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GEOLOGY AND ORE DEPOSITS

OF THE

MOGOLLON MINING DISTRICT, NEW MEXICO

BY

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OUTLINE OF THE REPORT

The Mogollon district is in the western part of the Mogollon Mountains, in southwestern New Mexico. The rugged topography is due to faulting along the western front of the range. The rocks of the district are principally lavas of Tertiary age with accompanying pyroclastic rocks and subordinate sandstone and conglomerate. Andesite and rhyolite predominate. Later gravel, of Pliocene or Pleistocene age, occurs to the west of the district, faulted against the older rocks, and small dikes of later (probably Pleistocene) basalt cut the Tertiary lavas.

The Tertiary rocks have been complexly faulted, and the geologic map shows a complex mosaic of fault blocks, the result of normal faulting in Tertiary time. These faults in the main follow two directions, approximately N. 20° E. and N. 65° W. A later fault of probable early Pleistocene date blocked out the present range and was accompanied by slight renewal of movement along the older fault lines. Since this later faulting the streams have had time only to cut narrow box canyons across the fault scarp.

The ore deposits of the district are silver-bearing quartz veins and copper ores of less commercial value, the latter no longer mined. The annual production formerly exceeded a million ounces of silver but is now much less. The veins follow very closely the earlier faults, and the vein system is therefore complex. The greater part of the production has come from a group of veins of westward trend in the central part of the district. Quartz is the principal gangue mineral. Calcite, in part manganiferous, and fluorite, together with rare adularia, are also present. The primary metallic minerals include pyrite, chalcopyrite, bornite, chalcocite, sphalerite, galena, stromeyerite, argentite, and probably tetrahedrite. Minerals of later origin include, besides iron oxides, malachite, azurite, horn silver, native silver, and native gold.

Primary sulphide ores are found close to the surface except where post-mineral movements have shattered the vein and locally permitted oxidation to a considerable depth. Supergene sulphide enrichment does not appear to have been extensive in the ore now being mined but may have been in places a factor in raising low-grade primary sulphide protore to ore.

The ore bodies are large and well defined. Commonly the horizontal dimension exceeds the vertical. The ore appears to be confined to a fairly definite zone, less than 1,000 feet in thickness; comparatively few ore bodies were found to reach the present surface, and on the other hand the deeper levels of the mines have so far proved barren.

The future of the district depends on the possibility of finding new ore bodies in the developed veins at greater depth than that to which exploration has extended, or of discovering ore in veins that have not yet been prospected because of lack of promise at the outcrop.

GEOLOGY AND ORE DEPOSITS OF THE MOGOLLON DISTRICT, NEW MEXICO

By Henry G. Ferguson

INTRODUCTION

The Mogollon (mo-go-yohn′) or Cooney district is in the southwestern part of Catron County, N. Mex., about 14 miles east of the

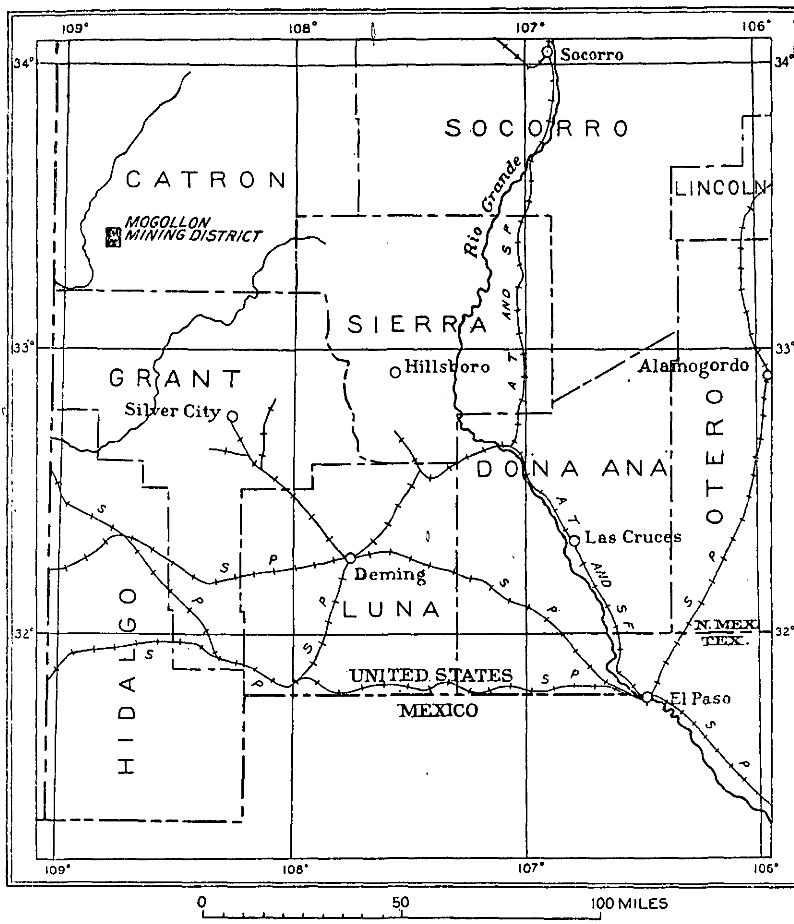

Figure 1.—Map of southwestern New Mexico, showing location of Mogollon district

Arizona line. (See fig. 1.) Silver City, the nearest available railroad point, is about 85 miles to the southeast. The district lies near the western border of the Mogollon Range, which here presents a steep front facing westward toward the valley of San Francisco River. The crest of the range, marked by a line of high peaks, is a few miles to the east. Near Mogollon the front of the range is marked by a steep escarpment. In places sheer cliffs several hundred feet high face the valley. To the south and north the change from mountain to valley topography gradually becomes less abrupt. (See pl. 3.)

The district was visited by L. C. Graton in 1905, and his report was published in 1910.[1] In 1915 a survey for a detailed topographic map of the district, on a scale of 1:24,000, was made by R. W. Berry. The writer spent three months during the autumn of 1916 in a study of the geology. The war prevented the completion of even a preliminary report, and the district was therefore revisited in September, 1919, when about two weeks was spent in the field. A preliminary report[2] was published in 1921, but pressure of other work has delayed the completion of the present somewhat more detailed report.

The writer desires to thank his friends in the Mogollon district, particularly Messrs. S. J. Kidder, C. A. Botsford, W. Johns, C. E. Wheelock, R. P. Wheelock, and G. C. Baer, for their assistance and helpful suggestions. Detailed reports on the geology of the Last Chance and Maud S. mines, by Mr. Wilbur H. Grant, of San Francisco, made available by the courtesy of Mr. S. J. Kidder, and geologic maps of the portion of the district adjacent to the Little Fanney mine, by Mr. G. C. Baer, were studied with much profit. Many data in regard to mine development and output have been derived from a paper by Mr. David B. Scott,[3] former superintendent of the Little Fanney mine.

Mr. M. N. Short, of the United States Geological Survey, has kindly made a study of polished sections of typical ores from the district, and the conclusions herein set forth as to the degree of supergene enrichment are based on this study.

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Besides the papers already cited, very little of value has been published on the geology of the Mogollon district. The following list comprises all the titles that have come to the attention of the writer:

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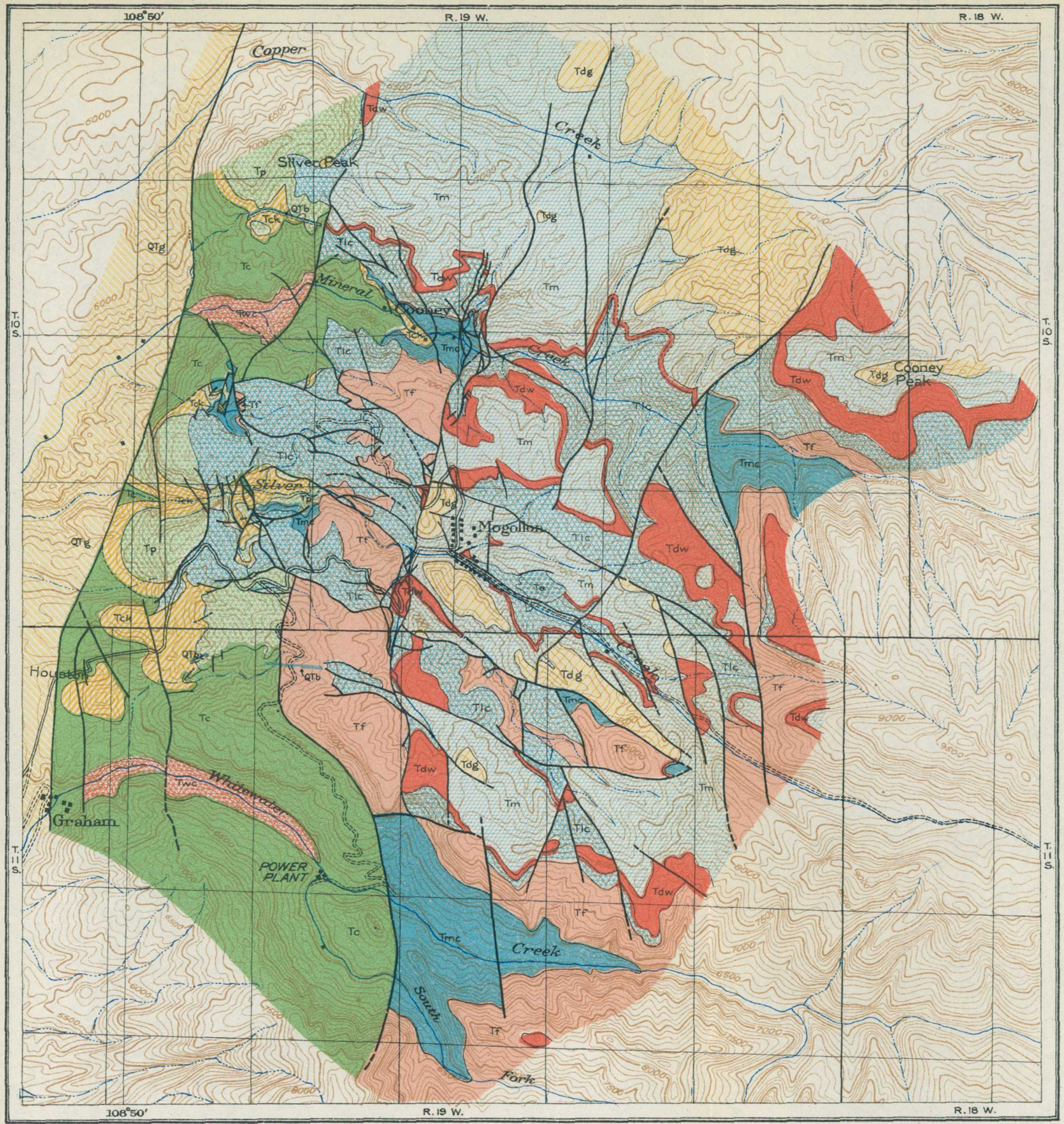
[1] Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, pp. 191–201, 1910.

[2] Ferguson, H. G., The Mogollon district, N. Mex.: U. S. Geol. Survey Bull. 715, pp. 171–203, 1921.

[3] Scott, D. B., Ore deposits of the Mogollon district: Am. Inst. Min. Eng. Trans., vol. 63, pp. 289–310, 1920.



Base from U. S. Geol. Survey Map of Mogollon quadrangle

A. HOEN & CO. LITH. BALTIMORE.

Scale $\frac{1}{62,500}$

0 1 2 3 Miles

Contour interval 100 feet

Datum is mean sea level

EXPLANATION

Tertiary or Quaternary — *Late Pliocene or Pleistocene*

- **QTg** — Gila conglomerate (*Poorly consolidated coarse gravel with lenses of sandy material*)
- **QTb** — Basalt dikes (*Probably contemporaneous with Gila conglomerate*)

Tertiary

- **Ta** — Intrusive andesite
- **Tdg** — Dog Gulch formation (*Conglomerate and sandstone with a few lenses of red shale*)
- **Tm** — Mogollon andesite (*Includes one or more dacite flows*)
- **Tdw** — Deadwood Gulch rhyolite tuff (*White banded rhyolite, in small fragments, in a very fine grained siliceous matrix*)
- **Tlc** — Last Chance andesite (*Chiefly andesite, some breccia and agglomerate*)
- **Tf** — Fanney rhyolite (*Characterized by spherulitic texture*)
- **Tmc** — Mineral Creek andesite (*Thin flows of vesicular andesite alternating with breccia and agglomerate; near base some beds of reddish-purple feldspathic sandstone*)
- **Tp** — Pacific quartz latite (*Flows in upper part of Cranktown sandstone; characterized by quartz phenocrysts*)
- **Tck** — Cranktown sandstone and Houston andesite (*Mapped separately on Plate 1*)
- **Tc** — Cooney quartz latite (*Alternating flows of quartz latite and beds of tuff, with a few lenses of red, purple, and green sandstone*)
- **Twc** — Whitewater Creek rhyolite (*Flow-banded glassy rhyolite with beds of rhyolite tuff*)
- Fault

RECONNAISSANCE GEOLOGIC MAP OF THE MOGOLLON DISTRICT AND SURROUNDING AREA NEW MEXICO

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1910. Graton, L. C., Mogollon district: U. S. Geol. Survey Prof. Paper 68, pp. 191–201, 1910. A careful reconnaissance study of the geology and ore deposits, with descriptions of the mines as developed at the time of visit, 1905.

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TOPOGRAPHY

The Mogollon Range owes its topographic expression to faulting along the present western front, which has elevated this part of the range relatively to the valley on the west now drained by San Francisco River. The Mogollon mining district is in the western part of the range, about a mile east of the fault scarp. The topography of the district and the surrounding area is that of a fault-block mountain in an early stage of erosion. The steep, forbidding cliffs that form the front of this part of the Mogollon Range face westward across the valley of San Francisco River. Between the flat river bed, which at Alma is about 4,900 feet above sea level, and the mountains are flat-topped mesas of partly consolidated gravel, whose altitude ranges from 5,400 feet on Whitewater Mesa to more than 6,000 feet on the mesa north of Copper Creek. These mesas and the mountain range to the east are trenched by deep stream canyons. Mineral Creek and Silver Creek cross the area covered by the accompanying detailed map (pl. 1), from east to west, and Houston

Canyon drains a small tract in the southwestern part. The magnificent canyon of Whitewater Creek is just south of the area, and to the north is Copper Creek; both these streams are about parallel with Silver and Mineral Creeks. As the faulting which has produced the present topography is of comparatively recent date, the stream canyons are extremely youthful, and their walls, particularly near the scarp that marks the front of the range, are precipitous. In Cooney Box (pl. 4, *A*), the western part of the Mineral Creek Canyon, the altitude at stream level is 5,450 feet; at the edge of the plateau, 600 feet to the north, it is 6,300 feet. The topography of the Silver Creek Canyon is similar, but for the most part the cliffs are not so steep. Along Whitewater Creek the canyon walls are as steep as in Cooney Box. Farther up the stream courses the valleys, although still bordered by sharp cliffs, are not of the box-canyon form which is characteristic at their exit from the range. To the east of the Mogollon district the stream valleys, though still with steep sides, lose the cliff-inclosed canyon form which is characteristic nearer the front of the range. (See pl. 4, *B*.)

Above the cliffs the topography changes abruptly and the interstream areas are comparatively flat between altitudes of 6,300 feet in the western part of the area shown on the map and 7,500 feet in the eastern part. The boundary between this upland bench and the stream canyons is nearly everywhere sharply defined. This plateau is less well developed in the interstream areas south of the Mogollon district and better developed in those to the north, particularly between Copper and Deep Creeks.

On the east the land rises steeply from this dissected plateau to the line of high peaks at altitudes of about 10,000 feet, which mark the crest of the range.

CLIMATE AND VEGETATION

The plains to the west and south of the mountains show the characteristic vegetation of the semiarid regions of the southwestern United States. The gravel mesas between the river bottoms and the mountains are nearly barren, but the irrigable river lowlands are the site of prosperous ranches. In the higher Mogollon district, however, there is considerable rainfall, and heavy showers are frequent, particularly during the late summer. A rather scrubby vegetation, including several varieties of small oaks, mountain mahogany, and small juniper and pinon is characteristic of the district itself. The higher mountain country east of the Mogollon district and the gentle eastern slope of the range are more heavily wooded and furnish an abundant supply of mine timber.

GEOLOGY

ROCK FORMATIONS

GENERAL SEQUENCE

The Mogollon Range is built up principally of Tertiary lavas with accompanying pyroclastic rocks (pls. 1 and 3) and subordinate quantities of sandstone and conglomerates, probably of fluviatile origin, that represent periods of quiet between volcanic outbursts. As no fossils were found, the exact age of the rocks is not determinable, but as there are considerable erosional unconformities in the section, the rocks of the Mogollon district must represent a fairly long time interval. Graton[4] considers that the lavas were probably extruded early in the Tertiary period. The rocks were later faulted, and the fault planes became the sites of quartz and calcite veins. In late Pliocene or Pleistocene time the rocks in the area of the Mogollon district were deeply eroded and later buried under a thick covering of gravel, with minor flows of basalt. Then came renewed faulting, mainly along a single plane which now defines the range front, with relative downthrow on the west. Since that time the streams have cut sharp canyons across the relatively uplifted eastern block, and the gravel has been stripped from its surface, leaving a well-defined bench bounded by the fault scarp on the west and the higher mountains on the east.

The following table shows the sequence of rocks as observed in the district, the oldest at the bottom of the column, with the maximum observed thickness:

Section of formations in Mogollon district

	Feet
Pliocene or Pleistocene:	
Gila conglomerate (loosely consolidated gravel)	700+
Basalt dikes (probably contemporaneous with the Gila conglomerate).	
Tertiary:	
Mineral-bearing veins.	
Intrusive andesite and diabase.	
Dog Gulch formation (conglomerate and sandstone with a few lenses of red shale)	400+
Mogollon andesite (including one or more dacite flows)	600
Deadwood Gulch rhyolite tuff	400
Rhyolite dike (possibly contemporaneous with Deadwood Gulch rhyolite tuff).	
Last Chance andesite (flows, breccias, and agglomerates)	600
Fanney rhyolite	1,200

[4] Op. cit. (Prof. Paper 68), p. 194.

	Feet
Tertiary—Continued.	
Mineral Creek andesite (latite) (flows, breccias, and agglomerates)	700
Pacific quartz latite (flows in upper part of Cranktown sandstone)	700
Houston andesite (single flow near base of Cranktown sandstone)	40
Cranktown sandstone	500
Cooney quartz latite (flows and tuffs)	1,400
Whitewater Creek rhyolite	700+

The sum of these maxima exceeds 8,000 feet, of which about 80 per cent consists of lavas and pyroclastic rocks and the remainder of fluviatile deposits. This total is not an adequate measure of the original thickness of the series, which undoubtedly varied greatly in different parts of even so small an area as that covered by this report and which was in part eroded at several stages in its history. The rhyolites in particular were very uneven in original thickness, and a flow may be lacking in one section and show a thickness of several hundred feet a short distance away. There was considerable erosion at different stages in the upbuilding of the mass, and parts of the flows have been removed. In many places exposed contacts show erosional unconformities, indicating that an extremely rugged topography was developed between periods of volcanic activity.

WHITEWATER CREEK RHYOLITE

The formation here named Whitewater Creek rhyolite is the oldest member of the volcanic series exposed in the Mongollon district and is found only where stream erosion has cut deepest, in the steep canyons along the lower reaches of Whitewater and Mineral Creeks. Several flows are present, and beds of white tuff mark periods of explosive activity. The rock of the flows is light purple and breaks with a platy fracture. It is glassy, commonly shows well-marked flow banding, and is in places minutely spherulitic. Small crystals of milky feldspar and biotite, not exceeding 2 millimeters in length, are sparingly present. Quartz does not appear in readily visible phenocrysts, but a characteristic feature of the rock is the presence of ellipsoidal cavities lined with small quartz crystals. These cavities are usually less than half an inch in length, though exceptionally found to a maximum length of 3 inches, and are arranged with their long axes parallel to the flow lines of the lava. In places the rhyolite carries small inclusions of andesite and dacite, showing the existence of older buried flows.

The maximum thickness observed was about 700 feet in Cooney Box, near the mouth of Silver Creek. The bed of Whitewater

Creek, south of the area shown on the detailed map, is cut in the Whitewater Creek rhyolite from a point a short distance below the old power plant to a point a short distance east of the main fault along the front of the range near the deserted town of Graham.

Under the microscope the feldspar grains prove to be principally orthoclase, though oligoclase is present in minor amount. Biotite is the only ferromagnesian mineral present and occurs only sparingly, in far less amount than the feldspar. Quartz is more common that might be inferred from inspection of the hand specimen; besides occurring on the edges of the cavities, as mentioned above, it is found in small lenticular nests of crystals and in minute grains scattered through the slide, in places thickly. The groundmass is glassy but in some places shows faint polarization, possibly in part due to divitrification or to the presence here and there of an unusually large amount of quartz in minute grains.

The tuffs are of less volume than the rhyolite flows and can not be always clearly differentiated from the more pumiceous facies of the flows, even after microscopic examination. The tuffs are commonly white and although approximating the rhyolite in composition appear to be richer in quartz. In general the grain of the rock is coarser, the glassy flow-banded groundmass of the rhyolite is replaced by a white chalky mass, and the characteristic lenticular quartz-lined cavities are lacking.

COONEY QUARTZ LATITE

The formation next above the Whitewater Creek rhyolite is here named Cooney quartz latite, from its exposures in the canyon of Mineral Creek near the old mining camp of Cooney. It also crops out in the headwaters of Gold Dust Gulch, on the divide north of Whitewater Creek, west of the power-plant road, and in the bed of Silver Creek near its mouth. It forms the principal rock along the west front of the range to the south of the area mapped in detail, at least at far as Little Whitewater Creek, 4 miles south of Whitewater Creek. In the eastern part of the area it was found only in the deepest workings of the Fanney mine.

The formation consists of alternate thin flows of quartz latite and beds of tuff, with a few lenses of red and purple or more rarely green sandstone. Flows predominate in the southern portion, especially along the power-plant road, and the tuffs farther north.

In the exposures cut by Mineral Creek the thickness of the Cooney quartz latite and its accompanying tuffs and sandstone is about 700 feet. In the southern part of the area it is much thicker. In the southwest corner of the area covered by the detailed map at least 1,200 feet is exposed. On the north wall of Whitewater Creek there is a thickness of 1,400 feet, and to the south of the creek the entire ridge southwest of the old power plant seems to be composed of the same lavas, which would give a thickness greater than 1,500 feet, with an unknown amount removed by erosion.

Except in the deepest workings of the Little Fanney mine the Cooney quartz latite was not found east of the line of faulting marked by the Great Western-Pacific group of veins.

The Cooney quartz latite is commonly a brick-red, highly porphyritic rock with small phenocrysts of feldspar and biotite, which equal in volume the surrounding groundmass. Quartz is usually inconspicuous or not visible to the eye, though in one or two of the flows quartz phenocrysts are prominent, causing the rock to resemble the Pacific quartz latite. In many of the flows the larger feldspar crystals contain intergrown quartz. Two kinds of feldspar are readily discernible in the hand specimen, one white and opaque, the other glassy and commonly showing delicate striations. Under the microscope the feldspar is seen to include both orthoclase and plagioclase; the plagioclase has the average composition of sodic andesine (Ab_7An_3). The relative amounts vary greatly in the different slides examined, but on the whole orthoclase seems to be slightly in excess. Biotite is next in abundance to feldspar and occurs in well-formed plates, in places altered to chlorite. Quartz is present in all the slides examined, but just as in the hand specimen, the amount is exceedingly variable. Very rarely large corroded phenocrysts occur. More commonly quartz occurs only in small nests of crystals or scattered in minute grains through the glassy groundmass. Magnetite is present in minor amount both as scattered grains or formed around the biotite and in part at its expense. In most of the slides examined the groundmass was found to be glassy, with faintly marked lines of flow; only rarely is a cryptocrystalline texture developed. Spherulites are lacking.

A partial analysis of a specimen collected by Graton,[5] made by W. T. Schaller, shows the rock to be relatively rich in soda, and it was therefore called soda rhyolite by Graton. It is believed, however, that the name quartz latite is more applicable.

Partial analysis of soda rhyolite from canyon above Cooney, N. Mex.

SiO_2	67.83
CaO	2.10
K_2O	5.46
Na_2O	3.30

The quartz latite appears to have been more fluid than the other silicic rocks of the Mogollon district and has spread out in thinner sheets. Probably none of the individual flows exceed 100 feet in thickness, and the average thickness appears to be much less.

[5] Op. cit. (Prof. Paper 68), p. 192.

The tuffs resemble the lavas in mineral composition but are white and pink instead of reddish and weather more easily. Many of them contain pebbles and andesite. In general the proportions of the minerals present are approximately the same as in the flows, but the feldspars commonly show some kaolinization, and the biotite is more or less chloritized. In places the groundmass is in part replaced by calcite. The tuff beds are of about the same thickness as the flows with which they are interbedded. A few small lenses of dark-purple to red and more rarely green feldspathic sandstone occur between some of the tuffs and flows in the wall of Cooney Canyon above the old Enterprise mill, but such lenses were not seen in the exposures of this formation in the southern part of the area or in Whitewater Creek.

CRANKTOWN SANDSTONE

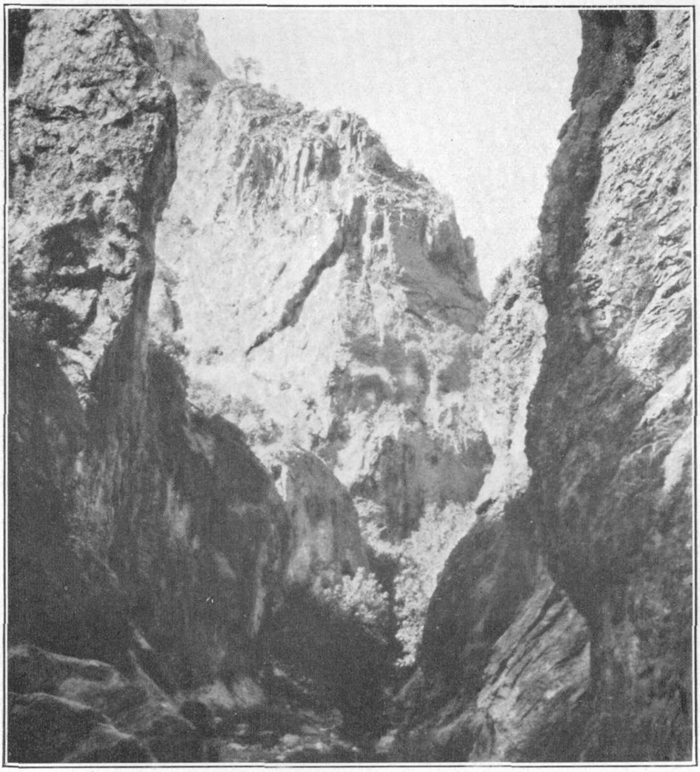
After the deposition of the Cooney quartz latite and tuffs there was a period of erosion in which deep canyons were cut and a probably very rugged topography developed. Later the steep-sided valleys were filled with sandstone containing lenses of conglomerate, here named the Cranktown sandstone, from the name commonly applied to a small group of prospectors' cabins on Silver Creek about a mile below Mogollon. Remnants of the old canyons are now revealed on the walls of Gold Dust Gulch and Houston Canyon. As shown in Houston Canyon a steep-sided gorge more than 100 feet in depth was cut in the Cooney quartz latite and later filled with sandstone. Plate 5, *A*, shows a portion of such a canyon. Here the wall was in part overhanging, so that the older Cooney quartz latite appears to overlie the younger sandstone.

The Cranktown sandstone is confined to the western part of the area, and owing to the irregular topography at the time of its deposition it varies greatly in thickness from place to place. The maximum observed thickness is 500 feet, near the mouth of Silver Creek. In Houston Canyon the exposed thickness exceeds 400 feet. At the edge of the buried canyon referred to above the thickness changes from 200 feet to about 20 feet within a horizontal distance of less than 300 feet, and 200 feet farther to the east the sandstone disappears altogether. It is lacking in the deep workings of the Fanney mine, which penetrate the Cooney quartz latite. Similarly it thins toward the south, as it was not found in the canyon of Whitewater Creek. The formation is about 100 feet thick on Silver Peak, near the northern edge of the area mapped. Here also it decreases in thickness eastward, though the change is not so abrupt as in Gold Dust Gulch.

The sandstone is commonly red to deep purple, and nearly everywhere shows cross-bedding. It is commonly rather fine grained and largely composed of small fragments of feldspar, for the most part angular. A little biotite is also present. Here and there the fine-grained beds contain pebbles of rhyolite and andesite. The conglomeratic lenses are rather rare and do not extend for long distances. Near Cooney there is, however, a thick bed of very coarse conglomerate containing angular boulders, the largest of which exceed 3 feet in width. (Pl. 6, *A*.) The irregular dips that characterize the Cranktown sandstone are, in large part at least, due to the initial angle of deposition. For instance, in the north wall of Mineral Creek Canyon, opposite the Cooney mine, the sandstone, which dips 5°–30° to the east and northeast, overlies the Cooney quartz latite, which here dips 10°–15° NW., and is itself overlain by andesite tuffs with sandstone beds that show easterly dips of 5°–8°.

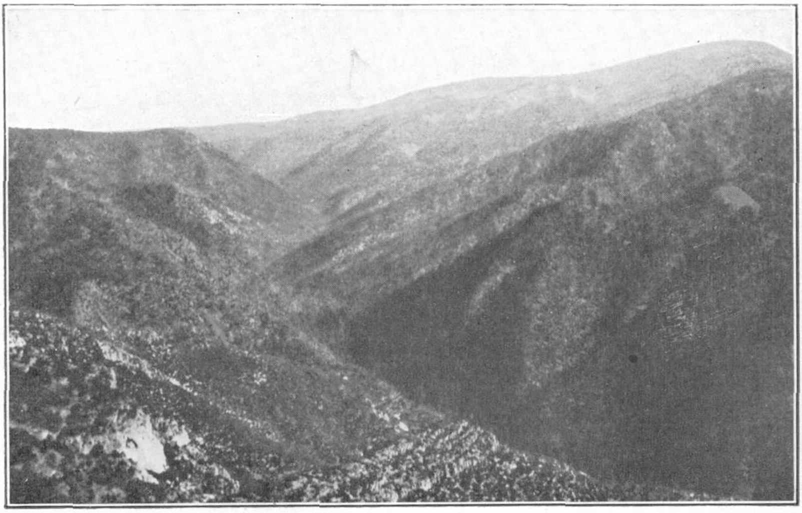
The deposition of the sandstone was thrice interrupted by volcanic activity, resulting in a flow of andesite, a bed of rhyolite tuff, and several flows of rhyolite. The andesite flow, near the base, and the rhyolite flows, near the top, have been mapped separately and are described below. The rhyolite tuff (pl. 5, *B*) occurs in the upper part a short distance below the massive rhyolite flows. Its maximum thickness is about 25 feet, and it is not everywhere present. This band of white tuff shows in striking contrast to the purple sandstone above and below, and in the walls of the Silver Creek Canyon, north of the Pacific mine, it is traceable for a distance of 2,000 feet. At the western end it is cut out by the overlying Pacific quartz latite, which here occupies a valley cut in the sandstone. To the east it dips below the creek bed. Tuff of a similar type, possibly the same bed, was seen on the west wall of Houston Canyon, close to the western border of the area mapped. The tuff is white to gray or pink and usually very fine grained, though here and there it contains small pebbles of rhyolite that closely resembles the overlying Pacific quartz latite. The principal components are small angular grains of quartz and sericitized feldspar, with small patches of chlorite probably representing original biotite.

The upper portion of the sandstone overlies the Pacific quartz latite and contains much material derived from that rock. As the Pacific quartz latite is lacking in the southern part of the area the two portions of the sandstone could not be separately mapped. In the north branch of Houston Canyon, just under the Silver City road, a conglomerate containing pebbles derived from the Pacific quartz latite as well as from the Cooney quartz latite shows that here the sandstone is younger than both.



