Geology and Ore Deposits Of the Steeple Rock Mining District, Grant County New Mexico

By ROY L. GRIGGS *and* HOLLY C. WAGNER

CONTRIBUTIONS TO ECONOMIC GEOLOGY

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A brief description of volcanic rocks and ore deposits of Tertiary age in southwestern New Mexico

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CONTENTS

ILLUSTRATIONS

[Plates are in pocket]

TABLE

GEOLOGY AND ORE DEPOSITS OF THE STEEPLE ROCK MINING DISTRICT, GRANT COUNTY, NEW MEXICO

By Roy L. Griggs and Holly C. Wagner

ABSTRACT

The Steeple Rock mining district of western Grant County, N. Mex., is in an area of block-faulted Tertiary lavas that have been intruded by rhyolite dikes and plugs. About $7 million in metals, mainly gold and silver, has been produced from mines in this district since 1882. A body of base-metal sulfide ore, uncommon in the Steeple Rock district, was exploited at the Carlisle mine from 1943 to 1946.

The ore occurs in veins that occupy premineralization faults which cut the volcanic sequence. The faults belong to three groups, but nearly all the known ore is closely related to the northwest-trending group or to fault intersections. The sulfide ore occurs in a breccia zone at the intersection of the east-trending Carlisle fault and the northwest-trending Apache fault. The sulfide ore minerals are sphalerite, galena, and chalcopyrite in a gangue of quartz and altered breccia. The precious-metal ores of the district, which are associated with quartz in fault breccia, were not being mined at the time of the investigation and could not be studied in detail. In one rich specimen the silver-bearing mineral is argentite; gold probably occurs as the native metal. Additional bodies of gold-silver ore probably will be discovered.

INTRODUCTION

SCOPE OF REPORT

The steeple Rock mining district, in Grant County, southwestern New Mexico, was selected in 1942 for study by the U.S. Geological Survey because additional sulfide ores of zinc, lead, and copper were urgently needed for defense purposes. The present report is far from comprehensive as it is based mainly upon data gathered during short periods of study between 1942 and 1945 when most of the mines were closed and inaccessible owing to government directives which curtailed gold mining early in 1942. Only those mines in operation during the period of the investigation (1942–45) were entered and their geology mapped. Data on other mines were obtained from old records, from discussions with miners and local residents, and from surface geologic mapping.

FIELDWORK AND ACKNOWLEDGMENTS

During the winter of 1942–43, the authors, Roy L. Griggs and Holly C. Wagner, spent 3 months studying the Steeple Rock district. At that time the accessible workings in the Carlisle mine were mapped at a scale of 20 feet to the inch, and the area surrounding these workings was mapped at a scale of 100 feet to the inch; a reconnaissance study was made of the entire district. More underground mapping was done by Griggs in November 1943, when additional levels became accessible at the Carlisle mine. The 600-foot level was mapped by A. E. Weissenborn and P. L. Russell in the spring of 1944, while Griggs was working on another project. In April 1945, Griggs returned to the area and remapped the entire district at a scale of 1:24,000.

B. S. Butler, E. T. McKnight, and A. E. Weissenborn visited the district with Griggs in 1943, and discussions with these men were invaluable. Miss Jewell Glass did a part of the petrographic work, and Mr. Harrison Schmitt of Silver City, N. Mex., generously made available his petrographic laboratory during the field study. The manuscript has been much improved by the reviews and suggestions of E. T. McKnight, W. R. Jones, J. R. Cooper, and Arnold Brokaw.

GEOGRAPHY

The Steeple Rock mining district is in western Grant County, southwestern New Mexico, 3 miles east of the Arizona State boundary and 16 miles northeast of Duncan, Ariz., the nearest town (see fig. 1). The district is about 20 miles southwest of the Clifton-Morenci mining district, about 35 miles south of the Mogollon mining district, about 35 miles northwest of the Lordsburg and Tyrone mining districts, and about 50 miles west of the Central mining district. Duncan, which has a population of about 1,000, is on the Morenci branch of the Southern Pacific Railway, and the crude sulfide ore and concentrates that were produced in the district were trucked to that town over dirt access roads and from there were shipped by rail to lead and zinc smelters at El Paso and Amarillo, Tex., respectively.

The district, which derives its name from Steeple Rock (fig. 2), a small, twin-spired mountain peak in the southern part of the district, is in a moderately rugged mountainous area where altitudes range from approximately 4,700 to 7,000 feet above sea level. The rocks composing the mountains are part of a thick and extensive Tertiary volcanic sequence that forms the Datil-Mogollon Plateau, a high upland lying just south of the Colorado Plateau. A short distance south of the district the volcanic sequence is overlapped by gravels along the Gila River, but in other directions, particularly to the north, volcanic rocks form the surface for many miles.

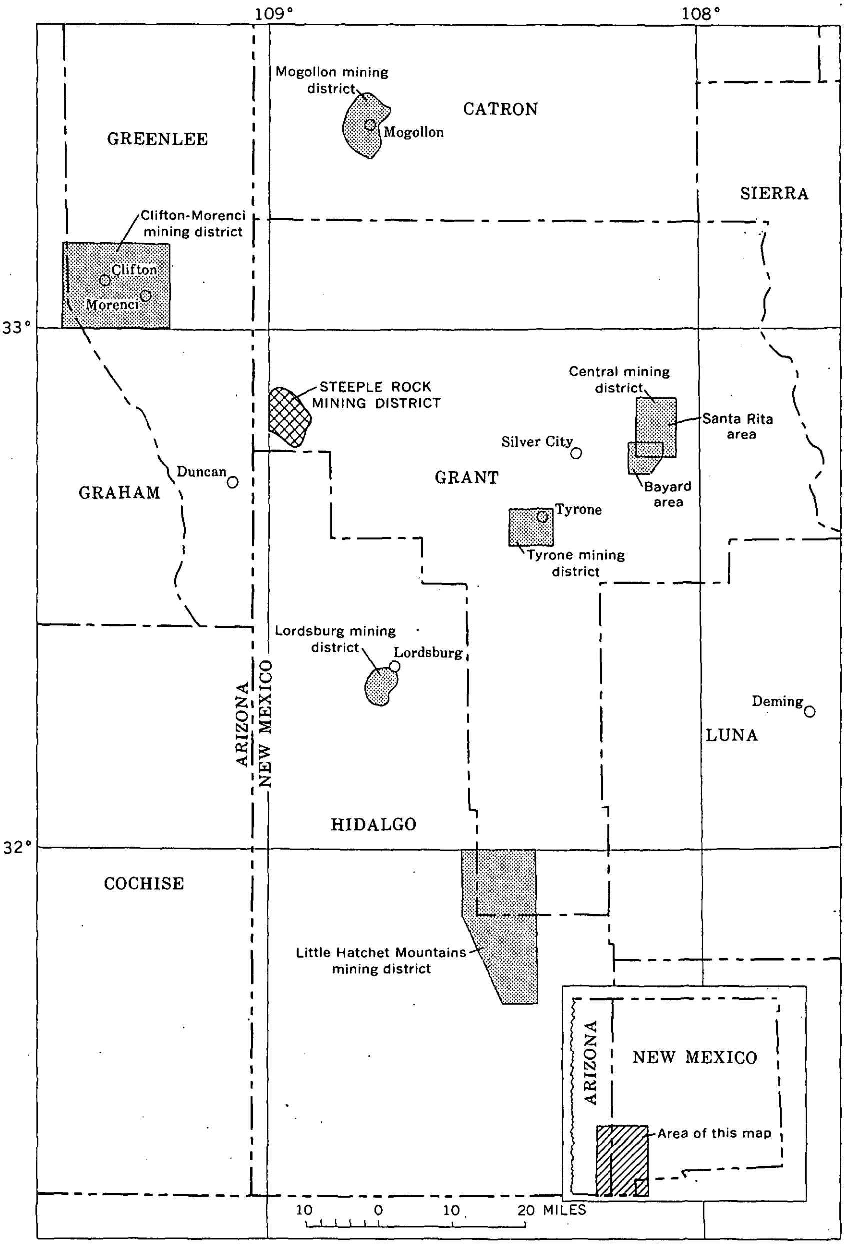

FIGURE 1.—Map showing the Steeple Rock mining district and its relation to other nearby mining districts.

