The Geology and Ore Deposits of the Reese River District Lander County Nevada

GEOLOGICAL SURVEY BULLETIN 997

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By CLYDE P. ROSS

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A geologic study of one of the old bonanza silver camps, with a section on geophysical surveys by E. L. Stephenson

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THE GEOLOGY AND ORE DEPOSITS OF THE REESE RIVER DISTRICT, LANDER COUNTY, NEVADA

By Clyde P. Ross

ABSTRACT

The old Reese River silver mining district near Austin, Lander County, Nev., was examined by both geological and geophysical methods in 1937. The geophysical work was done by E. L. Stephenson. The district, as originally defined, covered roughly 1,500 square miles of the Toiyabe Range, but the principal development has been in an area of nearly 2¼ square miles in the immediate vicinity of Austin, with some additional work in areas west of there. The earliest claims were located in 1862 and mining was active until 1886, with a number of renewals of interest since then.

Soon after its discovery in 1862 the district became so famous for the richness of its silver ore that 10,000 people are said to have visited it. Several thousand remained for a time, and Lander Hill, where early activity centered, became closely dotted with mine openings. About 100 veins are reported to have been recognized on Lander Hill alone, and there are numerous others in neighboring parts of the district. Operations were conducted at first by individuals and small groups, but companies soon began to be formed. The Manhattan Silver Mining Co., which began operations in July 1865, soon acquired the ascendancy, in part because of control of the superior Stetefeldt metallurgical process. Before it suspended operations in 1887 it had acquired all of the more valuable mines in the district and had honeycombed Lander Hill with extensive workings distributed through a vertical range of over 1,000 feet. The mines, even after consolidation of ownership under this company, continued to be operated as small units and most of the ore was mined by lessees. During most of this period mining and milling costs were so high that only ore valued at more than $75 a ton was milled, which necessitated careful hand sorting. Some of the selected ore contained thousands of ounces of silver to the ton and much of it contained more than 200 ounces. The gold content was commonly negligible, and base metals were not recovered. Even at the height of development in the district, however, the tonnage produced was small, and constant difficulty was experienced in finding enough new ore to continue operations. Some have estimated the total production during this period at $50,000,000 to $65,000,000, but tax records and other data indicate that it cannot have been much more than $20,000,000 and may have been materially less.

The Manhattan Silver Mining Co. ceased all operations in 1887. Since then several different companies have attempted at intervals to reopen the mines, and in addition there has been prospecting and intermittent development in outlying parts of the district. One of these periods of revival was in 1937, when data for the present report were gathered. The total production since 1886 has probably been about $1,000,000. This was mostly in silver, but some gold, copper, lead and zinc also have been recovered.

The district, on the western slope of the Toiyabe Range, is underlain by a quartz monzonite pluton, supposedly of about the same age as the Sierra Nevada batholith (Jurassic?), which is intruded into impure, carbonaceous quartzite

(Cambrian?) and locally overlain by residual patches of Tertiary lava and associated clastic rocks. The quartzite dips away from the gently sloping top of the stock on the north, and the volcanic rocks seem to form parts of a faulted anticline whose axis corresponds roughly to the crest of the Toiyabe Range. The pluton is intricately jointed, but so little evidence of mineral elongation or of systematic arrangement of inclusions and similar features has been obtained that little can be said in regard to the relation between the joints and structure. Dikes of lamprophyre, aplite, and pegmatite cut the quartz monzonite, mostly along joint-plane openings. Quartz veins and silicified ribs and zones are also widely distributed along joints in the pluton. The veins extend also into the quartzite but are, for the most part, older than the volcanic rocks.

The mineral content of the veins is simple, yet it records a long-continued process of vein filling. The principal constituent is quartz which was deposited in several successive stages under changing physical conditions. The earliest formed quartz is in large grains full of microscopic cavities; the latest formed is highly irregular in texture and is in part chalcedonic. Quartz of probably two and possibly more intermediate stages is present in the veins. There are few localities where all the different varieties of quartz can be recognized, and the succession probably differs in detail from place to place.

Rhodochrosite, other carbonates, and some sericite are locally present in the veins. Rhodochrosite is the most abundant and conspicuous of these, but it is rare or absent in many of the veins outside of the Lander Hill area and even in parts of the veins in that area.

The hypogene metallic minerals in the veins include pyrite, galena, sphalerite, chalcopyrite, arsenopyrite, tetrahedrite, stibnite, proustite, and molybdenite. Argentite, pyrargyrite, stephanite, polybasite, enargite, and xanthoconite, have also been reported. Pyrite is the most widespread and probably was the first of the sulfides to crystallize. The sulfides of copper, lead, and zinc also are widely distributed but are conspicuous in only a few localities, notably northwest of the principal mines on Lander Hill. The complex, silver-bearing sulfides are sufficiently abundant to be recognized readily only in the richer ore, but they occur in places throughout the district and at all depths yet reached in mining. All the sulfides listed above are thought to be hypogene, although it is possible that locally and to a limited extent argentite and some of the others may also have been formed by supergene processes. Small amounts of supergene chalcocite and covellite are known. The ore first mined consisted of oxidized material, but most of such ore has long since been mined, as oxidation was limited to shallow depths.

Products of mineralization in the wall rocks include sericite, calcite, dolomite, quartz, chlorite, pyrite and other sulfides, tourmaline, rutile, and minor quantities of other minerals. Alteration is intense locally near the veins and is widespread in the quartz monzonite throughout the district. Most of the quartz and sulfides fill openings in the rock. Pyrite is the most abundant sulfide in the wall rock and in places is in disseminated cubes formed by replacement. Metallic minerals of all kinds are so sparse in the wall rocks as to be of slight economic interest.

Nearly all the lodes in the district are veins that fill distinct fractures, although in places quartz lenses end in silicified ribs, and here and there are zones in which the quartz monzonite is permeated by secondary quartz and intricately cut by irregular quartz veinlets. Small amounts of aplitic and pegmatitic materials are associated with the silicified ribs and zones, and some quartz veins are on the borders of lamprophyre dikes. In the quartz monzonite, the veins are in shear zones; in the quartzite, breccia is conspicuous, and the veins are nearly parallel to the bedding planes. Many individual veins are only a few inches wide, and veins more than 3 feet wide are exceptional.

The veins in the quartz monzonite correspond in attitude to most of the diverse sets of joint planes traversing that rock, although in each locality particular trends of veins predominate. Most of the productive veins on Lander Hill range in strike from N. 20° W. to N 40° W., and dip 25°–45° NE. In the southwestern part of the district most veins strike N. 20°–60° E. and dip steeply northwest. Farther east the principal veins strike nearly north and dip both east and west. In the southeastern part of the district the more persistent veins strike N. 10°–40° E. and dip steeply. Locally the vein pattern is reticulate, and throughout the district innumerable minor veins cross and branch from the main ones. Many of the discontinuities and irregularities in the veins result from the complexity of the original vein systems rather than from later fracturing. Ore shoots are in part related to cross fractures and intersections of veins. Postmineral faults are widespread, but displacements on them are commonly small.

The veins are genetically related to the quartz monzonite. Vein filling began when the temperature of the rock was high and continued until it had dropped markedly. The vein-forming solutions migrated through preexisting openings, mainly joints, that were modified and enlarged by movements during mineralization. In a few places vein quartz distinctly different from that in most of the veins is present. Its character suggests that it formed at lower temperatures and pressure, possibly during the volcanism that occurred long after the main period of mineralization.

The Reese River district has been intensively prospected. Most of the promising areas have been tested. Exploration beneath the old workings on Lander Hill and in the relatively undeveloped area around the Union mine seems to offer better chances for finding ore like that originally mined than exploration in localities farther from the original discoveries. The veins in outlying areas seem, in general, lower in grade. They contain some metals other than silver, but, with the possible exception of gold, these hardly seem of significance with reference to the future of the district. Some of the veins in the quartzite are sufficiently large to be mined by cheaper methods than those applicable on Lander Hill.

Resistivity measurements made in two areas tend to support the conclusion reached by geologic methods that faults are present but are not dominant features of the structure of the district. The major anomalies are probably related to ground water, but others may reflect differences in original composition of the rock, as well as alteration and weathering, and also the influence of dikes and veins.

The self-potential measurements made at one place gave no measurable potential differences, a result since corroborated by later underground exploration, which showed that negligible quantities of vein matter are present.

The magnetometer seems likely to be of more practical value in this district than the other geophysical instruments tested. It may be possible under favorable circumstances to trace the larger dikes and veins by this means.

INTRODUCTION

LOCATION AND EXTENT OF THE AREA

The Reese River silver mining district is the area around the town of Austin, the county seat of Lander County, in central Nevada (fig. 1). The district was originally established July 17, 1862, and, as

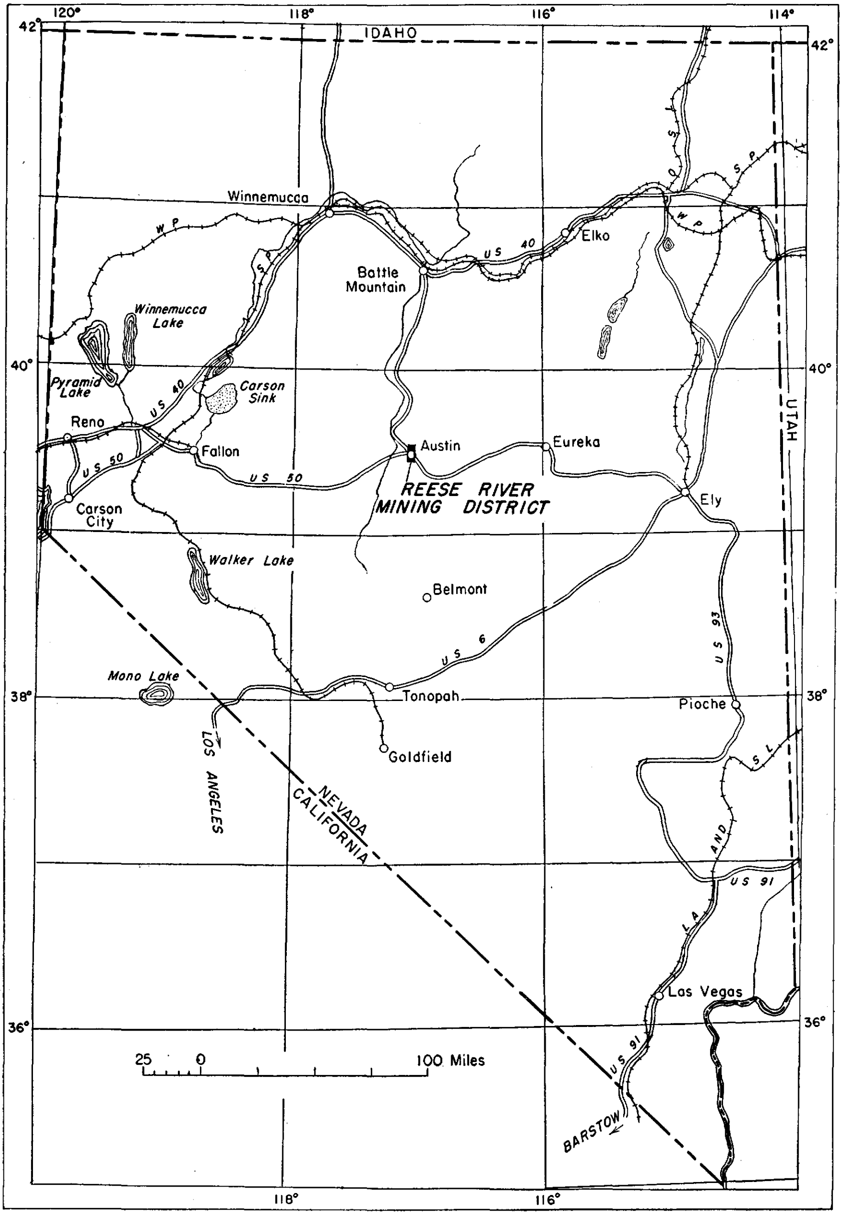

FIGURE 1.—Index map of Nevada, showing the location of the Reese River mining district and the principal access roads.

then defined, extended 10 miles north and 10 miles south of the Overland Stage road and from Dry Creek on the east to Edwards Creek on the west. These two creeks have not been identified, but it appears that the area between them corresponds to the entire width of the

Toiyabe Range, a distance of about 75 miles. The segment of the stage road referred to in the definition is believed to correspond essentially to the old, now almost impassable road, that, as shown on plate 1, passes from Emigrant Springs Basin across the Toiyabe Range to the southern part of Midas Flat. Actually the developed part of the district never embraced so large an area. At the present time it may be considered to correspond essentially to the area shown in plates 1 and 2. That is, the district extends from San Francisco Canyon on the north to Crow Canyon on the south (beyond the limits of pl. 1) and from the eastern border of the valley of Reese River to the crest of the Toiyabe Range. There are a few prospects on the east flank of the range. The central part of the district as thus defined contains no mines, although it bears evidence of having been carefully prospected. For the purposes of the present report, the Reese River district may be divided into the Yankee Blade area on the north, drained through San Francisco, New York, and Yankee Blade Canyons; Midas Flat, on the western pediment of the Toiyabe Range; and the area immediately surrounding Austin. There are a few notable old mines in the Yankee Blade area and some ore has been produced from shallow workings on Midas Flat, but by far the major part of the production of the district has come from the Austin area, especially from Lander Hill, north of town.

SCOPE OF THE REPORT

The geologic work in the district was done by C. P. Ross, assisted by John N. Faick in a period of about 2 months in the summer of 1937. At the same time the Austin area was mapped topographically by R. C. Seitz and his assistants. Mr. Seitz extended control westward, greatly facilitating mapping of the less thoroughly developed part of the district. Geophysical work by E. L. Stephenson and a group of assistants occupied about a month and a half.

The entire developed part of the Reese River district is shown in plate 1. This map includes generalized data from plate 2 and the results of rapid topographic and geologic work in the outlying part of the district by C. P. Ross, assisted by J. N. Faick. This latter work was chiefly of value in providing a setting for the area near Austin that was studied in detail. Comparatively few details of the mines in the outlying area could be obtained, as the greater part of the workings were inaccessible. There are scattered deposits in the granitic rock but the principal mines in areas at a distance from Austin are in shear zones approximately parallel to the bedding in impure quartzite on the northern border of the stock. Here, as near Austin, silver is the principal valuable constituent.

Particular attention was paid to the Austin area, including nearly 2¼ square miles of ground immediately surrounding the town of Austin, shown in plate 2. The topographic surveying by R. C. Seitz and the geologic surveying by Ross and Faick were done on a field scale of 400 feet to the inch. The principal underground workings have been added to plate 2 in necessarily somewhat generalized fashion. Parts of these were either entirely inaccessible or so masked by timbering and gob as to hinder observation. Natural outcrops are too scanty in most parts of the area to be of much value. Hence most of the geologic data on plate 2 were obtained from pits, trenches, and other man-made openings. Some pits are so slumped as to yield no information, and at others all that could be learned was that vein matter had been found. Even this scanty information is recorded in order to show the distribution of mineralization and to aid anyone who may undertake further investigations.

Sufficient data were obtained to give a clear picture of the major geologic features of this famous old camp. The deposits are in closely spaced, narrow veins filling a reticulate system of openings in a granitic stock. Contrary to the belief of many local miners, post-mineral faults are subordinate. Although the mineralogy of the veins differs from place to place, the principal value in all of the deposits is in the silver content. The ore minerals are believed to be mainly of primary origin, a conclusion that differs from that of some of those familiar with the district.

Geophysical work was confined to the Austin area. It was handicapped by the small size and close-spacing of the veins, by the ruggedness of the country, and by the fact that in the principal productive area essentially all deposits within several hundred feet of the surface had already been tested by mining. Interpretation would have been simplified if the area had contained sharply contrasting sedimentary beds instead of the granitic rock with its numerous minor, ill-defined variations. The larger veins, at least where near the surface, can be traced by means of the magnetometer. Resistivity and magnetic studies seem to indicate differences between mineralized and unmineralized areas in a general way.

Considerable data on the history and production of the district were obtained. The principal sources of this information were the files of the Reese River Reveille, a newspaper that began publication May 16, 1863; the records of the County Assessor; and copies of old letters stored in the office of the Austin Silver Mining Co.

PREVIOUS WORK

The annual mint reports by R. W. Raymond and J. Ross-Browne contain many references to events in the Reese River district and to its mineralogy and geology. These include quotations from reports by J. E. Clayton and other mining engineers and geologists familiar with the district. Emmons (1870, pp. 320–348) and Spurr (1903, pp. 93–97) made valuable contributions to our knowledge of the geology of the region. The files of the Reese River Reveille contain much miscellaneous information in regard to history, production, methods of mining and milling, and geology, which have been freely drawn on in preparation of this report. A short paper in the American Journal of Mining, signed only by the initial "R." (1896, pp. 99–100) gives data on costs and methods of mining in the early days. Manuscript reports by James D. Hague,[1] a consulting engineer, and James Humes,[2] who was superintendent for the Austin-Manhattan Consolidated Mining Co. in 1908 and 1909, give information on production, costs, and underground development not otherwise obtainable now. Taylor (1912, pp. 32–39) gives information on the mineralogy of the vein matter, some of which could not be obtained from the scanty material now available.

The most comprehensive available report on the district is that by J. M. Hill (1915, pp. 95–114). His visit to the district occupied only a few days but his report outlines the principal features of the general geology and the ore deposits, and gives facts in regard to a number of the workings that are now inaccessible.

ACKNOWLEDGMENTS

Without exception, the mining men of the Reese River district cooperated heartily in the investigation. J. P. Hart, manager of the Austin Silver Mining Co., contributed much of his own time and made available maps and other data. His staff also was cordial in furnishing information and in assisting in other ways. M. B. Koelliker, of the Austin Syndicate, furnished valuable information in regard to the Yankee Blade area, and owners of other properties in the district also provided information. Bert Acree, County Recorder, was of the greatest assistance, both in making records available and in permitting use of his office for their compilation.

A number of the members of the Geological Survey contributed to the office work. These include C. F. Park, who aided in study of polished sections, and W. T. Schaller, Jewell Glass, and Charles Milton, who furnished mineralogic and petrographic data.

TOPOGRAPHY AND CLIMATE

The Reese River mining district is on the western slope of the northern part of the Toiyabe Range. In this part of the range the

[1] Hague, James D., Report on the properties of the Austin Mining Co., addressed to the President, J. G. Phelps Stokes, Aug. 8, 1896.

[2] Humes, James. Unpublished manuscript dated June 17, 1911.

maximum relief is little more than 2,000 feet. The highest summit in the area covered by plate 1 rises a little over 8,400 feet above sea level and the dissected mountain pediment that borders the Reese River valley on the west side of the range is at altitudes of about 6,200 to slightly more than 6,500 feet. Cliffs are rare, and most slopes are only moderately steep. The gulches that traverse the west slope of the Toiyabe Range are locally spoken of as canyons, but in only a few places, such as part of San Francisco Canyon, are their sides steep enough to justify the term. The slopes in the more intensely mined area near Austin are particularly moderate. The town of Austin is at an altitude of about 6,600 feet and few of the workings have portals above 7,000 feet. The collar of the Lander shaft, the highest of the main workings, is 7,237 feet above sea level.

Austin is about 240 miles east of Reno on U. S. Highway 50, and was formerly served by a narrow gage railroad that reached the main line of the Southern Pacific Lines at Battle Mountain.

The climate is semiarid, with a precipitation of 12 to 15 inches annually, mostly as snow in the winter months. The district contains several small springs, but none of the streams maintain continuous flow at the surface during the summer. Marshall Canyon, in which water flows at the surface in certain stretches, has had its supply augmented by tunnels driven to open up springs in its headwater basin. Reese River, in the valley just west of the district, is divided into a number of small channels. Water in these channels remains at or near the surface most of the time. In consequence, enough moisture is present in Reese River valley to support a number of stock ranches. Hay is the principal crop.

Summer storms in the mountains are commonly of the short local thunder shower type. At rare intervals they attain destructive violence. The Reveille notes that in 1874, 1878, 1884, 1891, and 1901, floods severe enough to do significant damage came down the main street of Austin, which lies along Pony Canyon, and every hard shower causes some inconvenience.

Wells and shafts commonly encounter water at depths of 100 feet or less throughout the district. This comparatively shallow water level interfered with deep mining in the early days. On the other hand, the quantity of water that can be obtained from springs and wells is so small that throughout the history of the district there has been difficulty in getting enough to supply the town and the ore-dressing mills.

Frost and snow flurries come as early as September and as late as June, but it is rare for much snow to fall before January. In the more severe winters enough snow accumulates to interfere seriously with travel on the roads during the first few months of the year. In midsummer the days are decidedly hot, but, except for short periods, the nights are comparatively cool. In the fall and winter the wind frequently attains considerable force.

THE ROCKS OF THE AREA

The greater part of the Reese River mining district is underlain by a pluton of intrusive igneous rock of the average composition of quartz monzonite, with associated narrow dikes. On the margins of the pluton the intrusive rocks cut impure, carbonaceous quartzite. Residual patches of a formerly extensive cover of volcanic strata with associated tuffaceous and sedimentary beds rest on the older rocks, and in the valleys alluvium forms a thin veneer. Soil and hill wash cover almost the entire surface and outcrops are sparse.

Few data as to age relations or the broader structural features were obtained. No fossils were found, and the geologic age of the different units can only be inferred from what is known of similar rocks in neighboring regions.

PALEOZOIC SEDIMENTARY ROCKS

Sedimentary rocks of supposed Paleozoic age are widespread in the northern part of the district and extend far beyond its limits. Similar rocks are also present to the east and south, but, except for a few small xenoliths in the igneous rocks in Crow Canyon, they do not crop out in the areas that were mapped.

The strata that border Yankee Blade, New York, and San Francisco Canyons in the northern part of the district are quartzite of varying purity. Much of the quartzite is gray, somewhat granular, slightly micaceous, and on the whole, massive. In most places, however, the massive rock is interleaved with thin-banded material, and some of the bands are darkened with graphite, chlorite, and other constituents. There are all gradations from light colored rock with occasional dark streaks to nearly black, more or less well-bedded material. The dark rocks, some of which are distinctly shaly, are particularly well displayed between New York and San Francisco Canyons but are present throughout the area in which the Paleozoic sedimentary rocks crop out. All the quartzite has been so metamorphosed that the quartz forms closely interlocked mosaics, with little or no trace of the original clastic grains remaining. The quartz grains have a maximum dimension of about 0.1 millimeter but in many beds are less than half this size. Locally, rutile and tourmaline form tiny crystals in the darker beds.

The beds strike a little north of west and dip somewhat more than 20° northward, but there are local variations. On the assumption that there is no repetition as a result of structural disturbances, over

2,000 feet of beds appear to be present within the mapped area. Except that they are obviously older than the granitic rocks that cut them and are moderately metamorphosed, the quartzitic rocks of the Reese River district have yielded no clues as to their age. Spurr (1903, pp. 94–95) regarded these rocks as Cambrian (?) in age because of their resemblance to Cambrian strata near Eureka (Hague, 1892, pp. 34–47) and because of their supposed relations to Silurian(?) slate. Chips of slate are present in the soil on and near Central Hill, south of Austin, and Silurian(?) slate and shale with some limestone have been mapped by Hill (1915, pl. 13) along the southern border of the monzonitic pluton that underlies most of the Reese River district. These facts are in agreement with the supposition that the quartzite may be of Cambrian age. Hence the quartzitic rocks of the Reese River district are tentatively assigned to the Cambrian(?).

QUARTZ MONZONITE

The granitic rock that underlies most of the district is, on the whole, fairly uniform in both composition and texture except for inclusions and dikes (fig. 2) and for alteration. The unalterable rock is moderately light gray, but pinkish feldspar is sufficiently abundant to be noticeable in a few outcrops. In most places the component grains

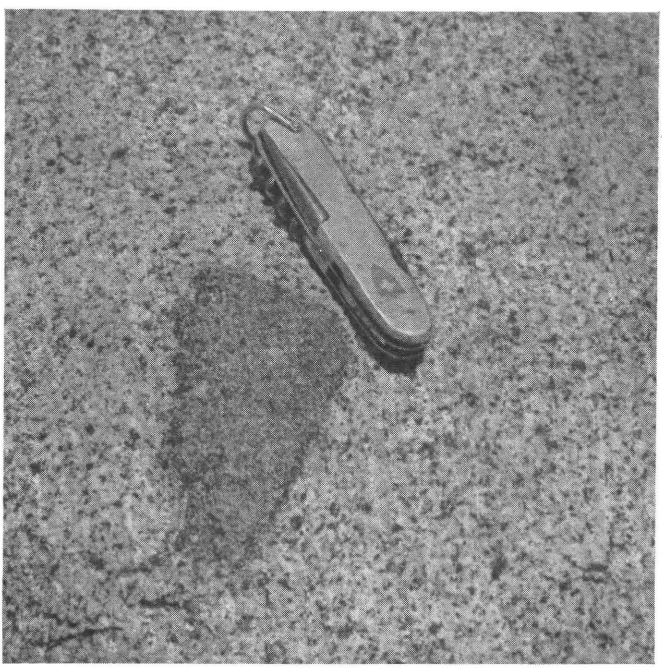

FIGURE 2.—Quartz monzonite, with inclusion, in an outcrop at Marshall Falls.

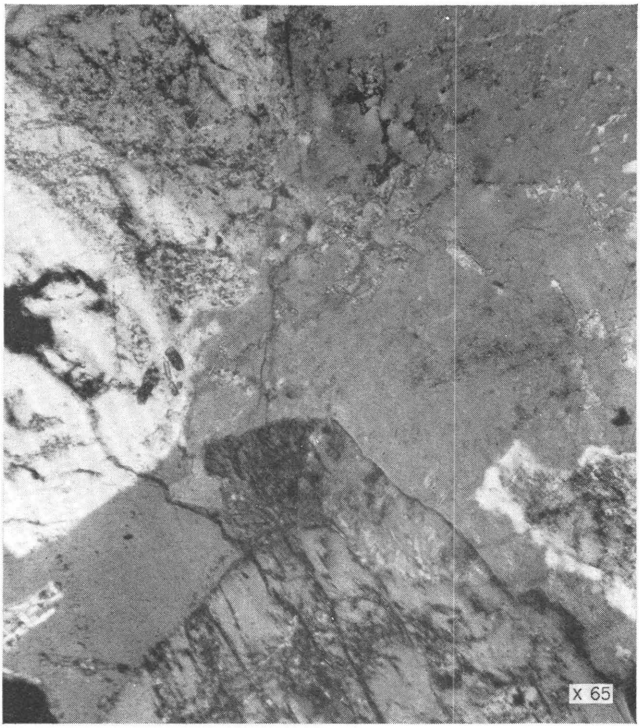

FIGURE 3.—Photomicrograph of quartz monzonite from the 200-foot level of the Jackpot mine. Shows typical texture of the quartz monzonite. Note the areas of myrmekite along contacts between striated oligoclase and unstriated potash feldspar. Crossed nicols.

range from 1 to 3 millimeters in maximum dimension, with occasional grains of potash feldspar as much as 6 millimeters wide. Figure 3 shows the general appearance of this rock under the microscope.

The rock of the main mass of the pluton contains on the average nearly 25 percent quartz, about the same amount of perthitic potash feldspar, a little more than 40 percent oligoclase (maximum index of refraction 1.55), and about 9 percent biotite. The rock is therefore a quartz monzonite. Exceptionally the oligoclase content rises to 50 percent or even a little more, and the potash feldspar may drop to as little as 17 percent. In these exceptional rocks, which are granodioritic in composition, a little hornblende takes the place of some of the biotite.

Apatite is rather conspicuous in all the granitic rock and sphene, zircon, and rarely tourmaline are present in small amounts. These minerals, at least in part, were introduced late in the history of consolidation of the rock. Myrmekite, an intergrowth of quartz and sodic plagioclase of late origin, is generally present and locally con-

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spicuous (fig. 3). In a few places the rock is seamed with irregular veinlets of micropegmatite. Such material is especially well displayed in the slivers of granitic rock included between lamprophyre bands in the large compound dike above the X-Ray mine. This granitic rock also contains conspicuous pink feldspar grains. In a few outcrops, notably near the crest of Union Hill, a fine-grained facies of the quartz monzonite merges into the more normal quartz monzonite with indefinite and irregular boundaries. The fine-grained facies contains numerous grains of the common minerals only 0.1 to 0.3 millimeter in maximum dimension scattered through material composed of mineral grains of average size.

Later changes, probably at lower temperatures and pressures are indicated by the widespread sericitization of the oligoclase and by some chloritization of the dark minerals. A little epidote is present, and few of the rocks are entirely free from disseminated grains of a magnesian carbonate. These minerals are so similar to those found more abundantly in the walls of the veins as to seem clearly related in origin to the process that resulted in alteration of the wall rock.

INCLUSIONS

Inclusions are widely distributed throughout the quartz monzonite stock. Some are clearly xenoliths of metamorphosed sedimentary rock but most of the inclusions have been so altered by the introduction of igneous minerals that their origin is obscure.

Definite xenoliths were noted only in Crow Canyon (pl. 4), south of the Laurent incline. One, which is fully 30 feet long, is shown on plate 2. The xenoliths here are thoroughly recrystallized quartzite containing considerable sericite and small amounts of biotite, zircon, and pyrite. In one of the xenoliths, indistinct schistose partings appear to trend about N. 30° W. and to stand nearly vertical.

Most of the inclusions are composed of igneous minerals and occur throughout the exposed parts of the intrusive mass stock. Except in certain localities, however, they are very sparsely distributed. Here and there in the southern part of the area, particularly in sec. 25, T. 19 N., R. 43 E., the dark inclusions are comparatively numerous. In some outcrops close to Marshall Falls (fig. 2), near the middle of the east border of section 25, and farther south on ridge whose summit has an altitude of 6,696 feet, scores of individual inclusions are visible. Here, as in other exposures throughout the district, most of the inclusions show little apparent regularity in shape or arrangement. In one outcrop near Marshall Falls, however, certain inclusions are arranged along a distinct zone that trends N. 65° W. and appears to be nearly vertical. No similar zone of inclusions is exposed nearby but at one spot on the 6,696-foot hilltop just mentioned, inclusions are systematically arranged parallel to an indistinct gneissoid structure in the granitic rock which trends N. 28° W. and dips 65° SW. Other equally fresh outcrops nearby do not appear to show anything of this sort. Neither distinct systematic arrangement of inclusions nor gneissoid structure in the granitic rock was detected in any other outcrop in the district.

The inclusions are dark gray to black and have rounded, irregular forms. Many look like angular fragments whose edges have been rounded off (fig. 2). Most range from a few inches to over a foot in maximum dimensions. At the borders the dark material of the inclusions merges slightly with the lighter colored granitic rock around it.

The inclusions have a rather irregular granitic texture in which individual grains range from less than 0.5 millimeter to over 3 millimeters in length. They consist mainly of oligoclase, hornblende, and biotite with some apatite, zircon, quartz, chlorite, and sericite. Some of the oligoclase grains have myrmekitelike intergrowths on their borders.