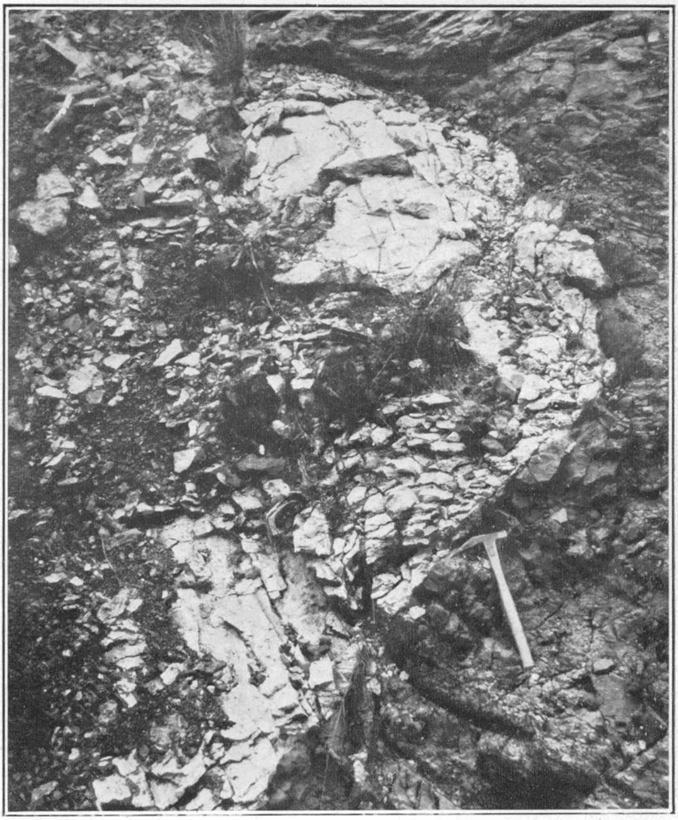
A. COONEY BOX, IN THE WESTERN PART OF MINERAL CREEK CANYON

Cliffs of Whitewater Creek rhyolite

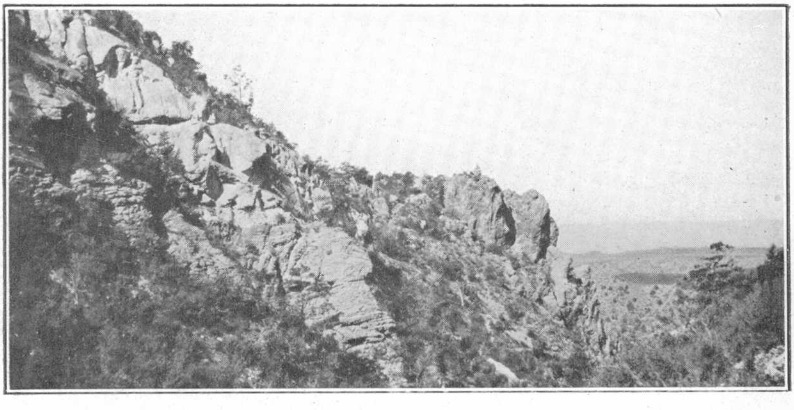


B. VIEW LOOKING EAST UP SILVER CREEK CANYON

Showing change in type of valley upstream

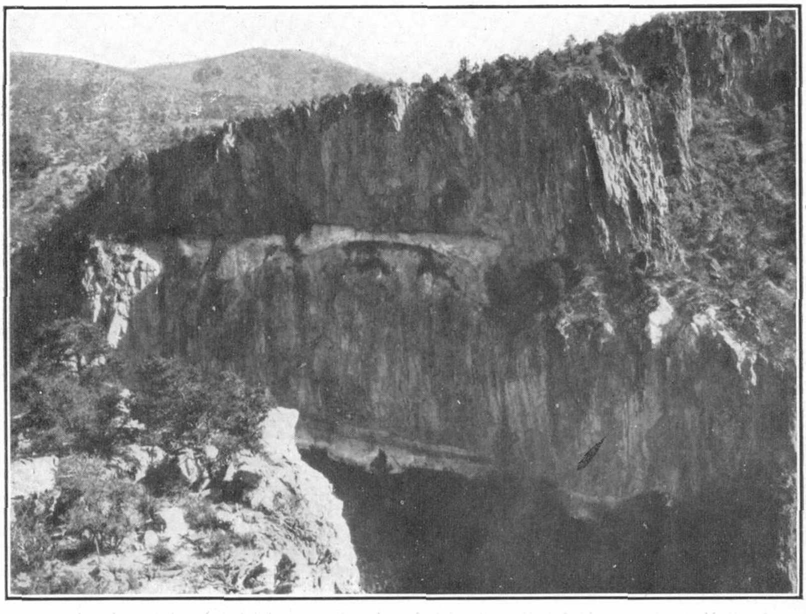


A. CRANKTOWN SANDSTONE (DARK) FILLING A STEEP-WALLED CANYON IN COONEY QUARTZ LATITE (LIGHT

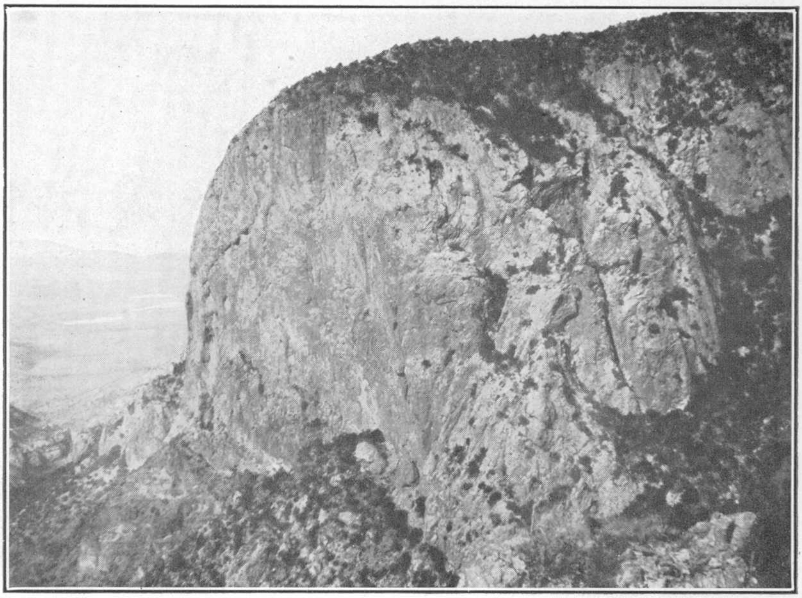


B. CRANKTOWN SANDSTONE, SHOWING CROSS-BEDDING, WITH INTERBEDDED LENS OF RHYOLITE TUFF

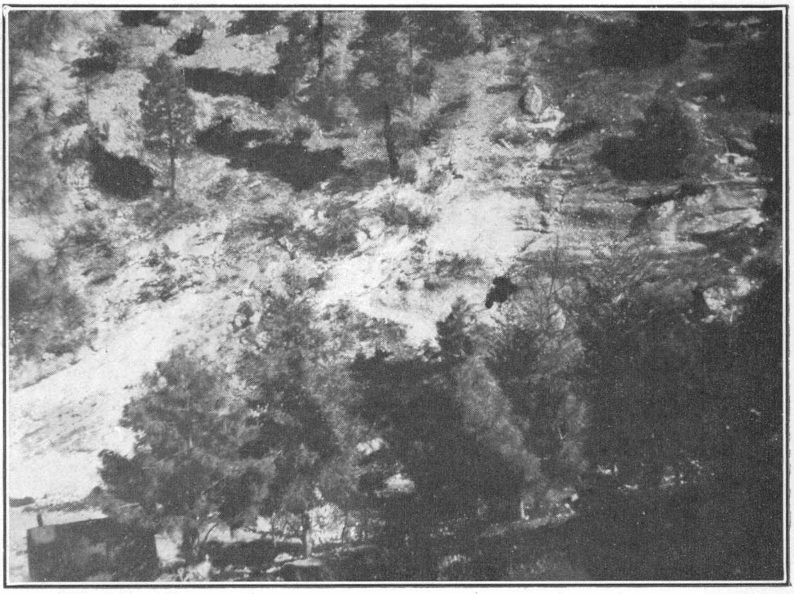
A. COARSE CONGLOMERATE IN CRANKTOWN SANDSTONE, MINERAL CREEK, NEAR COONEY



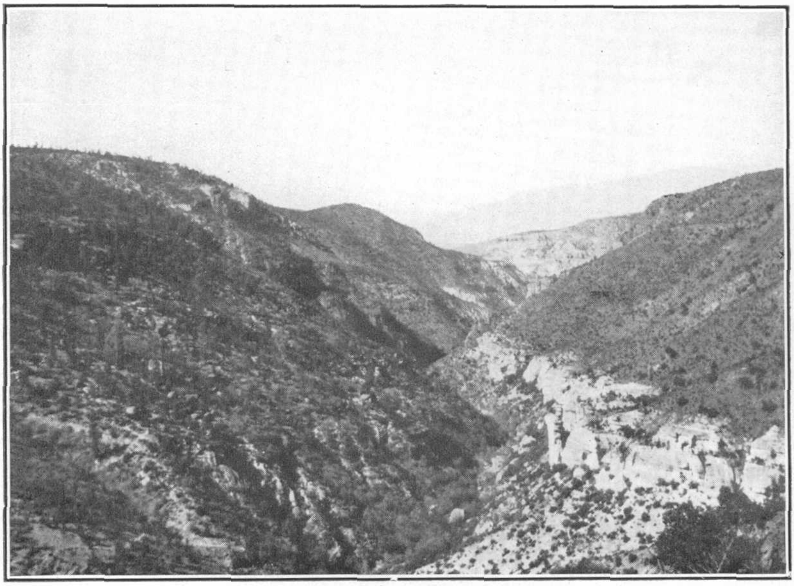
B. CLIFFS OF PACIFIC QUARTZ LATITE NEAR MOUTH OF SILVER CREEK CANYON, SHOWING SUCCESSIVE FLOWS



A. FAULT SCARP OF FANNEY RHYOLITE, NORTH WALL OF WHITEWATER CANYON

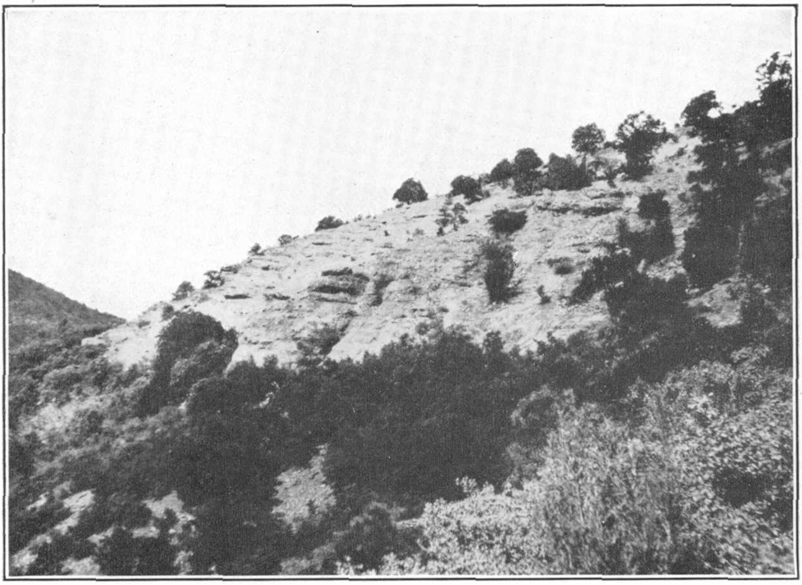


B. DEADWOOD GULCH RHYOLITE TUFF NEAR JUNCTION OF SOUTH FORK AND DEADWOOD GULCH

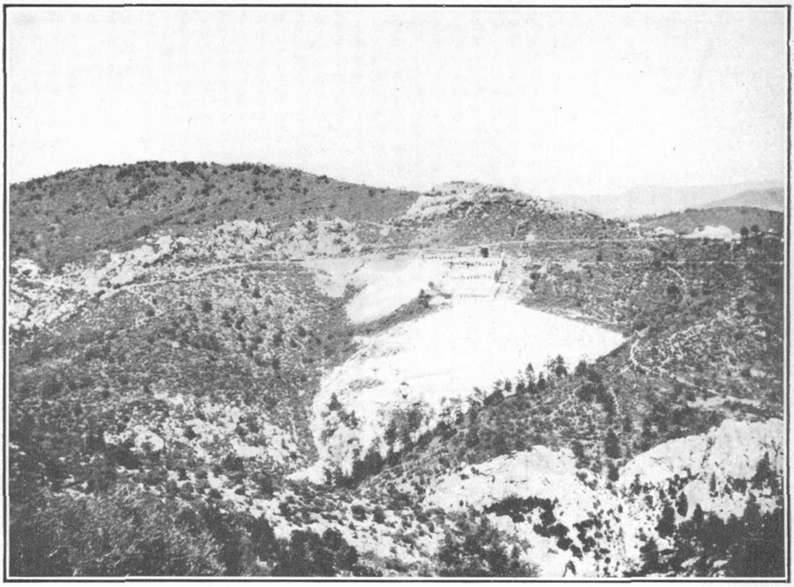


A. SILVER CREEK CANYON NEAR WESTERN BORDER OF MOGOLLON DISTRICT

White cliffs of Deadwood Gulch rhyolite tuff, overlain by Mogollon andesite

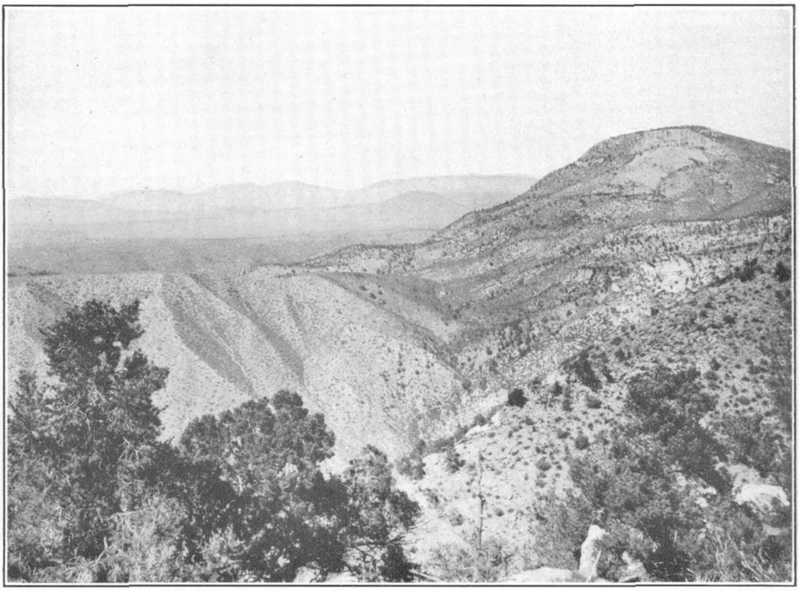


B. DOG GULCH CONGLOMERATE, HILL SOUTH OF MOGOLLON



A. FAULT CONTACTS OF FANNEY RHYOLITE (LIGHT) AND LAST CHANCE ANDESITE (DARK)

Dump of Fanney mine in center



B. SILVER PEAK

Gila conglomerate (left) faulted against Tertiary lavas

HOUSTON ANDESITE

The rock here named Houston andesite forms a flow about 40 feet thick near the base of the Cranktown sandstone and is best exposed in the valley of Houston Canyon, in the southwestern part of the area. What is probably the same flow appears in the lower part of the sandstone series near the mouth of Silver Creek. An andesite flow in the sandstone in Cooney Canyon has been doubtfully correlated with these rocks, although it may be another flow at a higher horizon.

The rock is porphyritic, but the phenocrysts are smaller and less numerous than in the other andesites higher in the series. All the phenocrysts, both the feldspars and the ferromagnesian minerals, are much altered. So far as could be determined the feldspars are mostly andesine, though the flow exposed at the mouth of Silver Creek contains some orthoclase also. The dark silicates are completely altered to limonite with a little chlorite. Apparently augite was originally the dominant ferromagnesian mineral, with subordinate biotite. The groundmass consists largely of small, slim feldspar rods with abundant alteration products, chiefly chlorite, calcite, and limonite.

PACIFIC QUARTZ LATITE

The Pacific quartz latite is so named because of its outcrops near the Pacific mine. Like the rocks just described, it is confined to the western part of the district, although encountered as far east as the deeper workings of the Fanney mine. It forms prominent cliffs near the mouth of Silver Creek and near the summit of Silver Peak, in the northwest corner of the area, and is also present in considerable thickness on the ridge between the power-plant road and Houston Canyon, south of the Confidence mine. It appears to have occupied part of the valley in which the sandstone was being deposited, and its maximum thickness is above the thickest portion of the sandstone.

The cliffs of the Silver Creek Canyon (pl. 6, *B*) show thick flows with rough columnar structure, separated by thin beds of tuff of the same general composition as the lavas. Here the thickness remaining is about 600 feet. In the area between Houston Canyon and the power-plant road the tuffs are present in much greater amount, and the alternate tuffs and flows make up a total thickness of about 700 feet. In Houston Canyon itself, however, the formation is lacking and the Cranktown sandstone, which here contains pebbles of the Pacific quartz latite, is overlain by a higher formation of the series, the Last Chance andesite. Half a mile east of the thickest part of the Silver Creek section only about 100 feet of the Pacific quartz latite is present. Similarly on Silver Peak, in the northwestern part of the area, about 500 feet of the Pacific quartz latite remains, whereas a mile to the east, where the quartz latite is cut off by a fault, the thickness hardly exceeds 50 feet.

The Pacific quartz latite was not encountered south of the area covered by the detailed map; to the north it appears to extend at least as far as Copper Creek.

The distinguishing field characteristic of this lava is the presence of abundant quartz, a feature which distinguishes it readily from all the other rhyolites and quartz latites of the district. The rock is commonly light colored and shows prominent quartz phenocrysts together with feldspar and subordinate biotite in a groundmass generally dense or glassy in appearance. Spherulitic texture is very rare but was observed in a few localities. The relative proportions of the minerals occurring as phenocrysts vary somewhat from place to place and in the different flows, but commonly quartz about equals or slightly exceeds the total feldspar in volume; biotite is subordinate. The microscope reveals both orthoclase and sodic plagioclase (oligoclase to andesine) in amounts which vary greatly in the different slides examined. In some thin sections, particularly those from the lowest flow, the plagioclase is distinctly in excess; in others orthoclase predominates; in one slide albite is present in place of the plagioclase, giving a soda rhyolite. Although at least one flow of rhyolite may be present and the proportion of plagioclase is on the whole less than in the Cooney quartz latite, the excess of plagioclase over orthoclase commonly observed in thin sections makes quartz latite the name most applicable to the formation as a whole.

The groundmass also varies in texture; in places it is glassy, with a tendency to spherulitic texture, but more commonly it is a minutely crystalline aggregate consisting of quartz and feldspar. In the groundmass orthoclase exceeds the plagioclase, and in the groundmass of some of the thin sections examined no plagioclase could be distinguished. All gradations in the texture of the groundmass from minutely yet distinctly crystalline through microfelsitic to glassy are observable. Biotite and probably both magnetite and ilmenite occur as minor constituents of the crystalline phases.

MINERAL CREEK ANDESITE

As noted above, deposition of the Cranktown sandstone continued after the outflow of the Pacific quartz latite. The deposition of the sandstone was succeeded by a period of active erosion, for the andesitic flows of the next series rest upon an uneven surface. In places this surface has been cut in the Cooney quartz latite and in the lower part of the Cranktown sandstone; elsewhere the andesite rests upon the Pacific quartz latite and the overlying sandstone and conglomerate, forming the upper part of the Cranktown sandstone. (See sections *A–A* and *B–B*, pl. 2.)

These flows are predominantly andesitic in type, and as they are best exposed on the walls of the Mineral Creek Canyon the name Mineral Creek andesite has been given to the series. The lavas spread out in thin flows, few or none of which exceed 50 feet in thickness, alternating with beds of breccia and agglomerate, and, particularly near the base, there are beds of reddish-purple feldspathic sandstone. The total thickness varies greatly in different parts of the area, and in places the formation is lacking, apparently owing chiefly to the uneven surface on which it was deposited and perhaps in part to erosion prior to the next great flow of rhyolite. In many places there is a few feet of sandstone between the andesite and the overlying rhyolite.

The only good surface exposure of the Mineral Creek andesite is in the south wall of the Mineral Creek Canyon above the Cooney mine. Here the total thickness of lava, breccia, and agglomerate is about 700 feet in the lower part of the canyon wall. In the Last Chance mine, nearly 2 miles south of Mineral Creek, the Mineral Creek andesite forms the footwall of the vein for a vertical distance of about 500 feet, with the base as yet undiscovered. In the Silver Creek Canyon, however, less than a mile northwest of the mine, the greatest thickness of andesite exposed scarcely exceeds 100 feet, and for a short distance the andesite is lacking altogether, and the next member of the series, the Fanney rhyolite, rests directly upon the older Pacific quartz latite.

Besides erosional unconformities such as are described in the preceding paragraph, a few feet of reddish-purple sandstone in many places above the andesite indicates a period of quiescence before the outflow of the Fanney rhyolite, next to be described.

The Mineral Creek andesite commonly varies greatly in color, from a light gray to nearly black, with a predominance of dark-red and purple shades. The flows are everywhere amygdaloidal, with amygdules of quartz, calcite, and chlorite. The phenocrysts are not as prominent as in other andesite members of the volcanic series of the Mogollon district and consist of ferromagnesian minerals, now completely altered to aggregates of iron oxide and chlorite. So far as can be determined from the shape of these pseudomorphs and from the rare unaltered remnants, pyroxene, apparently augite, was the only prominent ferromagnesian mineral. In a few specimens there appear to be also traces of original olivine crystals, and more rarely a suggestion of the original presence of rare biotite. The practically complete alteration of all the ferromagnesian minerals makes determination very uncertain.

The groundmass consists chiefly of feldspar, most commonly in a felt of small thin laths, more rarely rather stocky prisms. So far as can be determined most of the feldspar is calcic andesine or andesine-labradorite. In about a third of the slides examined minute feldspars have a refractive index lower than Canada balsam, indicating the presence of orthoclase, as suggested by the analysis quoted below, In addition to the feldspar, the groundmass contains interstitial augite, more or less altered, though less completely than the phenocrysts; also varying amounts of magnetite.

The following partial analysis of a specimen collected by Graton [6] from the Cooney mine expresses the general composition of the rock:

Partial analysis of Mineral Creek andesite

[W. T. Schaller, analyst]

SiO_2	48.00
CaO	7.72
K_2O	3.28
Na_2O	1.95

Graton adds the following note:

It is difficult to account for the amount of potash shown by the analysis, as by far the greater part of the feldspar appears certainly to be plagioclase. The analysis was repeated and found correct. Probably most of the so-called andesites of this region are in reality latite, and the potassium is probably contained in the groundmass.

No sericite, which if present might account for the high potash content, is mentioned in Graton's description, nor was any seen in the thin sections studied by the writer.

FANNEY RHYOLITE

The Fanney rhyolite, herein named from its prominent outcrops near the Little Fanney mine on Fanney Hill, is readily distinguishable from other members of the series in that it possesses a well-marked spherulitic texture. It crops out principally on the west side of the Queen fault southward from the south wall of the Mineral Creek canyon, where it forms the principal wall rock of several of the most productive veins of the district, along a belt roughly half a mile wide. (Pl. 1.) To the east of the Queen fault there is a smaller area exposed in the upper part of South Fork. The best development of the rock is south of the area mapped, in the canyon of Whitewater Creek. (Pl. 3.)

The rhyolite seems to have flowed out in a very viscous condition and solidified in a moundlike form. It varies greatly in thickness, attaining its maximum south of the area covered by the detailed map

[6] Op. cit., pp. 192-193.

and thinning out toward the north. Although thin beds of sandstone containing material derived from this flow occur at the base of the overlying andesite and between the andesite flows close to the rhyolite contact, there does not seem to have been any notable erosion interval between the rhyolite and the succeeding andesite. In places, as on Fanney Hill near the south end of the Ida May vein, steep contacts of the rhyolite and the overlying andesite may be observed.

The maximum thickness observed was at a point south of the area studied in detail, near the junction of Whitewater Creek and South Fork, where at least 1,200 feet is exposed. On the south edge of the area mapped the thickness does not exceed 1,000 feet. A mile to the north, in the Last Chance workings, the flow is 800 feet thick. The Little Fanney workings, on the south side of Fanney Hill, show a thickness of 600 feet. On the north side of the same hill the thickness decreases sharply until at a point 1,000 feet west of the Cooney mine a few feet of rhyolitic tuff is all that remains. Farther west only a thin bed of sandstone with rhyolite fragments separates the upper and lower andesites. On the north side of Mineral Creek there is a bed of rhyolitic tuff less than 10 feet thick, which is believed to mark the same horizon. To all appearances this mass of rhyolite represents a single flow. The only evidence to the contrary is the presence of rhyolite breccia on the point above the Eberle mine, about 150 feet lower than the upper contact. It is possible, however, that this is merely a flow breccia due to premature solidification of part of the flow.

The Fanney rhyolite is the only rock of the district in which spherulitic texture is prominent. Nearly everywhere there are abundant spherulites, and the characteristic appearance which these give to the rock forms the most useful criterion for distinguishing between the Fanney rhyolite and other siliceous flows. The andesites above and below can best be differentiated where the spherulitic Fanney rhyolite is present to serve as a horizon marker.

Most commonly the rock shows closely crowded light-pink to white spherulites in linear arrangement in a rather glassy groundmass of a delicate light-purple tint. The spherulites are usually from a quarter of an inch to more than half an inch in diameter and show a radial structure. In places they are so closely packed as to form over half of the rock mass; elsewhere layers composed largely of spherulites alternate with flow-banded rhyolite in which spherulitic texture is subordinate. The viscous nature of the flow resulted in the formation of cavernous open spaces before complete solidification. The larger of these spaces show clusters of spherulite-like bodies from a fraction of an inch to 2 inches in diameter. Some of these look almost like clusters of grapes; others have a reniform appearance. They consist of a thin shell of lithoidal matter surrounding an interior cavity lined with crystals of bluish quartz. Quartz crystals also line small cavities in the rock mass itself.

Obsidian is not common but was observed in places. A very striking variety of the rock was observed on the ridge northeast of the limekiln, where a dark-brown glass of resinous appearance is thickly studded with pink spherulites.

Small phenocrysts of feldspar are present in places, particularly in the flow-banded portions. These include both orthoclase and albite, but the orthoclase is much the more abundant. Many of the small spherulites seen in thin section under the microscope show a nucleus consisting of a minute crystal of feldspar. Definite quartz phenocrysts were rarely seen, but all the specimens examined microscopically show a much larger proportion of quartz than would be inferred from the hand specimen alone. The quartz appears to be of two generations—small segregations of crystals that are irregularly intruded by the glassy and microfelsitic groundmass and small elongate lenses of minutely crystalline quartz of a later generation, parallel to the flow lines of the groundmass. Biotite is of rather rare occurrence, but small plates are seen here and there. Small grains of magnetite form the only other identifiable mineral.

The groundmass shows a great variety of texture and structure. In the same thin section narrow bands which show microfelsitic texture may alternate with glassy material. The glass may be nearly homogeneous or may show abundant microlites of various kinds and spherulites of all sizes. Spherulitic texture is nearly everywhere present.

LAST CHANCE ANDESITE

The Last Chance andesite derives its name from the exposures at the Last Chance mine, south of Silver Creek, where for a considerable distance it forms the hanging wall of the vein. The formation consists of numerous thin flows, rarely exceeding 50 feet to a flow, alternating with pyroclastic rocks. The eruptions were evidently accompanied by considerable explosive action, for in places the breccias and agglomerates exceed the lavas in volume. In places these materials have been more or less reworked by water and consist of large subangular blocks of andesite in a matrix of coarse purple sandstone. Thin beds of finer-grained sandstone also occur.

The flows and breccias of this formation are found principally on or near the top of the plateau in the central part of the district, south of Mineral Creek and west of the Queen fault. East of this fault it is present, generally at much lower altitudes, as in the bed of Mineral Creek and in the upper part of the South Fork drainage basin.

The formation varies greatly in thickness, as the andesite flows and breccias lapped against the great mound of the Fanney rhyolite. The thickest section is naturally in the northern part of the area, where the rhyolite is represented only by a few feet of tuff. Here the thickness reaches 600 feet. In the southern part, where the rhyolite is much thicker, not over 300 feet of andesite is present.

In this as in the other andesites of the region the ferromagnesian minerals are completely altered, and where, as in the area near the Pacific mine and part of the plateau to the north of the mine, the Fanney rhyolite is lacking, the distinction between the Last Chance andesite and the older Mineral Creek andesite flows is not certain. On the whole, however, the flows of this series appear to be less basic than those prior to the Fanney rhyolite.

So far as can be judged from the shape of the altered phenocrysts, pyroxene was the principal phenocryst, with biotite next in amount and possibly a small amount of hornblende. Feldspar phenocrysts are only rarely present and commonly consist of andesine, though in one specimen small porphyritic crystals of orthoclase were found. In general the phenocrysts form but a small proportion of the rock and are nowhere prominent.

The groundmass is everywhere notably feldspathic and consists essentially of minute thin rods of feldspar, less than 0.3 millimeter long, in felted or subparallel arrangement. So far as can be determined, these are andesine, grading in some specimens toward labradorite. In a few specimens there is also a small amount of orthoclase in the groundmass, but the orthoclase content is distinctly less than in the Mineral Creek flows. Pyroxene, probably augite, in all stages of alteration is present in small grains between the feldspars; a little altered biotite is also found in the groundmass, and magnetite and ilmenite are common accessories.

Small andesite dikes were found here and there throughout the district, particularly in the Fanney rhyolite, and more rarely in the earlier flows. Commonly they do not exceed 3 or 4 feet in width and do not appear to be continuous for any great distance. Only one of these, the dike near the Good Luck prospect, south of the Last Chance mine, is large enough to be shown on the map. As this dike cuts the Fanney rhyolite, it is younger than the Mineral Creek andesite and so is arbitrarily included with the next higher andesitic formation, the Last Chance andesite. Microscopic study of the dike rocks of this type shows no difference from the effusive andesites. The phenocrysts are ferromagnesian silicates, so completely altered as to be doubtful but apparently including pyroxene and minor amphibole. The groundmass consists chiefly of small plagioclase laths, but a little orthoclase is present.

RHYOLITE DIKE

A small rhyolite dike crosses the central part of the area near the Charley mine and cuts both the Fanney rhyolite and the overlying Last Chance andesite flows. It is from 5 to 20 feet in width and is readily traceable across the dark andesites, but in the rhyolite the contacts can not be everywhere followed. Its northern limit on the surface appears to be just north of the Johnson vein, between the Johnson and Trilby mines. From this point it could be followed southward as far as the Last Chance-Confidence vein, but its southward continuation across the mass of Fanney rhyolite exposed south of this fault could not be determined. What is probably the same dike was encountered in the western workings of the Last Chance mine on the 500 and 700 foot levels.

Secondary silicification, particularly near the many veins that traverse this part of the district, makes determination of the rock difficult both in the field and under the microscope. The rock is commonly intensely brecciated, the fragments consisting of pumiceous rhyolite with rare flow-banded texture, in a cement of exceedingly fine-grained quartzose material. In part this brecciation may be original rather than the result of later crushing, as rare fragments of altered andesite are present. In places the altered rock suggests an original tuffaceous rhyolite.

In general the rhyolite is similar in appearance and apparent original composition to the overlying Deadwood Gulch rhyolite tuff, and it is considered likely that the dike is composed of tuffaceous rhyolite breccia and fills a channel through which the overlying tuff was erupted.

DEADWOOD GULCH RHYOLITE TUFF

The rhyolitic tuff that overlies the Last Chance andesite and is herein named the Deadwood Gulch rhyolite tuff is most prominently exposed in the eastern part of the area, on the downthrown side of the Queen fault. The name is derived from Deadwood Gulch, in the southern part of the district, in the upper portion of which the formation is particularly well exposed.

The tuff is persistent throughout the eastern part of the area, though it varies greatly in thickness. At the south about 400 feet is exposed in Whitewater Canyon. Northward the thickness decreases rather steadily until north of Mineral Creek only about 10 feet is present where the bed is lost against the Great Western fault. This change is believed to be due to thinning out away from the center of eruption, as well as to possible inequalities of the surface on which the tuff was laid down. Although a little sandstone is present at the upper surface of the tuff, it is not likely that any extensive erosion intervened between the deposition of the tuff and that of the overlying andesites.

Where any considerable thickness of the tuff is present, its glaring white color makes it a conspicuous bed in the canyon sections, as in the eastern part of Mineral Creek and Whitewater Canyons. Elsewhere, particularly where it is not protected by overlying harder rocks or rendered unusually resistant through later silicification, it forms gentle tree-covered slopes. (Pl. 7, *B*.)

The tuff is made up of small fragments of white flow-banded rhyolite in an exceedingly fine grained siliceous matrix. Secondary silicification of the matrix has been widespread, and in places, particularly near the Queen vein, the rock has the appearance of a very siliceous rhyolite flow. Elsewhere a faint bedding is usually discernible, particularly where weathering has been effective. Sandstone beds and lenses occur throughout, and nearly everywhere the tuff is capped by a few feet of red sandstone containing rhyolite pebbles.

Seen under the microscope the tuff consists of extremely minute angular fragments, too small to be accurately identified, but consisting largely of quartz, which is probably, in part at least, the result of replacement of minute cuspate fragments of glass. Here and there are larger grains of quartz whose rough outlines suggest a fragmental origin, but more commonly the clearly recognizable quartz is in definite nests of small crystals, apparently formed in place. Small fragments of feldspar, apparently orthoclase, are also present. The rhyolite fragments show a rock with glassy to microcrystalline base and strongly marked banding or flow structure, with less commonly minute spherulites and rare small phenocrysts of orthoclase and biotite. In general the resemblance to the Fanney rhyolite is fairly close, but the spherulitic structure is less pronounced.

The rock is commonly soft and easily quarried but hardens somewhat on exposure. It has therefore been used locally as a building stone to a minor extent and would undoubtedly have been more extensively used were it not for the cheap lumber at present available.

MOGOLLON ANDESITE

The youngest effusive rock of the Tertiary lavas of the area forms a series of flows of dominantly andesitic character to which the name Mogollon andesite is here given, from the prominent outcrops near the town of Mogollon. As this is one of the youngest rocks of the area, its principal extension is on the eastern or downthrown side of the Queen fault; west of the fault it has been preserved only on the high ridge north of Cooney.

The observed thickness of the Mogollon andesite ranges in different parts of the district from 250 to 600 feet. The difference is in part due to inequalities of the surface of the underlying Deadwood Gulch rhyolite tuff and in part to erosion after the cessation of the andesite flows.

A thin bed of red sandstone is found in places about 50 feet above the top of the Deadwood Gulch tuff. This rock contains numerous small fragments of rhyolite, indicating that a rhyolitic eruption, not otherwise represented in the Mogollon district, again broke the sequence of the andesite flows.

In the Mogollon andesite, as in the lower andesite flows, complete alteration of the original dark silicates makes field determination difficult. The Mogollon andesite flows appear, however, to be on the average distinctly lower in lime and magnesia than the lower andesites, and different flows show a wider range of mineral composition. Lavas compose a greater proportion of the section than in the lower andesites, in which the breccias and agglomerates are so prominent, and a flow of dacite near the top is distinctive where present, but as in the case of the other andesites the position of the formation relative to the more easily distinguished rhyolite members is the only sure criterion for distinguishing it.

Microscopic examination of the andesites does not aid in identification of the ferromagnesian phenocrysts, as the alteration is complete and only the crystal outlines remain. It appears, however, that pyroxene, amphibole, and biotite all occur, though one or the other of the first two commonly predominates. These phenocrysts are commonly smaller and less conspicuous than in the older andesites. A few small feldspar phenocrysts—calcic andesine where determinable—were observed. The groundmass consists largely of small feldspars, entirely without orientation. These, so far as they can be determined, are rather more sodic than the phenocrysts and have the average composition of andesine (about Ab_6An_4). Interstitial between the feldspars are small grains of ferromagnesian minerals, chiefly augite, largely chloritized. Biotite occurs sparingly in the groundmass. A few of the thin sections examined show a very small amount of orthoclase, apparently nowhere sufficient to classify the rock as a latite, though it may be that, like the andesite whose analysis is quoted by Graton, this rock contains a larger amount of potash than is apparent from the visible mineral composition. Titaniferous magnetite or ilmenite is a fairly abundant accessory.

The dacite flow or flows, for it was not certainly determined whether more than one is present, differs considerably from the andesites, which make up the major part of the formation.

The dacite occurs near the top of the formation and is apparently present in all parts of the area mapped in detail and also outside. It has the dark purplish-brown color that is characteristic of the andesite and might be readily mistaken for an andesite flow. On close inspection, however, it is seen that instead of the small specks of iron oxide representing the original dark silicates the rock contains rather rare, small crystals of quartz, which appear black against the dark background of the rock, more numerous small crystals of glassy feldspar, and rarely the altered remnants of small biotite plates. The groundmass is darker and more dense in appearance than that of the surrounding andesites, and amygdules are fewer and smaller.

The most abundant phenocryst is plagioclase feldspar, more calcic than that of the andesites, having about the composition Ab_5An_5. The feldspar phenocrysts are fairly numerous but small, not exceeding 1 millimeter in length. Most of the crystals show a peculiar zoning, due not to difference in composition but to minute inclusions of dark material arranged parallel to the crystal faces. Quartz phenocrysts are larger than the feldspars but far less abundant and in one or two specimens apparently lacking. They are as a rule deeply and irregularly embayed by the groundmass and rarely show definite crystal outlines. Small plates of chloritized biotite are also sparingly present as phenocrysts. The feldspars that compose the greater part of the groundmass are not sharply distinguished in size from the small feldspar phenocrysts. They commonly consist of slim lath-shaped crystals, with parallel arrangement in places. Interstitial quartz is present in small amount but no orthoclase. The ferromagnesian minerals are not present in large amount in the groundmass. Small plates of biotite and minute grains of what is probably hornblende occur between the feldspar laths.

DOG GULCH FORMATION

Sedimentary rocks to a considerable thickness were laid down upon the surface of the upper andesite. They consist of conglomerate and sandstone with a few lenses of red shale. To these rocks the name Dog Gulch formation is here given, from their exposures near the head of Dog Gulch, southeast of Mogollon. The conglomerates are best developed near the base but occur throughout the formation. They contain pebbles and subangular boulders of rhyolite and andesite in a dark sandy matrix. The andesite is especially abundant in the lower portions. Some of the rhyolite pebbles resemble the spherulitic rhyolite beneath the latest andesite series. In the area mapped the conglomerate and sandstone series has a maximum thickness of about 400 feet and is commonly brown to dark purple. To the north and northwest it appears to be much thicker, sandstone composes the greater part of the series, and the color is lighter, tints of pink and light brown predominating. Similar sandstone and conglomerate occur at the top of Cooney Peak, at an altitude of 8,000 feet. Here they are capped by a thin flow of basalt, possibly an outlier of a Pleistocene flow now eroded.

INTRUSIVE ANDESITE

The only large body of intrusive rock in the Mogollon district is an andesite which crops out in the valley of Silver Creek at the mouth of Dog Gulch. The intrusive cuts the Last Chance andesite, the Deadwood Gulch rhyolite tuff, here only a few feet thick, and the Mogollon andesite but does not reach the overlying Dog Gulch formation. It occupies an area about 2,000 feet long and 1,000 feet wide on the hill north of Silver Creek, parallel with the stream, and a smaller area south of the creek and in the lower part of Dog Gulch. Its maximum height above the creek bed is about 300 feet. The exact outlines of the mass are difficult to determine, for the rock closely resembles the effusive andesites which it has intruded, and numerous small apophyses extend outward for some distance from the main intrusive mass. Over a part of the outcrop the boundaries are concealed by talus.

The rock is rather more coarsely crystalline than the effusive andesites, and the amygdaloidal texture characteristic of the lavas is lacking. In the intrusive rock, as in the lavas, the ferromagnesian phenocrysts are almost completely altered. In the thin sections examined biotite, which is rarely unaltered but in places retains a core of unaltered material, is the principal phenocryst. It occurs in grains as large as 2 millimeters in diameter. Small hornblende crystals are mostly replaced by iron oxide and chlorite and are generally identifiable only by their shape. Feldspar occurs as small phenocrysts, and microlites of feldspar make up the greater portion of the groundmass. So far as can be determined the feldspars are rather more sodic than those of the effusive andesites and consist of sodic andesine, grading toward oligoclase. Besides the feldspar, the groundmass contains magnetite and various alteration products of the original ferro-magnesian minerals.

Outcrops of a similar rock were observed in the valley of Mineral Creek east of the area covered by the geologic map, at an altitude of 6,400 feet. The area here exposed is not known but is probably larger than that in the Mogollon district. It is possible, therefore, that there may be a considerable mass of intrusive rock present in the range.