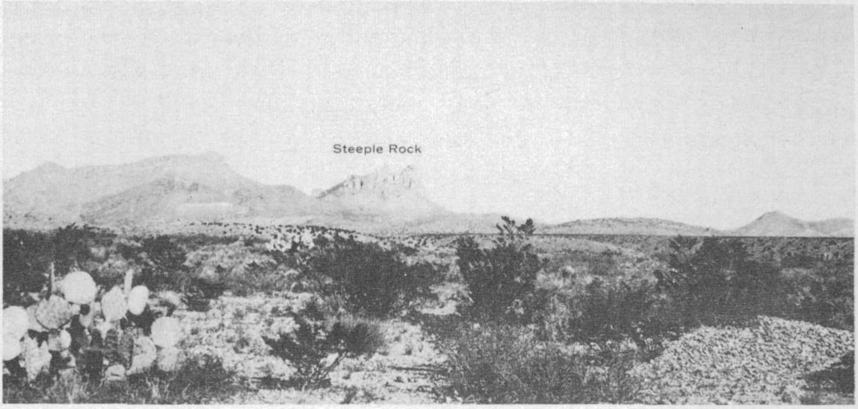

FIGURE 2.—View of Steeple Rock from the southwest. The fluted rock composing the two "steeples" is welded tuff, as is the upper part of Mount Royal on the skyline to the left.

The climate is semiarid; the average annual precipitation is about 13 inches, most of which falls during thunderstorms in the summer months. The vegetation consists of scattered junipers, several species of cacti, and, locally, lush expanses of gramma grass. All the streams within the district are intermittent.

HISTORY AND PRODUCTION

Government records indicate that the large veins of the Steeple Rock district were first prospected about 1880, but Russell (1947) reported that "the earliest available record of mining in the Steeple Rock district is a military report of the dispatch of troops from Fort Thomas to the district in 1860, when the Apaches were interfering with the miners in the area. Duncan, Ariz., is now on the approximate site of old Fort Thomas." Early records show that the Carlisle, Star of the West, Center, and Pennsylvania claims were the first locations to be staked in the district. These claims were filed on January 24, 1881 by Daniel Remington, James Mounts, William Johns, and A. G. P. George, all of whom are reported to have come to the region from Carlisle, Pa. In February 1882, Mounts sold his quarter interest in the Carlisle claim to a Chicagoan for $10,000. Whether or not the other three individuals sold their interests is unknown; however, the Carlisle Gold Mining Company was formed in the early part of 1882, and Marshall Field and N. K. Fairbanks are reported to have been members in this organization. A 20-stamp amalgamating mill was erected, and by 1886 it had been enlarged to 60 stamps (Russell, 1947).

About 1886 the Carlisle mine was bought by an English syndicate which removed the remaining blocked-out gold-silver ore on the property. While prospecting for additional gold-silver ore, the syndicate developed a base-metal ore body containing nearly 100,000 tons of copper, lead, and zinc sulfides and associated minor amounts of gold and silver. In 1887 the English company erected a smelter, and an attempt was made to mine and treat the recovered ore; however, the venture was unsuccessful, and the mine operation ceased in 1890. The mine was reopened for a short time about 1897, but no available records indicate that any ore was mined at that time. As late as 1910 the Carlisle was controlled by the Exploration Company (Limited) of London, but the greater part of the production was made while the mine was the property of the Carlisle Gold Mining Company (Graton, 1910, p. 328).

Nearly all of the other mines were located and worked to some extent from 1882 to 1897 during this early period in the history of the district. Small lots of gold-silver ore were shipped intermittently from these small mines, but production was not large.

From 1897 to 1934, there was no important production from the district: small lots of gold-silver ore were shipped between 1897 and 1916, and from 1916 to 1933 the district produced a few carloads of ore. In 1916, when the price of base metals rose because of World War I, the Carlisle was unwatered and, between 1916 and 1920, the mine produced about 7,500 tons of ore from the body of copper, lead, and zinc sulfides which had been developed in the late 1880's. Again, in 1927, the Carlisle was unwatered, and the sulfide ore body was examined and sampled. In addition, some development work was done, and one carload of ore was shipped; but in 1930 the property again was closed down.

After the price of gold rose from $20.67 to $35.00 per ounce in 1933, all the mines were apparently reopened and reexamined. Between 1934 and 1942 the mines produced about 30,000 ounces of gold and well over 1 million ounces of silver. The East Camp mine was by far the most important producer. All these mines closed in 1942 when government regulations restricted gold mining. The Carlisle then was reopened because of its sulfide ore body, and it yielded more than 8 million pounds of copper, lead, and zinc before being closed in 1946. Since 1946 a few mines have been worked, chiefly for gold and silver, and of these, the East Camp mine has again been the most important producer.

The Steeple Rock district has produced about $7 million in metals, mainly gold and silver. Most of this production was achieved during two main periods, and the values were derived largely from two mines.

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The first of these highly productive periods directly followed prospecting in the 1880's when rich gold-silver ore was discovered at the Carlisle mine. This period ended before 1900. The second period followed the rise in price of gold in 1933. At that time a second wave of prospecting resulted in the discovery of additional gold-silver ore at the East Camp mine. This latter period of production extended through World War II when activity switched back to the Carlisle mine and a body of sulfide ore was exploited. Intermittent activity at other times since the discovery of the district has been of minor importance.

Detailed records of the production of the district were not kept by any U.S. Government agency prior to 1904. The only detailed record prior to that date lists the production of the Carlisle mine from 1882 to 1887, inclusive, and shows that during that period more than $3 million in gold and silver were recovered from approximately 100,000 tons of ore. It is estimated that the other mines of the district produced less than $1 million in gold and silver prior to 1904. The production of the district from 1904 to 1959, given in table 1, is valued at more than $3 million.

PREVIOUS REPORTS

The earliest published report is a brief description of the district by Graton (1910). In 1943, Griggs and Wagner (1943) mapped and described the Carlisle mine area; and, in that same year, Johnson (1943) published a brief description of the Steeple Rock district, in particular of the Carlisle mine, and recommended an exploration program in the Carlisle area. The latest published article is by Russell (1947), who described the exploration done in the Carlisle mine area by the U.S. Bureau of Mines during 1944.

GEOLOGY

The rocks of the Steeple Rock district are all of igneous origin and comprise volcanic flows, less abundant volcanic clastics, and many small rhyolite intrusives, all probably of Tertiary age. Most of the volcanic rocks are of andesitic composition but range from andesitic basalt to rhyolite. Subsequent to their extravasation these rocks were tilted to their present attitude of northwesterly strike and low-angle northeasterly dip. A series of high-angle normal faults also formed. The tilting and faulting were probably closely associated, and some of the tilting may have been a direct result of the faulting.

TABLE 1.—*Production of ore and metals, 1904–59*

[Prepared from data compiled by U.S. Geol. Survey (1905–27) and U.S. Bur. Mines (1924–31, 1932–59)]

Year	Mines producing	Ore mined (tons)	Gold (ounces)	Silver (ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total value (dollars)
1904	1	4						
1905								
1906								
1907	1	1,000	750	15,150				
1908	1	750	375	17,000				
1909	3	65	17	1,410	770	9,140		
1910								
1911	2	224	143	5,902				
1912	5	269	402	5,157	3,706	950		
1913	2	381	417	1,453	7,602	7,914		
1914	1	41	42	88	1,342			
1915	3	295	229	11,031	7,276	3,000		
1916	4	165	124	3,491	17,500	6,753		
1917	3	5,202	88	10,642	68,502	617,989	139,490	
1918	2	82	39	999	10,677	6,775		
1919	2	228	27	3,817	11,027	157,812		
1920	3	2,111	642	3,566	5,837	36,937		
1921	2	91	45	2,363		1,000		
1922								
1923	1	36	23	1,685		286		
1924								
1925								
1926								
1927								
1928	1	23		130	1,132			
1929								
1930	1	50	15	891	121	23		
1931								
1932	2	19	13	780	21	152		493
1933	1	5	2	94	31	216		64
1934	2	1,617	421	21,141	1,769	809		28,553
1935	5	1,377	407	19,470	2,447	9		28,414
1936	10	3,777	850	54,173	5,885	514		72,222
1937	9	16,147	5,553	200,952	66,658	157,320	66,432	364,258
1938	11	14,740	5,687	239,119	34,882	77,104		358,654
1939	7	12,772	4,487	237,030	13,614	34,540		320,183
1940	11	22,915	5,414	216,374	23,003	122,061		349,418
1941	9	39,018	6,685	252,509	61,757	302,140	125,929	432,697
1942	5	9,426	1,390	60,220	35,035	104,556		100,791
1943	1	11,645	256	21,575	253,680	767,789	799,280	177,158
1944	1	15,460	300	21,812	263,245	938,225	1,287,039	228,541
1945	2	19,366	973	26,468	272,476	1,164,473	1,354,126	309,004
1946	2	9,535	426	9,346	103,797	438,681	376,053	119,893
1947 [1]	1	1,348	66	1,146	12,594	52,763	46,513	66,822
1948	1	428	150	1,776	3,550	3,552	2,719	8,022
1949	2	347	106	1,427	2,482	4,669	3,191	6,050
1950	2	855	259	11,004	1,370	2,850		19,523
1951	3	2,288	272	11,363	22,173	41,452	40,423	37,418
1952								
1953								
1954	1	104	8	52	542	2,293	4,376	667
1955	1	2,619	376	28,410	2,991	37	2,218	39,990
1956	1	1,979	186	11,345	1,644	5		17,476
1957	1	115	10	680	169	239		
1958								
1959								
Total		198,919	37,675	1,533,041	1,321,307	5,065,028	4,247,789	[2] 3,086,311

[1] Production in 1947 is the record of shipment of concentrates that were mined in 1946.
[2] In 1960 the district produced ore having a total value of $8,383.