The origin of these inclusions is unknown. Their shapes suggest strongly that they are fragments of some rock that was solid at the time that the quartz monzonite magma was intruded. As neither early mafic facies of the magma nor other igneous rocks of suitable age are known in this region, it seems quite possible that the inclusions are fragments broken from the Paleozoic sedimentary rocks that have been so thoroughly soaked with igneous material and recrystallized that all traces of their original sedimentary characteristics have been lost.

APLITIC AND PEGMATITIC ROCKS

Some of the rocks associated with the quartz monzonite are conspicuously rich in the alkalies and, commonly, also in quartz. These include material that forms hard ribs along joints, aplite in the form of irregular stringers, and, locally, long, narrow dikes, and irregular bodies of pegmatitic character.

Resistant material that stands out as narrow ribs on weathered surfaces (fig. 4) fills many of the joints in the quartz monzonite. These ribs are in part composed of quartz that was deposited by aqueous solutions, closely associated with mineralization. Along some of the ribs relatively coarse, in part pinkish, feldspar crystals, and rarely crystals of ferromagnesian minerals are discernible. It is probable that the joint openings served as passageways for fluids bearing the constituents of late-stage igneous silicate minerals as well as those of quartz. Sulfides, especially pyrite, are locally disseminated in these ribs.

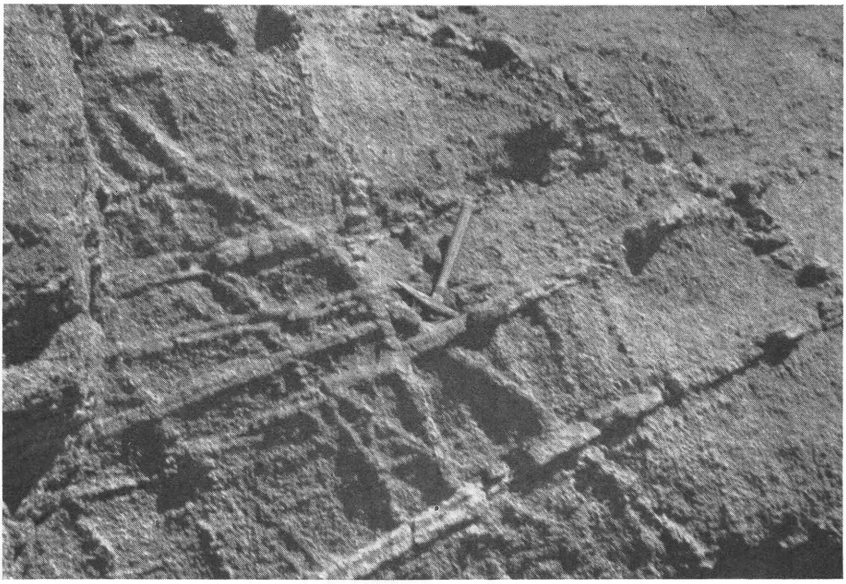

FIGURE 4.—Hard ribs on joints in quartz monzonite at the portal of the Silver Chamber incline.

Aplite dikes large enough to map, crop out principally in and near Yankee Blade Canyon and Emigrant Gulch (pl. 1); some of them are 10 to 20 feet wide and as much as 1,000 feet long. The dikes are composed of light gray, rather fine-grained rocks that differ from place to place in details of texture and composition. Commonly they consist of a somewhat irregularly sized aggregate of grains that have a maximum diameter of about 0.25 millimeter and include micropegmatite, perthitic potash feldspar, sericitized albite, and small amounts of muscovite and chloritized biotite.

The quartz monzonite near Austin contains small, sparsely distributed aplitic stringers. Some stringers are associated with the resistant ribs described above, others wind irregularly through the monzonitic rock and in part blend with the latter; an exceptionally large one is shown near the northeast edge of plate 2. The aplite of these stringers is on the whole finer grained and more pinkish than that described in the preceding paragraph. It has a granular texture and is composed mainly of quartz, potash feldspar, and somewhat altered albite with a little bleached biotite. The potash feldspar is at least in part microcline, and the albite is bordered locally by myrmekitic intergrowths.

Irregular intrusive masses that are obviously pegmatitic offshoots of the quartz monzonite stock are rather widely distributed through the quartzite in the northern part of the district. These range from mere stringers to bodies several hundred feet wide. Only the larger masses are shown on plate 1. The rocks composing such masses are nearly white but some, especially the coarser ones, are speckled with conspicuous aggregates of dark minerals, mainly tourmaline. There are all gradations in texture from that of a fine aplite to that of a pegmatite in which individual crystals are several inches across. The principal constituents are albite, microcline, quartz, biotite, and locally tourmaline.

LAMPROPHYRES

Many of the dikes large enough to map in the Austin area and some of those in the northern part of the district are lamprophyres. They range in width from a few inches to over 40 feet, and have a maximum length of over 3,000 feet. Most of the lamprophyres are dark green to almost black, but in a few the nearly white feldspar grains are sufficiently large and abundant to give the rock a speckled appearance. Some of the more altered dikes weather rusty brown. In a few places, such as near the portal of the Luetgen tunnel, the lamprophyres are so bleached and otherwise altered that they superficially resemble an aplite.

Many of the dikes, especially the larger ones, are composed of parallel layers of lamprophyre that differ slightly in texture and composition. Some lie directly against the adjoining lamprophyre layers; others are separated by narrow, residual slabs of monzonitic rock. Most of the lamprophyre layers have fairly distinct chilled borders, and some show flow structure. The best exposed composite dike extends from the X-ray mine to the Luetgen tunnel, a distance of over 3,000 feet. This dike has a maximum width of 40 feet. The largest single outcrop, shown in figure 5, is 10 feet wide and contains at least 11 separate layers of lamprophyre and 4 layers of monzonitic rock. The different bands range in width from 2 inches to 2 feet, but some of the wider bands may themselves be composite.

The dikes consist mainly of oligoclase, green biotite, and hornblende in varying proportions. In different rocks, the maximum index of refraction of the oligoclase ranges from slightly below to slightly above 1.55. In the coarser material the plagioclase is indistinctly zoned. In some of the rocks feldspar composes 75 percent and even more of the rock, but in most, the dark minerals are about as plentiful as the feldspar, and locally they are markedly more abundant. In a few of the dikes biotite is the principal dark mineral, but hornblende is rarely absent, and locally it constitutes fully half of the rock. The three minerals all tend to exhibit crystal form. The long axes of some hornblende and biotite crystals are as much as 3 millimeters long, and exceptionally, feldspar laths reach a length of 5 millimeters. More commonly, however, the maximum dimensions

FIGURE 5.—An outcrop along the large, composite lamprophyre dike above the X-Ray mine. Exposure is 10 feet wide and contains at least 11 distinct, vertical layers of lamprophyre and four of monzonitic rock, most of which are distinguishable in the photograph.

of the mineral grains are 0.5 millimeter and less. In a few of the bands in the composite dikes the crystal grains have a subparallel arrangement as a result of flowage, and in these individual grains are commonly less than 0.1 millimeter long.

Quartz is present in many of the dikes, but much of it is in stringers that cut across other minerals and may be related to the veins. Some of the quartz, however, is packed into interstices between grains, and some is in stringers consisting of intricate micropegmatitelike intergrowths with feldspar. These relations suggest that the quartz formed after the consolidation of much of the rock but before magmatic processes had ceased. Some of the lamprophyre dikes contain as much as 15 percent quartz in interstices and in micropegmatitelike intergrowths.

In those rocks that contain both hornblende and biotite the two are locally intergrown in a manner that suggests that the biotite in part replaces the hornblende. Apatite and sphene crystals are locally scattered through the lamprophyre without regard to the boundaries of other mineral grains. Such features as these suggest that the lamprophyres have been subjected to marked changes after consolidation began. Also, as noted on page 12, the slabs of monzonitic rock between successive bands of lamprophyre differ somewhat from the normal quartz monzonite nearby.

Almost all the lamprophyres contain sufficient hydrothermal alteration products to obscure earlier minerals. The hornblende and biotite have been altered to chlorite, epidote, and other alteration products. In some dikes the former presence of ferromagnesian minerals is attested only by casts of hornblende, now filled with fine-grained aggregates of alteration products. The plagioclase in some of the dikes contains abundant sericite. On the other hand, in a few of the dikes that contain few and small crystals of the dark minerals, the plagioclase is conspicuously fresh. Most of the dikes contain disseminated carbonate crystals.

Quartz veins commonly lie on one or both sides of the dikes and cut into the dike rock in such a way as to show clearly that the quartz was deposited later than the dikes. On the other hand, some of the layers in the composite dikes contain included angular fragments of vein quartz whose source is not known.

AGE OF THE INTRUSIVE ROCKS

No evidence was obtained concerning the age of the monzonitic mass and related dikes within the district. The quartzite cut by these intrusive rocks is older, and the overlying volcanic rocks, described below, are much younger than the intrusive rocks. Hill (1915, map p. 99) suggests that the pluton should be correlated with "the intrusive rocks farther west in the Great Basin province and in the Sierra Nevada." These are now commonly regarded as Jurassic(?) in age. Ferguson (1929, pp. 125, 130) on the basis of the association of different types of mineral deposits with the granitic intrusives in the eastern and western parts of the State, believes that the vein deposits prevalent in western Nevada, including those of the Reese River district, are associated with intrusives probably related to the Sierra batholith and therefore are to be regarded as of Jurassic(?) age.

VOLCANIC ROCKS

Lava flows, tuffs, and associated sedimentary rocks are widely scattered on the margins of the north part of the district. Within the area shown on plate 1 they are abundant only in the vicinity of Emigrant Springs Basin, but are exposed from the basin southeastward to the vicinity of the head of Marshall Canyon. Small residual patches of similar rocks on Midas Flat and south of Emigrant Gulch indicate that the volcanic strata once covered much and possibly all of the Reese River district. They were laid down after the quartz monzonite had been bared by erosion.

The volcanic rocks consist mainly of flows of dacite and more silicic rocks, most of which contain much glass. The recognizable minerals in the lavas are mainly feldspar, quartz, and small amounts of biotite and hornblende. None of the feldspar appears to be more calcic than sodic andesine, and some orthoclase is present in many flows. Brown and black obsidian containing scattered feldspar phenocrysts are especially conspicuous at and near the base of the unit on and near Mount Prometheus. Some of the strata that resemble lava are actually welded tuff composed mainly of glass shards as much as 0.3 millimeter in length, with indices less than 1.54. These contain scattered angular fragments of quartz, sodic plagioclase, and potash feldspar. A few felsitic dikes, apparently related to the lava cut the granitic rock on the ridge west of Emigrant Springs Basin. One of the largest is of dacite that consists of sodic andesine, biotite, quartz, apatite, and epidote. The groundmass is a mosaic of grains averaging 0.1 millimeter in diameter. Well formed andesine phenocrysts are as much as 2 millimeter in length.

Clastic rocks are present at and near the base of the volcanic rocks in several places on the borders of Emigrant Springs Basin. On the ridge crest west of this basin these beds are sandstone and conglomerate in which the pebbles include several kinds of lava as well as boulders of the quartz monzonite on which they rest. The lower ends of spurs near the northern end of the basin contain laminated light gray tuff, and locally, small amounts of similar tuff are exposed higher on the slopes. The tuff is composed of fragments of igneous minerals, mainly plagioclase, biotite, and quartz having a maximum dimension of 0.10 millimeter, embedded in a nearly transparent ground mass that contains some glass shards.

The volcanic beds are exposed for a distance of about a mile across Emigrant Springs Basin in a direction normal to the strike and with dips of 25° to 32°. This suggests a total thickness of more than 2,000 feet. The coarse sedimentary rocks on the ridge to the west are fully 50 feet thick and the thinly laminated tuffaceous beds at the head of the basin have a similar thickness.

The volcanic beds in the Reese River district were presumably formed during the Tertiary but cannot be dated more closely. Ferguson oral communication states that flows of similar composition associated with similar clastic beds in the Tonopah quadrangle, 50 miles to the south, are probably Miocene or early Pliocene in age.

STRUCTURE

The broader structural features of the district are simple. A nearly flat-topped monzonitic body has been intruded into folded sedimentary rocks. Erosion sufficient to expose much of the intrusive mass was followed by volcanism. The flows and tuffs then deposited have been somewhat deformed and extensively eroded. Minor movements of adjustment occurred during this last period of erosion.

STRUCTURE OF THE QUARTZ MONZONITE PLUTON

The quartz monzonite pluton has an exposed width of roughly 6 miles northward and is apparently much wider eastward (Hill, 1915, pl. 13). Along the northern border (pl. 1) the contact is irregular but has a slight northward inclination. This is shown not only by the pattern of the contact as mapped but by the fact that pegmatitic offshoots of the quartz monsonite cut the quartzite throughout the portion of that formation shown in plate 1. The main True Blue tunnel, which is on the north side of New York Canyon just under the contact of the quartzite and monzonite, continues in monzonitic rock for 500 feet northward to the point where the tunnel enters the quartzite. Farther south the evidence of a low-dipping contact is less positive but the fact that inclusions are widely distributed, though not very abundant or large, suggests that erosion has not cut deeply into the monzonitic rock. Small inclusions such as these would have been obliterated before sinking very far into the magma. Hence, the original top of the intrusive mass throughout the area mapped in plate 1 may have been almost as flat as it is where the cover of sedimentary rocks remains.

The monzonitic rock is intricately and extensively jointed. As plates 1 and 2 show, the altitudes of the major joints throughout the stock are diverse, but northwestward strikes predominate in most places. One conspicuous and comparatively uniform set of joints strikes somewhat north of west and dips northward at angles rarely much in excess of 45°. The more prominent joints in the two views shown in figures 6 and 7 belong to this set. Joints of this set are steeper and less prominent in the northern part of the district than they are in the southern part, where most of them dip 35° and less northward. In the Austin area such joints are conspicuous wherever adequate exposures exist, and in many outcrops are spaced a few inches apart. Many are either barren or have had just enough material deposited along them to produce narrow, resistant ribs. Another rather prominent set of joints strikes somewhat west of north. Minor joints are numerous and heterogeneous throughout the district. Commonly they are discontinuous and indefinite but where silica or other material has been deposited they may be conspicuous on the weathered surfaces of outcrops. Figure 4 in which an exposure is crisscrossed by many small ribs of hardened material typifies this.

The conspicuous set of joints that commonly dips less than 45° northward may correspond to what Balk (1937, pp. 105–108) pro-

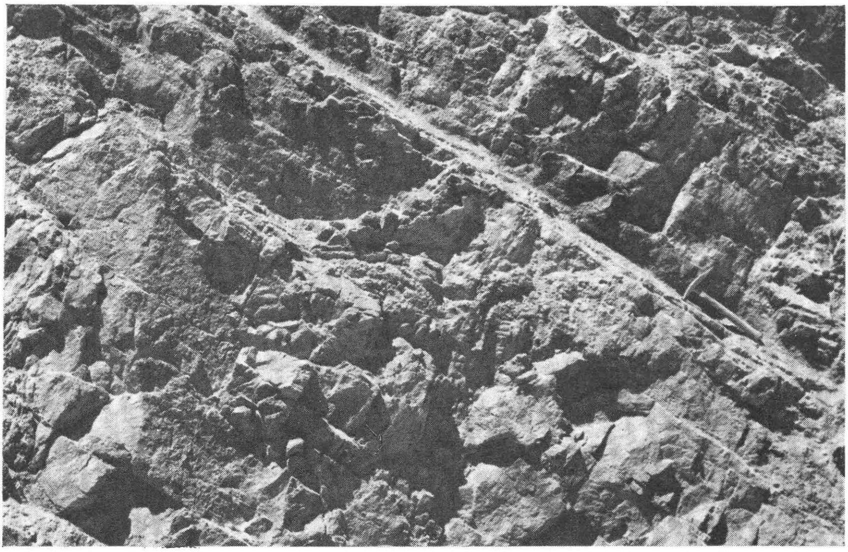

FIGURE 6.—Closely spaced joints striking northwest and dipping moderately northward in the west wall of the glory hole at the Jackpot mine. Subordinate joints of other attitudes are also visible.

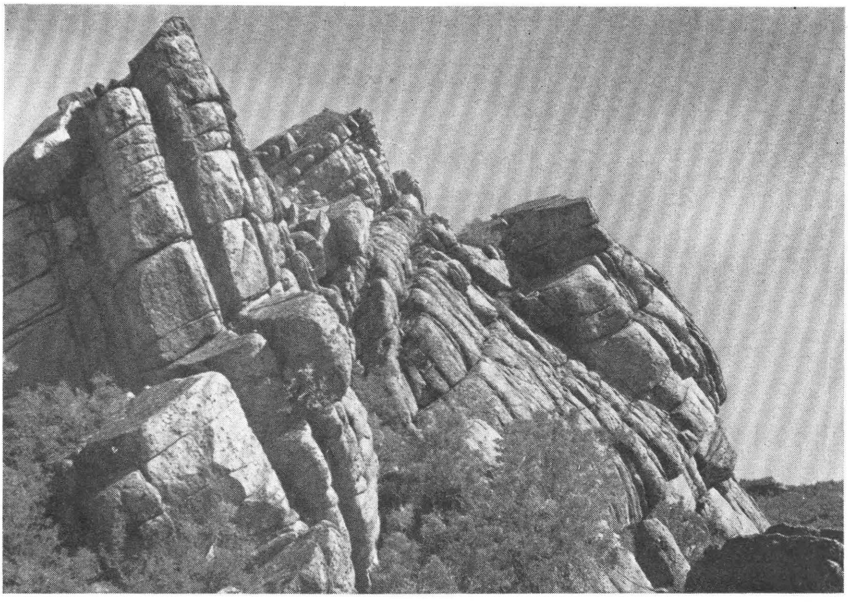

FIGURE 7.—Joints in quartz monzonite northeast of the Lander shaft. A typical outcrop of the quartz monzonite where topographic position is favorable to exposure of fresh rock. The more prominent joints here belong to the same set as the prominent joints in figure 6. Photograph by J. N. Faick.

visionally terms "flat-lying normal faults." This term is a substitute for the German expression "Streckflache" (plane of stretching) and is particularly applicable at Austin where the relation to flow structure is not known. Balk shows that joints of this kind may properly be called faults because displacements as great as 11 feet have been measured along such fractures.

The dikes and veins that are plentiful throughout most parts of the stock fill fissures that are similar in many respects to joint openings, with the exception that they appear to be more persistent. Many of the dikes have quartz veins on their borders. The quartz monzonite on the border of both the dikes and veins, especially the latter, is commonly sheared and locally brecciated, to a greater extent than that along barren joints.

After the upper part of the intrusive mass had become consolidated and jointed, late stage emanations, including silica-rich solutions, probably rose from below and circulated along joint openings. Some of the joints may have been longer and under less compression than others at the time that emanation began. The fluids would tend to concentrate in these, following the paths of least resistance. As they rose the fluids may have produced movements of the joint blocks and one result of such movements may have been to open certain joints sufficiently as to provide increased ease of circulation along the joints thus opened. In addition, some joints may have been more advantageously placed than others to receive fluids that rose from particular locations within the magma. Thus, in one way or another, the dikes and veins came to occupy the more persistent joints, which, however, are in other respects genetically similar to the barren joints. Further, the openings filled with dikes and veins seem more persistent because they are more easily traced than joints that are nearly or quite barren. Vein formation began before dike intrusion ceased and both are believed to be genetically related to the major magmatic activity.

In the southern part of the district, where dikes are especially numerous, they strike in general east of north and have steep dips. Near the 117°05′ meridian in this part of the district, both dikes and veins strike more nearly north and some strike even a little west of north. A short distance north of latitude 39°30′ in the vicinity of Slaughterhouse Gulch the strike of the dikes changes abruptly to 20° and more west of north; dikes of northward and northeastward trends are not exposed here. There is a corresponding change in the composition of the dikes. Those in the northern part of the district are, with minor exceptions, aplitic, and those farther south are mainly lamprophyres. Perhaps the difference in composition corresponds to a difference in the time at which fissures of the two systems opened to permit passage of the dike magmas.

DEFORMATION IN THE STRATIFIED ROCKS

The quartzite dips away from the stock on the north at angles of 20° to 30°, with steeper dips in places. The structure of neighboring areas is so little known, though, that the significance of the observed dips cannot be determined at present. The approximate parallelism between the attitude of the beds and the trend of a large part of the short section of the contact that has been mapped is so close that tilting during intrusion seems possible.

The only mass of volcanic rocks of any size within the area (pl. 1) dips eastward at about 30° on the east side of the Toiyabe Range. This mass extends upward to the summit of Mount Prometheus, one of the highest peaks in this part of the range. The patches of similar rock that have escaped erosion on the west slope of the range are at such low altitudes as to suggest that they once were low on the west flank of an anticline in the volcanic rocks. The axis of such an anticline would have been close to the crest of the range and roughly parallel to it. That is, the volcanic beds may have been bowed upward as the range rose by differential uplift. Obviously the volcanic rocks were deposited on a ground surface that had relief and consequently some of the flows may not have been horizontal when originally consolidated. The sedimentary rocks, however, can hardly have had original dips as steep as 30°. Even in the lava flows, it would be difficult to account for the observed relations on the hypothesis that they result to any significant extent from irregularities resulting from conditions during volcanism.

Although some of those familiar with the district think that faults are numerous, the direct evidence of faults with displacements of mappable size is meager. The only fault actually mapped on plate 1 is at the north end of Emigrant Springs Basin. Here the volcanic rocks have a nearly straight boundary that trends N. 50° E. The lava is sharply discordant in attitude with the older rocks to the north. The downthrow appears to be to the southeast but the displacement may not be great. The middle reaches of Yankee Blade Canyon and considerable stretches of New York and San Francisco Canyons and other streamways are so nearly parallel to the mapped fault as to suggest that erosion may have been guided by fractures in the rocks. If these fractures exist, displacements along them are so small that they have not been revealed by the geologic mapping. Farther south, in the Austin area, careful search has failed to produce evidence that the canyons are related to faults. In spite of the fact that numerous minor faults are exposed in mine workings, very few are mapped in plate 2 and these are much too small to show on plate 1. Geophysical studies tend to support the concept that faults of more than trivial size are rare in the district.

MINERAL DEPOSITS

The high-grade silver veins of the Reese River district were actively mined from 1862 to 1886. Since then there have been sporadic attempts at revival. Most of the early production came from rich silver-bearing veins on Lander Hill and from parts of the Yankee Blade area. The veins in other areas appear to have lower average silver tenor, even though some of them contain recoverable amounts of gold. The base metals, locally present in significant quantities, were disadvantageous in the early days but would present no problems to modern milling methods.

The principal gangue minerals are quartz and carbonates; mainly rhodochrosite, with calcite, sericite, and other minerals in the wall rocks. The rich ore for which the camp is famous is characterized by ruby silver minerals and tetrahedrite; but pyrite, arsenopyrite, and the common sulfides of lead, copper, and zinc are widespread in varying proportions. Oxidized minerals are confined to shallow depths, and most of the sulfides are of primary origin.

The vein systems are complex. The veins are narrow, discontinuous, and fill openings along joints in the quartz monzonite and along bedding planes in the quartzite. Postmineral faults are widespread but displacements are commonly small.

HISTORY AND PRODUCTION

The principal available source of information in regard to the history of the Reese River district is the files of the Reese River Reveille, a newspaper that has been issued continuously since May 16, 1863. A complete set of copies is stored in the office of the County Recorder, Bert Acree, at Austin, and was made available through his courtesy. Mr. Acree also kindly gave access to the tax records showing bullion produced in the county from 1865 to 1897, inclusive, as reported to the assessor. Copies of old letters and other records in the office of the Austin Silver Mining Co. were also consulted. These include some of the reports of operations written by successive managers of the Manhattan Silver Mining Co., the principal producer, to the company's home offices. Reports on the district written by engineers employed by different companies were of value, mainly because they contain summaries of production data and other figures not otherwise obtainable at the present time. Conversations with old residents yielded useful information of several kinds. Some data were obtained from the Mint reports and from the annual volumes of Mineral Resources of the United States and their successors, the Minerals Yearbooks.

DISCOVERY

Travel by white men in the part of Nevada in which Austin is now situated began in 1851, when Col. John Reese explored for a new route to connect Salt Lake City with a Mormon settlement at Genoa, on the Carson River. As a result of his work a road was made through a pass in the Toiyabe Range a couple of miles north of the site of Austin. This road crossed the Reese River near the present settlement of Ledlie. In 1860 this route was taken by the Pony Express, and in 1861 it was utilized by the Overland Stage. Construction of the transcontinental telegraph line along it began in September of the same year. A stage station, named Jacobsville, after the stage agent who founded it, was established at the place where the road crossed Reese River.

Early in May 1862 William M. Talcott, a former Pony Express rider then employed at the Jacobsville stage station, found the outcrop of a silver-bearing quartz vein while gathering wood for the station. He named the gulch Pony Canyon, in honor of the Pony Express. As a result of the discovery, the Reese River mining district was organized May 10, 1862, with the discoverer as recorder. The vein found by Talcott is near the mouth of Pony Canyon at or near the site of the mill of the Austin Silver Mining Co. The vein was worked for a time, but as much richer veins were found farther upstream, it was soon abandoned. The first location on Lander Hill, destined to be the principal productive area in the district, was made by John Frost in December 1862.

A rush from the Comstock district was precipitated when ore was taken from Pony Canyon to Virginia City. The County of Lander was soon formed, with Jacobsville as its first county seat. Clifton, now obliterated, was laid out January 16, 1863, at the mouth of Pony Canyon. Austin was founded a short distance up from the mouth of Pony Canyon. In May 1863, the first issue (300 copies) of the Reese River Reveille was published at Austin. This newspaper noted that nearly 1,000 claims had already been located and that litigation in regard to some of them had already begun. Several other small communities, in addition to those mentioned above, also sprang up in the vicinity, but most of them within a short time, were either abandoned or were absorbed in the rapidly expanding town of Austin, which was advantageously situated. On May 23, 1863, the Reveille noted that Austin already had two hotels, five saloons, a telegraph office, and a variety of other buildings. It had about 450 citizens, and the adjacent town of Clifton had 500 people. According to some accounts as many as 10,000 came to the district in 1863, although many soon passed on to other camps.

All supplies were scarce and exceedingly expensive. At one time in the summer of 1863, flour sold for $50 a hundredweight. Lumber, in part imported from California, retailed at $400 to $500 a thousand feet. Among the miscellaneous modes of transportation utilized at this time was a train of camels. A road across the mountains into Austin was built in July 1863, shortening the trip for overland coaches and freight from eastern points. Water was so scarce that the owner of a cart distributing it in Austin netted $1,000 to $2,000 a week (Farrell, 1874). When the mines were deepened, enough water to add materially to the cost of operation was encountered. This did not, however, solve the problem of water supply for domestic and metallurgical use.

EARLY DEVELOPMENT

At first ore was shipped to Virginia City for treatment but numerous plants for local treatment of the rich silver ore were soon erected. The first silver brick made in the camp was smelted May 28, 1863, from amalgam obtained in an arrastre by Mexicans on the Tesora claim near the present Dalton tunnel (pl. 2). Buell & Co. had the first stamp mill in the district in operation early in August 1863, but arrastres were used earlier. The first ore treated was 10 tons of oxidized material from the Morgan and Muncey mine, which, according to the Reveille of March 22, 1866, yielded $3,360. Within a few years, 29 mills, said to have had a total of 444 stamps, were working in the district. Nevertheless, the entire production until January 1, 1864, is reported to have been only about $100,000 (Farrell, 1874). The Reveille for March 10, 1864, notes that the cost of reduction was $75 a ton. This, added to the necessarily high cost of mining, must have made it unprofitable to mine any except exceedingly rich ore. Much of the selected ore milled at this time yielded several hundred dollars to the ton, and some of it assayed as high as $1,000 to $6,000 to the ton in silver.

The city of Austin was incorporated February 17, 1864. The Reveille estimated on November 22, 1864, that the population of the town was about 6,000 people. On January 31, 1865, the newspaper said that $500,000 in bullion had been shipped in 1864, but at an estimated total cost to the community of roughly $1,820,000. The winter of 1864–65 produced suffering because the population had grown out of proportion to the industries that could furnish employment.

Beginning in the summer of 1865 the rush to the new camp began to subside. Many had already drifted away. Control of many of the mines passed to capitalists in distant cities. This resulted in some increase in production. However, it is reported that some of the managers sent out were chosen on the basis of relationship to the new owners rather than ability and training. The Manhattan Silver Mining Co. was the only one of the numerous companies that came into existence at that time that survived.

In 1865 the oxidized ore, which extended only to depths of 50 to 100 feet below the surface, was still being worked and much of this was so rich and so amenable to treatment by amalgamation that little skill and equipment were required in milling. Much of the mining during the first few years was in trenches and pits so shallow that little or no trace of them now remains. Prospecting in the district has from the first been handicapped by poor outcrops. Patient tracing of quartz chips in the shallow soil to their bedrock source led to the discovery of many veins. Another method, said to have been extensively employed on Lander Hill in the early days, was to plow furrows down the hill slopes using oxen, a forerunner of modern bulldozing technique. So many people were prospecting in the small area around Austin that most of the veins now known were discovered during the first few years of work. On Lander Hill alone something like 100 separate veins are said to have been recognized, although many of these proved to be of comparatively slight value. J. Ross Brown (1867, p. 129) reported that 36 steam hoists were in operation in 1866 in the neighborhood of Austin. Depths as great as 300 feet had been attained but the daily production from all mines in the district was not more than 40 tons of ore. Early in the development of the district it was realized that an area roughly 2,000 feet square on Lander Hill was more intensely mineralized than most other parts of the district. Plate 12 in Hill's (1915) report will give an idea of the way in which the early workings were crowded together in this area. Prospecting was by no means confined to Lander Hill. For example, the Tesora claim, which in May 1863 yielded the first bar of bullion smelted in Austin, is near the southern border of the Austin area, over a mile from Lander Hill. A number of the mines in the Yankee Blade and Midas Flat areas were worked in 1863, and some were productive at least as early as 1865. In October 1865 the district included 6,000 claims of which only 500 were on the hills around Austin. Of the 20 ore-dressing mills then in operation, 9 were in Austin itself. Many of the others appear to have been in the Yankee Blade area where five villages had grown up.

As the early mills included no provisions for freeing the silver locked up in sulfides, they proved inefficient as soon as depth began to be attained in the mines, especially in the Yankee Blade area. Early accounts note that many of the veins here were barren near the surface and that it was necessary to go below water level in order to find rich ore. The difficulty in handling water with the equipment available was probably one of the principal reasons why the Yankee Blade area was not more extensively developed in the early days. On Lander Hill enough high-grade oxidized ore was found above water level to encourage sinking and to make it possible to provide capital for the necessary equipment.