Andesite with a pronounced diabasic texture was found on the dump of the Cooney mine and evidently came from the deeper workings, which were not accessible to the writer. Rock of the same type was encountered in the new workings on the 1,100 and 1,200 foot levels of the Fanney mine east of the shaft. Here its relations with the effusive rocks are not clearly exposed, but owing to its diabasic texture and slight areal extent and the fact it does not crop out in the walls of the Mineral Creek Canyon, it was considered an intrusive mass, the age of which can not be definitely stated except that it appears to be younger than the Cooney quartz latite and older than the period of vein fórmation. Scott[7] considers the rock a flow intermediate in age between the Cooney quartz latite and the Mineral Creek andesite.

The rock shows elongate feldspar crystals up to a maximum length of 3 millimeters in a fine-grained dense grayish-green groundmass. As the only specimens collected were obtained close to the veins, alteration of the feldspar makes its determination uncertain, but it is probably sodic andesine or andesine-oligoclase. Besides the feldspar there are small euhedral phenocrysts of what appears to have been augite, now altered to chlorite and calcite. There is complete gradation in size between the network of larger feldspars and the minute rods that form the bulk of the groundmass. The groundmass contains also considerable magnetite, in part in peculiar skeletal crystals, and remnants of small augite grains.

GILA CONGLOMERATE

Thick deposits of partly cemented gravel occur west of the fault scarp that forms the front of the Mogollon Range, where they are faulted against the rhyolite and rhyolite tuffs of the lower members of the Mogollon volcanic section. In the area covered by the detailed map these deposits appear only as a small strip along the northwestern border. To the west and south, however, they form the mesas along the sides of the broad valley of San Francisco River. They consist of roughly consolidated, rather coarse gravel with lenses of sandy material. The beds are thick, and the bedding planes in general are not well defined. In some places a gentle westward dip is observable. Flows of basalt were seen in the gravel of this type at points south of the district, on the stage road between Silver City and Mogollon. In the vicinity of the Mogollon district the exposed thickness, as measured from Mineral Creek to the top of the mesa on the north, is 700 feet. The pebbles include lavas of various types, among which basalt and a basic type of andesite appear to predominate.

As this formation is present to only a minor extent in the Mogollon district, no time was devoted to its study. According to Gilbert[8]

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[7] Scott, D. B., op. cit., p. 294.
[8] Gilbert, G. K., U. S. Geol. and Geog. Surveys W. 100th Mer. Rept., vol. 3, p. 540, 1875.

the gravel occupying the valley of San Francisco River is identical with that of the Gila drainage basin described by him under the name Gila conglomerate.

BASALT

A few dikes and sills of basalt cut the older formations. West of Cooney, near the Floride fault, numerous small sills have been intruded parallel to the bedding of the tuffaceous portions of the Cooney quartz latite. Elsewhere small dikes of basalt cut the older formations. The largest of these dikes were found on the south flank of Silver Peak and in Gold Dust Gulch. No flows of basalt occur in the Mogollon district. Basalt flows in the Gila conglomerate have been mentioned by other writers, but none were observed in the small area of this conglomerate in the Mongollon district. A small patch of effusive basalt occurs on the summit of Cooney Peak, 3½ miles northeast of Mogollon, resting unconformably on red sandstone that is believed to be the equivalent of the Dog Gulch formation of the Mogollon district.

The basalt dikes are generally distinguishable in the field from the very similar dikes and flows of older andesite by their darker color, denser texture, and fresher appearance. The phenocrysts are smaller, rarely exceeding a millimeter in diameter. The alteration of the ferromagnesian minerals to small iron-stained patches, characteristic of the andesites, is nowhere seen in the basalt, in which commonly minute grains of fairly fresh olivine can be distinguished. The thin sections examined under the microscope show that the basalt dikes are very much alike in mineral composition. The phenocrysts consist of olivine and augite in approximately equal amount. The olivine grains, though everywhere less than a millimeter in diameter, are the larger and more prominent. In contrast to the extreme alteration of the ferromagnesian minerals of the andesites the augite is unaltered. The olivine, however, shows more or less alteration, though usually unaltered cores remain. Calcite and chlorite are the principal decomposition products. The groundmass is very fine grained, the average diameter of the constituents being less than 0.05 millimeter, and consists of feldspar (calcic andesine and labradorite), augite, rather rare olivine, minute magnetite grains, and in some specimens a few small plates of biotite. In some of the slides the feldspars show a parallel arrangement of small closely packed laths, and comprise about half the area of the slide; in others the feldspar is rather less in amount and has no definite arrangement.

The basalt dikes of the Mogollon district are clearly younger than the faulting and subsequent mineralization, for at least one of them cuts a fault plane which is mineralized in places. They are likewise younger than the alteration of the andesites. The dikes are clearly older than the erosion that has stripped the Gila gravel from the relatively uplifted bench along the front of the range. Presumably they are contemporaneous with the deposition of the Gila formation and represent conduits which fed flows such as those now found elsewhere in the gravel and on Cooney Peak.

STRUCTURE

The Mogollon district as mapped in Plate 1 and the neighboring area as far as covered by reconnaissance (pl. 3) shows complex normal faulting. The whole region is crisscrossed by faults of different degrees of magnitude, which have brought blocks of the younger rocks of the series into juxtaposition with the older. Evidence of at least two widely separated periods of faulting is discernible. The older faults furnished the channels that were followed by the ore-bearing solutions, and their planes are nearly everywhere occupied by veins; the chief fault of the younger period is the great fault along the front of the range.

EARLIER FAULTING

The first period of notable faulting was later than the deposition of the Dog Gulch formation and the intrusion of the andesite, for both of these formations are cut by the faults, and it was much earlier than the deposition of the Gila formation. Further than this the date can not be definitely fixed. A guess may be hazarded that it was late Miocene, because the end of the Miocene epoch was marked by extensive mountain building and block faulting. The faulting of this period was widespread and complex, but the faults show a certain systematic arrangement. (See pls. 10 and 11.) The area was broken up into a number of irregular blocks of varying size and shape bounded by faults that follow two main directions—one a little east of north and the other a little north of west.

The accompanying block diagram (pl. 10) is not drawn to scale and does not show a multitude of minor faults but is intended merely to visualize the displacement of an assumed surface by the kind of faulting that took place during this period.

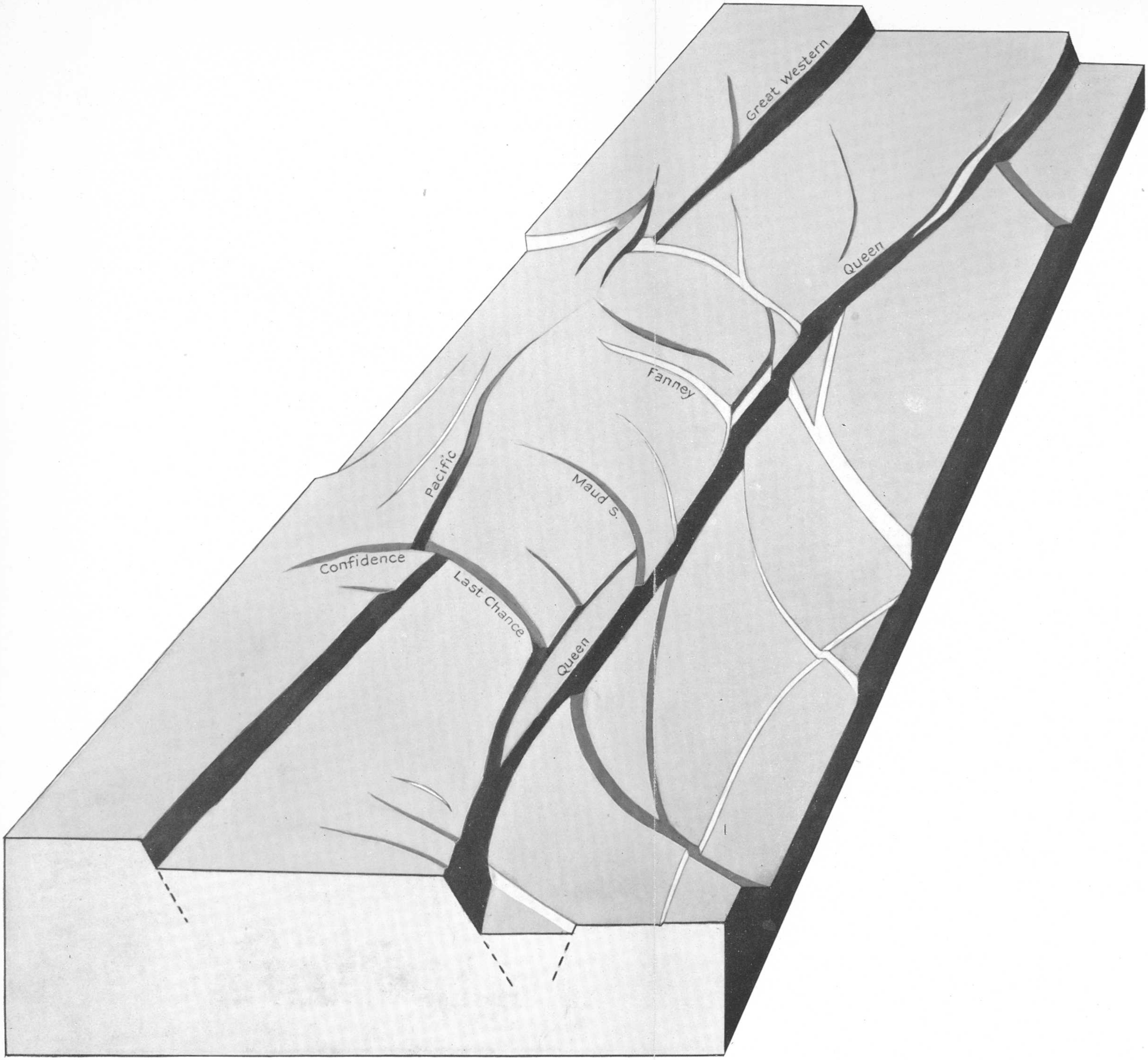
Two features of the district made possible the tracing out of this complicated fault net. In the first place, nearly all the faults of the older system are the sites of veins, and owing to the extensive prospecting and usually prominent outcrop of the quartz veins themselves the faults are more easy to trace than is usual in a complexly faulted district. Secondly, the deep trenching of the canyons that cross the district allows observation through a greater vertical range than is usually possible.

There was undoubtedly some faulting during the period in which the lava flows were poured out and prior to the development of the major fault system. In only one locality, however, was definite evidence of such early faulting observed. The dike of rhyolite on the ridge northwest of the Last Chance mine for a short distance follows what is apparently a fault contact between the Fanney rhyolite and Last Chance andesite. The displacement of the normal contact on the sides of the fault shows that the throw can not be more than a few feet. This fault must be older than or contemporaneous with the intrusion of the rhyolite dike, which is correlated with the Deadwood Gulch rhyolite tuff. It could not be determined to what extent the major faults may have been initiated at some earlier stage of the history of the district. Possibly the unusually steep contact of the Fanney rhyolite with the overlying andesite on Fanney Hill west of the Ida May vein may represent an older fault scarp.

There is evidence of some faulting of earlier date than the Last Chance andesite. In the canyon wall northwest of Cooney there is apparently a fault with northwesterly strike and downthrow of about 50 to 75 feet on the east, involving the Cooney quartz latite, the Cranktown sandstone, and the Mineral Creek andesite. The contact of the Mineral Creek andesite with the overlying Last Chance andesite, for the intervening Fanney rhyolite does not continue so far west, does not appear to be displaced, but the two rocks are so similar that this is not absolutely certain.

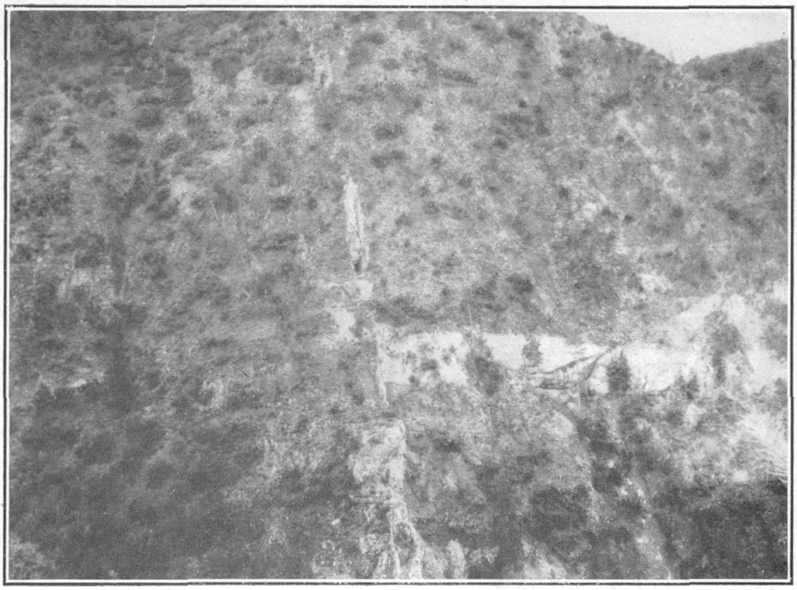
The most persistent fault crosses the eastern portion of the area in a nearly north-south direction and is the site of the Queen vein. The fissuring along the Queen fault is not simple, and in many places the total throw is distributed among several nearly parallel faults. This fault is very persistent, however, and was traced not only across the area mapped but for a distance of 3 miles to the north and 2 miles to the south, a total distance of nearly 7 miles. The fault plane dips steeply to the east. The amount of displacement varies from place to place, as the territory on each side is likewise broken up into blocks by faults at angles to the strike of the Queen fault, with varying amounts of throw. As shown by sections *A–A′*, *B–B′*, *C–C′*, and *D–D′*, Plate 2, the vertical displacement along the Queen fault is from 500 to more than 1,000 feet.

Near the western border of the area is another zone of northerly faulting, less well defined than the Queen fault. In the southern part, from the southern border of the area to the Confidence fault, it appears as a single fault of considerable throw, which brings the Fanney rhyolite against the much earlier Cooney quartz latite. In this portion it is chiefly remarkable as being one of the few fractures in the area along which there was no important mineralization.

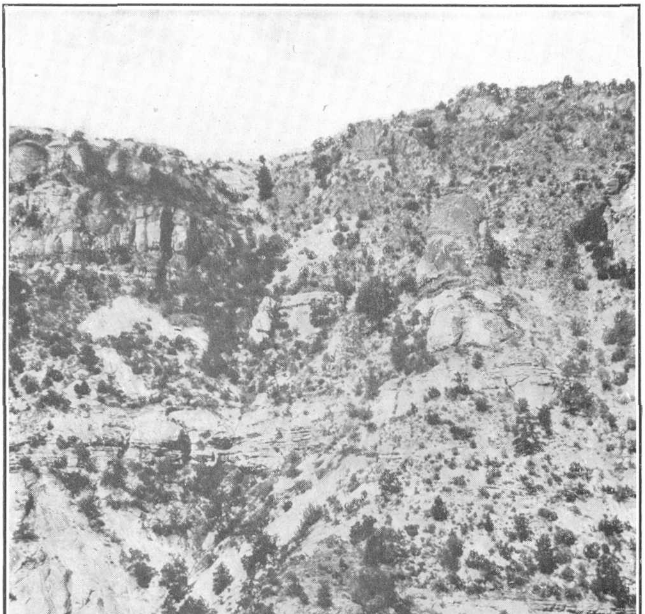


BLOCK DIAGRAM SHOWING PRINCIPAL FAULTS OF THE MOGOLLON DISTRICT

Not drawn to scale



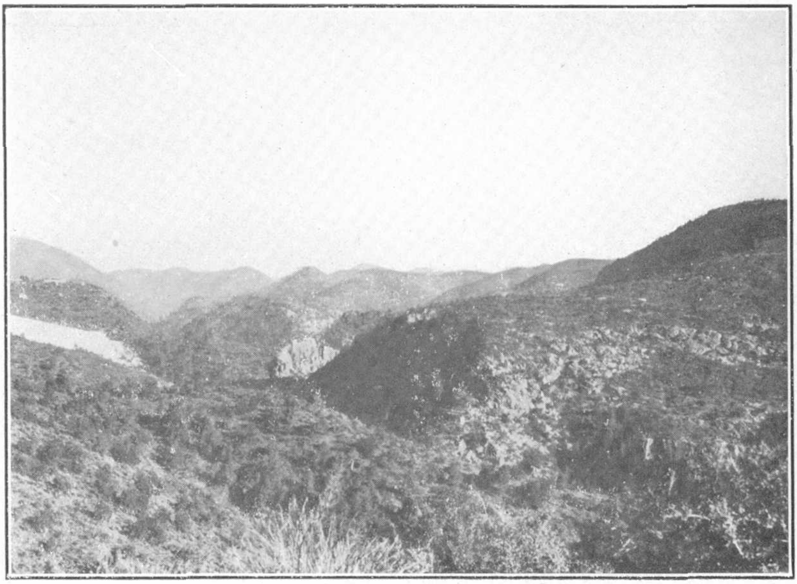
A. PACIFIC VEIN ON SOUTH ALPINE CLAIM, SOUTH OF SILVER CREEK, SHOWING FAULTING ALONG VEIN



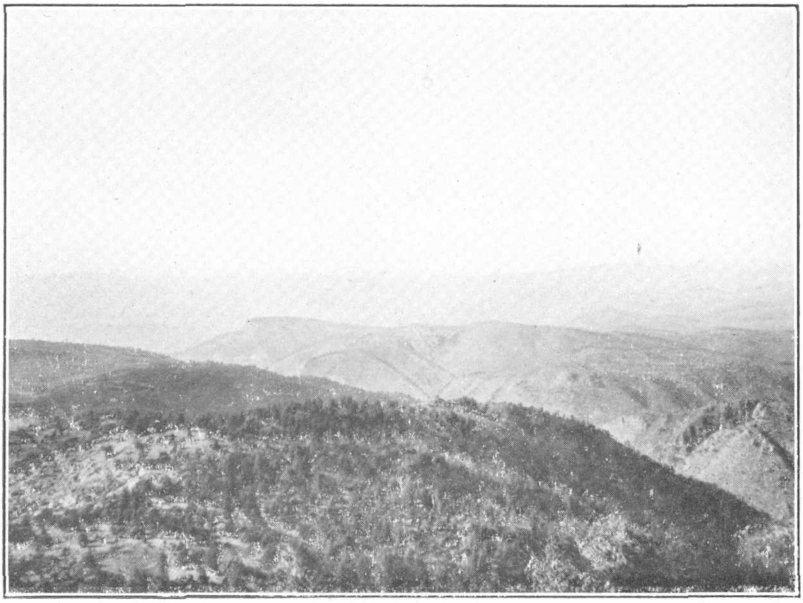
B. FLORIDE FAULT, CUTTING WHITEWATER CREEK RHYOLITE AND COONEY QUARTZ LATITE

A. UNDRAINED INTERSTREAM AREA NEAR HEAD OF GILITA CREEK, EAST FLANK OF MOGOLLON RANGE

B. HEAD OF TURKEY CREEK, EAST FLANK OF MOGOLLON RANGE



A. BENCH NORTHWEST OF SILVER CREEK CANYON OPPOSITE FANNEY MINE



B VIEW LOOKING WEST ACROSS NORTHERN PART OF MOGOLLON DISTRICT

Showing flat upland topography. Silver Peak in the distance

This fault is offset a short distance to the west along the Confidence fault. Between the Confidence fault and Silver Creek there is a complex fracture zone about half a mile in width, which consists of blocks bounded by minor faults of northward trend and has been depressed relatively to the blocks on either side. The most persistent of these minor faults is the one now occupied by the Pacific vein, but faults of greater throw cross Silver Creek farther west. Silver Creek at the mouth of Bluebird Gulch flows across the Pacific quartz latite, but above and below this point the bed of the stream is in the stratigraphically lower Cranktown sandstone, there being here a small depressed block bounded by normal faults of northward trend. On the whole, however, the downthrow along the western group of faults is to the east. The surface rocks are not well enough exposed in the flat interstream area north of Silver Creek to permit tracing with any certainty the faults that compose this complex series, though several small faults were observed on the northern edge of the plateau. Thence northward the system appears to be represented by a single fault, occupied by the Great Western vein, which strikes northeast and dips southeast. The maximum vertical displacement along this portion of the fault exceeds 600 feet.

The faults belonging to the westerly systems are most numerous and best developed near the Queen fault. All are the sites of veins; those west of the Queen have for the most part been productive, but those to the east have hitherto proved barren at the outcrop. Consequently the more intensive prospecting along the western group has permitted working out their relation in greater detail than those to the east. Besides having been more thoroughly prospected, the veins west of the Queen commonly have a quartz gangue, whereas in the eastern veins the filling is dominantly calcite, which is less resistant to weathering and consequently forms a less prominent outcrop. The veins east of the Queen and consequently the faults which they occupy are commonly considered to be continuous with these to the west, but the present work shows that this does not hold true in detail. The two blocks showing the greatest depression—that north of the Maud S. on the west of the Queen fault and that between Silver Creek and South Fork on the east—are, however, in the same latitude.

These faults with westerly and northwesterly strike are less persistent than the Queen fault, and the displacement seems to fade out away from it. The fault occupied by the Confidence vein, however, persists beyond the western zone of northerly faulting and can be traced for nearly 2 miles. The Floride fault, with northwesterly strike and northeasterly dip, lies west of the Great Western. Other faults with parallel trend are those occupied by the Maud S. and Fanney veins, west of the Queen, and those along South Fork and between Coffee Gulch and Mineral Creek, to the east.

These faults have steep dips, principally to the north in the southern part of the area and to the south north of Silver Creek, so that the resultant structure may be likened to two facing flights of steps, one leading down from the north and the other from the south, the lowest step, which is common to both flights, being represented by the block north of the Maud S. fault. This block has a total vertical displacement of about 1,000 feet below the highest block on the north and 1,200 feet below the highest on the south. East of the Queen fault the lowest block includes the conglomerate-covered ridge between the town of Mogollon and South Fork.

A peculiar feature of the faults with westerly strike is the marked change in strike which they exhibit close to the Queen fault. On nearly every fault that could be followed at the surface there is a marked tendency toward parallelism close to the Queen and increasing divergence in strike a short distance away. Commonly the intersection of two major faults shows a group of smaller faults, themselves mineralized, linking the two larger ones. This is particularly well shown on the surface near the intersection of the Independence and Fanney faults with the Queen.

East of the Queen vein the change in strike of the fault planes close to the Queen is less distinct, probably in part because these faults are less mineralized and consequently less easy to follow. So far as observable these fault planes turn sharply to the north as they approach the Queen, whereas those west of the Queen bend to the south.

The relative vertical displacement of the different blocks is shown in the accompanying sections. (Pl. 2.) The horizontal displacement or heave is, however, difficult to determine. It is evident that in a fault block which is bounded by inclined planes and in which the vertical displacement decreases away from the major fault some horizontal movement must have taken place. The grooves and slickensides on the walls of the faults indicate that the horizontal component of the most recent movement was less than the vertical, for these grooves stand at angles of 60° or greater in the plane of the fault. The small rhyolite dike that crosses the central part of the area shows horizontal offsets between 100 and 700 feet in the group of faults between the Maud S. and Trilby mines. These offsets, however, would afford a true measure of the horizontal displacement only if the dike were vertical. As it is notably irregular along its strike similar irregularities probably exist along the dip and render it of little value as a means of measuring horizontal displacement.

The general appearance of the entire fault system of the district, as shown in Plates 10 and 11, indicates that the northerly and westerly faults were formed at the same time. The Queen fault appears to be the site of the principal fissuring, and the faults branching out from it on either side represent subsidiary fissuring. It is thought probable that this branching is due to faulting under light load, and that if the cover had been heavier the change in strike of the minor faults close to the Queen fault would have been less pronounced, and the junctions would not be complicated with minor cross faulting.

Tilting accompanied the faulting. The amount has probably not been great, but the irregular contacts between the flows and the sediments and the extensive cross-bedding of the sandstones make the determination of the amount of tilting a difficult matter. On the whole, the older members of the series seem to show higher and more irregular dips than the younger, a difference which may indicate some movement prior to the principal period of faulting. The andesite intrusion at the mouth of Dog Gulch seems to have caused a gentle doming of the overlying formations. Close to the major faults, particularly the Queen, the dips of the flows and beds are in places steeper than elsewhere, owing to drag along the faults.

The Dog Gulch conglomerate and sandstone are the youngest beds in the district that have been disturbed by the faulting of the first period. If they represent the surface at the time of this faulting the region was presumably one in which aggrading streams were dominant, possibly a plain or broad intermontane trough. The earlier faulting just described broke these beds into a series of irregular blocks, but prior to the deposition of the Gila conglomerate there was probably again a broad valley occupying the site of the present district, with rising ground, probably less rugged than the present topography, to the west. In this valley the Gila conglomerate was deposited.

LATER FAULTING

The faulting of the later period, subsequent to the deposition of the Gila conglomerate, was principally effective along the present front of the range and to a minor degree in renewed movements along the earlier faults to the west. It is of course possible that the great range-front fault may itself have been initiated during the earlier period. Although the outcrop of the fault plane is not exposed, the section in the Mineral Creek Canyon just west of the mouth of Cooney Box shows the Gila conglomerate abutting against the steep rhyolite cliffs with only 200 or 300 feet of talus-covered ground intervening.

The physiographic evidence of the fault is unmistakable. Where the fault cuts resistant rock, such as the Pacific quartz latite, the mountain mass ends in a sharp cliff, which is broken only by the box canyons of Silver and Mineral Creeks. Where the less resistant Cranktown sandstone and Cooney quartz latite control the front of the range there has been a retreat of the scarp with a smoothing down of the steep front, and the canyons, such as that followed by the road from Silver City, have more flaring walls.

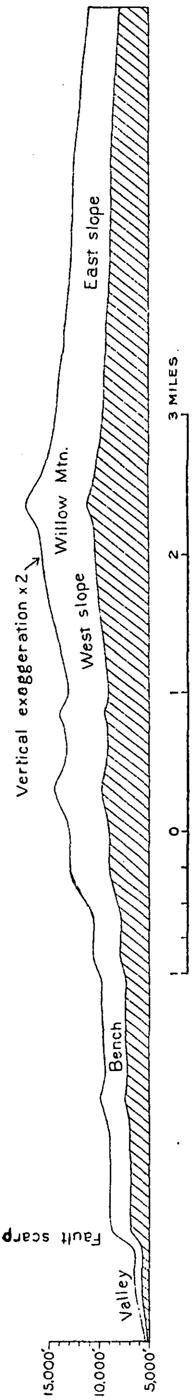


FIGURE 2.—Section across Mogollon Range, showing difference in type of topography on two sides of the range. Lower line shows true scale.

The streams flowing westward from the crest of the range across the fault scarp have canyons which are broadly V-shaped near their heads but which become narrower toward the west and close to the fault contract to narrow boxes through which the streams issue from the ranges. The eastward-flowing streams east of the crest of the range (pl. 3), on the other hand, have lower grades, and the interstream areas are flat or gently sloping.

The region east of the crest of the range was not studied, but the aspect of the eastern slope as seen from Bearwallow Peak and a study of the topographic map suggests that in addition to the relative uplift of the front of the range, or depression of a block along San Francisco River, there was actual tilting of the surface to the eastward. Definite evidence, however, other than the general gentle easterly slope and the marshy undrained interstream areas (pls. 3; 13, *A*, *B*) in the lower part of the east slope, is lacking. The accompanying section (fig. 2), drawn along the divide between Silver Creek and Whitewater Creek and thence eastward down the east slope of the range, shows the different aspects of the topography on the the opposite slopes of the range.

The fault cut the area covered by the Gila conglomerate and probably took the form of a relative depression along what is now the San Francisco Valley. It may also have involved tilting of the mountain block to the east. Erosion was greatly stimulated, and the streams began cutting new channels toward the new base-level established by the fault movements.

The date at which the present front of the range was thus developed was later than the deposition of the Gila conglomerate, of late Pliocene or early Pleistocene age, but sufficiently early in the Pleistocene epoch to allow drainage across the front to establish itself in narrow canyons cut through resistant rock. In a few places where softer rock was exposed the time elapsed was sufficient for the development of somewhat wider valleys. The gravel on the upthrown side of the fault was, of course, easily removed, leaving this relatively flat interstream area, which is so prominent a feature of the topography of the district.

The present topography is, therefore, the result of comparatively recent faulting, and the major streams cross the area without reference to the geologic structure. Few tributaries have been developed except where favorable conditions have allowed the cutting of small branch canyons. Thus, although the major streams cross rocks of all degrees of resistance, the few branch canyons show some adjustment to the structure. Houston Canyon and Bluebird Gulch have cut their valleys in the easily eroded Cranktown sandstone, and the same is true of the lowest and best-defined portion of Johnson Gulch. Along the fractured zone of the Queen fault there is a line of small gulches tributary to Mineral and Silver Creeks. The largest is Deadwood Gulch, which enters Silver Creek from the south. The zone of easy erosion, however, must have been of comparatively shallow depth, for these gulches are now cutting sharp canyons in the harder rocks and across the outcrops of quartz veins. South Fork, which joins Silver Creek below the town of Mogollon, owes its comparatively wide valley to a belt of soft rhyolite tuff. The uplift along the fault, at least in its later stages, must have been relatively rapid, as the canyons at the margin of the range show nearly vertical walls without the prominent benches that would mark pauses in the elevation of the range. The comparatively flat interstream area between the valley and the mountains on the east may owe its relatively smooth surface to planation of a bench during the retreat of an earlier and small scarp formed in the first stages of faulting. Here and there in the upper reaches of the canyons remnants of small benches remain, showing the development of streams at different stages in the growth of the range-front fault. The best defined of these minor benches shows the relics of a broad valley along the edges of the present canyon walls (pl. 14, *A*) and must represent a pause of considerable duration after the initiation of the present line of flow and before the range-front fault had developed to anything like its present extent.

On the south side of Silver Creek Canyon this bench, cut in the resistant Fanney rhyolite and the overlying Last Chance andesite, occurs at an altitude of 6,700 to 6,800 feet and has a maximum preserved width of about a quarter of a mile. On the north side of the canyon the bench does not appear, but the possible remnant of a still older one at an altitude of 7,100 feet is found on the point south of Fanney Hill. The only bench of similar nature in the Mineral Creek Canyon is found on the north wall, just south of Silver Peak, at an altitude of 6,350 feet. The well-defined bench on the south side of the Silver Creek Canyon is at about the same altitude as the two rhyolite hills that guard the mouth of the canyon. Probably the uncovering of the dome of resistant rhyolite retarded erosion to some extent. Other less well-defined benches occur in places along the canyon walls but are not sufficiently extensive to show on the topographic map. Here and there along Mineral and Whitewater Creeks there is a little waterworn gravel at about 50 feet above the present streams.

A rough estimate of the vertical displacement along this frontal fault can be made on the assumption that the nearly flat interstream areas in the Mogollon district between the fault scarp on the east and the higher mountains on the west represent approximately the surface from which the gravel east of the fault has been eroded, that on the west owing its preservation to downthrow by faulting. As stated previously, these flat interstream areas are a prominent feature of the topography in the immediate vicinity of the Mogollon district. The change from the steep walls of the transverse canyons to the nearly flat upland is everywhere sharp, and even the minor tributary canyons show very little gradation. This upland was cut on rocks of greatly different resistance and so must represent an old surface of erosion approximating a plain. As the faulting and consequent relative elevation of this region took place after the deposition of the Gila conglomerate, which now abuts against the fault on the west, it is evident that the gravel must have had a much greater extent toward the east, and therefore that this bench represents very closely the old valley surface upon which the gravel was laid down. East of the region covered by the map the rising ground toward the mountain marks the limit of this old valley. The bench ranges in altitude from 6,700 to 7,600 feet. The base of the Gila conglomerate west of the fault is not exposed, but Mineral Creek, close to the fault, flows on the conglomerate at an altitude of 5,400 feet. The minimum vertical displacement must therefore exceed 1,300 feet by whatever thickness of Gila conglomerate may lie below the valley of Mineral Creek west of the fault scarp, plus the thickness of whatever small amount of bedrock may have been removed in the planation of the upland bench.

This great displacement naturally had some effect on the region east of the fault, but as any new movement took place along the fault planes of the older series the amount is not measurable. As the older fault fissures had been cemented by the introduction of the veins, the new movement occured along the walls of these veins and to some extent within the veins, and is shown in the presence of gouge of postmineral age. The eastern veins and those immediately west of the Queen do not seem to have undergone any extensive movement at this time, but those nearer the fault scarp were all affected to some degree, particularly those with a northerly strike, such as the Pacific and Great Western veins, which carry thick postmineral gouge. Parts of the Last Chance-Confidence vein west of the junction with the small rhyolite dike and particularly west of the Pacific likewise show postmineral movement. Some recent faulting appears to have taken place also along the rhyolite dike.

The evidence obtained within the area included in the present study fails to throw light on the causes that produced the faults of the two widely separated periods. The simplest explanation is that the principal cause was local overloading of the crust due to the transfer of igneous rock from the interior to the surface of the earth. But the great bulk of the volcanic activity in the Mogollon region took place prior to a quiescent period long enough to allow not only considerable erosion but the building up of several hundred feet of bedded deposits. Faulting followed this period of quiescence, but whether further volcanic activity intervened is not known. Between the first and second periods of faulting there was no volcanism except the very minor amount represented by the basalt dikes and flows in the gravel. The true explanation therefore is probably to be sought in forces acting over a much wider area than the region studied.

A study of the sections shows that from north to south there was an apparent extension, due to normal faulting along fault planes dipping at angles of 60° or more, amounting to about 4.5 per cent, and a similar extension from east to west of about 5.5 per cent. This calculation neglects a considerable number of minor faults known to exist but of too small displacement to be taken into account. As faulting of the same type extends over a considerable region beyond the limits of the area studied in detail, the total apparent lengthening is probably greater. No thrusting or folding that would indicate compensating compression was observed in the region studied, and there is only one very small reverse fault of steep dip, so it is assumed that whatever evidences of compression that compensated the extension produced by normal faulting may exist must be sought outside the limits of the faulted area.

ORE DEPOSITS

HISTORY[9] AND PRODUCTION

The name Mogollon is probably derived from Juan Ignacio Flores Mogollón, governor and captain general in 1712 of the vast and indefinite territory then included under the name New Mexico.[10] As in other mining camps of the Southwest, there are legends of lost Spanish mines, but it is doubtful if the Spanish exploration and control reached into this wild region, which remained a stronghold of the Apaches until within the memory of men now living.

The first permanent settlement of the valley region began in 1868, and the settlements gradually pushed up the valley of San Francisco River. Constant Indian warfare was the rule, and it was not until 1885 that life and property were at all secure.

The credit of the discovery of the mining district belongs to Sergt. James Cooney, of the Eighth Cavalry. Sergeant Cooney had been in charge of a scouting expedition that had penetrated the Mogollon Mountains and had observed the prominent vein outcrops of the region.[11] In the fall of 1875, his enlistment having expired, he revisited the district and located claims that were afterwards developed into the Cooney mine, one of the most famous of the district. Indian troubles prevented Cooney and his little band of associates from doing any regular development work for some time, and it was not until 1879 that the first ore was shipped.

The valley settlements were almost wiped out in the attack by Victorio and his Apaches in 1880, and Cooney was killed while assisting in the defense of the little settlement of Alma. It was not until after the repulse of Geronimo's raiders in 1885 that the Apache danger ceased to be acute and mining development could really begin. The last Indian fighting in the region was the raid of Apache Kid and his followers in 1906.