EXTRUSIVE ROCKS

UNDIFFERENTIATED VOLCANIC ROCKS

On the basis of superposition of strata, the volcanic rock sequence in the southern part of the district appears to constitute the oldest exposed rocks in the map area. The sequence, however, was not mapped in detail and its true stratigraphic relation to the other volcanic rocks is not known with certainty.

The sequence is more than 1,500 feet thick and in the lower part is composed of andesitic breccia, agglomerate, and subordinate flows. These andesitic rocks are overlain by quartz latite flows and welded tuff which compose the upper part of the sequence. A pink flow of quartz latite is exposed a short distance north of the Jim Crow mine in Carlisle Canyon; the flow thins eastward and pinches out just west of Steeple Rock. This quartz latite has abundant phenocrysts of oligoclase, embayed quartz, and biotite. Above it is the pinkish-gray quartz latite welded tuff that forms Steeple Rock (fig. 2). The welded tuff is more than 700 feet thick at Steeple Rock but pinches out in both directions along the strike within the limits of the geologic map (pl. 1). A specimen obtained from the uppermost part of the tuff was studied by Miss Jewell Glass and found to contain numerous laths of oligoclase, many crystals of biotite, and a very few quartz phenocrysts in a devitrified groundmass of quartz and feldspar. The numerous spherulites near the top of the tuff were found by Miss Glass to be composed of cristobalite and orthoclase.

PURPLE ANDESITE PORPHYRY

The next younger unit is a thick sequence of purplish-gray andesite flows that contains a few tuff beds at and near the top of the sequence and, at some localities, a very subordinate amount of flow breccia. Although the total thickness of the unit is unknown, an exposed thickness of about 1,500 feet was measured north of the Carlisle fault in the northwestern part of the district. The flows and flow breccias have a very distinctive porphyritic texture with abundant large blocky tablets of andesine that are particularly conspicuous where whitened by weathering. Most of the flows carry both augite and hornblende as the mafic phenocrysts; a few have mostly hornblende with minor augite and (or) biotite, and a few have hornblende with a substantial amount of biotite. Augite phenocrysts are generally fresh whereas those of hornblende and biotite show progressive stages of magmatic alteration. Some hornblende and biotite phenocrysts are extensively replaced by an aggregate of augite, magnetite, and feldspar; some are sparingly replaced by augite and magnetite; some show only rims of magnetite. In a few rocks hornblende appears to have partially changed to biotite before this reaction took place. The fine- to medium-grained groundmass is composed mainly of sodic plagioclase, augite, and magnetite but locally contains appreciable quartz and potassium feldspar. The groundmass is dark gray where the rock is very fresh but is, in general, purplish gray throughout the district.

Included with this map unit on plate 1 are discontinuous bodies of felsic tuff. The tuff generally occurs in the uppermost part or at the top of the purple andesite porphyry and in places overlies it disconformably. Locally, the tuff may be divided into two parts: a lower part consisting of thin-bedded ash-fall tuff of dacite composition and distinct purple color, and an upper part made up of massive light-gray rhyolite welded tuff. Both parts are present in the Carlisle mine area (see pl. 2), but at other places, such as at and near Rhyolite Hill, at the top of the mountain east of the Laura mine, and half a mile west of the East Camp mine, only the massive welded part is represented.

AMYGDALOIDAL ANDESITIC BASALT

In contact with and apparently overlying the purple andesite porphyry and felsic tuff discordantly is a sequence, more than 1,000 feet thick, of dark-gray andesitic basalt flows. The individual flows are generally amygdaloidal and uniform in appearance and composition from bottom to top. Most of the andesitic basalt is finely porphyritic, the tiny subparallel plates of poorly twinned plagioclase showing successive stages of alteration to carbonate. These small plates can be distinguished readily with a hand lens and, where whitened by weathering, are observable with the unaided eye. Phenocrysts of altered olivine and (or) pyroxene are nearly always present; olivine is absent in only a few specimens. The groundmass is composed of subparallel to felted plagioclase, small altered olivine grains, pyroxene, and magnetite. A microscopically visible matrix, which is interstitial to the grains in the groundmass, makes up a very small part of the rock.

The olivine in these flows is altered to a dark-red highly birefringent mineral that probably is iddingsite, or to a pale-green platy mineral that probably is ferriferous saponite. The pyroxene is generally altered, though some is relatively fresh. Its optical properties were determined by Miss Jewell Glass to correspond with those of pigeonite. The plagioclase is sodic labradorite.

The abundant vesicles in these flows range from about 2 inches in diameter to tiny pinpoints that can only be seen microscopically. Most of the vesicles are filled with calcite and quartz.

Small patches of rhyolitic tuff are interbedded with flows of amygdaloidal andesitic basalt a short distance above the base of the sequence in the area north of the East Camp mine and in two other parts of the district. In the southwestern part of the district, the rhyolite in the lower part of the sequence is closely associated with rhyolite dikes that are possibly later in age, and the rhyolite has been welded to such an extent that it has the appearance of a rhyolite sill extending out from the dikes. When examined by Miss Glass, however, the tuff was found to contain relicts of volcanic glass shards. A thin patch of rhyolitic tuff north of the Mohawk mine is composed of rounded grains and, thus, probably was water laid.

BROWN ANDESITE PORPHYRY

Reddish-brown andesite porphyry caps the amygdaloidal flows at Vanderbilt Peak (Line Mountain) as well as along a line of hills in the northeastern part of the district. At Vanderbilt Peak a zone of vesicular material about half way between the base of the unit and the top of the mountain suggests that the porphyry is made up of two individual flows. A single flow caps the hills in the northeastern part of the map area.

Throughout the outcrop area the rock of this unit is dark reddish brown and has abundant large blocky tablets of zoned andesine as conspicuous phenocrysts. Phenocrysts of hornblende and less abundant biotite are much altered, the former more so than the latter; the hornblende is prominently replaced by an aggregate of augite, magnetite, and feldspar, whereas the biotite commonly shows only alteration rims of magnetite. Small phenocrysts of augite are fresh. The fine-grained groundmass is made up of andesine, augite, magnetite, and a small amount of potassium feldspar and quartz. Near the top of Vanderbilt Peak, the groundmass contains considerable glass.

INTRUSIVE ROCKS

DIORITE

As noted by Graton (1910, p. 327), dark-gray fine-grained porphyry, which corresponds to diorite porphyry, occurs locally at and near the Carlisle mine. The feldspar phenocrysts are mostly labradorite, and pyroxene is now represented by aggregates of chlorite and epidote. The finely trachytic groundmass is composed almost entirely of plagioclase feldspar laths. Contact relations suggest that the diorite porphyry intruded the purple andesite porphyry along a blocky joint system.

RHYOLITE

After the extrusion of the brown andesite porphyry, the volcanic pile was broken by a set of northwest-striking normal faults, and the fractures in some displaced blocks in the southern part of the district were intruded by rhyolite, both as dikes and as pluglike masses. Some of the larger rhyolitic intrusive bodies, however, may be much older and may have served as feeders to the welded tuffs that are intercalated in the undifferentiated volcanic rocks in the southeastern part of the district. They may also have served as feeders to the rhyolitic tuffs in the uppermost part of the purple andesite porphyry and lower part of the amygdaloidal andesitic basalt.

Most of the rhyolite is extremely fine grained, but there are generally a few minute quartz phenocrysts. The rock is normally light grayish pink, but many of the dikes are nearly white, and some contain thin bands of pale green glass. In the plugs and in some dikes, thin alternating pink and white bands are common. Two pale-buff dikes are exceptions to this general character and probably represent a different time of intrusion. These two dikes are porphyritic, the phenocrysts commonly consisting of oligoclase, sanidine, quartz, and sparse biotite.