Speculation in mining property early became active. In the first few years of its existence, Austin acquired a board of brokers, and there was much buying and selling of shares in the different claims on a footage basis. Prices were as high as $50 a foot. In this way outside interests acquired many of the properties, and opened the way for the inefficient operation mentioned above. As so many of the original properties were closely spaced on Lander Hill, and the vein systems were complex, much costly litigation resulted because of the apex law. The small size of many of the ore shoots and the close spacing of the veins induced the miners to drive exploratory crosscuts, resulting in the finding of many vein segments underground whose relations to surface exposures were unknown. The confusion was increased by the prevailing concept that the surface of Lander Hill had slipped down the slope, so that veins mined at the surface were not in their original relations to those found at depth. This concept appears to have arisen from the original complexity and close spacing of the vein systems rather than from any marked or widespread slippage of the surface of the hill. Some idea of the complexity of the workings on Lander Hill can be gained from plate 3. Most of the workings on this map were in existence in 1870, or were opened soon after that date.

Litigation continued to be a major factor hampering the development of the district until the Manhattan Silver Mining Co., about 1870, finally obtained most of the more valuable property in the camp.

As early as 1866, operation by companies had become an established feature, although there were still many small operators, as is shown by the fact that the County Assessor's records for the year contain 133 different names of producers in the Reese River district. The records for this year, like most of the early years, contain a few names of small producers of ore, the source of which is not now identifiable. Most of these doubtless belong to the Reese River district and they have been so considered in compiling production totals. Another source of uncertainty in interpreting the record is that the same property appears in some cases to be entered under more than one name. For example, in the records for 1866 there are references to the Savage Mine, Savage Consolidated, and Savage Gold & Silver Co. On the probable assumption that these all refer to a single mine, it was much the largest single producer in 1866, yielding 1,575 tons valued at $159,461.96. It is not, in general, possible to compile from the tax records data on production from individual mines. In the early years many entries are made in the names of the operators or lessees rather than of the mines, and later the yield of the different mines is merged in that of the few companies controlling most of the productive area. Some data on the production of the different mines are given in the mine descriptions.

THE MANHATTAN SILVER MINING COMPANY AND ITS CONTEMPORARIES

The Manhattan Silver Mining Co. began operations at Austin in July 1865 and for over 20 years thereafter held a dominant position, although difficulties in operation caused several shut-downs during this period. Its original property comprised the Southern Light, North Star, Blue Ledge, and Oregon claims, aggregating 3,800 linear feet (Clayton, 1873). The tax records for 1865 credit the company with a production of 745 tons of ore, which yielded silver bullion valued at $66,917.98. In 1866, however, the yield was less than half of this, and on July 20, 1866, its property was seized by the sheriff. Some adjustment, however, appears to have been made and James Bowstead assumed management in September. He proceeded energetically to reopen the North Star and Oregon mines. When he reopened the company's 20-stamp mill December 10, 1866, the cost of treatment was $40 a ton and the recovery was 80 percent of the silver content. Bowstead died January 28, 1867, and Allan A. Curtis took charge. His report at the end of the year credits the North Star with earning $252,076.95, from which was deducted a debit of $1,123.39, and the Oregon with earning $463.39, from which a debit of $181 was deducted. The tax records credit the company with 5,621.5 tons valued at $81,137.19 during the first quarter of 1867 but the rest of the record for this year is not available. The tax records for 1868 show a production of 2,131 tons valued at $339,079.02. Apparently much of the money obtained from the sale of bullion had to be used in equipping the plant and the year was not a profitable one for the company.

The district as a whole produced more bullion in 1868 than in any other year throughout its history. J. Ross Brown's report for the year says that more than 6,000 claims had been located in the district, of which 1,000 had been sufficiently developed to show that they possessed value. Few, however, were in operation. The mines he lists as worthy of note at that early date include a large part of those that have since proved productive, not only on Lander Hill, but in the other parts of the Reese River district as well. Milling costs at that time were $35.34 a ton. Under date of January 31, 1869, Curtis wrote to the company's office in New York: "I am forced to believe that the veins of Lander Hill instead of becoming richer as they are worked down on become poorer and change rapidly after reaching a certain depth." Similarly pessimistic remarks appear in the Reveille of February 16, 1869. These remarks, coupled with such fragmentary descriptions of early operations as are available, indicate that individual ore shoots were small and pinched out within short distances down the dip. Nevertheless, new ore shoots continued to be found, so that active mining on the hill continued for more than 15 years longer.

Mining costs (Raymond, 1873, pp. 141–142; "R," 1869) early in 1869 were estimated at $15 to $50 a ton in the best managed mines in the district. The average mining cost was about $30, and the milling cost was $36.16 a ton. In consequence of such costs, ore was carefully hand-sorted, and only material worth more than $75 a ton was milled. The small operators who sent custom ore to the Manhattan mill sorted so carefully that some of this ore was valued at several thousand dollars a ton. Much of the ore milled contained more than $200 a ton in silver. The Manhattan Silver Mining Co. shut down in October 1869 in part because of difficulty in getting efficient labor. Many of the better miners had left Austin for the White Pine and other new districts. However, the company was soon able to resume operations.

The following table, adapted from one in Raymond's report for 1870, will give an idea of the grade of the better ore sent to the Manhattan mill. The lots tabulated were among those milled during a single fortnight. This table also serves to illustrate the small size of the individual lots, which must have been a factor in the high costs.

Selected list of ore lots milled in 1870

Mine	Pounds	Value per ton	Mine	Pounds	Value per ton
Aurora West	70,000	$326.25	Oregon	4,288	$429.22
Tuolumne	2,100	949.73	Oregon	5,940	738.31
Morris and Cable	2,000	2,788.94	Oregon	5,850	809.00
Morris and Cable	7,982	819.91	Plymouth	6,386	859.26
Dollarhide	3,208	945.00			

In November 1869 custom ore was reported by Curtis, the superintendent of the Manhattan Silver Mining Co., to show a profit of $26 a ton. His summary letter for 1869 shows a profit of $2,124.38 after $42,142.31 had been expended on necessary improvements to the plant. In 1870 the profit was $66,511.22. Reduction costs were lowered by installation of Stetefeldt furnaces in place of the reverbatory roasting furnaces formerly used, but full advantage could not be taken of the new furnaces because of the limited supply of ore. According to Raymond (1873, pp. 170–171), the advantage in ore dressing, which the Manhattan Silver Mining Co. got by securing the exclusive rights to the use of these furnaces in the district, had much to do with the company's future success. This is corroborated by Vanderberg's statement (1939, pp. 70–76) that the Stetefeldt furnace was "an important contribution to the metallurgy of refractory silver ores, not only at Reese River but in other districts in the West."

In 1871 the company produced 1,371.19 tons, valued at $275,728.38. Data on the amount of profit are not available but this appears to have been one of the best years in the company's history. The first dividends of which record has been found were paid in February 1871, and amounted to $19,375, equivalent to 5 percent in coin.

In February 1872 a miners' union was organized and a crowd of 40 union men went to the Lane and Fuller mine of the Pacific Mining Co. demanding a minimum wage of $4 a day for miners. The president of the union and 28 members were arrested for riot. Unionization could not be very effective in Austin at that time because much of the mining was still being done by owners of small properties, who did their own work, and by lessees in the larger mines. According to the Reveille of February 19, 1872, the Manhattan Silver Mining Co. had 112 miners and the Pacific Mining Co. had 50, but not over 50 of those employed in the district were working for wages. The census of 1870 credits Austin with 1,324 inhabitants.

During much of 1872 and 1873 there was little activity in the district. Only two mills appear to have been in operation near Austin, and the Manhattan mill was much the more productive. In 1872, according to the tax records, the Manhattan produced 1,793.91 tons valued at $252,143.91, and in 1873 the yield was 2,785.02 tons valued at $428,134.15. Its reduction works had cost the company about $180,000. The cost of the hoisting works and pumps at the different mines totaled $237,530.76. The prices of mines and other properties purchased within the previous 15 years totaled $91,712.83, and the cost of exploration and other dead work in opening the mine aggregated $200,000 (Raymond, 1873, pp. 138–141). The company's original debt in 1865 was $180,000. Its total capital investment up to this time was, therefore, about $890,000, much of which was paid out of profits.

In August 1873 (Raymond, 1873, p. 198), the Pacific Mining Co., the largest competitor of the Manhattan Silver Mining Co., failed, and the attempt to reorganize and resume operations apparently met with little success. At the time of its failure this company owned 68 mining claims, so grouped as to be equivalent to about 35,000 linear feet.

In 1875 the Manhattan Silver Mining Co. was reorganized and its main office transferred to San Francisco, but the local management remained the same. Its capital stock was increased from $387,500 to $1,000,000. By this time ranching had become so important that Lander County was no longer entirely dependent on mining.

In 1874, 1875, 1876, and 1877 the operations were so profitable that $566,320.59 is reported to have been paid in dividends [3] during the last 3 of those 4 years. The total dividends prior to 1875 were $96,875, according to Hague. The major period of prosperity terminated in 1877. In his report for 1878, Raymond noted that during 1877 and 1878 the bullion yield was insufficient to pay the cost of mining and milling, because of decrease in the grade of ore. At this time, according to him, the dividends that had been paid out totaled $400,000, less than 60 percent of the figure quoted by Hague. Gradually declining production, coupled with decreases in the price of silver, resulted in the levy of assessments of $150,000 in October 1878.

Allan Curtis' letter of January 31, 1879, summarizing the past year's operations, records a profit of $163,071.44, largely from the Frost and Curtis shafts, but concludes with the comment that, "Prospects for the coming year depend on the price of silver. At present prices the ore developed warrants no large profit." The same letter mentions 138 feet of sinking and 842 feet of drifting done in unsuccessful search for the Whitlatch vein on the southern slopes of Central Hill. This is one of the few references to activities of the Manhattan Co. in localities not on Lander Hill. Curtis' letter of January 24, 1880, summarizing the results of the previous year, notes that discounts and costs of shipment were equivalent to 17.65 percent of the value of the bullion that was shipped. Throughout the life of the Manhattan Silver Mining Co., such items constituted a major factor in the total costs. Subsequent to 1879, according to Hague, additional dividends totaling $37,500 were paid.

Although the company's operations were confined essentially to the eastern part of the developed area on Lander Hill (pl. 3), it had more than eight mines in operation, with separate hoisting equipment and separate cost accounts. These included the Frost, Curtis, Oregon, North Star, Bowman, Ogden, Isabella, Mohawk, and some smaller properties, some of which were in the southern part of the district. Pumping, which was one of the major items of expense, was concentrated at as few points as possible. Connections were run to carry the water from outlying workings to the pumping plants. By 1883 the workings were so interconnected that all the water was raised to

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[3] Hague, James D., Report on the properties of the Austin Mining Co., addressed to the president, J. G. Phelps Stokes, August 8, 1898. The only available copy of this report contains many obvious typographical errors. The figures quoted, however, are consistent with such other data as are available.

the surface through the Frost shaft, which eventually was used for this purpose exclusively. Allan Curtis started a drainage tunnel in lower Pony Canyon but did not drive it far enough to be effective. This tunnel was called the Clifton because its portal was in the old settlement of that name. It has since been extended as far as the Frost shaft. The company maintained a reduction mill in Pony Canyon at the upper end of the town of Austin. Ore from its own mines and custom ore from properties in the surrounding region were treated here. Throughout the history of the company the process consisted essentially in crushing the ore, roasting that which contained sufficient sulfide, and recovering the silver by amalgamation.

After the Stetefeldt furnaces were installed in 1870, the sulfide ore was chlorinated during roasting. Bar bullion was made from the amalgam. Commonly the mill was shut down from one to several months a year because of insufficient ore. During most of the period of operation of the Manhattan mill the charge for treating custom ore was $35 a ton and payment was made on the basis of 80 percent of the assay value. Ordinarily material valued at less than about $75 a ton was not treated, but in 1883 lower-grade material was handled for a time. According to advertisements in the Reveille, 10 percent of the value was paid on ore assaying $40 to $44 a ton, and the rate was increased to 24 percent for ore assaying $60 to $70 a ton. Throughout the life of the Manhattan Silver Mining Co. discounts on the price of silver and costs of shipping bullion were large elements in the total costs.

The Nevada Central Railroad, a narrow-gage line, was completed from Battle Mountain to Austin on February 9, 1880. This line was still in operation in 1937 and was reported to have some of its original rolling stock still in use. It went into the hands of a receiver in 1885, and apparently never attained marked financial success. In 1938 the line was abandoned, and the rails were sold.

In 1878 the decline in the number of individual operators became marked. In the earlier years well over 100 different names appear on the tax records for the district as a whole. In 1878 there were 20; in 1880 there were 12; in 1884 the number had dropped to 5; and from that time until 1888, the Manhattan was the only producer recorded in the district. In 1881 Melville Curtis became superintendent, a position that had been held by his brother, Allan Curtis, during most of the company's life.

About 1886 or 1887 the company became hopelessly in debt. A reorganization resulted in the appointment of J. J. Hanchett as local manager, but active underground operation was not resumed.

During the period in which the Manhattan Silver Mining Co. held the dominant position at Austin, several other organizations and individuals were working in the Yankee Blade and Midas Flat areas where considerable high-grade ore was found. In the Yankee Blade area water was struck closer to the surface and apparently in greater quantities than at Austin. The cost of pumping proved to be a serious handicap in the development of this part of the district. The initial activity died down by 1870 when the population of this part of the district had shrunk to 56 people. In 1875 and 1876 a marked increase in the number of producers in the Yankee Blade area was recorded by the County Assessor. The total production recorded for 1875 is 251.2 tons, valued at $42,316.15. This is the largest tonnage credited to this part of the district by the County Assessor in any 1 year, although there were several other years in which the value of the ore was higher. In the quarter ending December 31, 1882, the Patriot mine had a recorded production of 84.7 tons valued at $31,197.45. This constitutes the largest tonnage and value recorded in the tax books in any single quarter for any mine in the Yankee Blade area since 1865. According to the Reveille, this mine was operated at the time by Melville Curtis and his associates, a fact which suggests that, in view of the declining ore reserves in the mines of the Manhattan Silver Mining Co. at Austin, an attempt was being made to find another suitable place for mining. No other mine in the Yankee Blade area recorded any production in 1882. Four produced considerable amounts in 1883, and one, the Columbia, produced ore valued at $5,808.43 in 1884. From that date until 1891 no entry from this part of the district appears in the tax records.

Most of the references to production given above are based on the records of the successive county assessors. A State law levying a tax on gold and silver bullion made it the duty of the county assessors to collect from the mines and mills quarterly statements of the amount of ore mined and reduced, and the average yield per ton. Statements were taken under oath, with value estimated in coin (Brown, 1868, p. 403). Except for a few missing quarterly statements, the entire record thus compiled for 1865 through September 30, 1897, is on file in the Court House at Austin. Copies of most of the statements missing in these files have been published either in the Mint Report or in those of the State Mineralogist, so that an almost complete record is available for the entire period in which the district was actively productive. A summary of these records has recently been published (Vanderberg, 1939, p. 15).

Comments in the Mint Reports indicate that revisions in the tax laws exempted from record certain low-grade ores and the production of mines that yielded only small quantities of ore. Details concerning exemptions are not available but they cannot have affected materially the accuracy of returns from the Reese River district. Ore milled here has been with some exceptions, of high grade. During the early days, when a considerable fraction of the total production was obtained by small operators, there can have been no exemption from the duty of filing returns on the basis of small production. The quarterly tax records are full of items of less than 5 tons, and even of fractions of a ton, produced by individual operators. The tax records give the value of recovered bullion, whereas most other tabulations appear to be expressed in terms of assay value of the ore as delivered to the mills. The difference would be from 10 to 40 percent; in some instances even more. During most of its career the Manhattan Silver Mining Co. had such a large and superior mill that material was shipped there for treatment from mines within a radius of 75 miles or more. In the early years, especially, Austin was a shipping center for the surrounding region and was the point of delivery of much of the bullion from outlying camps to such companies as the Wells Fargo Express. Prior to such deliveries, permanent record may not have been made. Therefore much bullion that originated in mines in other camps was handled in Austin and thus swelled estimates of the production of the Reese River district.

One source of great uncertainty in comparing different estimates of production is in the wide differences in the prices received for the bullion and between such prices and the so-called coinage value of silver. Apparently during the early days of Austin, payment was made only for silver. Gold was present, generally, in negligible amounts, and other metals in the bullion only decreased its fineness and, therefore, its value. Available data on production give the silver in terms of dollars rather than ounces. Apparently, in most such lists the value was calculated at the coinage rate of $1.2929 per ounce. The amounts actually received by the operators differed in accord with various factors referred to as discounts, but in most instances were markedly different from the coinage rate. The table below, taken from Mineral Resources of the United States, gives an

Prices of silver, 1865–1884

[From annual volumes of Mineral Resources of the United States]

Year	Price	Year	Price	Year	Price	Year	Price
1865	$1.337	1884	$1.11	1903	$0.54	1922	$1.00
1866	1.339	1885	1.07	1904	.58	1923	.82
1867	1.33	1886	.99	1905	.61	1924	.67
1868	1.326	1887	.98	1906	.68	1925	.694
1869	1.325	1888	.94	1907	.66	1926	.624
1870	1.328	1889	.94	1908	.53	1927	.567
1871	1.325	1890	1.05	1909	.52	1928	.585
1872	1.322	1891	.99	1910	.54	1929	.533
1873	1.297	1892	.87	1911	.53	1930	.385
1874	1.278	1893	.78	1912	.615	1931	.290
1875	1.24	1894	.63	1913	.604	1932	.282
1876	1.16	1895	.65	1914	.553	1933	.350
1877	1.20	1896	.68	1915	.507	1934	.646
1878	1.15	1897	.60	1916	.658	1935	.719
1879	1.12	1898	.59	1917	.824	1936	.77
1880	1.15	1899	.60	1918	.980	1937	.77
1881	1.13	1900	.62	1919	1.12	1938	
1882	1.14	1901	.60	1920	1.09	1939	
1883	1.11	1902	.53	1921	1.00	1940	

idea of the average annual prices paid for silver in the United States. During the period of operation of the Manhattan Silver Mining Co., the Reese River district was remote from markets, and its bullion cannot, on the average, have been of high purity. Such factors lowered the prices obtained for bullion, so that they must frequently have been less than those given in the table. For example, Raymond (1873, footnote p. 180) remarks that in 1871 Selby & Co. of San Francisco generally paid $1.15 an ounce for silver, instead of the $1.325 listed in the table. Again, on October 15, 1878, the Reveille notes that the New York price for silver was $1.08 an ounce, subject to a discount of 20 percent on silver from Austin. At first, when silver was at a premium, the coinage rate was used in calculating the value of the yield for tax purposes. No record has been found concerning the basis of calculation after 1873, when commercial prices dropped below the coinage rate, but probably the assessor's returns did not exceed the actual payments received for the bullion. In the late seventies and later the difference would be material.

The following table gives data summarized from the tax records and, for comparison, from available annual reports of the superintendents of the Manhattan Silver Mining Co. Some of the reports are taken from direct copies of letters on file in the office of the Austin Silver Mining Co.; others have been published in the annual Mint Reports. The superintendents' letters do not always refer to

Summary of records for the Reese River district through 1865–1887

Assessors' records					Reports of mine superintendents [1]	
Year	Total production (tons)	Gross value of bullion	Production of Manhattan Silver Mining Co. (tons)	Value of bullion Manhattan Silver Mining Co.	Tons of ore	Value
1865	5,013.50	$551,179.04	745.00	$66,917.98		
1866	5,083.68	627,000.09	333.14	32,836.78		
1867	[2] 5,085.00					
1868	5,370.31	1,239,335.54	2,141.07	339,079.02		
1869	3,943.64	643,871.22	1,222.63	141,825.23		
1870	[2] 3,600.00	[2] 707,964.33				
1871	4,378.08	725,615.04	1,371.19	275,728.38	1,537.00	$387,589.00
1872	4,652.16	578,940.75	1,793.91	252,163.91	1,741.55	335,876.18
1873	4,165.12	653,989.71	2,785.39	428,134.15		
1874	6,486.66	836,611.13	5,331.00	630,676.90	5,330.56	898,478.44
1875	6,153.14	885,568.83	4,820.10	602,860.13		
1876	7,992.04	754,718.50	5,217.50	511,769.85		
1877	4,685.66	557,047.98	4,143.13	421,065.96		
1878	5,654.91	662,990.11	5,259.80	528,550.46	5,588.86	848,648.75
1879	3,084.31	537,083.56	3,430.75	400,698.08	3,384.49	589,511.53
1880	2,608.49	533,997.22	2,430.51	479,662.76	2,861.61	719,106.96
1881	3,777.51	782,279.86	3,416.36	663,000.95	2,133.74	613,897.19
1882	2,220.25	522,429.28	2,051.46	440,452.97	2,295.50	587,724.01
1883	4,638.07	826,716.24	4,392.60	766,937.43		
1884	3,553.45	701,097.93	3,171.75	633,165.36		
1885	1,542.75	406,408.83	1,546.75	499,799.24		
1886	1,765.75	245,907.80	1,765.75	245,907.80		
1887	3,253.25	231,457.80	3,253.25	231,457.00		
Total	98,707.73	14,212,210.79	60,623.04	8,592,670.34		

[1] Bullion yield from mines of the Manhattan Silver Mining Co. as reported to the home offices.
[2] Estimated from incomplete records.

calendar years. Some, for example, are from November to November. This doubtless explains the fact that the tax records for the 8 years for which figures from both sources are available differ from the superintendents' reports. They show about one percent larger tonnage. On the other hand, the value of the product as reported by the superintendents to their main offices is nearly 36 percent greater than that reported to the assessors for the years for which both records are available. This difference seems best accounted for by some such differences in the basis of calculation as those referred to above. If milling losses of 10 to 25 percent and discounts on bullion as much as 20 percent are to be subtracted from the figures in the superintendents' reports, the totals might well be reduced by the 36 percent that is necessary to bring them into line with the tax records.

Hague (p. 31) evidently had access to records of the Manhattan Silver Mining Co. not now available. He states that in a period of "more than 20 years" the company had "a mill production of more than $18,000,000, reckoned at coinage value, or with due allowance for actual discounts in the price of silver, say a money value of $14,-000,000 to $15,000,000. * * *" He says that the mill ore produced from 1868 to 1881, inclusive, amounted to 70,227 tons with an average assay value of $223.56, of which 90 percent was recovered in the mill. This would be equivalent to a total yield for the period of $14,-129,953.33. Hague's report also says that the total product of the company's mines and mill from the beginning through 1886 "would doubtless be little more than 100,000 tons with an assay value of $20,000,000 to $22,500,000." Apparently in all three estimates custom ores are included in the mill production. If so, the first two estimates and the tonnage estimate in the third agree fairly well with the tax records, but the estimate of $20,000,000 or more for the total yield is high as compared with these records.

It is striking that for the period from the start of operations through 1886, the average production per day appears to have been less than 20 tons from all sources within the district. The Manhattan mill, whose daily capacity was about that amount, was idle from one to several months each year because of lack of ore. These facts emphasize the difficulties in mining ore shoots that are so narrow and so discontinuous as those of the Reese River district.

The Reveille of February 13, 1891, presents a table summarizing the production of the Reese River district for 1865 to 1888, inclusive, which is reproduced below. A table giving almost identical values for the years 1865 to 1879, inclusive, but without data on tonnage, appears in the Reveille of October 4, 1880. Although the article printed in 1891 states that the data are introduced "to give an idea of output of the mines situated on Lander Hill," and are "the exact figures," the totals, and especially the tonnages, are so large that they cannot represent material mined in the Reese River district alone. This is corroborated by the fact that for the 2 years that the total value of bullion shipped from Austin by Wells Fargo is known the values agree with the corresponding items in the table below.

Production of the Reese River district 1865–1888

[From the Reese River Reveille of February 13, 1891]

Year	Tons of ore produced	Value	Year	Tons of ore produced	Value
1865		$782,368.18	1878	87,145	$1,181,307.62
1866	20,676	400,587.07	1879	70,677	934,774.43
1867	123,527	1,872,264.23	1880	70,559	985,481.63
1868		2,745,948.63	1881	73,850	1,026,685.55
1869	64,677	939,635.55	1882	61,409	877,865.78
1870	60,250	895,888.71	1883	93,150	1,337,799.75
1871	103,231	1,166,707.31	1884	80,592	1,186,555.43
1872	84,675	1,074,618.92	1885	51,925	792,810.26
1873	70,670	985,717.47	1886	40,370	577,651.94
1874	91,914	1,165,594.88	1887	34,759	532,751.75
1875	88,975	1,196,015.24	1888	2,707	31.531.65
1876	84,828	1,224,590.19			
1877	67,428	1,015,157.75	Total	1,527,994	24,930,309.92

Undoubtedly Wells Fargo shipped from Austin bullion that had its origin throughout the surrounding region. The table serves, however, to emphasize the fact that recent estimates of $50,000,000 and more for the production of the Reese River district are far too high. Estimates of this magnitude appear in the Reveille from time to time during the present century, but are unsupported by any details.

Taking into consideration the probable production prior to 1865, and probable deficiencies in the tax records, it can be assumed with considerable confidence that the mines of the Reese River district through 1887 produced between 100,000 and 150,000 tons, which yielded silver worth between $15,000,000 and $20,000,000. The most liberal estimates for which there appears to be any support would make the total value of the product during this period not over $25,000,000. Vanderburg (1939, p. 70) has recently estimated that the production from 1862 to 1903 was about $26,000,000. As the production during the latter part of this period was not large his estimate is somewhat more liberal than that adopted here.

THE INTERIM PERIOD

In December 1887 the "personal property" of the Manhattan Silver Mining Co. was sold by the sheriff to the Lander Co. After some litigation, the Manhattan Mining & Reduction Co. was organized. A little work was done in the mines in 1888 and 1889, mainly by lessees. At this time much of the activity appears to have been at the Plymouth and Union shafts. In 1890 the former was abandoned, and company work was concentrated at the Union, southeast of Austin, with 45 men employed there. Early in the year the ore from this mine averaged 250 ounces to the ton. This is the first time that the principal company in the camp concerned itself mainly with any part of the district other than Lander Hill, although the Union mine had been brought into production by the Manhattan Silver Mining Co. some years earlier. At this time Austin had a population of 1,215. In June the Patriot mine, in the Yankee Blade area, was pumped free of water down to the 500-foot level on the incline.

The tax records show that the Manhattan Mining and Reduction Co. produced 15,590.26 tons, valued at $286,556.86 from 1888 through June 1891. A considerable part of this came from the old dumps, mainly on Lander Hill, which explains the low average value per ton. According to Hague,[4] these operations were conducted at a net loss. The table below, compiled from the annual reports of the Director of

Production of the Manhattan Mining & Reduction Co., 1888–1891, according to the Mint Reports

Year	Tons produced	Yield	Cost
1888	335. 62	$29, 987. 48	$32, 810. 20
1889	12, 429. 51	115, 802. 47	121, 390. 22
1890	2, 398. 49	82, 577. 45	88, 076. 76
1891	217. 05	32, 043. 85	29, 867. 15
Total	15, 380. 67	260, 411. 25	272, 144. 33

the Mint, is in essential agreement with the tax records. It also supports Hague's statement that operations were unprofitable. The data in the Mint Reports doubtless are based largely on the county assessors' compilations, but they are not identical, a fact which suggests that independent data were obtained.

On September 8, 1891, according to the Reveille, all the property of the Manhattan Mining & Reduction Co. was acquired by the Austin Mining Co. This new company, with P. T. Farnsworth as manager, deepened the vertical shaft at the Union mine from the 200- to the 700-foot level and stoped ore in several veins.

The Clifton drainage tunnel, which had been begun by Allan Curtis early in the operations of the Manhattan Silver Mining Co. and extended somewhat by Hanchett near the end of that company's life, was reopened by the Austin Mining Co. in 1893. The water in the old workings on Lander Hill was tapped by the tunnel in 1896, and successfully drained. This tunnel, when completed, was about 6,000 feet long and had one long crosscut leading from it. Some development work was done on veins encountered in the tunnel and

[4] Hague, J. D., Report on the properties of the Austin Mining Co., addressed to the president, J. G. Phelps Stokes, August 8, 1898, page 4, unpublished.

the crosscut, but the Austin Mining Co. stoped little ore from the tunnel level.

A large mill near the mouth of the Clifton tunnel was completed in January 1897 but was never operated more than a few weeks. From about this time on the operations of the Austin Mining Co. were curtailed. Beginning in the following year, a series of civil suits were filed by the Nevada Co. and the Austin Mining Co. against P. T. Farnsworth. J. G. Phelps Stokes was president of both companies. The suits were brought in the belief that Farnsworth, the manager at Austin, through misrepresentation or concealment, had acquired larger personal profits in certain business transactions conducted for the two companies than was legitimate. Judgments against Farnsworth amounting to several hundred thousand dollars were secured in several of these suits.

The following table summarizes the tax records for the period from the close of the activity of the Manhattan Silver Mining Co. in

Summary of the assessor's records of production for the Reese River district from 1888 to 1897, inclusive

Year	Total production (tons)	Gross value of bullion yielded	Year	Total production (tons)	Gross value of bullion yielded
1888	340.48	$29,987.48	1894 [1]		
1889	12,429.51	115,802.47	1895	402.13	$73,604.75
1890	2,484.14	94,596.41	1896	438.51	57,745.37
1891	723.00	70,569.56	1897 [2]	262.27	46,372.37
1892	863.00	119,121.10			
1893	2,232.30	144,863.53	Total	20,175.34	752,663.04

[1] No record.
[2] For first 3 quarters only.

1887 through September 30, 1897, the date of the last entries found in the county courthouse. So far as can be judged from the tax records, nearly the entire production of the district was obtained by the Manhattan Mining & Reduction Co. and its successor, the Austin Mining Co. During this period the principal new development was in the Union mine, but the yield from dumps on Lander Hill and from operations in the Yankee Blade area is grouped with that from the Union in the tax records. Hague [5] states that from the beginning of the operations of the Austin Mining Co. in 1891 to June 30, 1898, the total realized value of the product was $482,077.57. The Mint Reports give data on the production of this company for the years 1891 and 1892 only. For this period they record a production of 1,066 tons, which yielded $119,084.30 at a cost of $151,137.05. So far as they go, these figures support Hague's statement that the value of the total production of the company was roughly equal to its

[5] Hague, J. D., op. cit., p. 12.

cost of operation. Both in tonnage and yield they are somewhat lower than the corresponding data in the tax records. Hague's statement of total yield is in reasonably close agreement with the total of $444,773.83 for the same period shown by the tax record, with 1894 missing. To this should be added the sum of $21,432.32, which, according to the tax records, was produced in the quarter ending September 30, 1897. Hence, in the period from the end of 1887 through 1897 the district had an aggregate production of nearly 20,400 tons, which yielded about $890,066.74. The large amount of dump material accounted for the low average yield. The scattered data at hand show that much of the ore obtained from the Union mine at this time yielded over $100 a ton. Apparently the estimates of costs referred to above are independent of any losses sustained by the company as a result of the transactions for which Farnsworth was sued.