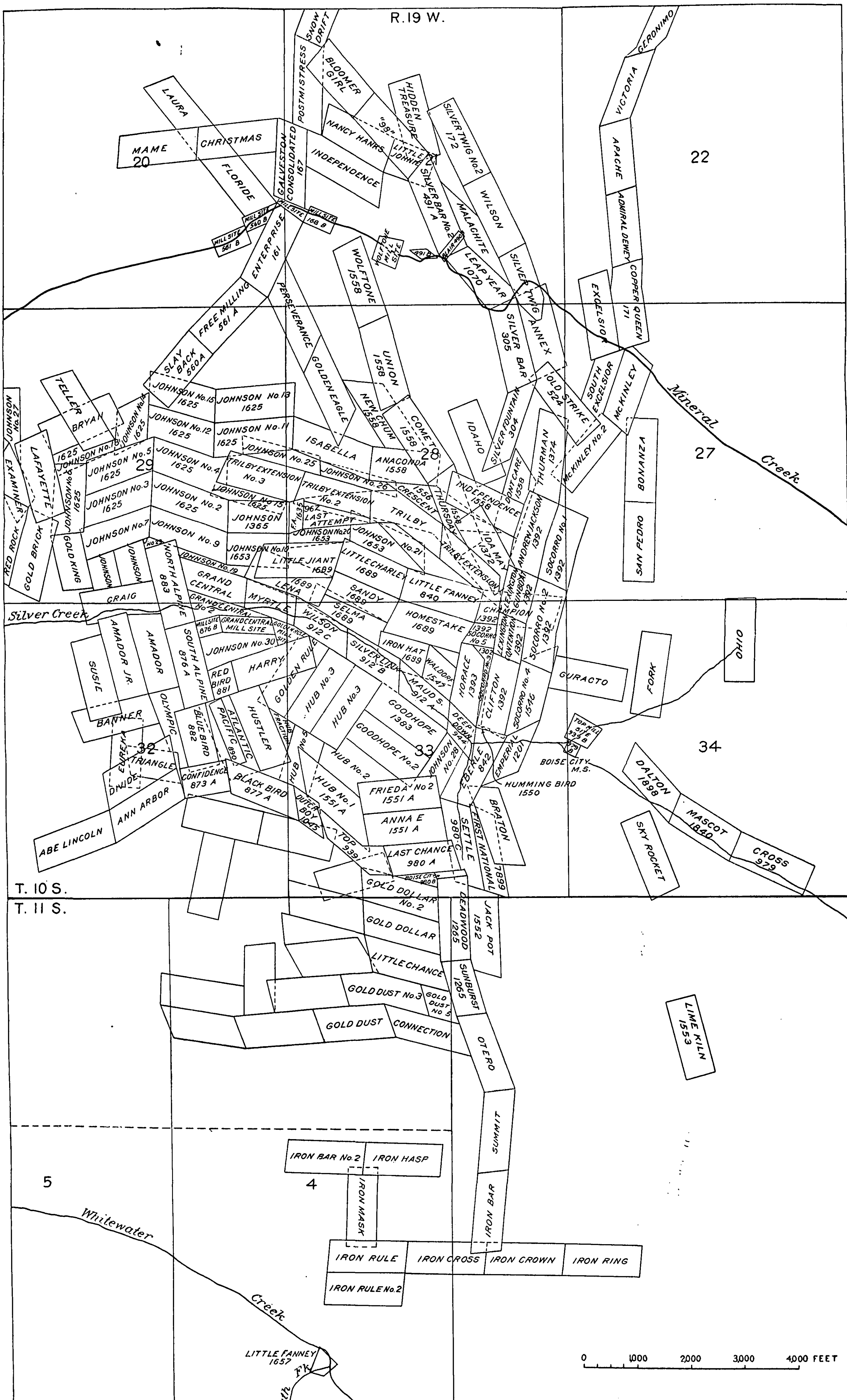
After the menace of Indian attack ceased to be acute mining proceeded rapidly, and Graton[12] estimates that prior to 1905 the total production was about $5,000,000 in copper, silver, and gold. The mines first developed were those of the veins that crop out in the valley of Mineral Creek, particularly the Cooney mine, and attention was first confined to the small surface patches of rich oxidized ore. The first mines of the silver-bearing sulphide group developed were the Maud S. and Deep Down, in the canyon of Silver Creek below the town of Mogollon. The development of the cyanide process aided the exploitation of the silver ores, and the

[9] This sketch of the early history of the district is derived almost entirely from Mogollon Mines, 1915, pp. 32–47; 1916, pp. 36–48.

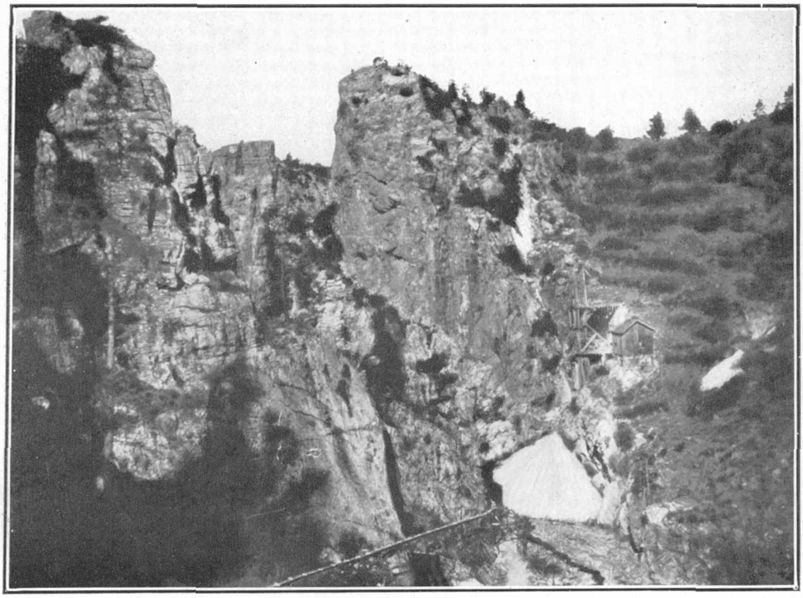
[10] The word "mogollón" is Spanish for parasite and is locally applied to the mistletoe common in the mountains; according to some the name of the range originated in this way.

[11] According to Jones (New Mexico mines and minerals, p. 129, Santa Fe, 1904), the deposits of the Mogollon Mountains had been known as early as 1870.

[12] Op. cit., p. 192.

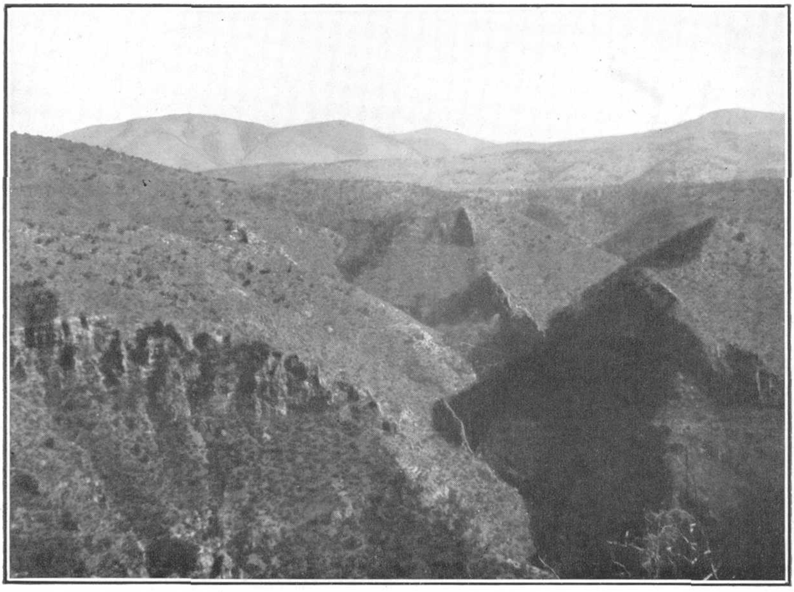


CLAIM MAP OF THE MOGOLLON DISTRICT

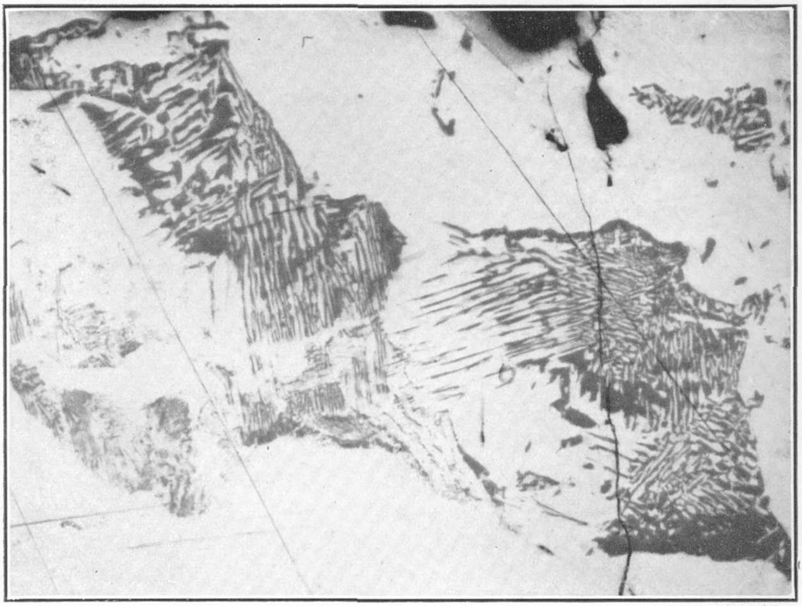


A. MAUD S. VEIN AT OLD SHAFT OF MAUD S. MINE

Fanney rhyolite (left) faulted against Last Chance andesite (right)

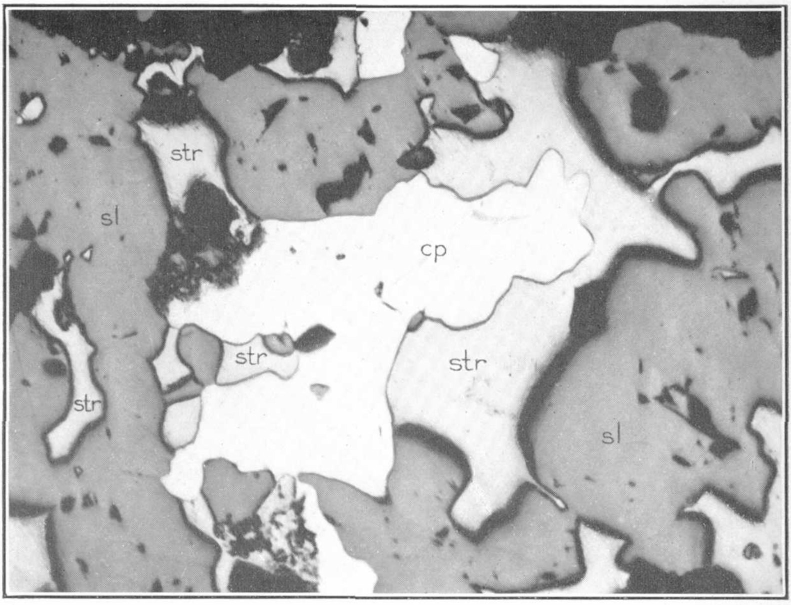


B. OUTCROP OF QUEEN VEIN, NORTH OF MINERAL CREEK



A. ORE FROM SILVER BAR TUNNEL

Showing graphic intergrowth of bornite (black) and chalcocite (white). Enlarged 250 diameters



B. MUTUAL INTERGROWTH OF STROMEYERITE (str) AND CHALCOPYRITE (cp), LAST CHANCE MINE, 300 LEVEL

sl, Sphalerite. Enlarged 120 diameters

center of mining activity gradually shifted southward from Cooney, which is now deserted, to Mogollon. As the richer surface ores were exhausted larger operations became the rule, and a gradual

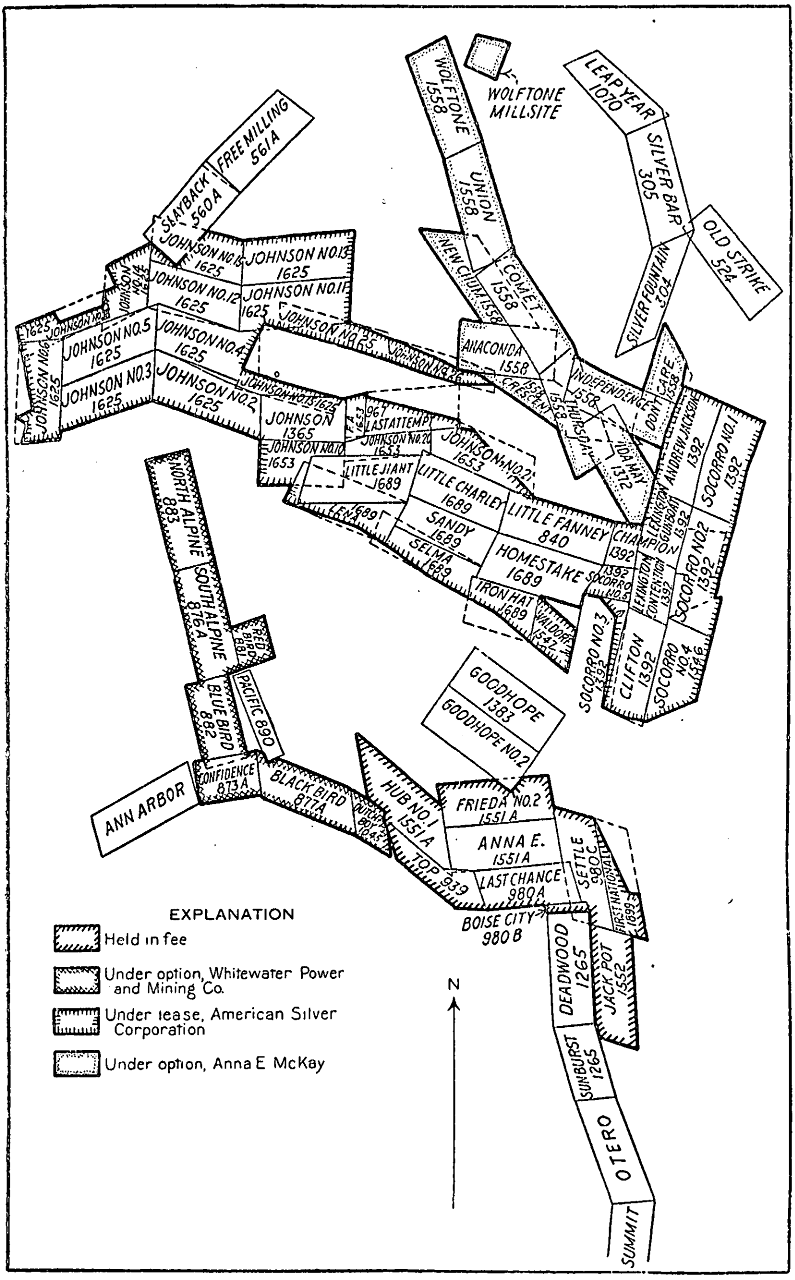


FIGURE 3.—Claims controlled by the Mogollon Mines Co.

consolidation of mining properties took place. In 1924 the major part of the district was owned, held under option, or operated under lease by the Mogollon Mines Co. (See fig. 3.)

The following table[13] shows the annual production since 1904:

Mine production in Mogollon or Cooney district, N. Mex., 1904–1925

Year	Ore	Gold	Silver	Copper	Lead	Total value
	Short tons		*Fine ounces*	*Pounds*	*Pounds*	
1904	11,276	$61,880	79,014	422,308	------	$162,484
1905	15,534	97,158	240,943	295,175	------	288,735
1906	16,075	127,907	268,567	------	------	307,847
1907	20,698	105,413	418,338	150,000	------	411,516
1908	19,546	116,418	278,939	------	------	264,256
1909	23,945	111,464	249,413	46	49	241,167
1910	50.514	304,210	595,669	------	------	625.871
1911	102,219	531,358	1,067,038	1,873	1,862	1,097,206
1912	101,361	524,858	1,093,158	184	386	1,197,197
1913	115,739	619,886	1,306,766	4,418	1,217	1,409,912
1914	136,124	629,102	1,410,327	------	590	1,409,035
1915	119,710	509,165	1,301.059	------	2,426	1,168,916
1916	118,257	373.068	1,008,483	858	3,232	1,037,084
1917	111,934	258.620	722,642	414	1,593	854,327
1918	56,450	119.710	302,902	235	282	422,690
1919	56,531	148,136	382,800	9,521	------	578,643
1920	41,895	125,631	329,489	582	2,050	485,045
1921	48,870	126,791	310,774	------	------	436,565
1922	48,106	142,123	322,460	------	------	464,593
1923	47,644	179,351	398,714	------	------	506,296
1924	72.736	230,960	618,094	------	------	645,083
1925	52,118	163,522	449.659	------	------	475,613
	1,387,282	5,606,731	13,155,248	885,614	13,867	14,490,081

The largest annual tonnage was mined in 1914, and since that time the output has declined, slowly at first but more rapidly since 1917, owing partly to the exhaustion of several of the larger ore bodies without compensating discoveries of new ore and partly to the fact that even the higher average price of silver did not cover the great increase in costs. The larger mines are now nearing exhaustion of the known ore bodies, and unless discoveries are made at greater depth, the future production will come from minor veins not yet thoroughly developed.

Lack of adequate transportation facilities has always hindered the development of the district. The road from Silver City, although greatly improved in recent years, particularly by the construction of a bridge across Gila River in 1915, was formerly impassable in very wet weather, and up to a short time ago it was not unusual for the district to be isolated for weeks at a time. Recent improvements, however, have rendered the district accessible throughout the year. A road is under construction across the range to Magdalena, and another road connects the district with Clifton, Ariz. At different times there have been projects for the construction of a railroad up the San Francisco Valley.

FORM AND STRUCTURE

The ore deposits of the Mogollon district are veins, which follow closely the faults already described. The faults are nearly every-

[13] U. S. Geol. Survey Mineral Resources, 1923, pt. 1, p. 599, 1925. Figures for 1924 and 1925 furnished by Bureau of Mines, U. S. Dept. Commerce.

where accompanied by veins, and there is no important fault in the district, except the large recent fault along the mountain front, which does not show some mineralization. Moreover, though in places the veins leave the fault planes for short distances, all the major veins of the district lie along faults, a relation that greatly facilitated the working out of the complex geologic structure.

The vein system is therefore identical with the fault system described in an earlier section and shown on Plates 1 and 11—namely, two major groups striking a few degrees east of north and dipping to the east, intersected by a series of fissures striking between west and northwest, with dominant northerly dips in the southern part of the district and dominant southerly dips north of Silver Creek. The veins of the second system are best defined in the area between the two major northerly fault systems. The vein outcrops have been plotted on Plate 11.

Although the mineralization of the fault planes persists for a considerable distance outside the mining district, the productive area is of very small extent. The veins that have yielded notable production lie in an area less than 2 miles long by a mile wide, bounded by the Last Chance-Confidence vein on the south, the Pacific on the west, the Queen on the east, and the southern part of the Silver Bar on the north. Within this area the three most prominent lateral veins, the Last Chance-Confidence, Maud S., and Fanney, have proved the most productive. Of the northward-trending veins of the western group only the Pacific has been a large producer, and that chiefly near the junction of this vein with the Last Chance-Confidence. The Ida May vein has a strike intermediate between those of the two systems. The Queen vein group has yielded small ore bodies at a few points, chiefly near the junctions with the transverse veins. No ore has yet been developed east of the Queen or west of the Pacific, except for small bodies on the Confidence vein.

Although it is convenient to speak of separate veins and systems of veins, the evidence afforded by exposed junctions of veins shows that the vein filling was contemporaneous over the district as a whole. The most striking evidence is afforded by the junction of the Pacific and Confidence veins and that of the Last Chance with one of the Queen group on the 700-foot level of the Last Chance mine. Structural features inherent in one vein, such as banding and a rather indefinite sheeting parallel to the walls, are not cut off by the other but blend together; nor is there anywhere any sharp change in mineral composition, although the veins on the whole vary somewhat in their mineral content. Near the junctions of the major veins there is commonly a complex of small veins which themselves follow minor faults, linking the two larger ones.

This feature is particularly well shown on the surface near the junctions of the Independence and Fanney veins with the Queen.

The veins are on the whole well defined and tend to form prominent outcrops. In places, particularly along the larger veins, such as the Queen, the resistant quartz forms walls that stand above the surrounding surface. (Pl. 16, *B*.) Here and there along the strike no mineralization is seen, and only the fault contacts mark the direction. Underground drifts show, however, that absolute lack of mineralization is rarer than would be expected from surface observation, and there is nearly everywhere at least a small vein along the guiding fault. The maximum thickness is attained on the Queen vein, which in places is as thick as 50 feet. Other veins have a maximum thickness of about 30 feet. For the most part, however, from 3 to 10 feet is the usual thickness of the productive portion of the vein. Small veins occur near and parallel to the major veins in places but do not appear to be continuous over long distances along either strike or dip.

In places, as on the Fanney vein near the Queen and at one point on the Last Chance vein, there are splits in the vein, where the major part of the mineralization occurred not along the fault but a short distance away in the hanging wall, the fault being for a short distance only slightly mineralized.

PRIMARY VEIN FILLING

NONMETALLIC MINERALS

Quartz is the principal gangue mineral of the veins and occurs in a great variety of forms. Commonly small elongate crystals project from the vein walls or bands of a previously formed mineral or radiate outward from included and partly replaced fragments of wall rock. In the larger veins, particularly in the more productive portions, this type grades into one in which the individual quartz crystals lose their orientation, giving a texture similar to that of a granitic igneous rock. Many veins show banding near the walls and "granitic" texture in the central part. Another common variety of quartz is so minutely crystalline that it resembles porcelain in the hand specimen or, where banding is developed, suggests chalcedony. The microscope, however, shows a distinctly crystalline quartz which in places grades into the drusy quartz described above. Chalcedony-like banding of this type may persist through a considerable thickness of the vein. The bands may be roughly parallel to the walls or may be concentric around fragments of included country rock. A third type of quartz, present in many places but less abundant than the other two, is the hackly lamellar type formed by the replacement of thin plates of calcite.

Calcite is the next most abundant mineral, and perhaps if all the veins of the district rather than simply those of the productive part were considered it would exceed quartz in volume. The barren veins east of the Queen, much of the Queen vein, and parts of the other veins consist largely of coarsely crystalline calcite, whose varying content of manganese causes a light and dark banding parallel to the walls, in some places approaching the fine-grained quartz in delicacy of banding but more commonly in bands half an inch or more in width. Calcite also is present to a greater or less extent in all the veins, except the portions occupied by the fine-grained porcelain-like quartz. Intergrowths and rough banding of white calcite with bands of drusy quartz are common throughout the district, though the relative amount of calcite present varies greatly from place to place. To a minor extent calcite occurs in thin plates showing varying degrees of replacement by quartz.

Here and there, particularly in the barren veins east of the Queen, a little rhodochrosite is associated with the manganiferous calcite.

Fluorite, usually of a deep to pale green color, is abundant in places and is most commonly associated with the type of vein filling showing intergrowth of calcite and drusy quartz. In many veins a rough banding of calcite and fluorite was observed. As a rule the highest fluorite content seems to be in the westerly veins in the central part of the district. Fluorite was rarely seen in large amount in or near the ore shoots. An unusual occurrence of fluorite was seen on the Queen vein on the 700-foot level of the Little Fanney mine. Here there is a delicate banding of dark-green fluorite with extremely fine grained quartz, the average width of the individual bands being only about 1 millimeter.

Adularia is sparingly present in the portions of the veins that contain quartz of the coarser granular type. No crystals of adularia could be identified in the hand specimen, and it does not appear in the numerous small druses, but under the microscope small crystals with rhombic cross section occur here and there, scattered like phenocrysts in a porphyritic rock, the sharp adularia crystals surrounded by interlocking quartz grains.

Chlorite, though abundant in the altered andesite near the veins, occurs only sparingly as a vein mineral, chiefly associated with quartz in small veinlets that penetrate the andesite wall rock for short distances from the main vein but locally in small amount in the major veins, particularly near the walls.

METALLIC MINERALS

The metallic minerals of undoubted hypogene origin include, in the approximate order of their abundance, pyrite, chalcopyrite, galena, sphalerite, bornite, argentite, stromeyerite, chalcocite, and probably tetrahedrite. Small grains of pyrargyrite were noted in examination of concentrates from the Last Chance mine, but the mineral was not seen in place in any of the specimens collected. Graton [14] observed probable pyrargyrite present as minute specks on a scraped surface of tetrahedrite in ore relatively rich in copper. Graton considers that native silver of hypogene origin is present, but in all specimens showing this mineral seen by the writer a supergene origin is considered more probable.

Specularite, probably associated with other iron oxides, was identified by M. N. Short in a polished section of ore from a small copper-bearing vein on the Buffalo No. 1 prospect. Graton in describing the veins in which copper minerals predominate says, "Rosettes of specularite are found occasionally in veinlets of calcite and fluorite."

Except for pyrite, which shows a wide range of deposition, the sulphides are nearly everywhere associated with the granular quartz, but here and there, as in the ore developed on the Queen vein on the Andrew Jackson claim, sulphides occur in the extremely fine grained quartz. In the veins worked at present, in which silver is the valuable metal, the principal sulphides are pyrite, chalcopyrite, galena, sphalerite, argentite, and stromeyerite. In other veins, not now worked, copper sulphides, principally bornite intergrown with chalcocite in graphic texture, chalcopyrite, and probably secondary chalcocite, predominate. In such veins calcite, apparently both contemporaneous with and later than the sulphides, is present in places. Graton [14] found considerable tetrahedrite in places in ore of this type, but none was certainly identified in the course of the present investigation.

PARAGENESIS

Several varieties of vein filling exist, but these are common to most of the veins and are not sharply separable in any one vein. The chief varieties represented are (1) very fine grained porcelain-like quartz, grading into more coarsely crystalline quartz, with only subordinate sulphides; (2) fairly coarsely crystalline drusy or granular quartz, with minor adularia, fluorite, and calcite and locally abundant sulphides showing both banded and "granitic" texture; (3) quartz of the same type, with abundant fluorite and only rare sulphides, usually associated with more calcite than the preceding; and (4) coarsely crystalline manganiferous calcite with subordinate quartz.

There is much variation in different parts of the district, and no regular sequence holding good throughout the district could be

[14] Op. cit., p. 197.

observed. On the whole, however, the order in which the different types of vein filling are named above seems to represent their general age relations, beginning with the oldest. The earliest form is a minutely crystalline quartz which in places shows a delicate banding and in the hand specimen suggests chalcedony and elsewhere is massive and porcelain-like in appearance. In places bands of more coarsely crystalline quartz with parallel crystals normal to the bands alternate with the dense fine-grained type. In some of the veins this earlier quartz appears to have been brecciated before the introduction of the later quartz and calcite. Sulphides are only rarely present in this early quartz and consist principally of minute pyrite specks, but argentite is found in places. The comby and granular quartz that forms the productive portion of the veins is in some places distinctly later than the earlier type; in others no clear age relations can be established.

The productive portions of the veins are characterized by crystalline quartz of varying size of grain, comby and banded or composed of interlocking grains, with which is associated a small amount of adularia. Calcite and fluorite are present in small amounts but are less prominent where the sulphides are relatively abundant than in the barren portions. In places the quartz shows angular cavities, due to the solution of calcite.

Two types of productive vein filling are represented, distinguished by the predominating sulphides.

The filling of the copper sulphide type is found in the western veins, particularly in the region north of Cooney Creek, as in the Buffalo prospect, and in the veins of the central part of the area, chiefly at greater depth than the silver mineralization, although a little ore of this type was found as high as the 300-foot level of the Last Chance, and copper sulphides occur in the Buffalo No. 1 prospect at an altitude of nearly 7,000 feet. The production from the Cooney mine was probably in large part if not entirely derived from ore of this type. Andesite in most places forms both walls of the veins that carry the copper-rich ore.

The principal hypogene sulphides of the copper ores are chalcopyrite, bornite, and chalcocite, with minor pyrite; tetrahedrite has been reported, and a little galena was found in one specimen from the Cooney dump. The sulphides are apparently contemporaneous and both the two principal ones, chalcopyrite and bornite, occur as scattered grains and crystalline masses in the veins and in small veinlets penetrating the altered andesite wall rock. Several specimens collected show when polished a graphic intergrowth of bornite and chalcocite. (Pl. 17, *A*.) In a specimen from the Cooney dump chalcopyrite is distinctly later than the other sulphides and occurs in small crystals on the quartz and calcite. Quartz, for the most part finely crystalline and drusy, is the chief gangue mineral. The type of quartz found in the silver ores in which quartz replaces tabular calcite was seen only in one specimen. In some specimens two generations of quartz are present. Calcite occurs in places but is far less prominent than in the vein material of the other types. In some specimens calcite is clearly later than the quartz and sulphides but earlier than a second generation of quartz; more rarely calcite is apparently contemporaneous with the sulphides, and one specimen showed deposition of chalcopyrite both before and after the calcite. Fluorite is rare as a gangue mineral but occurs in places, as a rule closely associated with calcite, and like the calcite it is both contemporaneous with and later than the sulphides.

Ore of the type described above merges into the silver-bearing ores, in which the more massive sulphides that are present in the copper ores are lacking and finely divided sulphide minerals form the metallic content. These sulphide minerals, named in approximately the order of abundance, are pyrite, chalcopyrite, galena, sphalerite, argentite, and stromeyerite. They appear to be essentially contemporaneous. A mineral that occurs in small grains in the richest silver ores, bordering and in part replacing the grains of the older sulphides, particularly sphalerite, is very finely divided, and whether it consists of argentite or stromeyerite or of both could not be definitely determined. As will be shown in the section on alteration the evidence points to a hypogene origin for this mineral. The sulphides are all younger than or contemporaneous with the major part of the quartz and occur as fillings of small vugs and intergrown with the quartz crystals of the massive portions of the vein. In many places small included fragments of wall rock, commonly andesite, have served as nuclei for the deposition of the sulphides. In some specimens there appears to be later banded quartz formed after the sulphide deposition. Rarely the sulphides have been introduced after movements that have slightly shattered the vein quartz along thin zones. This relation is apparent only in thin section under the microscope, where thin bands of broken quartz crystals carrying mixed sulphides are seen to traverse barren unbroken and more coarsely crystalline quartz.

The quartz and sulphide vein filling of this type passes gradually into banded vein material containing abundant calcite and fluorite. No sharp lines of distinction are observable. As has been already noted, calcite, quartz molded upon tabular calcite, and fluorite are all present to some extent in association with the sulphide-bearing quartz. As fluorite and calcite increase in amount the sulphides show a marked decrease, so that on the whole the barren vein filling of the fluoritic type is fairly distinct from the productive sulphide-bearing quartz.

Apparently of distinctly later age is the type of barren vein filling with abundant coarsely crystalline calcite, which is largely manganiferous. Quartz in varying amounts is also present but generally in subordinate amount. The characteristic feature of the veins of this type is massive calcite whose irregular light and dark bands indicate a variable content of manganese. Rhodochrosite is also present in places. Mineralization of this type was the dominant process in the formation of almost all the veins east of the Queen and parts of the Queen vein. West of the Queen it occurred here and there, particularly in the upper parts of the productive veins and in the veins crossing the plateau north of Mineral Creek.

ORE SHOOTS

The ore shoots of the two principal veins, the Last Chance-Confidence and the Fanney, are large, commonly from 300 to 600 feet in drift length and about the same along the dip. The largest single ore body was mined from the upper part of the Little Fanney mine, where the stoped ground measures 1,500 feet on the strike and about 500 feet down the dip. The projection of Last Chance-Confidence vein shows stoped ground over half the area between the Last Chance tunnel and the 500-foot level. So far as could be judged from such old stopes as were accessible, the bodies mined on the other veins were all of much smaller size. In many places the ore bodies coincide with the wider parts of the vein, but this is not universal, for many of the swells in the veins consist chiefly of the barren calcite. The width of the ore as stoped in the two principal mines is usually from 5 to 15 feet, though in places the ore bodies exceed 20 feet in width. As a rule the best ore is found close to one or both walls, and more often along the footwall than close to the hanging wall. In many places the ore bodies grade off down the dip into material of similar appearance but below workable grade. Commonly, however, especially along the strike, the boundary between ore and waste is fairly sharp. Many of the ore shoots show a straight boundary on one side. This could be generally correlated with a minor vein branching off from the major vein, though not everywhere involving faulting of the country rock. On the whole no rule could be deduced as to the occurrence of the ore shoots, but it may be said that in general the wider parts of the vein are favorable to the formation of ore and that many ore bodies owe their position to the junction of the main vein with minor fissures. This seems to be particularly the case in the western part of the Little Fanney mine (pl. 22), where the west limit of the ore body is established by the junction with a minor vein that is only slightly divergent in strike and dip from the main fissure.

The major ore shoots are commonly greater in horizontal than vertical extent and are apparently confined to a shallow zone. In the Last Chance mine little ore has been mined below the 500-foot level (about 850 feet below the highest point of the outcrop), and none below the 700-foot level, although exploration has extended to the 1,000-foot level. In the Little Fanney almost all the ore mined came from above the 900-foot level (about 1,500 feet below the apex), and none from below the 1,100-foot level. The ore bodies of the Pacific mine appear to have been definitely bottomed above the 400-foot level, and those of other mines at even less depth.

Scott [16] makes the following observations with reference to the relation of the ore bodies to country rock, particularly as regards the Little Fanney mine:

> The ore bodies in both of the principal mines are notable in one particular: They are situated at a horizon which contains a change and a reversal of the wall rocks—that is, they are found in greatest development where the rhyolite is succeeded by andesite on the footwall and where the hanging-wall andesite is underlain with rhyolite. Above and below this change in wall rocks, and at no great distance from it, have been found the best ore bodies of the district. This change in opposing wall rocks is due, of course, to faulting, the throw of the principal faults being from 450 feet (137 meters) to nearly 700 feet (213 meters). The principal deposits have been found under two conditions—with the upper andesite as hanging wall and rhyolite as footwall; or with the lower andesite for footwall and a rhyolite hanging wall. The latter combination has produced almost 60 per cent of the stoping area of the Fanney vein. Taking the Fanney mine as a further example, we find that the zone having a rhyolite footwall and andesite hanging wall, which is. the upper 500 feet, yielded ore of profitable grade from 28 per cent of its total area; the next zone, having andesite footwall and rhyolite hanging wall, about 450 feet in vertical extent, contained minable ore in 47 per cent of its area. The bottom zone, generally with andesite on both walls, contained profitable ore in 13 per cent of its area. This example is believed to be fairly characteristic of the district.

It is believed by the writer, however, that the composition of the different wall rocks has exerted relatively little influence on the primary mineral content of the veins, and that the association of ore and wall rock cited by Scott is probably fortuitous with respect to control of ore by chemical character of wall rock, although the tendency of the rhyolite to break in somewhat sharper fractures than the andesite may cause a narrowing of the vein where both walls are in rhyolite, and the dip of the original fracture was doubt-

[16] Scott, D. B., Ore deposits of the Mogollon district: Am. Inst. Min. Eng. Trans., vol. 63, p. 300, 1920.

less controlled to some degree by the physical character of the rock, thus forming, after faulting, certain zones more favorable to circulation. Other mines, however, such as the Cooney, have yielded much ore from a zone in which both walls were andesite.

Rocks of different physical character have undoubtedly exerted some control over the size and shape of the veins. The more massive lavas, particularly the Fanney rhyolite and Pacific quartz latite, tend to break cleanly in well-defined fissures and so favor the development of sharp distinct veins. The same is true to a less extent of the andesite, though veins crossing andesite commonly contain a larger number of wall-rock inclusions and show a distinct tendency for small branching veins to extend for short distances out from the main vein. Mineralized shear zones parallel to the major fissure are likewise more numerous in the andesite than adjoining the veins that are inclosed in rhyolite walls. Where, as is common, rhyolite forms one wall of the vein and andesite the other, the included fragments of wall rock are predominantly andesite. The tuffaceous members of the series, particularly the Deadwood Gulch rhyolite tuff and the tuffs of the Cooney quartz latite, owing to their more porous texture appear to be less favorable for vein formation, and in places a vein that is well defined in the adjoining andesite is represented in the Deadwood Gulch tuff only by an indefinite zone of silicified tuff without sulphides.

The only probable influence of the wall rocks on the mineralogic character of the veins appears to be the tendency already noted for the mineralization of the predominantly copper sulphide type to be chiefly associated with the andesite. Exceptions to this tendency are numerous, however, and it is considered more likely that the dominantly cupriferous mineralization is characteristic of certain veins or zones in the veins and that the common association with andesite wall rocks is a coincidence rather than a general rule. As noted elsewhere, the copper ores generally occur at greater depth than the silver ores.

ORIGIN OF THE VEINS

Very few facts were observed that bear directly on the mode of origin of the quartz veins themselves. There are, however, a few points that deserve special mention. The veins have been found along the planes of normal faults. The fault system indicates a condition of tension relieved by faulting, hence more likely to permit the existence of open fissures than if the faulting had been of the reverse type. Under present conditions great stopes stand open without timbering, and large open fissures, the result of solution of the calcite bands, persist to the greatest depths reached in mining, about 1,500 feet below the highest point of the outcrop.

The closely banded agate-like quartz seems to represent on the whole the earliest stage of vein filling. The banding is extremely fine in texture; in places the vein consists of great numbers of minute bands less than 1 millimeter in width. These are in general roughly parallel to the walls, but are in places irregular. Commonly inclusions of wall rock at a distance from the walls are surrounded by concentric bands of the same type as those parallel to the vein walls, and blend with them at a distance of an inch or two from the rock fragment that served as a nucleus. It seems difficult to explain banding of this type of vein structure, either by supposing growth due to accretions on the walls of an open fissure or on the assumption of successive injections of minute amounts of material. The same condition is seen, though less clearly, in the banding of the later quartz and calcite and the close banding of the light and dark calcite of the barren veins.