Autobrecciation is common along the borders of plugs where some of the magma solidified as it was being injected.

STRUCTURE

The general structure of the Steeple Rock district is that of a series of tilted fault blocks. The volcanic rocks of the district were apparently tilted gently to the northeast at approximately the same time that the area was broken into large discrete blocks along generally northwest-trending faults. The faulting presumably recurred or prevailed over a considerable period of time during which silica-rich solutions invaded the fault zones at separate intervals.

The volcanic flow rocks in the fault blocks generally strike parallel to the most conspicuous group of faults (about N. 50° W.) and dip 5°–20° NE. The major breaks in the northeastern part of the mining district are normal faults downthrown to the northeast; those in the southwestern part of the district are normal faults downthrown to the southwest. The large block between the Carlisle and the Summit and East Camp faults in the western part of the district and between the Blue Goose and East Camp faults in the eastern part of the district acted generally as a horst.

Many of the faults, particularly those of northwesterly strike, formed the sites of deposition of quartz veins or were intruded by rhyolite dikes (see fig. 3). The faults are high angle, and all were formed during the same period of faulting. They can be classified by their strike direction into (1) northwest-trending faults, (2) east-trending faults, and (3) north-trending faults.

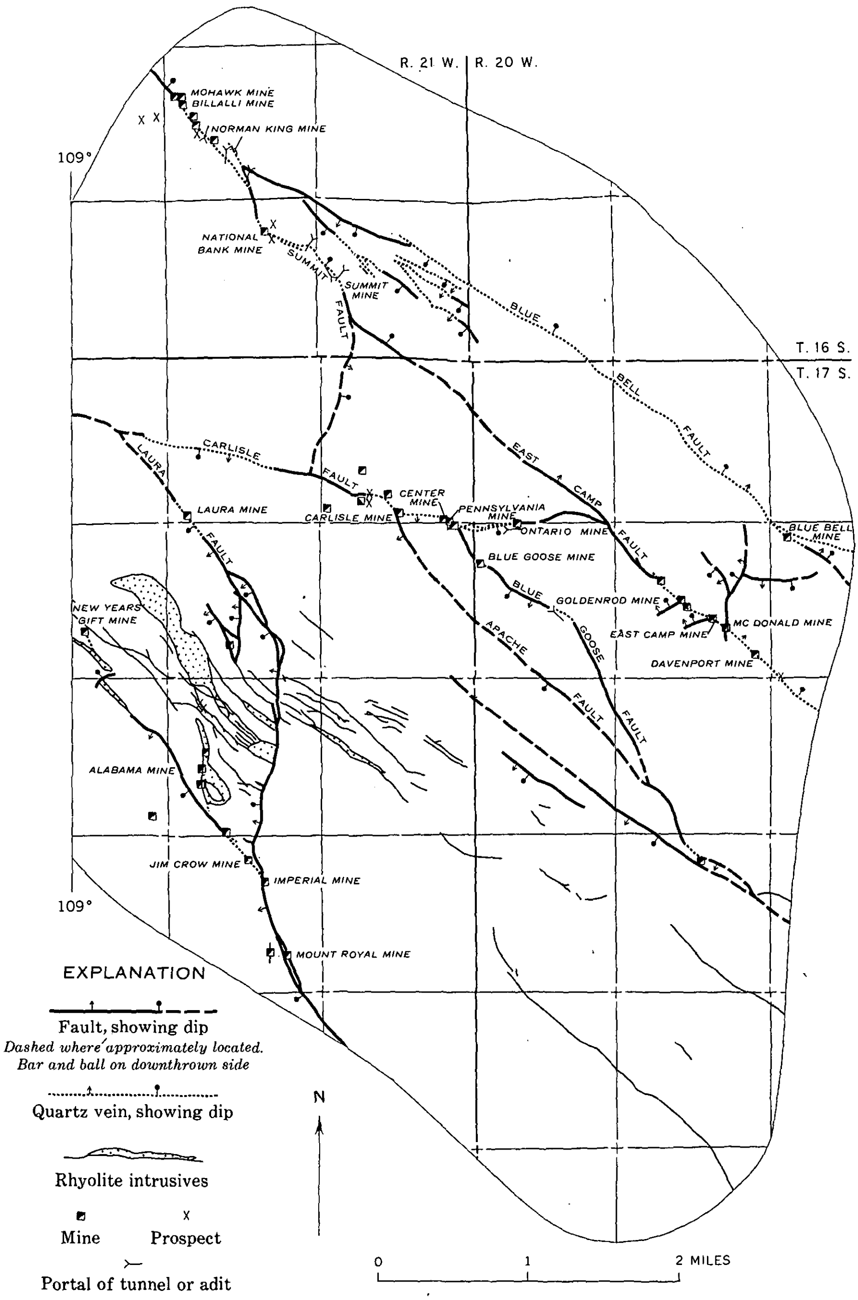

FIGURE 3.—Faults, quartz veins, and rhyolite dikes.

NORTHWEST-TRENDING FAULTS

The northwest-trending faults form by far the largest group in the district. These faults have an average strike of about N. 50° W. and include such large faults as the Laura, Apache, Blue Goose, East Camp, and Blue Bell. The same trend is followed by the rhyolite dikes of the district, some of which are along definite faults and others along possible fractures or joints.

South of the Carlisle fault all the northwest-trending faults dip southwest and are downthrown to the southwest. North of the Carlisle fault, the main northwest-trending faults (the East Camp and Blue Bell) are nearly vertical or dip to the northeast and are mainly downthrown to the northeast. However, near the northwestern end of the Blue Bell fault, where it is joined by a southwest-dipping normal fault, the Blue Bell is apparently downthrown to the southwest. The somewhat greater throw on the subsidiary fault where it joins the Blue Bell seems to account for the apparent reversal in movement on the Blue Bell. Several other small normal faults, which have northwest strike and southwest dip, occur in this general area of reversed movement (see pl. 1). The only other normal fault with southwest dip and northwest strike between the East Camp and Blue Bell faults occurs just north of the East Camp mine near the east margin of the map. It is of small lateral extent and of little importance.

EAST-TRENDING FAULTS

The Carlisle fault is the only major fault that trends east-west in the district. The strike ranges, however, from N. 75° W. to N. 85° E., and the dip averages about 65° S. The Carlisle fault can be traced from its intersection with the northwest-trending East Camp fault westward to beyond the limits of the mining district. The fault is downthrown on the south side, and displacement is least at its eastern end. Movement on the fault increases to the west, partly because the fault is joined on the south side by three northwest-trending faults that are downthrown to the southwest. Just west of the Pennsylvania shaft, the throw is approximately 700 feet; west of the junction with the Apache fault at the Carlisle mine, the throw is approximately 900 feet; at the western margin of the mining district west of the junction with the Laura fault, the throw, although not accurately measurable, is presumably more than 2,000 feet.

All along the Carlisle fault the numerous striations plunge about 55° SW. and indicate the oblique movement on the fault. The southwesterly slip is also demonstrated where the Blue Goose and Apache faults intersect the Carlisle fault. These northwest-trending faults do not offset the Carlisle, but instead the Carlisle bends to their strike direction at the intersections. These bends were apparently opened several times by a westerly component of displacement during recurring movement on the Carlisle fault.

The only other strictly east-trending fault, which occurs between the East Camp and Blue Bell faults near the eastern margin of the mapped area, is of small lateral extent and little importance. Three other small faults, of northeast rather than east trend, may be classified with this group. Two of these faults occur just west and northwest of the East Camp mine; the other is somewhat south of the New Years Gift mine near the western margin of the mapped area. None of the three seems to have important displacement.

NORTH-TRENDING FAULTS

A few faults in the district have a northerly trend. The most important of the group extends generally northward from the Mount Royal mine to the Laura mine and brings the amygdaloidal basalt into juxtaposition with older rocks. The fault has a northerly to northwesterly trend, is downthrown to the west, and possibly has the greatest displacement of any fault in the district. Two north-trending segments of this fault extend into the purple andesite porphyry and then curve into the northwest-trending part of the fault southeast of the Laura mine.

Four other north-trending faults do not have important displacement but two of them—at the Alabama and New Years Gift mines—seem to have served as channels for ore solutions. The other two are northwest of the Carlisle mine and between the East Camp and Blue Bell mines.

ORIGIN OF FAULTS

The origin of the faults of the Steeple Rock district is not completely clear, and several factors may have played major and minor roles in their formation. Tensional release rather than compressive stress is indicated by the great preponderance of normal fault movement and by the evidence of growth of vein quartz in open spaces.

