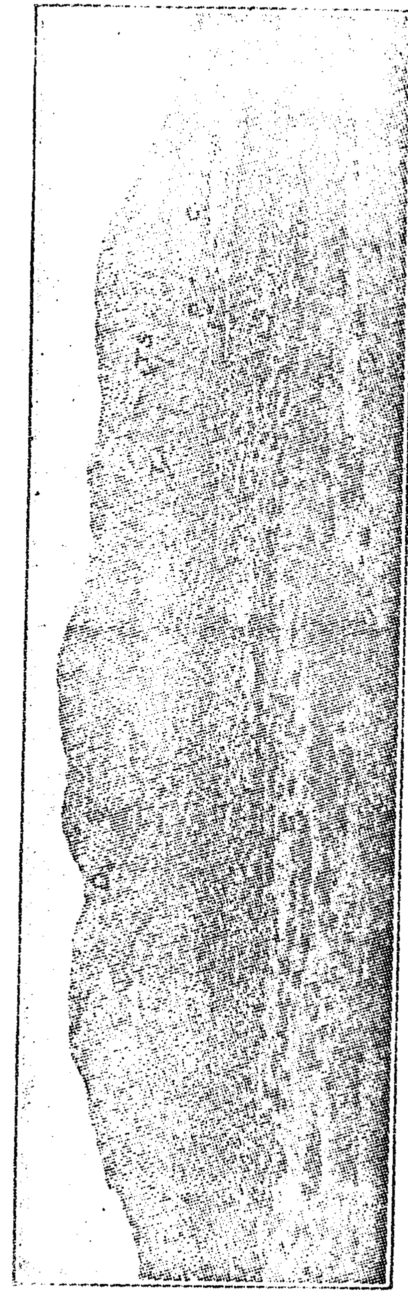


Fig. 2.—Looking east at Gleeson Ridge. C, Copper Belle shaft; D, Defiance tunnel; P, Pemberthy shaft; S, Silver Bill shaft; T, Tejon shafts; TS, Tom Scott tunnel.

washes head in the Dragoon Mountains and have a good-sized drainage area, the occasional torrential rains of the wet seasons may for a few hours fill them with violent torrents. At such times, they constitute important erosive agencies; for they move a surprisingly large amount of sand, gravel, and boulders, only to redeposit the same as alluvial fans at the edge of Sulphur Spring Valley, where gradients begin to decrease. When a fan so made becomes high enough, the arroyo may break through the natural levees it built for itself and establish a new and easier channel. A fine example of such action is exhibited by the wash that comes out from between Turqoise and Gleeson ridges. Formerly, upon leaving the canyon, this wash flowed southeastward; but now a shift toward the northeast has caused it to miss its old ..n and start a new and neighboring one.

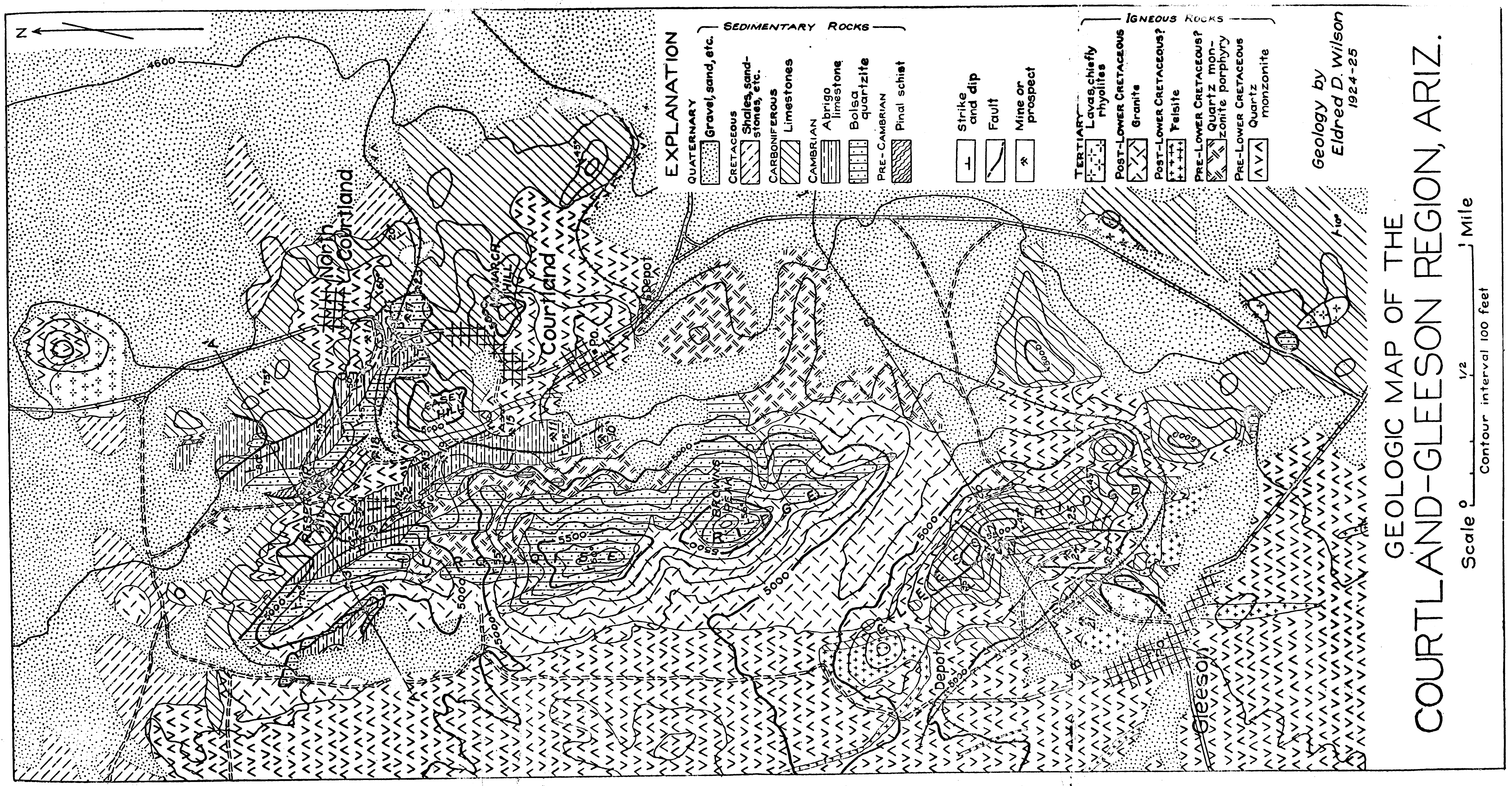
WATER SUPPLY

The Turquoise district obtains its water-supply from shallow wells situated in flat or gently-sloping areas of porous rocks, such as the fractured quartz monzonite about Gleeson, or in gulches and along arroyo-beds. Water is reached at depths of from about 30 to over 100 feet; but fluctuations in rainfall greatly affect the groundwater level, so that in wet seasons many of the wells fill to within a few feet of the surface.

Courtland and Gleeson have separate water systems, in addition to many private wells. The general supply for Courtland is pumped from two dug wells situated about 1½ miles northwest of the village, in a sand wash underlain by decomposed granite, at the northwestern termination of Turquoise Ridge. According to Meinzer,* these wells are 32 and 35 feet deep; and in 1910 they together produced, before the rainy season, about 15,000 gallons per day, but, after the summer rains, were yielding 3,200 gallons per hour. The general supply for Gleeson comes from a well in the quartz monzonite, situated about one-quarter mile west of that village, on the edge of the main sand wash. This well, according to Mr. Wm. Saundercock,† is approximatey 100 feet deep and usually contains water to within 30 feet of the surface.

*Meinzer, O. E., and Kelton, F. C., Geology and Water Resources of Sulphur Spring Valley, Arizona: U. S. Geol. Survey, Water-Supply Paper 320, pp. 114-115. 1913.

†Personal communication.



GEOLOGIC MAP OF THE
COURTLAND-GLEESON REGION, ARIZ.

GENERAL GEOLOGY

Rock formations* ranging in age from pre-Cambrian to Quaternary are represented in the Courtland-Gleeson region. Sedimentary and metamorphic rocks, igneous intrusives, both major and minor, and lava flows are all present there. In the following description, the formations are considered, within their particular classes of sedimentary and igneous, in the order of their relative ages, beginning with the oldest, or pre-Cambrian. Because faulting and igneous intrusion have so complicated and obscured many of the relations and features of the sedimentary rocks within the area, it was not possible to determine the exact total thickness of each of the formations, or, in many cases, to write detailed stratigraphic descriptions of them.

SEDIMENTARY ROCKS

PRE-CAMBRIAN

Pinal Schist: The only pre-Cambrian rock exposed in the region is a schist that is probably equivalent to the Pinal schist of the Bisbee region.† Its exposures in the Turquoise district are limited to one small area near Courtland, where a road to the Leadville and Herron mines passes through an old railway cut near the eastern foot of Reservoir Hill. Here the schist, which outcrops in a narrow belt about one-fourth mile long and up to 200 feet wide, underlies Cambrian Bolsa quartzite with which it has been thrust-faulted over Carboniferous limestone. The planes of schistosity strike N. 50° E., and dip about 40° NW.

As seen in surface exposures, the formation is mediumly schistose, and has weathered to a rusty gray color. On fresh fracture, it presents a gray, silken, and slightly granular appearance, due to abundant quartz and sericite.

Viewed in thin section under the microscope the schist from this locality is shown to consist of an aggregate of quartz, in poorly-rounded to markedly angular small grains of varying size; magnetite in irregular grains or small scattered particles; and abundant sericite and kaolin. The quartz grains generally show wavy extinction, and the sericite and kaolin, although scattered throughout the rock, sometimes are in faintly-parallel bands.

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*For the benefit of the non-technical reader, it may be stated that "formations" used in this sense does not refer to forms or shapes, but to definite units delimited for purposes of mapping and description.

†For a description of the Pinal schist of the Bisbee region, see Ransome, F. L., U. S. Geol. Surv. Prof. Paper 21, 1904, or U. S. Geol. Survey Folio 112 (reprint) 1914.

An occurrence of several square miles of pre-Cambrian schist northwest of South Pass in the Dragoon Mountains, about 5 miles in an air line west-northwest of Courtland, was mentioned by Dumble.* This schist extends unconformably beneath Cambrian Bolsa quartzite on the west side of the main mountain ridge. The strike of schistosity ranges between NW.-SE. and NE.-SW., with a dip varying somewhat from vertical. In weathered outcrops and fresh faces, the rock, except for a more pronounced fissility, is very similar to the schist near Courtland. This similarity is shown, in a thin section viewed under the microscope, to hold for composition and texture, except that more kaolin is present and certain beds are much finer-grained; but there is a more visible parallel banding within the kaolin and sericite, and a very marked parallel elongation of the quartz grains, which shows that this rock has suffered greater deformation than has the schist near Courtland.

CAMBRIAN

Bolsa quartzite: In this region, the next formation younger than Pinal schist is a quartzite that is undoubtedly equivalent to the Upper Cambrian Bolsa quartzite† of Bisbee. It is a hard, medium to fine-grained, occasionally pebbly and slightly cross-bedded formation, massive to distinctly stratified. The rock presents a semi-vitreous, light to brownish-gray fresh fracture, but weathers generally rusty brown with local dark streaks and splotches. A thin section of a fine-grained bed from near the granite contact west of Browns Peak is shown by the microscope to consist of very fine, irregularly-rounded grains of quartz mingled with larger subangular quartz grains, frequent medium-sized splotches of limonite, some sericite, and abundant kaolin in irregular branching veinlets and masses.

Of all the formations in the region, the Bolsa is the most resistant to erosion; so its surface exposures are typically bold and rugged. As may be seen from the geologic map (Plate I), the formation makes up the crest and most of the eastern side of Turquoise Ridge, where an irregular thickness of it rests, with steep eastward dip, upon the surface of intrusions of post-Carboniferous granite and quartz monzonite-porphyry. Here the maximum thickness was estimated to be about 300 feet. An area of Bolsa that has been thrust-faulted, together with Abrigo limestone and a small amount of Pinal schist, over

*Dumble, E. T., Notes on the Geology of Southeastern Arizona: Am. Inst. Min. Eng., Transactions, Vol. 31, p. 713, 1902.

†For a description of typical Bolsa quartzite, see Ransome, F. L., U. S. Geol. Survey Prof. Paper 21, or U. S. Geol. Survey Folio 112.

Carboniferous limestone lies south of the Maid of Sunshine Mine and extends northwest along the crest of a low ridge. Three small areas of quartzite, slightly cross-bedded, locally pebbly, and strikingly similar to Bolsa, occur thrust-faulted over Pennsylvanian limestone east of Gleeson.

The Arizona Bureau of Mines geologic map of Arizona shows Bolsa quartzite in the main Dragoon Range, for several miles northwest of South Pass, resting unconformably upon pre-Cambrian schist, and underlying the Paleozoic succession. This quartzite is the Dragoon quartzite of Dumble,* and resembles very closely the Bolsa of the Courtland-Gleeson region.

The economic importance of the Bolsa of the district has, so far, been limited to the deposits of turquoise contained therein.

Abrigo limestone: Next younger than the Bolsa quartzite is a dolomitic limestone and shale formation that, although fossil evidence is lacking, appears to be equivalent to the Abrigo limestone of the Bisbee and Tombstone regions. It is usually a dense, somewhat dolomitic, cherty, sandy, and shaly limestone of thin stratification; but occasional beds are of thicker, rather pure, dark-gray crystalline limestone. On fresh fracture, the rock is generally dark gray; but weathering often produces a slightly yellowish-green color, and causes the thin, parallel, alternating chert bands that are so characteristic of the formation to stand out in relief.

Metamorphism, near contacts with the quartz monzonite-porphyry or the granite, has strongly affected the Abrigo and introduced pyrite, quartz, and various silicates into it. Weathering of such affected portions has produced dull yellow to deep green colors; and oxidation of the pyrite has liberated sulphuric acid which has further bleached, stained, and altered the rock. This action has been so intense in some places, as for example in the small area west of the Mame shaft and south of the Leadville property, that the Abrigo can not always be distinguished from the quartz monzonite-porphyry in the field. Microscopic examination of a thin section of this metamorphosed Abrigo shows it to be made up of abundant garnet, usually in crystal grains, some of which have euhedral outline and exhibit zonal structure; considerable granular, colorless, and green epidote; occasional secondary quartz, in large and small irregular crystals; occasional calcite, in veinlets and poorly-formed crystals; some limonite, in veinlets and irregular splotches; and a thick sprinkling of sericite. A like examination of the deep-green metamorphosed Abrigo near the northwestern ex-

*Dumble, E. T., op. cit., p. 713.

tremity of Turquoise Ridge shows it to be similar to that just described, except for more epidote, more fine-grained quartz, and little or no garnet.

Because of the disturbances of faulting and igneous intrusion, no measurement of the thickness of the Abrigo in the Courtland vicinity was made; but there, and in the Dragoon Mountains, it appears to be considerably less than the 770 feet of the Bisbee* section, and the 700 feet of the Tombstone* section.

As may be seen from the geologic map (Plate I), the Abrigo limestone forms a belt of steeply eastward-dipping strata, intruded by quartz monzonite-porphyry, along the eastern foot of Turquoise Ridge. There, by containing the Leadville and Great Western mines, it has been of great local economic importance. The beds of this belt that lie between the prominent fault and the Carboniferous to the east are, however, lacking in typical Abrigo features, and may be younger. Another area of Abrigo occurs in the overthrust north of Courtland, and a small fault-block, intruded by granite, outcrops near the northwestern extremity of Turquoise Ridge.

Ordovician, Silurian, and Devonian rocks are not known to be represented in the Courtland-Gleeson region.

CARBONIFEROUS

Mississippian: The next formation in the district, definitely younger than Abrigo limestone, is Mississippian limestone. It is typically a medium-bedded, pure, crystalline limestone that weathers dark gray. Usually, it is of darker color and less pronounced stratification than the Pennsylvanian limestone; but there are enough exceptions to render these differences unreliable. The few poorly-preserved fossils found in the formation were stated by Dr. A. A. Stoyanow,† Professor of Paleontology at the University of Arizona, to be of Escabrosa (Mississippian) aspect. Because of the lack of sufficient distinguishing evidence, no attempt was made to separate the formation from Pennsylvanian upon the geologic map. However, the Mississippian of the district seemingly is confined to approximately the western three-fourths of the Carboniferous limestone area in the vicinity of Courtland. It is separated from the Abrigo limestone by faulting and by quartz monzonite intrusions. A minor amount of faulting, not clearly

*For a description of the Abrigo limestone of Bisbee, see Ransome, F. L., U. S. Geol. Survey Prof. Paper 21; or U. S. Geol. Survey Folio 112. For the same of Tombstone, see Ransome, F. L., U. S. Geol. Survey Prof. Paper 98, pp. 148-149

†Oral communication.

exhibited, has affected the formation itself, and precluded the possibility of measuring its thickness. Some marbleization and silicification of the limestone are apparent near the intrusive massses of quartz monzonite; but with the exception of the area north of Reservoir Hill, this metamorphism is usually slight.

The economic importance of the Mississippian limestone near Courtland has, so far, been limited to a few small, uncommercial bodies of complex sulphides.

Pennsylvanian: Resting conformably upon the Mississippian is Pennsylvanian limestone, which here is probably equivalent to the Naco limestone of Bisbee and Tombstone. It is a dense to crystalline limestone with well-pronounced bedding of from less than 1 foot to 3 or more feet in thickness. Its color varies from dark, slightly bluish-gray on fresh fracture to light gray or nearly white on weathered surfaces. Much of the limestone is quite pure; but cherty and silicified members are common, shaly beds are occasional, and, west of Gleeson Ridge, there are many somewhat sandy beds.

The following fossils, collected from Gleeson Ridge, were identified by Dr. A. A. Stoyanow: *Productus semireticulatus* Martin, *Spirifer Rockymontanus* Marcou, *Composita argentea* Shepard, *Hustedia mormoni* Marcou, *Rhipidomella pecosi* Marcou, and *Cophophyllum profundum* Me. & H. Another lot, collected east of Gleeson Ridge at the edge of Sulphur Spring Valley, contained the same forms. These fossils are typical of the Naco fauna of the Bisbee, and Tombstone regions. Apparently, all of the Carboniferous limestone mapped in the vicinity of Gleeson, and approximately the eastern fourth of the Carboniferous in the vicinity of Courtland, are of Naco age. The Naco limestone of the Bisbee region was found by Ransome to be at least 3,000 feet thick.* Its thickness in the Turquoise district, however, on account of faulting, has not been measured.

Near contacts with the igneous intrusive rocks, there is little metamorphism, beyond a slight baking and silicification, apparent in the formation.

The economic importance of the Pennsylvanian limestone of the district has been great because it contains practically all the ores mined near Gleeson.

CRETACEOUS

Resting unconformably upon the older formations in the northern portion of the area mapped, there is a series of sedimentary rocks that

*Ransome, F. L., U. S. Geol. Survey, Folio 112, p. 4.

possesses the general lithologic characteristics of the Lower Cretaceous (Comanchean) of other portions of southeastern Arizona. In the Courtland region, these rocks consist chiefly of coarse sandstones; conglomerates with poorly-rounded to angular pebbles derived from the older formations of the region, and occasional beds of shale, limestone, and quartzite. East of South Pass, two andesitic lava flows about 3 feet thick are intercalated a few feet apart within maroon, sandy, Cretaceous beds. Composition and texture of the formation are, however, characteristically variable within short distances. The prevailing color ranges from maroon to brown, yellow, or light gray, and stratification is medium to thin. No igneous rocks, except the granite, were found to cut the formation, and very little metamorphism is apparent. No ore deposits of economic importance have thus far been found in the Cretaceous of the district.