The veins cut a thick series of lava flows which differ greatly in petrologic character. Had inclusions been carried upward from any great depth, fragments of the rather distinctive lower flows, such as the Cooney and Pacific quartz latites, should be easily recognizable above their normal horizons. At only one point, however, was any evidence observed of even moderate upward movement of wall-rock inclusions.

The Queen vein where developed by the Queen tunnel has both walls of Last Chance andesite, but here carries also inclusions of the underlying Fanney rhyolite. The Fanney rhyolite, here represented only by a bed of rhyolite tuff, crops out in the stream bed about 30 feet below the portal of the tunnel. It seems possible, therefore, that fragments have been carried upward at least this much. On the other hand, between the flows of andesite and agglomerate that make up the Last Chance andesite there are, particularly near the base, thin beds of sandstone that contain rhyolite fragments derived from the Fanney rhyolite. It is possible that the rhyolite fragments seen in the vein came from one of these sandstone beds.

At one point in the Little Fanney mine where the Fanney rhyolite forms the hanging wall and the Mineral Creek andesite the footwall, the inclusions near the hanging wall consist only of rhyolite, whereas close to the footwall both rhyolite and andesite fragments are present.

The very fine-grained quartz is in many places clearly earlier than the later quartz carrying the sulphides. Fragments of the earlier banded fine-grained type are frequently found entirely surrounded by quartz of the later type, with the banding at variance from its original direction, as if the result of a sudden solidification of the vein-forming solution which had torn them from their original positions.

The degree of alteration of the included fragments of the wall rock varies greatly. One fragment may be almost completely absorbed by the vein quartz and its original outlines determinable only by a slight difference in color and texture of the quartz, while a neighboring fragment may be almost unaltered, as if the two fragments had been exposed to the chemical action of the solutions for different periods. On the other hand, rims of sulphide minerals are found around wall-rock inclusions in all stages of alteration and surrounding also the included fragments of older quartz.

OXIDATION

DEPRESSION OF THE WATER LEVEL

The physiographic history of the district indicates that after the formation of the veins they were subject to deep erosion in late Tertiary time, and a broad valley was cut which was later filled with the Gila conglomerate.

Prior to and during the cycle in which the veins were being eroded there was probably opportunity for the formation of zones of oxidation and supergene enrichment, but whether any portion of such zones survived would depend on the relative speeds of oxidation and erosion. As to this point data are entirely lacking. The development of the broad valley, which now in part forms the relatively flat interstream plateaus, was followed by a period of aggradation in which several hundred feet of Gila conglomerate was laid down. During this time the water level must have been above the apices of the veins, and hence there could have been little opportunity for further oxidation and enrichment, though any remnant of an enriched zone that might have survived from the earlier cycle would have been preserved. It is reported that in the early days of the camp extremely rich ores were mined in places close to the surface. These ores may possibly have been remnants of such Tertiary enrichment. After the deposition of the Gila conglomerate the valley was dislocated longitudinally or diagonally by a fault, which depressed the valley region west of the district more than 1,300 feet relatively to the interstream plateau of the district itself. (See p. 32.) This faulting lowered the base-level of the region, but the date of this depression was geologically so recent that the streams have not yet been able to reach grade and have cut narrow canyons through the relatively uplifted block.

The ground-water level of the productive part of the district, however, is lower than the level of the down-cutting streams that flow through the canyons. The greatest depths reached in mining, the 1,000-foot level of the Last Chance mine and the 1,300-foot level of the Little Fanney mine, are respectively 700 feet and 800 feet below Silver Creek. The level of permanent ground water in the productive part of the district is therefore dependent not upon the streams that cross the district but upon the level of the bedrock beneath the Gila conglomerate in the valley to the west. This level is unknown but can not be far below the greatest depths to which mining has reached.

The cause of this abnormal depression of the water level is to be found in conditions peculiar to this district. The chief collecting area for the ground water is the mountain region east of the district. The portion of the underground water which does not reach the streams at higher points flows underground toward the mining district but is prevented from entering the area in which the productive veins crop out by the eastward-dipping Queen fault and vein, which form an effective dam. The effectiveness of the Queen as a dam is shown by the number of springs in the walls of the two canyons just east of the vein. A crosscut to the Queen vein on the 500-foot level of the Little Fanney encountered so copious a flow of water that the working had to be bulkheaded. A similar crosscut on the Last Chance 700-foot level did not yield water, but surface exposures in the vicinity show that the Queen is here split up into two or more parallel veins, and it is probable that the easternmost branch was not reached. The comparative wetness of the Deadwood mine may be due to crosscuts penetrating the Queen vein. Although the district has during certain seasons a fair amount of rainfall, the ruggedness of the topography and comparative sparseness of vegetation favor a quick run-off, and there is comparatively little ground water originating within the productive part of the district. Of course possible seepage through the Queen vein is also to be considered. The relations that are believed to exist relative to the different ground-water levels east and west of the Queen are shown diagrammatically in Figure 4.

DEGREE OF OXIDATION

It will be readily deduced from the preceding paragraphs that the oxidation of the veins is extremely irregular, as the time since the depression of the water level has been too short to allow oxidation of the materials above this level except where conditions are favorable. Evidences of the work of surface waters in the presence of abundant iron oxide and iron-stained quartz and of cavities resulting from the solution of calcite are to be found in the deepest mine working, both the 1,000-foot level of the Last Chance and the

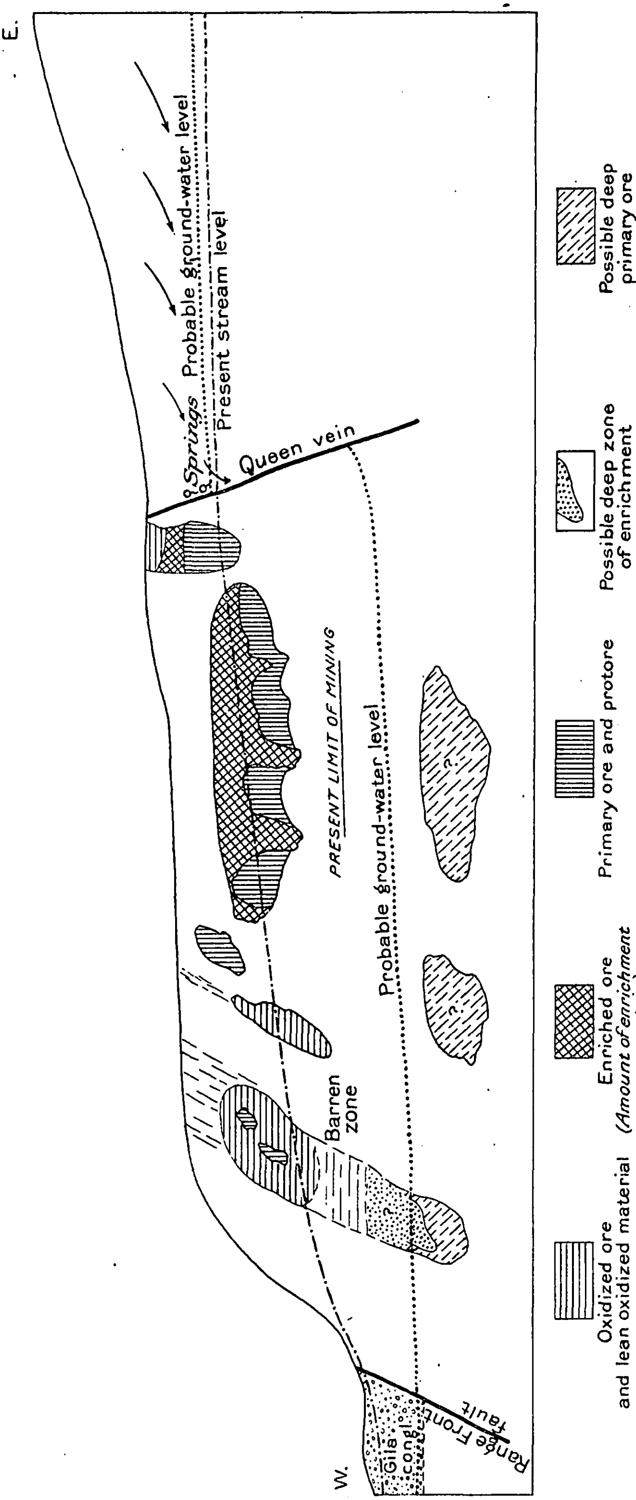


FIGURE 4.—Probable position of ground-water level in Mogollon district and inferred relations of oxidized, enriched, and primary ores west of Queen vein

1,300-foot level of the Little Fanney, but the ore bodies themselves show comparatively little direct evidence of oxidation.

The metallic minerals of the oxidized ores include limonite, malachite, azurite, chrysocolla, "copper-pitch ore," and rare cuprite. Besides these, in the oxidized ore of the silver-rich veins have been observed cerargyrite and probably other silver haloid minerals and rarely specks of platy native silver. Even more rarely native gold is found associated with limonite derived from the oxidation of pyrite. Manganese oxide is commonly associated with the manganiferous calcite found in certain veins.

Oxidized ores have yielded only a comparatively small part of the total production of the district, however, and their distribution appears to have been extremely irregular, depending more on the permeability of the vein at any one place than on the depth below the surface. Veins such as the Pacific, where there has been postmineral movement along the walls with some shattering of the quartz itself, naturally show a greater degree of oxidation than the tight veins that carry the major ore bodies of the eastern parts of the Fanney and Last Chance veins. On the whole oxidation is deeper in the western part of the district than in the eastern part, a difference which accords with the relatively greater amount of postmineral fissuring nearer the range-front fault. The eastern ore bodies of the Little Fanney mine, where the vein is relatively tight, although in places reaching to the surface, were essentially unoxidized, and the ore now being recovered from pillars in the old stopes on the 200-foot level resembles that from the lower ore bodies. In the western part of the mine, where the vein begins to feather out, partly oxidized ore was mined in places as deep as the 700-foot level. The ratio of gold to silver from the western workings was also distinctly higher than in the eastern part of the mine.

The No. 2 ore body of the Last Chance mine (pl. 21), which was mined out during the early operations, is reported to have contained oxidized ore only for a shallow depth below the surface, and even above the tunnel level the ore was entirely unoxidized. Near the west end of the same vein, west of the junction of the Pacific vein, there has been postmineral movement along the walls of the vein, and the ore formerly mined from the Confidence was oxidized to a much greater depth.

The deepest oxidized ore so far mined was that of the No. 6 ore body of the Last Chance mine, where ore containing horn silver reached the 700-foot level, although the neighboring ore bodies, even at and above the tunnel level, contained only sulphide ore. This unusual depth of oxidation is clearly due to fracturing of the vein and wall along the small rhyolite dike, which here abuts against the vein on the hanging-wall side. Postmineral movement along this dike and along and in the vein to the west of the dike has given opportunity for thorough permeation by surface waters. This ore body showed a relatively higher proportion of gold in the upper part and more silver in the lower portion.

SUPERGENE ENRICHMENT

The question of the degree to which the sulphide ores, which have furnished the great bulk of the production, owe their value to enrichment by supergene waters is one of vital importance, as the possibility of predicting the future life of the district depends largely on the answer which can be given to it. The writer is obliged to confess that his data do not lead to any very definite conclusion. In the following paragraphs observations bearing on the problem will be set forth and tentative conclusions drawn, but these, it must be realized, are in the nature of inferences rather than definite conclusions from a series of accordant facts. In Figure 4 the inferred relations are shown diagrammatically. This diagram should be considered only as an attempt to visualize the following discussion, rather than a definite statement of conclusions.

MINERALOGIC EVIDENCE

Clear evidence of deposition of minerals by supergene waters is rarely obtainable. Alteration of the copper sulphides, particularly of those ores that are relatively rich in copper minerals, has produced small amounts of covellite and supergene chalcocite, but in all specimens seen by the writer these are present only in very subordinate amount. Most of the chalcocite appears to be hypogene, as it is found associated in graphic intergrowth with bornite. (Pl. 17, *A*.) Graton [17] states that in many specimens intergrowths of chalcocite and bornite are completely surrounded by chalcopyrite. Scott [18] also considers the chalcocite of the copper veins "almost certainly primary."

In certain of the rich silver ores of the Last Chance and Little Fanney mines the quartz is crossed by narrow fissures that carry minute crystals of pyrite with a little native silver. Native silver is also rarely seen in small druses in the quartz. In these druses and in the pyrite-filled fractures it differs in habit from the minute platy specks found associated with the oxidized ore, as here it occurs in small thin wires or little curving plumes, rarely over 1 millimeter in length, but reproducing on a small scale the spendid silver plumes from Kongsberg, Norway, seen in museum collections.

Mr. M. N. Short kindly undertook a study of polished sections of the silver ores, particularly the richer ores of the Last Chance and

[17] Graton, L. C., op. cit. (Prof. Paper 68), p. 197.
[18] Scott, D. B., op. cit., p. 298.

Little Fanney mines, with a view to determining the probable importance of supergene enrichment. He summarizes his conclusions as follows:

The only hypogene silver minerals observed were argentite and stromeyerite. These are intergrown with sphalerite, chalcopyrite, and galena in mutual boundary patterns which strongly suggest contemporaneous deposition. (Pls. 17, *B;* 18, *A*, *B*.) In no instance was replacement of other sulphides by argentite and stromeyerite observed.

The only supergene silver mineral observed was native silver. This occurs as tiny veinlets replacing argentite and stromeyerite and as minute wires and plumes in small open spaces in quartz. (Pls. 18, *A;* 19, *A*, *B*.) The amount of native silver is small in comparison with the amount of argentite and stromeyerite. In a few instances small blebs of argentite have been as much as 50 per cent replaced by native silver. This is unusual, and in most of the sections examined the amount of native silver does not exceed 1 per cent of that of argentite and stromeyerite. In many of the specimens of rich argentite ore no native silver was observed. High silver assays are therefore not indicative of enrichment.

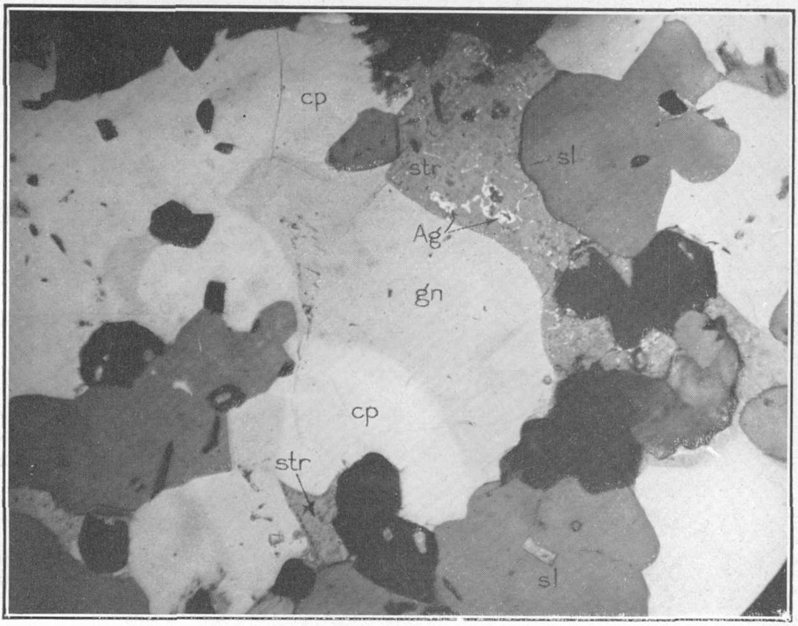
In places in the silver veins to as great depths as the 1,100-foot level of the Little Fanney mine the vugs in the quartz contain small patches of a finely divided white mineral whose optical properties correspond to those of halloysite. It is possible that this is the result of deposition from supergene waters at or below a former water level.

Scott[19] notes that where the silver content of the ore rises above 10 ounces to the ton the ratio of silver to gold, which in the average ores of the district is about 50 to 1, usually rises and in the highest-grade ores may reach 150 to 1. This might be taken to suggest that unusually rich ore may owe a portion of its high silver content to the deposition of supergene silver on the primary sulphides, but Short's examination of polished sections of rich argentite ores shows that that is not necessarily true.

RELATIONS OF ORE TO LOW-GRADE VEIN MATERIAL

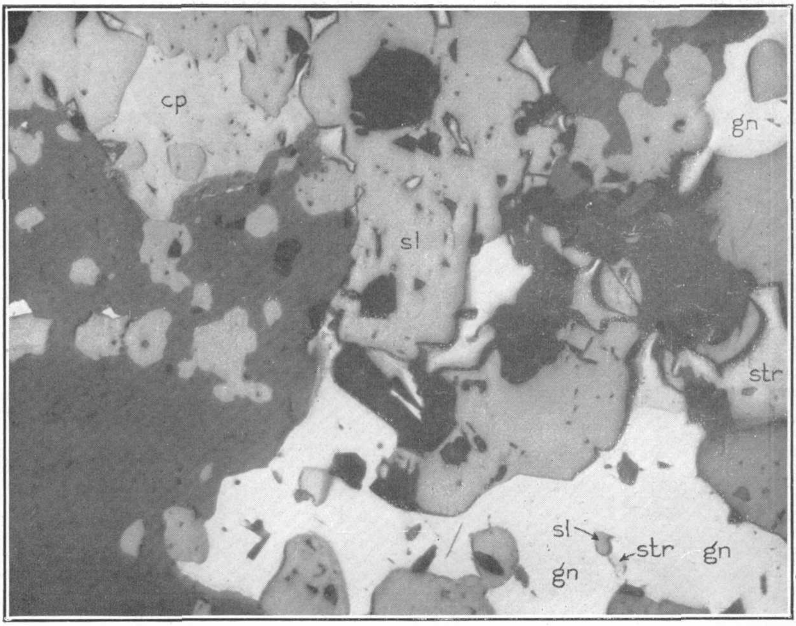
Nearly everywhere there is a sharp change from ore (above about 8 ounces to the ton) to low-grade material carrying 3 ounces or less of silver. Material of intermediate grade and just below the limit of profitable exploitation is comparatively rare, but on the other hand such lean material of 3 to 8 ounce tenor as is present is commonly found beneath the ore bodies, as might be expected if a part of the silver content of the higher-grade ore were due to enrichment. Where, as in the Last Chance mine, a large ore body has been definitely bottomed, the vein beneath in places shows the same type of mineralization but is of too low a tenor to constitute ore. In the lower parts of some of the large ore bodies, particularly those of the

[19] Scott, D. B., op. cit., p. 299.



A. MUTUAL INTERGROWTHS OF STROMEYERITE (str), CHALCOPYRITE (cp), AND GALENA (gn), LAST CHANCE MINE, 300 LEVEL

Ag, Native silver; sl, sphalerite. Enlarged 120 diameters

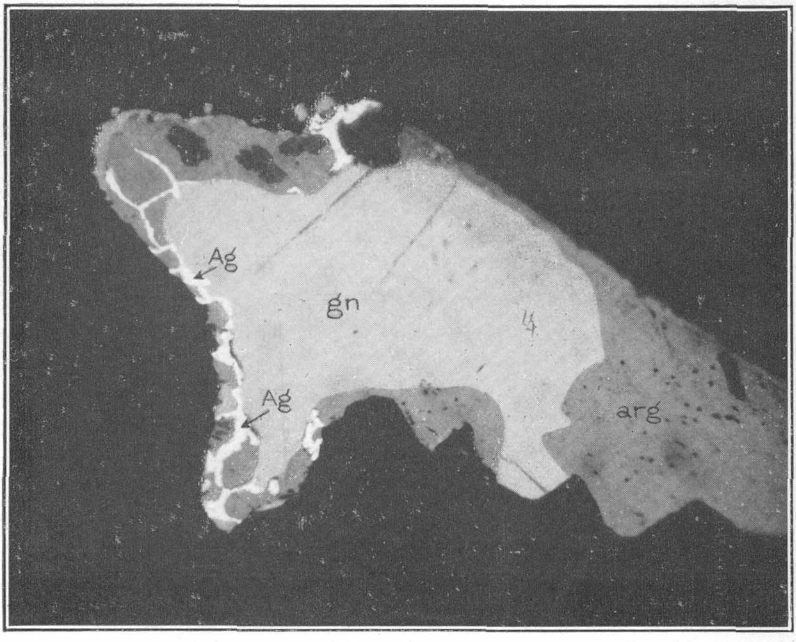


B. MUTUAL BOUNDARY BETWEEN STROMEYERITE (str) AND GALENA (gn), LAST CHANCE MINE, 300 LEVEL

cp, Chalcopyrite; sl, sphalerite. Enlarged 250 diameters

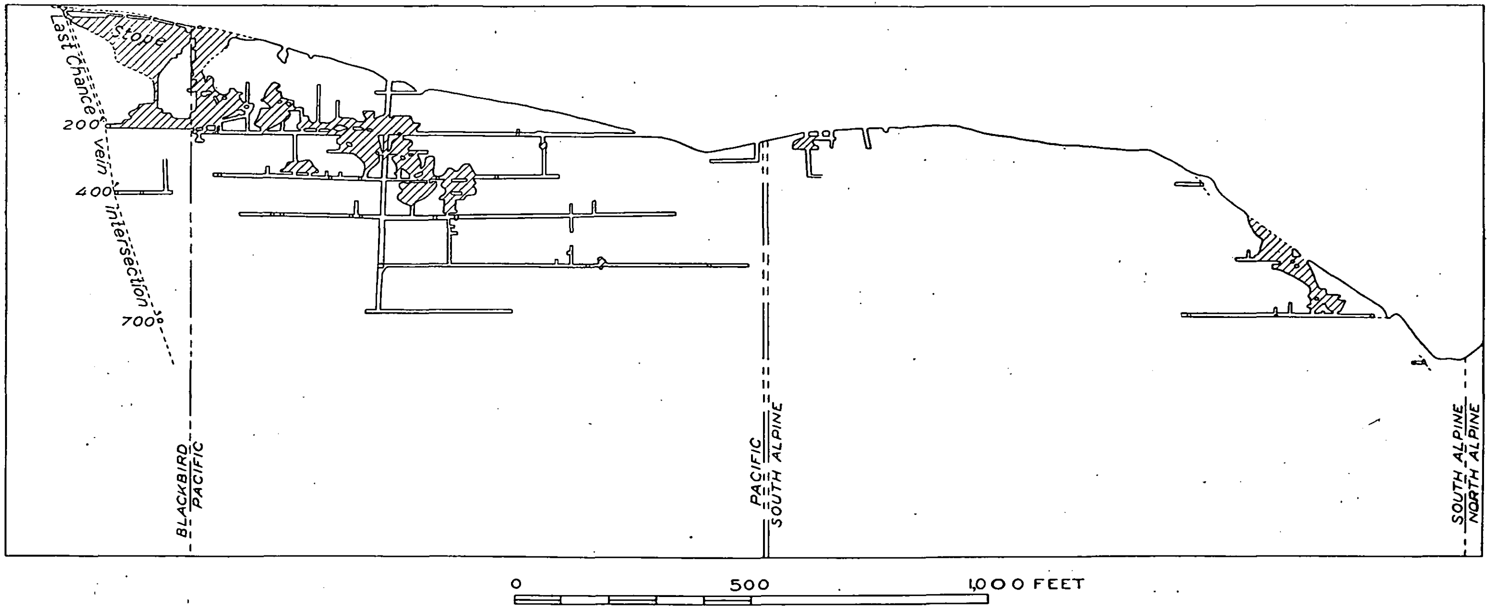
A. ARGENTITE (arg) REPLACED BY NATIVE SILVER (Ag), LAST CHANCE MINE, 300 LEVEL

Enlarged 180 diameters



B. GALENA (gn) AND ARGENTITE (arg) IN MUTUAL BOUNDARY STRUCTURE, THE ARGENTITE IN PART REPLACED BY NATIVE SILVER (Ag), LAST CHANCE MINE, 300 LEVEL

Enlarged 250 diameters



PACIFIC MINE, VERTICAL PROJECTION

Last Chance mine (pl. 21), wedges of ore of workable grade projected downward into the low-grade material, as if supergene waters concentrated in particularly favorable vertical zones had effected a sufficient enrichment to raise the vein matter in these downward pointing areas to the grade of ore. No structural features such as intersecting fissures that would explain the existence of these projections were found.

VERTICAL RANGE OF ORE BODIES

Another feature of the ore bodies which perhaps may be taken as an indication of enrichment is their general position within narrow vertical limits, not only in single mines but throughout the district as a whole. The Last Chance-Confidence vein produced ore between altitudes of 6,100 to 7,200 feet, but the greater part between 6,300 and 6,800 feet; the Pacific from about 6,200 to 6,600 feet; and the Maud S. from 6,200 to 6,800 feet. On the Fanney vein the stopes lie between altitudes of 5,900 and 7,100 feet, but the principal production was obtained between 6,100 and 6,900 feet. The Johnson ore was mined between 6,400 and 6,800 feet. Such ore as has been mined on the Queen vein falls within the same zone—that in the Eberle and Clifton mines at about 6,600 feet and the old stopes of the Queen mine between 6,200 feet and 6,400 feet. The Cooney mine, in which the ore was of the copper-rich variety, was productive to a somewhat greater depth, from the surface at an altitude of 6,400 feet down to about 5,700 feet.

The narrow vertical range of the ore bodies as shown by these figures might indicate a delicate adjustment of conditions governing hypogene deposition, which caused precipitation of the bulk of the metallic minerals at essentially the same altitude in the different veins, or it might mark a position at which the water level stood essentially stationary for a period long enough to allow notable deposition of supergene sulphides. Against the first hypothesis is the difficulty of supposing that conditions in each vein were so exactly similar that hypogene ore was deposited within narrow vertical limits simultaneously throughout the district. Against the second is the lack of evidence of extensive leaching above the ore bodies and the fact that the mineralogic evidence indicates relatively slight enrichment. Moreover, the traces of a broad valley along the edges of the present canyon walls (pl. 14, *A*) indicate that there was a pause of considerable duration in the depression of the great valley west of the fault, after the initiation of the present drainage lines but before the present fault scarp had attained more than a fraction of its present height.

If the hypogene material as deposited contained sufficient silver to be of workable grade, there is no inherent reason why other ore bodies should not be discovered at greater depth. The depth of the barren zone as far as explored does not yet equal that of the overlying productive zone, and other Tertiary silver deposits of the same general type have yielded hypogene ore to a much greater depth.

ALTERATION OF THE WALL ROCK

The veins commonly show sharply defined walls, with only rarely any evidence of replacement of the wall rock, even close to the vein. Fragments of wall rock included in the vein have, however, been largely replaced by quartz and have served as nuclei for the deposition of sulphides. All stages of replacement of inclusions can be observed from the faintest "ghosts" to fragments scarcely altered. In places, particularly where andesite forms the wall rock, small veinlets extend out into the country rock for short distances from the vein, and near these veinlets and along the wall of the main vein there is evidence of some slight replacement. Rock alteration by vein-forming solutions has, however, been more or less effective over the entire district, the degree of alteration depending on the type of rock. The dense rhyolites have been but little affected, some silicification is observable near the veins, and sericitization of the feldspars and chloritization of the biotite is a common feature. Sericitization was not observed in the rhyolites far from the veins, though abundant sericite is in places developed in the more permeable Deadwood Gulch rhyolite tuff. In places close to the veins feldspar phenocrysts of the Fanney rhyolite have been dissolved out, and the cavities partly filled with small quartz crystals. In the siliceous tuffs, such as the Deadwood Gulch rhyolite tuff, silicification near the veins has been so intense as to give the normally soft rock the appearance of a dense, hard rhyolite. In a tuffaceous quartz latite there has been in places a partial replacement of the groundmass by calcite, which holds its optical continuity over considerable areas, presenting the appearance of large poikilitic crystals. The andesites, owing to their higher content of more easily altered minerals and their more porous texture, have suffered widespread alteration. The ferromagnesian minerals have been altered to aggregates of chlorite and iron oxide, the latter derived in part from pyrite, together with varying amounts of calcite. In some places the plagioclase feldspar phenocrysts show replacement by calcite, as well as the development of quartz, kaolin, and chlorite and here and there minor sericite. The groundmass contains many alteration products, of which the chief are chlorite and calcite. The amygdules that are characteristic of the andesite show everywhere a filling of quartz, calcite, and chlorite in varying proportions, rarely all three present in the same amygdule.

The mineralogic evidence presented above indicates that the widespread alteration of the andesites is chiefly the result of hydrothermal action rather than weathering. This is confirmed by physiographic and geologic data. The andesites that crop out on the flat interstream plateaus must have been exposed to weathering for a greater length of time, both before the deposition of the Gila conglomerate and during the present physiographic cycle, than those which have been more recently exposed in the canyon walls. Thin sections from rocks from each type of outcrop show, however, the same kind and degree of alteration. The small basalt dikes which are of postmineral age and hence free from the action of the permeating solutions at the time of vein formation show but little alteration of their ferromagnesian minerals, even fairly fresh olivine remaining.

It is impossible to avoid the conclusion that at the period of vein formation the more porous rocks of the district, including the andesites, the tuffs, and to a minor extent the quartz latites, were permeated throughout by solutions that effected extensive alteration, the new minerals formed depending to a large degree on the original composition of the altered rock. Thus calcite and chlorite were abundantly developed in the more basic andesites, while in the rhyolite tuffs, though they were equally permeable, only secondary quartz and sericite were formed.

Although the presence of adularia in the veins implies the presence of potash in the mineralizing solutions, sericite does not appear to have developed to any great extent except in rocks that contained considerable original potash feldspar.

MINES AND PROSPECTS

In the following pages a short description of the developed mines will be given, as far as they were studied by the writer, together with some notes on the undeveloped veins, as the possibility of continued production depends largely on what discoveries may be made in veins that are not now being worked. The veins of the productive part of the district, from west to east, will be described first, and then the surface features of the undeveloped veins in the eastern part of the district.

EUREKA MINE

The Eureka mine lies outside the area mapped, at the base of the cliff that forms the western front of the range, between Mineral and Silver Creeks. A hasty visit was paid to the property in 1916, but it was not revisited during the later trip to the camp, and recent developments are not described.

As might be expected from the nearness of this mine to the great fault on the edge of the range, postmineral faulting is here of considerable extent. The lower of the three tunnels starts in unconsolidated gravel and passes through the fault zone, which brings the gravel against the rhyolite.

From the work done at the time of the visit it could not be determined whether there were several veins present or whether a single vein had suffered complex postmineral faulting. The principal vein seems to strike about north and has an unusually flat dip—35° W. Intense postmineral movement is evident in the heavy gouge carrying particles of ore and in the crushed condition of the vein itself.

At the time of visit 95 tons of ore had been taken out. Of this 50 tons of high-grade ore assaying $98 in gold and silver to the ton was shipped direct to the smelter, and 45 tons assaying $22 to the ton was milled at the Deadwood and Socorro mills.

The ore is partly oxidized and carries a larger proportion of gold than is usual in the district. The gold-silver ratio is about 1 to 25, and free gold can be panned from samples of the best ore.

VEINS OF THE PACIFIC GROUP

In the western part of the district several veins that strike for the most part a few degrees west of north can be traced from the Confidence vein northward across Silver Creek. One of these, the Pacific vein, has proved productive in the Pacific and South Alpine mines. This vein system becomes indefinite on the plateau between Silver and Mineral Creek Canyons, but northward from the northern rim of this plateau a single well-marked vein, the Great Western, can be followed beyond the northern limit of the area mapped.

PACIFIC MINE

The Pacific mine has been the most productive mine of those on the group of northerly veins in the western part of the district, but its output has been small as compared with that of the larger mines on the westerly veins. Although the mine is one of the oldest in the district it has produced only about $200,000.[20] It was being operated by the Socorro Mining & Milling Co. in 1916, and the ore was carried to the Fanney mill by a cable tramway across the Silver Creek Canyon, but the mine was idle in 1919. Recently, according to Scott, it has been taken over under a working agreement by the Oaks Co.

The mine is developed by an inclined shaft to a depth of 385 feet vertically below the tunnel level, which is 120 feet below the highest

[20] Scott, D. B., op. cit., p. 307.

point of outcrop. Levels extend out from the shaft at 100-foot intervals.

The Pacific vein joins the Confidence near the point where the Silver City road crosses the Confidence outcrop. The junction is well exposed both in the surface prospects and in the adit level of the Pacific mine. The filling of quartz and calcite is continuous both in the two major veins and in the network of smaller veins close to the junction, and the rough banding that is characteristic of the Confidence at this point continues without break into the Pacific vein. One of the principal ore bodies on the Pacific vein, but within the Confidence ground, was close to this junction.

The vein follows a fault plane northward from the Confidence vein. It here has an average strike of N. 30° W. and dips about 70° E. Along the outcrop both walls are in andesite, probably the Last Chance andesite, although the absence of the Fanney rhyolite makes uncertain the determination of the andesites in this part of the district. Below the tunnel level the footwall side is in the Pacific quartz latite, which is here either thicker than would be inferred from the exposures in Blue Bird Gulch, a short distance to the west, or shows an apparent greater thickness due to repeated faulting. Below the 500-foot level the Pacific quartz latite forms the hanging wall also. Here a few feet of Cranktown sandstone intervenes between the rhyolite and andesite. On the 400-foot level the vein in places leaves the major fault, and crosscuts for 20 feet back into the footwall show the fault contact of quartz latite and andesite, carrying only a small vein.

The vein is well defined throughout the mine and ranges in thickness from 1 to 15 feet. Near the junction with the Confidence vein there are a number of small stringers linking the two major veins. The junction of the Pacific and Confidence veins is shown in the old workings above the tunnel level and in the surface cuts. The filling of the two veins blends without any line of demarcation, showing contemporaneity of formation.

The vein filling is almost entirely quartz with a little fluorite in places and very little calcite, although a smaller calcite vein crops out on the surface 30 feet north of the shaft. The quartz is mostly of the fine-grained variety but carries bands of comby quartz with crystals to a maximum length of 1 centimeter. Associated with this quartz is a small amount of pyrite, preserved only in the lower levels. No other sulphide could be identified, although very minute dark specks in the richer ore are supposed to be argentite. Besides abundant limonite, manganese oxide, a little malachite and azurite, horn silver, and rare specks of native silver and gold are present. The wall rocks, particularly the andesite, are much altered and the andesite, besides the development of chlorite, calcite, and minor quartz, shows considerable pyritization. The pyrite in the andesite is said to be barren, although that of the veins carries silver and gold. Oxidation extends to the greatest depth worked and in the upper workings is complete.

Evidence of postmineral faulting was observed in many places along the hanging wall, more prominently in the northern part of the vein than in the southern part. It consists in a streak of sticky red gouge, at most a foot wide, containing fragments of andesite, rhyolite, and quartz. In places little nests of quartz crystals in gouge indicate movement prior to the vein formation. Except where marked by the later gouge the andesite walls are less well defined than the rhyolite and, particularly on the hanging wall, show many small stringers from the main vein. The altered andesite tends to slake off, especially in the upper levels, so that the old stopes are all caved, and even in the working stopes it is impossible to avoid mining a certain amount of the barren andesite.

The vertical projection in Plate 20 shows an ore-bearing zone roughly parallel to the surface and for the most part within 200 feet of the surface, extending along the vein to a point 600 feet north of the south end of the section. Within this zone are a number of small, irregular ore bodies, which do not extend to the surface. The ore is spotty, and the shoots are more irregular than the projection would indicate, as much material below the grade of ore has been taken out in the course of exploring for the continuation of the ore bodies. Scott[21] estimates that development work yielded only 1 ton to the foot, as against 10.5 tons to the foot for the Fanney, 11.8 tons to the foot for the Deadwood, and 16 tons to the foot for the Last Chance.

The appearance of the ore, which is iron-stained quartz of varying grain, does not differ from that of the low-grade material except perhaps in the greater proportion of comby quartz and the absence of calcite and fluorite. Picked specimens of the high-grade material, however, contain horn silver in association with streaks of limonite, a little native silver, and rare specks of free gold. The average ratio of gold to silver as shown by assays is about the same as for the sulphide ores of the other districts, 1 part to 50 by weight, though there is commonly a larger proportion of gold in the richest material.

The mine is essentially dry. The north end of the third level, where postmineral faulting is best developed and which receives the seepage from a branch of Bluebird Gulch, is bulkheaded off from the main workings and fills to a depth of 2 feet in about a week. During a period of a year in which no pumping was done water rose only 50 feet in the shaft.