A northward progression of faulting is suggested by the concentration of rhyolite dikes in the southern part of the district along northwest-trending fractures that presumably formed during an early period of faulting, and by the presence of preore quartz in the veins along the Carlisle, the Blue Bell, and a few other faults in the northern half of the district. Composite veins, consisting of alternating barren quartz and ore-bearing quartz, suggest a relatively long period of fault activity during which mineralizing solutions traversed the same fissures several times. Mineralized rhyolite at the Alabama mine is evidence that some mineralization postdates the intrusion of rhyolite. Faults that are barren of vein quartz and of rhyolite may have formed after the vein quartz and rhyolite or may never have extended to the depth of the quartz- or rhyolite-forming fluid.

The possibility that the northwesterly direction of faulting reflects movement on a N. 75° W.-trending structure in the basement rock beneath the southern part of the Steeple Rock district was suggested by J. R. Cooper (written commun., 1962). He proposed that slight right-lateral movement on such a major structure could result in second-order northwest-trending breaks in the overlying rocks and also noted that a N. 75° W. direction is characterized in southeastern Arizona by many large, old, and repeatedly active faults.

The actual fault pattern, with its predominant northwest-trending fractures and minor north-trending and east-trending groups, has the basic features of the pattern formed by a stress couple as described by Billings (1942, p. 105) from an experiment by W. J. Mead. The direction of maximum elongation would be approximately N. 50° E., almost at right angles to the northwest-trending group which would then be analogous to the experimental tension faults. A measure of the northeasterly distension could be approximated by the calculation of the volume of rhyolite and vein matter that fill the presumed tensional voids and through a reconstruction of the geologic setting prior to displacement along the normal faults. Right-lateral movement in basement structures trending about N. 85° E. could have created a structural couple that would produce the fault pattern shown in figure 4.

A third hypothesis assumes an intrusion of batholithic proportions at depth. The vast majority of ore deposits in the general region are found in contact, or nearly so, with large intrusions of quartz monzonite or related intrusive rocks with which the ore-bearing solutions are obviously associated. The structural pattern in the Clifton-Morenci district can be clearly related to intrusion of granitic to dioritic magma (Lindgren, 1905, p. 88–89), as can the patterns in the Santa Rita mining area (Spencer and Paige, 1935, p. 42–56), and at Lordsburg (Lasky, 1938, p. 24). Although no such intrusion crops out in the Steeple Rock district, evidence of the former presence of large quantities of ore-bearing solutions in conjunction with a horstlike uplift away from which normal faults dip both northeast and southwest allows speculation that the horst overlies an area uparched by moderately deep-seated magmatic intrusion and that the adjacent fault blocks moved compensatingly downward to the northeast and southwest during the period of uplift.

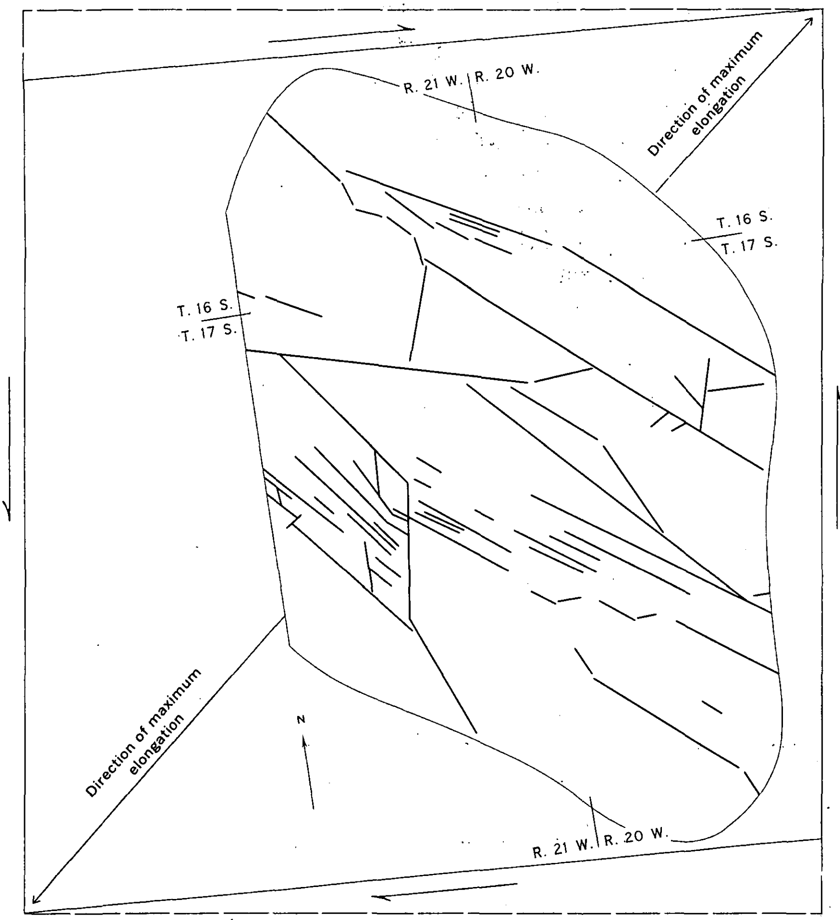

FIGURE 4.—Generalized fault pattern of the Steeple Rock mining district showing a possible superimposed stress couple and direction of maximum elongation.

ORE DEPOSITS

The district is mainly a producer of gold and silver. At the Carlisle mine, however, an exceptional body of base-metal sulfide ore yielded approximately 0.7 percent copper, 3 percent lead, 3 percent zinc, and about 0.02 ounce of gold and 1.60 ounces of silver per ton.

Much of the ore of the district is localized as lenslike bodies within brecciated material between the fault walls. The relative amount of replacement as opposed to open-space deposition is difficult to evaluate. In the sulfide ore body at the Carlisle mine, part of the ore and gangue filled open spaces and part of it replaced gouge, breccia, and earlier minerals of the country rock. The sulfide ore replaced perhaps as much as 50 percent (by volume) of the previously existing material. The small sampling of the high-grade gold-silver ore examined suggests that the precious-metal ore was deposited mainly in open spaces.

The predominant material of the veins associated with sulfide ore at the Carlisle mine is brecciated, highly silicified wallrock; the next most abundant material is fine- to medium-grained vein quartz. Individual ore shoots, in which the sulfides occur in very thin tabular bodies of quartz and some fine breccia, are arranged in sheeted zones wherein the sheets of ore are separated from each other by thin ribs of barren quartz and altered breccia. These small sulfide-bearing sheets are the principal parts of the larger lenslike ore shoots.

The most conspicuous type of wallrock alteration is silicification which formed when the fault breccias were silicified. Most of the ore bodies are associated with intense silicification, which is the best guide to ore in the district although it formed mainly if not completely before any of the metals were deposited. The reason for the common association is that both the greatest silicification and the ore deposition apparently took place along through-going channels where the mineralizing medium probably had a particularly voluminous and steady flow. Sericitization, chloritization, and epidotization are less prominent types of wallrock alteration, though both chlorite and sericite are conspicuous in some places. At the Carlisle mine, chlorite is fairly abundant in the footwall of the fault and extends many feet beyond the zone of silicified rock. It is less noticeable close to the ore because it has been masked there by later silicification.

Analysis of the structural setting indicates that fault intersections were very important in the localization of ore bodies. This controlled localization is most obvious at the Carlisle mine (see pls. 1, 2) where the west-trending Carlisle and the northwest-trending Apache faults intersect and where continued reopening is believed to have been most effective in producing an exceedingly wide channelway and the most valuable ore bodies in the district. At the Center-Pennsylvania mine, northwest-trending faults also intersect or extend out from the Carlisle fault and were important points of weakness where opening and reopening could occur. The northwest-trending fault at the Center shaft is in the footwall of the Carlisle fault. This footwall fault is of very short strike length and insignificant displacement, but it apparently allowed significant opening of the fault wall for ore deposition. At the Pennsylvania shaft the situation is much like that at the Carlisle mine, though ore deposition was much less important. The northwest-trending Blue Goose fault curves into the Carlisle fault at the Pennsylvania shaft, and the intersection became a small channelway that reopened during the period of ore deposition. At the East

Camp mine, the second most important mine in the district, three relatively small faults intersect the main northwest-trending East Camp fault. These three points of weakness may have been influential in the opening and reopening of the main northwest-trending fault.