In 1900, only 702 people were recorded in Austin by the Census Bureau. In the early years of the twentieth century little mining was done at Austin, but there was some activity in the Yankee Blade area. The Watt (Cambrian) mine in New York Canyon was reopened and some material mined. In 1905 the Austin Gold Mining Co. did some work in what is now called the Byers incline, south of Austin. The ore found in June of that year was reported to assay 1.75 ounces of gold and 150 ounces of silver to the ton, and similar ore was also found in July. About the same time work was in progress at the Jackpot mine, still farther south. The Reveille of August 5, 1905, reports a shipment of 13 tons valued at $480 by T. G. Elgie from this mine. Activity in the Yankee Blade area continued on a small scale. On July 12, 1905, the Reveille reported that a vein 8 inches wide, with an average content of 11,000 ounces of silver to the ton, had been struck in the Watt mine. In 1905 to 1907 the principal mines at Austin were held by the Austin-Hanopah Mining Co., but this organization appears to have done almost no mining. In the fall of 1907 the Nevada Equity Mines Co. began operations on a group of claims north of the mouth of Pony Canyon and northwest of those formerly worked on Lander Hill. On November 30, 1907, the Reveille reported a rich strike in the Jackpot mine. It quoted assays of 2.1 ounces gold and 361 ounces silver, and of 3.4 ounces gold and 365 ounces silver to the ton. During the same year some work was also done at the Luetgen tunnel and on the X-Ray and Baker properties. All of these are south of Lander Hill, in a part of the Austin area that had hitherto received little attention.

Early in 1908 the property of the Austin-Hanopah Mining Co. was obtained by the Austin-Manhattan Consolidated Mining Co. In May 1908, the new company had begun work in the Clifton tunnel and also at the Union shaft. At this time work was continuing in the Yankee Blade area, particularly in the Watt mine reported by the Reveille of January 15, 1908, to have a past production of $100,000. Ore was also shipped from the Jackpot and Dudley B. in the southern part of the Austin area. The Reveille of April 10, 1909, reports that the Clifton tunnel had been reopened to the Frost shaft at a cost of $50,000. The work of reopening the north lateral and of cutting a station preparatory to sinking at the Frost shaft was then undertaken. The north lateral, which is reported to have yielded some ore to previous operators, was not completely reopened by this company. In May 1909, the Austin-Nevada Consolidated Mining Co. began work on ground east of the developed area on Lander Hill, and the Maricopa Mines Co. began to reopen the Patriot mine in the Yankee Blade area under lease from the Austin-Manhattan Consolidated Mining Co.

In 1910 some work was done in the Union and Jackpot mines. A winze from the Frost station cut a vein about 80 feet below the level of the Clifton tunnel. An electrostatic mill of 25-ton capacity was built and put in operation on material from the Jackpot. Of the two veins exposed in this mine, one was reported to contain ore valued at $10 a ton, and the other at $25 to $80 a ton. At this time the population of Austin was 755 people, a slight increase over 1900, but still far below that of its prosperous years. In 1911 operations continued at the different properties in much the same fashion. On August 26, 1911, the Reveille noted that since the previous November the Jackpot had produced ore that had been sold for more than $80,000.

In 1912 the Austin-Manhattan Consolidated Mining Co. suspended operations. The Maricopa Mines Co. and Austin-Nevada Consolidated Mining Co. did some work that year and the next. On March 22, 1913, the Reveille reported that the Maricopa mill, at the mouth of New York Canyon, had made its first clean-up, which yielded $6,000. A few days later it shut down for repairs and has never been reopened.

In 1914, the Austin-Dakota Development Co. began work on the OK mine, in the southern part of the Austin area. By September 1915, the shaft had been driven to the 300-foot level on the incline. At this time they shifted operations to the nearby X-Ray mine, where they began to sink a vertical shaft. For several years following this the Austin-Dakota Development Co., working at the X-Ray, the Dalton, and other places in the southern part of the Austin area, continued to be one of the principal operators in the district, although little ore was ever shipped. The Nevada Equity Mines Co. and the Austin-Nevada Consolidated Co. continued to work sporadically at the opposite ends of Lander Hill. The Nevada Jackpot Mining Co. did some work at the Jackpot and neighboring mines. A little ore was shipped from the Watt and other mines in the Yankee Blade area. On the whole, however, activity was declining. In 1920 the population of Austin was only 666 people.

The Austin-Dakota Development Co. appears to have ceased work in 1920, and the Nevada-Equity Mines Co. and Austin-Nevada Consolidated Co. have accomplished little since 1922. In the following 12 years mining was essentially at a standstill throughout the District. During this period the population of Austin remained nearly the same, consisting of 661 people in 1930.

From 1897, when production fell so low in proportion to costs that the assessors ceased to gather data, until 1902, when the Geological Survey began compilation of statistics for precious metals, little detailed information is available regarding the production of the district. The total yield during these 4 years must have been very small. The table (pp. 44–45), compiled by C. W. Merrill, summarizes the available data from 1902 through 1936. During this period most of the activity was in the Yankee Blade area and other outlying parts of the Reese River district.

The most striking feature of the table is that for the first time in the history of the camp, recovery of metals other than silver is recorded. These metals were present in the material mined throughout the history of the district but during most of the time could not be profitably recovered. The content of gold in the ores of Lander Hill was too small to be of economic importance and material containing base metals was avoided as much as possible because these metals served only to contaminate the bullion. The record for 1902 to 1905 in the table (pp. 44–45) is probably incomplete, or it refers to material from some neighboring area. Probably no ore in the Reese River district was mined solely for its gold content. Possibly some of the other ore included in the table originated outside of the Reese River district, as that term is used here.

RECENT ACTIVITY IN THE AREA

The increase in production recorded in 1935 and 1936 reflects the activity of the Austin Silver Mining Co. Since that time production has been very small. Notably, the gross value of the ore mined since 1902 is only $14.94 per ton, in contrast to that of the early days. The first year that the Austin Silver Mining Co. operated the value rose sharply, mainly because stringers of rich ore were found in the older mines. The decrease to a value of $5.61 per ton in 1936, is due largely to treatment of low grade material from old dumps.

In 1936 the Isabella and Magnolia workings were reopened and some material was taken from the gob and pillars in the old stopes.

The Reveille of March 14, 1936, in summarizing the operations of the company says that 1,588.25 tons were treated in the new mill through February 29, 1936. Of this, 399 tons were stope fill from Lander Hill; 20 tons were newly mined ore from the Isabella; 244.75 tons of an average tenor of 9.87 ounces silver came from the X-Ray, OK, and Pony dumps; 100 tons came from the Gold Star dumps and 267.5 tons of newly mined material came from the same property; 100 tons came from the Belle Wilder; and 273 tons of custom ore was treated. At that time the mill was running two shifts and treating 40 tons per day at a reported cost of $1.45 a ton. During the spring and summer work continued in the Isabella and the Diana was reopened. The mill capacity was somewhat increased, and the mill was operated mainly on material from the dumps on Lander Hill and other parts of the Austin area. Apparently much of the dump material averaged 3.5 to 4.0 ounces of silver to the ton. The grade was raised by screening and hand-sorting, so that the mill heads from the dump were reported to average 12 ounces of silver to the ton.

In September 1936, the Jackpot mine was reopened, and for the next year the principal underground work was done in this mine, although some work was also done in the Bartlett and Luetgen tunnels and in other places. The mill was not operated during the winter but was reopened in the summer of 1937 to treat rock from the dumps in the southern part of the Austin area, together with a little newly mined material from the Jackpot. About 90 tons daily were being treated in September 1937, when the field work of the present study was completed. Shortly afterwards the Jackpot was shut down, and activity was centered on the reopening of old workings on the southern slope of Central Hill. According to reports, all operations were suspended in January 1938.

A number of other operators were engaged in development work in the district in 1937 and subsequent years. Some of them have shipped small amounts of ore in recent years. Most have small mines on the borders of the more productive areas, such as the Roosevelt in the town of Austin, and the Gus Laurent and Rundberg properties near the southwest boundary of the Austin area. Lessees did some work in 1937 at the old Watt mine in the Yankee Blade area, and at that time the Austin Syndicate, the successor to the Maricopa Mines Co., began to reopen the True Blue tunnel in the same area, but there is no record that much was accomplished.

Very little mining appears to have been carried on from 1938 until the spring of 1946 [6] when the Nevada Equity Mining Co. was formed to explore the Kilborn or Nevada Equity group of claims north of

[6] This paragraph is based on notes furnished by Robert H. Baring of Battle Mountain, Nev., August 1950, who was the engineer in charge for the Nevada Equity Mining Co.

Gold, silver, copper, and lead production from Reese River district, Lander County, Nevada, 1902–1936, in terms of recovered metal

[Compiled by Charles White Merrill, Mineral Production and Economics Division, Bureau of Mines (Vanderburg, 1937, pp. 71–72)]

Year	Placer						Lode			
	No. of mines	Gold		Silver		Total value	No. of mines	Ore, short tons	Gold	
		Fine ounces	Value	Fine ounces	Value				Fine ounces	Value
1902							1	50	26.60	$550
1903 [1]								3,000	500.00	10,000
1904										
1905							3	205	77.64	1,605
1906							4	193	54.71	1,131
1907							2	586	32.26	667
1908							10	161	65.55	1,355
1909							3	618	158.28	3,272
1910							6	674	182.11	3,765
1911							7	3,043	1,054.61	21,801
1912							8	86	76.25	1,576
1913							8	3,952	199.44	4,123
1914							4	3,015	12.22	253
1915							4	63	12.79	264
1916							2	78	.20	4
1917							7	101	7.50	155
1918							9	107	54.96	1,136
1919							4	55	2.54	53
1920							5	121	33.13	685
1921							3	18	2.79	58
1922							2	52	32.07	663
1923							2	9	1.35	28
1924							2	231	9.66	200
1925							1	1	1.01	21
1926							2	40	18.20	376
1927	1	1.71	$35	2	$1	$36	4	42	6.65	137
1928–29										
1930							2	28	14.25	295
1931										
1932							1	36	40.14	830
1933	1	1.56	40			40	3	7	12.25	313
1934							5	12	7.92	277
1935							8	966	33.51	1,173
1936							8	7,682	79.50	2,783
Total		3.27	75	2	1	76		25,232	2,810.09	59,549

Year	Lode								Total value (lode and placer)
	Silver		Copper		Lead		Total value	Average recoverable value of ore per ton [2]	
	Fine ounces	Value	Pounds	Value	Pounds	Value			
1902							$550	$11.00	$550
1903 [1]							10,000	3.33	10,000
1904									
1905	22,321	$13,482					15,087	73.60	15,087
1906	54,634	36,605	3,109	$600	14,000	$798	39,134	202.77	39,134
1907	27,788	18,340	2,640	528			19,535	33.34	19,535
1908	15,953	8,455	212	28	6,691	281	10,119	62.85	10,119
1909	9,127	4,746	1,562	203	19,837	853	9,074	14.68	9,074
1910	27,159	14,665	6,797	863	72,076	3,172	22,465	33.33	22,465
1911	101,592	53,844	1,972	246	29,067	1,308	77,199	25.37	77,199
1912	3,390	2,085	12	2	47	2	3,665	42.62	3,665
1913	18,246	11,021	348	54	922	40	15,238	3.86	15,238
1914	12,783	7,069	104	14	4,076	159	7,495	2.49	7,495
1915	4,745	2,406	96	17			2,687	42.65	2,687
1916	3,707	2,439	121	30			2,473	31.71	2,473
1917	3,455	2,847	284	78	10,476	900	3,980	39.41	3,980
1918	7,638	7,638	181	45	3,227	229	9,048	84.56	9,048
1919	4,013	4,495	35	7	43	2	4,557	82.85	4,557
1920	8,810	9,603	153	28	3,754	300	10,616	87.74	10,616
1921	2,575	2,575	225	29	1,563	70	2,732	151.78	2,732
1922	4,972	4,972	39	5	124	7	5,647	108.60	5,647
1923	984	807					835	92.78	835
1924	2,571	1,723			3,009	241	2,164	9.37	2,164
1925	1	1					22	22.00	22
1926	1,300	811					1,187	29.68	1,187
1927	7,134	4,045	652	86	3,934	248	4,516	107.52	4,552
1928–29									
1930	1,647	634					929	33.18	929
1931									
1932	384	108			363	11	949	26.36	949
1933	223	78			56	2	393	56.14	433
1934	4,554	2,944	101	8	311	12	3,241	270.08	3,241
1935	16,179	11,629	647	54	14,702	588	13,444	13.92	13,444
1936	51,504	39,890	1,869	172	5,897	271	43,116	5.61	43,116
Total	419,389	269,957	21,159	3,097	194,175	9,494	342,097	13.56	342,173

[1] Added from other sources by C. P. Ross, and totals modified accordingly.
[2] Not to be confused with average assay value of ore.

Pony Canyon and west of the principal old workings on Lander Hill. They later acquired options on a group of 39 patented claims east of those on which they started. These claims, called the Lander Hill group, appear to have included those described in the present report as the property of the Lander Hill Mining Co. It is not clear from available data whether the claims southeast of the principal workings on Lander Hill that were reported in 1937 to be held by the Lander Hill Mining Co. were included. The Nevada Equity Mining Co. is reported to have opened a 1,700-foot adit in which six veins were encountered, all too narrow to be valuable. Later the Hillside shaft was cleaned out and rehabilitated down to its bottom, about 200 feet on the incline. This shaft is 800 feet southwest of the Belle Wilder incline. A drift was opened off the inclined shaft on the so-called 200 level, following a vein reported to average 3 feet in width and containing an average of 7 ounces of silver, with notable amounts of lead and zinc and some copper. This work was followed by drifting west at the bottom of the incline on a vein said to have yielded higher assays than that on the 200 level. However, this drift was not carried far enough to give conclusive information. Prospecting was also done off the Belle Wilder incline, where a vein 2½ feet wide was found. It contained 6 ounces to the ton of silver and appreciable quantities of lead and zinc. The Nevada Equity Mining Co. also did an aggregate of 1,438 feet of diamond drilling on Lander Hill. Assays made during their underground work are reported to have revealed indium associated with zinc and cadmium in the sulfide ore. A little nickel and, in some samples, platinum, as much as 0.30 ounce to the ton, were noted. The Castle Mountain Mining Co. did some work in the vicinity of the Castle and built a small mill in Marshall Canyon. This company worked in 1947, 1949, and 1950. Apparently little or no other mining has been done in recent years in the area covered by the present report.

EVALUATION OF THE RECORD

It is clear that the years from 1866 to 1886 is the only period in the 92 years of the district's history that any considerable profits were made. In this period a number of miners, acting as lessees under some of the larger companies, or as individuals and groups working small mines independently, earned much more than prevailing wages by carefully hand-sorting silver ore. On the other hand, many such men worked for months or years with slight returns for their labor. As roughly 40 percent of the total production of the camp was the aggregate result of the work of hundreds of small operators and most of the rest was mined by lessees, it may be assumed with confidence that many individual miners, prior to 1887, found work in the district profitable. So far as the record shows, few of them acquired wealth, and since 1887 few, if any, have earned more than an average wage for any considerable interval of time.

The Manhattan Silver Mining Co., by far the most successful of the larger operators, produced something over $8,000,000 from its own mines and treated custom ores that may have aggregated $5,000,000. According to J. D. Hague, it paid $700,695.39 in dividends and prior to 1887 levied $150,000 in assessments, making a net disbursement of profits of $550,695.39 during its life of a little over 20 years. If Raymond's figures are complete the net disbursement would be only about $287,000. Its capital stock for the last half of its career was nominally valued at $1,000,000, but its actual value is not known. The cost of purchasing, equipping, and developing the property must have been large, but part of this expense was paid out of operating profits in the early years. It seems possible, therefore, that the net dividends of this one company may have exceeded the original purchase price of its stock. Apparently each of its larger competitors either went bankrupt or sold out to it after a brief period of operation. Although complete data are not available, the total silver produced between 1862 and 1887 cannot greatly exceed $20,000,000 in value. The tax records suggest a materially smaller total. Prior to the Austin Silver Mining Co., each of the successors to the Manhattan Silver Mining Co. that has attempted actual mining operations on any considerable scale has ended in bankruptcy. The total gross production of these successive companies in the 50 years prior to 1938 has been only about $1,000,000, and a considerable part was from the reworking of old dumps.

MINERALOGY

Quartz, of several varieties, constitutes the principal gangue mineral in all of the lodes. In places it is almost the only mineral. Most of the veins contain milky quartz, irregularly distributed, flamboyant, clear quartz, mosaics of clear quartz in distinct, parallel bands, and in a few places a fourth variety that consists of highly irregular grains cut by chalcedony. Distinct quartz crystals occur with each variety but are rarely abundant. Some quartz extends into the wall rocks.

The carbonate minerals that are locally abundant include calcite, rhodochrosite and ankerite. Calcite is disseminated in the wall rocks and is locally in veinlets that cut both the veins and the wall rocks. Rhodochrosite is most conspicuous in the veins of Lander Hill but is also present in places farther south. Possibly rhodochrosite is concentrated in the parts of the veins, that contain the silver minerals but available data are inconclusive. Ankerite takes the place of rhodochrosite in veins in the Yankee Blade area but is rare elsewhere.

Sericite is plentiful in the altered wall rocks and in gouge. Chlorite in small amounts is also locally present in these rocks and is the principal mineral in the gouge along some fracture planes. Clay minerals are not plentiful in the veins, and much of the clay found near the surface is doubtless a result of weathering. Tourmaline and rutile occur locally in the wall rocks and in pegmatitic dikes and veins.

Data on the sulfides are incomplete because little rich ore was available for the present study. The sulfides that have been recognized include pyrite, galena, sphalerite, chalcopyrite, arsenopyrite, tetrahedrite, stibnite, and proustite, with a little covellite and chalcocite. Small quantities of molybdenite were recognized in the veins in quartzite. Several other sulfides have been reported from the veins on Lander Hill. Pyrite is the principal sulfide in much of the vein matter which, like that in the Jackpot, contains appreciable gold. Arsenopyrite, although widely distributed, is particularly conspicuous near New York Canyon. Galena, sphalerite and chalcopyrite are comparatively abundant in the western part of Lander Hill and around North Hill. Proustite and similar sulfides, to which the district owes its fame, are particularly abundant on Lander Hill but have been recognized also in other parts of the district, especially south and east of the crest of Central Hill.

The products of oxidation of the sulfide minerals are said to have been plentiful in the shallow workings on Lander Hill but are now so rare that little was learned in regard to them. The common oxides and carbonates of iron, copper, and manganese are widely but sparsely distributed, and several sulfates are locally present.

VEIN QUARTZ

Quartz is the principal gangue mineral in all the veins in the district. In most places it is the only nonmetallic mineral visible on casual inspection. Under the microscope, vein matter from the vicinity of Austin commonly shows three or more varieties of quartz, and that from veins in the quartzite of the Yankee Blade area contains at least two varieties. Each variety of quartz records a different stage in the process of vein filling. The different stages are not necessarily synchronous throughout the district.

Near Austin a large part of the vein quartz consists of mosaics of milky white grains, which under the microscope appear to be dusty with inclusions. This variety is widespread and appears to have been deposited during the first stage of vein filling, apparently before most of the valuable minerals had crystallized. Much of it is devoid of sulfides except for sparse pyrite cubes. The maximum dimensions of the milky grains are 5 millimeters or more, but commonly they are

2 to 3 millimeters. Some of the inclusions are tiny grains of birefringent minerals, probably mainly sericite, but most are minute cavities. Many of the cavities are rounded and have diameters of 0.003 millimeter and less. Some are drawn out into lenticular forms that may be as much as several hundredths of a millimeter long. Some of the larger cavities have the form of negative crystals, and a few contain visible bubbles in liquid. Most of the cavities, however, are too small for such features to be seen clearly. Commonly the cavities and other inclusions are arranged along straight lines, and in many quartz grains two or more sets of such lines cross each other. In some grains lines of cavities or, more rarely, sericitic inclusions outline several successive parallel sets of crystal faces. The outlines of the present grains, however, are irregularly rounded and show little relation to crystal form except that their longest dimensions correspond roughly to the C-axes of the crystals as outlined by the growth lines. These axes, in neighboring grains, appear to be heterogeneously arranged with respect to each other. Especially perfect growth lines, like those described above, are shown in a photograph of a specimen from the Union mine described by Adams (1920, pl. 23*A*). These features are also illustrated in figure 8.

In places near Austin hexagonal crystals of quartz are surrounded by irregular zones of radiating flamboyant grains. These crystals are similar in average size and commonly in content of inclusions to the milky grains described above. They may be merely milky grains

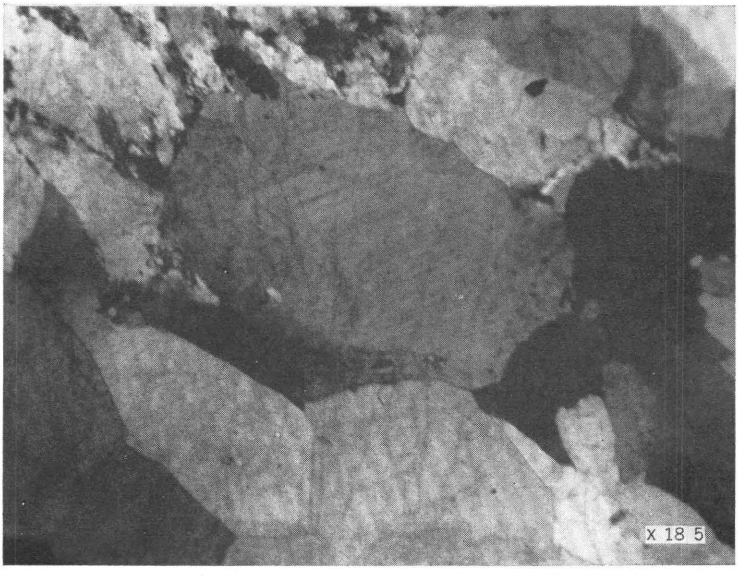

FIGURE 8.—Photomicrograph of vein matter from the Belle Wilder showing growth lines corresponding to crystal faces within irregular grains of milky quartz. Crossed nicols. × 18.5.

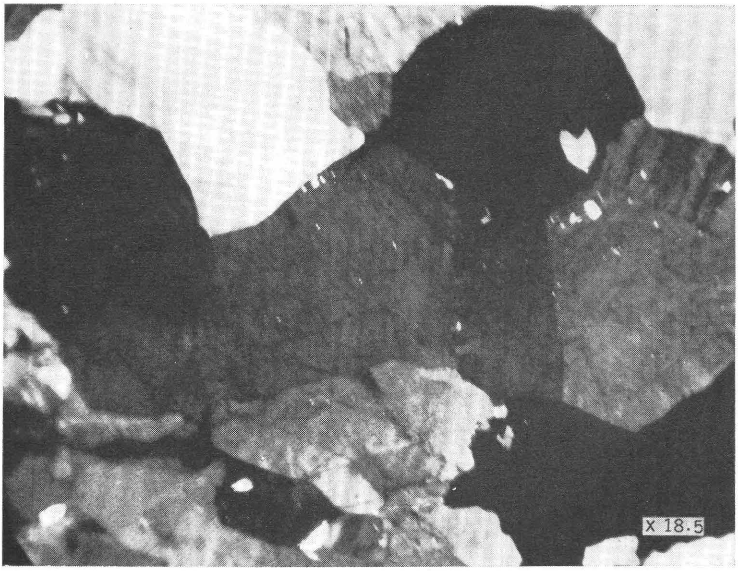

FIGURE 9.—Photomicrograph of vein matter from the Belle Wilder. Shows crystals of old quartz, with growth lines, surrounded by aurioles of later quartz. Two such crystals are clearly visible, and others are present. Crossed nicols.

that maintained their crystal form throughout deposition of this variety of quartz and have since been surrounded by haloes of later quartz. Figure 9 shows an example.

Much of the vein filling consists of irregularly distributed, more or less distinctly flamboyant grains of nearly clear quartz that have a maximum length of about a millimeter. Here and there grains with crystal faces, otherwise similar in size and clarity to the flamboyant grains, are present. Aggregates of the flamboyant grains cut across grains of milky quartz and fill fractures in shattered aggregates of such quartz.

Still another variety of quartz that is common in the veins near Austin consists of mosaics of irregular to rounded, clear grains, few of which are much over 0.1 millimeter in maximum dimension. The grains within the mosaic rarely have crystal form but in places perfect, doubly terminated crystals of similar size are enclosed in large grains of quartz of other varieties. The fine mosaic forms parallel bands, roughly 0.5 mm in width, that cut across quartz aggregates of the varieties described above. In and near ore shoots these bands are closely spaced and conspicuous, but in the comparatively barren parts of the veins they are rare or absent. In addition to the sharply marked nearly straight bands, quartz of similar appearance forms irregular aggregates and stringers. In places stringers of this material lie along the boundaries between large grains of older quartz and appear to merge into the latter.

Nearly all the quartz in the veins of the Austin area belongs to the varieties described above. In minor prospect pits near the crest of Lander Hill and on hills north of Slaughterhouse Gulch (fig. 8), chalcedony is conspicuous in the veins. In these pits much of the quartz is moderately coarse-grained and superficially similar to quartz that is common in other veins in the district. The vein matter, however, is honeycombed with irregular, drusy cavities, 15 mm and more in maximum dimension, and fine-grained white chalcedony ramifies through the more normal quartz (see fig. 10).

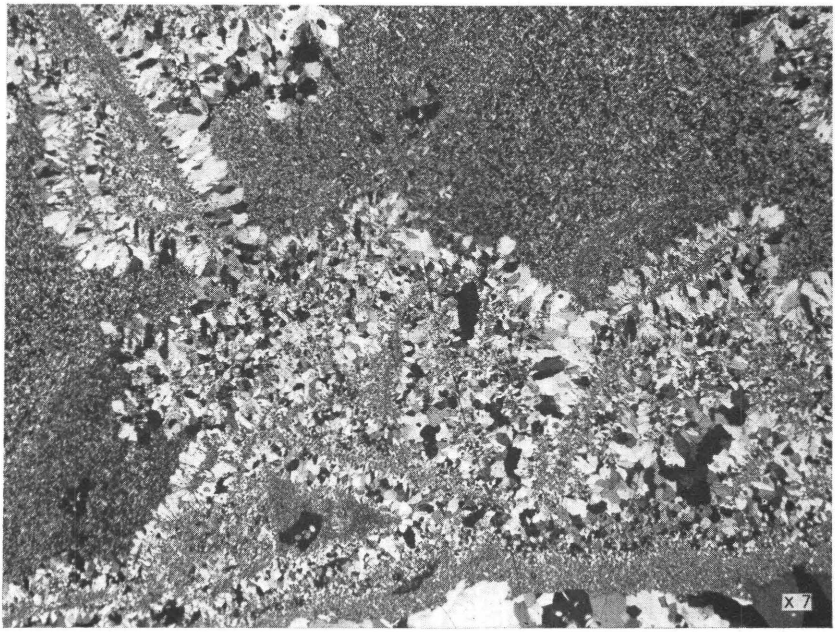

FIGURE 10.—Photomicrograph of vein matter from a prospect pit on the crest of Lander Hill. Fine-grained areas are chalcedony, irregular textured areas are haloes of flamboyant quartz; coarse-grained quartz shows along bottom edge and in upper left corner of picture. Crossed nicols.

Under the microscope material from these veins is entirely different in appearance from any other veins in the district. The most conspicuous feature is the irregularity in texture. Some grains are nearly 10 mm long by about 3 mm wide. In cross section some of these large grains are roughly hexagonal. They contain some tiny cavities similar to but fewer than those in the milky quartz first described. The cavities tend to be concentrated in certain areas and, in places, along a few sharp lines. Many of the large grains are bordered almost completely by haloes of radiating, flamboyant quartz crystals. In places, especially on the long edges of the grains, the bands of flamboyant quartz appear to lie within the borders of the large grains, as though the flamboyant material had taken the place of part of the quartz in the original grains. Fine-grained chalcedony is abundant and cuts the large quartz grains. The chalcedonic masses are rimmed by veinlets in which elongate quartz grains as much as 1.5 millimeters in length are set with their long axes perpendicular to the borders of the veinlets. In places roughly parallel veinlets of this sort are interleaved with elongate masses of the chalcedony. Some groups of bands of quartz and chalcedony are sharply curved. The trends of the different groups of subparallel veinlets and chalcedony masses bear no apparent relation to each other.

The wall rocks of most of the veins contain little introduced quartz. The quartz in ribs on joints has already been noted. In addition there are a few places where introduced quartz is abundant in the quartz monzonite. Much of this fills fissures and crevices in the shattered rock. The product ranges from comparatively large quartz lenses to microscopic and in part exceedingly irregular veinlets. A relatively small amount of the quartz appears as if intricately interwoven in the rock, suggesting that it resulted from chemical replacement rather than the filling of openings.

CARBONATES

The veins and wall rocks of the Reese River district contain several different varieties of carbonate minerals, in part represented in the table on page 53. If slight differences are disregarded, these varieties may be grouped as calcite, rhodochrosite, and ankerite.

Calcite is in small grains disseminated through the quartz monzonite and lamprophyre throughout the district, but its abundance is proportional to its nearness to veins. In addition, irregular masses and veinlets of comparatively coarse calcite locally cut veins and wall rocks. The indices of refraction indicate that most of the calcite is nearly pure, but some of the vein calcite contains appreciable magnesium.

Rhodochrosite is conspicuous locally in the veins of Lander Hill and in some of those farther south. It is not known to occur in the northern part of the district or in any of the veins, such as those in the Jackpot mine, that contain appreciable quantities of gold. In some spots on Lander Hill rhodochrosite comprises nearly 25 percent of the vein matter but is absent from large segments thereof. Where present, it tends to form bands perhaps 10 to 30 mm wide that are approximately parallel to the sides of the veins. In detail, the rhodochrosite bands are irregular and in many places cut across the vein quartz in random fashion. Some rhodochrosite forms isolated aggregates with feathery edges that lie between the quartz grains. Some of it is arranged along the borders of quartz veinlets that cut irregularly through the main body of vein quartz. In the few places in the southern part of the district where rhodochrosite was found, its relations to the rest of the vein matter are broadly similar to those on Lander Hill. Much of the vein quartz on the numerous small dumps on the south slopes of Central Hill and near the Rundberg workings farther west is so deeply stained with manganese oxides that it seems clear that rhodochrosite was originally widespread in these localities. In places, notably at the Rundberg incline, the manganese oxides lie in very thin, closely spaced seams that resemble the straight-sided bands of quartz described above.

The optical and chemical data presented in the table below show that the rhodochrosite differs somewhat in composition in different localities. Its most conspicuous feature is the high content of calcium carbonate.