[21] Scott, D. B., op. cit., p. 309.

SOUTH ALPINE MINE

The South Alpine claim, on the northward extension of the Pacific vein, is the property of the Mogollon Mines Co. In past years it has produced ore from surface stopes near the top of the south wall of the Silver Creek Canyon, and recently new ore bodies have been discovered farther north, about 100 feet above Silver Creek, and at the south end of the claim, adjoining the Pacific. (Pl. 20.) The postmineral faulting seen in the Pacific mine is less prominent here, and at the north end of the claim a well-defined vein with tight walls follows the earlier fault contact.

The ore is oxidized and shows a large proportion of copper minerals, principally malachite and cuprite. In a few places small masses of partly oxidized pyritous ore with a high silver content have been found. Here small plates of native silver occur close to the pyrite crystals or in the threadlike veinlets associated with iron oxide. Horn silver is found in vugs and fractures in the quartz. Free gold occurs in small amount.

MINOR NORTHERLY VEINS

The Bluebird vein joins the Confidence about 250 feet west of the Pacific and roughly parallels it, though less regular in strike. Only indefinite veining appears at the junction with the Confidence vein, but a few feet to the north there is a well-defined vein of white quartz, which can be followed on the surface as far as the gulch near the Pacific mine. North of this, along the fault contact between andesite and sandstone, there is little mineralization, though the contact is sharp. The vein has been prospected here and there but shows no surface indication of valuable mineralization. Where best developed it is about 3 feet in width, with a definite fault along the hanging wall showing evidence of postmineral movement, and small stringers entering the andesite on the footwall side.

Several small veins in the Gold Dust Gulch show no continuity on the surface. On the south bank a vein of dense white quarts 2 feet wide has been extensively prospected at one point, but so far as could be seen no encouraging indications were discovered. The small andesite dike north of the gulch shows in places a little shearing and quartz veining.

The fault that crosses the Silver Creek Canyon west of the Pacific vein apparently carries mineralization only near its junction with the Pacific, on the north wall of the canyon. Similarly the group of faults in the vicinity of Bluebird Gulch only here and there carry small discontinuous veins of dense white quartz.

A well-defined fault that can be traced from the western edge of the area mapped northward across Silver Creek to the high hill north of the canyon carries no distinct vein except for a short distance near its north end. About 200 feet to the west and diverging from this fault a small but well-marked vein carrying quartz and fluorite was seen on the south wall of the canyon near the creek.

The relatively flat area north of the Silver Creek Canyon shows many outcrops of small quartz veins, but few can be traced for any distance, and although there are many prospect pits here and there, none show evidence of the presence of any metallic minerals. Owing both to their probable lack of continuity and to the fact that this is almost the only part of the area in which outcrops are poor, it is uncertain whether these veins occur along faults that connect those of the Pacific group with those observed on the north edge of the plateau near the Laclede Trail. This irregular branching group of northerly and northeasterly faults shows for the most part merely shear zones with minor quartz mineralization, grading in places into better-defined small veins of white quartz with numerous andesite inclusions. One of the group, however, which extends northward from a point near the head of the small gulch crossing the Laclede Trail to the rim of the canyon, shows a width of as much as 10 feet in places and is exceptional among the veins of this part of the area in that the filling consists largely of coarsely crystalline light and dark calcite associated with finely crystalline and hackly quartz.

GREAT WESTERN MINE

The Great Western vein is the longest and most continuous of the northerly veins in the western part of the district. It can be followed almost without interruption from the Anaconda vein, on the south rim of the Mineral Creek Canyon, northward and northeastward to the edge of the area mapped. On the knoll south of the canyon there is dense porcelain-like quartz with varying amounts of light and dark calcite. In places this material splits up into small stringers, exclusively fine-grained quartz cementing small brecciated zones in the Cooney quartz latite and tuffs. The old workings of the Great Western mine are on the south wall of the canyon just south of Sheridan Gulch. Here mineralized rock extends through a broad shear zone 50 to 100 feet in width. The principal veining is in the outer parts of the zone, and the greater brecciation and more recent faulting in the central part, so that here the vein shows two prominent roughly parallel narrow ridges projecting above the surface like walls. The material on the tunnel dump is largely mottled black and white calcite showing in places considerable manganese oxide.

ENTERPRISE MINE

The Enterprise mine has developed the portion of the Great Western vein just south of Mineral Creek. A large mill was built, but so far as known no important production was made. The developments consist of a shaft on the vein outcrop about 200 feet southwest of the old mill and a tunnel over 1,000 feet in length.

The vein, which has here a hanging wall of Cooney quartz latite and a footwall of Whitewater Creek rhyolite, both largely tuffaceous, is poorly defined on the outcrop, consisting chiefly of a broad silicified zone of brecciated quartz latite. Its junction with the Floride vein on the ridge to the southwest of the tunnel is marked by the same type of silicification and brecciation, here covering a broad zone. As shown by the material on the shaft dump, the vein is better defined a short distance below the outcrop and consists of an intimate mixture of quartz and calcite deeply stained with manganese oxide. Near the creek this broad zone narrows to a shear zone about 50 feet in width in which blocks of silicified rhyolite are cemented by small veinlets of drusy quartz.

The Enterprise tunnel has explored this shear zone for about 1,000 feet southward from the canyon wall above the old mill. The tunnel follows a continuous streak of gouge, which is later than the mineralization. Throughout most of its length the same type of mineralized shear zone persists, though here and there for short distances the small quartz veins coalesce into larger ones, which commonly show calcite as well as quartz. No sulphides or any great amount of iron or copper oxidized minerals were seen, and there is no evidence of stoping in the accessible portion of the workings, but it is reported that small patches of good ore, valuable chiefly for gold, were encountered.

BUFFALO AND MOUNTAIN VIEW PROSPECTS

On the north wall of the Mineral Creek Canyon the principal venation largely follows two parallel zones, as in the stretch south of Sheridan Gulch. Near the rim of the canyon about 500 feet south of the point where it is crossed by the trail there is a single brecciated zone about 50 feet wide in the andesite, and the veinlets here carry a little calcite with the quartz. The fissuring and veining is confined to the andesite, and the rhyolite shows only slight sheeting parallel to the contact. The andesite is bleached near the vein but not pyritized.

The workings of the Buffalo No. 1, Buffalo No. 2, and Mountain View claims are on and near the Great Western vein, on the high ridge that forms the divide between Mineral Creek and Copper Creek, near the northern limit of the area mapped in detail.

Although some promising ore has been found, little development work had been done at the time of visit.

The shallow prospects on this part of the Great Western vein show chiefly dark calcite. Branching off from this is a small vein striking N. 25° W., from which copper sulphide ore, chiefly bornite, with chalcocite and covellite, has been obtained. A possible continuation of this vein, though here the average strike is east of north, has been prospected at a point 500 feet to the north. Here small quartz veins cut the andesite irregularly. The quartz is iron stained and apprently free from copper minerals. Small specks of free gold can be seen in picked specimens, and a good string of very minute colors shows in the pan.

On the crest of the ridge west of the copper-sulphide locality just described, another copper-bearing vein has been prospected on the Mountain View claim. At this prospect the vein strikes about N. 20° W. and dips steeply to the west but can not be traced on the surface. Where it is opened little quartz is present, but a streak from 2 to 5 inches wide of nearly solid chalcocite.

In the small gulch north of the ridge, close to the northern border of the mapped area, the Great Western vein is prospected by the Buffalo No. 2 workings, tunnels 150 and 170 feet in length on opposite sides of the gulch. The width of the vein as shown by crosscuts is from 30 to 40 feet, or perhaps greater in places, as the hanging wall is not everywhere exposed. The filling consists of alternate irregular bands of fine-grained flinty quartz, in places delicately banded, and calcite, for the most part dark and coarsely crystalline. A little quartz pseudomorphic after calcite is present. Assays across the whole width of the vein are said to show an average tenor of $3 to the ton in silver and gold. Postmineral movement is shown in streaks of gouge along the vein walls.

FLORIDE PROSPECT

The Floride vein (pl. 12, *B*) branches off from the Great Western on the cliff south of Mineral Creek and has a prominent outcrop on both walls of the canyon but dies out above the northern cliff. It strikes northwest and extends from the Great Western vein above the Enterprise shaft across Cooney Box to the north rim of the canyon. South of the creek the outcrop consists of an indefinite zone of shearing with some silicification, which prevails also on the north as far as the upper limit of the Whitewater Creek rhyolite. At the Floride tunnel, on the north wall, 400 feet above the creek, a well-defined fault has been followed northwestward for over 400 feet. For most of the distance there is no distinct vein, but here and there along the fault are small lenses of dense quartz, in places iron stained. These lenses increase in amount toward the face, which shows a 5-foot width of blue-gray drusy quartz. Above the cliff the vein is developed by a shaft of unknown depth and a tunnel 50 feet in length. At the shaft the vein carries drusy quartz and a little calcite, with partly oxidized pyrite crystals in the quartz and the adjoining silicified tuffaceous quartz latite. Where developed in the tunnel the vein is similar in character but with predominant flinty quartz. The width ranges from 2 inches to 1 foot, but the quartz latite shows silicification through a zone about 30 feet in width. A smaller vein on a minor fault parallels the main fissure about 40 feet to the west. The major fault zone can be traced a short distance to the northwest but carries no definite mineralization.

Silver and gold in commercial quantity are reported to have been obtained in assays of material from the upper tunnel.

VEINS BETWEEN THE QUEEN AND PACIFIC GROUPS

The system of parallel veins with westerly to northwesterly strike that links the two groups of northerly veins has furnished by far the greater portion of the production of the district. All the veins occupy fault planes of varying displacement. Most of those in the southern part of the district dip to the north, and most of those north of Mineral Creek dip to the south. The veins that occupy the faults of greatest displacement, such as the Last Chance-Confidence, the Maud S., and the Fanney, are the best defined and have proved most productive. The Deadwood, Last Chance, and Confidence mines have exploited the Last Chance-Confidence vein; the Deep Down and Maud S. mines and several minor prospects are on the Maud S. vein; and the Little Fanney, Trilby, and Johnson mines are on the Fanney group of veins.

The mines will be described in order from south to north and so far as possible along each vein from east to west.

GOLD DUST MINE

The Gold Dust vein is the southernmost of this group and follows the fault plane separating the Fanney rhyolite and Last Chance andesite westward from the Queen fault near the forks of Deadwood Gulch. No prominent mineralization is observable on the outcrop for a distance of 1,300 feet northwest from the Queen vein to the point where the strike changes from northwest to west. Here an old inclined shaft has developed a 2-foot vein of dense white quartz. Westward from this point there is no prominent mineralization on the outcrop to a point a short distance west of the split in the fault. Here for a distance of about 600 feet the vein, which has been prospected at greater depth in the Gold Dust mine, crops out. At its maximum the mineralized zone is 8 feet wide, consisting of 3 feet of brecciated rhyolite cemented by quartz on each side and 2 feet of hackly white quartz in the center. This zone pinches out a short distance to the west. This part of the vein has been developed by the two tunnels of the Gold Dust mine. The northern spur of the fault shows no surface mineralization.

The Gold Dust mine, near the head of Gold Dust Gulch, had not been worked for some years prior to 1916. It is doubtful if any great production was made. The vein is developed by two tunnels from Gold Dust Gulch, the upper one of which was accessible at the time of visit, and by smaller workings at a higher altitude. The strike is about east, and the dip 70°–75° N. Along the outcrop both walls are in the Fanney rhyolite, but at the adit level the foot-wall rock is the Mineral Creek andesite.

The adit level at an altitude of 7,250 feet, 350 feet below the outcrop, reaches the vein from a long crosscut through the rhyolite and follows the vein in a drift over 500 feet in length. No stoping has been done. The vein is rather irregular, nowhere over 3 feet in width, and consists of white sugary quartz without apparent sulphide minerals but showing here and there some iron staining and in places abundant dark patches of manganese oxide. With the quartz is a small amount of an undetermined kaolin-like mineral, possibly halloysite. A little calcite and fluorite are present in places. Near the east end of the drift the vein appears to split into two branches, joining at an acute angle, of which only the northern one has been explored. Movement of post mineral age is shown by the presence along the hanging wall of a belt of sticky gouge from 6 inches to 2 feet in width carrying rolled fragments of quartz and rhyolite.

The lower tunnel, whose portal is 1,500 feet to the west and at an altitude 350 feet lower, is caved a short distance in. As far as it was accessible the drift follows the northerly fault that is regarded as the southward extension of the Pacific group of faults. The fault shows here and there a little quartz, but any vein originally present has been obscured by later intense fissuring and faulting, which have produced a thick zone of crushed material with bands of gouge. It may be that the lower tunnel reached the vein explored above, for the dump shows very fine grained agate-like quartz grading in places into the minutely drusy variety.

VEINS BETWEEN THE GOLD DUST AND LAST CHANCE VEINS

The next vein to the north roughly parallels the Gold Dust vein at a distance of about 500 feet, but the fault that is followed by the vein dips in the opposite direction, to the south. Divergence in strike to the west separates the veins, so that in spite of opposing dips they are farther apart downhill to the west than on the ridge to the east. The fault plane lacks prominent mineralization on the outcrop for a quarter of a mile northwest from its junction with the Queen. There has been considerable underground development at a point a short distance east of the summit of the ridge, but the workings are inaccessible. The dump shows fragments of dark calcite. Westward from this point, though the fault plane is generally well defined, there is little surface evidence of veining.

The next fault northward is not well defined near the Queen, where both walls are rhyolite. The fault contact of andesite and rhyolite begins at the head of the small gulch tributary to Deadwood Gulch. Here the fault plane carries a vein about a foot wide of dense dark quartz filled with minute rhyolite fragments, which preserve their original outlines. No vein was observed across the flat-topped ridge, but for a short distance on the opposite side near the crest from 1 to 2 feet of quartz is exposed. The vein has not been prospected.

The southern contact of the andesite dike that cuts the Fanney rhyolite shows mineralization of the calcite type at the Good Luck prospect, 1,600 feet north of the Gold Dust mine. The vein is small and indefinite and shows no evidence of valuable metal content, though the andesite close to the wall is slightly pyritized.

The Hard Luck vein follows a fault contact between the Last Chance andesite and Pacific quartz latite 500 to 1,000 feet south of the Confidence vein and roughly parallel to it. This vein has been prospected in places and shows as much as 2 feet in width of white quartz with included fragments of andesite. Beyond the andesite contact it is less definite and apparently fades out near the point where it is crossed by the Silver City road.

DEADWOOD MINE

The Deadwood mine is the easternmost of the three mines that occupy the Last Chance-Confidence vein. This vein branches out from the Queen vein a short distance south of the surface plant of the Deadwood mine and for about 1,500 feet has a northerly strike nearly parallel to that of the Queen. The outcrop of the vein along the northerly stretch is mostly concealed under talus from the rhyolite cliffs to the west. Near the surface junction with the Queen vein, south of the Deadwood mine, the outcrop shows rather irregular small quartz veins in rhyolite in a zone 6 to 10 feet in width.

The Deadwood mine has developed the portion of the Last Chance vein between the Queen vein and the Last Chance mine. It was worked intermittently from 1905 to 1915 and since that time has been idle except for development work extending from the workings of the Last Chance mine. Since 1919 the property has been under the control of the Mogollon Mines Co., the owner of the Last Chance mine, and all work has been carried on through the Last Chance workings. Between 1911 and 1914, 38,480 tons of ore was mined, yielding 6,653 ounces of gold and 323,510 ounces of silver, or 0.173 ounce of gold and 8.40 ounces of silver to the ton. According to Scott the total production up to the time of suspension of operation in 1915 was 44,000 tons of ore, valued at $325,000. The only working accessible at the time of the writer's visit was the extension of the 500-foot level of the Last Chance in the Deadwood ground.

The vein has been explored in depth for 500 feet below the collar of the shaft and along the strike on several levels for a distance of 1,600 feet. The vein is said to have a maximum width of 20 feet and where stoped to range from 8 to 13 feet in width. Two large ore bodies (pl. 21) have been developed above the 300-foot level. The Queen vein, which is approximately parallel to this part of the Last Chance vein, has been crosscut in several places and explored by a drift for a short distance on the 500-foot level, and one small body of low-grade ore was developed.

The ore bodies did not reach the surface, and so far as known no oxidized ore was mined. Specimens of ore seen by the writer are identical with the silver-rich sulphide ore of the neighboring Last Chance mine.

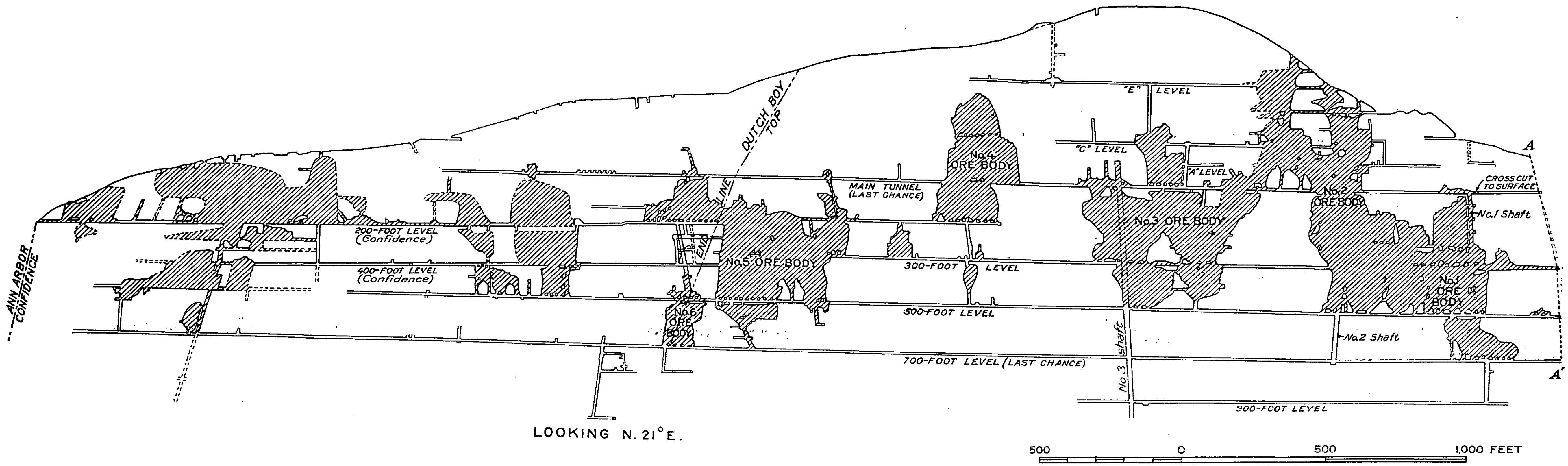
The ratio of gold to silver, calculated from the figures of production given above, is 1 to 48.6, about the same as for the same type of ore in the Last Chance and Little Fanney mines. The ratio of tonnage to development work, as calculated by Scott,[22] is 11.8 tons to the foot, which is higher than for most other mines of the district.

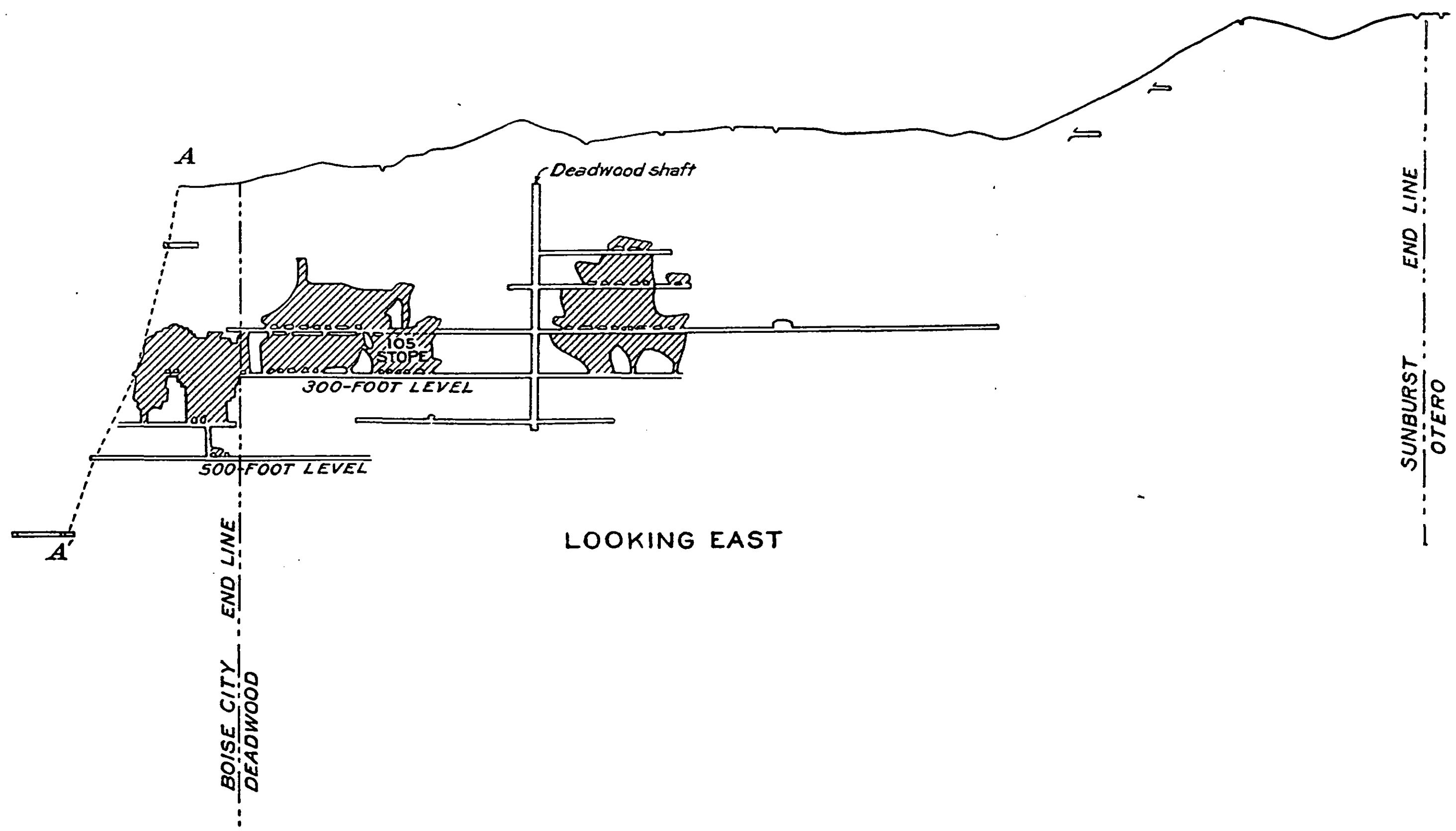
The mine is the only one in the district that receives enough water to require pumping. How far this water is derived from downward seepage through the broken zone near the veins of the surface waters collected in Deadwood Gulch or whether it comes chiefly from the east side of the Queen vein is not known.

LAST CHANCE MINE

The Last Chance mine of the Mogollon Mines Co. has developed the portion of the Last Chance vein lying between the Deadwood mine on the west and the Confidence workings to the east. The mine has been the largest and most continuous producer in the district. The production of the company for the 25 years prior to 1919 was about $7,500,000, almost all of which came from this mine. The surface equipment includes a 40-stamp cyanide mill of 200 tons daily capacity, a concentrating plant, and a power plant

[22] Scott, D. B., op. cit., p. 309.





CONFIDENCE, LAST CHANCE, AND DEADWOOD MINES, VERTICAL PROJECTION equipped with De la Vergne oil engines. A small part of the precious-metal content is recovered by concentration, the silver-rich concentrates being shipped to the smelter, but most of the product is obtained by cyanidation.

The property includes that portion of the vein between the Deadwood mine on the south and the Dutch Boy claim of the Confidence on the west. (Pl. 21.) All three mines are now controlled by the Mogollon Mines Co. and are being worked as one. The portion included in the Last Chance comprises 1,500 feet of the vein. The vertical development has reached 1,000 feet below the adit level, or more than 1,500 feet below the outcrop. The 900-foot and 1,000-foot levels, however, revealed no ore, and only in the eastern part of the mine did a major ore body extend as far as the 700-foot level. In the southern part of the property adjoining the Deadwood the strike of the vein is about north. A short distance to the north there is a sharp bend, and within a short distance the course is altered to N. 69° W. The dip, however, remains constant to the east and northeast at 60° to 70°. The vein closely follows the fault plane, which in the central part of the workings has a vertical displacement of about 400 feet, decreasing toward the west. At one point between the two larger ore bodies there is a split in the vein, and for a short distance only minor mineralization follows the fault plane, while the main vein is a few feet to the south.

The width of the vein ranges from less than 1 foot to more than 20 feet. The average width of the stopes, which above the 500-foot level occupy over half the area of the vein, is about 12 feet in the western ore bodies and 8 to 10 feet in the eastern. In the vicinity of the sharp bend in the vein already referred to there is complex fissuring, with small veins both parallel to the principal vein and radiating outward from the hanging wall to the junction with the near-by Queen vein. On the 300-foot level a parallel vein, 30 feet west of the principal vein, yielded good ore for a short distance. Two parallel branches are traceable on the surface northward from the Last Chance vein at the bend to about the south end of the Maud S. vein. These have been explored close to the surface by tunnels, but no ore was found. The filling consists of quartz with a little partly oxidized pyrite and rare traces of other sulphides. Included fragments of andesite show partial replacement and slight pyritization.

Along the outcrop of the main vein the principal vein filling is of the productive type and consists chiefly of the more coarsely crystalline variety of white quartz, with minor amounts of quartz pseudomorphic after tabular calcite, calcite, and fluorite. Near the west end of the claim the very fine grained barren quartz predominates at the outcrop but good ore was mined in depth.

The ore bodies are large and irregular in outline. No definite pitch is observable, but as may be seen from the projection (Pl. 21) most of the stoped ground, not only of the Last Chance but of the neighboring Deadwood and Confidence mines, lies within a horizontal zone only 500 feet in vertical extension, between the tunnel level and the 500-foot level. A projection of the 200-foot level of the Last Chance would lie in ore for more than half its length in all three mines. For the total development work of the mine during a period of nine years there has been an average production of 16 tons of ore to the foot.[23] Only a very small amount of ore has been won from downward extensions of these bodies below the 500-foot level. The No. 1 ore body, which was mined in the early days of the camp, was the only one in which the ore reached the surface.

Although the ore bodies are irregular in outline the change from ore to waste is fairly sharp. In places, as at the west end of the No. 5 ore body, the end of the stope is sharply defined and can be correlated with the widening of the vein at the junction with a minor branch vein or split in the main vein. Locally the boundary between ore and waste is indefinite, the width of the vein remaining the same but the ore grading off into barren calcite. The boundaries to the downward extensions of the ore bodies are much less sharp, the lower boundary is commonly irregular with points of ore projecting downward, and the ore passes more gradually into material below the limit of profitable exploitation.

The ore in the upper part of the No. 1 ore body, close to the surface was largely oxidized, but the oxidation extended only to a shallow depth. The other ore bodies, with the exception of No. 6, contained sulphide ores almost exclusively. The principal sulphides are pyrite and argentite, with minor sphalerite and galena. Copper minerals are rare; a little chalcopyrite is found here and there, and near the east end of the 300-foot level a mass of several tons of bornite with chalcocite in graphic intergrowth was mined in a small vein parallel to the major vein.

The ore of the No. 6 ore body on the west end line between the 500-foot and 700-foot levels was almost completely oxidized and contained free gold besides horn silver and native silver, but the No. 5 ore body, only a few feet distant, carried sulphide ore throughout. This peculiar condition is clearly due to postmineral movement transverse to the vein along the small rhyolite dike that here meets the vein on the hanging-wall side. A heavy streak of gouge crosses the vein but does not penetrate the footwall. The upper part of the No. 6 ore body was particularly rich in gold, and several assays of

[23] Kidder, S. J., Mining methods in Mogollon district, N. Mex.: Am. Min. and Met. Eng. Trans., March, 1924, p. 12.

material from the broken ground along the postmineral fracture even showed a gold content exceeding that of the silver. In the lower portion, however, there was a corresponding increase in the proportion of silver, so that for the ore body as a whole the silver-gold ratio was not far different from that of the unoxidized ore, about 50 to 1.

The major ore bodies, with the exception of No. 6, have tight walls and show no evidence of postmineral fissuring or leaching. The barren vein material of the lower levels, on the other hand, shows abundant evidence of the action of oxidizing waters, consisting of patches and stains of iron oxide and of elongate open spaces in the veins that have resulted from the solution of calcite bands.

The known ore bodies have now been nearly exhausted, and exploration below them, on the 900-foot level below the No. 1 and No. 3 ore bodies and to the 1,000-foot level below the No. 6 ore body, though showing a greater degree of oxidation than in the ore bodies, has yielded no ore.

CONFIDENCE MINE

The Confidence mine, comprising the Dutch Boy, Blackbird, and Confidence claims, adjoins the Last Chance on the west and is now under option by the owner of the Last Chance, the Mogollon Mines Co. The mine was formerly one of the large producers of the district but was idle from 1902 until it was taken over by the Mogollon Mines Co. in 1919. Since that time there has been renewed production but not on a large scale. Scott gives the production to 1919 as $1,200,000.

No ore was found near the surface from the east end line westward to a point near the junction of the Confidence vein with the Pacific vein, although at a short distance below the surface, there was an almost continuous ore body.

The dump of the Dutch Boy shaft, on the west side of the ridge, shows varied types of mineralization. Very fine grained barren quartz predominates, but in places this grades into coarser white drusy quartz of the productive type, which here in part shows an amethystine color. In some specimens bands of the two types alternate. The coarser quartz is in places intergrown with calcite, and here and there solution of the calcite has left small elongate cavities. The quartz is iron stained in part, and pyrite is present in small grains around the edges of small included fragments of andesite, but no other sulphides were seen.

There is no noticeable vein outcrop for over 2,000 feet westward from the Dutch Boy shaft, though valuable ore bodies have been developed below the surface. Farther west varying amounts of quartz are present at the outcrop. A prospect tunnel 500 feet east of the junction with the Pacific vein shows a mixture of quartz and green fluorite. Postmineral movement is shown by heavy gouge along the footwall.

At the intersection of the Last Chance-Confidence and Pacific veins there are a number of minor veins linking the two larger veins, just as there are near the intersection with the Queen vein. The vein fillings coalesce and are clearly contemporaneous, although there has been postmineral faulting along the footwall of the Confidence vein. The Confidence vein is here about 3 feet wide and has been mined to a small extent at the surface. The quartz is principally fine grained and drusy, rarely lamellar. In places projecting crystals surround small included fragments of andesite; around these are minute dark metallic specks, possibly argentite. Rare cerargyrite occurs in the vugs. The vein is well defined westward from this point to the portal of the Confidence tunnel, in Bluebird Gulch. In places the stopes from the adit level of the Confidence mine reach the surface, showing that the ore as mined had an average width of about 6 feet. The footwall on the Cooney quartz latite is sharp and shows slickensides, but the andesite on the hanging wall is blurred by partial replacement and contains many branching stringers.

On the west side of the gulch the vein is less regular, and for a short distance there is a parallel vein about 50 feet to the south of the contact vein, in the Cooney quartz latite. At the point where the vein crosses the road a little ore has been taken from workings on the Ann Arbor claim. Here there is a single vein for a short distance, 2 to 3 feet wide, consisting of white quartz with a little disseminated sulphide showing only slight evidence of oxidation. West of the road at the end of the old stopes the vein splits into two branches. The northern branch with andesite on both walls, continues westward across the head of Houston Canyon and is traceable for about 1,300 feet. For the first 1,000 feet it carries chiefly quartz, ranges from 1 foot to 5 feet in width, and has been prospected in places. Beyond this it grades off into small irregular stringers of calcite. The southern branch is a narrow quartz vein, which has been stoped in places as far as the point where it enters the Cranktown sandstone.

According to Graton the mine workings extend to a depth of 1,030 feet. No ore seems to have been mined below the 450-foot level, and but little below the 250-foot level. The accompanying projection (western part of pl. 21), although probably not accurate in detail, shows the general relation of the ore bodies. So far as could be seen from the accessible portions of the adit level the large ore shoot shown on the projection includes two ore bodies separated by a short barren interval just west of the Pacific intersection, perhaps uniting above the tunnel level. The western limit of the western body appears to be determined by the oblique intersection of a small vein on the hanging-wall side. The eastern part of the ore body extends from the Pacific intersection eastward to a southerly vein, which appears to be on the same fault that at the surface forms the western boundary of the Fanney rhyolite south of the vein. The wall rocks west of this fault on the adit level comprise the Pacific quartz latite on the footwall and andesite on the hanging wall. The Fanney rhyolite occurs on the hanging wall near the east end of the 150-foot level. Although the footwall contact of the Fanney rhyolite and Mineral Creek andesite, as projected from the Last Chance mine, should bring in the rhyolite on the footwall east of this fault at and below the adit level, only andesite was seen. This may indicate an upward swing of the contact, the rhyolite filling a broad trough in the andesite, or, more probably, the vein has here left the fault and for a short distance at least is entirely within the Last Chance andesite. On the 250-foot level near the shaft the Cooney quartz latite forms the footwall and the Pacific quartz latite the hanging wall.

West of the large ore body the vein is a mere streak of quartz along the fault; elsewhere, however, it is well defined and in places reaches a width of 200 feet. Near the old stopes quartz predominates; elsewhere there is a large amount of dark calcite with minor fine-grained quartz and quartz pseudomorphic after tabular calcite. The ore mined is said to have been similar in general character to that of the Last Chance but more oxidized, particularly in the upper stopes.

The western part of the vein follows the same general course as in the Last Chance mine, the strike averaging N. 65° W. with minor variations, and the dip being about 65° N. at the surface and steepening to nearly 90° at the adit level. About 200 feet west of the Pacific intersection the strike changes to an average of S. 80° E.

At the Pacific intersection a network of small connecting veins is visible on the surface. Recently lessees have mined small pockets of oxidized ore from these veins. This ore does not appear to extend down for any considerable depth.

PROSPECTS BETWEEN THE LAST CHANCE AND MAUD S. VEINS

Several small veins north of the Last Chance and south of the next productive vein, the Maud S., have attracted the attention of prospectors, but so far have not proved of commercial importance.

Of these the Anna vein is best defined. It follows a well-defined fault parallel to the Last Chance and about 500 to 1,000 feet to the north. A prospect tunnel near the east end is accessible for 175 feet along the strike and shows a small vein of white quartz without apparent valuable mineralization, which ranges in width from 6 to 12 inches. Westward along the surface no evidence of mineralization is visible until the next small gulch is reached. West of the point where the trail crosses the fault irregular veins of flinty white quartz surround fragments of andesite. The maximum width of the zone of mineralization is here about 5 feet. Veins of this type can be followed westward as far as the crest of the ridge.

A small northerly vein with steep eastward dip is traceable on the surface and in small prospect cuts for about 800 feet to the north of the stage road. The filling consists of white quartz showing copper stains in places, about a foot wide at its maximum. Apparently it does not occupy a large fault plane. The rhyolite contact a few feet to the west does not appear to be mineralized. It is, however, largely concealed by talus.

The dike of tuffaceous rhyolite that extends northward from the Last Chance veins on the west side of the ridge is in places highly silicified, and at one point a parallel vein in the andesite a few feet west of the contact has been opened in a prospect cut.

In the next gulch east of Bluebird Gulch, about 1,200 feet west of the Pacific mine, a prospect on a small westerly vein shows cupriferous mineralization. The vein occurs as irregular stringers of finely crystalline quartz within a zone about 2 feet wide. The quartz to some extent replaces the andesite. Associated with the quartz in places are small patches of limonite, malachite, and azurite, and more rarely small masses of "copper pitch" inclosing cores of chalcopyrite. No extension of this vein was traceable on the surface.

Another small vein with westerly strike extends from a point near the same gulch across the hill north of the Pacific mine to the Pacific vein. Where exposed it consists of dense white quartz as much as 2 feet in width with small specks of malachite and azurite.

DEEP DOWN MINE

The Maud S. vein occupies a well-defined fault, which extends northward from the Queen vein near the mouth of South Fork as far as the lower part of Johnson Gulch. It has yielded ore near the surface in the Maud S. and Deep Down mines, but exploration in depth has so far been unsatisfactory. In this as in the other veins of the group the strike is nearly north close to the Queen vein and swings more to the west a short distance away. At the Eberle mine the junction with one of the veins of the Queen group has been exposed, but the Maud S. vein has not been explored. The quartz is here of the usual white, rather coarsely crystalline variety commonly associated with valuable mineralization. Calcite is also present, roughly banded with the quartz. Here, as elsewhere near the Queen vein, the junction is complicated by a large number of smaller quartz veins linking the two major ones.