QUATERNARY

The youngest formation of the region includes the general outwash material that has been derived from erosion of higher rock masses. This material consists of variable thicknesses of ill-assorted, unconsolidated, poorly stratified gravels, sands, and silts. No fossils were found in this formation within the area mapped; but, since some of the material is obviously recent, and some appears to be older, its general age is tentatively assigned to the Quaternary.

As may be seen from the gelogic map (Plate I), the formation occurs as irregular patches and tongues occupying local flats or gullies. These masses range in constitution, progressively from their source, through coarse, bouldery talus fans to fine material, and, along the eastern margin of the Courtland-Gleeson group of hills, coalesce with the general fill of Sulphur Spring Valley.*

The economic importance of the Quaternary of the Turquoise district is limited to potential gravel, sand, and water resources, and to the support of a small number of ranches and dry-farms.

IGNEOUS ROCKS

The igneous rocks of the Turquoise district consist of intrusions of quartz monzonite, quartz monzonite-porphyry, felsite, diorite-porphyry, and granite, and flows of rhyolite. The geologic age of the intrusions, except in a few cases, can not be determined more closely than post-Pennsylvanian.

*For a description of the fill of Sulphur Spring Valley, see U. S. Geol. Survey Water-Supply Paper 320.

PRE-LOWER CRETACEOUS

Quartz monzonite: As may be seen from the geologic map (Plate I), quartz monzonite is rather prominent areally among the rocks of the region. It makes up most of the rock-cut plain west of Turquoise and Gleeson ridges, and, as irregular masses, dikes, and sills, intrudes the Carboniferous and Cambrian limestones of the district.

On fresh fracture, the rock shows abundant gray plagioclase feldspar; some pink orthoclase; semi-clear, vitreous quartz; occasional crystals of green hornblende; a few fine, honey-yellow crystals of titanite; and generously interspersed books of rich-brown biotite mica.

Under the microscope the rock is shown to consist of plagioclase, orthoclase, quartz, hornblende, biotite, and accessory magnetite, titanite, and apatite. The plagioclase, which was determined as andesine, is in well-formed crystals that show albite and pericline twinning and occasional zonary banding. Most of the feldspars have been considerably altered to kaolin and sericite. The quartz occurs as clear anhedral grains marked by trains of clear and dusty inclusions. The hornblende shows pronounced prismatic cleavage, is dark green in color, weakly pleochroic, and generally unaltered. The biotite is of dark brown color, is considerably altered to green chloritic material, and contains frequent inclusions of titanite within bird's-eye mottlings. The magnetite occurs as irregular grains, while the titanite, outside of the biotite, is in well-formed crystals, some of which show diamond-shaped cross-section. A yellowish-brown substance, probably leucoxene, is developing by alteration of the titanite. The apatite occurs as occasional well-formed, slender prisms.

Progressive changes in texture of the rock toward its borders can be seen in the field, but are better exhibited under the microscope. Some distance away from contacts with older formations, the texture is holocrystalline and hypidiomorphic, with a tendency toward equigranularity. Nearer borders, however, it becomes progressively porphyritic, and shows larger phenocrysts surrounded by a holocrystalline, equigranular groundmass.

This quartz monzonite does not weather into rugged forms, or leave residual boulders upon the surface; but it weathers into a dark gray, even contour that in places is thinly mantled with a coarse, sandy, gray soil consisting mainly of quartz and feldspar.

The intrusion is earlier in age than the quartz monzonite-porphyry, granite, felsite, and andesitic dikes that cut it, and also older than the Lower Cretaceous sediments that in some places overlie, but are not intruded, by it.

This rock is of no economic importance in the district. It has been mineralized only to a slight extent in a few places, and there is no evidence that it was responsible for the origin of the ores.

PRE-CRETACEOUS (?)

Quartz Monzonite-Porphyry: Quartz monzonite-porphyry occurs as irregular masses and dikes intruding mainly the Bolsa quartzite, Abrigo limestone, and quartz monzonite along the eastern side and foot of Turquoise Ridge.

On fresh fracture, the rock shows a dense, fine-grained, light-gray groundmass that is made up partly of fine, sparkling quartz grains and surrounds occusional larger phenocrysts of quartz and badly altered feldspar. Abundant sericite and frequent tiny grains of pyrite are scattered throughout the mass.

Under the microscope, the rock is shown to consist of a fine-grained, equigranular groundmass of anhedral quartz, in part secondary, and altered feldspar; occasional small phenocrysts of anhedral quartz and highly altered orthoclase and plagioclase; and some accessory magnetite. As secondary constituents are frequent veinlets of small, equigranular, anhedral quartz crystals, much sericite from the alteration of the feldspars, and considerable pyrite in disseminated grains. The plagioclase of the thin sections examined was too highly altered for accurate determination; but the rock has been provisionally classified by Ransome* as a quartz monzonite-porphyry.

The intrusion is younger than the quartz monzonite, but older than the granite, and by indirect evidence is regarded as pre-Cretaceous; for it appears to be responsible for the primary mineralization of the district, none of which was observed affecting the Cretaceous rocks.

This quartz monzonite-porphyry weathers into resistant outcrops of mild relief. These outcrops, due to bleaching and staining action of sulphuric acid liberated during oxidation of the pyrite, range in color from nearly white to yellow or rusty. As already stated in this report, some of the most altered outcrops of this rock are scarcely distinguishable in the field from the most altered Abrigo limestone.

POST-CARBONIFEROUS

Felsite: Felsite occurs as irregular masses and dikes intruding the quartz monzonite and Pennsylvanian limestone near Gleeson (see geologic map, Plate I).

*Ransome, F. L., U. S. Geol. Survey Bul. 530, p. 129.

On fracture, the rock in hand specimens shows a hard, very fine-grained, almost shiny, brownish-gray groundmass that is flecked with small shiny phenocrysts of quartz.

Under the microscope, the rock is shown to consist of a very fine, equigraniular groundmass of anhedral quartz, in part secondary, and badly decomposed feldspar; and a few small, scattering phenocrysts of quartz. Such feldspars as were originally among the phenocrysts are now altered to sericite. The rock is everywhere too deeply altered to permit a closer classification than felsite.

The intrusion is younger than the quartz monzonite. It was not found in contact with the granite, quartz monzonite-porphyry, or Cretaceous rocks; therefore the upper limit of its age can not be stated.

Economically, the felsite appears to be of no importance in this district.

Basic dikes: Cutting the quartz monzonite and the felsite dikes west of Gleeson, near the edge of the area mapped, are occasional narrow, fine-grained, dark-colored dikes. Although the rock is deeply altered, microscopic examination shows it to contain considerable hornblende and magnetite, scattered needles of apatite, and lath-like skeletons of badly altered plagioclase. This composition makes the dikes diorite porphyry. Their age may be either Cretaceous or Tertiary.

POST-LOWER CRETACEOUS

Granite: Granite, intrusive into the Bolsa quartzite, Abrigo limestone, Carboniferous limestone, quartz monzonite, quartz monzonite-porphyry, and Lower Cretaceous sediments, outcrops as an irregular belt and as a few dikes on the west side of Turquoise Ridge.

On fracture, the rock in hand specimen shows abundant quartz mingled with sericite, granitic texture of less than medium fineness, and color from light yellow to nearly white.

Viewed in thin section under the microscope, the rock, although deeply altered, is seen to consist of quartz, orthoclase, and microcline, together with apatite and a little zircon as accessories. Much sericite and considerable kaolin have been formed by alteration, chiefly of the feldspars. This sericite often completely surrounds, or fills cracks within, the quartz phenocrysts. The apatite occurs as long, slender needles, and the zircon as occasional short, well-formed prisms.

The granite of this district is of some economic importance because it is related to the turquoise deposits in the manner stated on page 51.

TERTIARY

Rhyolite flows: Small, isolated remnants of rhyolite flows occur, as shown on the geologic map (Plate I), southeast and east of Gleeson, southwest of the Copper Belle Mine, and north of Courtland. The greater part of Sugarloaf Hill, which lies southeast of Gleeson, just off the area mapped, is made up of rhyolite flows.

As already mentioned under structure, the rhyolites of the district have been affected by faulting, and the small mass southwest of the Copper Belle Mine appears to have been involved in the thrusting. On weathering, the rock generally appears brown and dense, but some of the flows show abundant dark mica flakes. Such portions as came in contact with the older rocks during eruption show abundant picked-up inclusions of them.

Under the microscope, a thin section of the rhyolite north of Courtland shows quartz, orthoclase, oligoclase, and biotite, in a glassy groundmass. The quartz occurs as abundant anhedral phenocrysts many of which show inlets of the groundmass. The feldspars have been considerably sericitized, and the biotite has been altered.

Thus far, the rhyolites of the district have been of no economic importance.

STRUCTURE

GENERAL STRUCTURE

In the Courtland-Gleeson region the geologic structure has been considerably affected by normal and thrust faulting. Almost nowhere are the sedimentary strata or the small remnants of lava-flows in their original flat-lying position, but dips that range from a few degrees to nearly vertical are the rule. This tilting of the strata appears to be due almost entirely to faulting rather than folding; for practically every noticeable dip can be followed to a fault, and only a few minor unbroken flexures are in evidence.

DISTRIBUTION OF FAULTING

Upon the surface, the faulting of the district is more easily detected and studied in sedimentary than in igneous intrusive rocks; and because of the essential uniformity of character of the larger porphyry areas, it is practically impossible to obtain much light upon the question of faulting within them, except where mine workings penetrate. Generally, the major amount of faulting of all the rock formations is in the vicinity of the mines. Thus, as may be seen from the geologic map (Plate I), most of the faults of the northern portion of the districts are north and west of Courtland, but east of Turquoise Ridge; and of the southern portion they are on the south and southwest sides of Gleeson Ridge.

SYSTEMS OF FAULTING

Not enough evidence could be gathered to show definitely how many systems or periods of faulting have taken place in the region; but, in the light of the best data obtainable, there appears to have been possibly three periods of normal faulting, and one of thrust faulting. No classification of these periods can be based upon directions of trend; for there seems to have been a general zone of weakness trending slightly north of west and south of east which most of the normal faults followed in a general way. The following tentative grouping, however, is proposed: (1) Oldest, or pre-porphyry faults, post-Pennsylvanian and pre-Cretaceous; (2) block-tilting faults, post-Cretaceous and possibly late Tertiary; (3) thrust faulting, probably late Tertiary; and (4) post-thrust faults, probably late Tertiary.

Pre-porphyry faulting: The oldest period of faulting is assumed to have provided a large proportion of the passageways for the dikes of quartz monzonite-porphyry that were intruded, and accompanied by mineralization, between the close of the Pennsylvanian and the deposition of the Cretaceous sediments. The rough parallelism of many of these dikes suggests that they came up along a pre-existing system of faults; and since the dikes cut the quartz monzonite, but not the Cretaceous beds, it is likely that this system of faulting took place after the first, or quartz monzonite intrusion, and before deposition of the Cretaceous. No evidence could be obtained relative to the intensity of this faulting, but the pre-Cretaceous unconformity of the region re--quired some displacement and tilting of the earlier rocks.

Block faulting: The next oldest discernible period of faulting was of the block type ,and mountain-making in magnitude. The rocks of the southern Dragoon Mountains, Turquoise Ridge, Gleeson Ridge, and Sugarloaf Hill, southeast of Gleeson, all may have been elevated and eastwardly tilted at this time, although it is possible that their uplift may have been initiated by the first period of faulting. This second period is believed to have been late Tertiary in age; first, because the supposedly Tertiary lavas of Sugarloaf Hill appear to have been affected by it; and, second, because the greater part of the mountain-making block faulting of southern Arizona is known to be of late Tertiary age.

Thrust faulting: Eroded remnants of overthrust faulting are exhibited near Courtland by pre-Cambrian schist, Cambrian Bolsa quartzite and Cambrian Abrigo limestone overlying Carboniferous limestones; and near Gleeson by Bolsa quartzite and Tertiary rhyolite faulted over Pennsylvanian limestones. The age of this great movement can not be definitely determined; it may have preceded the main mountain-making block faulting, like the best known examples of overthrusts in the West and Southwest; or, it may have taken place afterward, as suggested by the following indirect evidence: The thrust planes of the different overthrust blocks rest upon the beveled edges of underlying tilted strata, which suggests that the thrusting occurred after those underlying beds had been tilted and considerably eroded. Since the thrusting occurs well away from the edges of the higher ridges, rather than somewhere upon them, it would seem to have taken place after the present topography had been well outlined. Further evidence of such pre-existing topography is suggested by the indurated, iron oxide-cemented, stream gravels exposed east of the Armstrong shaft, along the main arroyo that passes through the Leadville property. These gravels form an irregular mantle, as much as 60 feet thick in some places, and their accumulation can be explained by a marked obstruction of the local drainage. Such an obstruction also, by slowing down run-off and promoting ground-water circulation, might help to account for the fact that the copper deposits of the Abrigo limestone north of the Turquoise Ridge-Casey Hill divide show much more secondary enrichment than do those of the Abrigo south of that divide. Inasmuch as part of the overthrust extends across the above-mentioned main drainage channel, it appears to be responsible for the obstruction. An interesting fact in this connection is that this arroyo has cut, southwest of the Leadville property, a wider gap through Turquoise Ridge than it has through the much lower ridge of overthrust strata farther downstream. This fact suggests, since there is no evidence that the overthrust mass has been appreciably raised by later normal faulting, that the drainage had eroded a gap through Turquoise Ridge before the thrust faulting took place.

If the tilting of the supposedly-Tertiary rhyolite flows of Sugarloaf Hill took place at the time of the mountain-making block faulting, then those flows are earlier than the thrusting. Furthermore, the small area of rhyolite southwest of the Copper Belle Mine appears to have been moved there by thrust-faulting. No other surface relations between the thrusting and any lava flows are exposed in the district; but Ransome* in 1911 observed abundant gray andesitic or latitic tuff-breccia on the dump of the Casey workings, and stated that it possibly had considerable extent underneath the overthrust mass of Cambrian quartzite.

Post-thrust faulting: Examples of post-thrust normal faults are well exposed in some of the underground workings of the Maid of Sunshine Mine. There is a possibility that at least part of the normal faults of the east side of Turquoise Ridge and of Gleeson Ridge belong to this period, or else represent renewed movements upon faults of an older period. The magnitude of throw of the faults of this last period could not be determined accurately; but in the Maid of Sunshine Mine a displacement of at least 50 feet is indicated. Its age is regarded tentatively as late Tertiary, but possibly some of the movement took place in Quaternary time. That this post-thrust faulting is of post-enrichment age is demonstrated by its cutting enriched ore in the Armstrong workings, and oxidized ore in the Maid of Sunshine Mine.

FOLDING

Such minor flexures as occur occasionally in the region are of little importance and only a brief mention of them need be made. In some instances they are due to the intrusion of the large mass of quartz monzonite; for example, where the railroad bends around the southeastern corner of Gleeson Ridge, the small, but fairly sharp, local folding of the Pennsylvanian limestones near the quartz monzonite contact clearly appears to have been caused by pressure of the intrusion. In some other example, as, for instance, the buckling of the Cambrian Abrigo limestones exposed along the highway near the Maid of Sunshine Mine, the cause was clearly lateral pressure of overthrust faulting.

DETAILED STRUCTURE

Turquoise Ridge: The sedimentary strata of Turquoise Ridge strike about N. 10° W., dip about 55°-75° eastward, and overlie, on intrusive contact, the younger granite and quartz monzonite-porphyry which constitute most of the west side of the ridge. Faulting, in part at least of the last period, and fracturing have considerably disturbed the strata. These faults, most of which can be found in mine work-

*Op. cit., p. 130.

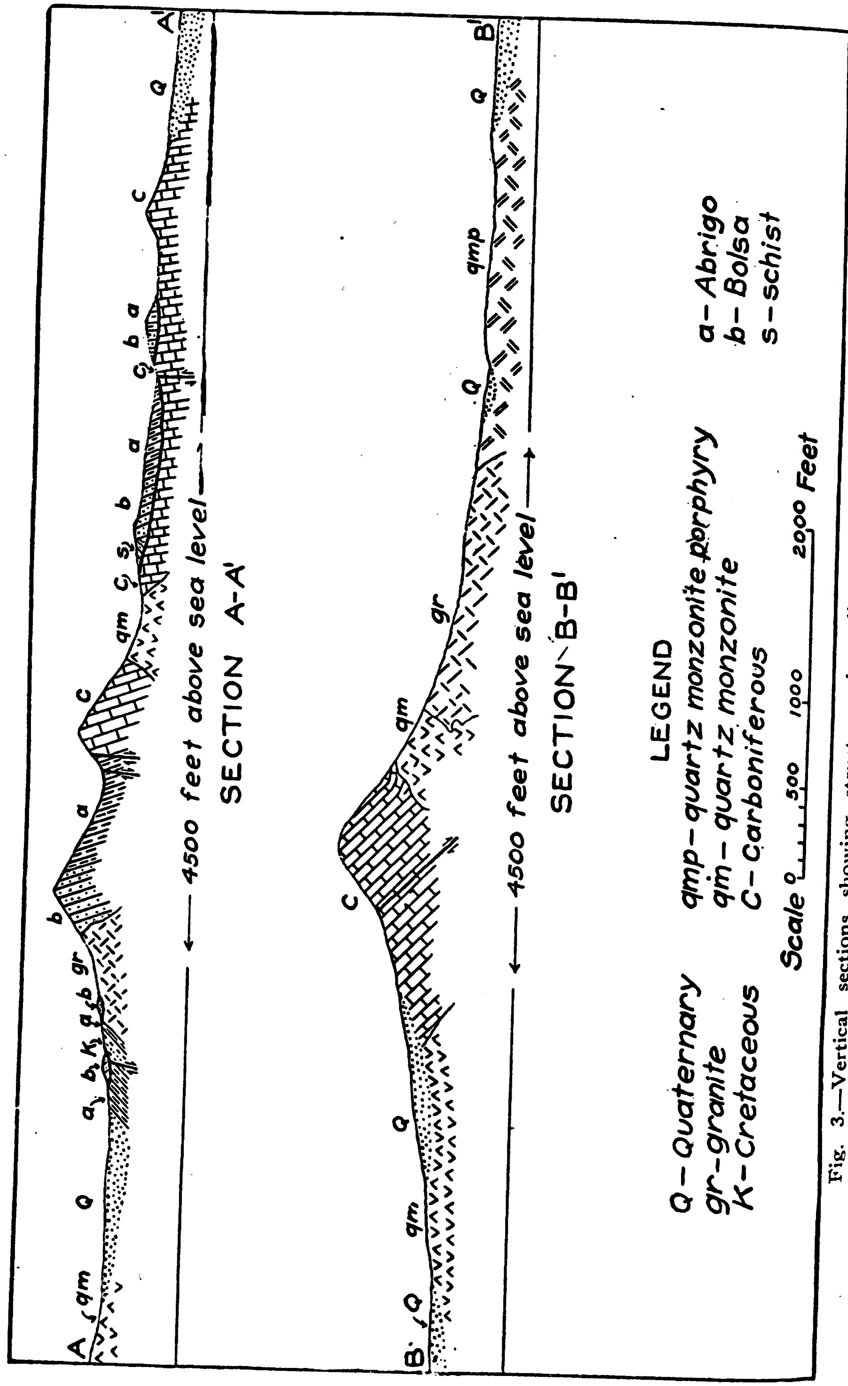


Fig. 3.—Vertical sections showing structure along lines A-A' and B-B' of geologic map.