Ankerite takes the place of rhodochrosite in the veins in the quartz monzonite in the northern part of the district. Its relations to the vein quartz are broadly similar to those of rhodochrosite described above, except that it seems to be less abundant. Neither carbonate has been

Composition of vein carbonates from the Reese River district, Nevada

[The first 4 analyses are by Geo. Steiger and the last 2 by Roger Wells, both of the U. S. Geological Survey]

	15	22	60	95	36	118
Analyses						
Insoluble in nitric acid	24.45	32.03	15.08	26.20	4.58	[1] 39.22
Ferric oxide and related material [2]	.29	.39	1.04	.40	Not det.	1.20
Manganese carbonate	65.14	58.09	73.24	56.79	78.24	2.27
Ferrous carbonate	1.61	1.48	1.72	2.48	2.16	13.16
Calcium carbonate	5.37	6.51	4.75	10.40	10.92	31.48
Magnesium carbonate	2.82	1.63	4.77	4.19	4.18	13.21
Total	99.68	100.13	100.60	100.46	100.08	100.54
Analyses [Recalculated with the omission of insoluble matter and ferric oxide and related material]						
Manganese carbonate	87.27	85.79	86.92	76.88	81.92	3.77
Ferrous carbonate	2.14	2.18	2.03	3.35	2.36	21.92
Calcium carbonate	7.16	9.61	5.63	14.78	11.43	52.35
Magnesium carbonate	3.76	2.47	5.67	5.66	4.34	21.97
Total	100.33	100.05	100.25	100.67	100.05	100.01
Indices of refraction [Determined by Jewel Glass]						
Ordinary ray (ω)	1.801	1.80	1.803	1.793	1.792	1.721
Extraordinary ray (ϵ)	1.579	----------	1.588	----------	1.580	----------

[1] Specimen 118 was treated with HCl instead of HNO_3.
[2] Includes alumina but appearance of precipitates shows small amounts.

15 from the Belle Wilder mine.
22 from the Cummings Lease mine.
60 from a dump of 1,800 feet east of the X-Ray shaft.
95 from the bottom of the Ruby incline.
36 from the south drift on the 527 level, Isabella mine
118 from a prospect dump in Yankee Blade Canyon.

recognized in veins which cut the quartzite. Ankerite has been noted near Austin only in disseminated grains in the intensely altered lamprophyre near the portal of the Luetgen tunnel, but may be present in other places in this part of the district.

MICACEOUS MINERALS

Sericite and chlorite are the principal micaceous minerals related to the veins. Biotite, which is one of the principal constituents of both the monzonitic and lamprophyric rocks, survives in places in the wall rocks of the veins but is commonly much bleached. Clay minerals are present close to the surface and in some fault zones but are not conspicuous in most of the material now available for mining.

Chlorite, commonly with some epidote, is locally abundant as an alteration product in the wall rocks and as the principal constituent of the linings of some fractures. It is in general neither as universally present nor as abundant as sericite. In some places it is sufficiently plentiful to darken the quartz monzonite. For example, in several places in the Jackpot mine the interior parts of joint blocks in the vein are dark green to nearly black (fig. 11). In this kind of material the feldspar is comparatively fresh but is intricately seamed with chlorite. In places rock of this type forms bands without apparent relation to the form of the joint blocks. In some of the shear

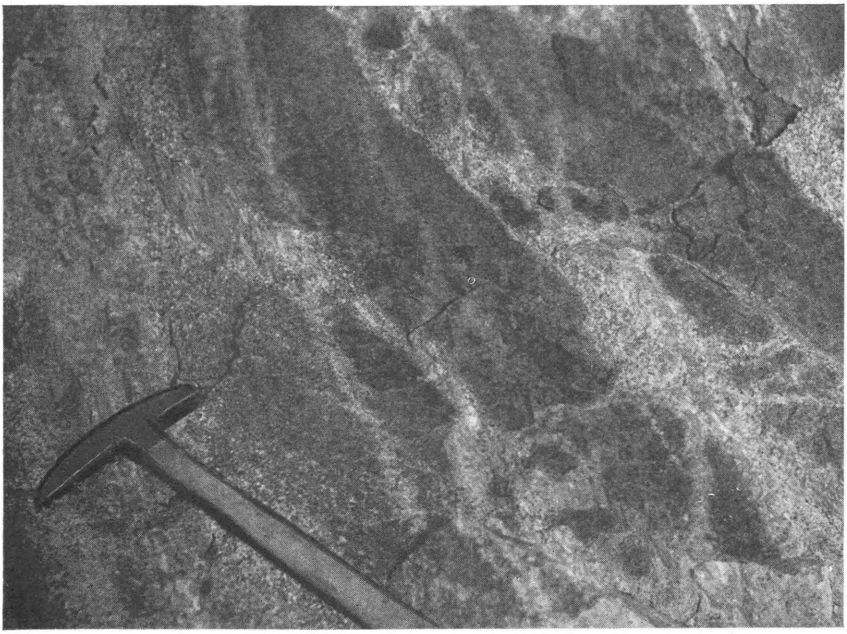

FIGURE 11.—Wall rock north of 201 raise, 200 level, Jackpot mine. The quartz monzonite is irregularly jointed, and the interiors of the joint blocks are darkened by chlorite, but that near the joint openings is bleached as a result of sericitic alteration.

zones the rock is conspicuously banded because some slabs contain abundant chlorite.

Sericite is present throughout the district as an alteration product in the igneous rocks and is also found in gouge and, to a minor extent, in the quartz veins. In the igneous rocks it is most commonly present in the plagioclase, but in the walls of veins and in fragments of wall rock included in the vein quartz sericite is locally so abundant as to obscure all other features. Increase in sericite results in an increase in the whiteness of the rock. The sericite is especially abundant along joints and other fractures spreading outward from them into the unbroken rock. The effect is especially striking in places like that shown in figure 11 where the sericite invades rock darkened by abundant chlorite, which was formed prior to the sericitization. Sericite is the principal constituent in most of the gouge that locally borders quartz veins and fractures in the wall rocks. Much of the sericite gouge contains abundant quartz crystals.

Sericite is nowhere abundant in the quartz veins. Where present it is commonly in small aggregates and strings of flakes that lie either within the straight-sided bands of late-stage quartz or in nearby quartz aggregates of intermediate or indefinite age. Here and there in the veins sericite forms thickly matted clusters that probably represent intensely altered bits of wall rock.

In places the gouge in fracture zones consists largely of clay of the beidellite-montmorillonite group, according to C. S. Ross. Some of the material in the broad shear zone near the junction of the principal branches of the Bartlett tunnel is of this kind.

TOURMALINE AND RUTILE

Both tourmaline and rutile are sporadically developed in the quartz monzonite and quartzite. Tourmaline is also locally conspicuous in pegmatitic bodies in the northern part of the district (p. 15). Both minerals are plentiful as small crystals in sericitic gouge in the Watt mine in New York Canyon. Hill (1915, p. 98) reports a vein about half an inch wide of tourmaline with a little quartz and apatite in quartz monzonite on the south side of Pony Canyon opposite the International Hotel.

SULFIDES

On the whole, sulfides are sparsely distributed in the veins of the Reese River district. The richer ore shoots contain narrow bands and irregular aggregates of almost solid sulfides, but even here much of the vein matter is nearly free from sulfides. In the veins that contain notable amounts of base metals, sulfides are locally conspicuous but their distribution is irregular. This segregation of the valuable sulfides facilitates hand sorting and accounts in part for the high tenor of much of the ore that has been milled.

Pyrite is almost invariably present and in much of the vein matter is the only visible metallic mineral. It is sparsely distributed in some of the wall rock but, like other sulfides that locally appear in such rock, is generally associated with quartz veinlets that fill minor cracks. The pyrite is commonly in cubes that range in width from a fraction of a millimeter to 10 millimeters or so. Where other sulfides are present, the pyrite is generally surrounded by them and is fractured and corroded. Assays of pyritic vein matter and of selected pieces of pyrite are reported to show silver, and commonly also some gold, but the form in which these metals occur with the pyrite is unknown.

The sulfide minerals identified during the present study include galena, sphalerite, chalcopyrite, arsenopyrite, tetrahedrite, stibnite, and proustite, with small quantities of covellite and chalcocite in some of the material close to the surface. In addition Hill (1915, p. 107) reports argentite, pyrargyrite, stephanite, and polybasite and Taylor (1912, pp. 32, 36) also found enargite and xanthoconite. Molybdenite has also been reported (Raymond, 1870, p. 134) and this is corroborated by qualitative tests by Charles Milton of the Geological Survey, which show that small amounts of this mineral are present in veins in New York Canyon. However, most of the dark material locally conspicuous in these veins is graphite, presumably derived from the quartzite.

Galena, sphalerite, and chalcopyrite generally occur together in coarse aggregates. They are abundant in parts of many of the veins in the western part of the developed area on Lander Hill and along the slopes that surround North Hill. These parts of the district are locally termed "the base range area" because of the comparative abundance of sulfides containing base metals. Much of the development work undertaken in the district since the field work for the present report was concluded was in this area. Some of the veins near the Castle, notably the one in the Byers incline, and parts of those in the Bartlett tunnel also contain these minerals. They are distinctly less abundant in other parts of the district but are probably completely absent in few of the veins. Even in the lower workings near the Frost shaft, base metals are locally plentiful (p. 207). Such data as are available suggest that where these sulfides are abundant the silver tenor is not as high as where they are sparse.

The aggregates of galena, sphalerite, and chalcopyrite commonly surround and fill cracks in pyrite crystals. Chalcopyrite forms blobs in sphalerite and locally in tetrahedrite. Chalcopyrite also forms larger masses from which irregular stringers extend into and cut sphalerite and galena.

Tetrahedrite is widely distributed in the veins of the district, especially on Lander Hill and Central Hill, and appears to be one of the principal constituents of the richer ore that was common in the early days. Little of the vein matter now available contains enough of this mineral to be readily identified in the hand specimen. It is comparatively abundant in some of the stope fill from workings near the glory hole on the southeast slope of Central Hill. (See pl. 2.) In this material tetrahedrite appears to surround and fill cracks in fractured galena. Qualitative chemical tests by W. T. Schaller on specimens from this place show that sufficient arsenic is present to constitute the variety of mineral he terms arsenoan tetrahedrite (Schaller, 1930, p. 571). Tetrahedrite from Lander Hill is intricately intergrown with galena and proustite and is locally in irregular tongues that appear to cut the galena.

Most of the stibnite and arsenopyrite show crystal forms. Stibnite was identified during the present study only in coarsely bladed aggregate from San Francisco Canyon but has been reported also from other localities. Arsenopyrite forms groups of small crystals scattered through quartz. It is especially conspicuous in veins near New York Canyon, where other sulfides are rarely abundant, but is widely distributed in veins throughout the district.

Proustite forms irregular blebs and aggregates, commonly in tetrahedrite, in material from the Isabella and North Star workings (fig. 12). Small amounts of proustite are present in several other localities. According to accounts of early activities in the district, proustite and other complex silver sulfides were widespread. They were especially abundant on Lander Hill, being present here and there throughout the extensive workings. These minerals were less conspicuous in the veins of the "base range area" northwest of the principal mines on this hill, but proustite has been recognized in a specimen reportedly from the Belle Wilder incline. Proustite also occurs on the south side of Central Hill, and in New York Canyon. It and similar minerals are reported to have been plentiful in the better ore mined in Yankee Blade Canyon. These minerals have not been reported from veins with appreciable gold such as those in and near the Jackpot mine.

Covellite and chalcocite replace tetrahedrite and chalcopyrite along cracks and grain boundaries in trivial quantities in some of the material studied, notably that from the vicinity of the glory hole. Presumably these minerals result from supergene processes.

Some of the sulfides are in the variety of quartz that forms straight-sided bands. Many are in fractured aggregates enclosed in and cemented by irregular masses of clear, flamboyant quartz. Except for some of the pyrite, the sulfides do not appear anywhere to be included in grains of the early-formed milky quartz.

MINERALS OF THE OXIDIZED ZONE

Ore that was mined near the surface early in the history of the district was reported to be thoroughly oxidized but specimens are rare, and little was learned about its mineral composition. The common oxides and carbonates of iron, copper, and manganese are sparsely present in many places. Scattered films and crystals of several different sulfates occur in shallow workings along New York Canyon and less conspicuously in other parts of the district. Chemical study by Charles Milton shows that the more abundant sulfates in the Watt mine are related to pisenite, $(Fe,Cu)SO_4.7H_2O$, with some magnesium and zinc included. Another sulfate similar to siderotil, $FeSO_4.5H_2O$, containing small amounts of copper, manganese, magnesium, and possibly zinc is also present. Cerargyrite and other halogen compounds of silver, as well as native silver, were reportedly abundant in the very rich ore first mined in the district but have not been identified in the present study.

PARAGENESIS

The vein quartz in the Austin area formed in at least three stages, probably more. In the veins in quartzite, farther north, the products of two stages have been recognized and more may exist. The milky quartz, crowded with microscopic cavities, was the earliest and, in many places, the most abundant variety to form. Where later varieties are abundant it is not everywhere possible to recognize this kind of quartz. Its characteristic features have been obscured, in such places, by fracturing, obliteration of included cavities, and recrystallization. The fine-grained quartz that is banded because it fills comparatively straight, parallel cracks in earlier quartz formed near the end of the process of vein filling in most places. Much of the irregular, partially flamboyant quartz is intermediate in age between the two above mentioned varieties. There may have been more than one of these intermediate stages and, in places, quartz of similar flamboyant structure seems to be later than the banded variety. Definite correlation has not been made between the quartz introduced into the wall rocks and the vein quartz.

The chalcedony and the associated irregularly-textured quartz apparently record a late stage absent from all of the veins except a few in quartz monzonite close to the original contact with the volcanic beds. The two localities where such material has been recognized are some distance from the principal remaining bodies of volcanic rocks. In one, north of Slaughterhouse Gulch, however, there are small residual patches of lava. The largest are shown on plate 1. The shallow prospect pits here do not afford conclusive evidence but the relations suggest that the chalcedony and associated quartz formed at and close to the contact between the monzonite and the lava. Fragments of both occur in the same small pits. The abundant vugs and extreme irregularity in texture in the quartz associated with chalcedony set it sharply apart from that in most parts of the district. These features suggest crystallization under distinctly lower pressure and, coupled with the association with lava, raise the possibility that the chalcedony-bearing veins are related to the Tertiary volcanism. If hot siliceous water circulated through favorably situated parts of the preexisting quartz veins during the volcanism it might well have deposited chalcedony and so recrystallized some of the quartz as to produce the irregularities in texture now present.

Carbonate may have begun to form early in the process of vein filling. However, rhodochrosite in some places, and ankerite in others, is associated with the fine-grained quartz that filled the parallel cracks in earlier quartz. Thus these carbonates formed late in the sequence. Calcite veinlets formed still later.

Wall rock alteration began at an early stage. Those minerals which, like tourmaline, formed at relatively high temperatures presumably were among the first to crystallize. On the other hand sericite and calcite, abundant in the wall rocks, were among the comparatively late minerals to crystallize in the veins, which suggests that changes in the wall rocks may have continued throughout the long history of vein filling. Chloritization in the wall rocks locally preceded sericitization, but chlorite is not now visible in many places where sericite is conspicuous.

Much of the pyrite may be contemporaneous with the early, milky quartz, but most of the other sulfides, particularly the silver-rich ones, crystallized at about the same time that the filling of the parallel cracks referred to above was in progress. Apparently the galena, sphalerite, and much of the chalcopyrite formed comparatively early and the tetrahedrite and ruby silver minerals somewhat later. The age relations of the arsenopyrite and stibnite are not known. The chalcocite and covellite formed from descending solutions as a result of weathering. The trivial quantity of such supergene copper sulfides in the material examined corroborates the impression gained from other facts that supergene processes were of negligible effect below the shallow oxidized zone. Some have assumed that the ruby silver minerals are of supergene origin (Taylor, 1912, pp. 36–37; Hill, 1915, pp. 106–108), but the fact that they have been reported through a vertical range of roughly 1,000 feet on Lander Hill and are widespread in other parts of the district is opposed to such a concept. The proustite seen during the present study seems just as distinctly a part of the aggregates of hypogene sulfides as the tetrahedrite does (fig. 12). Both these minerals seem later than other sulfides, but they do not in any way resemble the supergene copper sulfides that replace the

FIGURE 12.—Photomicrograph of a polished section of ore from the Rast and O'Brien lease, North Star mine. Shows grains of proustite, galena, and pyrite intimately intergrown with the tetrahedrite that forms the main mass of the specimen.

hypogene sulfides along openings of comparatively recent origin. A similar conclusion has been reached by Merritt (1931).

CHARACTER OF THE VEINS

Most of the lodes in the Reese River district are quartz veins that contain low to moderate quantities of sulfides and minor amounts of other constituents. Parts of some lodes are silicified and altered zones containing interlacing quartz veinlets. The veins enclosed in quartzite differ in structural and mineralogic details from those in the quartz monzonite. Some veins in the igneous rock are distinguished by comparatively abundant sulfides of copper, lead, and zinc and others by an appreciable gold content, but silver is the principal valuable constituent. There is marked diversity in the attitudes of the veins, but most of the veins in each locality have approximately the same attitude. In the quartz monzonite, banded veins and quartz lenses with rather steep dips are common in sheeted and silicified zones. In the quartzite the veins are comparatively persistent, wide, and low in dip because they follow bedding planes.

In the discussion that follows the term lode is used in a broad sense. It is applied, generally, to mineralized rock which may or may not contain distinct veins or veinlets. The term vein is used where there are fairly definite walls with a filling of quartz and other vein minerals between the walls. Some altered wall rock may be included in the vein filling.

VEINS IN QUARTZITE

Most of the veins in the quartzite in the northern part of the district lie nearly parallel to the bedding planes. They consist of zones of brecciated quartzite cemented by vein quartz with stringers of quartz penetrating the less thoroughly shattered quartzite along cracks. Parallel quartz-filled fractures, connected by anastromosing veinlets, give a banded appearance to most of these veins. The vein matter in each of the bands is itself banded by fractures parallel to the walls, with or without a filling of clear, flamboyant quartz, but this kind of banding is less conspicuous than it is in some of the veins near Austin. Long stretches of the veins contain almost no sulfides, and metallic minerals are not abundant in any of the exposures accessible at the time of visit. Sulfides are sparsely disseminated through the quartzite, in places at a distance from known veins, but apparently not in sufficient amount to be of commercial interest. Arsenopyrite is relatively more abundant in lodes in quartzite than it is in most places farther south. Judging by sacked material on the dump of the Silver Cliff mine, stibnite is abundant at that mine. Other sulfides are commonly present but seem nowhere to be abundant. Nonmetallic minerals other than quartz are not abundant. Graphitic material, presumably derived from the quartzite in which it is abundant, is concentrated along cracks roughly parallel to the veins. Here and there discontinuous fractures are filled with sericitic gouge containing tourmaline and rutile. Oxidized minerals are rarely abundant and sulfides remain even in outcrops.

The lodes in the quartzite persist for hundreds, perhaps even thousands of feet along the strike (fig. 13). In detail, however, there is much variation both in thickness and in continuity along both strike and dip. The incomplete information available from historical records and from the few stopes that could be entered suggests that most of the ore shoots do not exceed a few score feet in stope length, and many, if not most, are equally restricted down the dip. The widths of the veins in quartzite are on the whole greater than those in quartz monzonite. In their less favorable sections the veins may be represented by mere groups of stringers and essentially barren fractures but in the parts that have been mined the mineralized breccia zones are commonly several feet wide.

Most of the veins in the quartzite strike a little north of west and dip northward at angles from 10° to over 30°. Minor quartz-filled fractures of different attitudes are present in places, but none is known to be of economic interest. The comparative steepness of the canyon

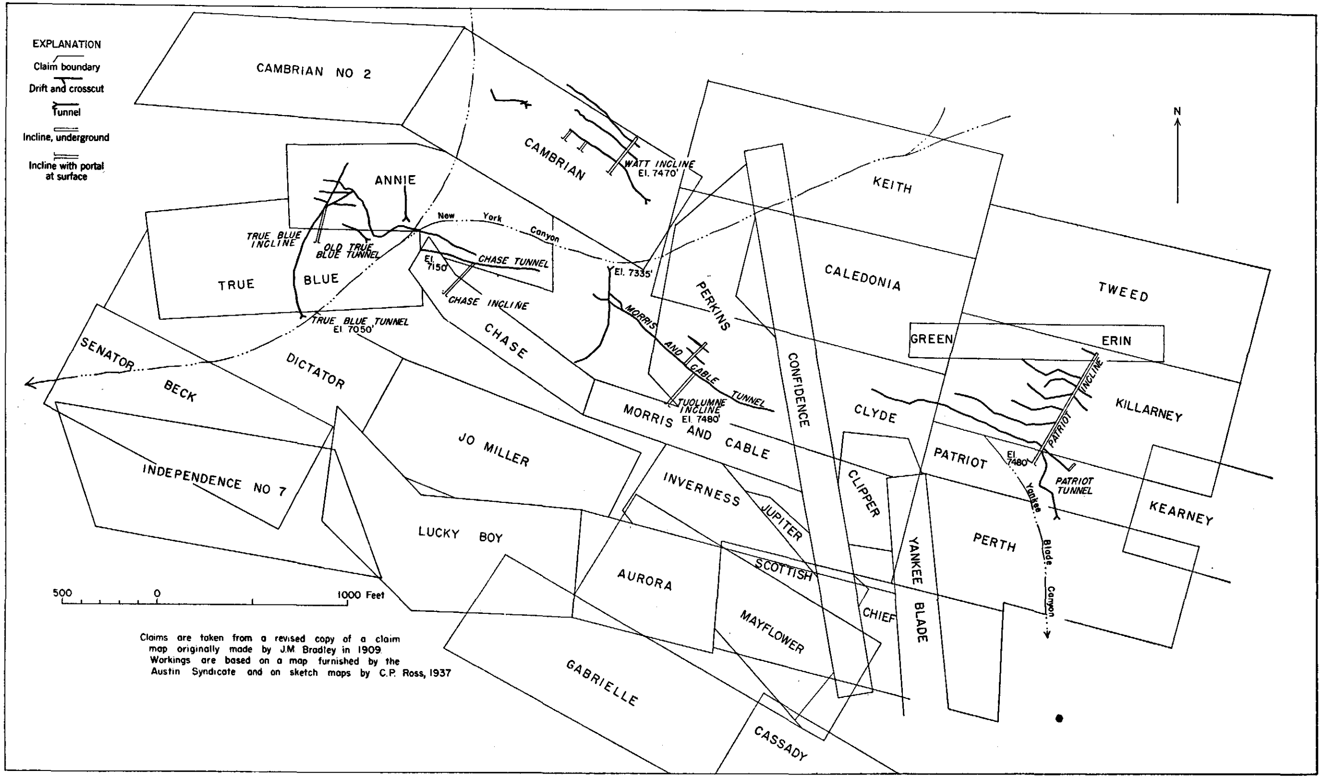

FIGURE 13.—Map showing the relations of certain workings in New York Canyon and Yankee Blade Canyon.

walls of this area have encouraged the use of crosscut tunnels, but the low dip of the veins makes very long tunnels necessary if they are to intersect the vein at convenient depths below the outcrop. Consequently much of the mining has been by means of inclines driven on the veins, with drifts at intervals. The low dips in many places are less than the slope on which broken rock will move by gravity alone, and must be taken into account in mine development.

VEINS IN QUARTZ MONZONITE

The veins within the quartz monzonite pluton are composed of series of narrow quartz lenses, locally separated by rock slabs, and irregular stringers (fig. 23). Commonly both walls are composed of altered quartz monzonite but many of the lamprophyre dikes have vein matter on one or both walls. The lamprophyric rock on vein borders is less conspicuously altered than the quartz monzonite. The principal known exception to this statement is in the outer part of the Luetgen tunnel, where, in places, lamprophyre is so thoroughly altered as to be almost unrecognizable. None of the more productive ore shoots border lamprophyre dikes.

Individual quartz lenses range from a fraction of an inch to, rarely, more than 3 feet in width. Exceptionally they may persist for hundreds of feet. As these are very narrow in proportion to their length the lenticular form is not strikingly apparent, but in the shorter masses it is conspicuous. All the veins have irregularities of different kinds as can be seen from most of the geologic mine maps in this report. The longer component lenses are generally curved. The lens in the Ruby incline (p. 97) is a good example. In many places the lenses branch, and some branches split into stringers of different trends and may end in a group of almost barren fractures. In others the lens that constitutes the main vein continues without interruption, but branches split off from it at an angle of 10° to 20°, or even more. In still other places a large lens may cross a less persistent and commonly narrower lens nearly at right angles. The main vein continues beyond the transverse stringer, but in some instances is slightly offset. In some such places relations are obscured by comparatively recent brecciation, but in others the quartz in the transverse stringer bends into one of the bands that make up the main vein, or, where well-defined bands are absent, the quartz in the two lenses coalesces at the junction. Figure 14 is an idealized sketch illustrative of this feature. It is based on observations at numerous places on Lander Hill and in the area between the Castle and the Jackpot mine. Features of the sort shown in the drawing prove that the offset occurred before mineralization.

In other places a vein may end against a transverse fracture that is not filled with quartz. At first glance the relations suggest

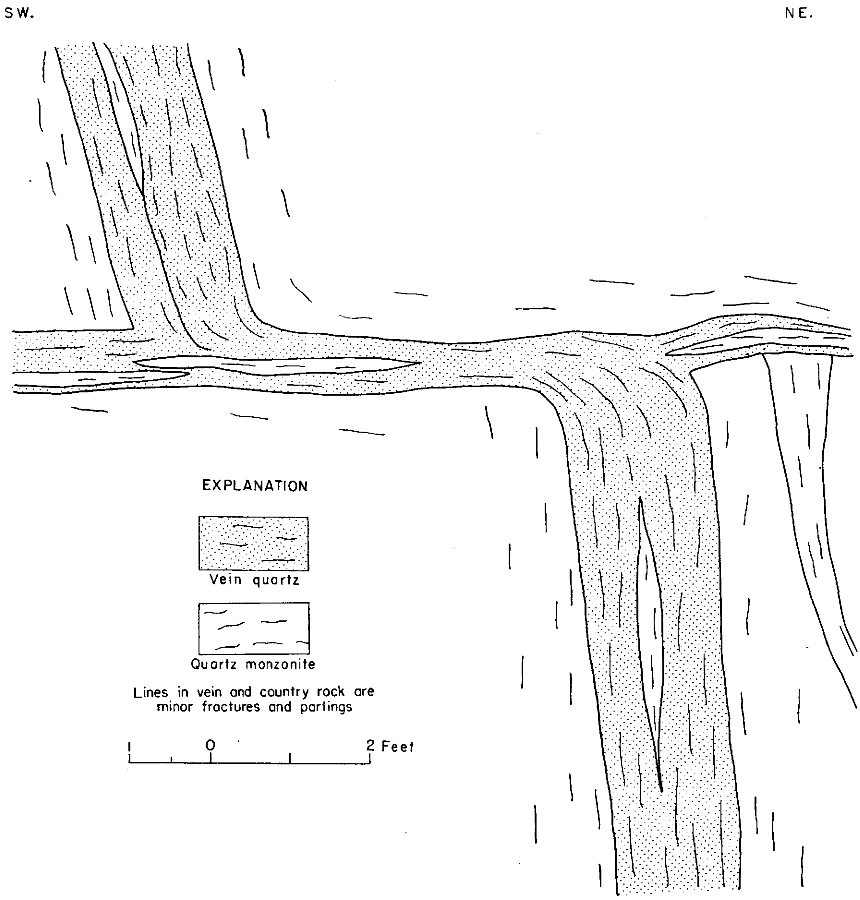

FIGURE 14.—Idealized vertical section across a vein deflected along a premineral opening also containing quartz. The distribution of vein quartz shown eliminates the possibility of postmineral faulting.

that the vein has been cut off by a postmineral fault of low dip. However, the quartz bands widen and bend at the contact in such a way as to show that deposition was guided by the cross fracture. The quartz is not broken nor is there any other suggestion of movement after deposition of the quartz such as would be expected if the cross fracture was postmineral. Thus it is clear that such a feature is identical in character with the one sketched in figure 14 except that the vein quartz did not fill the cross fracture. This kind of feature may terminate a quartz body at the top, as in the example shown in figure 15, or at the bottom, as in the lower part of the Rast and O'Brien incline.

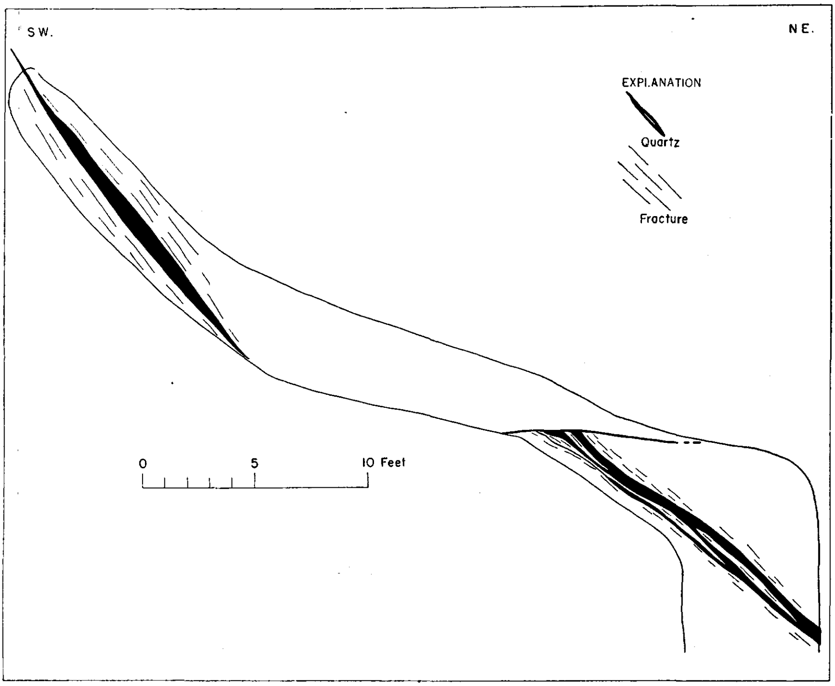

FIGURE 15.—Section through the raise at the face of the Cummings Lease tunnel showing relation between quartz and unfilled fractures.

Here and there quartz lenses end in mere ribs of hardened rock which are similar in every respect to those that are thickly clustered along joint planes in many parts of the district. Most such ribs are not connected with quartz lenses of substantial size, but ribs that correspond in attitude to the principal veins in a particular locality may lead to such a lens within a short distance. In a few places, notably along the ridge south of Marshall Falls, ribs broadly similar to these attain widths of more than 10 feet and stand out as conspicuous surface features for distances of hundreds of feet. The rock is bleached, iron-stained, and seamed and impregnated with quartz. These large silicified ribs have been extensively prospected, but all of the deeper workings that start in the ribs are on quartz lenses comparable in size to those of other veins. Apparently the silicified rock has nowhere yielded sufficient silver to encourage much development. Some of the large ribs are near lamprophyre dikes.