Both the unusual sulfide ore body at the Carlisle mine and the precious-metal deposits which contain sparse base-metal sulfides are related to wide vein openings; therefore, the width of the opening probably controlled the permeability along the faults and, in turn, the volume of flow of the mineralizing fluid. The site of the Carlisle ore body must have been particularly open during both the sulfide and precious-metal stages of mineralization.

AGE OF MINERALIZATION

The mineralization in the Steeple Rock district is believed to have been late Miocene in age and to have been contemporaneous with that in the nearby Mogollon district (Ferguson, 1927), where the mineralogical and structural setting is similar. The mineralization in the other nearby mining districts shown in figure 1, however, generally is prelava in age, and two periods of ore deposition are thus indicated in this region. The dominantly base-metal mineralization in the Clifton-Morenci district (Lindgren, 1905, p. 198; Butler and Wilson, 1938, p. 74), in the Central mining district (Lasky, 1936), in the Tyrone district (Paige, 1922, p. 16), in the Lordsburg district (Lasky, 1938, p. 24), and in the Little Hatchet Mountains district (Lasky, 1947) is either Late Cretaceous or early Tertiary in age. In these mining districts, prominent northeasterly and northwesterly directions of faulting have served as guides to ore deposition, and in most of these districts Miocene(?) volcanic rocks that partly cover the older rocks have been broken during a late period of faulting. In the Steeple Rock district, the mineralizing solutions were introduced somewhat later than intrusive rhyolite, as shown by relations at the Alabama mine.

MINERALOGY

The most obvious minerals of the ore deposits are—

Argentite	Epidote	Malachite
Barite	Fluorite	Pyrite
Calcite	Galena	Quartz
Chalcanthite	Gold	Sericite
Chalcopyrite	Gypsum	Silver
Chlorite	Limonite	Sphalerite

NATIVE ELEMENTS

Gold (Au).—Native gold has been reported from the district, and it, or electrum, is probably the main source of the metal in the ore.

Assays shows that the gold is commonly associated with chalcopyrite, chlorite, and late fine-grained comb quartz, but no gold could be seen in any of the polished sections examined. It is evidently too finely divided to be resolved by a microscope.

Silver (Ag).—A small amount of native silver was identified in a specimen taken at the Ontario mine. The silver was associated with galena, chalcopyrite, and late fine-grained quartz.

SULFIDES

Sphalerite (ZnS).—The sphalerite is the reddish-brown variety and is abundant only at the Carlisle mine, where it forms about 7 or 8 percent of the vein matter. East of the mine, along the Carlisle vein, it gradually disappears. The sphalerite forms 1 or 2 percent of the ore at the Center mine, somewhat less at the Pennsylvania, and only traces at the Ontario, the next claim east. The mineral was not seen elsewhere in the district.

Galena (PbS).—Galena, the only lead mineral known in the district, is fairly widespread in small amounts but is of economic importance only at the Carlisle mine. It is fine grained except in parts of the Carlisle ore body where a few cleavage faces are as much as three-quarters of an inch across. The galena replaced, to a considerable extent, previously altered gouge and finely brecciated material, although some galena was also partly deposited in open spaces in the fault-zone breccia. Galena is closely associated with sphalerite and chalcopyrite in the Carlisle area where it is partially replaced by chalcopyrite. It appears to have replaced sphalerite to a slight extent, for some tiny stringers of galena project into sphalerite.

Chalcopyrite ($CuFeS_2$).—This mineral makes up about 3 percent of the vein matter at the Carlisle mine and about 1 percent at the Center mine. Elsewhere in the district it occurs very sparingly. The material on the East Camp dump suggests that the chalcopyrite was fairly well distributed through the ore though in very small grains. It probably constituted less than 0.5 percent of the ore.

The chalcopyrite is predominantly fine grained, occurs as a replacement of galena and, to a lesser extent, altered wall rock. It is present also along grain boundaries of the other sulfides and, locally, occurs with late-stage quartz that cuts the other sulfides. Tiny chalcopyrite stringers that cut the other sulfides are fairly numerous in the polished sections examined.

Pyrite (FeS_2).—Fine-grained pyrite is ubiquitous in the district, though never in large amounts, and in places is the only sulfide. The pyrite was deposited during at least two phases of the mineralization: in very small quantities, usually as tiny cubes, during the "early quartz" stage, and as slightly coarser material at the beginning of the main sulfide stage.

Chalcocite (Cu_2S).—Sooty chalcocite was seen as thin bluish-black coatings on chalcopyrite at one place in a stope on the 160-foot level of the Carlisle mine. It is not of economic importance.

Argentite (Ag_2S).—A dull, black fine-grained mineral was noted in a specimen taken on the Ontario claim. This mineral occurs along the margins of veinlets that are partly filled by comb quartz and tan siderite. Other associated minerals are chlorite, galena, and chalcopyrite. According to Miss Jewell Glass, this mineral gives positive reactions to all the standard tests for argentite. Most of the silver in the district may occur in this mineral, but since silver values here are commonly associated with chalcopyrite, some stromeyerite is suspected.

HALOIDS

Fluorite (CaF_2).—Pale-green fluorite is present as a vein mineral in the northwestern part of the district. A small body of siliceous fluorspar ore was exploited at the Mohawk mine in 1941, but the remaining material seems too siliceous to be worth mining.

OXIDES

Quartz (SiO_2).—Quartz, the most abundant vein mineral, exhibits a variety of types whose relations to each other are fairly clear. Several stages of quartz deposition are recognizable because of crosscutting relations, but the precipitation of silica was probably continuous once the mineralizing solutions became saturated.

The earliest quartz is very fine grained, has mutual boundary grain relations, and appears in a few places to be almost chalcedonic. Some of it is pseudomorphic after platy calcite. This first-stage quartz produced the intense silicification of the fault walls, breccia, and gouge, is barren of gold and silver, and contains only traces of pyrite. A fine white sugary type of quartz from this stage was deposited in open spaces between brecciated fragments.

The second-stage quartz ranges from medium to moderately coarse grained and is nearly colorless, grading through whitish to amethystine. The quartz of this stage partly replaced the earlier quartz in irregular splotches, but much of it was deposited in open spaces where prismatic and terminal crystal faces formed. Some quartz occurs as narrow veinlets which in thin section are seen to contain lamellar quartz. Reopening of the faults preceded this quartz and, before the end of this silica phase, the pyrite of the sulfide stage had begun to precipitate. Some fine-grained quartz cuts the second-stage quartz and is closely associated with, and apparently accompanied by, the sulfides.

The latest stage quartz commonly has terminal faces and occurs as veinlets cutting across the sulfides. Some specimens show it cutting all the sulfides, but in a few samples chalcopyrite is present in the veinlets. All the earlier quartz is barren of gold and silver, but quartz of this last stage is accompanied by these precious metals.

Limonite.—A very small amount of brown hydrous iron oxide is present at the surface as an oxidation product of pyrite and chalcopyrite.

Manganese oxide.—An unidentified manganese oxide tends to outline the ore on the walls of the mine workings at the Carlisle mine.

SILICATES

Chlorite (*hydrous silicate of aluminum, magnesium, and iron*).—This mineral is abundant as an alteration product of the country rock in the Carlisle mine area where it is prominent beyond the zone of pronounced silicification. Chlorite is also a fairly common constituent of the vein matter in places, and where common is an early alteration product of thoroughly brecciated wallrock within the fault walls. Apparently it formed at about the same time as the early platy calcite, because it has been extensively replaced by the earliest quartz. The chlorite is so closely associated with gold and silver locally that one wonders if it could have acted as a precipitant for these precious metals.

Epidote ($HCa_2(Al,Fe)_3Si_3O_{13}$).—Epidote, associated with chlorite, is an alteration product of the wallrock.

Sericite ($H_2KAl_3(SiO_4)_3$).—Material having the general optical properties of sericite is found in the wallrock in the immediate vicinity of the veins and in fragments of wallrock within the veins. This material is an alteration of feldspar, particularly of feldspar phenocrysts.

CARBONATES

Calcite ($CaCO_3$).—Remnants of early platy calcite remain in places along the veins, although this calcite generally has been replaced by the early quartz. At the Summit mine, both platy and massive calcite are abundant, however.

Siderite ($FeCO_3$).—A light-brown manganese-bearing siderite occurs as small rhombohedrons perched on the walls of drusy cavities at the Carlisle mine.

Malachite ($CuCO_3 \cdot Cu(OH)_2$).—Traces of malachite as an oxidation product of chalcopyrite are present in the upper levels of the Carlisle and Center mines and at various places at the surface along other veins in the district. It also occurs in small quantities in the material in the East Camp dump.

SULFATES

Barite ($BaSO_4$).—Barite was identified in one thin section from the Carlisle mine. It was an early mineral in the depositional sequence.