...ngs, but are not traceable upon the surface, vary in strike from NE.-SW. to nearly N.-S., and vary greatly in amount of dip. Cambrian Bolsa quartzite forms most of the crest and the steep east side of the ridge and is flanked on the east by Cambrian Abrigo dolomitic limestone and shale. Mississippian limestones, intruded by quartz monzonite, and likewise steeply eastward-dipping, are in fault contact with the Abrigo. These relationships are illustrated in the accompanying cross-section (Fig. 3).

The structural relationship of the strata of Turquoise Ridge with those of Gleeson Ridge can only be surmised. If a single vertical fault were postulated between the two ridges, its vertical throw would need to be more than a mile in magnitude. There is evidence of some faulting in the intrusive rocks at the southwest end of Turquoise Ridge; but these faults, which can be traced only where clean-cut arroyos cross them, do not show evidence of any such great movement. Perhaps the displacement was caused by some accumulative combination of faulting, igneous intrusion, and further faulting.

Gleeson Ridge: The Pennsylvanian limestones of Gleeson Ridge in general strike about N. 30° W., dip about 45° eastward, and overlie, on intrusive contact, younger quartz monzonite and felsite. Occasional local flexing of the strata, for example, where the railroad turns around the southeastern corner of the ridge, was induced by these intrusives prior to the tilting uplift of block faulting. A fault, which strikes and dips approximately with the beds, shows a semi-continuous, limonitic, silicified, brecciated outcrop along the west slope of the whole length of the ridge; but near the Silver Bill shaft it appears to be broken by a cross-fault, and near the Tom Scott tunnel it forks into two parts, one of which continues south into the quartz monzonite. Exposures are poor at the point of contact with the quartz monzonite, but the east side of this branch of the fault appears to be down-thrown, with a vertical displacement of about 100 feet. The above-mentioned cross-fault, which passes through the saddle of the ridge above the Silver Bill shaft, appears to be nearly vertical and to have a downthrow on the north of about 125 feet.

Overthrust at Courtland: Exposed in the vicinity of the Maid of Sunshine Mine at Courtland and extending northwest is a mass slightly over a mile long by about one-eighth to one-fourth mile wide, of Abrigo limestone, Bolsa quartzite, and pre-Cambrian schist, plainly overthrust on top of Carboniferous limestones.

Ransome* states that at the Mary shaft the shattered, overthrust

*Ransome, F. L., op. cit., p. 129.

quartzite is 115 feet thick; that southeast of there the layer of brecciated material produced by the overthrust is steeply upturned; the under surface of the mass is apparently irregular; and that principal fractures dip steeply to the northwest, suggesting that the thrust may have come from that direction.

Except for some considerable variations toward the northwest end of the overthrust, its strata strike about N. 45° W., and dip from 45° to 65° NE. The small wedge of pre-Cambrian schist, however, strikes N. 50° E., and dips 40° NW. Except for some local variations near the southeast end of the mass, the beveled strata upon which the overthrust rests strike in general about N. 30° to 40° W., and dip 60° to 75° NE. Opposite edges of the thrust plane, practically wherever exposed, are within 100 feet of being equal in elevation. Later normal faulting has affected the overthrust, particularly near its southeast extremity.

Breccia made by the thrusting, where exposed on the surface, consists of an irregular, indurated aggregate ranging in thickness from a few inches up to 30 feet or more, and varying in texture from gouge up to fragments, several inches across, of iron-stained, unsorted quartzite, quartz monzonite, porphyry, and altered limestone. Where explored by the underground workings, however, this breccia shows less induration, and is considerably thicker. Whether all of the ore-bearing, limonitic, breccia-like material that lies beneath the overthrust in the Maid of Sunshine Mine is or is not overthrust breccia is unknown. There is a possibility that at least part of it may represent a pre-thrust stream-gravel deposit.

Overthrusts near Gleeson: A short distance southwest of the Copper Belle, or Leonard, shaft, and east of the Shannon Copper Company mine office, is a small knoll of Cambrian Bolsa quartzite that clearly has been thrust over Pennsylvanian limestone. This area of quartzite is about one-eighth of a mile long and 250 feet wide. The overthrust plane strikes about NW.-SE., and dips about 20° SW. The low ridge of rhyolite that extends south of the Shannon office, and adjoins the knoll of Bolsa quartzite just mentioned, shows evidence of a fault plane skirting the base of its southeast, south, and southwest margins. This fault has about the same general strike and dip as, and appears to be a continuation of, the thrust fault plane that underlies the adjoining knoll of Bolsa quartzite.

Near the south extremity of Gleeson Ridge, about three-fourths of a mile east of the Gleeson postoffice, is another small area of overthrust Bolsa quartzite lying on Pennsylvanian limestone. It is about

... feet long and 250 feet or less wide. The fault plane dips southward about 15°, and disappears under Quaternary valley-fill.

Constituting a small but prominent knoll about 1¼ miles southeast of Gleeson, just east of the main highway, is still another area of overthrust quartzite. The quartzite is slightly cross-bedded, occasionally pebbly, and typical Bolsa. Its beds strike N. 45° W., and dip 40° SW. The plane of thrusting here strikes NE.-SW. and dips 15° NW.

Probably these three isolated overthrust masses just described represent erosional remnants of a once-continuous, single body. The fact that there is not over 150 feet difference in elevation, through a distance of 1¼ miles, between the two most widely separated masses suggests but slight influence of post-thrust faulting upon them.

GEOLOGIC HISTORY

Exposures of the oldest rocks of the district, namely, the pre-Cambrian schists, are so limited that very little of the record of the series to which they belong can be read; and the history of the long train of events that preceded the Cambrian is lost, except for what can be inferred from other localities. Microscopic examination of the schist from South Pass, and from near Courtland, shows it to be of sedimentary origin. A great series of fine, sandy sediments, therefore, was deposited in this portion of Arizona in pre-Cambrian time. Before Cambrian they were subjected to sufficient deep burial, squeezing, and folding to bring about their entire recrystallization and present schistosity. Then they were uplifted and subjected to the extensive and prolonged erosion that is recorded by the present unconformity beneath the Cambrian Bolsa quartzite.

Whether or not the very long and widespread erosion that started before Cambrian time continued uninterrupted in this region until Upper Cambrian, or Lower and Middle Cambrian passed without deposition, or such sediments as were deposited suffered complete erosion, remains unknown. The earliest Cambrian sediments of the region are probably equivalent to the Upper Cambrian Bolsa quartzite of the Bisbee district. The well-rounded pebbles in the lower beds of this formation consist chiefly of vein quartz, and seem to represent wave-erosion material derived from the old schist land mass. That all of the Bolsa was probably deposited along the shore of a steadily advancing sea is suggested by its slightly cross-bedded and pebbly texture throughout large areas.

After the deposition of the Bolsa, a rather rapid subsidence lowered the region into deeper, quieter waters, and allowed the Upper Cambrian Abrigo dolomitic limestone and shale to be deposited. That primitive marine life, such as linguloid brachiopods, pteropods, and trilobites, was present in these waters is demonstrated by the fossil remains in the Abrigo of other localities.

Although it is possible that the Abrigo formation as mapped at Courtland may be in part of Ordovician age, no Ordovician fossils were obtained, and no known Ordovician or Silurian beds are present anywhere in the region. If the Ordovician limestones that are well represented near Dos Cabezas, about 30 miles to the northeast, or any Silurian beds, ever extended over the Turquoise region, they were removed by pre-Devonian erosion.

Whether non-deposition, or merely erosion, continued until Upper Devonian time cannot be detected; but the region was again beneath the sea during Upper Decvonian time, and Martin limestone, containing abundant Devonian fossils, was deposited with apparent conformity upon the Abrigo formation in the Dragoon Mountains area. No definitely Devonian rocks were observed at Courtland and Gleeson; but probably they have been obliteratd by faulting and igneous intrusion.

In Mississippian time the region was again beneath the sea, and fairly quiet waters obtained for a long period, with the result that a thick series of limestones, namely, the Escabrosa, was deposited throughout this portion of the Southwest. Apparently there was no break in sedimentation between Mississippian and Pennsylvanian, and the long continuance of deposition through the latter period resulted in a very thick limestone formation, namely, the Naco, which Ransome* found to total 3000 feet in the Bisbee region. There is no evidence of Permian strata in the Turquoise region, and if any were deposited they suffered complete removal by post-Pennsylvanian erosion.

Some time after the deposition of the Naco limestone the region was again elevated above sea level, and subjected to long-continued erosion. Intrusion of large, irregular masses of quartz monzonite took place either during or after this uplift; then came the intrusion of dikes and masses of quartz monzonite-porphyry, and, possibly also, of felsite and the diorite porphyry. Inasmuch as these dikes are often roughly parallel, they are believed to have been preceded by faulting; and, because they were not found cutting any rocks later than Pennsylvanian, they are regarded as pre-Cretaceous. Primary mineralization, resulting in the primary ores of Courtland and Gleeson, occurred during this interval, and is believed to have been related to the intrusion of the quartz monzonite-porphyry.

*Ransome, F. L., Bisbee Folio: U. S. Geol. Survey Folio 112 (Reprint). 1914.

No Triassic or Jurassic sediments are known to be present in this portion of Arizona; but, if any ever existed, they were removed by pre-Cretaceous erosion. In Lower Cretaceous time the region again subsided, so that, probably along the shore of an advancing sea, and in alternating deep and shallow water, a great thickness of conglomerates, sandstones, limestones, and shales were laid down. No upper Cretaceous rocks are known in this portion of Arizona; and, if any ever were deposited, they were stripped away by post-Cretaceous erosion.

After deposition of the lower Cretaceous sediments of the region, irregular bodies and dikes of granite were intruded, mainly near the base of the Bolsa quartzite.

Considerable outpourings of lava, of which but a few remnants of rhyolitic flows remain, spread over the Turquoise region in Tertiary time.

Presumably in the late Tertiary, mountain-making, block faulting elevated, with more or less tilting, a large portion of the Southwest, and initiated the present topography. The advance of erosion was accompanied by enrichment of the ore bodies. In the wide valleys separating the mountain ranges, deposition resulted from erosion of the uplands. The age of this deposition, at least in the San Pedro Valley, has been determined by Gidley,* from vertebrate fossil remains, as Pliocene; and the climate indicated by these fossils must have been sufficiently moist to support abundant plant life.

After considerable erosion had ensued, nearly flat thrust faulting took place in the Courtland-Gleeson vicinity. Further normal faulting, which may have continued into the Quaternary, followed.

Quaternary time in the region was marked principally by further erosion of the uplands, deposition in the valleys, and the completion of the present-day topography.

ORE DEPOSITS

MINERALOGY

Listed below are the ore and gangue mineral species that occur in the Courtland-Gleeson mining district. The metallic minerals are

*Gidley, J. W., Preliminary Report on Fossil Vertebrates of the San Pedro Valley, Arizona: U. S. Geol. Survey, Prof. Paper 131-E, pp. 120-121. 1922.

grouped according to their principal metal, and listed as nearly as possible in the order of their local economic importance. The gangue minerals, or minerals of no economic importance, occur associated with the ores and consequently deserve attention. Following the list each mineral is described briefly as to chemical composition, simple physical aspects, association, and peculiarities of occurrence in the district. It is to be noted, however, that the percentage of metal stated for a given mineral holds only for strictly pure material.

COPPER MINERALS

Chalcopyrite	Tenorite (melaconite)
Chalcocite	Copper Pitch
Bornite	Chrysocolla
Malachite	Native copper
Azurite	Turquoise

LEAD MINERALS

Cerussite	Wulfenite
Anglesite	Galena

SILVER MINERALS

Cerargyrite	Native silver

GOLD MINERALS

Native gold

ZINC MINERALS

Smithsonite	Sphalerite
Calamine	Aurichalcite

IRON MINERALS

Pyrite	Magnetite
Limonite	Jarosite
Hematite	Xanthosiderite

MANGANESE MINERALS

Pyrolusite	Wad

GANGUE MINERALS

Quartz	Kaolinite
Sericite	Garnet
Calcite	Chlorite
Epidote	Aragonite

COPPER MINERALS

Chalcopyrite, or Copper Pyrites ($CuFeS_2$): A copper-iron sulphide containing 34.5 percent copper. Color brass-yellow, often tarnished; luster metallic; can be scratched with a knife; usually massive. Chalcopyrite occurs, in varying amounts, with all the unoxidized ores of the district. The mineral is of primary origin. It gives the pyritic deposits most of their copper value, and is probably the most important copper mineral of the district.

Chalcocite, or Copper Glance (Cu_2S): A cuprous sulphide containing 79.8 percent copper. Color blackish lead-gray, but dull when tarnished; luster metallic to sooty; soft enough to be cut readily by a knife; crystalline to massive. Chalcocite occurs with bornite, chalcopyrite, and pyrite in the later Leadville workings, with chalcopyrite and pyrite in the Herron workings, and to a slight extent in some of the pyritic ores of the older Leadville, Great Western, Copper Belle, and Tejon mines. The mineral is supergene, or secondary, in origin, and of considerable economic importance in the district.

Bornite, or Peacock Copper (Cu_5FeS_4): A copper-iron sulphide containing 63.3 percent copper. Color pinchbeck-brown on fresh fractures, but tarnishes readily to peacock colors; luster metallic; soft enough to be cut readily by a knife; usually massive. It occurs with chalcopyrite, chalcocite, and pyrite in the later Leadville workings, and as scattered bunches with galena and sphalerite in the older Leadville, Great Western, Copper Belle, and Tejon mines.

Malachite ($CuCO_3\ Cu\ (OH)_2$): A basic cupric carbonate containing 57.4 percent copper. Color bright green; luster dull to glassy; can be scratched by a knife; massive to radiating-fibrous. Associated with azurite, probable melaconite, cuprite, pyrolusite, limonite, and kaolin, malachite occurs in large masses in the Maid of Sunshine Mine; and with generally similar mineral associations it has been found in smaller masses near the surface in the oxidized zone of practically every mine in the district.

Azurite ($2CuCO_3.\ Cu\ (OH)_2$): A basic cupric carbonate containing 55.22 percent copper. Color various shades of blue; luster glassy to dull; can be scratched by a knife. Azurite occurs, both massive and in beautiful crystalline forms, along with malachite, but generally less abundantly, in the oxidized zone of most of the mines in the district.

Melaconite (CuO): The black, earthy, massive variety of tenorite, a cupric oxide containing 79.8 percent copper. Probable tenorite occurs most notably in the Maid of Sunshine Mine associated with malachite, azurite, cuprite, pyrolusite, limonite, and kaolin. Associated more or less with these minerals, it is found in small amounts in the oxidized zone of most of the mines of the district.

Copper-pitch ore: An impure oxide, containing variable amounts of copper, zinc, manganese, iron, and aluminum oxides, together with considerable silica and water. Color dark brown to black; luster sometimes dull, but generally shiny; can be scratched rather easily by a knife; brittle. The substance occurs with malachite, azurite, and probable melaconite in the oxidized portions of most of the copper ore bodies of the district.

Cuprite, or Red Copper (Cu_2O): A cuprous oxide containing 88.8 percent copper. Color various shades of red; subtransparent; luster glassy to dull; can be scratched by a knife; usually in crystalline masses. Cuprite occurs with the other oxidized copper minerals, but sparingly, in the oxidized zone of most of the mines of the district.

Chrysocolla ($CuSiO_3 \cdot 2H_2O$): A hydrous copper silicate containing 36.05 percent copper. Color mountain-green to sky-blue, but brown to black when impure; luster dull to waxy and glassy; can be scratched rather easily by a knife; enamel-like. The mineral occurs in the oxidized portion of the copper properties, usually associated with malachite, azurite, limonite, kaolin, and quartz. It is not an important constituent of the ores.

Native copper (Cu): The metal was found in the Armstrong workings as small, thin flakes within soft limonitic material.

Turquoise ($CuO \cdot 3Al_2O_3 \cdot 2P_2O_5 \cdot 9H_2O$): A hydrous phosphate of aluminum and copper. Color sky-blue to greenish gray; luster somewhat waxy; difficult to scratch by a knife; usually amorphous. The mineral occurs as described on pages 51 and 52. From it the district was named.

LEAD MINERALS

Cerussite, or White Lead Ore ($Ph\ CO_3$): A carbonate of lead, containing 77.54 percent lead. Color white, gray, to grayish black; often transparent; luster glassy sometimes like oiled glass; can be cut readily by a knife; heavy; crystalline to massive and compact. The mineral occurs associated with varying amounts of anglesite, limonite, and oxides of manganese in the oxidized lead-silver deposits. It is the the principal lead ore of the district.

Anglesite ($Pb\ SO_4$): A sulphate of lead containing 68.3 percent lead. Color white, tinged yellow and gray; transparent to opaque; luster glassy to dull; can be cut readily by a knife; heavy; crystalline to compact and massive. The mineral occurs, generally surrounded by anglesite, associated with limonite and manganese dioxide in the oxidized lead-silver deposits. Good crystals of it lining cavities were ...ed in the Silver Bill Mine.

Wulfenite ($PbMoO_4$): A lead molybdate containing 56.43 percent lead and 26.14 percent molybdenum. Color generally bright red, orange, or yellow; luster resinous to adamantine;* can be cut readily by a knife; heavy; commonly as thin tabular crystals. The mineral occurs in the Mystery, Silver Bill, and Tom Scott workings as crystals lining cavities and scattered through the ores.

Galena, or *Lead Glance* (PbS): Lead sulphide, containing 86.6 percent lead. Color pure lead-gray; luster metallic; can be cut readily by a knife; cleaves into cubes; usually as crystalline masses intergrown with other sulphides; heavy. The mineral occurs, associated with sphalerite, chalcopyrite, and bornite, as scattered bunches in the pyritic ores of the district.

SILVER MINERALS

Cerargyrite, or *Horn Silver* (Ag Cl): Silver chloride, containing 75.3 percent silver. Colorless to grayish-green; transparent to translucent; luster resinous to adamantine; soft enough to be cut by fingernail; cubic crystals to wax-like masses. Cerargyrite occurs disseminated in the oxidized lead-silver ore deposits of the district. Crystals of it are occasionally found in the Silver Bill and Mystery mines.

Native silver (Ag): No native silver was seen in the ores of the district, but very minor amounts doubtless are contained within the gold that is present in practically all the ores.

GOLD MINERAL

Native gold (Au): Practically all the ores of the district carry a small amount of gold, usually less than one ounce per ton, that is too finely scattered to be visible even with aid of the microscope.

ZINC MINERALS

Smithsonite, or *Dry Bone* ($Zn\ CO_3$): Zinc carbonate, containing 52.15 percent zinc. Color white, often gray, green, or light brown; subtransparent; luster glassy to pearly; difficult to scratch by a knife; rarely well crystallized. The mineral occurs as radiating crystalline masses lining cavities, and also as porous incrustations, associated with calamine, limonite, and manganese oxides, and with lesser amounts of

*Diamond-like.

cerussite, anglesite, wulfenite, and probable melaconite, in the Mystery and Silver Bill workings.

Calamine ($H_2Zn\ SiO_5$): A hydrous zinc silicate containing 37.[illegible] percent zinc. Resembles smithsonite, but does not effervesce in acid. The mineral occurs in the same manner as, and associated with, smithsonite in the Mystery and Silver Bill workings.

Sphalerite, or *Zinc Blende* (ZnS): Zinc sulphide, containing 67 percent zinc. Color commonly brown, yellow, or black; luster resinous to adamantine; can be scratched easily by a knife; powder is yellow to light brown; usually as crystalline masses intergrown with other sulphides. Sphalerite occurs in scattered bunches associated with galena, chalcopyrite, and bornite in the pyritic deposits of the district.