The veins in the quartz monzonite differ from those in the quartzite in that they fill openings in sheeted or sheared zones in which any wall rock included in the vein is in the form of thin slabs parallel to the walls, rather than of angular pieces of breccia. This is well illustrated in most of the veins on Lander Hill and to a greater or less extent in most other localities. In such deposits vein quartz alternates with films and slabs of intensely altered and almost completely crushed monzonite. The banding that results from veinlets of late-stage quartz in the quartz lenses (p. 50) is conspicuous here. In places, instead of a shear zone with numerous quartz bands, one or two massive quartz lenses are enclosed in quartz monzonite. Where the veins have this simple character the wall rock is comparatively little altered. Both in the direction of strike and in that of dip, successive massive lenses of this kind tend to overlap at the ends. This feature is well illustrated in the Jackpot mine and in other places between that mine and North Hill. Many of the veins on Midas Flat and in and near Yankee Blade Canyon appear to be of this character. The lenses that compose both kinds of veins branch and pinch and swell. The rock beyond the ends of some lenses is fully as altered as that which borders the lenses themselves, is broken by numerous slips, and is lined with chlorite, sericite gouge, or, locally, with irregular quartz veinlets.

The distribution of the metallic minerals in the veins is erratic. The valuable minerals in the banded veins in sheeted zones are commonly confined to streaks in certain quartz bands, although adjacent bands may be almost barren. Data obtained from operations in progress in 1937 and such information as could be gathered regarding past operations indicate that in general the wider the vein the lower its content of valuable minerals. Some of the largest of the more massive variety of quartz lenses contain no visible sulfides except sparsely disseminated cubes of pyrite.

VEIN SYSTEMS IN THE QUARTZ MONZONITE

In each of several localities within the quartz monzonite pluton the principal veins have nearly the same attitudes. In the area north of Lander Hill, however, the scanty available data reveal little system in the veins. Near the top of North Hill and in the area from there southwest to Pony Canyon the numerous but relatively undeveloped veins also have diverse trends although northwesterly trends predominate. On Lander Hill itself veins are exceptionally numerous and have many different attitudes. Most of the productive ones, however, strike northwest. The long Independent vein is a conspicuous exception.

In the area south of Pony Canyon the known veins are less closely spaced but several are more persistent than those on Lander Hill. Many are closely associated with lamprophyre dikes, which are comparatively rare on Lander Hill. On the western border of this area the dominant trend is northeast. Farther east, near the Jackpot, the trend is more nearly north, while still farther east many again strike northeast except on the southern slopes of Central Hill where many strike nearly east. Further details in regard to the different parts of the district are summarized below.

Little is known about veins in the area between the southern border of the quartzite and the northern part of the developed area near Lander Hill. In most workings seen the veins strike northeast and dip moderately steeply to the northwest. A few strike northwest, and Hill (1915, p. 113) says that the veins on Midas Flat range in strike from N. 20° W. to due north except in Yankee Blade Canyon about a mile south of the Patriot mine. Veins in this part of the district proved sufficiently favorable at the outcrop to encourage development. There are a few prospect pits in the volcanic rocks, but none showed any veins.

The most northerly of the prospects in the Lander Hill area are along the upper reaches of Slaughterhouse Gulch. The long Moss crosscut tunnel (pl. 1) farther down the gulch encountered veins several hundred feet in from the portal. These are, at least in part, of northwest trend, but most of them were inaccessible in 1937.

On the slopes around North Hill considerable prospecting has been done, especially in the gulches tributary to Pony Canyon, but no large mines have been opened. Veins are numerous and some are large, but apparently the tenor was too low to encourage development. Near the top of North Hill most of the veins that have been explored strike N. 20°–40° W. and dip 40° or more to the northeast. In the area from the top of North Hill to the vicinity of the big mill in lower Pony Canyon are veins of several different attitudes. Some of the veins that have been traced farthest have the same attitude as those near the top of North Hill. Others trend northeast, parallel to and in part along the walls of lamprophyre dikes. A few strike west or a little north of west. Most of these dip northward, some at angles as small as 10°. The Clifton drainage tunnel cuts large veins of this kind that are offset along smaller and steeper veins of northeast trend.

On Lander Hill itself veins of many different attitudes have been found. Most of the productive veins range in strike from about N. 20° W. to about N. 40° W. The Independence vein is the only one so far as known that strikes so nearly west, but there are several veins, like the Panamint, whose strikes range between N. 80° W. and N. 40° W. Dips are commonly to the northeast and most are between 25° and 45°, although locally they are steeper. The main veins are spaced from 50 to 200 feet apart. It is reported (Hill, 1915, p. 104) that the veins of low dip join the steeper veins at depth and that the veins in the inaccessible deeper workings are less closely spaced than they are at the surface. Some of the veins explored by surface cuts are of trivial size, and it may be that such minor veins were ignored in the deeper workings. This would lend support to a belief that veins were less numerous at depth.

South of Pony Canyon the dominant trends differ in different localities. Close to the western border of the district most of the veins strike N. 20°–60° E. and have steep northwesterly, and locally, even vertical dips. Some of the veins are on or near the borders of curved dikes. On the whole, these dip southeast. In some places, such as the vicinity of the Rundberg mine, there are a few veins of diverse attitudes.

In a zone in this part of the district from a little west of the 117°05′ meridian almost to the 117°04′30″ meridian the veins commonly trend a few degrees either side of north. These veins are crossed and linked by less persistent ones nearly normal to them. The main veins commonly dip steeply westward but locally are 35° and less. Here and there the dips are eastward. The veins in the Jackpot mine are the principal representatives of the group. At the Mizpah mine some of the workings follow a nearly flat vein. Several of the veins of northerly trend in this area are known to be over 1,000 feet long.

Lamprophyre dikes are not exposed at the Jackpot mine but in other places in this part of the district they are prominent. Here as elsewhere they are bordered locally by quartz lenses. As already stated, some veins cut lamprophyre, but some lamprophyre includes fragments of vein quartz. In addition, the monzonitic rock on their flanks is in places so silicified that it is resistant to erosion. In most outcrops such silicified rock is iron-stained and differs so much in appearance from fresh quartz monzonite that it might be mistaken for a silicic dike rock. This appearance is heightened by the fact that stringers of aplitic material, without definite boundaries, are locally present in the silicified rock.

In some places, particularly near and north of the Castle, there are conspicuous veins similar in trend to the quartz-lined cross fractures in the Jackpot mine. Most of these veins trend within 20° of due west, although some, like that on the Sunset No. 2 ground, swing farther north of west. Dips are northward, but range from more than 50° to less than 30°. These veins are commonly wide, in places more than 3 feet, but probably pinch and swell within short distances. Wide exposures are common in the pits and inclines east of the Bartlett tunnel and the Castle, but few have been followed far along the strike. The limited extent of individual lenses is also shown in exposures such as the Byers incline where a vein locally as much as 3 feet wide near the incline becomes discontinuous a short distance away from it. In the drifts off the Byers incline the vein is interrupted by cross fractures of northerly trend, most of which are lined with quartz. This is the reverse of the situation in the Jackpot mine, where the principal lenses strike nearly north and the interrupting veinlets strike more nearly west.

The third group of veins south of Pony Canyon is in the southeast part of the Austin area. The boundary between this group and the one just described is irregular and ill-defined, largely because there is somewhat more diversity in trend in this group than in those farther west. The most persistent of these veins strike N. 10° E. to N. 40° E. and are generally steep. These veins are close to dark dikes. The quartz lenses are discontinuous, but it seems clear that essentially one vein extends from the X-Ray shaft to the Luetgen tunnel, a distance of more than 3,000 feet. This is the longest vein in the entire district that has been traced on the surface and underground so continuously, but some of the others may well be equally long. Some of the veins in the southern part of the district, such as those in the Dalton and Hardy workings, resemble the one in the Luetgen tunnel, particularly in their relation to dikes, and might likewise be traced considerable distances if sufficient development work were done.

On the southern slopes of Central Hill, on both sides of the long vein and dike that extend north from the X-Ray, shallow workings are exceptionally closely spaced. Most workings are on veins that trend roughly due west although some are fully 20° either side of this. The dip is northward and is commonly less than 40°, although a few veins dip more than 75°. Some of these veins, like the one in the OK mine, have been traced for hundreds of feet, but the fact that most have been followed only short distances and the openings on them are close together suggests that the quartz is generally in small, closely spaced lenses. The vein matter is somewhat banded, but, with local exceptions, fracture and alteration in the wall rock is not marked.

A few of the veins on the southern slopes of Central Hill strike N. 20° to 40° W. and dip northeast at moderate to low angles. Near the old Union mine most of the veins are of this group. They constitute an extension into the area south of Pony Canyon of the principal vein system in Lander Hill and, so far as known, have the characteristics of the veins of that hill.

ORE SHOOTS

Speculations as to the characteristics of ore shoots in the Reese River district are necessarily based on the examination of the scanty exposures of ore accessible in the summer of 1937 and on the study of maps, most of which are known to be incomplete and inaccurate. The ore shoots in all parts of the district have in general been rather small, and the distribution of valuable minerals within them has been erratic.

Available maps and the data accumulated by Hill (1915, p. 106) suggest that ore shoots in the principal mines on Lander Hill had a tendency to plunge northwest. This tendency cannot have held throughout the district because in many places so many of the stopes are almost directly under each other down the dip.

In the Union mine (pl. 7) the principal ore shoot plunged about 55° to the northwest in the plane of the vein, which dips at about the same angle to the northeast. This shoot was mined out for a stope length of over 500 feet on the upper levels but below the 200-foot level the stopes, as mapped, are separated by from 50 to 100 feet of unmined material.

In the Jackpot mine, where the veins are steep and strike nearly north, the stopes are small. The largest are close to the Jackpot shaft, where there is a stope length of 180 feet on the 200-foot level. The arrangement of the stopes suggests a plunge of about 45° north, which is a little steeper than the average dip of the principal cross joints in this vicinity (fig. 6). Many of these cross joints are lined with silicified ribs and with quartz veinlets. The engineers in charge of the development at the Jackpot mine in 1937 report that pockets of ore are commonly found at points where branch veinlets join the main vein. Some of these veinlets correspond to the major cross joints; others have different trends.

Similar relations between pockets, branch, and cross veinlets are reported to have existed in places in the old mines on Lander Hill. It has been suggested (Taylor, 1912, p. 33; Hill, 1915, pp. 106–108) that ore shoots in the area were localized along faults of northerly trend formed during the later stages of the mineralization. Both Taylor and Hill regarded the ruby silver minerals as of supergene origin; they thought that the veins were enriched in silver at places where cross fractures permitted water containing suitable products of weathering to descend and deposit such minerals in the veins. As stated on page 59 the ruby silver minerals are here regarded as of hypogene origin, formed at a rather late stage in the process of vein filling. Even so the cross fractures may well have aided in localizing much of the silver.

In general, ore shoots are to be expected where veins branch and cross each other or where barren fractures intersect veins. At such places circulation would have been increased, permitting silver-bearing solutions, whether supergene or hypogene, to come in contact with pyrite or other sulfides of earlier origin that might serve as precipitants.

POSTMINERAL FAULTS

Many observers consider that postmineral faults are numerous in the Reese River district and have been among the outstanding reasons for the difficulties encountered in blocking out ore in advance of stoping. The results of the present study suggest that, while the effects of minor postmineral adjustments are widespread and faults of marked displacement exist locally, many of the principal irregularities and discontinuities in the veins are of premineral origin.

In most exposures of veins accessible in 1937, such as those in the Jackpot mine, the vein matter has been broken and even brecciated locally by fractures, many of which roughly parallel the veins. The branches and cross fractures, containing quartz and related minerals which prove their premineral origin, also show similar evidence of recent movements. Where minerals related to the veins are scanty or where all such minerals have been shattered, it may be difficult to decide how much of the apparent displacement is of premineral and how much of postmineral origin. Where such a fracture is parallel to nearby quartz veins or silicified ribs on joints or where it is lined with chlorite or sericite gouge, it is probable that a considerable part of the movement was premineral. This inference is strengthened if the fracture contains essentially unbroken quartz lenses. Distinction can generally be readily made between such lenses and slivers and angular fragments of quartz that have been dragged into a fault fissure. As clay minerals in the veins of this district result mainly from weathering, in any fracture where they are abundant it may be assumed that much of the movement took place after deep erosion. Clay minerals can be readily distinguished from sericite by the fact that they feel soapy when rubbed with the fingers. In the massive quartz monzonite and in quartzite without distinctive horizon markers, it is generally difficult to determine the direction and amount of total displacement.

Faults that displace veins and have no obvious relation to premineral openings are visible in several places even in the few workings that were accessible in 1937. The best examples are in the Cummings lease, Belle Wilder, and Isabella workings.

Emmons (1870b) says the veins are broken by numerous faults that strike north and dip 30°–40° W. with displacements that range from 30 feet up to, perhaps, several hundred feet. He also mentions the presence of faults along which the upper parts of veins have slid down hill, that is, to the southwest. Raymond (1869, p. 78) also refers to shallow faults of the latter kind which he says affect all the veins in the eastern part of Lander Hill. From his statements, and references to such faults in old letters and in accounts in the Reveille it appears that they were of low dip and were regarded by some as landslides. Present exposures give no hint that Lander Hill has been subjected to extensive landslides of this sort. However, the Cummings lease and Belle Wilder workings contain low angle faults that are in part lined with chlorite and, therefore, of premineral origin. The rock at the surface is so thoroughly weathered that downhill creep of disintegrated rock has occurred. Even where not actually disintegrated, deeply weathered rock contains more fracture planes than fresher material at greater depth. These factors have hindered prospecting and may have provided some basis for the concept that the upper part of the veins have slid down hill. The movement has extended, however, for only a few feet below the surface of the ground.

Taylor (1912, p. 33) says that faults with throws as much as 50 feet, cut the veins and trend north and dip about 20° E. These are the faults that he believes are associated with the ore shoots. He speaks of a later fault of northeast strike which has a throw of approximately 100 feet "and cut off all the veins in depth." Hill (1915, p. 106) mentions the faults of northerly trend associated with ore shoots but says that they dip west at medium or fairly steep angles. In those he saw, the displacement is normal and ranges between 10 and 70 feet southward. The diversity in attitudes recorded by Emmons, Raymond, Hill, and Taylor agrees with the fact that both premineral and postmineral fractures seen during the present investigation have many different attitudes. It is not possible now to judge to what extent the faults to which these men refer resulted from premineral or postmineral movements.

GENESIS

The data summarized above show that mineralization was a prolonged process. The veins generally occupy joints, bedding planes, and similar openings, rather than faults. Hence it is evident that major diastrophic disturbances were not needed to provide channels for the ore solutions. The metallic and nonmetallic minerals, deposited both in the veins and in the wall rocks, indicate that a number of successive steps were required to produce the lodes, and suggest that as vein filling proceeded, the temperature and pressure tended to decline.

Some veins are associated with dikes related to the monzonite pluton, and, locally, vein quartz is in fragments enclosed in the dike rock and hence even preceded the intrusion of some of that rock. Hence it seems clear that mineralization began soon after the quartz monzonite pluton came to place. Within the quartz monzonite the vein-forming solutions are thought to have taken advantage of joint openings, formed in connection with the consolidation of the magma and modified and enlarged somewhat by movements that took place during the course of mineralization. There is fully as much diversity in the attitudes of the veins as in those of the joints. The hardened ribs and many of the small veins are parallel to and have the same relation as multitudes of joints that are essentially free from evidence of mineralization. Many of the larger veins record repeated renewal of movement, followed by further fillings not evident in unmineralized joints. This, and the addition of vein minerals constitute the only essential differences between these veins and nearby unmineralized joints, implying that there is little difference in origin between the two kinds of openings. In the sedimentary rocks the vein-filled fractures are on and nearly on bedding planes thought to have been opened enough to permit circulation of ore solutions during movements related to the intrusion of the quartz monzonite pluton, whose contacts are almost parallel to the bedding.

The veins are widely distributed throughout the exposed part of the quartz monzonite pluton and in the sedimentary rocks that remain at one locality on the border. By far the greater part of the production, however, has come from the numerous veins concentrated within a small area on Lander Hill. There is no obvious reason for this localization.

The tourmaline and rutile in crush zones in the veins and in wall rock supplement the structural evidence of a genetic relation between the veins and the quartz monzonite. Tourmaline is a prominent constituent in pegmatitic offshoots, and both tourmaline and rutile require moderately high temperatures for their formation.

Mineralization probably began with alteration of the rock in the walls of the openings. The products of early wall-rock alteration include, in addition to the tourmaline and rutile, at least part of the chlorite and aplitic material. The sericite and other introduced minerals formed in later steps.

The minerals of the vein filling give even more evidence of successive stages under changing conditions. In the first recognizable stage of vein fillings, the early-formed, milky quartz was the principal product. This quartz in places merges with that of the hard ribs, which in turn merges locally with aplitic material. Such facts strengthen the concept that the early-formed quartz was deposited at relatively high temperatures. This quartz, much the most abundant and widespread vein mineral throughout the district, is commonly devoid of sulfides except for sparse pyrite cubes. In long stretches of the veins the quartz is homogeneous and contains few drusy cavities, which suggests deposition under enough pressure so that openings could not be maintained. The quartz formed at later stages does locally contain such cavities, presumably because pressure was less. The chalcedony in a few of the veins seems clearly to have been formed under distinctly lower temperature and pressure than the original, milky quartz. The changes in the character of the carbonate minerals that are locally abundant seem in keeping with the concept of successive lowering of temperature and pressure as vein filling proceeded. Rhodochrosite in many districts is found in veins formed at moderately high temperatures whereas calcite may crystallize under surface conditions. Similarly suggestive but inconclusive evidence is afforded by the metallic minerals. Such minerals as arsenopyrite, normally formed at high temperatures, on the one hand and ruby silver minerals, commonly formed at low temperatures, on the other suggest that the metallic contents of the veins were introduced at sufficiently long intervals to permit marked variation in the physical conditions that influenced deposition.

Most of the metallic minerals, especially those rich in silver, were introduced fairly late, during the interval in which the distinctly banded quartz was formed. The successive stages of vein filling imply that there were successive renewals of movement in fractures along which solutions could be forced. Either because the later movements had only local effect or for some other reason, the valuable minerals are confined to limited parts of the veins, commonly the narrower parts. Wall-rock alteration is less pronounced on the borders of the wide, relatively barren veins composed largely of early-formed quartz than along the narrower veins with more abundant metallic minerals. Perhaps the movements that provided passageways for the silver-rich solutions found the narrow veins in wide zones of alteration weaker than the wider quartz masses in less extensively altered wall rock.

Erosion finally brought the veins so close to the surface that they were attacked by the agents of weathering. A shallow zone of oxidized material was produced. Present data lead to the belief that little sulfide enrichment resulted from the weathering.

PRACTICAL CONSIDERATIONS

RELATIVE ADVANTAGES OF DIFFERENT PARTS OF THE DISTRICT

The history of the Reese River district shows that successful development has been almost entirely confined to a small area on Lander Hill. Since 1886, when the principal period of activity in the district came to a close, mining in outlying parts of the district has been undertaken by several companies. The total production during this period of over 50 years is thought to have been only about 5 percent of that attained in the 20 years prior to 1886. A large part of this came from veins in the Union mine where conditions are very similar to those of Lander Hill. Several attempts to reopen the mines on Lander Hill have been made but none lasted long, and the small production that was obtained came in large part from pillars and fill in old stopes. A few small ore bodies have been opened on Lander Hill comparatively recently. The ore mined in 1916 by Con Cummings near the Belle Wilder is an example. Doubtless some material that might now be mined profitably if accessible was left because, under the conditions of 50 years ago, it was either of unsuitable tenor or too inconveniently situated to pay. New work in the highly developed parts of Lander Hill would be difficult and expensive because of bad ground and bad air.

Exploration below the old workings might be more successful. The essential characteristics of the veins appear to have remained constant from the bottom of the shallow oxidized zone to the lowest workings of the Manhattan Silver Mining Co. Some rich material has since been found near the Frost shaft below any of the workings of that company. Increasing difficulty in finding new ore bodies was doubtless one of the principal reasons why the Manhattan Silver Mining Co. abandoned the exploration project. The costs and difficulties in haulage, ventilation, and pumping entailed by conditions at increasing depths may have influenced the decision to cease operations as much as any decrease in the size, number, or tenor of the ore bodies. Modern haulage, ventilation, and pumping equipment would permit work in places difficult of access in the eighties. Also the Clifton drainage tunnel, completed 10 years after the shut-down, would aid materially in any campaign of deep exploration. This tunnel effectively drains the ground above it, part of which is unexplored. It aids in ventilation, and parts of it were in sufficiently good shape in 1937 to be used for haulage if adequately reconditioned.

The area that extends from near the highway north of the Union mine to a few hundred feet south of latitude 39°29′ yielded some good ore in the early days but was comparatively little developed at that time. In this area the Union mine appears to have had a better production record than most of those operated since the Manhattan Silver Mining Co. shut down. Some of the veins in this area are similar in attitude to most of those on Lander Hill and, like the latter, locally contain considerable ruby silver and tetrahedrite. These minerals, which were the outstanding constituents of the bonanza ore of the old days, have been reported from several places, but in the Austin area appear to be abundant only on Lander Hill and near the Union mine. For these reasons the area southward from the Union mine is regarded as among those that might be worthy of further prospecting. Except that unmined ore may remain in the Union mine, little information is available on which to base a prospecting campaign. The Austin Silver Mining Co. was prospecting here at the time of the present investigation.

Exploration in other parts of the Austin area indicates that the veins are not as rich in silver as those of Lander Hill and the material so far mined in those areas to date of the present study does not appear to have been profitable. The deposits in the Jackpot and some of the nearby workings contain appreciable amounts of gold, and some of the veins north of the Jackpot and west of the principal mines on Lander Hill contain copper, lead, and zinc. The difficulty in handling base metals in the old mills must have been among the reasons why veins in the area received little attention in the early days. Modern metallurgy would help in this respect, if large enough deposits can be found.

The limited development in the part of the monzonitic pluton north of Lander Hill and the long time that most properties there have lain idle suggests that the results of early exploration were not encouraging. Very little could be learned from the scanty exposures accessible in 1937. Data in regard to the veins in quartzite are almost equally scanty, but some mines, such as the Patriot, are reported to have yielded considerable silver and interest in this part of the district has been manifested at intervals. Some mining was in progress in 1937. Probably few shoots are equal in grade to the best of those on Lander Hill, but the veins appear to be persistent and wider than many of those farther south, a fact which may justify further prospecting here. Gold is apparently not present in commercial quantity and base metals appear to be only abundant enough to complicate recovery of the silver. The abundant graphite would also need to be considered in designing a plant to treat ore from this locality.

SUGGESTIONS FOR PROSPECTING

In this district good outcrops are sparse. Quartz veins are so numerous that chips from them are widespread in the soil and hillside wash in many localities, but only a comparatively small number of the veins are of economic interest. On the other hand, veins that contain ore in depth may be represented by mere silicified ribs in the outcrop. Thus mere inspection of the surface cannot lead to positive conclusions, and valuable veins could be overlooked.

In each locality the principal ore shoots are likely to be in veins of the attitude dominant in that place, but this is by no means an invariable rule. Plate 2 shows the dominant attitudes of the veins in different parts of the Austin area. Prospecting at any particular place will be aided if detailed maps are made. All veins and their branches, and, so far as practicable, all slips, shears, and joints exposed at the surface and in underground workings should be plotted and studied. This procedure should show the vein system at the locality under investigation and decrease the underground exploration in barren ground.

Several observers have suggested that ore shoots tend to form where minor veins meet or cross the main vein. Detailed information on the relation of ore to vein junctures is lacking, and can only be obtained by systematically recording all pertinent data on maps whenever new work is done or old workings reopened. Presumably the factors controlling ore shoots differ in different localities much as the attitudes of the principal veins do. It seems probable that the shape of an ore shoot in the plane of the vein is controlled to some extent by the major joints. For example, the plunge of ore shoots in the Jackpot mine is roughly parallel to the dip of the conspicuous joints that are nearly normal to the veins.

Some idea as to the possibility of finding ore shoots can be gained from the character and mineral content of the exposed parts of a vein. Thick lenses of milky white quartz without conspicuous banding or relatively plentiful sulfides are not likely to be near shoots of silver ore of the highest grade. They may, possibly, be associated with shoots that could be mined at a profit, especially if appreciable quantities of gold or of base metals supplement the silver content. Significant quantities of gold are to be expected only in veins in the general vicinity of the Jackpot mine or, perhaps, on Midas Flat. Base metals are most likely to be abundant in the area northwest of Lander Hill although present to some extent nearly everywhere. Zones of fracture in which the rocks are intensely altered might be worthy of being followed for they may represent barren intervals between quartz lenses and do not necessarily imply that the vein has been displaced by faulting. Banded vein matter and sheeted structure in which quartz alternates with wall rock are both favorable features. Sufficient ruby silver or tetrahedrite to be seen easily in the hand specimen are to be expected only in the vicinity of high grade ore shoots.

GEOPHYSICAL SURVEYS IN THE AUSTIN AREA

By E. L. Stephenson

INTRODUCTION

Geophysical tests were made in the Austin area to supplement the geological work. These included measurements of electrical resistivity, natural or self-potential, and variations of magnetic intensity. Geophysical field work was carried on from August 24 to September 30, 1937. The primary purpose of the tests was to determine the feasibility of using geophysical methods in the area and to determine which methods might have value for detailed prospecting. Strong resistivity contrasts in certain localities are thought to correspond to the presence of numerous veins or dikes. Less localized highs and lows, as in the area between Marshall Basin and Central Hill may be related to ground water. Most of the veins are too narrow to be detected by resistivity methods. Results of natural potential methods were not very significant. Results of magnetic surveys suggest that the veins and altered rock give sufficiently lower magnetic readings than the unaltered rock to be of possible significance, but this requires further study.

RESISTIVITY SURVEYS

Electrical resistivity [7] measurements were made by customary standard methods using the Lee partitioning method. The measurements included two traverses on Lander Hill and eight traverses and three individual station centers in the area between Marshall Basin and Central Hill (pl. 2). In all, 52 sets of measurements were made. In the area near Marshall Basin (pl. 2), resistivity depth measurements were made at intervals of 500 feet along five northeast-trending traverses. Two northwest-trending cross traverses were established by seven stations, the centers of which on the northeast-trending lines are designated by the letter *A*. These traverses all were spaced 500 feet apart. Three single stations with measurements made in two perpendicular directions were run in the western part of this area. To the east, near Union Hill, measurements were made at two stations on a north-trending line, spaced 750 feet apart. Measurements were carried to a depth of 500 feet at all stations except 2*A*, where measurements were made to a depth of 1,000 feet.

On Lander Hill the stations were spaced 500 feet apart on the traverse lines, and resistivity measurements were carried to a depth of 1,000 feet at all stations except station 12, where measurements were carried to a depth of 700 feet.

The resistivity measurements in the Austin area show many anomalies. Some of these anomalies may result from differences in the original composition of the monzonite, others from variations in the hydrothermal alteration and weathering of the rock. Still others probably result from the dikes and veins, which are widely distributed and locally numerous. The effect on resistivity determinations of these different factors, or combinations of factors, is difficult to evaluate, especially as local differences in porosity and depth to ground water introduce further complication. It is especially difficult to judge the effect of individual veins, as many of these are so small that their influence on the conductive properties of the ground may be masked by other variables.

The measurements in the area between Marshall Basin and Central Hill show a definite distribution of resistivity values within the limited area studied. Figures 16 and 17 are isoresistivity maps that show by resistivity contours, or lines of equal resistivity, this areal distribution for two depth ranges. It should be emphasized that such maps are generalized in character, and that the effects of local anom-

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[7] Resistivity is the electrical resistance of a volume of material so shaped that the current path through it has unit length and unit cross-section.

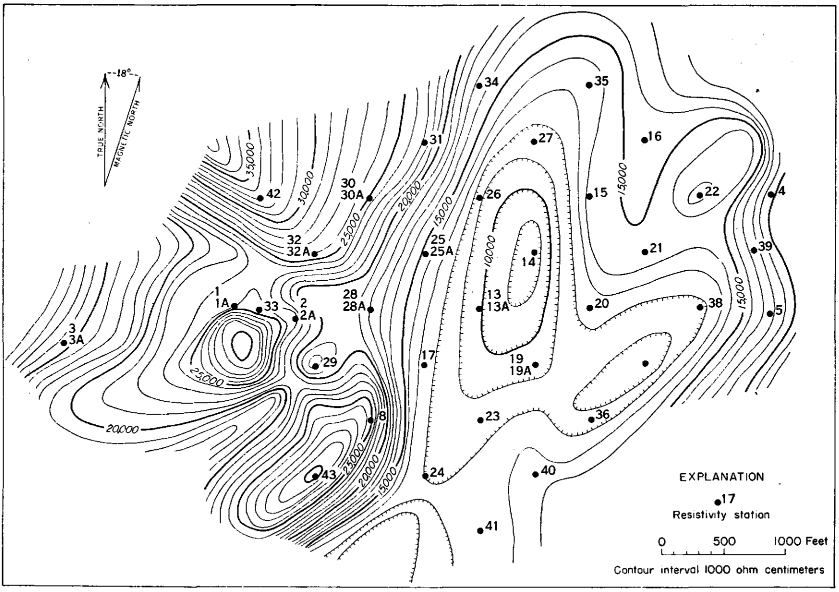


FIGURE 16.—Isoresistivity contour map for depths 220–300 feet in the area between Marshall Basin and Central Hill.

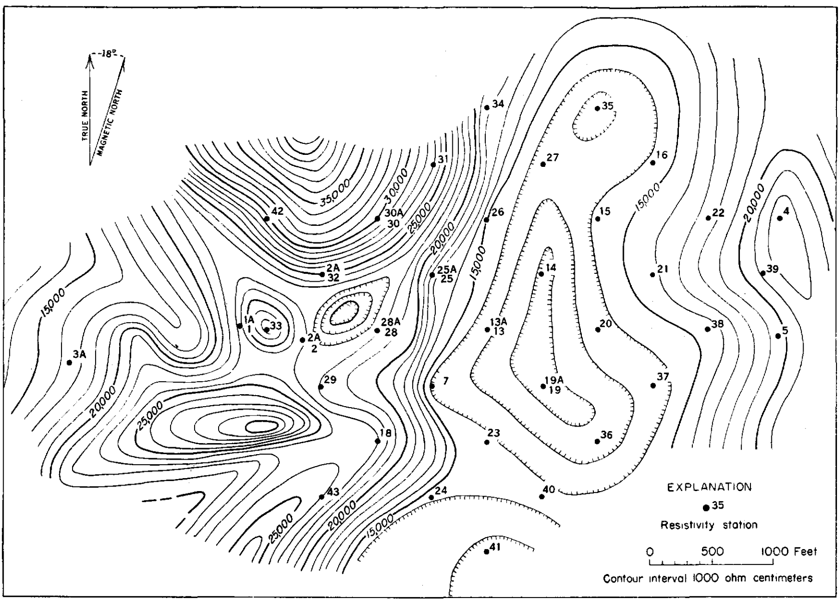


FIGURE 17.—Isoresistivity contour map for depths 420–500 feet in the area between Marshall Basin and Central Hill.

alies are more or less averaged into the whole. On both maps the contours show that a resistivity low occurs near the center of the area. This resistivity depression is bordered in part by several areas of high resistivity, the most prominent of which lies in the northwest part of the mapped area.