Chalcanthite ($CuSO_4 \cdot 5H_2O$).—Small amounts of chalcanthite were noted in the upper levels of the Carlisle and Center mines where the mineral had been deposited by ground water.

Gypsum ($CaSO_4 \cdot 2H_2O$).—Crystals of selenite gypsum have been deposited from the mine water onto the walls of the workings at the Carlisle mine.

PARAGENESIS AND ORIGIN

The sequence of mineral deposition in the ore deposits is fairly clear. The earliest stage of the mineralization consisted of chloritization of the fault walls and of the breccia within the faults. This alteration was particularly intense in the Carlisle mine area. The platy calcite was deposited at about the same time as the chlorite, possibly contemporaneously with it, and was followed by sericitization. The next stage consisted of a prominent early silicification which was accompanied by a small amount of pyrite deposited as tiny cubes. In the Carlisle mine area the chlorite extends farthest from the fault walls, the sericite is closer to the fault, and the fine-grained quartz of the silicification stage is still closer. This relationship is believed to indicate a decreasing vigor of the solutions that accomplished the alteration. The silicification, however, is the most striking alteration because it rendered the rock resistant to erosion, and "blow-outs"[1] are conspicuous along the veins where this alteration is pronounced. After silicification by fine-grained microcrystalline quartz, there was reopening along the faults and the second-stage quartz, somewhat coarser grained, was deposited, partly in open spaces and partly by replacement. Where pyrite was deposited in second-stage openings, paragenetic relations indicate that the pyrite of the main sulfide stage began to precipitate toward the end of second-stage quartz deposition. This pyrite was closely followed by the deposition of sphalerite and galena, and some of the galena was slightly later than the sphalerite. Chalcopyrite was still later, though most of it was deposited during the main sulfide stage. The final stage consisted of quartz, some late chalcopyrite, and gold and silver toward the end of the stage.

The rhyolite dikes occupy premineralization faults and fractures and commonly show some mineralization along their walls or within the dikes where the rhyolite has been somewhat brecciated by the postdike movement along the faults. Also, one of the rhyolite plugs shows a

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[1] The miners term for conspicuous exposures of vuggy limonitic jasperoid that occurs with vein quartz in varying proportions.

considerable amount of the early formed quartz and calcite along its border. The ore-depositing solutions may have come from the parent magma sometime after the rhyolitic differentiate had been injected. The deposition occurred at moderate or shallow depth from solutions which, if judged on the basis of the early pronounced alteration, were of moderate temperature in their early manifestations. Early alteration at the Carlisle mine extends for many feet into the footwall of the fault, presumably indicating moderate temperatures. By the time the gold and silver were deposited, the solutions were probably of low temperature.

DESCRIPTION OF MINES

CARLISLE MINE

The Carlisle mine is opened by a three-compartment vertical shaft that extends to a depth of 523 feet. The shaft is collared in the hanging wall of the Carlisle fault but passes into the footwall above the first level of the mine. An inclined winze within the Carlisle fault zone extends from the 520-foot level to a depth of 716 feet and opens the two lowest levels. There are six working levels which are known as the 160-, 300-, 400-, 500-, 600-, and 700-foot levels (pls. 3, 4). These working levels are at the following depths below the collar of the shaft: 162, 304, 405, 520, 619, and 716 feet. The total length of workings, including the shaft, winzes, raises, drifts, and crosscuts, is approximately 10,000 feet. Although purple tuff is present to shallow depth in the hanging wall of the Carlisle fault zone, virtually all the workings are in the purple andesite porphyry.

Ore mined from February 1943 to July 1944 was milled in a 50-ton unit at Duncan, Ariz. Ore mined from July 1944 to July 1946 was milled in a 100-ton unit at the East Camp mine in the northeastern part of the district.

In the area where the Apache fault joins the Carlisle fault, the latter makes an abrupt bend from its nearly east-west strike to a northwesterly strike. The Carlisle mine is on this digressing segment of the Carlisle fault. Just west of the mine, the Carlisle fault bends back to its normal westerly course, which it maintains to beyond the limits of the mining district. Thus, the mine is on a structural feature which, although a part of both faults, is more closely related to the Apache fault than to the Carlisle. This bending of the Carlisle fault is a response to the stresses which gave rise to the Apache fault. The former is not offset by the latter, but rather the two faults appear to have formed simultaneously; the displacement of the northwest-trending Apache fault is taken up by the Carlisle fault in the area of the bend.

The ore is in the bend where the fault zone is very wide, and the ore shoot plunges somewhat westerly down the fault zone. The abnormal width of the fault zone was the result of a combination of forces. The wide zone probably formed as a result of oblique-slip movement at the junction of the Apache and Carlisle faults, where low pressure and intense breaking presumably created a broad permeable zone. Figure 5 is a diagrammatic sketch showing the mechanics of this movement.

The sulfide ore occurs as lenslike bodies which have an en echelon arrangement when viewed in cross section through the fault (pl. 4). Local miners have distinguished these bodies as veins 1 and 2. Vein 1 lies against the footwall of the fault on the 160-foot level and gradually migrates toward the hanging wall of the fault with depth. Vein 2 lies near the footwall on the 500- and 600-foot levels, joins vein 1 along the strike on the 500-foot level, and then pinches out upward against the footwall near the 400-foot level (pls. 3, 4).

The gold ore mined in the 1880's was southwest of the low-grade sulfide ore recently mined, and just above the 400-foot level it was closer to the hanging wall. A map prepared in 1888 carried the notation that very rich ore was near the surface and that between the 300- and 400-foot levels, near where the ore pinched out, the ore grade gradually became lower. This ore carried high gold-silver values. Its sulfide content is unkown; however, sulfide vein 1 is reported to have joined the gold vein along the strike near the west end of the mine on the 160-foot level. The two veins probably joined also on the 300-foot level, in the same manner as the two sulfide lenses join on the 500-foot level.

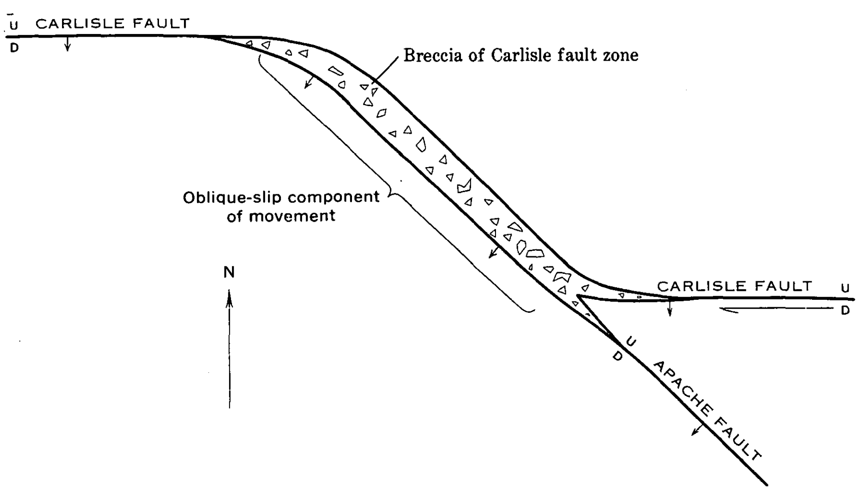


FIGURE 5.—Diagrammatic sketch showing how oblique-slip movement could have formed the site of ore deposition at the Carlisle mine.

Most of the old gold workings have caved, but in a line of chutes and in an old stope that can be seen in the east end of the surface caving, the outline of one gold vein immediately southwest of the sulfide ore is visible. The large caved area at the surface above the central part of the workings (see *C–C′*, pl. 4) suggests that in this part of the mine the gold vein was either extremely wide or there were two or more steeply dipping gold veins. The latter view seems more probable.

The ore deposition took place in the bend of the Carlisle fault because this area was a particularly permeable, through-going zone which transmitted a great, overall volume of solutions. In more detail, it seems that local irregularities along the fault strike and swells in the fault zone in general were of considerable importance, probably because of their permeability.

A rough quantitative composition of the sulfide ore mined from 1943 to 1946 is as follows:

Mineral	*Percent*
Chalcopyrite	3.5
Galena	5.0
Sphalerite	8.0
Pyrite	3.0

The U.S. Bureau of Mines conducted an exploratory program at the Carlisle mine during the period February to December 1944 (Russell, 1947). In this program, which consisted of diamond-drill exploration, 10 holes were drilled. Eight holes were drilled from a crosscut driven into the hanging wall of the Carlisle fault zone on the 700-foot level, and two were drilled from the surface. Three of the holes drilled from the underground station were pointed at different angles downward in a vertical plane which was perpendicular to the fault zone. These three holes cut the fault zone at depths of 90, 165, and 240 feet below the 700-foot level. The other five holes drilled from the underground station were pointed downward and fanned to the left and right of the station. These holes penetrated the fault zone at depths ranging from 50 to 240 feet below the 700-foot level.