Aurichalcite ($2\ (Zn, Cu)\ CO_3 .\ 3(Zn, Cu)\ (OH)_2$): A basic carbonate of variable percentages of zinc and copper. Color pale-green to sky-blue; luster vitreous. The mineral occurs as cavity-druses and incrustations in the oxidized lead-silver deposits.

IRON MINERALS

Pyrite, or *Iron Pyrites* (FeS_2): Iron disulphide, containing 46.6 percent iron and 53.4 sulphur. Color pale brass-yellow, may tarnish darker; luster metallic; is crumbled slightly, but not cut, by a knife. Pyrite occurs abundantly as stringers, disseminations, and large crystalline masses in the unoxidized zone of all the ore deposits of the district. It also occurs widely as fine disseminations in the quartz monzonite-porphyry.

Limonite ($2Fe_2O_3 .\ 3H_2O$): A hydrous iron oxide theoretically containing 59.8 percent iron. Color ocher-yellow to dark brown; luster dull; massive to earthy; sometimes as iridescent films. Limonite occurs in the oxidized portions of all the ore deposits of the district, and forms the superficial dark brown stain that marks the areas of iron mineralization. It is a particularly abundant constituent of the oxidized lead-silver ores.

Hematite (Fe_2O_3): An iron oxide containing 70 percent iron. Color brick red to dark red and dark gray; luster dull to metallic; difficult to scratch with a knife. The mineral occurs as the specular or flaky brilliantly metallic variety associated with the ores of the pyritic deposits in Abrigo limestone, and as the earthy variety with the oxidized ores of the district.

Magnetite (Fe_3O_4): An iron oxide containing 72.4 percent iron. Color iron-black; luster metallic to rather dull; rather difficult to scratch with a knife; strongly magnetic; crystalline to massive. Magnetite occurs as occasional thickly disseminated masses in the ores of the pyritic deposits in Abrigo limestone.

Jarosite ($K_2\ Fe_6\ (OH)_{12}\ (SO_4)_4$). A hydrous sulphate of potassium and iron theoretically containing 33.4 percent iron and 9.4 potash. Color ocher-yellow, yellowish-brown, clove-brown; luster vitreous, brilliant to dull. The mineral occurs generally as small flaky bunches associated with limonite in the oxidized lead-silver deposits.

Xanthosiderite ($Fe_2O_3 .\ 2H_2O$): A hydrous iron oxide containing 57 percent iron. Color brownish-red, brown, to golden yellow. The mineral occurs as fine needles coating azurite in the Maid of Sunshine Mine.

MANGANESE MINERALS

Pyrolusite (MnO_2): Manganese dioxide, theoretically containing 63 percent manganese, but usually impure. Color generally black, sometimes very dark steel-gray; luster metallic to dull; soft enough to be scratched with a finger nail. Pyrolusite occurs as dull, earthy masses and as semi-crystalline crusts, associated usually with some wad, in the oxidized ores of the district.

Wad: An impure hydrous mixture of various oxides of manganese, containing variable proportions of the oxides of copper, iron, and a number of other elements. The proportion of manganese is usually relatively low. Color brownish black; luster dull, earthy; soft enough to soil the fingers. Wad occurs as earthy masses with pyrolusite in most of the oxidized ores of the district.

GANGUE MINERALS

Quartz (SiO_2): Silicon dioxide. Colorless to white; luster glassy; hard enough to scratch glass; six-sided crystals and crystalline masses. Quartz is present as a secondary constituent in all the mineralized limestones, and particularly in those containing the pyritic ores. It is associated, in varying amounts, with practically all the ores of the district.

Sericite ($H_2KAl_3(SiO_4)_3$): Orthosilicate of aluminum and potassium. Colorless to white; pearly to dull; usually as small micaceous flakes. The mineral is a common constituent of the ores and wall-rock of the pyritic and turquoise deposits, and is generally conceded to be a product of hydrothermal alteration.

Calcite ($CaCO_3$): Calcium carbonate. Colorless to white; glassy; soft enough to be cut readily by a knife; easily cleavable into rhombs; usually as crystalline masses. Varying amounts of the mineral occur in the wall-rock and ores of all the deposits, except those of turquoise, of the district.

Epidote (HCa_2 (Al, Fe)$_3$ Si_3 O_{13}): An orthosilicate of calcium, aluminum, and iron. Color yellowish-green; transparent to opaque; luster glassy to resinous; hard enough to scratch glass; prismatic crystals and crystalline masses. Epidote is a very common wall-rock constituent of the pyritic copper deposits in Abrigo limestone.

Kaolinite ($H_4Al_2Si_2O_9$): Hydrous aluminum silicate. Color white; luster dull; rather soft; earthy to scaly masses. Kaolin is particularly abundant in the Silver Bill Mine, where bands of it and manganese dioxide often occur alternating. The development of the mineral in the unmetamorphosed limestones may be explained by the action of aluminum sulphate on free silica in the presence of cupric sulphate; and in the other rocks by the alteration of sericite during oxidation.

Garnet ($Ca_3Fe_2(SiO_4)_3$, variety andradite): Calcium-iron silicate. Color yellowish-brown; luster glassy; hard enough to scratch glass; commonly as crystals. Garnet is a common wall-rock constituent of the pyritic copper deposits in Abrigo limestone.

Chlorite: A complex hydrous silicate of magnesium, iron, and aluminum. Color dark green; luster dull to pearly; soft; usually as foils and masses of flakes. Chlorite is a common superficial weathering product of the mineralized Abrigo limestone.

Aragonite ($CaCO_3$): Calcium carbonate. Color white, gray, or yellowish; luster glassy; soft enough to be cut readily by a knife; commonly stalactitic or stalagmitic. Probable aragonite occurs associated with the lead-silver deposits as stalactites and stalagmites within limestone solution-cavities.

CLASSES OF DEPOSITS

Two major classes of ore deposits, namely, copper and lead-silver, are present in the Turquoise district. A third class, but of less economic importance, are the turquoise deposits from which the district derived its name.

The following description deals with the general features of location, geology, ore bodies, ore minerals, origin, enrichment, and oxidation of each type of these classes of deposits. Descriptions of the mines mentioned occurring within them are given in another part of this report.

COPPER DEPOSITS

Types: The principal copper deposits of the district were grouped by Ransome* into the following types: (A) Blanket-like, oxidized deposits associated with thrust faulting; (B) pyritic deposits, with some associated bodies of oxidized and enriched ore, in the Cambrian dolomitic limestone and shale; (C) pyritic deposits, with associated bodies of oxidized and enriched ore, in the Carboniferous limestone.

Blanket-Like Copper Deposits Associated with Thrust Faulting:

Location: Restricted to the area of thrust faulting north of Courtland is a type of copper deposit that has been very important in the district through containing the Silverton, April Fool, Germania, Mary, and Maid of Sunshine mines, and smaller prospects.

Geology: As already described in this report under Structure, there lies upon the Carboniferous limestone, beneath overthrust Bolsa quartzite and Abrigo limestone, an irregular blanket of thrust breccia that consists of angular to poorly-rounded fragments of quartzite, limestone, porphyry, and quartz monzonite. The size of these fragments varies from that of gouge and sand up to boulders several feet through. Much of the material in general resembles old "gob" or stope-filling, and there is a possibility that part of it may be pre-thrust stream gravel rather than true thrust breccia. The thickness of the overthrust material above the breccia is rather variable; for instance, it is 115 feet thick† at the Mary shaft, and about 100 feet at the Maid of Sunshine shaft. Later faulting and fracturing have affected the overthrust mass considerably, so that there are many sharp irregularities to its under surface and frequent abrupt terminations to the horizonal continuity of the breccia.

Ore bodies: The ore bodies are found mainly in this breccia, and to some extent in the upper surface of the underlying limestone. Although somewhat blanket-like, they vary greatly in size and shape, as shown by Fig. 4. Their thickness ranges from that of a thin streak up to about 50 feet, with an average of about 15 feet in the Germania Mine, according to Ransome, and about that amount in the Maid of Sunshine Mine.

*Ransome, F. L., The Turquoise Copper Mining District, Arizona: U. S. Geol. Survey, Bulletin 530, p. 131. 1913.

†Ransome, F. L., op. cit., p. 129.

Ore minerals: The ore minerals which are entirely oxidized, occur as replacement masses, streaks, and occasional cavity-linings, with much earthy limonitic and some manganitic matter. Malachite, azurite, chrysocolla, cuprite, probable tenorite (melaconite), copper-pitch, xanthosiderite, and copper-stained kaolin are abundant. No sulphides whatever were observed in the ores; but some very lean pyrite has been reported as occurring disseminated in the Carboniferous limestone below the 300-foot or water level of the Maid of Sunshine Mine.

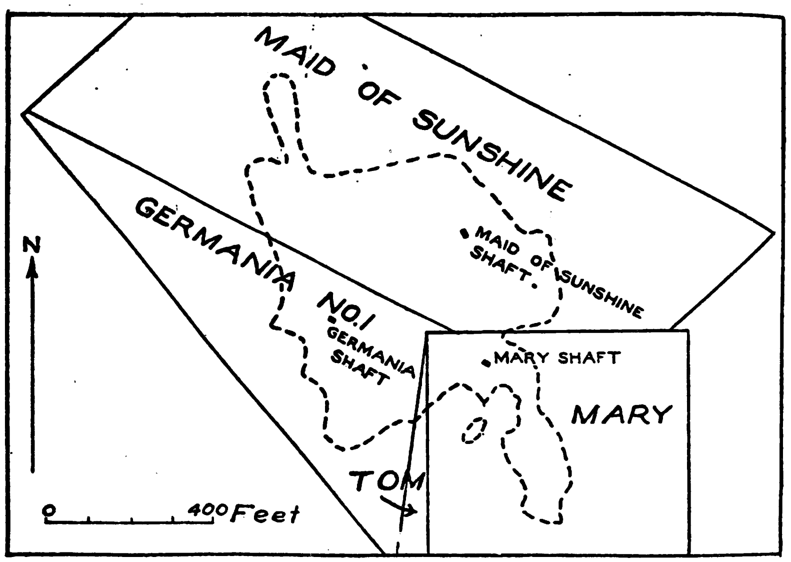


Fig. 4.—Sketch showing approximate extent of ore bodies on Maid of Sunshine, Germania No. 1, Tom, and Mary claims.

Origin: It does not seem likely that the original, or primary, sulphides which provided the copper for these oxidized ores were contained in the overthrust capping; for there is no notable gossan, or any other suggestion of their presence. Nor is it possible that the primary ores were deposited in the breccia and oxidized essentially in place: for all the available evidence indicates that the primary mineralization took place before the thrusting occurred. A seemingly tenable explanation, however, is that the primary ores were contained within the area of Cambrian Abrigo limestone along the eastern foot of Turquoise Ridge. As already shown in this report under Structure, the overthrusting probably obstructed the eastward-flowing drainage channel at a point about one-fourth mile west of the Maid of Sunshine Mine. Consequently, the surface run-off and the sub-surface drainage of the mineralized Abrigo limestone area that lies between the Turquoise Ridge-Casey Hill divide and Reservoir Hill could escape easiest by seeping through the loosely-consolidated breccia and gravel beneath the overthrust. Those waters that came from, or passed over, the mineralized Abrigo limestone area would naturally contain more or less copper in solution as sulphates; for the oxidation of the abundant pyrite would generate sulphuric acid and ferric sulphate, which are active solvents of nearly all natural sulphides. Due to the fact that this Abrigo limestone is rather impure and has been considerably altered by contact metamorphism, it did not have the power to neutralize these acid solutions as rapidly as they were formed; consequently the dissolved copper remained in solution, and that which did not descend joined the surface run-off and sub-surface drainage. Upon filtering slowly through the comparatively shallow and active oxidation zone of the breccia and gravel beneath the overthrust, however, the copper-bearing solution would replace the more nearly pure limestone fragments, and even some of the quartzite fragments, thereof with malachite, azurite, and chrysocolla. The cuprite, probable tenorite, copper-pitch, and manganitic oxides in part may have been deposited directly, or be the result of later oxidation process. Where the solutions came in contact with certain favorable portions of the upper surface of the limestone underlying the breccia and gravel, a thin shell of it also was replaced by the above-mentioned minerals. As erosion continued and the drainage again established an outlet by cutting across the overthrust block, the secondary deposition practically ceased.

Pyritic Copper Deposits in the Abrigo Limestone:

Location: The principal known copper deposits in the Abrigo dolomitic limestone and shale of the Turquoise district are situated west of Courtland, on the east side of Turquoise Ridge. They provided the ore for the old Mame, Humbot, Leadville, and Muso mines, and for the more recent Armstrong, McLenden, and Herron workings.

Geology: The Abrigo formation containing these deposits outcrops, as already described in this report under Structure, on the east side of Turquoise Ridge as an irregular belt about 1¼ miles and length and up to aboue one-eighth mile in width. Its strata, which dip about 70° E., are bounded on the west by underlying Bolsa quartzite, together with intrusive quartz monzonite-porphyry; and on the east by Mississippian limestones with fault contact, together with intrusive quartz monzonite (see Plate I and Fig. 3). This Abrigo limestone belt is cut by many irregular dikes of quartz monzonite-porphyry, and, near the contact, especially, is strongly metamorphosed* with the introduction of garnet, epidote, secondary quartz, calcite, and pyrite. This metamorphism and the subsequent alteraiton resulting from oxidation of the pyrite have been so intense in some places, for example near the north boundary of the Great Western property, that the Abrigo cannot always be distinguished with accuracy from the quartz monzonite-porphyry.† Here the porphyry itself, probably by solutions emanating from its parent mass during solidification, has been largely changed to quartz, sericite, and pyrite; and, by later oxidation of the pyrite, has been bleached and iron-stained.

Faulting, in large part post-enrichment, and fracturing have considerably disturbed the strata. These faults, most of which are visible in the subsequent alteration resulting from oxidation of the pyrite have SW. to nearly N.-S., and dip from 25° NW. to 45° E. Many of them are of small, indeterminable throw.

Ore bodies: The ore bodies are replacements mainly in the Abrigo limestone and to a very slight extent in the quartz monzonite-porphyry. These replacements are usually of rough, lenticular shape and approximately parallel the stratification; but their shape, size, and extent seem to depend upon the amenability of certain calcareous beds to replacement. In the McLenden and Herron workings the ores occur mainly along fractures and minor faults; but in the Armstrong workings the best ore follows two distinct beds of limestone. Ransome‡ in 1911 found the ore bodies of the Mame Mine to be generally of lenticular form, with their greater dimensions approximately in the planes of bedding, but with no obvious relation to fissuring.

Ore minerals: The ore minerals present include pyrite and chalcopyrite in disseminations, stringers, and masses; occasionally, as in the Armstrong workings, a little galena and magnetite; and chalcocite, bornite, native copper, malachite, azurite, copper pitch, probable tenorite (melaconite), and cuprite.

Origin: Field evidence suggests that the ores are genetically connected with the quartz monzonite-porphpry intrusion. Old workings indicate that the ore bodies were often largest and most frequent near contacts with this intrusion; but not all the contacts are near ore bodies.

*See page 19.

†For a detailed description of the quartz monzonite-porphyry, see page 24 of this report.

‡Ransome, F. L., op. cit., p. 133.

As suggested by Ransome, probably hot ascending solutions that emanated from the parent porphyry mass during its solidification carried copper, together with certain other minerals and abundant iron; and these solutions were forced through the fissures, pores, and bedding planes of the Abrigo limestone at the time of its metamorphism, with the result that those portions of the limestone amenable to replacement were mineralized.

Enrichment: The pyritic ore bodies south of the Turquoise Ridge-Casey Hill divide show but slight chalcocite enrichment.* North of that divide, however, much more secondary enrichment is evident. In the Armstrong workings, a chalcocite and bornite ore body was present between the 100- and 160-foot levels, but was terminated both above and below by faulting; in the McLenden workings, less pronounced chalcocitization was noted extending 120 feet below the surface; and, in the Herron workings, enrichment continued for a known depth of 60 feet below the adit tunnel.

A possible explanation for the enrichment being greater on the north side than on the south of the divide is that the overthrust fault north of Courtland obstructed the local drainage of the north side of the divide, and so, by retarding run-off and erosion, promoted greater downward migration of the surface waters.

Oxidation: As a result of oxidation, the oxidized copper minerals malachite, azurite, cuprite, probable melaconite, and native copper extend down for about 100 feet in some of the Leadville workings. Considerable malachite, azurite, copper pitch, and probable melaconite occur, as shown in shallow open cuts, upon the Great Western claims. These oxidized bodies, however, are generally small, spotty, irregular pockets, and seldom extend over 50 feet below the surface. Such shallowness of depth is probably due to erosion being almost as rapid as oxidation.

Pyritic Copper Deposits in the Carboniferous Limestone:

Location: The known important pyritic copper deposits in the Carboniferous limestone of the Turquoise district are situated a short dis-

*For the benefit of the non-technical reader, the most generally accepted explanation of enrichment of a pyritic copper ore body may be given, very briefly, as follows: Oxidation of the pyrite at and near the surface generates sulphuric acid and ferric sulphate, which dissolve the copper as copper sulphate. Surface waters may take part of the solutions away as run-off, but may also carry part of them down into the underlying rocks. Below the zone of active oxidation, or generally at about water-level, the copper is precipitated as sulphide by chemical reactions between this copper sulphate and the sulphides encountered.

tance northeast of Gleeson, at the southwest foot of Gleeson Ridge. Considerable exploration of them has been effected by the Copper Belle (Leonard), Pemberthy, and Tejon mines; but these workings were inaccessible during the writer's visit, and the only first-hand information obtainable was that which the mine-dumps and surface exposures offered. However, through the generous courtesy of Messrs. J. W. Bennie and Wm. Saundercock of the Shannon Copper Co., it was possible to view that company's private maps and reports, mainly by Augustus Locke and A. S. R. Wilson, upon the Copper Belle, or Leonard, Mine. The underground data so obtained have been largely used, with some changes, in the following description.

Geology: An irregular outcrop of Carboniferous limestone, about one-half mile long and up to about 800 feet wide, is separated from the main limestone mass of Gleeson Ridge by a sill of quartz monzonite 350 to 700 feet wide, and on the southwest, beneath a mantle of surface wash, is in thrust-fault contact with rhyolite. This body of limestone is probably hull-shaped in vertical section, and its bedding dips about 45° E. Three sills of altered quartz monzonite cut approximately parallel to the bedding, with the result that the limestone and quartz monzonite make alternate irregular layers of about 250 feet maximum thickness. The limestone, which is more shaly and sandy than that of Gleeson Ridge, shows a little bleaching and recrystallization along cracks near the contacts; and the quartz monzonite is altered into a fine-grained mixture of sericite and quartz, traversed by minute calcite veinlets and speckled sparingly by tiny pyrite grains.

Faulting, both pre-ore and post-ore, has affected the rock formations of the vicinity. One fault of the earlier class strikes nearly north-south, and dips 65° SE. Several east-west faults of steep north or south dips are probably in part of pre-ore age. Numerous movements that occurred along, or roughly parallel to, the limestone-quartz monzonite contacts are also probably in part pre-ore. Many minor, post-ore faults are evident. An overthrust fault, the plane of which dips about 40° W., lies between the limestone and the rhyolite.