The resistivity depression is in the headwater area of streamways tributary to Marshall Canyon. Water stands at shallow depths in the Baker incline, and in inclines and shafts near station 13 and northwest of station 30. The resistivity of geologic bodies depends to a large extent upon the amount and the chemical content of the water that they contain. Experience indicates that if a given body of rock contains a larger percentage of water in one part than in another, the more saturated part will usually possess a lower resistivity than the part that is relatively dry. As the area in which the resistivity measurements were made is small it is difficult to draw definite conclusions, but probably the resistivity depression results in a general way from the fact that ground water is nearer the surface here than it is on the slope of Central Hill, where the maps show higher resistivity values. The dissimilarities in detail between the resistivity contours and the topography must result from structural or compositional changes in the rocks, the character of which cannot be determined from present information. Under these circumstances the general changes of resistivity values obtained in the area between Marshall Basin and Central Hill are believed to be without direct significance for the prospector.

There is some evidence that strongly variable resistivity values are to be expected where dikes or veins are numerous. For example, the largest and most northwesterly of the "areas of variable resistivity" (strong contrast) plotted on figure 16 is in the vicinity of the X-Ray shaft where both dikes and veins are known to be numerous, although underground exploration from this shaft resulted in the discovery of comparatively little ore. Figure 18 shows anomalies in resistivity at one of the stations within the large area of variable resistivity. The anomalies in these curves are thought to result from the presence of the dike that crops out a little over 100 feet to the northwest. Similar anomalous curves were obtained at other stations in this part of the district where the traverses crossed, or were close to, the dike zone. Anomalous curves were also obtained on Lander Hill in a locality where no dikes crop out but veins are known to be present.

In addition to the area near the X-Ray shaft, three smaller areas of strongly variable resistivity contrasts are shown on figure 16. As closely spaced resistivity traverses were made only in the general locality shown on plate 2 comparable data for the rest of the district are not available. Allowance was made for the possible effects of topogra-

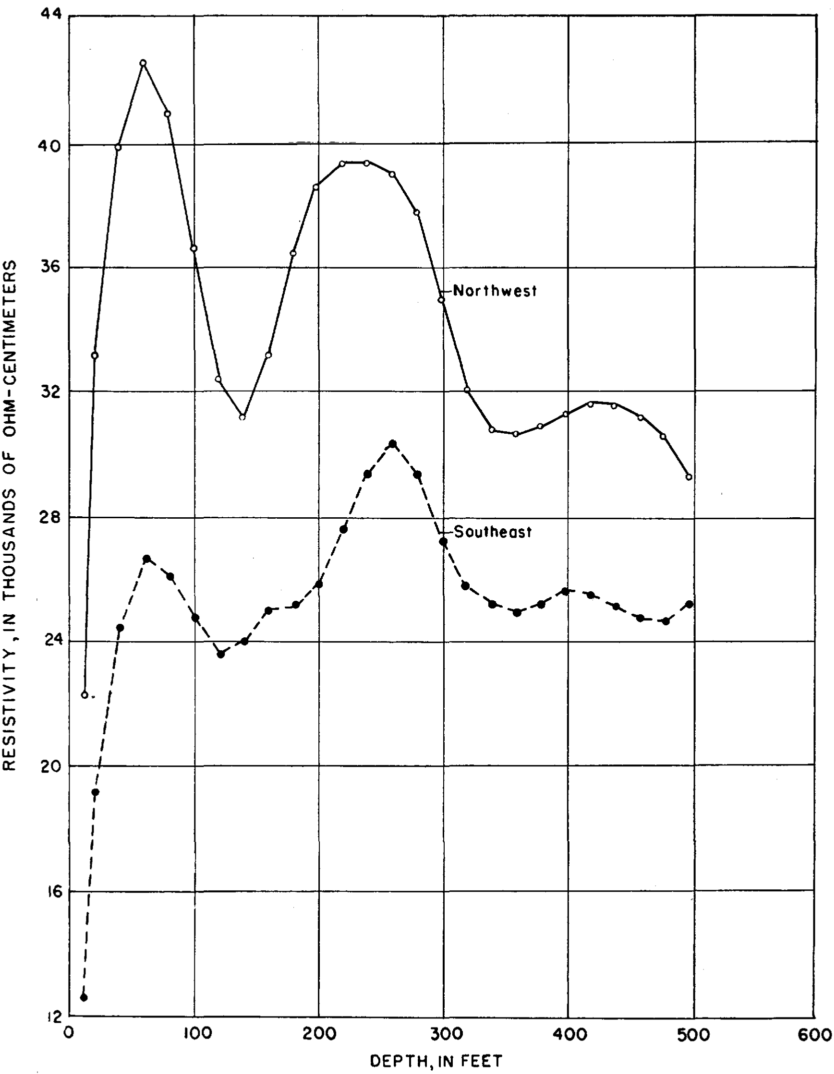


FIGURE 18.—Resistivity curves of station Na42 showing variations produced by a dike.

phy and groundwater. The rock in these four areas is believed to be more variable in character than the rest of the ground tested. The resistivity variations may be caused at least in part, by dikes, veins, or silicified zones.

The measurements at stations 1, 2, and 3 (pl. 2) were made to determine whether a fault might be present in the valley in which the X-Ray shaft is located. The detection of faults by resistivity methods depends upon an alteration or "offsetting" of the sequence of resistivity in conformity with the offsetting of the geologic horizons.

In general, faults are easily detected on this basis by resistivity measurements. The fact that, apart from the dikes and veins, the Austin areas is underlain by relatively homogeneous igneous rock hampers the detection of faults by geophysical methods, much as it does by geological methods. In such rock the resistivity sequence may be more uniform and, accordingly, the "offsetting" less pronounced. The numerous anomalies to which reference has already been made would tend to obscure the effects of faulting.

The resistivity measurements made near the X-Ray shaft, especially at stations 1 and 2, result in anomalous curves, but the anomalies differ in some particulars from those ordinarily produced by fault. Magnetometer measurements along the same traverse lines as the resistivity work showed no evidence of a break in the bedrock, but this evidence, also, is not entirely conclusive because of the homogeneous character of the bedrock. Thus the geophysical data, while indecisive, suggest that no major fault exists in the valley near the X-Ray shaft.

Work at station 7 on Lander Hill (pl. 2) suggests that the partitioning method of resistivity study may be capable of detecting major faults even under the geologic conditions that exist in the Austin area. This station is in a topographic saddle beneath which some of the veins of Lander Hill appear to extend. While there is no geologic evidence of a major fault it is possible that the saddle results to some extent from the presence of fractures in the monzonite. The curves obtained at station 7 are shown in figure 19. They show distinct "off-

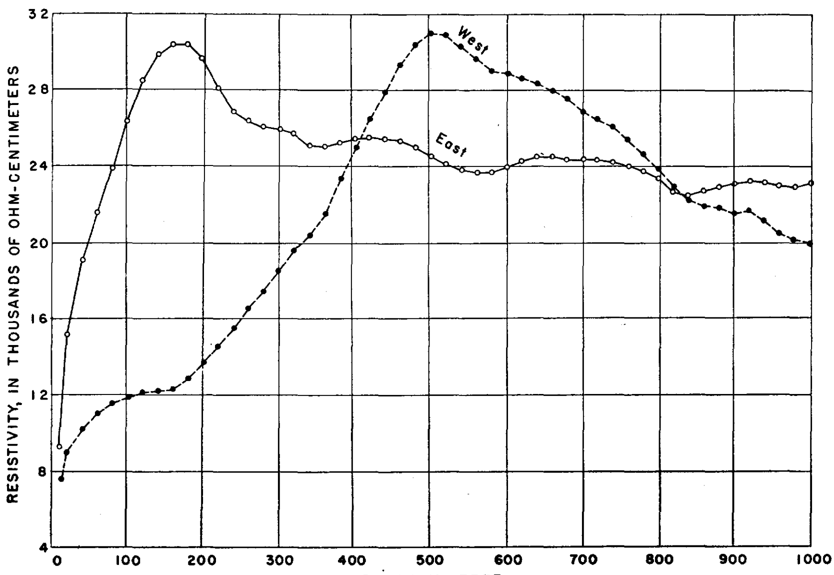


FIGURE 19.—Resistivity curves at station 7 on Lander Hill, showing variations thought to be due to a fault.

setting" but are strikingly similar in form. Features of this kind in resistivity curves are generally thought to be indicative of a fault. No similar evidence of faulting was obtained in resistivity studies in other parts of the Austin area. This lends support to the concept, based on geologic data, that major faults are rare.

The exceptionally deep resistivity measurements on Lander Hill were made in order to test the possibility of detecting structural discontinuities of possible economic significance at depths of 700 feet or so. The results seem to show essentially no change in the rock to a depth of 1,000 feet. The natural variations in the monzonite, however, have affected the curves so that, in the absence of correlative geologic data at depth, they are difficult to interpret. Apparently veins as small as most of those in the Austin area cannot be detected directly by resistivity methods at a depth as great as 1,000 feet.

NATURAL POTENTIAL SURVEYS

Measurements of potential differences in the natural electrical field that occur on the earth's surface are called natural or self-potential measurements. By forming a "natural battery", sulfide minerals undergoing oxidation in the ground may produce potentials which are much stronger than those normally expected in the area. Where a relatively large body of sulfides occurs the potential differences may be strong enough to be detected and measured at the surface of the ground. A study of the distribution of the measured potential differences may enable the operator to determine the position of the buried sulfide body.

Self-potential measurements were made on a 10-foot-unit grid over a part of the Bartlett tunnel (pl. 9) that had encountered a quartz vein. The grid measured 100 by 150 feet, and was laid out to cover the place where the vein in the main branch of the Bartlett tunnel was expected by the mine operator to intersect a vein exposed at intervals on the surface between the Castle and the Tripod shaft (pl. 9). It was thought by the mine operator that a concentration of sulfide minerals might occur at or near the vein intersection. Two series of self-potential measurements were made on the grid, but no localization of potential differences was found such as would indicate the presence of a large deposit of sulfide minerals (fig. 20). This has been corroborated by underground exploration made since the geophysical work was done.

MAGNETIC SURVEYS

Variations in the intensity of the vertical component of the earth's magnetic field were measured at several locations in the Austin district. A standard Askania vertical variometer was used. The pur-

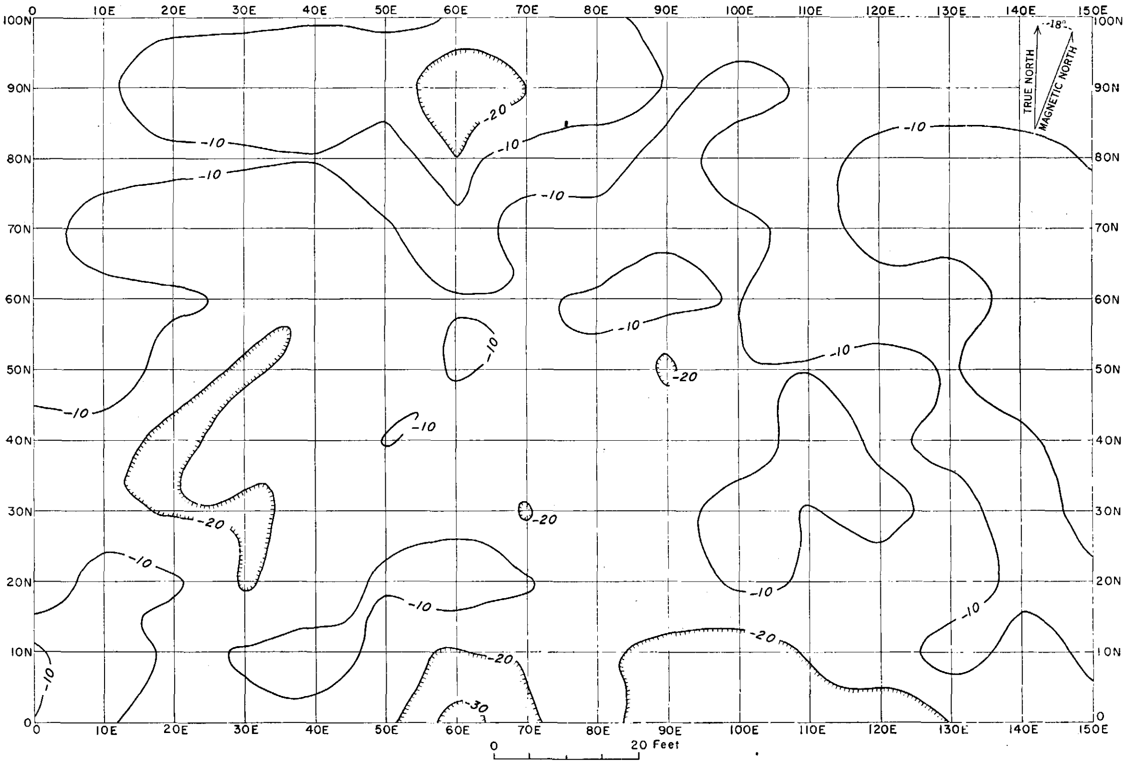


FIGURE 20.—Natural potential map of Bartlett tunnel grid.

pose of the tests was to determine the possible value of the magnetometer for locating dikes and veins. Traverses were run across several known dikes and veins to determine whether appreciable magnetic anomalies occur over them. The measurements also gave information on areal variations in magnetic intensity in the district.

Seven magnetometer traverses were run across the "Jackpot vein," south of the Jackpot shaft (pl. 2), to points 50 feet on either side of the vein. Measurements were made at 10-foot intervals along each traverse line. Later four of these traverses were extended to points 200 feet on either side of the vein by making measurements at 50-foot intervals along the traverse lines. Measurements were made at 20-foot intervals along the line of resistivity station 1 to points 200 feet on either side of the stream bed (pl. 2), and similar measurements were made to points about 100 feet on either side of the stream bed along a traverse 200 feet east of the first traverse. North of the X-Ray shaft two traverses with 20-foot measurement intervals were run across a dike, henceforth called the X-Ray dike, to points 100 feet on either side of the dike. Measurements were made at 20-foot intervals across a dike, henceforth called the Dalton dike, along a 400-foot traverse line located about 900 feet southwest of resistivity station 43 (pl. 2). Two traverses with 10-foot measurement intervals were run across a narrow quartz vein near the Rundberg incline, to points 100 feet on either side of the vein.

Some of the magnetometer readings are plotted as magnetic profiles in figures 21 and 22. In these figures the traverse lines are plotted in feet, as abscissae, and the readings of magnetic intensity are plotted in gammas,[8] as ordinates. A drop in the profile line indicates decreased magnetic permeability in the underlying rock; a rise of the profile line indicates increased magnetic permeability.

Figure 21 shows the magnetic profiles obtained at the "Jackpot vein." A decrease in magnetic intensity, averaging about 80 gammas, occurs over the vein in each of the profiles. The widths of the sags suggests that the wall rock as well as the vein material has a lower permeability than the unaltered monzonite, probably owing to alteration of the magnetic minerals by the vein-forming solutions. The results of measurements at the Rundberg vein (fig. 22, *b*) were inconclusive.

Figure 22, *a* shows the magnetic profile obtained at the Dalton dike. An increase in magnetic intensity occurs over the east edge of the dike, and reaches a minimum of about 160 gammas near the center of the dike. The high magnetic intensity and the irregularities of that portion of the profile west of the dike are probably caused by large boul-

[8] 1 gamma $=10^{-5}$ orested (the fundamental unit of magnetic intensity). The intensity of the earth's field is approximately 0.6 oersted, or 60,000 gammas.

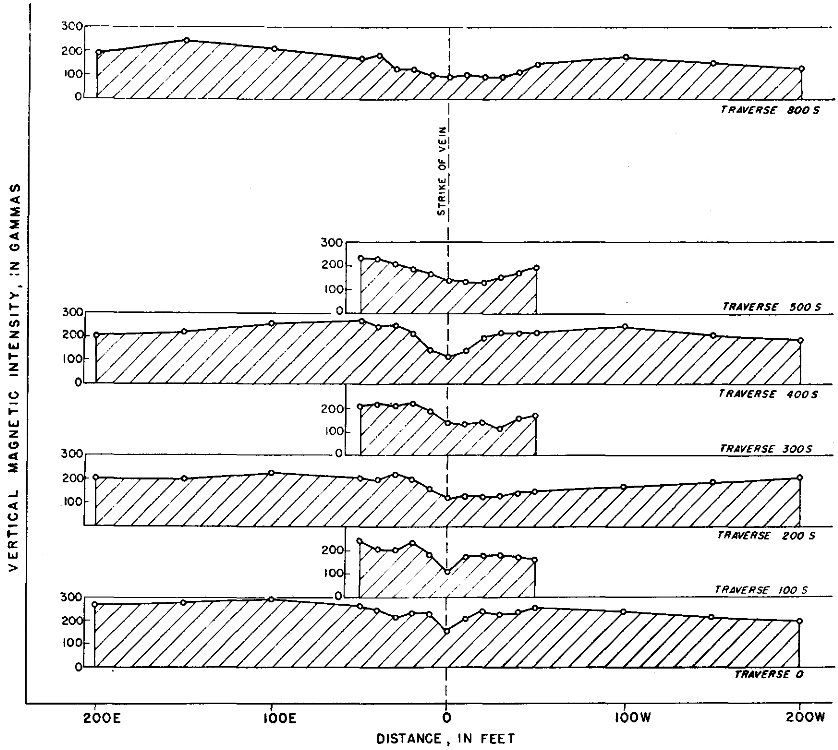


FIGURE 21.—Magnetic profiles showing variations in magnetic intensity over the "Jackpot vein".

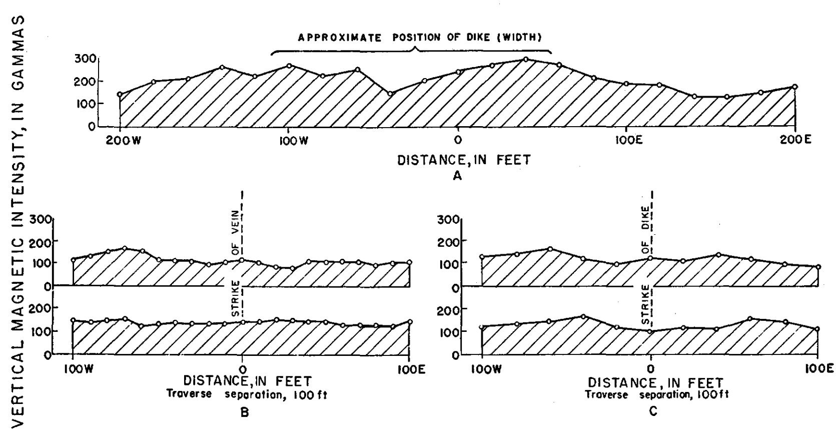


FIGURE 22.—Magnetic profiles showing variations in magnetic intensity over (*a*) the Dalton dike, (*b*) the Rundberg vein, and (*c*) the X-Ray dike.

ders of monzonite on the surface of the ground. The monzonite has fairly high magnetic permeability, and the boulders close to the magnetometer produced abnormally high values of magnetic intensity. This effect emphasizes the fact that, where the magnetic anomalies are small, much care must be taken in making magnetometer measurements and due allowances must be made in interpreting them.

The measurements at the X-Ray dike (fig. 22, *c*) show a slight decrease in magnetic intensity over the dike. The low permeability of the dike may be a primary characteristic, or it may be due to alteration of magnetic minerals in the dike. As quartz veins occur in the dike or at the contact of the dike with the monzonite, alteration of magnetic minerals by vein-forming solutions is a possible reason for the low magnetic permeability. However, quartz lenses also border the Dalton dike.

The magnetic profiles across the Jackpot vein (fig. 21) show a magnetic low following the strike of the vein and suggest that it may prove possible to trace other veins in the area by means of such magnetic contrasts. The explanations for the magnetic anomalies associated with the Dalton dike, and the Rundberg and X-Ray veins (fig. 22) are less obvious. The data obtained at the latter localities are so few that conclusions drawn from them are of doubtful value.

If sufficient magnetic contrasts exist it may be possible to detect and trace dikes or large veins concealed by surface wash by magnetic measurements. If possible the measurements should be started where the bedrock is known and then extended into areas where the rock is concealed. In this way magnetic anomalies associated with the veins or dikes may be recognized and used to trace the veins into undeveloped ground or to recover "lost" segments of veins. The magnetometer can be used in totally unexplored areas, but in such areas the magnetic readings must be interpreted with caution.[8a]

For means of comparison with the magnetometer results, the magnetite content of eight rock specimens was studied in the laboratory of the Geological Survey. Each specimen was crushed by hand-operated roller, weighed, and the magnetite separated from it as well as possible with a hand magnet. This preliminary work was done by C. P. Ross. One of the specimens of altered wall rock from the Jackpot mine yielded no magnetic material and, therefore, was not further treated. The magnetic residues obtained from the other seven were treated by W. T. Schaller to eliminate the impurities and learn the amount of magnetite present. The metallic iron introduced during grinding was dissolved in dilute sulfuric acid, which does not dissolve magnetite under the conditions followed. Next each residue

[8a] The following part of the section, Geophysical surveys in the Austin area, was written by C. P. Ross.

was further ground by hand in a small agate mortar and the magnetite separated from it as completely as possible by a hand magnet in a liquid medium (acetone) was weighed. The next step was to weigh the remaining gangue. The magnetite still in it was then dissolved in dilute hydrochloric acid. The insoluble residue was filtered off, washed, and weighed. The percentage of magnetite in each of the original specimens was calculated, with the results shown in the following table.

Magnetic content of selected specimens

Specimen	Weight (grams)	Percentage of magnetite
Altered monzonite with pyrite and quartz, Jackpot mine	46.83	0.002
Chloritized monzonite 200-ft level, Jackpot mine	40.76	.51
Comparatively fresh monzonite, 200-ft level, Jackpot mine	69.10	.38
Completely fresh monzonite from the dump of the King Alfred shaft	58.98	.83
Dark inclusion in the monzonite near the Tommy incline	65.69	.06
The large dike near the X-Ray mine	68.68	.0003
A small, dark dike south of the Tommy incline	35.90	.42

Evidently the fresh monzonite and lamprophyre contain distinctly more magnetite than those altered by mineralization, a fact which in general is consistent with the results of the magnetometer tests.

MINE DESCRIPTIONS

The Reese River district has been so thoroughly prospected that dumps dot the hillsides at close intervals, especially in the Austin area. Most of the extensive old workings have long been inaccessible, and even the maps of them that are now available are incomplete and inaccurate. Adequate description is therefore impossible, but the available data regarding all workings in the district are summarized below.

Many of the claims in the Reese River district were laid out a long time ago. They include some of the earliest patented claims in the United States, as can be seen from the low patent numbers assigned to some in plate 4. This map, although somewhat incomplete and inaccurate in detail, represents the best information available in 1937 as to the position and ownership of the claims in the district. Some of the numerous unpatented claims in the district have never been surveyed. The boundaries of some of them are shown approximately on plate 4. The position of some claims on the margins of the developed area are shown by placing their names appropriately on the map even though their boundaries are unknown. A few claim corners that were found in the course of the topographic mapping are shown on plate 2 as an aid in future claim surveying.

MINES OF THE AUSTIN SILVER MINING COMPANY

The property controlled in 1937 by the Austin Silver Mining Co. embraces most of the developed part of the Austin area and includes claims in the Yankee Blade and Midas Flat areas. This company also has interests in the Amador and other nearby districts, but these areas were not visited during the present study. The property includes about 89 patented claims near Austin, 5 in the Yankee Blade area, and 2 on Midas Flat. There are 3 mill sites near Austin with a flotation mill on one site in Pony Canyon a short distance below the town. There are also more than 60 unpatented claims, most of which were formerly worked by the Austin-Dakota Development Co.

The claims held by the Austin Silver Mining Co. were in process of being resurveyed in the summer of 1937 but the work had not progressed far enough so that the claims could be accurately placed on plate 2. However, enough had been accomplished to show that the discrepancies on plate 4 are, in general, not large. The east and west bases shown on plate 2 are the ends of the base line used by the company's engineers in their resurvey.

MINES ON LANDER HILL

GENERAL OUTLINE

The mines on Lander Hill controlled by the Austin Silver Mining Co. include most of those operated by the old Manhattan Silver Mining Co. They are in a roughly triangular area a little more than a quarter of a square mile, which at one time contained hundreds of small mines. Some of the original operators did no more than dig shallow pits and trenches to obtain oxidized ore that could be easily mined and treated. As development progressed more capital and technical skill were required, and consolidation of ownership resulted. Even after most of the properties were acquired by a single company, they continued to be operated as a group of small units rather than as a single mine. However, unification of control resulted in more economical and efficient pumping and haulage, and thus made it possible to mine to greater depths. Most of the actual mining of ore was done by lessees, who were almost as independent of each other as the individual owners had been before the consolidation. As a result the area is honeycombed by irregular workings, said to total between 20 and 30 miles in length, which ramify from the numerous, closely spaced inclines and vertical shafts. One result of company management was the connection of the different mines by underground openings to aid in access, drainage, and ventilation.

Underground development began with inclines which were often sunk several hundred feet on the veins before beginning lateral exploration. Later, vertical shafts were used, and the deeper workings lead from these. Exploration of the discontinuous ore shoots in rather closely spaced veins with complex systems of premineral and postmineral fractures necessitated many cross cuts. Many of the veins were first encountered in underground workings and only a few have been stoped as far upward as the surface. Commonly there was little correlation between veins found underground and those discovered in surface cuts. Litigation under the apex law was the inevitable result and continued until the claims were consolidated in ownership.

The principal workings on Lander Hill are shown on plate 2 which is based on compilations made by engineers of the Austin Silver Mining Co. This map shows 14 named veins but many others exist. The correlations suggested on this map and also on plate 6 are those adopted by the compilers and could not be checked during the present study. The named veins were worked through 21 inclines, 15 deep vertical shafts, and several deep winzes. The table below, which lists the principal connections with the surface, shows the vertical range through which the veins have been explored. The extreme range is from the collar of the Lander shaft (7,237 feet) to the bottom of the Frost shaft (6,085 feet), a vertical distance of 1,152 feet. Altitudes given in the table are not precise as available data are not consistent in all respects.

The principal shafts and inclines on Lander Hill

Name	Altitude of collar (feet)	Altitude of bottom (feet)	Depth (feet)
Vertical Shafts			
Curtis	6,957	6,353	604
Frost	6,961	[1] 6,089	872
Great Eastern	6,813	6,473	340
Lander	7,237	6,015	1,022
North Star	6,938	6,335	603
Oregon	7,018	6,328	690
Pacific	6,987	6,445	542
Plymouth	6,951	6,251	700
Sherman	7,257	6,987	270
South American	6,858	6,474	384
Toiyabe	6,934	6,518	146
Inclines			
Bedford	7,068	6,864	538
Belle Wilder	6,835	6,711	160
Blue	6,878	6,520	578
Bowman	6,760	6,469	600
Buel North Star	----------	----------	410
Florida	6,958	6,719	488
Isabella	6,937	6,713	527
Jackscrew	7,012	6,833	417
Magnolia	6,996	6,790	392
Paxton	7,020	6,381	1,800
Ruby	7,091	6,764	576
Silver Wedge	7,057	6,919	360
Troy	6,925	6,710	503
Ward	7,051	6,802	575

[1] Includes connections made from Clifton tunnel.

The veins differ in attitude from place to place but most have an average trend of about N. 30° W. and dip northeasterly. In the different workings they have been explored for a maximum distance along the strike of the vein of about 3,600 feet. Several have been followed for hundreds of feet down the dip, generally at angles of 20° to 40°.

The Farrell vein appears to have been traced for nearly 1,700 feet down the dip. The mine map for this vein is somewhat more complete than those available for most of the workings on Lander Hill (pl. 5). This map shows that drifts were driven close together. Stopes were small and somewhat irregular but closely spaced.

A number of the veins, at least locally, have strikes of N. 50°–60° W., and the Independence, now inaccessible, trends nearly west. This vein differs more from the average attitude than any of the other extensively developed veins, although some minor veins parallel it. Some of the deepest workings on the hill are reported to have been in ore at the time development ceased. Northwest of the main workings there are numerous cuts and shallow inclines, as shown on plate 2, but apparently few were sufficiently favorable to encourage development to depths greater than 50 feet below the collar. Most of the workings in this part of the district are even shallower. Tunnels driven from both Pony and Slaughterhouse Canyons, however, cut veins hundreds of feet below the principal outcrops on the hillsides. None of the veins thus exposed at depth have been stoped to any extent. To the southeast, along the trend of the veins of Lander Hill exceedingly little development has been undertaken, except for the cross-cut tunnel driven some time ago by the Austin-Nevada Consolidated Mining Co.

Only small parts of the intricate workings in the more thoroughly developed section of Lander Hill were reconditioned by the Austin Silver Mining Co. Where reconditioning has not been done recently the soft, weathered rock at the collars of shafts and inclines has caved. At many places slumping makes it difficult to determine where the opening formerly was. Poor ventilation is also a serious handicap in many of the workings in the district. Each portion of the old mines that was entered during the present investigation is described below. The data given refer to conditions as they were in the summer of 1937. The names of veins used in the descriptions are those assigned to them on available maps. It is not now possible to follow the different veins from one mine to another in such a way as to check correlations.

CUMMINGS LEASE TUNNEL

The portal of the Cummings Lease tunnel is on the Dollarhide and Defiance claim and it is nearer to the summit of North Hill than any of the other accessible workings on the slopes of Lander Hill, except for pits and shallow prospect inclines and shafts. Much of the work here was done by Con Cummings under lease in 1916. He mined ore that, according to the Reveille of April 8, 1916, ranged in content from 300 to 1,500 ounces of silver to the ton. This must have been carefully hand-sorted material. Some of the ore from these workings contained as much as 2 percent copper and 5 percent lead, but most of the ore now exposed does not show much sulfide other than scattered pyrite. The gold content, even in selected ore, is probably less than 0.05 ounce to the ton. The total production by Cummings is uncertain but did not exceed a few thousand dollars in value. Some work has also been done here by the Austin Silver Mining Co.

The tunnel (fig. 23) follows a quartz vein for a distance of 290 feet into the hillside. Three raises, one reaching the surface, explore the upper part of the vein; and winzes with drifts leading from them follow the vein for a distance of more than 100 feet down the dip below the tunnel level. There is much irregularity in both the continuity and the attitude of the quartz lenses and seams. The quartz monzonite is sheared and altered for widths of several feet, but the quartz lenses range from a few inches to slightly more than 2 feet wide. In several places quartz lenses pinch out down the dip against fractures of low inclination. One such slip, believed to be premineral, is illustrated in figure 15. Similar low-angle slips with various strikes are exposed in different places along the main winze. There are also a number of steeper postmineral fractures that traverse the vein but cause little offset.