The Deep Down mine, now owned by the Oaks Co., is on the Maud S. vein on the south bank of Silver Creek between the Eberle and Maud S. mines. From the shaft there is a connection with the old workings of the Maud S. mine. The mine has not been worked for many years and was inaccessible at the time of visit. According to Graton the production, which came entirely from workings near the surface, was over $75,000.

The vein strikes about N. 20° W., dips 75°–82° E., and ranges from 4 to 12 feet in width. The Fanney rhyolite forms the footwall and the Last Chance andesite the hanging wall. The vein filling is similar in character to other productive veins of this group, consisting principally of white, distinctly crystalline quartz, with minor fine-grained quartz and in places minor calcite and fluorite. Here and there quartz occurs in tabular form. Exploration below the level of the stream is said to have been unprofitable. So far as could be judged from the old stopes, the width of ore nowhere exceeded 4 feet, but the stopes were of considerable length.

MAUD S. MINE

The Maud S. mine, owned by the Mogollon Mines Co., adjoins the Deep Down on the west and is situated on the north bank of the stream in the picturesque canyon of Silver Creek about half a mile west of the town of Mogollon. (Pl. 16, *A*). The mine was the site of the discovery of silver-bearing sulphide ore and was the first worked in this part of the district. It has been idle for many years. Scott estimates the production at $800,000, but an earlier statement[24] gives the production to 1901 as 65,000 tons of ore valued at $800,000.

Only a portion of the adit level was accessible at the time of the writer's visit. Through the courtesy of Mr. S. J. Kidder a report by Wilbur H. Grant was made available for study, and the information here presented is in large part derived from that report.

The workings include two shafts at opposite ends of the steep-sided mass of rhyolite that is cut off from the larger mass to the south by the stream canyon. The shafts are connected by an adit 1,100 feet long. The new shaft, at the west end, reaches a depth of 700 feet

[24] Jones, F. A., Mines and minerals of New Mexico, p. 76, Santa Fe, 1901.

on the dip of the vein, or about 580 feet vertically; the old shaft, at the east end, has a depth of 250 feet on the incline. Besides the adit level there has been extensive development work on the 500 and 700 foot levels from the new shaft, each of which follows the vein for about 800 feet, and shorter drifts have been run at higher levels.

At the collar of the western shaft both walls are Fanney rhyolite, with Last Chance andesite a few feet above on the hanging-wall side and Mineral Creek andesite just below the 100-foot level on the foot-wall side. The contact of the Fanney rhyolite with the overlying Last Chance andesite dips gently to the southeast, so that near the old workings the adit level shows an andesite hanging wall and a rhyolite footwall. The contact deepens toward the old shaft, where the vein has a hanging wall of Last Chance andesite to a depth of a few feet below the adit level, with Fanney rhyolite below, whereas on the footwall side the rhyolite overlies the earlier Mineral Creek andesite just below the 150-foot level.

At the 700-foot level the footwall consists of an andesite breccia capped by a few feet of andesite tuff, which is considered by Grant to be the same rock that incloses the bottom of the commercial ore at the Cooney mine.

The west end of the 700-foot level has entered a coarse-grained rhyolite with glassy quartz phenocrysts which, according to Grant, resembles the footwall rhyolite of the Pacific mine and is therefore probably to be correlated with the rock described in this report as the Pacific quartz latite.

The vein throughout most of the workings seems to follow the fault plane but, like the similar veins, here and there leaves the main fault for short distances. In plan it follows a broad curve; the strike is N. 35° W. in the southeastern part and gradually changes to N. 70° W. near the new shaft. The average dip is 60° at the new shaft and somewhat steeper in the old workings.

The productive portion of the vein contains quartz, calcite, and a little fluorite. The unproductive portion consists of fine-grained hornstone-like quartz inclosing partly replaced fragments of andesite and rhyolite. Below the 200-foot level of the old workings a little ore of the cupriferous type, containing chalcopyrite partly altered to chalcocite, chrysocolla, and malachite, was encountered, but elsewhere the ore seems to have been of the same type as that mined in the neighboring Last Chance and Little Fanney mines, though possibly oxidized to a greater degree.

PROSPECTS WEST OF THE MAUD S. MINE

West of the Maud S. mine the vein is on the south bank of the creek for about 1,500 feet. Here the outcrop is less prominent, and the vein is smaller. At one point, about the center of this section, the main vein leaves the major fault plane and shows both walls in Fanney rhyolite a few feet south of the fault, which itself carries a small vein. Here the main vein has been explored by a small tunnel, and a little ore has been taken out. Pale-green fluorite and white calcite are prominent constituents of the vein filling. Northwest of this point the vein rejoins the fault and shows principally as a breccia of andesite fragments cemented by fine-grained quartz.

Beyond this point, again on the north side of the creek, the vein lacks definition. Here and there a little quartz occurs on the fault plane. Along a short stretch on the south side of the ridge between Johnson Gulch and Silver Creek the vein has been prospected to some extent. The prospect pits and tunnels show little irregular seams of quartz, in places containing considerable fluorite. Small amounts of azurite and malachite and rare specks of partly altered chalcopyrite are present. This is the westernmost point at which any definite vein was seen. Beyond there is in places a little quartz along the fault plane, and the adjoining tuff and sandstone show silicification.

PROSPECTS BETWEEN THE MAUD S. AND FANNEY VEINS

A small and poorly defined vein of fine-grained quartz strikes northward up the north bank of the creek from a point opposite the Deep Down shaft. It has been prospected to some extent without revealing anything of promise.

The outcrop of the next westerly vein north of the Maud S., known as the Iron Hat, can be traced from the Queen vein on the north bank of the stream westward nearly to the point where the Maud S. crosses the creek, about 2,000 feet east of Johnson Gulch. The vein is not as well defined close to the Queen as about 800 feet to the northwest, where it shows 3 feet of quartz intimately intergrown with white fluorite. Beyond this the vein is narrower, but the outcrop is traceable to the point where it is lost under the tailings from the Fanney mill. There is a small amount of quartz on the vein for about 800 feet west of the stretch covered by tailings, beyond which no surface evidence of mineralization is apparent.

The Little Charley mine on the Homestake vein now forms a portion of the workings of the Little Fanney mine. The vein is roughly parallel to the Fanney, and about 500 feet to the south. The portion nearest to the Queen vein is not well defined. A small quartz vein near the Queen, cut by the Little Fanney tramway, probably represents the eastern continuation. It is only on the west side of the area covered by the Fanney mill tailings that a definite vein can be traced on the surface. From this locality westward for 1,500 feet the vein is well defined, with a maximum width of 4 feet, and is remarkable for the large proportion of fluorite present. The vein consists of white quartz with varying amounts of fluorite, which seems to be distinctly younger than the quartz. In a few places pyrite is present in small amounts, but nothing of promise has been developed in the numerous prospects along the vein. The portion beyond the gulch west of the Little Charley mine shows only a little quartz here and there along the fault plane. A northward-dipping branch extending northward from a point near the Little Charley mine carries a little fluorite near the intersection but fades out within a short distance to a stringer of fine-grained quartz 6 inches or less in width.

LITTLE FANNEY MINE

The Little Fanney mine is owned by the American Silver Corporation, the successor of the Socorro Mining & Milling Co. It is one of the largest mines in the district, and according to Scott [25] its total production in gold and silver to 1919 was $4,869,000. In 1923 the mine was leased by the Mogollon Mines Co., the whole production of the district being thus concentrated under one management.

The outcrop of the Fanney vein can be traced almost continuously from the Queen vein on the knoll south of Fanney Hill westward as far as Johnson Gulch. As with all the other major veins of the group the junction of the Fanney with the Queen is complicated by numerous small veins linking the two, of which only the largest are shown on the map. The strike on the surface is nearly south close to the Queen vein but slightly north of west on the ridge to the west.

The vein outcrop is not as distinct on the crest of the ridge, where rhyolite tuff forms the southern boundary, as farther west. The adjoining tuff is so highly silicified that it stands out as a prominent knob south of the vein outcrop. At one point, however, 3 feet of white quartz is exposed. Westward for a short distance the porcelain-like type of very fine grained quartz predominates at the outcrop, and the vein is not prominent at the surface. Only a comparatively short distance below, however, much ore was taken out in the old workings of the upper levels of the Little Fanney. From a point northwest of the shaft westward for about 700 feet the vein is split. Along the fault plane there are only minor quantities of fine-grained quartz, and the principal vein is in the hanging-wall andesite at a maximum distance of 50 feet to the south. Here the old stopes reached the surface. The width mined was from 3 to 8 feet. The vein rejoins the fault plane at the point where it is crossed by the road to the Alberta mine, and westward from this point the ore does not reach nearer the surface than about 300 feet, nor is the outcrop so well defined. At a prospect shaft north of the Little Charley a small

[25] Scott, D. B., op. cit., p. 303.

westerly branch can be traced for a short distance, but the main fault plane is almost without mineralization. This point appears to be the western limit of productive vein filling in depth. Westward as far as the vein can be followed the outcrop shows only a small vein, rarely as much as a foot wide. Here fluorite, which is lacking in the eastern portion, is prominent. A northerly branch, the southern junction of which is well exposed in a prospect shaft on the ridge west of Johnson Gulch is traceable almost to the Johnson vein.

The workings, which include those formerly known as the Little Charley mine, cover a vertical range of 1,500 feet and a length of

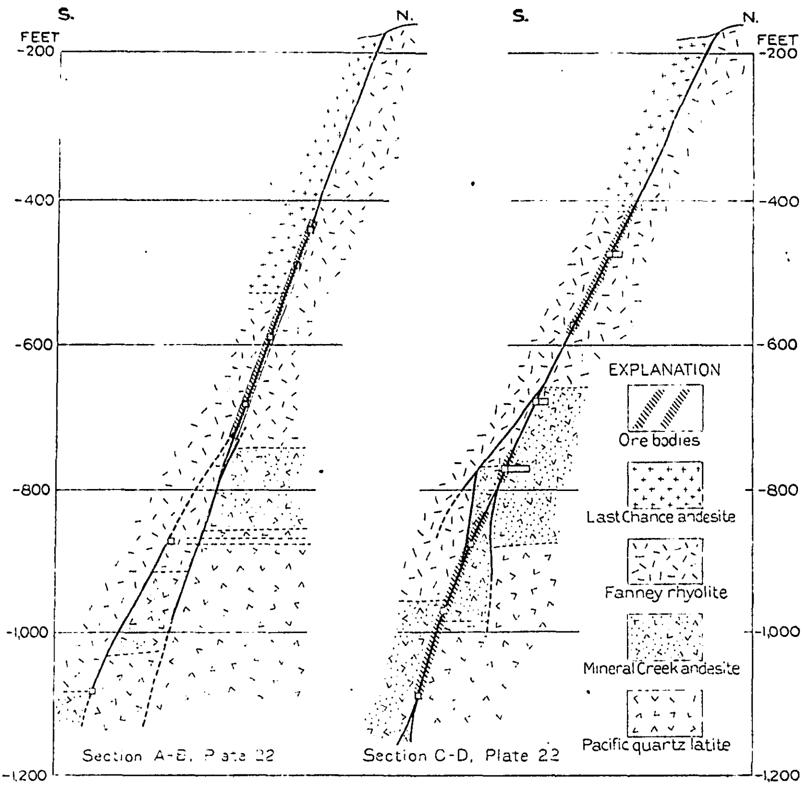


FIGURE 5.—Transverse sections across Fanney vein, Mogollon district

4,000 feet on the strike of the vein. (See pl. 22.) Ore has been exposed through a vertical distance of 1,200 feet, to the 1,100-foot level, and for about 2,700 feet along the strike. The strike over the greater part of the deposit is N. 74° W., and the dip about 70° N. In the eastern part, near the Queen vein, the strike is about northwest, and on the surface close to the Queen a north-northwesterly strike is observable. In the western part of the workings the vein appears to split into several branches. Minor splits in the vein are numerous and appear to exercise some degree of control over the position of the ore bodies. (See fig. 5.)

The ore is of the silver-rich type common to the district, copper minerals occurring only sparingly. The average ratio of gold to silver is 1 to 70.4 by weight. The usual grade of ore mined has a tenor of $10 to $12 a ton.

Two large and rather irregular ore bodies have been mined. The eastern of these appears to consist of two shoots—an upper flat shoot that bottoms at about the 300-foot level, which was inaccessible at the time of visit, and a lower irregular body between the 400-foot and 900-foot levels, embracing a maximum drift length of about 900 feet. The ore in this lower body consists entirely of sulphides, although traces of oxidation were observable in places down to the 1,100-foot level. Subsequent to the writer's visit a body of ore was found in the eastern part of the mine on the 1,100-foot level, supposedly at the junction of the Fanney and Ida May veins. The western ore body is divisible into two parallel eastward-pitching shoots, the western of which has been opened to the 1,000-foot level and the eastern to the 1,100-foot level. These shoots appear to be formed at the junction of the Fanney vein with intersecting fault veins. The ore in the western workings is in part oxidized and in places shows specks of free gold. The proportion of gold to silver is higher than in the unoxidized ore.

TRILBY MINE

The Trilby mine, 2,000 feet west of the summit of Fanney Hill, has long been idle and was inaccessible at the time of visit. At the shaft the vein, which is not prominent along the outcrop, follows the contact between Fanney rhyolite and Last Chance andesite, which strikes a few degrees north of west and dips steeply to the north. West of the shaft the Fanney rhyolite of the footwall is overlain by the Last Chance andesite. The vein may be the eastward extension of the Johnson vein, but the connection along the outcrop could not be established.

The shaft dump shows abundant coarse calcite with some quartz and fluorite, and, according to Scott,[26] the west end of the vein is notable for the quantity of fluorite it contains.

The development work consists of a 250-foot inclined shaft with a small amount of lateral development.

JOHNSON MINE

The Johnson mine was being prospected by the Socorro Mining & Milling Co. in 1916 but was idle in 1919. This mine is developed by two inclined shafts 400 and 450 feet deep and drifts at four levels, which have explored the vein for a total distance of 1,800 feet. (Pl. 23.)

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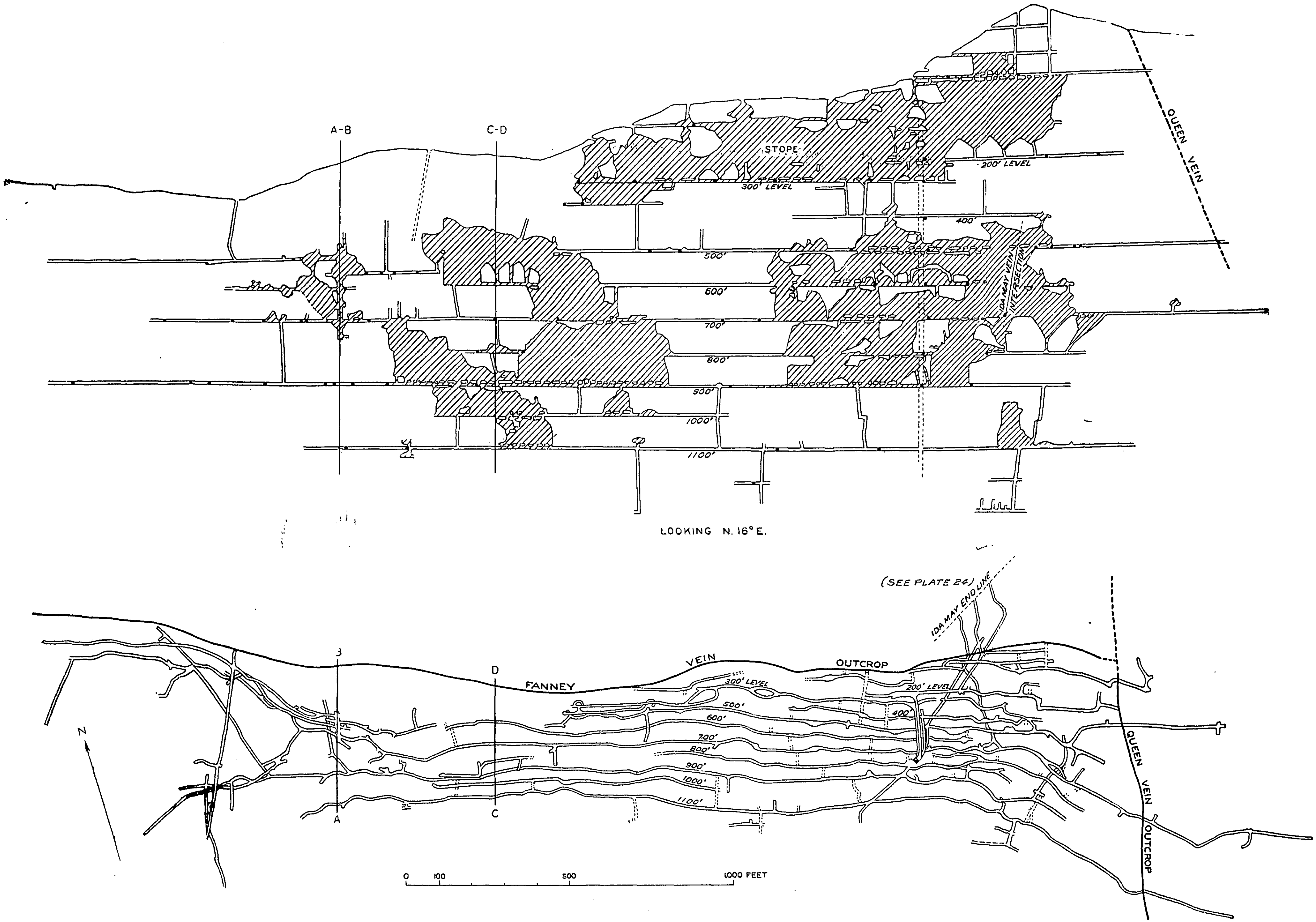
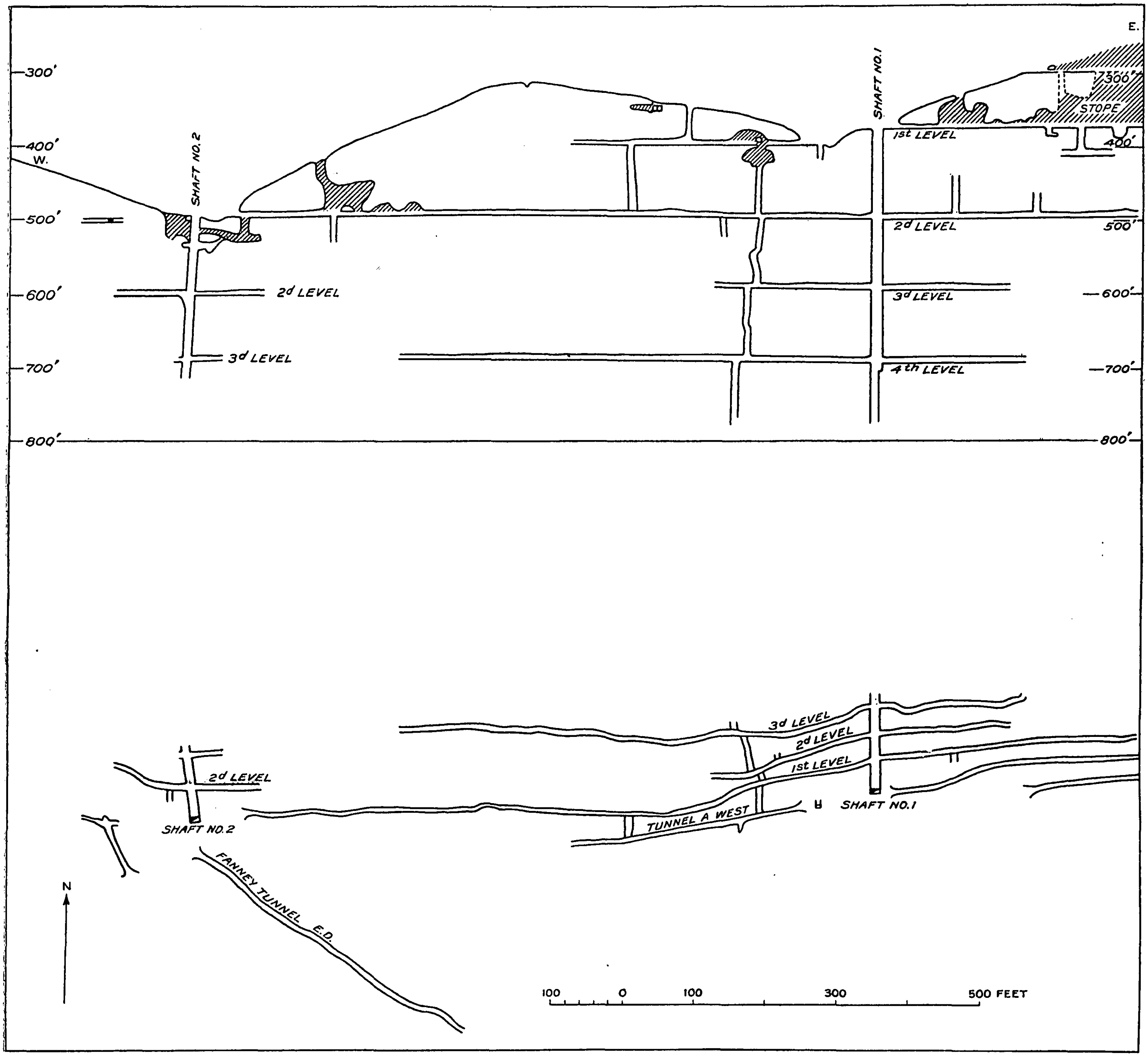
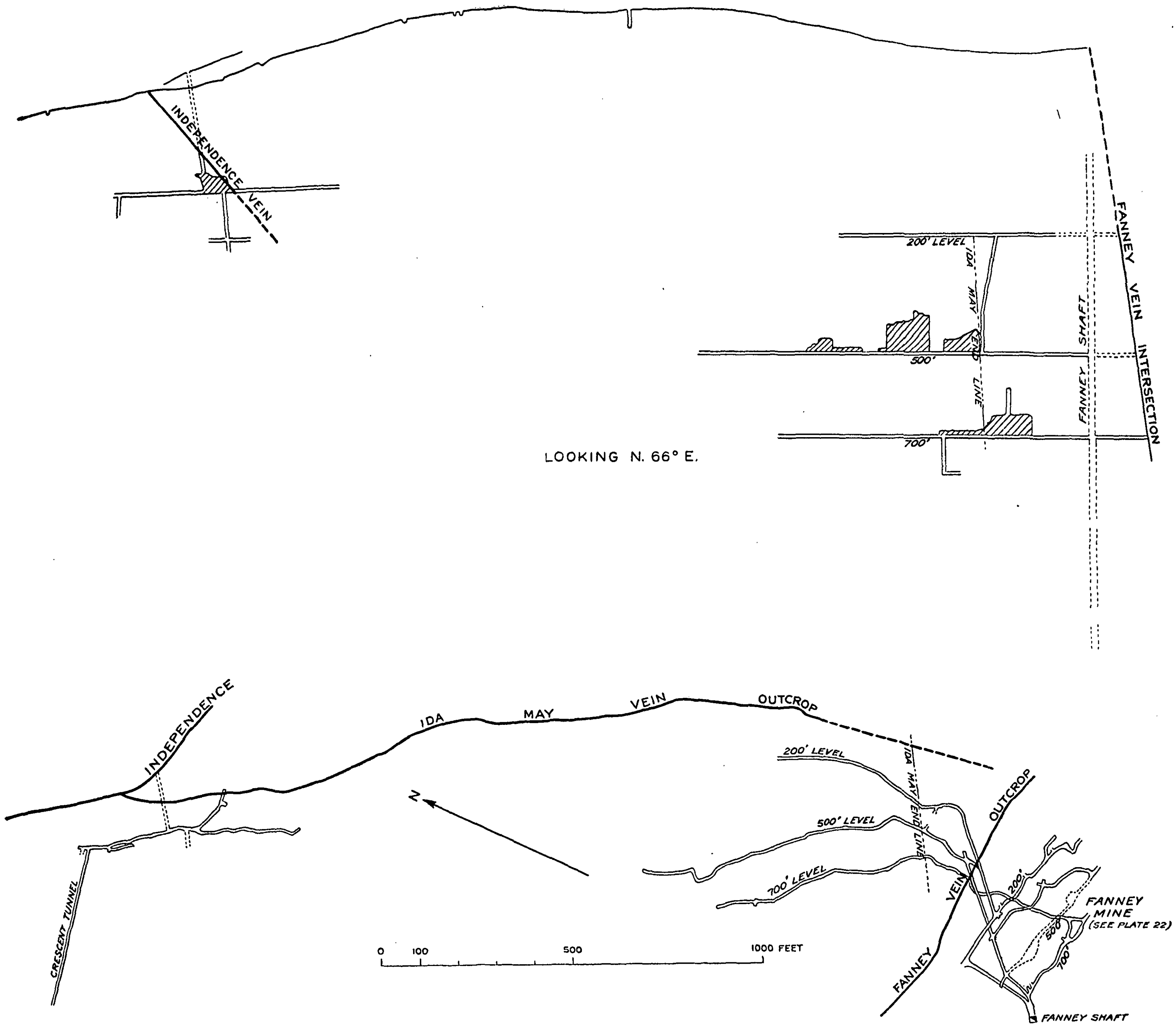
[26] Scott, D. B., op. cit., p. 307.



LITTLE FANNEY MINE, PLAN AND VERTICAL PROJECTION



JOHNSON MINE, PLAN AND VERTICAL PROJECTION



PLAN AND VERTICAL PROJECTION SHOWING WORKINGS ON IDA MAY VEIN, ALBERTA MINE AND PORTION OF LITTLE FANNEY MINE

3222—26. (Face p. 78.) No. 3.

The principal vein strikes about west and dips 70°–80° N. The vein is narrower than the average of other veins in the vicinity and in few places exceeds 3 feet in width. West of the mine it is linked with a branch of the southward-dipping Fanney vein by a small vein that strikes about northwest and dips steeply to the southwest, and another rather obscure northerly vein joins the Johnson vein from the south a short distance farther west.

During a previous period of exploitation considerable stoping was done above an adit level east of the eastern shaft, possibly on ore at the intersection of the vein and the irregular mineralization that follows the small dike of rhyolite on the hanging-wall side. Recent work has disclosed small bodies of good ore as far as the 300-foot level, principally near the junction with the northwesterly vein referred to above. A small amount of exploration on the small northerly vein has revealed patches of copper sulphide ore, oxidized in places, with a high tenor of silver. Other than this and the presence of a little unaltered pyrite, the ore is oxidized and resembles that of the Pacific mine. The quartz is of the common type, but in places fluorite is unusually abundant. Calcite is absent.

Outcrops of small and apparently discontinuous veins have been prospected here and there in the area between the Johnson vein and the Laclede Trail. A prospect 750 feet north of the Johnson mine shows a rather indefinite shear zone in which are quartz veins with considerable fluorite carrying a small showing of oxidized copper minerals.

ALBERTA MINE

The Alberta mine in 1924 was being worked under option by the Mogollon Mines Co. The vein, known as the Ida May, strikes about N. 40° W. in its southern part, near the Little Fanney Mine, and dips 60°–65°SW. At the south end the outcrops are obscure and the vein is not well defined on the surface. Apparently there are two branches, one joining the Fanney a short distance west of the Queen vein and the other uniting with the Queen north of the northern branch of the Fanney. The first has been developed underground from the Little Fanney workings. Northwestward across Fanney Hill the outcrop is nowhere prominent, and on the northwestern part of the hill, above the workings of the Alberta mine, where the vein is best exposed, it shows very fine grained quartz of chalcedonic appearance varied in places by hackly quartz. Development work on the Alberta mine shows that this material passes in depth into quartz of the productive type, associated with sulphides.

Northwestward as far as the 7,200-foot contour both walls of the vein are in andesite, and the vein is irregular in detail. Beyond this point the footwall is rhyolite and sharply defined, but the andesite hanging wall is much brecciated and penetrated by small stringers. The vein here splits; the northern branch continues in the same direction and is known as the Independence, but the southern branch strikes a few degrees north of west, parallel to the Fanney vein. The southern branch near the junction is about 4 feet wide and consists of hackly quartz without calcite or fluorite. Farther west the vein, though traceable along the outcrop, is nowhere conspicuous. It consists chiefly of fine-grained quartz, though at a prospect north of the Johnson calcite is dominant. From this prospect to its west end the outcrop shows a width of less than a foot, principally of fine-grained quartz.

The mine was first developed by an adit that cut the vein not far from its junction with the Independence vein, at an altitude slightly higher than the collar of the Little Fanney shaft. (Pl. 24.) The vein has been developed on the adit level for about 300 feet northwestward from its junction with the Independence vein. At the outcrop the vein is in the Last Chance andesite on both walls; at the tunnel level the footwall rock is Fanney rhyolite. The average strike is about N. 40° W., and the dip 60°–65° SW. The vein is well defined and over most of the distance developed exceeds 5 feet in width.

For 200 feet northwestward from the junction the drift is in ore, said to have in places a tenor exceeding 70 ounces of silver to the ton. There has been no postmineral faulting and, although the depth below the surface is less than 300 feet, practically no oxidation. The ore consists of alternate bands of calcite and quartz with finely disseminated sulphides and is similar in general appearance to the sulphide ore of the Little Fanney and Last Chance mines, but the metallic minerals are more finely divided. In the low-grade material northwest of the ore shoot calcite predominates. Recently a shaft has been sunk in ore to a depth of more than 100 feet.

At the northwest end of the drift a 30-foot winze has been sunk, and a short crosscut runs southwest from it and this cuts a 4-inch vein of chalcopyrite, partly oxidized to malachite and azurite.

Since the mine has been worked by the Mogollon Mines Co. operations except for the shaft below the adit level have been conducted from the Little Fanney mine. Work carried on from the 200, 500, and 700 foot levels of the Little Fanney has revealed a large ore body with an apparent southerly pitch. The grade of the ore is equal to that of the ore bodies of the Little Fanney and Last Chance, though the average width of the vein is less.

COMET PROSPECT

The Comet vein strikes nearly due north across the ridge followed by the Sheridan Trail. Near its south end it has been prospected in the Comet tunnel, which shows for 150 feet south of the gulch a vein of white comby quartz, about a foot wide, dipping steeply to the west. Its continuation across the ridge to the north is marked by shearing in the andesite with only faint mineralization. North of the ridge and for a short distance down the wall of the Mineral Creek Canyon the fault plane carries a small calcite vein.

GOLDEN EAGLE MINE

The Golden Eagle vein is roughly parallel to the Comet and from 1,000 to 1,500 feet to the west. In the gulch an irregular quartz vein has been developed to some extent.

The Golden Eagle mine was inaccessible at the time of visit. The vein, known as the Golden Arrow, follows a fault of comparatively small throw and strikes about N. 20° W. at the mine but swings to the northwest a short distance to the north. The dip is 67° E. at the mine but is steeper a short distance to the north, on the ridge. At the mine both walls are in the Last Chance andesite, but in the gulch a few feet to the north the Cooney quartz latite comes in on the footwall. A short distance to the south the Fanney rhyolite occurs on the hanging-wall side. Scott[27] says that the mine is interesting chiefly on account of the predominance of gold, which constitutes 70 per cent of the total value, the ratio of silver to gold being only 9 to 1 by weight. If this statement refers to oxidized ore it might point to the possibility of silver enrichment in depth. The material on the dump shows quartz with numerous andesite fragments, here carrying considerable pyrite, in part oxidized to limonite. Along the gulch the vein is concealed, and on the ridge it shows only as a shear zone in andesitic agglomerate with very little quartz. The dump of the closed tunnel on the north side of the ridge shows vein material consisting of small veinlets of porcelain-like and drusy quartz, cutting and to a slight extent replacing the Cooney quartz latite. No vein was seen on the surface northward from this point.

COONEY MINE

The Cooney mine is on the Silver Bar (or Cooney) and Twig veins, in the Mineral Creek Canyon near the deserted town of Cooney. At the time of the writer's examination it was the property of the Socorro Mining & Milling Co. The mine was once the most productive in the district but has been idle for many years. The underground work is extensive, but only the tunnels were accessible at the time of visit.

The Silver Bar vein at its south end has a northerly strike and easterly dip. Beyond the intersection with the Twig vein the strike

[27] Scott, D. B., op. cit., p. 309.

is northwesterly. The vein occupies a fault plane, but the throw is small, probably not over 40 feet. Near its south end, just below the talus slope of rhyolite from the cliff above, the vein is small and irregular, and numerous small stringers penetrate the wall rocks for short distances. The filling is a comby quartz grading into sugary crystalline quartz that carries sulphides with minor amounts of fluorite and calcite. The Silver Bar tunnel of the Cooney mine, which extends southeastward from the south bank of Mineral Creek, follows a well-defined southeasterly vein for about 400 feet. Beyond this the strike changes to nearly south, and the vein is less well marked and consists chiefly of a small, rather irregular seam of calcite from which several ill-defined branches extend to the southeast. The stopes are small and confined to the first 300 feet. The ore is of the cupriferous type; specimens from the dump show chalcopyrite, bornite, and chalcocite, the last apparently formed chiefly at the expense of the bornite. A little galena is also present. Although close to the surface the ore shows little oxidation, but little rosettes of azurite crystals are formed on the quartz crystals, and in places the chalcopyrite shows partial alteration to "copper pitch." The fluorite is intergrown with quartz and the calcite is distinctly later. Small stringers, proportionately richer in copper minerals, especially bornite, than the main vein, penetrate the andesite for short distances. The adit level on the Leap Year claim, on the north side of the creek, is accessible for about 300 feet and shows a well-defined vein of similar type. The quartz in places shows the characteristic lamellar structure after tabular calcite. In places both bornite and chalcopyrite appear to be partly replaced by later chalcocite. The vein is traceable on the surface diagonally up the wall of the canyon to a point just above the Fanney rhyolite, which is here represented only by a thin bed of rhyolite tuff, but nowhere does it show the same type of filling as at the mines near the creek. Commonly small stringers of quartz, which in places show very coarse crystallization, penetrate irregularly a narrow shear zone in bleached and somewhat silicified andesite or andesite agglomerate. Rarely for short distances there is a well-defined quartz vein as much as a foot in width.

The Twig vein is a branch of the Silver Bar with a more northerly strike. Near the intersection at the surface both veins have been stoped, but elsewhere the Twig vein, though easily traceable, is narrow and mostly lacks indications of valuable mineralization on the outcrop. The strike is north at the south end but north of the creek changes to northwest, nearly parallel to the Silver Bar. The actual change in strike is less marked than is shown on the outcrop, as the easterly dip accentuates the change in direction near the stream.

The vein has been stoped for a short distance at the junction with the Silver Bar and shows the same type of cupriferous mineralization. A short distance to the north it fades out to a shear zone in andesite marked by quartz stringers. Northward from this the vein is not prominent until a point 1,000 feet northeast of Cooney is reached. Here on the shelving edge of a point extending south from the divide it shows a width of 3 feet and consists of white quartz. A thousand feet to the north there is an outcrop of white quartz a foot wide, which continues across the gulch, in places slightly wider but containing andesite fragments. In neither place is there any copper or iron staining. The vein is traceable northward nearly to the edge of the plateau and shows a similar character, though at its north end a prospect shaft shows slight copper staining in the andesite wall rock close to the narrow vein.

The mine was studied by Graton and later in part by Scott. In view of its past importance and the unusual type of ore it seems desirable to quote their descriptions in full.

Graton says: [28]

The Cooney mine, sometimes called the Silver Bar, is owned by the Mogollon Gold & Copper Co. It is situated in the canyon of Mineral Creek just above Cooney camp. The claim was among the earliest locations, having been staked by the discoverer of the district. In the early days the precious metals only were sought, the copper not being recovered by the extraction processes then employed. In recent years copper has been the chief product of value. The total output up to 1905 was stated to have been over $1,000,000. At that time the mine was idle, but production has since been resumed. The workings consist of an adit at the level of Mineral Creek, which follows the vein to connect at a depth of 100 feet with an inclined shaft on the vein. Below the adit level there were in 1905 six levels, the lowest being 600 feet below the surface at the shaft. The shaft has since been extended to a depth of 760 feet. The mill equipment consisted of rolls, Huntington mills, Wilfley tables, and Frue vanners, with a capacity of 100 tons daily.