Ore bodies: Most of the ore bodies are confined to the limestone and show close limitation to contacts with quartz monzonite, although the latter itself often contains abundant stringers and disseminations of pyrite. The ore bodies are irregular lenses along these contacts, but nevertheless maintain a tabular, roughly vein-like character, and are widest where there is a flattening of the dip. Sometimes the ore bulges into the limestone as far as 100 feet, but usually one side remains against the quartz monzonite, and fails to wander off along fractures or breccia zones. Generally, the richness of the deposits increases with intensity of rock alteration, although in some cases this alteration shows but little dependence upon proximity to ore.

Ore minerals: The ore consists of massive pyrite with minor chalcopyrite and bornite, and occasionally contains very small quantities of accessory galena and sphalerite. Some oxidized ore was present in the upper 100 feet of the workings, where the minerals cuprite, malachite, azurite, and probable tenorite are said to have been well developed. There was probably some rich chalcocite between this oxidized zone and the primary sulphides.

Origin: The limestone-quartz monzonite contacts seem to have furnished merely channels for the passage of mineralizing solutions. The ore-bearing solutions appear to have come from some other intrusive, possibly the quartz monzonite-porphyry, and found this particular limestone body favorable, in composition, structure, and location, to replacement. Downward-percolating, oxygen-bearing, surface waters gave rise to approximately 100 feet of oxidization of the ore body, and in the general manner explained on page 47 brought about the relatively thin zone of enriched chalcocite ore.

LEAD-SILVER DEPOSITS

Location and geology: The important lead-silver deposits of the Turquoise district are confined, so far as is known, to the oxidized zone, above ground water level, of the Pennsylvanian Naco limestones of Gleeson Ridge. These limestones, which have already been described under Stratigraphy and Structure, owe only part of their present structure to post-mineralization faulting. The major faults affecting Gleeson Ridge have already been described under Structure. There are also many minor faults and prominent fractures, of ages both earlier and later than the mineralization, that will be considered in connection with the separate mines.

Ore bodies: The ore bodies, as seen in the Silver Bill, Mystery, Tom Scott, and Defiance workings, are of very irregular shape and size, and occur as replacements along an early pattern of fractures and minor faults. Where two or more such mineralized fractures intersect, or where a single one turns or flattens, the ore bodies are generally largest and richest. Variations in size and shape from small stringers and pockets up to irregular masses about 100 feet long, 50 feet wide, and 50 feet high have been indicated by stoping. One of the largest and richest ore bodies mined in the early days occurred along a zone of fissuring parallel to the bedding in the Silver Bill Mine. This ore body extended almost continuously from the surface for about 45 feet down the dip, with a width of about 35 feet and a varying height up to over 20 feet.

The ore mined from this class of deposit in the early days is reported to have been very rich in silver, and to have yielded large profits, in spite of the 30-mile wagon-haul to Cochise. At the present time the ores are generally of considerably lower grade, although occasional rich pockets are encountered. The principal metals contained in the ore are lead and silver, together with a little gold and copper; but in some workings, zinc is the predominant metal.

Ore minerals: With but a very few minor exceptions, all of the ore and associated minerals are oxidized, and are present as rather pulverulent, often siliceous, brown, yellow, or dark masses. These yellow and brown colors are due mainly to oxides of iron, and the black represents oxides of manganese and copper. Cerussite, anglesite, wulfenite, malachite, azurite, probable melaconite, aurichalcite, smithsonite, calamine, pyrolusite, cerargyrite, hematite, limonite, jarosite, calcite, aragonite, and kaolin are present. It is probable that most of the silver occurs as cerargyrite disseminated within anglesite and cerussite; but quite often the silver content varies independently of the lead content. The small amount of gold present is probably contained both within the silver and finely disseminated within the siliceous limonitic matter. A small amount of pyrite and chalcopyrite was observed where water was percolating down a fracture; and minor occurrences of galena have been reported, but none was seen by the writer. The zinc minerals usually occur a few feet below or away from, rather than with, the lead minerals of a given stope. The wulfenite occurs as crystals, lining solution cavities or scattered through masses of the lead ore and manganitic material.

Origin: The ores appear to have been deposited originally as replacements along fractures of the limestone by hot, ascending solutions emanating from one of the igneous intrusive masses, probably the quartz monzonite-porphyry, immediately after intrusion. Galena, sphalerite, and pyrite, with lesser amounts of chalcopyrite and molybdenite, were most likely the original ores deposited; the galena was doubtless high in silver, and the pyrite probably carried a little gold. The presence of fractures within the limestone, and the amenability of certain beds to replacement, were factors in determining the position of this primary mineralization; but there are doubtless other unknown and hidden factors governed by certain special features of the quartz monzonite-porphyry intrusion.

Oxidation: Later faulting, uplift, fracturing, and erosion exposed these primary ores to the action of downward-percolating surface waters which, charged with small amounts of oxygen, chlorides, and carbon dioxide, brought about their oxidation. The lead ores seem to have been oxidized essentially in place. It is possible that some of the silver may have been dissolved and transported slightly by these waters, so that it is now disseminated more widely than the lead. The oxidation of the pyrite and sphalerite yielded sulphuric acid, which dissolved the copper minerals as sulphates; and, probably soon after solution, they were largely redeposited as malachite and azurite by the calcium carbonate of the limestone, and as probable melaconite along with oxides of manganese. Practically all of the zinc was moved by solution, and precipitated a short distance below or away from the lead ore bodies by the calcium carbonate of the limestone.

TURQUOISE DEPOSITS

Location: The principal turquoise deposits, for which the district was named, are located about three-fourths of a mile northwest of Courtland, immediately west of the top of Turquoise Ridge. There are also many minor showings of the mineral along the entire length of the west flank of that ridge.

Geology: Post-Lower Cretaceous granite here underlies, with intrusive contact. Bolsa quartzite that strikes about N. 10° W., and dips from 55° to 75° eastward. Along the plane of intrusion, some slight schistosity and visible alteration to kaolin and sericite have been developed. A few minor faults and frequent prominent fractures, of ages both earlier and later than the turquoise, traverse these rocks in various directions.

Features of occurrence: The turquoise occurs mainly as thin, pinching stringers up to a few inches wide, and small, nugget-like lenses, occupying joints and fractures in the quartzite and in the granite. Associated with the turquoise, generally between it and the walls of the stringers or veinlets, are kaolin, sericite, and limonite. The widest stringers of turquoise extend out from intersections of fractures transverse to the granite-quartzite contact with fractures parallel to the quartzite bedding. The best quality of material is found in the quartzite, within a few feet from the granite. The turquoise in the granite, and whenever associated with abundant limonite, tends to be too soft and green, due to too high a copper content. Nothing concerning the continuity of the turquoise with depth could be ascertained from the comparatively shallow workings within its deposits.

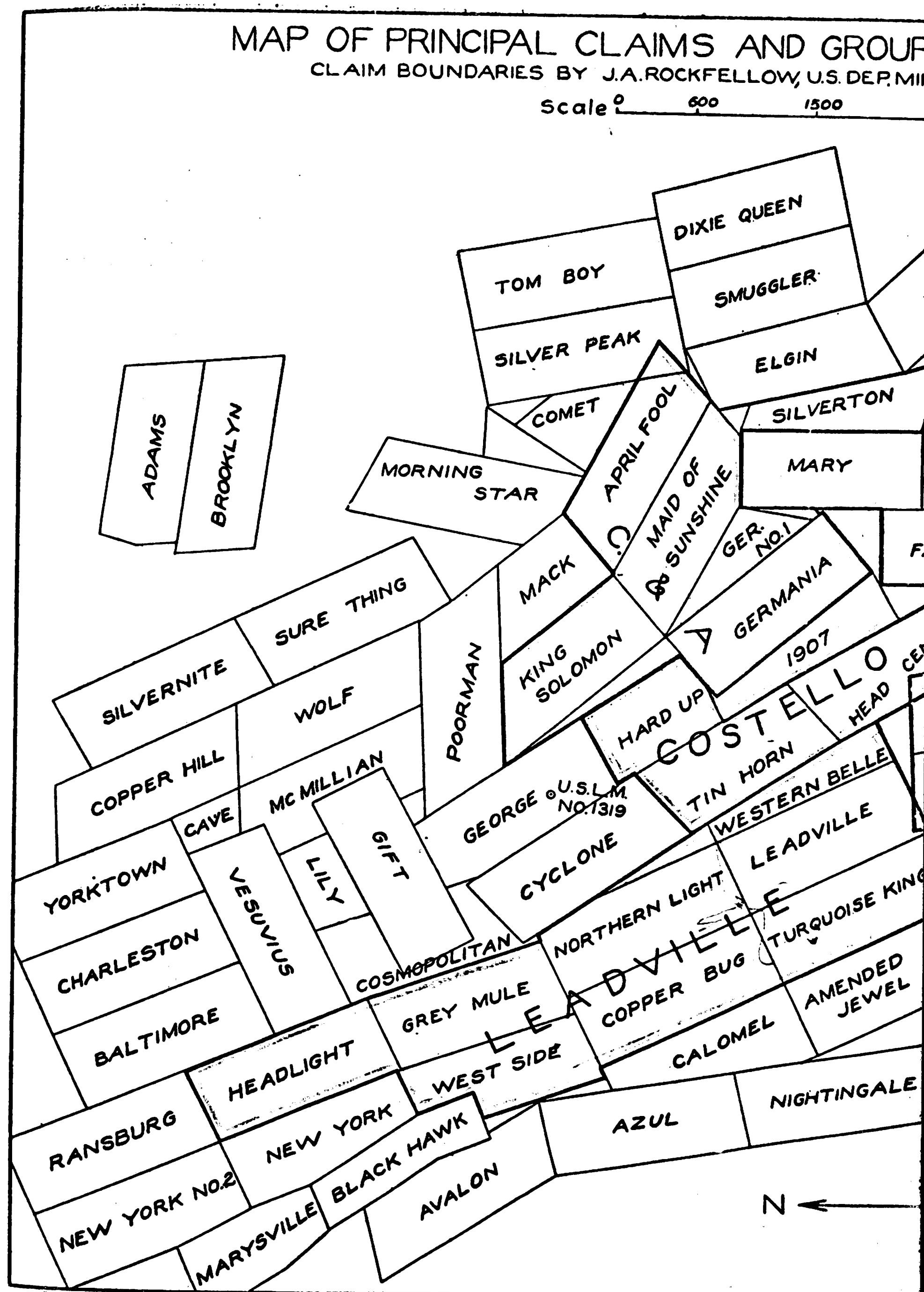
Origin: To form turquoise, certain compounds of phosphorus, aluminum, copper, oxygen, and water must be brought together under suitable conditions. The fact that the turquoise in this district is limited to the quartzite-granite contact indicates that the granite had something to do with its origin. The phosphorus required may have been derived from the mineral apatite, which is present in the granite. The small amount of copper necessary may have been present in the quartzite, migrated in from the Abrigo limestone, or been derived from the granite. Aluminum may have come from any of the rocks. The bringing together of these compounds in proper proportions and the depositing of them as turquoise in the quartzite and granite could have been accomplished in various ways. Either normal ground water circulation, ground water heated by the granite intrusion, or hot solutions emanating from the parent granite mass during its solidification could have been the agency. The association of sericite with the mineral strongly suggests a hydrothermal origin.

MINES AND PROSPECTS

The principal mines and prospects of the Courtland-Gleeson region are indicated on the geologic map (Plate I), where their names are referred to by numbers as follows:

1. April Fool
2. Armstrong
3. Avalon
4. Casey
5. Copper Belle
6. Cyclone
7. Defiance
8. Germania
9. Herron
10. Highland
11. Humbot
12. Leadville No. 1
13. Leadville No. 2
14. Maid of Sunshine
15. Mame
16. McLenden
17. Mary
18. Mona
19. Muso
20. Mystery
21. Pemberthy
22. Silver Bill
23. Silverton
24. Tejon
25. Tom Scott

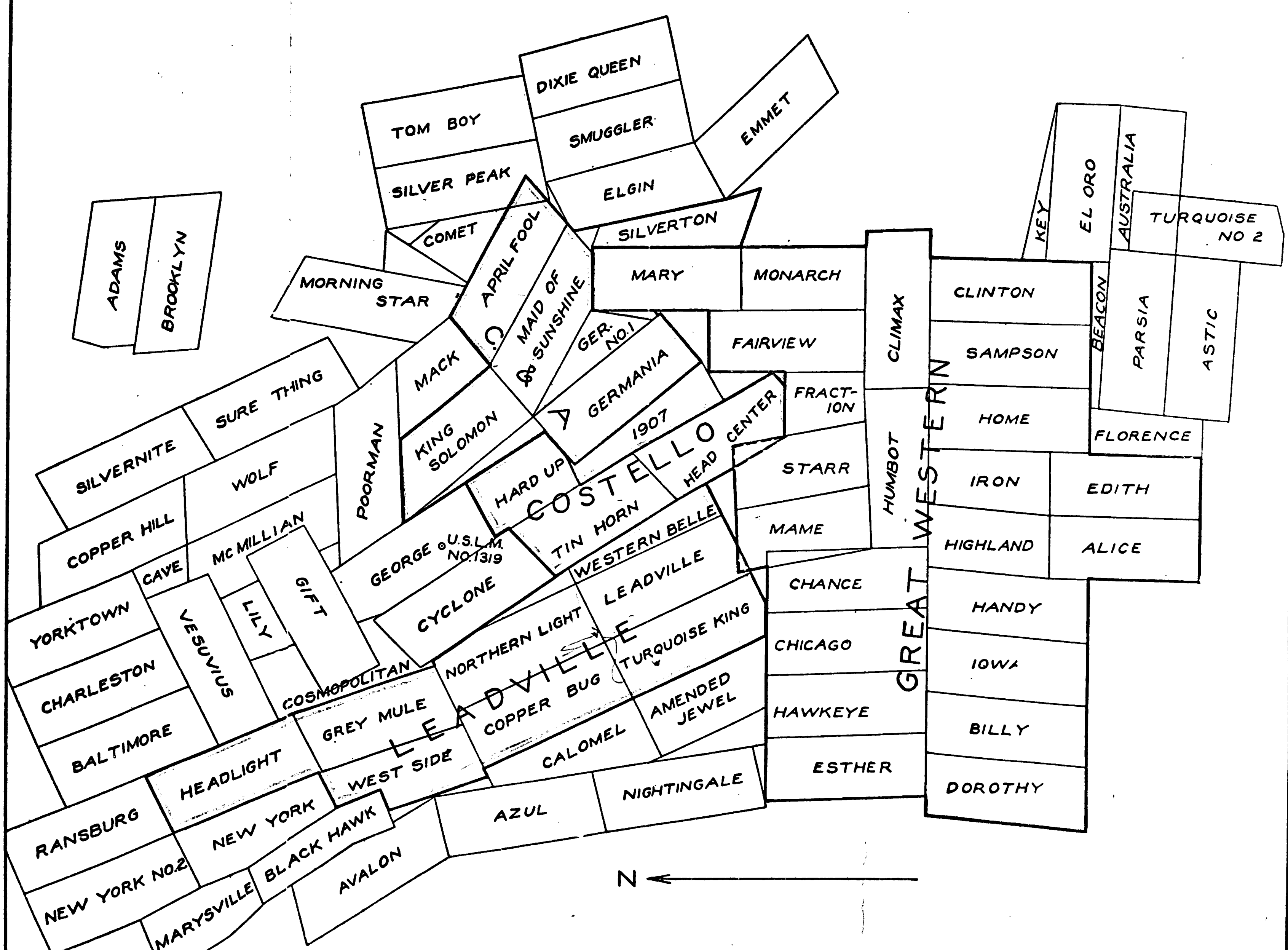
Many other prospect pits and tunnels are distributed throughout the district; but because of being inactive and showing no appreciable promise or importance when visited, they are not described in this re-



MAP OF PRINCIPAL CLAIMS AND GROUPS IN COURTLAND VICINITY

CLAIM BOUNDARIES BY J.A. ROCKFELLOW, U.S. DEP. MIN. SURVEYOR, TOMBSTONE, ARIZ.

Scale 0 600 1500 3000 Feet



port, and are left off of the geologic map in order to avoid confusion.

A map of the claims and groups of Courtland vicinity is shown in Plate II and of Gleeson vicinity in Plate III.

COURTLAND VICINITY

GREAT WESTERN COPPER COMPANY GROUP

The property of the Great Western Copper Co. in the Turquoise district includes twenty-three patented claims as shown on Plate II.

Original locations upon most of the property were made in the early nineties by Messrs. McCormack, Hardy, Warnekross, and others, and the first group of eight claims was purchased in 1899 by the Young Brothers, of the Great Western Copper Company. Underground development has proceeded intermittently since the early days; but the most active years were 1901, 1908-1912 inclusive, 1917, and 1918. Considerable diamond drilling and churn-drilling also were done prior to 1918, since which year mining has been limited to lessees.

The principal workings upon the property are the Mary, Mame, Highland, and Humbot mines. Altogether, about 25,000 feet of underground work has been done, for the most part in the Mary and Mame. Equipment includes a 150 h.p. steam-electric plant, hoists, pumps, compressor, shop, etc.

Production, according to Mr. W. J. Young, Jr.,* president of the company, in 1901 amounted to about $100,000 worth of oxidized copper ore from the Humbot claim; and for 1909-1920, inclusive, it totaled 176,458 tons, principally oxidized ore from the Mary and sulphides from the Mame. Since 1920, lessees have been making small, fairly steady shipments, mainly from shallow workings. This production for 1923 amounted to 1442 tons of oxidized ore, and 740 tons of sulphide ore.

Mary Mine: The Mary shaft is situated immediately north of Courtland, or about 1,000 feet south of the railroad, on the Mary claim. This shaft was sunk in 1908, and a large production of oxidized ore was made from the mine before it was closed down in 1913.

The rock formations at the mine consist of Bolsa quartzite overthrust on Carboniferous limestone, as described on page 31, and occasional dikes of altered monzonite of pre-thrust age. According to Mr. W. J. Young, Jr.,* solid limestone was met with in the shaft at about 200 feet.

*Oral communication.

All of the Mary workings were inaccessible at the time of the writer's visit; but the following description of the ore occurrences is given by Ransome:* "The ore is as irregular in thickness as in plan, the maximum being 50 feet and the average probably about 15 feet. The ore body is accompanied by much soft limonitic and clayey material. . . . Definite boundaries are lacking, but the ore body as a whole rests on Carboniferous limestone and is overlain by shattered quartzite, which at the Mary shaft is 115 feet thick. . . . In the main, the ore is a replacement of the limestone.

"The ore itself is as a rule a soft mass of earthy oxides of iron and copper, flecked and streaked with malachite and mingled with clay-like decomposition products of varied color and constitution. Here and there are irregular crevices or cavities lined with crusts of chrysocolla, malachite, and azurite. No sulphides have been found, . . . and the limestone is not metamorphosed."

Development includes a 300-foot shaft, and several thousand feet of workings. Surface equiment and head-frame have long since been removed.

Mame Mine: The Mame shaft is situated on the Mame claim ,about 1,100 feet northwest of the Courtland postoffice. It was sunk in 1909, and development on the different levels continued until about 1919. A large tonnage of sulphide ore was produced from this mine between 1910 and 1918.

West of the shaft is the belt of steeply eastward-dipping Cambrian Abrigo limestone, which has been intruded and metamorphosed by quartz monzonite-porphyry as described on page 19 and affected by faulting of a minor character as shown in part on Plate I. East of the shaft is a narrow belt of Carboniferous (probable Mississippian) limestone surrounded by quartz monzonite. The collar of the shaft is in this latter rock, but the workings, which were inaccessible at the time of the writer's visit, are said to be mainly in the Abrigo limestone and quartz monzonite-porphyry.