The two holes drilled from the surface explored the fault zone beyond the ends of accessible workings. One of the holes penetrated the fault zone at a depth of about 400 feet at a point about 350 feet east of the Carlisle shaft; the other cut the fault zone above inaccessible workings on the 300-foot level at a point about 675 feet northwest of the shaft. The drilling did not indicate any new ore bodies.

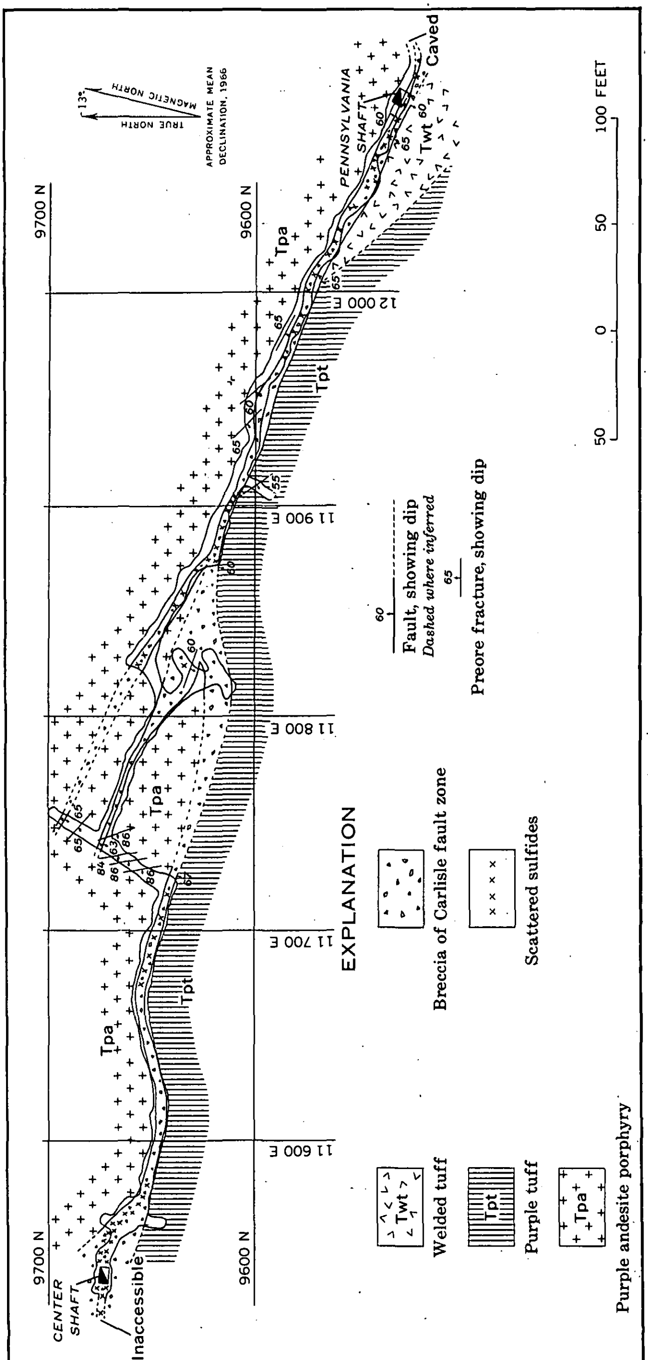
CENTER-PENNSYLVANIA MINE

The Center and Pennsylvania claims are on the Carlisle fault just east of the Carlisle mine. Each claim has an inclined shaft which was sunk down the dip of the Carlisle fault zone. The Center shaft is about 300 feet deep; the Pennsylvania shaft is about 120 feet deep. The two shafts are connected on the 120-foot level (see fig. 6). Workings at the Pennsylvania claim consist of a shaft and a drift that extends westward on the 120-foot level to the Center shaft. Workings on the Center claim include a shaft and drifts on the 100-, 120-, 250-, and 300-foot levels. All workings were inaccessible in 1943 except those on the 120-foot level.

Three ore shoots have been worked at the Center-Pennsylvania mine (see pl. 2 and fig. 6). The shoot at the Center shaft contained the richest ore and was mined from the surface to the 300-foot level. This ore shoot had a northwesterly trend and was directly related to the northwest-trending footwall fault. A second, relatively insignificant ore shoot lies about 200 feet east of the shaft and has a somewhat less northwesterly trend than the ore shoot at the shaft. The second ore shoot trends about N. 60° W., and is close to the hanging wall in the area where the Carlisle fault has two footwall branches. A small amount of ore was mined above the 120-foot level in this shoot. The third ore shoot was mined at and just east of the Pennsylvania shaft in the area where the Blue Goose fault joins the Carlisle fault (see pl. 2). Mining in this third shoot was entirely above the 120-foot level. Extensive caving just east of the shaft indicates that most of the ore occurred in that area but makes determination of the trend of the ore shoot impossible.

The ore minerals at the Center-Pennsylvania mine are the same as at the Carlisle mine, but base-metal sulfides are much less abundant, and the value of the precious metals was reported higher than the value of those in the sulfide ore body at the Carlisle mine. The total combined copper, lead, and zinc content of the ore is estimated to be about 3–4 percent at the Center claim and less at the Pennsylvania claim.

In the course of the exploratory program of the U.S. Bureau of Mines during the period February to December 1944, four diamond-drill holes were drilled from the surface on the Center and Pennsylvania claims. One of the holes on the Center claim was directed to intersect the Carlisle fault zone about 150 feet west of the Center shaft; the other was directed to intersect the fault zone about 100 feet east of the shaft. Both holes cut the fault zone at a depth of about 400 feet. The two holes on the Pennsylvania claim were directed in the same vertical section, perpendicular to the strike of the fault zone. The fault zone was penetrated about 1,200 feet east of the Pennsylvania shaft. One hole intersected the fault zone at a depth of 50 feet below the ground surface and the other at a depth of 90 feet. None of the four holes indicated additional ore.



Geology by R. L. Griggs and H. C. Wagner, 1943

FIGURE 6.—Center-Pennsylvania mine 120-foot level.

EAST CAMP MINE

The East Camp mine was inaccessible in 1943, the mine having been closed in 1942 so that materials and labor could be diverted to mines producing strategic minerals. Irregularities in the strike of the vein at the surface, as well as those reported down the dip, were probably important in the localization of the ore. Where three minor faults intersect the main vein, ore was also localized.

MOHAWK MINE

The Mohawk mine is in the northwestern part of the mining district about 3 miles east of the Arizona-New Mexico State line. This mine is on the Summit vein, a northwest-trending vein which, on the Mohawk claim, is almost vertical and about 6 feet wide. The workings consist of an open stope about 100 feet long, 80 feet deep, and 6 feet wide. A small body of fluorspar ore was mined from the stope in 1941. The ore was milled at Duncan, Ariz.

Present on the walls and at each end of the open stope is pale-green fluorspar in a matrix of fine-grained quartz. The ore mined in 1941 was unquestionably of higher grade than the material that remains.

OTHER MINES

Other mines, such as the Jim Crow, Imperial, Laura, National Bank, and Norman King, may have sizable workings, but all were inaccessible in 1943.

SUGGESTIONS FOR PROSPECTING

The sulfide ore body of the Carlisle mine probably represents an exceptional occurrence and any additional ore that can be mined primarily for its base-metal content is unlikely to be found in the Steeple Rock district. Additional bodies of gold-silver ore may be discovered, however. In future prospecting for precious metals, it should be kept in mind that structural configurations that would have yielded permeable channelways for ore-carrying solutions are the most likely sites for ore. Abnormally wide areas of conspicuously silicified breccia along faults may be regarded as definite evidence of channelways that were permeable during the early stages of mineralization. There is a possibility that such areas were also permeable later during the gold-silver stage of mineralization.

A specific site which we regard as worthy of prospecting for a gold-silver ore body is the intersection of the Carlisle and Laura faults northwest of the Laura shaft. This area is now covered by talus derived from the steep slopes of Vanderbilt Peak to the south; hence, the type and amount of mineralization at the intersection cannot be observed except by removal of the talus or northwestward drifting from the Laura mine. Nevertheless, the intersection should have produced a permeable opening similar to that at the Carlisle mine.

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