The predominating rock is andesite, much of it brecciated; soda rhyolite is present also, though the two rocks can not be distinguished underground. Both rocks show the alteration common in the district. The mine is located on the Cooney vein, which strikes about northwest and has an average dip of about 72° NE. It is a quartz-calcite-fluorite vein and has practically been described in the statement regarding the copper veins. The proportions of copper, silver, and gold are given on page 199.[29] The principal ore body extends downward from the surface a little southeast of the shaft. It has been stoped through most of its extent. On the first level, 115 feet below the adit, the stope was 100 feet long and 12 to 15 feet wide; and on the second, 50 feet lower, the stope was of similar dimensions. On the third level, 50 feet below the second, the stope was 60 feet long and 25 to 30 feet wide, but not all the ore was mined out. It was at this point, especially in a stringer 3 to 8 inches wide lying in the hanging wall a foot or two from the main vein, that were found the finely crystalline specimens described on page 197, and consisting of calcite,

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[28] Graton, L. C., op. cit., pp. 200–201.

[29] On p. 199 the returns from shipments in 1903–4 are given as follows: Gold $3,648; silver, at 55 cents, $42,926.95; copper, at 13 cents, $138,438.80.—H. G. F.

fluorite, and quartz with bornite, chalcocite, and chalcopyrite. This streak was very rich in copper. The stope on the third level was said to be at the junction of the Twig vein, which lies just northeast of the Cooney vein, but the writer was unable to observe any junction. A crosscut to the northeast revealed, about 35 feet from the Cooney vein, a narrow streak carrying calcite and bornite, but this appears to be simply a stringer running east and west. Little pay ore had been encountered in a long drift on the fourth level. The two lowest levels were not visited. It is reported that in the new workings at the bottom of the mine bornite and chalcocite have practically disappeared and pyrite, carrying some gold, is more abundant than it is above. Such a statement at once suggests secondary enrichment, but the writer believes that if this condition is general through the mine it is due to difference in original deposition resulting from unlike temperatures and pressures at different depths from the surface.

Scott's description [30] is as follows:

The Cooney vein was the first source of ore in the Mogollon district, its discovery in 1875 being the first mineral location in this part of New Mexico. The vein has a northwesterly strike and curves somewhat to the south as it approaches the Queen vein. All the the development is on the eastern end of the vein, at the crossing of Mineral Creek. The production credited to this vein is valued at $1,700,000, most of the ore being copper-silver.

The Cooney mine, with its related Peacock mine, is located at the junction of the Cooney and Twig veins. Mining was confined to the Cooney vein, extending 900 feet laterally and to a depth of 750 feet (229 meters) below outcrop, the bottom workings being nearly 500 feet lower in elevation than any of the Silver Creek mines. The ore body has an extreme length of 250 feet (76 meters), but much of it was restricted to narrower limits. The copper values in the upper workings evidently did not persist at great depth; it was reported that the horizon 400 feet (122 meters) below the tunnel level showed a preponderance of silver ore. The vein varies in width from 2 to 50 feet, the extreme widths including a considerable mineralization of the hanging wall. The junction of the Twig vein with the Cooney vein is easily seen on the surface, but it is not conspicuous in the mine workings. The main ore shoot of copper sulphides was in close proximity to this junction, and most of it was found to the north of the intersection; only unimportant amounts of copper were found elsewhere. The ore consisted chiefly of chalcocite, bornite, chalcopyrite, and various oxides of copper, associated with considerable silver and gold. It is stated that some of the ore, as mined, ran as high as 45 per cent copper, and some of the specimens preserved from this deposit show that parts of the vein were nearly pure chalcocite. There is no evidence of leaching, and little to suggest secondary enrichment.

The wall rocks in the upper workings are both andesite, but differing in texture, one of them being tuffaceous and the other fine grained and probably approaching latite in relation of the feldspars. Specimens from the dump, derived probably from the lower levels, now inaccessible, indicate that an andesite having the diabase features noted in the Fanney mine was found in this mine. The vein matter is mostly hard and siliceous, and much hackly quartz was found in the early days. Prospecting on the vein to the south revealed a probable faulting of the Cooney by the Twig vein; the Cooney vein is apparently cut off on the south, and exploration was never carried far enough to develop its extension.

[30] Scott, D. B., op. cit., pp. 308–309.

Connected with the Cooney mine, on the 400 level, is the Peacock mine, lying to the northward. A little development has been done here on three levels, and irregular deposits of silver ore have been mined. The absence of copper is noteworthy, considering its close proximity to the copper mineralization in the Cooney mine. The vein is about 4 feet in width, between andesite walls. The vein filling is quartz-calcite-fluorite, and some very high grade pockets of argentite have been found. The Cooney vein at this point has not yet indicated continuous ore deposits.

PROSPECTS NORTHWEST OF THE COONEY MINE

Another group of northwesterly veins branching out from a single stem lies southwest of the Twig and about north of the most northerly point to which the Silver Bar vein could be followed. This vein differs from the others in that premineral faulting appears to have occurred here only to a very minor extent. At its south end it shows on the outcrop only small stringers of quartz in the andesite. A short distance to the northwest these stringers coalesce into a well-defined quartz vein 6 inches wide accompanied by a little copper staining on the joint cracks of the andesite wall rocks. The traces of copper become stronger to the northwest, and at the southernmost of the group of gulches tributary to Mineral Creek a well-defined and prominent vein carries patches of oxidized copper minerals. The vein has now been prospected by tunnel and shaft, but apparently no encouraging indications were found. As seen in the tunnel the vein is less well defined than along the outcrop above and in places tends to split into irregular quartz stringers in a narrow zone of andesite bounded by fault planes. From this point a northerly branch is traceable for about 500 feet. This differs from the trunk vein in carrying in places abundant pyrite, both in the drusy quartz of the vein itself and disseminated in the andesite near the vein. It becomes less distinct toward the north and at 500 feet from the main vein fades out into a streak of discolored andesite.

The vein again shows a prominent outcrop at the next split, 300 feet beyond. The southern branch holds a course between west and northwest. It is nowhere over a foot in width, but here and there small showings of oxidized copper minerals have encouraged shallow prospecting. The main vein holds its northwesterly course and can be followed to a point within a few feet of the Enterprise vein. Near the junction it has been prospected in places and found to be a small but continuous vein carrying both quartz and calcite. Farther northwest, where it crosses the thin layer of Deadwood Gulch rhyolite tuff, it shows only as a brecciated zone with very indistinct quartz mineralization. It is more definite near the Enterprise vein; where it crosses the point of the cliff east of the Enterprise vein it is about a foot wide, and where the trail crosses the outcrop it shows a width of 2 feet of white quartz without iron or copper staining. A minor branch that leaves the main vein about 500 feet southeast of this point was traced to the northeast for about 500 feet. This differs from the other in consisting entirely of dark coarsely crystalline calcite, similar to that of several of the veins east of the Queen. Where observed the width ranges from 6 inches to 3 feet.

VEINS OF THE QUEEN GROUP

The Queen vein occupies the Queen fault throughout the length of the district. As far as traced mineralization was practically continuous for a distance of 7 miles, although it is only in a few places that any ore has been developed or surface indications were sufficiently promising to encourage prospecting. Within the area covered by the detailed map the Queen vein crops out for a total distance of over 20,000 feet; less than 1,000 feet of this length has so far proved worthy of exploration, and of this portion the total drift length of the ore bodies developed is less than 200 feet. The vein, like others in the district, varies greatly in width, but the average width is greater than that of any other, and the maximum in places exceeds 40 feet.

Over much of its course what for convenience is designated the Queen vein is a system of nearly parallel veins occupying fault planes of varying throw, rather than a single vein. These veins either join again in a single vein or diverge at small angles and gradually die out as the fault displacement lessens. Along most of the outcrop the vein filling is of the type which has proved barren elsewhere, in some parts coarse manganiferous calcite, in others fine-grained dense quartz.

As explained above, the dryness of the mines west of the Queen is due to the diversion of the major part of the ground water by the Queen vein, and therefore development of the Queen in depth would probably involve additional expense in handling water. On the other hand, some hope is afforded by the fact that the three places where ore has been developed on the vein, at the Eberle, Oaks, and Queen mines, are those of the lowest altitude of the outcrop—in the valleys of Silver and Mineral Creeks. The usual type of barren calcite forms the filling where the vein has been cut at depth in the Little Fanney mine, but the branch of the Queen cut on the 500-foot level of the Last Chance mine showed quartz of the same type as the productive Last Chance vein, and it is said that ore of low grade was found where the vein was explored on the 500-foot level of the Deadwood mine.

IRON CROWN PROSPECT

The Iron Crown prospect lies just south of the area included in the detailed map, near the top of the north wall of Whitewater Canyon. The vein appears to be the southern extension of the Queen vein. Faulting is complex and, at least in part, is post-mineral. The vein is accompanied by a thick seam of gouge containing crushed fragments of vein matter.

The property, which consists of several claims, is developed by numerous surface cuts, two small tunnels, about 100 feet vertically apart, and a shaft from the upper tunnel reaching nearly to the lower. The best ore is said to have come from the shaft, and 32 tons with an assay value of $15 to $20 a ton has been mined. The ore shows a much brecciated chalcedonic to fine-grained quartz, with the fragments cemented by red iron oxide. The fragments of chalcedonic quartz are in places cut by veinlets of drusy quartz. Rare specks of pyrite are visible, usually close to small fragments of altered wall rock, included in the vein. Another vein, as yet undeveloped, strikes about west along the base of a steep rhyolite cliff. Along the outcrop of this vein are masses of psilomelane, together with brecciated rhyolite cemented by quartz.

SOUTHERN PORTION OF THE QUEEN VEIN

At the southern border of the area and for some distance northward the fault contact is well marked, but there is little evidence of mineralization observable near the surface, owing in part to the fact that the talus from the hills to the east obscures the outcrops. Quartz, principally of the porcelain-like type, occurs in places, and the rhyolite tuff near the southern border is silicified near the vein. Here and there the Fanney rhyolite close to the vein shows distinct alteration.

From a point about 1,000 feet south of the Deadwood mine northward to Silver Creek the single mineralized fault plane is split on the surface into a number of slightly divergent planes, all carrying more or less quartz. Near the junctions of the Queen with the Last Chance and Maud S. veins the relations are particularly complex. In the Deadwood mine two northward-trending veins have been developed. One of these is the southward extension of the Last Chance vein, which in the eastern workings of the Last Chance mine makes a sharp bend to the south. The second vein, a short distance to the east and parallel, is apparently the westernmost branch of the Queen vein. This has been explored for a short distance on the 500-foot level of the Deadwood mine, and a small body of low-grade ore is said to have been discovered. What is probably the junction of this same segment of the Queen vein with the Last Chance vein is exposed in the 700-foot level of the Last Chance mine. Here the filling is of the same age and character as that of the Last Chance vein. Minor branches from the sharply curving Last Chance vein connect the two veins. The surface relations of these linking veins are obscure, owing to the concealment of a large part of the critical area by the gravel of Deadwood Gulch and the mine buildings and dumps of the Deadwood and Last Chance mines. The easternmost branch of the vein shows principally the type of quartz associated elsewhere with ore, but the small amount of development work undertaken has not revealed ore of profitable grade.

EBERLE MINE

The Eberle mine is on the westernmost vein of the Queen group at its junction with the Maud S. vein. The intersection has been exposed in the workings, but development work has been confined chiefly to the Queen vein. No stopes had been opened in 1916, but in 1919 preparations were being made by the owners, Weatherhead & Cleaveland, to send ore from the mine to the Fanney mill. About $10,000 had been produced from development work prior to 1916.

The workings consist of two tunnels from opposite directions and a 50-foot shaft. The northern tunnel follows southward a small vein in andesite, which is apparently one of the Queen group. The vein dips steeply to the east and apparently the rock on the footwall is the Last Chance andesite and that on the hanging wall the Mogollon andesite. A short crosscut intersects the Maud S. vein, which here nearly parallels the Queen and dips 80° E. The footwall is rhyolite, and the hanging wall is andesite. Postmineral movement parallel to the vein has formed a thick gouge. The southern tunnel cuts the intersection of the Queen and Maud S., which here unite to form a thick mass of quartz and calcite. Here also there has been recent movement along the rhyolite footwall. In this tunnel a small streak of very rich oxidized ore carrying cerargyrite and native silver was mined.

A 50-foot shaft near the tunnel portal has disclosed promising sulphide ore. Here the vein, though still well defined, is narrower, having an average width of about 5 feet. Apparently it leaves the main fault, or a branch vein has been followed, for both walls are in rhyolite. Disseminated mixed sulphides of the usual type associated with the silver ores occur both in fine-grained dark quartz and also in the rather coarsely crystalline white calcite that here forms the major part of the vein—an unusual association. Small calcite stringers carrying sulphide minerals also penetrate the rhyolite.

The quartz is irregularly intergrown with the calcite and shows in places a cellular texture. Quartz pseudomorphic after calcite is prominent here and there. The quartz, however, is more commonly rather compact and shows indefinite dark streaks due to the presence of minute dark sulphide minerals, probably in part argentite, which surround and partly replace pyrite grains that are larger but still less than 1 millimeter in diameter. The productive sulphide-bearing quartz grades off into a mixture of fluorite and white quartz free from sulphides.

CLIFTON PROSPECT

The Clifton tunnel of the Oaks Mining Co. prospects the Queen vein northward from the north bank of Silver Creek. The tunnel in 1916 had a length of about 500 feet, of which the first 100 feet was reported to disclose ore with a tenor of $10 to $12 to the ton in gold and silver, along a band 3 feet wide close to the hanging wall.

Both walls are andesite, the Last Chance andesite on the footwall and the Mogollon andesite on the hanging wall. The dip of the vein is here about 70° E. Although narrow and inconspicuous on the hillside above, the vein in the tunnel is wide, exceeding 20 feet in places, and persistent.

The bulk of the vein filling is coarse white calcite, but the ore shoot near the portal consists of quartz, in places amethystine, carrying a larger proportion of pyrite than is usual in the ore of the district. The gold content as shown by assays is relatively higher than is common, the ratio of gold to silver being about 1 to 15 by weight instead of the usual ratio of about 1 to 50. The amethystine quartz is cut in places by small veins of barren white quartz. Included fragments of andesite from the walls show varying stages of replacement.

On the surface northward from the tunnel to the Fanney power house the Queen group is represented only by a single vein, which shows a maximum thickness of 3 feet of flinty white quartz.

ANDREW JACKSON PROSPECT

The Queen vein north of the Clifton prospect passes through the property of the Little Fanney mine, owned by the American Silver Corporation and now under lease by the Mogollon Mines Co. In the workings of the Little Fanney the vein has been cut at three points, on the 500, 700, and 1,100 foot levels, but the junction of the Queen and Fanney veins is not exposed.

On the surface the Queen and Fanney veins near their junction are linked by a number of small quartz veins, and the bordering rhyolite tuff is highly silicified. Farther north the calcite filling is predominant, and 800 feet east of the Little Fanney shaft an open cut shows 25 feet of coarse banded calcite, with only a little quartz along the footwall, and rare quartz-lined vugs occur within the massive calcite. The footwall is well defined, and the small fault linking the Fanney and Queen faults is not noticeably mineralized at the junction. On the hanging-wall side small calcite veins branch out from the main vein. The wide calcite vein has been quarried for lime burning. Quartz again becomes the dominant gangue mineral a short distance to the north. The vein has here a width of 30 to 50 feet.

On the Andrew Jackson Consolidated claim, the property of the Socorro Mining & Milling Co., the Queen vein is unusually wide, at one point exceeding 90 feet. The open cut is on the ridge between Silver and Mineral Creeks close to the point where the Sheridan Trail crosses the vein.

The footwall is here the Fanney rhyolite and the hanging wall the Mogollon andesite. The vein consists for the most part of dense flintlike quartz, which here and there shows minute druses and more rarely a hackly texture due to the solution of intergrown calcite. Along the hanging wall is a band of coarse white calcite about 3 feet wide. The content in precious metals is low, not exceeding $3 to $6 a ton, but the tough and resistant character of the fine-grained quartz has led to its being quarried for use in the tube mills of the Fanney mill.

Near the point where the Sheridan Trail crosses the vein the Queen fault and vein divide again into several branches. South of Mineral Creek the principal throw, and with it the greatest mineralization, is found along the western branch. This dies out toward the north, and the eastern member of the group carries the principal vein. The western branch has a maximum width of 10 feet and carries the same type of fine-grained quartz as farther to the south, but along the footwall there is more or less coarse white calcite. No sulphides were seen.

QUEEN MINE

The vein is narrow and not prominent in the canyon of Mineral Creek, the principal mineralization having occurred along the eastern branches. Northward toward the plateau this branch again splits into three minor branches, which show only slight mineralization and can not be followed for any distance. The quartz for the most part is of the fine-grained barren type, but near the canyon rim there is a small shaft in which fine-grained lamellar quartz, with sharp "saw cut" cavities due to the solution of calcite crystals, is associated with a small amount of more coarsely crystalline drusy quartz. A little partly oxidized pyrite and small masses of malachite are present.

The junction of the principal eastern and western branches near the Sheridan Trail is hidden by talus, and the vein is not well defined across the silicified Deadwood Gulch rhyolite tuff to the north. From the edge of the tuff belt northward to the edge of the district and far beyond the vein is very prominent and usually stands out as a sharp wall. (Pl. 16, *B*.) The vein is less prominent south of Mineral Creek, but north from the old Queen mine it gains importance as its western neighbor diminishes in size.

The Queen mine, on the north bank of Mineral Creek, has long been idle, and little information is available as to the extent of its workings, type of ore, or output. Most of the work seems to have been done above the adit, which enters the north wall of the canyon a few feet above the creek level and in 1916 could be followed for a distance of about 800 feet to a point where it is caved in an old stope. The throw of the Queen fault is here divided between several faults, so that at the adit level both walls are of Last Chance andesite. The Deadwood Gulch rhyolite tuff, the base of which east of the Queen vein and north of the creek is about 100 feet above the creek and which is here 100 feet thick, is cut off obliquely by a westerly fault and apparently does not come into contact with the vein, which above the intersection has Mogollon andesite on the hanging wall. The strike is a few degrees east of north, except near the portal, where it is slightly west of north, and the dip is 75°–85° E. The width of the vein ranges from less than 3 feet to more than 10 feet and through most of the distance exceeds 6 feet. The vein material remaining in place is largely calcite, with which is intergrown lamellar quartz pseudomorphic after tabular calcite. Numerous included blocks of andesite are scattered through the vein, and there are a few smaller inclusions of what appears to be Fanney rhyolite. If so, these may have been carried up, as the lowest formation cut by the adit is the Last Chance andesite, which overlies the Fanney rhyolite. It may be, however, that these inclusions are derived from the sandstone beds that occur here and there between the andesite flows and in places contain fragments of Fanney rhyolite. Locally the coarse white calcite has been brecciated and recemented by finer-grained quartz. As a rule there is a larger proportion of quartz in the vein near the stopes, and it is probable that the ore shoots mined were largely quartz. The first stope is at a distance of 340 feet from the portal and is 20 feet in drift length. Other stopes of 20, 30, and 50 feet drift length have been mined between this one and the caved portion of the adit. The only metallic minerals seen were small grains of pyrite in the quartz, mostly concentrated around included andesite fragments, and very rare minute specks of a dark mineral, possibly argentite.

Northward from the Queen mine no ore has been found along the vein. Quartz continues as the principal mineral, and in many places, particularly near the edge of the plateau, the outcrop stands out as a distinct ridge above the surrounding country. Small prospect pits have been sunk in places, but nothing of promise was discovered. Over most of the distance the prevailing filling is quartz of the very fine grained type, chalcedonic in appearance, which in a few places is veined by later white crystalline quartz associated with a little quartz pseudomorphic after tabular calcite.

VEINS EAST OF THE QUEEN GROUP

The veins that crop out east of the Queen are entirely undeveloped, as what prospecting has been done close to the surface has not been encouraging. The outcrops contain a larger proportion of calcite than those in the productive part of the district, but many of them show predominant quartz, particularly of the fine-grained type, and it is thought possible that ore may yet be discovered in this portion of the district.

MASCOT VEIN

The Mascot vein lies along the fault that parallels the course of the upper part of Silver Creek. About 800 feet east of the mouth of Dog Gulch it is from 2 to 3 feet wide and consists of banded dense white quartz. The Mascot prospect is nearly opposite the mouth of Dog Gulch. The main tunnel was not accessible at the time of visit, but the dump showed chiefly dense white quartz associated with a minor amount of quartz pseudomorphic after calcite, together with a little calcite. Small specks of pyrite are sparingly present in the quartz. The upper tunnel revealed a vein from 1 to 3 feet wide of similar character, in which the relative amounts of quartz and calcite vary greatly within short distances along the strike. Thick gouge occurs along the footwall. A short distance to the west a small open cut shows a vein 6 feet wide, composed of white quartz largely pseudomorphic after tabular calcite. Northwestward from this point the vein is not exposed until the west end of the town is reached. Here at a point 1,500 feet southeast of the mouth of Coffee Gulch there is a vein of white quartz 2 feet wide. Westward from this point to the Queen vein there is no well-defined outcrop, although the tuff is silicified near the fault.

OTHER VEINS

The other veins east of the Queen group have so far given no encouragement to prospecting. The outcrops of those which are best defined shows either coarse calcite or fine-grained quartz, most commonly the former. Nevertheless, it is possible that as production from the major veins declines more intensive exploration of this group will be undertaken, and hence a brief statement of the observed features along the outcrop may be helpful. The veins are described in order from south to north.

The branched fault along the upper part of Deadwood Gulch seems to be entirely lacking in mineralization, at least on the surface.

The next fault to the north extends from the southern edge of the mapped area south of the limekiln to its junction with the Queen vein, at a point about east of the Gold Dust mine. At the east end there is a well-defined fault contact between the Fanney rhyolite and the Mogollon andesite, but no surface evidence of mineralization. A short distance to the west, on the saddle north of the 7,760-foot hill, boulders of coarse dark calcite with irregular veins of later white calcite mark the outcrop of a vein. Beyond this no vein was found until a point just west of the trail was reached. Here along the contact between tuff and andesite there are minor veins with a filling of very fine grained quartz of the porcelain-like variety grading in places into minutely drusy quartz. For the remaining distance to the Queen vein the surface is largely obscured by float, but nothing was observed indicative of any notable veining.

A well-marked fault extends northward from the southern border of the area near the limekiln for 2,000 feet, for most of the distance between a wall of rhyolite on the west and andesite on the east. The dip is everywhere steep to the west. Coarse calcite is prominent at two points—near the limekiln, where a small amount has been quarried for lime, and on the edge of the canyon about 1,000 feet to the north. A little very fine porcelain-like quartz occupies the fault plane close to its junction with the South Fork fault, on the hill east of the gorge.

The faults with northwesterly strike between the head of Dog Gulch and the mouth of South Fork carry veins in places and have been prospected to some extent. At the eastern edge of the area there are two faults that unite on the north side of the hill south of Dog Gulch. Just beyond the border of the area mapped the southern fault carries a 4-foot vein of calcite. The calcite has a varying content of manganese, the difference in composition showing in bands from half an inch to 3 inches wide of alternating light and dark material. A little rhodochrosite is also present. Quartz occurs only as small drusy crystals lining rare vugs in the coarse calcite. At this point both the vein walls are rhyolite, and the fault contact is about 10 feet from the vein. At the next good exposure, about 1,000 feet to the northwest, the vein is on the fault contact and has a width of over 20 feet. The filling is the same—banded light and dark calcite with minor rhodochrosite. From this point uphill to the saddle the outcrop is concealed, but fragments of the same type of vein calcite were found in the float. The vein could not be traced northwest of the saddle. No evidence of mineralization was seen along the northern fault from the eastern boundary of the area to a point 1,000 feet west of the junction of the limekiln fault, where a small vein of fine-grained quartz incloses numerous angular fragments of rhyolite and andesite. Just beyond this point coarse white calcite is prominent. Northwest of this point the fault splits. One branch has a nearly westerly course and joins the Queen near the Deadwood mine; the other follows closely the course of South Fork. The southern branch shows no mineralization westward as far as the small area of Deadwood Gulch rhyolite tuff north of the fault, in the gulch draining northward into South Fork. From this point westward to the top of the ridge there are irregular veins along the fault. For the most part the veins consist of very fine grained quartz, but here and there are cavities lined with quartz crystals of a maximum length of 2 inches, larger than were found elsewhere in the district. The vein is small and in places full of inclusions. The vein outcrop is not prominent on the west side of the hill, but the rhyolite tuff on the contact shows a high degree of silicification.

The branch of the fault that follows the valley of South Fork carries coarsely crystalline calcite at the point where the fault crosses the stream, about 1,000 feet northwest of the intersection with the fault just described. Elsewhere no surface effects of mineralization were observed except a little fine-grained quartz on the hill east of the junction of South Fork and Deadwood Gulch.

The fault with northeasterly strike which crosses Dog Gulch and Silver Creek has been mineralized in a few places. A vein about 6 feet in width, consisting entirely of white coarsely crystalline calcite is exposed on the north bank of Dog Gulch; just south of Silver Creek there is a thin vein of fine-grained white quartz; north of the creek at an altitude of about 6,900 feet coarse white calcite again occupies the fault plane.

The small fault running northward from the Mascot fault across Coffee Gulch is slightly mineralized in places. A prospect tunnel north of Coffee Gulch has followed a small vein of dark manganiferous calcite for a distance of 70 feet.

The westerly fault that crosses the heads of Coffee and Graveyard Gulches shows a well-marked brecciated zone, which is in places cemented by fine-grained quartz. On the ridge between the two gulches a prospect shaft shows about 5 feet of this breccia consisting of angular blocks of andesite cemented by drusy quartz, which here and there shows small specks of malachite. Just west of the road up Graveyard Gulch the fault splits, but the junctions of the two branches with the Queen are masked by talus. The southern branch is not mineralized at the outcrop, but the northern branch in places carries coarse white calcite.

Veins follow two faults of small throw which extend northward from the Coffee Gulch fault to the plateau south of Mineral Creek.

A prospect 800 feet west of the 7,467-foot hill on the eastern fault shows a 5-foot vein of banded light and dark coarse calcite, which changes 300 feet farther north to flinty white quartz about a foot wide. Northward from this point across the ridge the only evidence of mineralization consists of silicification where the fault cuts the rhyolite tuff and in places small stringers of quartz in the andesite. The fault that extends northward from the 7,150-foot hill north of Coffee Gulch to the plateau northeast of the cemetery carries a well-marked vein. Near its south end the vein is about 3 feet wide and consists of coarse banded light and dark calcite with a little quartz. Filling of the same type is shown in the prospect near the head of Graveyard Gulch and again 500 feet to the north. Beyond this point there is no distinct vein, though the rhyolite tuff close to the fault is silicified.

FUTURE OF THE DISTRICT

Several of the mines that were formerly large producers, such as the Cooney, Maud S., and Deep Down, have been closed for many years. Most of those still in operation, the Little Fanney and the three mines on the Last Chance-Confidence vein, have nearly exhausted the known ore bodies. In 1924 only the South Alpine and Ida May mines were developing new ore bodies, and these appear to be much smaller than those formerly mined in the Last Chance and Fanney mines. The only prospect of a continued important production seems to be, therefore, either in the discovery of new ore bodies at greater depth in the older mines or in discoveries in veins not hitherto productive or previously condemned as unpromising, either in the present productive portion of the district or in the area east of the Queen vein.

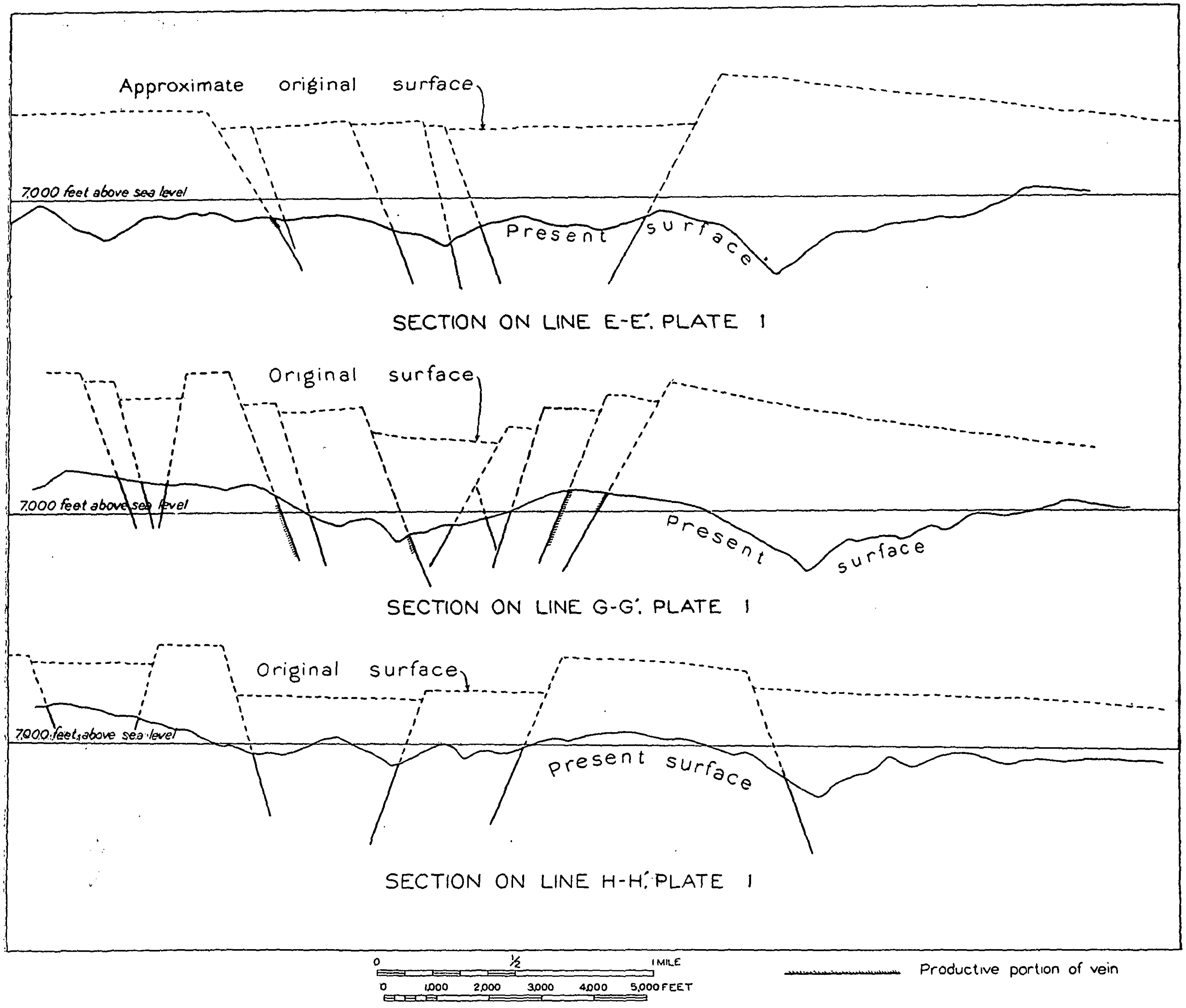
Possibility of deep ore.—The conditions that govern the possible existence of deep ore have been outlined in the sections on oxidation and supergene enrichment. Although the present ore bodies have been definitely bottomed, the water level has not yet been reached, and there is abundant evidence of oxidation to the greatest depth yet attained in mining in the barren zone below the ore bodies. It may therefore be possible that at or near the present water level there exists a zone of silver enrichment and that the present ore bodies are perched remnants which have escaped the action of the down-flowing waters because of the relative impermeability of portions of the veins. The most promising localities for such enrichment would be below ore or vein matter in which leaching is indicated by a ratio of gold to silver higher than is usual for the district. On the other hand, the ground water available for action on the primary sulphides is small in amount, and there is therefore a tendency for the silver salts to form insoluble chloride minerals in the zone of oxidation rather than to be carried down in solution and deposited as supergene sulphosalts. This is illustrated in the No. 6 ore body of the Last Chance mine, where owing to fissuring along the vein there was deeper oxidation than elsewhere in the mine. This ore body extended from the 500-foot to the 700-foot level. In its upper part the ratio of gold to silver was notably high, and a little free gold was found. In its lower part there was much cerargyrite, with consequent greater proportion of silver, and for the ore body as a whole the ratio of gold to silver was the same as for the sulphide ore of the larger ore bodies. Evidently here, although conditions for leaching were favorable, the silver did not migrate far downward. Also the comparatively small amount of enrichment shown in the specimens studied microscopically by Short does not favor the probability of a greater amount in depth. The facts summarized in this paragraph do not, however, preclude the possibility of additional primary ore at greater depth.

Possibility of new ore bodies at shallow depth.—Many of the best ore bodies of the district have been found beneath outcrops that gave no indication of the ore below. The projections of the Last Chance and Fanney veins (pls. 21, 22) show how few of the ore bodies reached the surface. On both these veins, particularly the Last Chance-Confidence, the quartz at the surface above the ore bodies was of the unpromising chalcedony-like type. The Ida May vein, which is obscure and without any indication of ore along the outcrop, shows very promising ore at moderate depth, both in the Alberta mine and in the workings of the Little Fanney mine, to the south. On the other hand, it is probable that in some of the older mines now abandoned, such as the Deep Down, Trilby, and Golden Eagle, most of the output was obtained from ore bodies that either cropped out or were close to the surface.

It seems likely, therefore, that there may yet be a considerable quantity of ore in veins in the area west of the Queen which at the surface do not appear to be promising. The recent developments on two such veins, the Ida May and the South Alpine, are extremely encouraging, and the Mogollon Mines Co. was, in 1924, preparing to explore the Queen vein northward from the 700-foot level of the Little Fanney.

The veins east of the Queen present another phase of the problem. These have been prospected here and there by shallow surface pits without encouraging results, but there is at least a possibility that exploration in depth may be productive.

The downthrow along the Queen fault is to the east, and the net amount ranges from 800 to 1,100 feet between the different blocks



SECTIONS SHOWING ASSUMED POSITION OF SURFACE IN MOGOLLON DISTRICT AFTER FAULTING bounded by faults with westerly trend. If any condition dependent on a geologic horizon, such as the juxtaposition of the Fanney rhyolite and either of the lower andesites, has controlled the deposition of the ores, the chances are favorable for ore at depth on these veins, as these formations lie at greater depth east of the Queen fault.

The veins east of the Queen show, along their outcrops, a larger proportion of coarsely crystalline manganiferous calcite than those in the western part of the district. This calcite, as has been shown in a preceding section, was commonly deposited later than the quartz. The presence of a calcite vein at the outcrop does not therefore preclude the possibility of productive quartz veins, for it is quite possible that the later calcite was, on the average, deposited at a higher level than the productive quartz.

It is possible that, as has been suggested on page 53, the ore bodies owe their position to a nice balance of conditions which caused the deposition of the primary ores in a zone of narrow vertical range. If this relation holds true throughout the area there is a chance that ore will be found at these altitudes east of the Queen, for on the whole the land rises toward the east, and most of the eastern veins crop out at higher altitudes.

If, however, the development of this hypothetical zone of primary ore deposition west of the Queen vein depended on the distance to the original surface at the time of deposition, ore to the east of the Queen, if present, might be at greater depth, as the region east of the Queen vein is relatively depressed along the Queen fault, and vein formation probably followed fairly closely upon the faulting. If it is assumed that the surface at the time of faulting was 1,000 feet above the base of the Dog Gulch formation, the surface at the time of ore formation was much higher, both absolutely and relatively to the present surface, to the west of the Queen than to the east. (See pl. 25.)

The abundant ground water from the mountains to the east is confined to the region east of the Queen by the Queen vein, and there is no reason to suppose that in this section the ground-water level was ever depressed below the bottoms of the canyons, as it is now west of the Queen, or that the topography was ever more deeply incised than at the present time. The conditions are therefore not as favorable for supergene enrichment east of the Queen vein as to the west, and it has been shown that even west of the Queen the amount of enrichment is not great.

Conclusion.—The inferences that may be drawn from the geology of the district relative to the possibility of new discoveries may be summed up as follows:

There is perhaps a possibility of an enriched zone below the greatest depth to which mining has extended. The chances are best below partly oxidized ore or lean material in which assays indicate a higher ratio of gold to silver than is usual for the district, and worst below ore bodies in which the ratio for the total ore extracted was normal or relatively high in silver.

There is no inherent reason why hypogene ore bodies of workable grade should not exist at greater depth than has yet been reached, but there is no direct evidence pointing to their existence.

It is thought probable that further exploration at moderate depth of veins whose outcrops are unpromising may reveal new ore bodies similar to that now being developed on the Ida May vein.

There is some basis for the hope that hypogene ore bodies may be present at moderate depth in the veins east of the Queen, but in this section of the district conditions that would favor any extensive supergene enrichment are absent.

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