The ore bodies of the Mame Mine belong to the type described on pages 45-47. The ore is of a low-grade pyritic nature, and depends upon the chalcopyrite contained for its copper content. Consequently, the size of the ore bodies varied directly with such factors as price of copper, mining and reduction costs, etc. According to Ransome† the

*Ransome, F. L., The Turquoise Copper Mining District of Arizona: U. S. Geol. Survey, Bulletin 530, pp. 131-132. 1913.
†Ransome, F. L., op. cit., p. 133.

pyritic masses have no sharp boundaries, but are merely those portions of the formation where the pyrite has been more thickly disseminated than elsewhere or where it has formed in solid replacement masses. He found that the ore bodies are generally of lenticular form, with their greater dimensions approximately in the planes of bedding, with no obvious relation to fissuring; that the quantity of oxidized ore is wholly inconsiderable; and that there has not been much chalcocitic enrichment.

Development of the Mame consists of a 350-foot shaft, about 12,000 feet of workings distributed on the 100-, 200- and 300-foot levels, and considerable drilling.

Fig. 5.—Mame shaft. Slope of Abrigo limestone and quartz monzonite-porphyry in background.

Highland Mine: The Highland shaft is situated on the Highland claim, about three-eighths mile south of the Mame shaft. Its sinking was completed in 1918, at the time of the slump in copper prices, and so no production was attempted.

In geology and type of ore deposit, this mine is similar to the Mame Mine. According to Mr. Young,* considerable rich chalcopyrite and bornite ore was encountered by diamond drilling.

Workings of the mine consist of a 350-foot shaft, and several hundred feet of drifts on the 250- and 350-foot levels.

Humbot Mine: The Humbot shaft is situated on the Humbot claim, about 800 feet south of the Mame shaft. It was the first shaft on the Great Western property, and was sunk in the late nineties. Before

*Oral communication.

closing down, about 1908, the mine produced a notable quantity of oxidized ore and some sulphides.

This mine also is similar to the Mame Mine in geology and type of deposit, except that there was a considerable concentration of oxidized ore in about the first 100 feet of its depth.

Workings of the Humboldt include a 200-foot shaft, and drifting on tthe 100- and 200-foot levels. Its water drains into the 200-foot level of the Mame Mine.

CALUMET & ARIZONA GROUP

The Calumet & Arizona group, which is situated north of Courtland, includes nine patented claims, as indicated on Plate II. Development of the group has been principally in the Maid of Sunshine, Germania, April Fool, and Silverton mines.

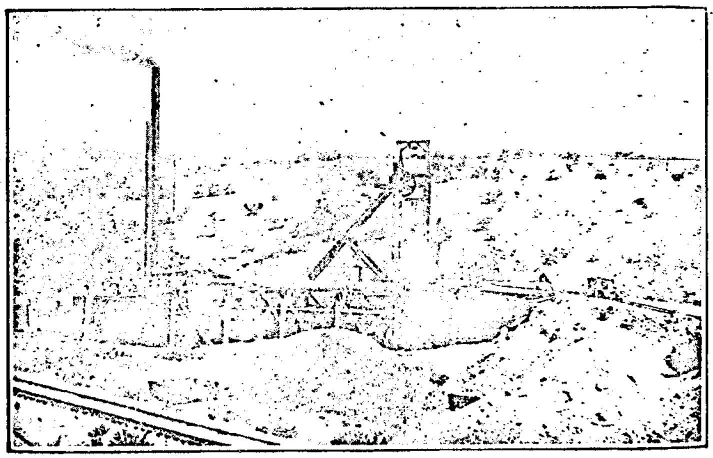


Fig. 6.—Maid of Sunshine shaft.

Maid of Sunshine Mine: This mine is situated beside the railroad, about 225 feet north of the junction of the Maid of Sunshine, Germania No. 1, and Mary claims. After having been worked intermittently for about twenty-five years by the Leadville Mining Company, it was purchased by the present owners in 1923, and has since been operated by lessees. No record of its earlier production is available; but a total of 11,432 dry tons of ore has been mined since April, 1923, as follows:

1923	3,552	1925	1,906
1924	5,268	1926	706

The general geologic features of this type of ore deposit already have been described on pages 43-45; but the post-thrust faulting in the mine now may be considered more specifically. In general, the most prominent of these faults strike from N.-S. to NW.-SE., and dip from about 50° to 70° eastward. They have broken the thrust plane and the ore body into irregular steps, with displacements up to about 50 feet, as shown in Fig. 7. Although a thin shell of the Carboniferous limestone below the ore-bearing breccia-like material associated with the thrusting is often replaced by ore, the post-thrust faults, even where accompanied by little or no gouge, make clean-cut divisions between ore and shattered, unmineralized limestone. This fact indicates that the post-thrust faults are also later than the ore.

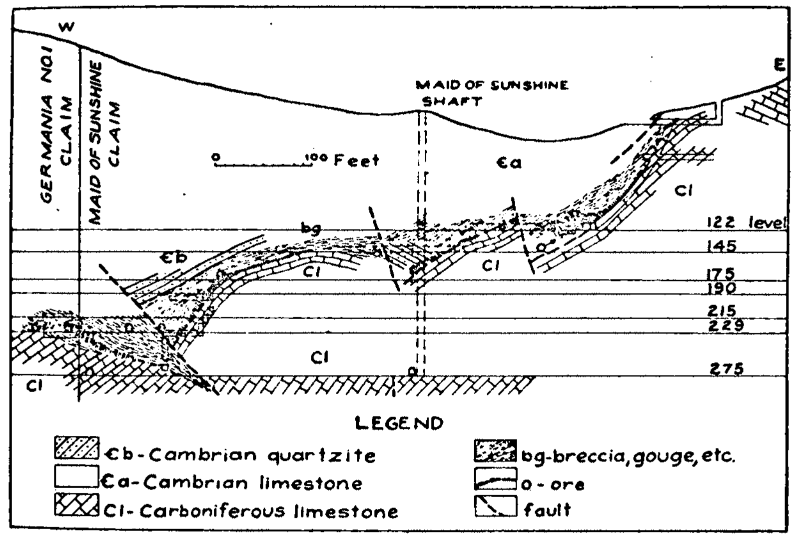


Fig. 7.—East-west vertical section through part of Maid of Sunshine and Germania No. 1 claims.

Workings of the Maid of Sunshine claim include a 400-foot shaft, a 150-foot incline to the surface, many stopes and raises, and approximately 10,450 feet of drifting. The approximate footage distribution of this drifting, by levels, is as follows: 145-level, 1,150 feet, connecting with the Mary drifts; 200-level, 650 feet; 215- and 229-levels, 1,800 feet, extending from Germania; 260-level, 1,000 feet, connecting with Germania; 275-level, 2,600 feet, connecting with Germania; 311-level, 1,350 feet, extending from Germania; and 500-level, 1,950 feet, extending from April Fool. A geologic sketch of a typical vertical section through the mine, based upon maps of the Calumet and Arizona Mining Company, is shown in Fig. 7.

Surface equipment includes a steam plant, hoist, compressor, and blacksmith shop.

Germania Mine: The Germania shaft is situated on the Germania claim, about 370 feet south of the railroad. This shaft was sunk in 1909, but is said to have been abandoned in 1911, after which time the mine was operated from the Maid of Sunshine workings. Its ore production to the end of 1925 amounted to 74,017 dry tons, as follows:

1909	3,625	1918	1,188
1910	17,624	1919	593
1912	12,644	1920	432
1913	29,568	1921	72
1914	410	1923	542
1915	968	1924	166
1917	4,701		

In geology and ores, the mine is similar to the Maid of Sunshine and Mary mines.

Workings of the Germania claim include a 500-foot shaft, many stopes and raises, and approximately 4,900 feet of drifting. The approximate footage distribution of this drifting, by levels is as follows: 145-level, 850 feet, connecting with the Mary; 215- and 229-levels, 1,100 feet, connecting with the Maid of Sunshine; 260-level, 1,750 feet, connecting with Maid; 275-level, 300 feet, connecting with Maid: 311-level, 250 feet, connecting with Maid; and 500-level, 650 feet, extending from April Fool.

April Fool and Silverton Mines: These mines have long been inaccessible, and very little was learned of them. The April Fool shaft is situated in the southwest corner of the April Fool claim, and the Silverton shaft near the north end of tthe Silverton claim. Except that they lie near the edges of the overthrust, the geology and ores of these two mines are essentially similar to those of the Maid of Sunshine, Germania, and Mary mines. The 500-level of the April Fool extends southeastward across the Maid of Sunshine and Germania No. 1 claims, and into the Germania claim. but for the most part penetrates only barren, fractured and faulted Carboniferous limestone and quartz monzonite.

LEADVILLE, OR ANDES COPPER COMPANY, GROUP

The Leadville group, which is situated within three-fourths of a mile northwest of Courtland along the eastern foot of Turquoise Ridge. north of the Turquoise Ridge-Casey Hill divide, includes nine patented claims as shown on Plate II. Most of these claims were located in the early nineties; but notable development of them, which was begun about 1897, has been subject to frequent intermissions. The Leadville Mining Co., which was organized in 1903, let options upon the property to various concerns, among which were the Calumet & Arizona Mining Co., about 1907, Fuller & Near, about 1912, the Needles Mining & Smelting Co., about 1916, and the U. S. Smelting & Refining Co. in 1916-1917. Some ore was produced by the Leadville Company during several of the early years of its existence; but according to Mr. Wm. Holmes, principal owner of the property, none of these option-holders made any shipments. After 1917, intermittent production and explorations, principally by lessees, were made. Early in 1926, activity again ceased, and in the same year a reorganization of the company was effected under the name of the Andes Copper Company.

The mines of the company consist of the old Leadville No. 1, No. 2, and Muso, and the more recent Armstrong and McLenden. No complete figures of the production of the older mines are available; but shipments from 1923 to 1925, inclusive, are shown by the company's records to have been 4,856 tons, worth about $78,500.

The general geology and type of ore deposit of the area containing the Leadville group of claims already have been outlined on pages 45-47 of this report; but more specific descriptions of these features now will be given for the individual mines.

Leadville No. 1 Mine: The old Leadville No. 1 shaft is situated on the Copper Bug claim, about 1,200 feet west of the termination of a railroad spur. This shaft was sunk in the years 1897-1900, but has been abandoned for many years. No record of its production could be obtained other than that some copper ore carrying about $5.50 in gold per ton is said to have been shipped to the Old Dominion smelter at Globe, Arizona.

The workings of the mine seem to have been for the most part in the belt of thin-bedded, cherty, dolomitic Cambrian Abrigo limestone, which strikes about N. 15° W., and dips 70°-80° NE. This belt of Abrigo, as shown on the geologic map (Plate I), is bounded on the east, with fault contact, by mediumly thick-bedded Carboniferous limestone, and on the west by Cambrian Bolsa quartzite. Dikes of quartz monzonite-porphyry cut these rocks, and normal faulting has influenced their structure.

Inasmuch as the mine workings were inaccessible at the time of the writer's visit, no observations of the ore bodies could be made; but the dump shows abundant lean pyritic ore.

According to Mr. Holmes, No. 1 shaft is 316 feet deep, and about 875 feet of drifting has been done on the three levels of the mine. About 75 feet of this work was on the 100-foot level; 300 feet on the 200; and 500 feet, in north, south, and east directions, on the 300. The depth to water level was about 175 feet, but the quantity of water was sufficiently small to be handled by bucket during the shaft-sinking.

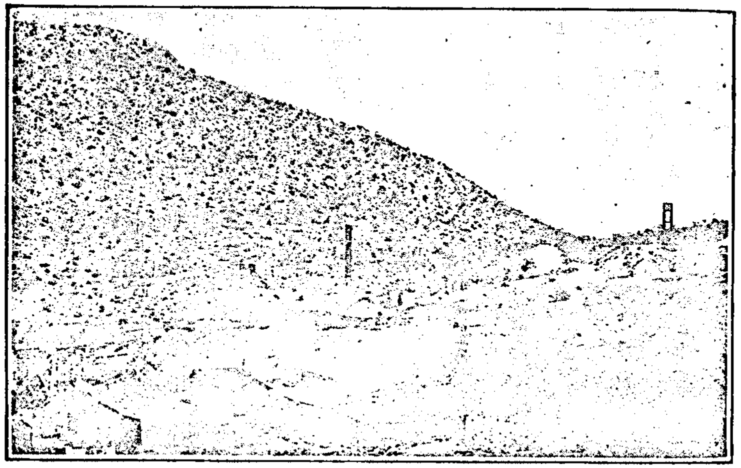


Fig. 8.—Leadville No. 2 shaft in foreground, Muso shaft at extreme right, Casey Hill of Carboniferous limestone in left background.

Leadville No. 2 Mine: Leadville No. 2 shaft is situated on the Leadville claim, about 900 feet south of the termination of the railroad spur, and about 1,000 feet southeast of No. 1 shaft. According to Mr. Holmes, 300 feet of its depth were sunk by the Calumet and Arizona Co. in 1907, and an additional 100 feet by Fuller & Near in 1912. The mine has been closed down since late 1916. Its production is reported to have been about 1,300 tons of ore in 1912.

The workings are in Cambrian Abrigo limestone which, although more metamorphosed, is in geologic relations and aspects similar to that of No. 1 shaft.

The workings of this mine also were inaccessible at the time of the writer's visit; but the dump shows abundant low-grade pyritic ore. Mr. Holmes* states that a large body of low-grade ore has been de-

*Oral communication.

veloped on the 300-foot level, near the south end-line of the property, under the Muso shaft.

Two main levels constitute the workings of the mine. On the 300-foot level drifting is said to extend 300 feet west of the shaft, and 150 feet southwest beneath the creek-bed; about 1,000 feet south; and northwest, under No. 1 shaft. On the 400-level, there is said to be about 1,200 feet of southwesterly drifting. The depth to water level is reported to be about 150 feet. Equipment includes a 250-horsepower steam plant, a steam hoist, an air-compressor, and a blacksmith shop.

Muso Mine: The Muso shaft, which is situated about 500 feet south of No. 2 shaft, was sunk in early 1917, but has been idle for several years. According to Mr. Holmes,* over 12,000 tons of pyritic

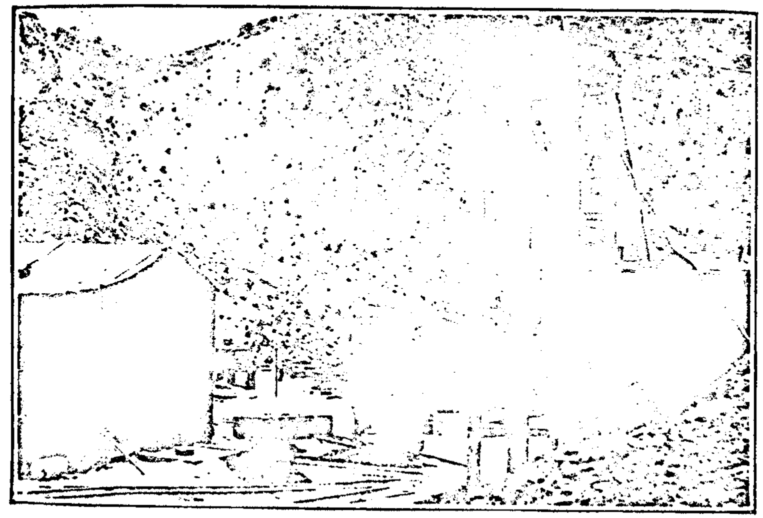


Fig. 9.—Looking southeast at Armstrong shaft. Bolsa quartzite in background.

copper, worth about $100,000, has been shipped from this mine.

The rocks at the surface consist of steeply eastward-dipping, highly metamorphosed Cambrian Abrigo limestone. The workings of the mine were inaccessible at the time of the writer's visit, but are said to consist of a 150-foot shaft, about 150 feet of drifting near the shaft, and some stoping.

Armstrong Mine: The Armstrong workings are situated on the Copper Bug, Northern Light, Leadville, and Turquoise King claims of

*Oral communication.

the Leadville group. Several years ago a 150-foot shaft was sunk in the extreme southeast corner of the Copper Bug claim, at a point 200 feet S. 42° E. of Leadville No. 1 shaft. This old 150-foot shaft, now called the Armstrong, was reopened in early 1923 by lessees Haywood, Armstrong, and Richard. Fortunate development led to the discovery of a small, but rich, ore body, from which shipments were made until operations were suspended in late 1924. This production amounted to about 3,400 tons, the general average of which was about 9.2 percent copper, $2.75 silver, and 23 cents gold per ton; the total value was over $61,000; and a few railroad cars of the ore netted about $3,000 each.

The important rocks in the vicinity, as shown on the geologic map (Plate I), consist of steeply eastward-dipping, thin-bedded, cherty, dolomitic Cambrian Abrigo limestone; intrusive quartz monzonite-porphyry and monzonite; Carboniferous limestone, faulted against the Abrigo limestone on the east; and Cambrian Bolsa quartzite on the west. Faulting and fracturing have affected these rocks to a considerable extent.

A vertical section exposed in some workings that connect with the surface approximately 100 feet N. 20° W. of the Armstrong shaft, shows the geologic relationships there. Below about 10 feet of hillside talus is a thickness of about 55 feet of so-called gossan material which, although very thoroughly leached and altered to limonite, appears to have been Abrigo limestone, originally. In rather indefinite contact with this gossan there follows about 30 feet of still more altered material that bears certain textural resemblances to the quartz monzonite-porphyry, although it is so changed to kaolin and limonite along numerous fractures as to be doubtfully determinable. A fault, the plane of which is marked in places by about a foot of clayey, limonitic gouge, strikes NE.-SW., dips 30° NW., and forms the contact between this altered porphyry and the underlying ore-bearing Abrigo limestone at the 100-foot level. Here the beds strike N. 15° W., and dip 80° NE. About 10 feet below the 150-foot level, the Abrigo is cut by a nearly N.-S. fault of 45° E. dip.

The best ore bodies occurred as two vein-like replacements, separated by an 8-foot wall, along the nearly vertical bedding of the Abrigo limestone. They each varied up to 6 feet in width; their vertical extent was limited to about 55 feet by faults at the 100 and 150-foot levels; the westernmost body carried commercial ore through a length of 120 feet; and the eastern was ore-bearing through an interrupted length of 42 feet. A characteristic of these ore bodies was their rather

...ar-cut walls, beyond which the copper content faded very rapidly ...wn to one percent or less. Near these walls the ore minerals oc...rred finely disseminated in bands, or as solid rich streaks; but toward ...e centers of the ore bodies they existed in large masses.
...rs of the ore bodies they existed in large masses.

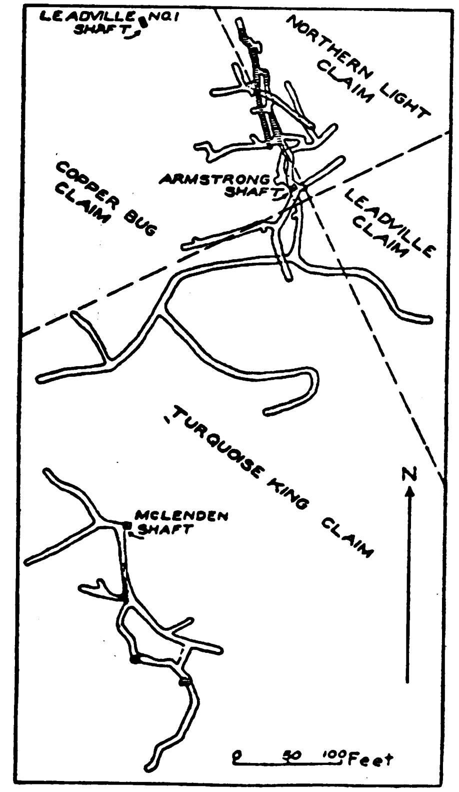


Fig. 10.—Sketch of Armstrong and McLenden workings. Shading indicates approximate distribution of high grade ore mined.

Chalcopyrite, bornite, and chalcocite, associated with considerable pyrite and occasional minor amounts of galena, were the principal ore minerals present. A little magnetite was observed near the west wall of the east body, and near the south end of the west body. Small amounts of native copper were present, associated with limonite and magnetite in both ore bodies, and with limonite near the top of the west body. The west body showed more enrichment near its top than did the east one, and was generally about twice as rich throughout in copper, silver, and gold values. Some malachite, together with a little azurite and cuprite, occurred above the west ore body as an irregular pipe-like mass extending up into the gossan to within about 40 feet of the surface.

In 1924 the workings of the Armstrong consisted of a one-compartment shaft 150 feet deep, a little over 150 feet of drifts, about 1[illegible] feet of raises, and considerable stoping. Fig. 10 shows a sketch of these workings. Water, the level of which is between 70 and 80 feet below the collar of the shaft, amounted to about 600 gallons per day in 1924.

McLenden Mine: The McLenden shaft is situated on the Turquoise King claim at a distance of 345 feet S. 25° W. of the Armstrong shaft. The shaft and part of the workings were driven in 1924 by lessees McLenden and Brown. Some additional work was done in 1925 by the Leadville Co., but operations were suspended at the beginning of 1926. Production from the mine has amounted to about 1,463 tons of ore that averaged 5.75 percent copper and carried some low silver and gold values.

The rock formations in the vicinity of the McLenden workings are in general rather similar in character, strike, and dip to those of the Armstrong. However, there are more dikes of quartz monzonite-porphyry, in-faulted blocks of quartzite, and prominent fractures evident. The faults, which for the most part dip steeply, trend in random directions.

All the ore bodies found were comparatively small, and consisted of stringers, disseminations, or irregular replacements along faults and fractures. Some ore occurred in the quartz monzonite porphyry and in the quartzite, but the best was in Abrigo limestone. The ore minerals were chalcopyrite, bornite, and chalcocite, associated with pyrite. This chalcocite was mainly of the sooty variety.

Workings of the mine consist of a one-compartment shaft 120 feet deep, and about 550 feet of drifts as shown in Fig. 10. Water, the level of which is approximately 70 feet below the collar of the shaft, amounted to about 180 gallons per day in 1924, and was hoisted by bucket. Surface equipment included a 40-horsepower gas engine hoist, a two-drill gas engine compressor, and a blacksmith shop.

HERRON MINE

The Herron Mine, which is held by Mr. Jas. Herron and associates is situated on the Calomel claim, a short distance south of Reservoir Hill, on the east slope of Turquoise Ridge, and a little more than one-fourth of a mile west of the railroad spur. The workings were started early in 1924, and production up to October, 1925, amounted to slightly over 1,600 tons, dry weight, of copper ore that carried some silver and small gold values. The smelter returns on this ore, which was shipped to Douglas and to El Paso, showed a range between 8.01 and [illegible]8 percent copper, and between 2.6 and 0.98 ounces of silver, or an average of 4.38 percent copper and 1.52 ounces of silver per ton.

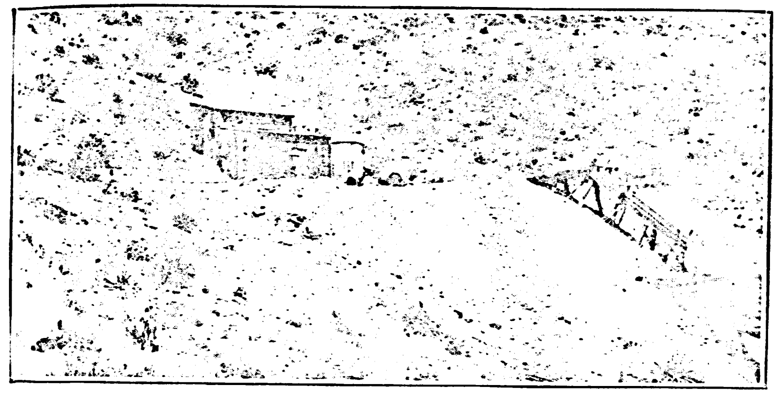


Fig. 11.—Looking west at Herron Mine. Slope is of weathered, steeply eastward-dipping Abrigo limestone.

The rock formations in the vicinity of the mine consist of thin-bedded Abrigo dolomitic limestone and shale that strikes N. 25° W., and dips 70°-80° E.; Bolsa quartzite on the southwest; and Carboniferous limestone, intruded by monzonite, in fault contact on the northeast. Much less metamorphism, somewhat less faulting, and much less fracturing are apparent in the Abrigo here than obtains farther south.

Some small, irregular, replacement ore bodies were found, about 80 feet below the surface, along a small strike-fault. The best body was about 50 feet long, up to 10 feet wide, and in places over 35 feet high. The ore was discovered by following down a fissure, of N. 40° E. strike and 5° SE. dip, that carried considerable limonitic material and some copper stain. Chalcocite, generally sooty, and chalcopyrite, associated with pyrite, were the ore minerals.

Workings of the mine in 1925 consisted of about 200 feet of branching adit tunnels, extending in a general S. 65° W. direction to the Abrigo-Bolsa contact; a 60-foot winze, inclined with the dip of the bedding, and connected with the surface by a 40-foot raise; and about

190 feet of drifting and stoping near the bottom of the winze. These workings are dry. Surface equipment included a 15-horsepower gas-engine hoist, a 16-horsepower one-machine compressor, and a small assay and blacksmith shop.

TURQUOISE WORKINGS

Old turquoise workings are scattered near the Bolsa quartzite-granite intrusive contact along most of the length of the west side of Turquoise Ridge. Indians probably gathered the turquoise to a slight extent before the advent of white men; and early residents of the district report having found shallow diggings that contained crude Indian

Fig. 12.—Turquoise Mine on Avalon claim. Rock face is Bolsa quartzite.

implements. Claims upon the best deposits are said to have been located in the early nineties by Messrs. Raskum, Tannenbaum, and George; later, they were worked by a Mr. Goode; and, since several years prior to 1924, they have been held as copper claims by Mr. Lynn Shattuck. In the late nineties, several hundred pounds of the semi-precious gem material, which then sold for about $10 a pound, are said to have been mined by Mr. Goode. Part of that production was worked up in a small grinding laboratory near the diggings. During 1926, about 50 pounds of the material was mined and shipped to Gallup, N. M., by Mr. Shattuck.*

*Oral communications.

The geology and features of occurrence of the turquoise have already been described on pages 51-52.

Mining has been limited to short tunnels, and shafts and winzes inclined with the granite-quartzite contact. A few of the shafts are over 50 feet deep, but most of them are less than 30 feet deep. The workings that yielded the 1926 production were extensions of some older ones on the Avalon claim, about one-half mile south of the northwest termination of the ridge, and consisted of a small open cut, a short adit, and a few feet of tunneling near the bottom of a 15-foot inclined shaft.

COSTELLO GROUP

This group, which is situated northwest of Courtland, includes three patented claims as shown in Plate II. It is owned by Mrs. Mary Costello of Los Angelees, California, and leased to Messrs. Troglia and

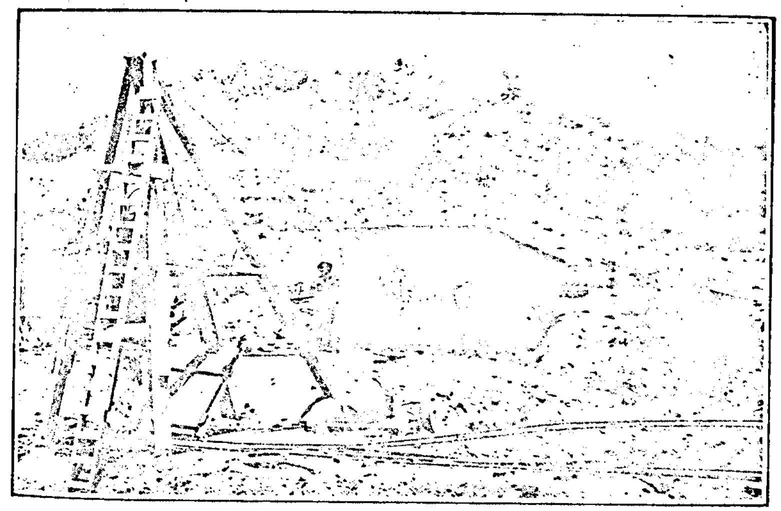


Fig. 13.—Mona prospect.

Bratti. The principal developments are the Mona prospect and the old Casey workings.

Mona Prospect: The Mona prospect (see Fig 13) is situated near the north end of the Tin Horn claim, a few rods west of a railroad spur. Production from the prospect during the first five months of 1926, according to Mr. Troglia, amounted to three cars of ore that averaged about 10 percent copper.

The formations of the immediate vicinity consist of Carboniferous limestone, intrusive quartz monzonite, overthrust Bolsa quartzite, and loosely consolidated, unstratified, sand and gravel. This latter material, which appears to have been deposited by stream action, was found underground to contain occasional limestone boulders, and to be separated from the Carboniferous limestone by a definite, although irregular, nearly vertical wall.

Ore was discovered to occur as small, frequent, irregular masses and narrow streaks within the sand and gravel material near its contacts with the Carboniferous limestone. Tenorite (melaconite), chrysocolla, malachite, and azurite, associated with kaolin and limonite, were observed. Probably this copper was deposited by percolating waters that had dissolved it from mineralized outcrops on the east slope of Turquoise Ridge.

Developments in May, 1926, included a 45-foot shaft, which had encountered a small seepage of water, and about 200 feet of northeasterly drifts.

Casey Workings: Very little was learned of the old, inaccessible Casey workings. The shaft is situated at the edge of Casey Hill, near the northeast corner of the Tin Horn claim, in quartz monzonite near its intrusive contact with the Carboniferous limestone. Some of the workings are said to extend north under the overthrust.

Cyclone Prospect: The Cyclone prospect, which is reported to be owned by Mr. Paul Warnekross, is situated on the Cyclone claim, at the southern foot of a low Bolsa quartzite ridge, a few rods from the southeast foot of Reservoir Hill. Here Carboniferous limestone is in contact with intrusive quartz monzonite, and a short distance north underlies overthrust Pinal schist and Bolsa quartzite. The workings of the prospect were not accessible, but the vertical shaft, which was sunk along a contact of the limestone with monzonite, was estimated to be about 75 feet deep. Ore on the dump showed pyrite with fair-sized bunches of galena and sphalerite; and some cerussite and anglesite associated with calcite and limonite.

GLEESON VICINITY

CHARLESTON GROUP

The Charleston group, which is situated northeast and east of Gleeson, contains nine patented claims as shown in Plate III, and is owned by the Shannon Copper Company. Development of the group has been

ity consist of Carbonifer...
rthrust Bolsa quartzite, a...
gravel. This latter materi...
y stream action, was foun...
ne boulders, and to be sepa...
y a definite, although irreg...

, frequent, irregular masse...
gravel material near its con...
enorite (melaconite), chryso...
th kaolin and limonite, were
osited[redacted] percolating water...
itcrops on the east slope of

a 45-foot shaft, which had
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ned of the old, inaccessible
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m, in quartz monzonite near
ous limestone. Some of the
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ect, which is reported to be
ted on the Cyclone claim, at
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Carboniferous limestone is in
and a short distance north
lsa q[redacted]zite. The workings
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NITY

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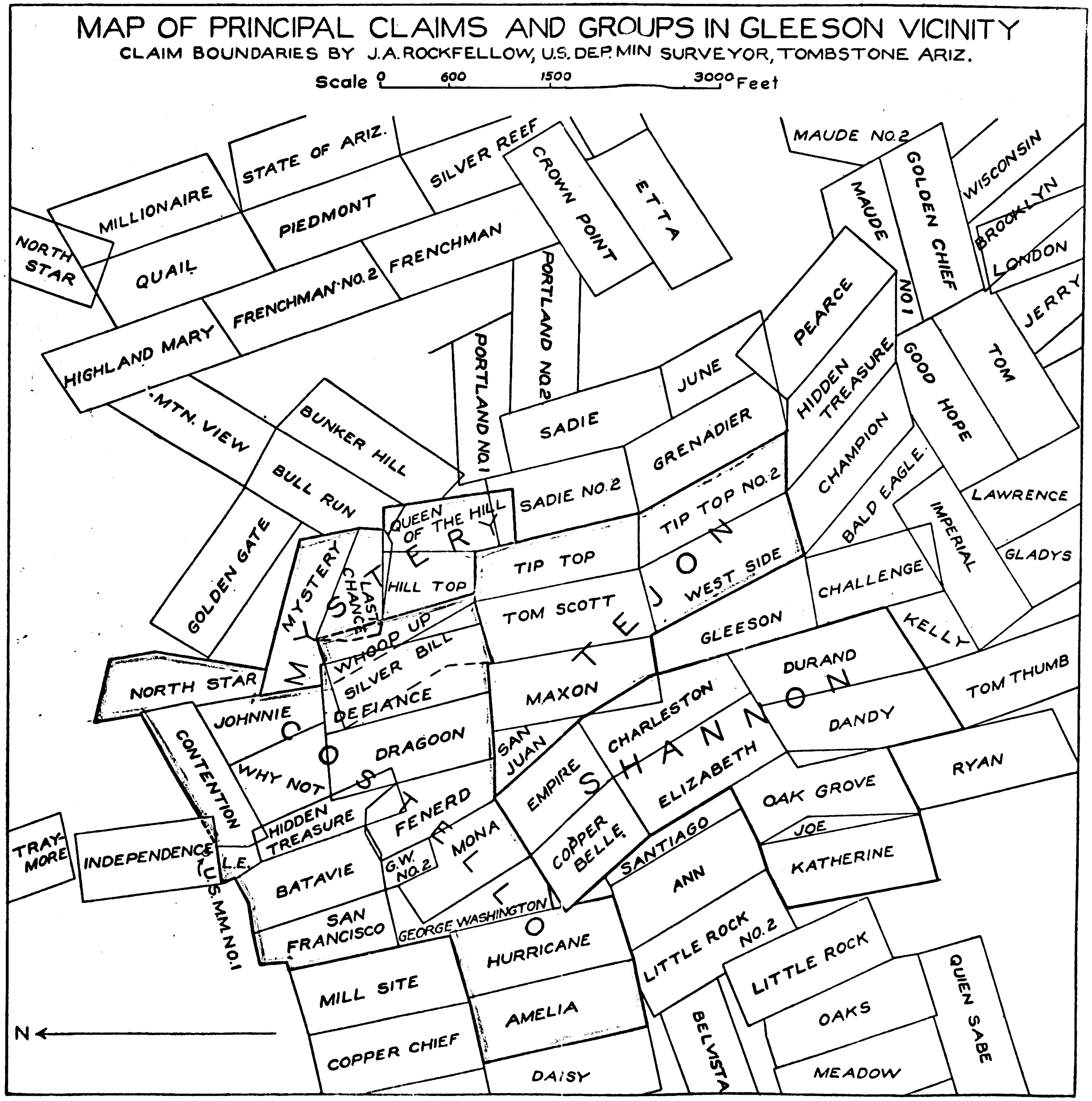

mainly in the Copper Belle Mine, which includes also the Pemberthy workings.

Copper Belle, or Leonard Mine: The old Copper Belle, or Leonard, shaft is situated on the Charleston claim a short distance northeast of Gleeson, near the southwest base of Gleeson Ridge, and adjacent to the railroad. This claim was located by Mr. Kit Charleston about 1887 or 1888; and several adjoining claims are said to have been located by Messrs. Alexander Casey and Silas Bryant at about the same time. The Copper Belle, or Leonard, deposit was discovered in 1896 by Mr. John Gleeson, who obtained the claim and in a few years developed it into an important copper producer. In five years he is said to have shipped about $280,000 worth (gross) of ore containing from 4 to 7 percent copper, mainly to the Clifton smelter, where also the iron and sulphur content were paid for. Due to the fact that these shipments involved a 30-mile wagon-haul to the railroad at Cochise, an attempt was made to smelt the ore at the mine by roasting the sulphides in pits with juniper; but this effort was not very successful. Two copper furnaces, one of 350 tons and one of 70 tons daily capacity, were tried out on the property, but it was found that it was more profitable to ship the ore.

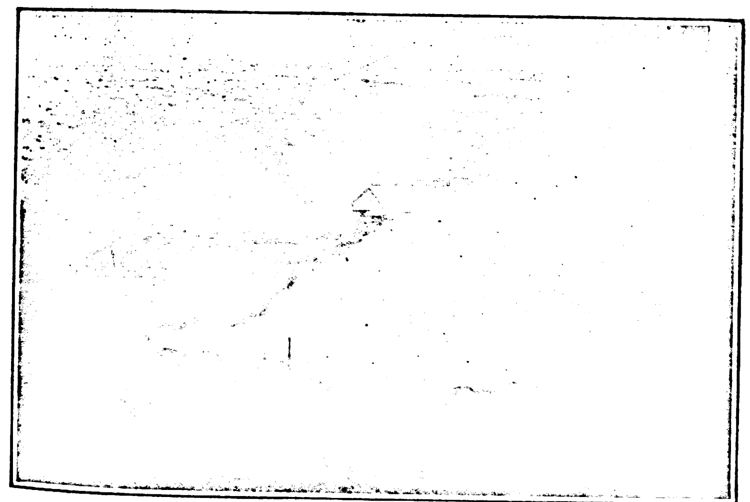

Fig. 14.—Sulphur dioxide smoke from burning Copper Belle Mine during summer of 1924.

Later, the Shannon Copper Company obtained a 5-year lease and bond upon the property, and eventually purchased it, according to Mr. Gleeson, for about $100,000. This company during 1907 shipped

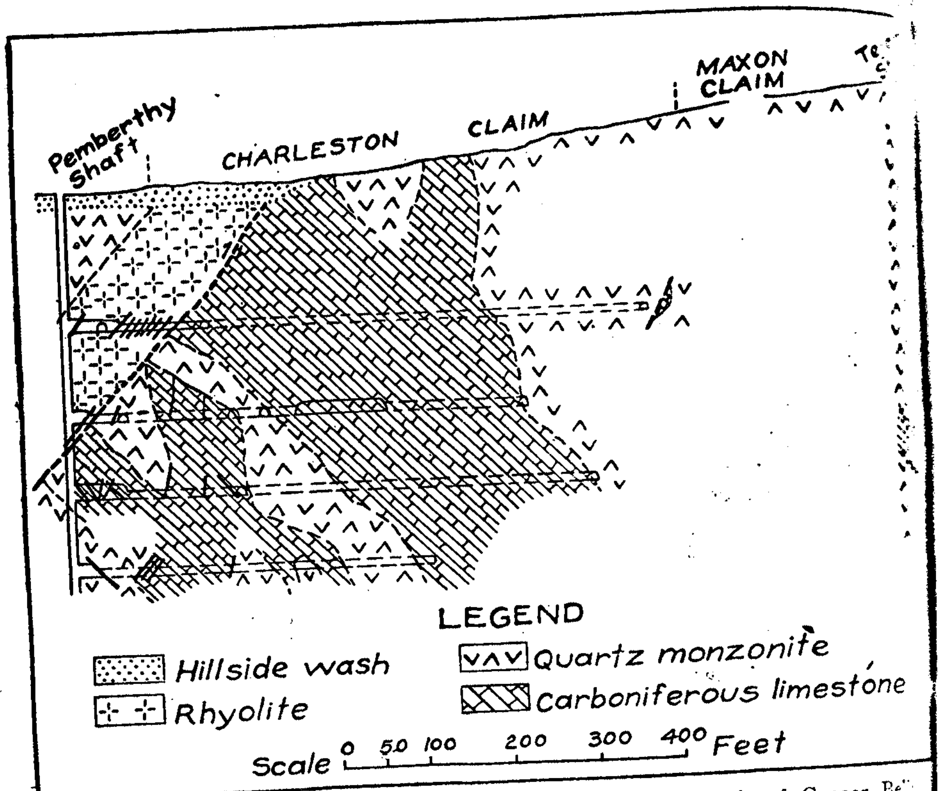

Fig. 15.—East-west vertical section through Pemberthy shaft of Copper Belle Mine, after Locke and Wilson, with slight modifications.

from the property ore that contained 64,982 pounds of copper, 20,84[illegible] ounces of silver, and 307 ounces of gold, aggregating in value $32,96[illegible] and between 1911 and late 1922 mined about 305,000 tons of ore, most of which was sent to Clifton, where its high sulphur content and lack of gangue were at a premium for fluxing other ores. In 192[illegible] there was begun an attempt to extract copper from the mine ores by a unique method of roasting and leaching in place. This plan entailed, first, setting fire to the mine workings, in the belief that the sulphide ore bodies, once they were kindled, would burn in the persistent fashion of other known sulphide mine fires; next, after the fire had burned itself out, flooding the workings with water to dissolve the copper sulphates; and, finally, pumping out the water and passing it over iron scrap to precipitate the copper from solution. Accordingly the timbering of the mine was ignited, quantities of fuel-oil, fire-wood and old railroad ties were dumped down the shaft, and the fire burned satisfactorily for a few months (see Fig. 14); but after about a year

unfortunately, it gradually died down without accomplishing its purpose. For a time, the water was allowed to rise in the workings; but in May, 1926, it was being pumped out, and partial retimbering was in progress.

A description of the geology and ore deposits of the property will be found on pages 48-49 of this report. A geologic section of a portion of the mine, prepared by Augustus R. Locke and A. S. R. Wilson, and furnished through the courtesy of the Shannon Copper Co., is shown in Fig. 15.

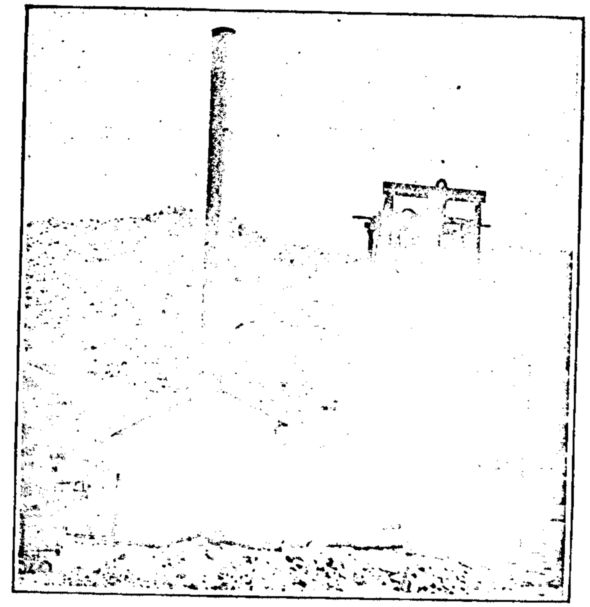

Fig. 16.—Pemberthy shaft. Gleeson Ridge in background.

The workings of the Copper Belle Mine are confined almost entirely [illegible] the Charleston claim. Up to the end of 1918 these workings [illegible]mounted to about 38,000 feet, which included 4,213 feet on the 100-[illegible]oot level; 8,961 on the 200; 12,232 on the 300; 8,658 on the 400; [illegible]536 on the 500; and 645 on the 600; and 1,405 feet of shaft sinking. [illegible]he original Copper Belle shaft is a little over 400 feet deep, and the [illegible]ree-compartment Pemberthy shaft, which was sunk in 1917 on the [illegible]lizabeth claim, to connect with the Copper Belle workings, is 581 [illegible]et. The surface equipment of the Copper Belle was removed before [illegible]e fire; but the Pemberthty still maintains steam boilers, hoist, com-[illegible]essor, and blacksmith shop.

TEJON GROUP

The Tejon group, which is situated northeast of Gleeson, contains six patented claims as shown in Plate III, and is owned by Mrs. Mary McKittrick of Santa Barbara, California. Development of the group has been restricted mainly to the Tejon and Tom Scott mines.

Tejon Mine: The Tejon shaft is situated on the Maxon claim, near the southwest base of Gleeson Ridge, about 1,000 feet northwest of the railroad. This claim is said to have been located in about 1888 by Mr. Kit Charleston, and the Tejon shaft was sunk in 1912 in an endeavor to find an ore body similar to that of the Copper Belle. No records of any production are available.

The geology and structure of the general vicinity have been already outlined on page 31 of this report. Exposed on the surface at the mine is a belt of quartz monzonite about one-eighth mile wide that is bounded on the northeast by the Naco limestone of Gleeson Ridge and on the southwest by a small area of probably the same limestone. Normal faulting, the pattern of which in most cases can not be traced upon the surface, has affected the formations to a moderate extent. The Tejon shaft was started in the quartz monzonite, at a distance of about 200 feet west of its contact with the limestone of Gleeson Ridge. The mine workings were inaccessible at the time of the writer's visit, and the accompanying section (Fig. 15) is based mostly upon data obtained from the Shannon Copper Company. At a depth of 400 feet, about 40 feet of eastward-dipping limestone, in contact with quartz monzonite both above and below, was passed through. Thin, irregular replacements of pyritic ore, said to contain one to 1.5 percent copper, were found along these contacts. The extent of this ore is not reported; but the mine dump showed abundant granular pyrite with slight amounts of chalcopyrite. As already stated on page 49, these ores are not of contact metamorphic origin, but were probably deposited by solutions that emanated from some other porphyry mass, and gained access to the limestone along its contacts with the quartz monzonite.

Development in the Tejon Mine consists of five levels extending from the shaft, which is 518 feet deep. Of these levels, there is said to be about 150 feet of workings on the 100-foot level; 1,000 on the 200; 65 on the 300; 1,500 on the 400; and 500 on the 500-foot level.

Equipment includes an electric and steam power plant, hoist, compressor, and blacksmith shop.

Tom Scott Mine: The portal of the Tom Scott tunnel is located near the south end center of the Tom Scott claim, on the west slope of Gleeson Ridge, about one-fourth mile from the railroad. This claim was one of the first locations made in the district, and is said to have produced about $50,000 worth of lead-silver ore during the eighties. Except for occasional operations by lessees, it has been idle for many years. During the late war, according to Mr. Marchello,* the mine produced over 2,500 tons of ore that contained an average of about 20 ounces of silver and $2.25 gold per ton, 7½ percent lead, and 3½ percent copper. Further shipments were made from it in 1919 and 1923. Early in 1925, a 10-year lease upon it was obtained by the Tejon Leasing Company. For this company, Messrs. Wilson and Wheelock worked the lease until the end of 1925, and shipped to El Paso about 4,000 tons of lead-silver ore that carried some gold and copper values.

The mine is entirely in Naco limestone, the beds of which here vary in thickness from 1 to 4 feet, strike N. 10° W., and dip about 45° E. Many faults and fractures are exposed by the mine workings in this limestone. The most prominent fault strikes and dips with the strata, and, because its limonitic, silicified breccia has been more resistant than the limestone to weathering, is traceable along the hillside for about 1,000 feet north of the tunnel portal. Most of the other faults and fractures, which are much less prominent, have a general north-south strike; but there are many trending in every direction. In general, most of these faults have brought about only minor zones of crushing within the limestone; but in some cases, surface waters percolating down along planes of fracturing have dissolved out extensive cavities and later more or less refilled them with loose material. These cavities are of irregular shape, and vary in size with abrupt bulgings that are sometimes as much as 10 feet across and 6 feet high. Their secondary filling, which is poorly consolidated material derived wholly from the limestone, consists of limestone, chert, and iron-stained quartz, in semi-rounded fragments that range in size from fine sand to over an inch in diameter.

Since the ore bodies of this mine belong to the class already described on pages 49-51 of this report, little further needs be said of them here. Their distribution and size exhibit the irregularities characteristic of their type. Commercial ore is also found in many of the above-mentioned filled caves. An unusual amount of yellow, siliceous, limonitic material, reported to carry gold values up to $2.00 per ton, occurs with the ore in some of the stopes of this mine.

*Oral communication.

The mine workings, which extend in a northerly direction from the tunnel portal, lie wholly within the boundaries of the Tom Scott claim. These workings are distributed over five principal levels. On the main, or tunnel, level are about 1,280 feet of workings, besides a few stopes; connected with it from above by raises is the fourth level, with about 35 feet of workings; above that is the third level, with about 485 feet; next above is the second level, with about 250 feet; next is a short intermediate level, extending about 40 feet; and connecting with the surface is the highest, or first, level, with about 500 feet of workings.

COSTELLO GROUP

The Costello group, which is situated north and northeast of Gleeson, contains 18 patented claims as shown in Plate III, and is owned by Mrs. Mary Costello of Los Angeles. Development upon the group has been principally in the Silver Bill and Defiance workings; but several shallow diggings are said to have yielded considerable rich silver-lead ore during the eighties.

Silver Bill Mine: The old Silver Bill shaft is situated on the Silver Bill claim, three-fourths mile northeast of Gleeson, on the west slope of Gleeson Ridge, at an elevation of 5,300 feet.

Rich silver-lead ore was mined from near the surface of the Silver Bill claim in the eighties. It is said that the Silver Bill shaft was sunk in 1890, and most of the workings driven between 1893 and 1896. During part of that time, the mine is said to have been owned by a Mr. Severens of London, and later by the Costellos. A large tonnage, as evidenced by the size of the old stopes, was mined during those years; but, due to the drop in silver prices and grade of ore, only occasional underground work was done for many years. In 1922 Messrs. F. J. Gibbons and M. Marchello obtained a 2-year lease upon the mine, but confined their operations largely to sorting the dump. Although it previously had been sorted more than once, they recovered and shipped to El Paso from 150 to 900 tons of ore per month for nearly two years. This ore is said by Mr. Gibbons to have averaged about 10 ounces of silver and $1.50 in gold per ton, 10 percent lead, a small amount of copper, and about 3 percent manganese. In 1925 Mr. C. K. Jacobson and others obtained a 5-year lease upon the mine, and started some new underground work. Their shipments between August, 1925, and June, 1926, amounted to 920 tons.

The Naco limestone at this place is in beds from 1 to 4 feet thick, strikes N. 30° W., and dips from 40° to 50° NE. This limestone is in contact with quartz monzonite about one-eighth mile south of the collar of the shaft, and, immediately north of the shaft, is cut perpendicularly to the bedding by a dike of quartz monzonite-porphyry. A prominent fault that appears to be a continuation of the major one exposed in the Tom Scott workings cuts through the shaft and strikes and dips in general with the bedding, but forks north of the shaft, as shown on Plate I. This fault is expressed in about an 8-foot fissure zone that is often marked by angular fragments of limestone and silica in gouge, which weathers red-brown to black. Many minor faults and prominent fractures show up underground. These features strike in many directions and dip from 40° to 80°, but the most numerous, persistent ones strike about N. 50° to 80° E., and are cut at about right angles by another general system. A characteristic feature of most of these faults is that their dip varies considerably within a short distance. Irregular solution cavities in the limestone, from an inch up to about 2 feet across, are frequently met with underground.

The ore deposits of this mine belong to the class already described on pages 49-51. The accompanying sketch (Fig. 17) of the workings shows the areas of stoping that mark the distribution of the ore bodies. The large ore body mentioned on page 50 was followed down by, and stoped out north of, the inclined shaft. About 2 to 2.5 percent zinc was present in all the ores mined by Mr. Jacobson,* except in one stope a short distance north of the bottom of the shaft. There it ran as high as 20 percent, and was associated with abundant massive, black, copper oxide (probably melaconite).

Workings of the Silver Bill, a sketch of which is shown in Fig. 17, consist of a 271-foot shaft that follows down the dip of stratification with an inclination of about 47°; about 525 feet of drifts; and several raises, winzes, and open, untimbered stopes.

Surface equipment was all removed many years ago, but the ore mined since 1924 has been trammed through the Mystery tunnel.

Defiance Mine: The Defiance tunnel is situated on the Defiance claim, about 400 feet northwest of the Silver Bill shaft. This claim, which also yielded rich silver-lead ore in the early days, was worked during parts of 1923 and 1924 by Mr. M. Marchello. His shipments* from the mine during those years amounted to about 300 tons of ore that carried from 8 to 14 percent lead, 4 to 7 ounces of silver, and some zinc.

The geology and ore bodies of the Defiance are similar to those of the Silver Bill. A fork of the fault that passes through the Silver

*Oral communication.

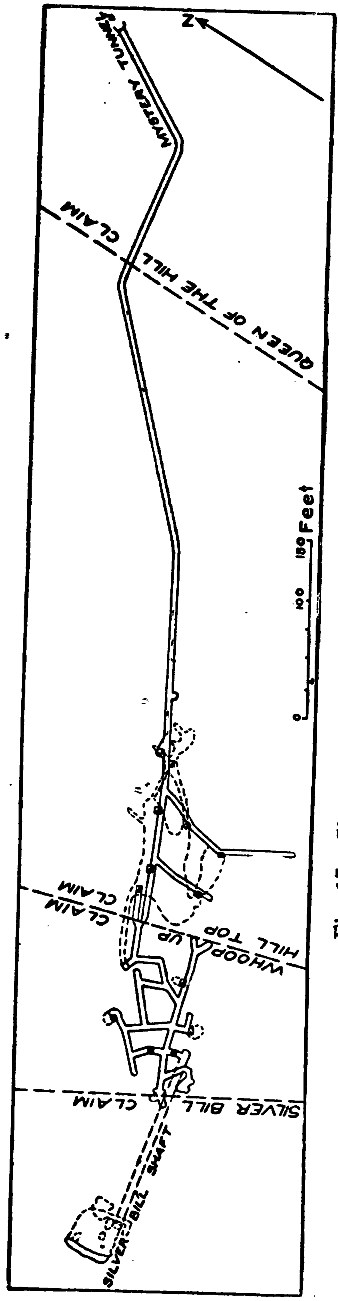

Fig. 17.—Sketch of Silver Bill and Mystery workings.

Bill shaft is followed by the Defiance tunnel, and the very irregular, scattered bunches of ore found occurred along its zone.

Workings in 1924 consisted of about 125 feet of tunnel and some stoping.

MYSTERY GROUP

The Mystery group, which is situated on the east slope of Gleeson Ridge, includes four patented claims as shown in Plate III. This ground was located in about 1879 by Mr. J. McMann, was held later by Mrs. P. Warnekross, and is now owned by the Mystery Mining Company. Development of the group has been confined mainly to the Mystery Mine.

Mystery Mine: The portal of the Mystery tunnel is situated near the north end-center of the Queen of the Hill claim, about one-half mile west of the railroad. Most of the workings were driven in 1923 and 1924. Shipments from the mine totaled 1,098 tons in 1924, and 6,041 tons in 1925. Several cars of zinc ore were shipped early in 1926 to Mineral Point, Wis.

Above the tunnel portal, the Naco limestone, due to a local flexure, has a nearly flat dip; but a few hundred feet west, this dip increases to 40° to 50° NE. At the tunnel portal, the limestone is intruded by quartz monzonite, which, a short distance down the slope, is in turn cut by quartz monzonite-porphyry as shown on Plate I. The plane of intrusion between the quartz monzonite and limestone, as exposed 30 feet in from the tunnel entrance, dips 5° W., and shows only a slight marbleization of the limestone. Very little fracturing is apparent in the limestone for the first 600 feet of the tunnel; but, at about that distance in, there is a zone of several small faults that dip for the most part at rather low angles to the east and show some limonitic and manganitic stain. West of that point in the mine occur frequent fractures and minor faults that strike E.-W., NW.-SE., and NE.-SW. The most prominent one of these features strikes S. 70° W. along the main drift, and dips 80° SE.

The ore deposits of this mine, since they are typical of the class considered on pages 49-51, need not be described further. The distribution and area of the bodies already mines are indicated by the areas of stoping shown in Fig. 17. Their vertical extent varies from a few inches up to about 50 feet. The only occurrence of sulphides noted was about 625 feet from the tunnel portal, where, along one of the few wet fractures in the mine, a narrow area of oxidized siliceous copper ore, said to contain about 3 percent copper, surrounds a small amount of disseminated pyrite and chalcopyrite grains.

Workings of the mine consist of about 785 feet of main tunnel, connecting with the Silver Bill workings, and the various raises, stopes, and side-drifts indicated by Fig. 17.

Surface equipment includes a gas engine compressor, blacksmith shop, and loading bins.

PRACTICAL DEDUCTIONS

In light of the data recorded in this report, it is possible to draw a few practical conclusions regarding the future economic possibilities of the Turquoise district.

As in any mining district, future activity will depend mainly upon the inter-dependent factors of amount and kind of ore in the ground, the metal market, and costs of mining, transportation, and reduction.

A large portion of the considerable tonnage shown by mining and drilling explorations to exist still in the district is of too low a grade for profitable mining under 1926 conditions of metal market and costs. The largest of these reserves is that of the pyritic copper deposits in Abrigo limestone, but smaller ones obtain in all the deposits.

Additional small bodies of higher-grade ore will doubtless be discovered by fortunate prospecting, properly guided by an understanding of the origin and occurrence of the ores already found in the different deposits.

In the area of thrust faulting north of Courtland, explorations have shown the ore to occur northeast of Casey Hill, for the probable reason, postulated on pages 44-45, of the relation of the drainage area to the origin of the ore. The shallow ore of the Mona prospect, found in the older gravels northwest of Casey Hill, is very significant in this connection.

The pyritic ore bodies of the Abrigo limestone, described on pages 45-47, are said to have been largest and most numerous near contacts with the quartz monzonite-porphyry. Comparatively small, enriched bodies, as the Armstrong, McLenden, and Herron, have been found in the Abrigo by following fractures that, a few feet below the surface, carried abundant, more or less copper-stained, limonitic material.

The pyritic ores of the Carboniferous limestone, as described on pages 47-49, seem to have depended upon the quartz monzonite contacts to furnish routes of access for the mineralizing solutions. These

ore bodies have been found to increase in richness and size with certain types of rock alteration.

In the lead-silver deposits of the Naco limestone, as described on pages 49-51, the zones of fracturing and minor faulting that show either or both iron and manganese mineralization usually have been found to lead to ore. These ore bodies seem to be largest and richest where two or more such fractures intersect, or where one turns or flattens. Higher percentages of zinc have been found a short distance below or away from the lead-silver ore bodies.

The best turquoise has been found in the Bolsa quartzite within a few feet of the granite, associated with fractures that are transverse to the quartzite-granite contact.

Mining costs in the district probably will not decrease materially unless cheaper power is made available. Transportation facilities are probably as adequate and cheap as they will be in many years; supplies can be brought in either by highway or by rail, and the district is only 40 miles by rail from the smelters at Douglas, or 254 miles from El Paso. Certain marked improvements that may be made in the efficiency and economy of concentrating and reducing the types of ores that occur in the region constitute intangible possibilities. Closer coöperation among the mine owners and operators would be of eminent benefit in promoting and maintaining the future economic prosperity of the district.