ECLIPSE TUNNEL

The portal of the Eclipse tunnel is about 40 feet below and 160 feet southeast of the Cummings Lease tunnel portal. The tunnel cuts two veins (fig. 24).

BELLE WILDER INCLINE

The portal of the Belle Wilder incline is in the northwest part of the Belle Wilder and Audubon claim, a short distance down the slope northeast of the two tunnels described above. The incline was driven downward 160 feet on the hanging wall of a vein, which trends N. 18° W. (fig. 25). A crosscut northeast from the bottom of the winze cuts 3 veins, each of which has been drifted on for a short distance. The quartz lenses vary in width from about an inch to more than a foot. Some contain bands of rhodochrosite.

Assays made in 1915 to 1919 of samples from the Belle Wilder show that the vein matter contained as much as 100 ounces of silver to the ton. One sample supposed to represent first-class or high-grade material contained a trace of gold, 68.8 ounces of silver to the ton, 8.4 percent lead and 11.2 percent copper This is an exceptionally high

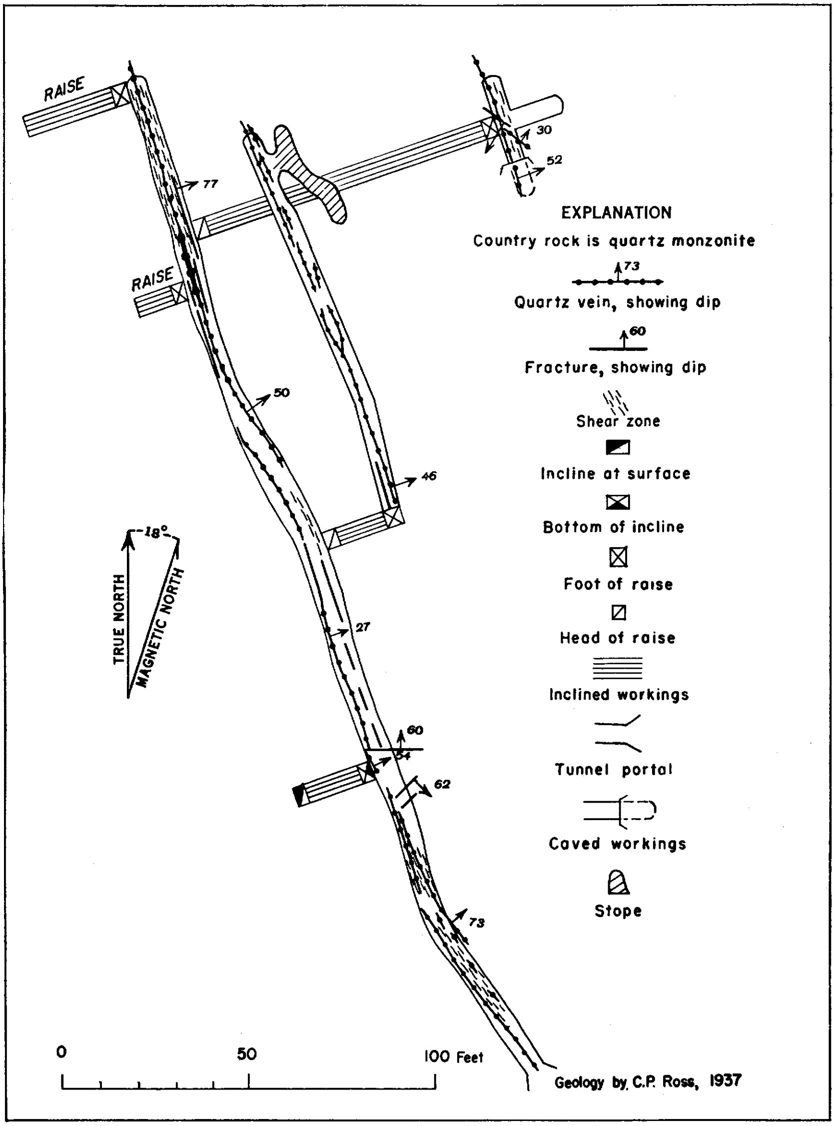


FIGURE 23.—Geologic map of the Cummings Lease tunnel and associated workings.

content of lead and copper, but much of the vein matter in this mine contains appreciable quantities of base metals. The high content of base metal is probably the reason why the deposit, long known, has not been productive until recently. A picked piece assayed in 1919, contained 0.12 ounce of gold and 419.9 ounces of silver to the ton, 1.8 percent lead, 1.2 percent zinc, 4.7 percent copper, 13.5 percent iron, and 52.8 percent silica. This is probably roughly representative of

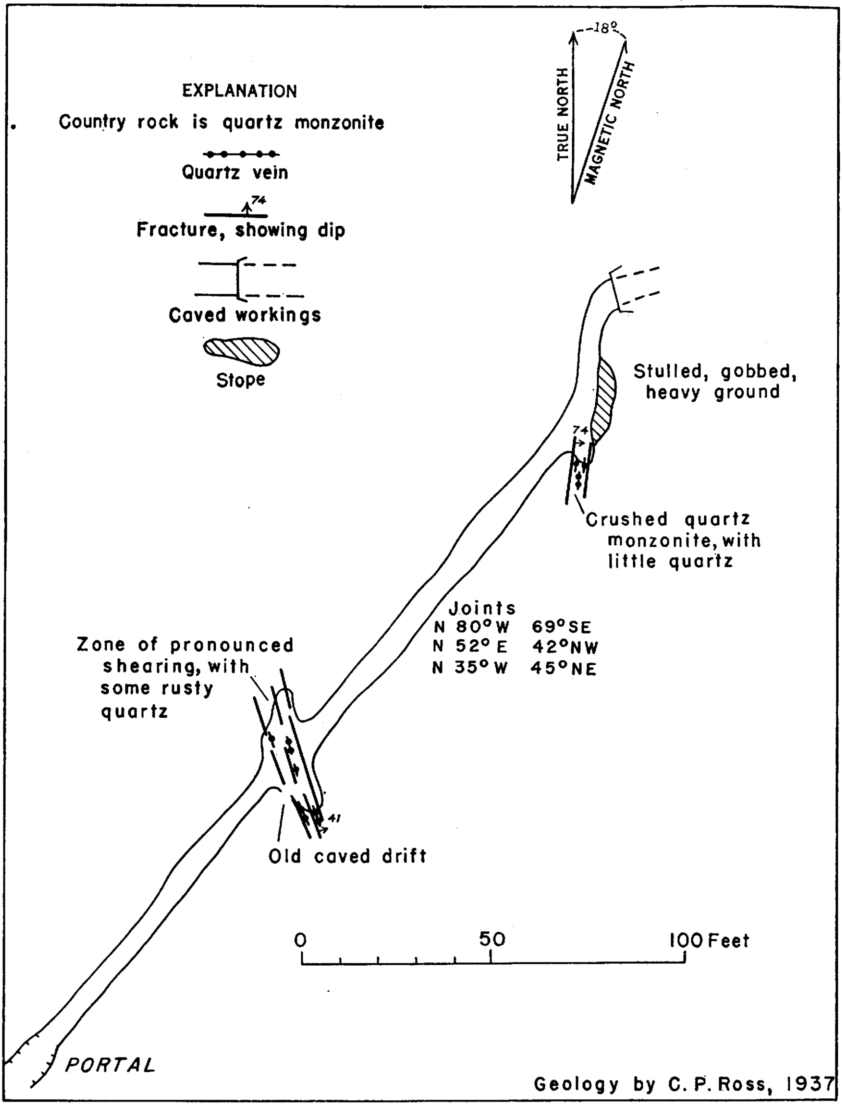


FIGURE 24.—Geologic map of the Eclipse tunnel.

the proportions of the different constituents, although of course, of more than average richness.

ISABELLA INCLINE

The Isabella incline has its portal on the Wall and Isabella claim a little more than 1,000 feet southeast of the Belle Wilder portal. It is a part of the main workings originally developed by the Manhattan Silver Mining Co., whereas each of the openings previously de-

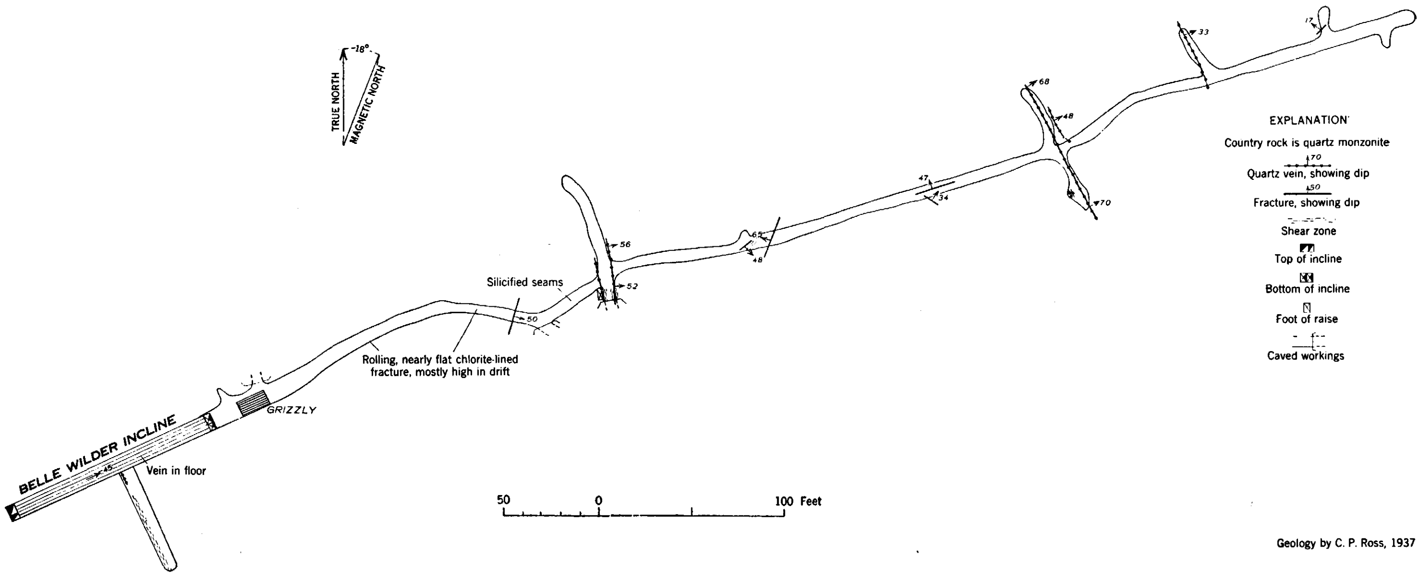


FIGURE 25.—Geologic map of the Belle Wilder workings.

scribed is isolated. The Isabella was one of the more productive workings of the company and stopes connected with it were worked as late as January 1887. The aggregate production before October 1887, is reported to total $626,798.78. This figure presumably represents assay content of the original ore calculated at $1.2929 per ounce of silver. Some work has been done here more recently. The Isabella was one of the first of the old workings to be reopened by the Austin Silver Mining Co.

The incline is 527 feet long and its bottom is 224 feet below the collar, equivalent to an average slope of a little over 25° to the northwest (pl. 6). The Isabella vein is exposed near the floor of the incline down to the 200-foot level where old stopes were reopened by the Austin Silver Mining Co. for a short distance to the northwest. The drifts and stopes on the Isabella vein originally extended northwest and connected with workings from the Toiyabe shaft. Much stoping has been done on the Hays vein northeast of the Isabella above and below the 200-foot level, but most of the stopes are now inaccessible. In the parts reopened by the Austin Silver Mining Co. ruby silver ore was found in some of the pillars.

No vein is exposed along the incline for about 90 feet on the dip below the 200-foot level. At places in this stretch the quartz monzonite is much jointed and somewhat crushed. Below this the incline exposes several small veins, some of which have been faulted.

A crosscut extends northeast from the bottom of the Isabella incline. Caved drifts on a narrow vein intersect this crosscut a short distance from the incline. Farther northeast a curved drift leaves the main crosscut along what is supposed to be the Hays vein. This drift explores a quartz vein containing ruby silver. In 1937, a winze below the drift was safely accessible only to a depth of 54 feet on the incline, where there are short drifts.

The main crosscut from the Isabella incline is accessible only to the Currelly vein. At this place either two veins exist or the Currelly vein has been offset by faults. At the time of visit the nearby drifts and stopes were largely inaccessible so that it was impossible to see which explanation is the more probable. At a point nearly 200 feet to the southeast there is a wide zone of crushed rock and the vein may be offset a short distance. The crosscut beyond the crushed zone passes through two other veins, both of which have been explored by drifts. In one of these drifts the vein, said to be the Alabama vein, is stepped over slightly along slips which themselves contain enough quartz to show that they are premineral. It is possible that all the irregularities in these veins result more from the vagaries of original deposition in a much jointed rock than from displacement by postmineral faults.

MAGNOLIA INCLINE

The portal of the Magnolia incline is on the Black claim, 300 feet southeast of the portal of the Isabella incline. From the portal to the first drifts, a distance of about 300 feet on the slope, the incline is believed to follow the Magnolia vein, but little of the vein matter is visible (pl. 6). Even on the 300-foot level there are few exposures of this vein, and the drifts are closed within short distances on either side of the station.

A crosscut to the northeast, 30 feet northwest of the station, cuts the Hays vein about 40 feet out and the Currelly vein at the end of the crosscut about 180 feet farther northeast. Both veins have been opened by drifts and stopes, parts of which were accessible at the time of visit.

About 25 feet northwest of the first crosscut mentioned above, another crosscut leaves the drift on the Hays vein to the northeast. This crosscut was in poor condition in 1937 but was explored for a distance of 200 feet where it turns southeast and becomes a drift on a vein. The drift could be followed only 60 feet. Near the middle of the crosscut several segments of a vein, broken by slips, are exposed.

The Magnolia incline continues downward below the workings on the 300-foot level. At two points, drifts leave the incline on a vein locally regarded as the Hays vein. At the first of these drifts, approximately at the 400-foot level corresponding to the bottom of the original Magnolia incline, the vein appears to be sharply curved near the incline. Below this level the incline turns slightly and now continues nearly 100 feet farther down. At its bottom there is a drift to the northwest, supposed to be on the Hays vein. This is connected with the Isabella workings for ventilation by a winding, partially collapsed passageway.

RUBY INCLINE

The Ruby incline, the highest accessible opening on Lander Hill, has its portal on the Jo Lane claim about 800 feet north of the portal of the Magnolia. Little work has been done here for a long time, but in 1937, it was still possible to get down the incline and traverse part of the irregularly curved drift that extends southeast from a point 295 feet down the slope of the incline. The original incline was 576 feet long, and its bottom, now inaccessible, was 327 feet below the collar, which is equivalent to an average slope of about 36°. It is reported that the gross production through August 1891 had an aggregate value of $804,052.77. The Ruby incline follows a vein throughout its accessible extent. Within this short distance the vein varies considerably in attitude. The dip changes from more than 50° NE. in the upper part of the incline to 34° NE. and the strike swings from N. 2° W. to N. 10° W. at the bottom of the accessible part of the incline. In the drift to the southeast from this point the vein is discontinuous and curved. Its dip decreases to 26° NE., and its strike ranges from N. 10° W. to N. 60° W. The vein contains quartz, rhodochrosite, and locally calcite. It has not been stoped in the accessible workings.

NORTH STAR MINE

The North Star mine in the southern part of the Lander Hill area is one of the first and most productive of the mines acquired by the Manhattan Silver Mining Co. Operations centered around it during much of the history of that company and this mine contributed a large proportion of the silver obtained by the company. The North Star shaft, one of the earliest of the vertical shafts on Lander Hill, came to be used mainly for purposes of ventilation and pumping during the company's later operations. This shaft was 603 feet deep but has long been inaccessible. Unlike many of the ore shoots on Lander Hill, the main ore body in the North Star mine was stoped to the surface, a fact which may have contributed to the extensive caving near the shaft. It is reported that material of a gross aggregate value of $2,159,602.64 was taken out of this shaft from the start of operations through 1882.

A minor ore body within a few feet of the North Star shaft was opened up by John Rast and John A. O'Brien under lease from the Austin Silver Mining Co. in 1937. They drove an incline about 125 feet long (fig. 26).

The workings follow an irregular, rolling vein, which locally attains a maximum width of about 6 inches in a zone of disturbed and altered granitic rock about 3 feet wide. In the lower 45 feet of the incline the vein pinches out and merges with low angle joints. Sacked ore from this lease contains disseminated proustite, and a little of the mineral was left in the unmined quartz lenses. The ore shows incipient oxidation.

TUNNEL EAST OF THE DIANA SHAFT

The Diana shaft is one of those in which work was done by the Austin Silver Mining Co. in 1935, but lack of ventilation prevented entrance in 1937. During the activity of the Austin Silver Mining Co. in this vicinity, a tunnel was opened about 375 feet east of the Diana shaft. The tunnel and its branches expose three roughly parallel veins (fig. 27).

MINES IN OTHER PARTS OF THE AUSTIN AREA

CLIFTON TUNNEL

The long drainage tunnel which starts near the old town of Clifton and the mill of the Austin Silver Mining Co. and ends under the Frost shaft has been known by different names including Clifton,

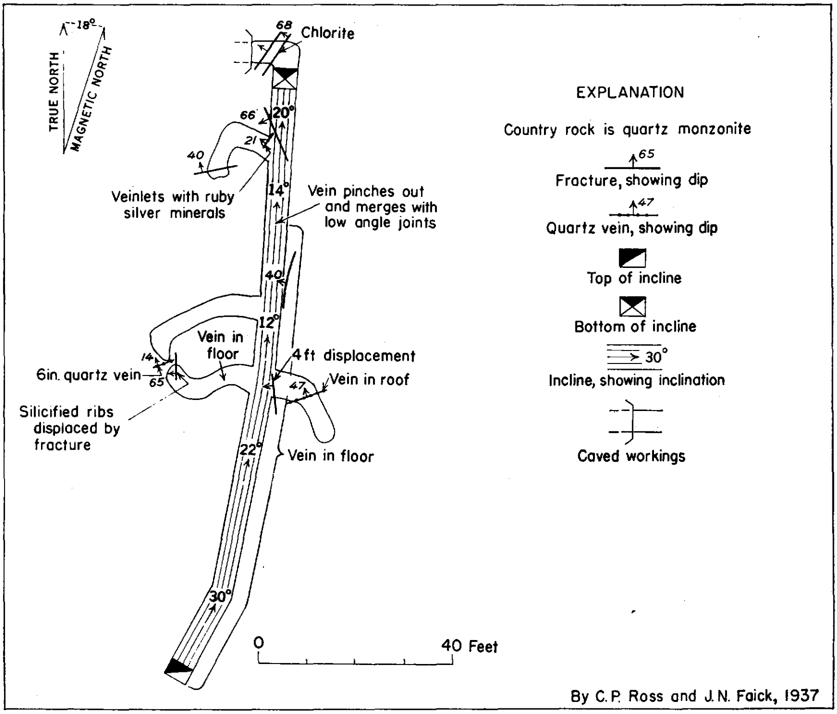


FIGURE 26.—Geologic sketch map of the Rast and O'Brien workings.

Austin, Manhattan, and Austin-Manhattan. Most of the work of driving this tunnel was done by the Austin Mining Co. in 1897. The tunnel was begun while Clifton was still in existence, although most of it was driven after nearly all traces of that town had vanished.

The Clifton tunnel is about 5,930 feet long and trends about S. 73° E. for nearly its entire length, with slight deviations at both ends. The end of the tunnel is 80 feet below the bottom of the Frost shaft but is connected with it by a raise. Since its completion it drains the workings of the Manhattan Silver Mining Co. As can be seen from the table on page 90, the old workings on Lander Hill, with a few notable exceptions, are above the tunnel level. A crosscut, called the first north lateral, has been driven from a point 3,855 feet from the portal in a N. 57° E. direction for a distance of about 2,800 feet. This further facilitates drainage from the more northerly of the old workings.

The tunnel and its lateral apparently have drained those parts of Lander Hill above an altitude of about 6,280 feet. Originally openings were to be used as haulage ways to save hoisting costs for ore from the deeper parts of Lander Hill. The ground in the vicinity of veins, however, is so broken that it caves readily even though much timber has been used. The tunnel and lateral were originally driven in 1897

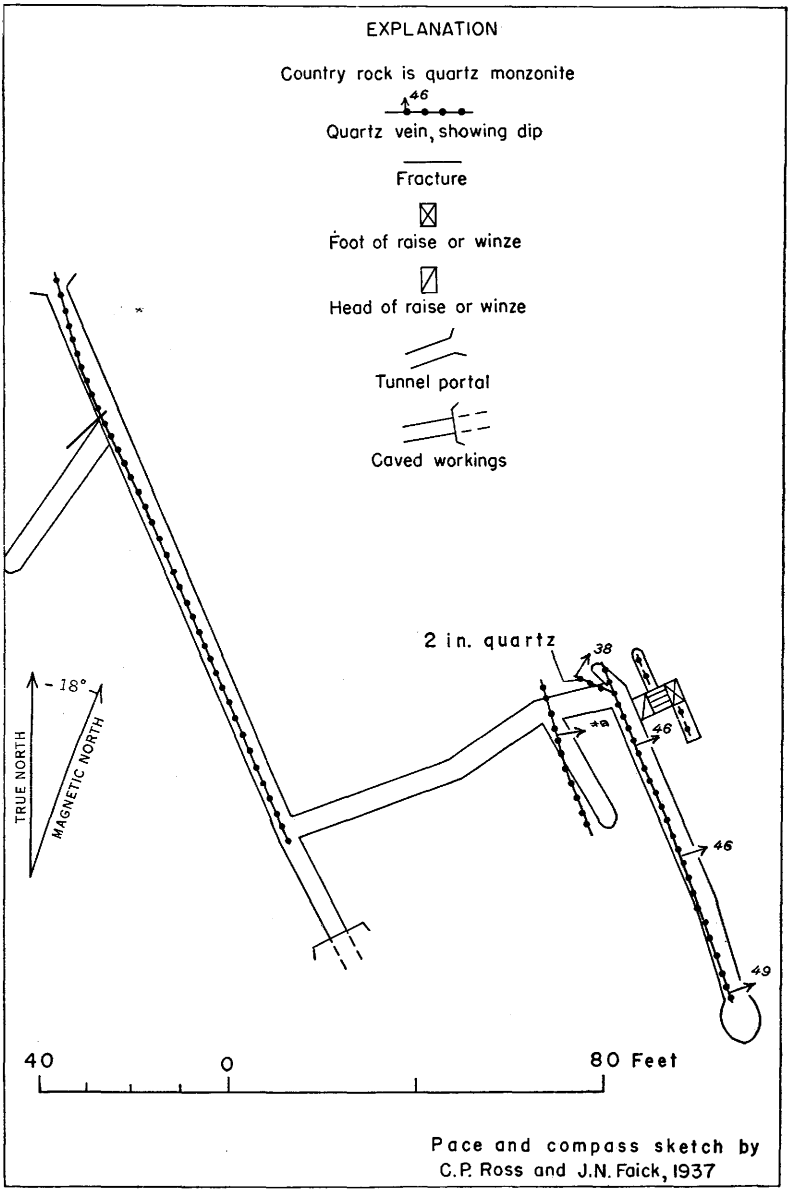


FIGURE 27.—Geologic sketch map of a tunnel east of the Diana shaft.

but were caved when the Austin Manhattan Consolidated Mining Co. started reopening in 1908. Although this company completed the work of opening and retimbering the tunnel and most of the lateral, the latter was again caved when the district was visited by Hill (1915, p. 111) in the spring of 1912. The Austin Silver Mining Co. reconditioned 1,275 feet of the tunnel in 1935 and this part was open in 1937, but the air in it was so deficient in oxygen that oxygen helmets were required in order to inspect it. This tunnel was being used as the source of water for the mill. Although a low dam had been constructed 300 feet from the portal to collect the water that trickles along the tunnel floor, the quantity was so small that it was generally used up by the mill between 8 a. m. and 10 p. m. daily. A well near the mill is available to supply additional water if required.

The tunnel is not advantageously located for prospecting at depth because much of it lies southwest of the old workings; both the tunnel and the principal veins of Lander Hill trend northwest. Except near the Frost shaft, the tunnel cut no veins that warranted development. Neither Hague (1896, pp. 5–8), who saw the tunnel shortly after it was driven, nor Humes,[9] who reopened it in 1908 and 1909, mentions any valuable veins. Hill (1915, pp. 111–112) notes several minor veins and one quartz monzonite porphyry dike with a vein at its center. The dike trends N. 12° E. and dips 85° SE. He also mentions the fact that a lateral, inaccessible to him, leaves the tunnel about 1,760 feet farther in than the first north lateral. This is said to expose two veins. These inaccessible workings are doubtless on the Panamint vein referred to below.

In the 1,275 feet of the tunnel accessible in September 1937, veins of two systems are visible. One system consists of quartz lenses a foot or more thick that trend north of west and dip northeasterly at angles of a maximum of about 25°. These lenses are cut by narrower quartz veins that strike north to N. 10° E. and dip steeply eastward. The veins of both systems contain disseminated pyrite, mainly in cubes. No other sulfide minerals were recognized. The veins of the steep set commonly show evidence of fracturing by minor postmineral movement. No veins were seen in the first 500 feet of the tunnel where the rock is light-colored and fresh. Near the dam there is a westward dipping clay seam that may represent a narrow, altered dike. Hill notes that some of the lenses of northwesterly strike in the deeper part of the tunnel contain rhodochrosite. He saw galena and sphalerite disseminated in a vein 2 inches wide that trends N. 7° E. and dips 75° E. about 1,050 feet from the portal.

Closer to the Frost shaft more promising veins are cut by the tunnel. Hague reports that the Panamint vein is exposed about 5,500

[9] Humes, James, manuscript report dated June 17, 1911, pp. 5–6.

feet from the portal. This vein, according to Hague, "seems to be well defined but not rich". He adds that the vein at the tunnel level is discontinuous but in places contains rich streaks. A considerable amount of exploration work was done on this vein at and near the tunnel level in 1897.

At the point where the main tunnel comes under the Frost shaft a large station was cut to facilitate proposed future operations. A vein was exposed at this station and, according to Hague, was drifted on southeasterly for more than 300 feet and northwesterly for 100 feet. The southeasterly drift was already caved at the time of Hague's visit in 1898, and neither drift is referred to by Humes.

About 1909, the Austin-Manhattan Consolidated Mining Co. did much work below the tunnel level in the vicinity of the shaft. A large three-compartment winze was sunk 230 feet below the tunnel level from the station. When the tunnel and the old Frost shaft were connected, this made a continuous vertical shaft 872 feet deep. The only deeper working in this district is the old Lander shaft, 1,022 feet deep. Apparently, however, the Frost shaft was never used throughout that depth, except for ladderways. Below the tunnel, at the 800-foot level, a station was cut and a drift was run 20 feet southwest along what Humes called "a break that passes through all the Lander Hill veins." A vein was cut near the end of this crosscut. A map in the files of the Austin Silver Mining Co. indicates that one sample from this vein assayed 0.15 ounces in gold and contained $104.50 in silver, another 0.15 ounces in gold and $14.00 in silver to the ton. A 150-foot crosscut northeast from the same station cuts a vein at a distance of 50 feet from the shaft. Drifts revealed an average width of 6 inches of vein with a value of $52.60 a ton in silver for a total distance of 65 feet. Some of the vein matter at the 800-foot level must have been of materially higher grade than the averages indicated on the map. Humes mentions an assay of 1,400 ounces and a number of assays made in 1910 by James Preston show a silver content of several hundred ounces to the ton, with a trace of gold. One shows 1,029.72 ounces to the ton. Humes notes that the drift southeast from the north crosscut was continued for a length of 120 feet and that the smelter returns showed an average of 326 ounces of silver per ton. Another vein was encountered in an extension of the northerly crosscut 37 feet beyond that first mentioned. A vein was also cut in the shaft between the 800- and 900-foot levels. According to Paul Klopstock, the veins on the 800-foot level contain chalcopyrite.

According to Hague, several veins were cut in the first north lateral that leaves the main tunnel 3,855 feet from the portal. One of these is 700 feet from the start of the lateral and is about 2 feet wide. This contains abundant sulfides of lead, zinc, and other metals. Drifts and stopes were opened on it in 1897. Another vein about 2½ feet wide and 275 feet farther along the lateral was also drifted and stoped on at that time. A drift here, according to Hague, was continued northeast far enough to intersect the Plymouth shaft 30 feet above its bottom and must, therefore, have been about 700 feet long. The veins cut in the deeper part of the lateral were regarded by Hague as of less value. He says that material from workings along the tunnel, mostly from the stopes mentioned in this paragraph, aggregated 549.5 tons in May to September 1896, inclusive, 2025.4 tons in 1897, and 45.5 tons sacked at the mill for shipment to the smelter. As most of this material was mixed with that from other sources before assay its content is not known. From October 18 to October 30, and from November 19 to November 28, 1897, all the ore sent to the mill came from workings off the Clifton tunnel. The average assay of 18 samples taken between these dates is reported to be 9.28 ounces of silver to the ton. The average assay value of shipping ore at that time was 206 ounces of silver a ton. Hague states that the new mill in operation in 1897 recovered only 52 percent of the content of the original mill feed and that material of the value indicated above could not be profitably handled. Hague sampled the first vein cut in the first north lateral and reports that the weighted average of 23 samples indicates 11.7 ounces of silver to the ton for an average width of 10.5 inches. One sample assayed 123.5 ounces. If this is omitted from the calculation, the weighted average becomes 7.7 ounces to the ton.

UNION MINE AND VICINITY

The Union and Ophir shafts, both inaccessible in 1937, are near the eastern margin of plate 2. They are almost due south of the intensely developed area on Lander Hill. The presence of lodes in this vicinity has long been known, and some work was done early in the history of the camp. After activity on Lander Hill had subsided, extensive development was undertaken here, in part by the Manhattan Silver Mining Co. in the eighties. This company, however, carried the work down to the 200-foot level only. Most of the later development was done by the Austin Mining Co. in the nineties. The data below are taken mainly from maps and reports of the Austin Silver Mining Co.

The Union shaft is 625 feet deep, cutting the Union vein about 40 feet above its bottom (pl. 7). Levels have been opened at depths of approximately 125, 200, 350, 450, 550, and 625 feet below the shaft collar. A winze on the vein near the bottom of the shaft has been extended to the 700-foot level. An ore shoot on the Union vein has been stoped from the 625-foot level almost to the 125-foot level. This vein has not been traced through to the surface but it or offshoots from it may be seen in shallow inclines south of the crest of the ridge near the 39°29′ parallel. The Union vein strikes about N. 40° W. and dips about 40° NE. The developed ore shoot plunges about 45° NW. It has been mined for about 600 feet down the dip and across an average stope length of about the same amount. Stopes also extend from the 200-foot level to some distance above the 125-foot level. So far as can be judged from available maps (pl. 7 shows the major workings and approximate positions of the principal veins) these stopes may be on a branch of the Union vein or a separate, slightly steeper vein about 100 feet in the hanging wall of the Union vein.

Crosscuts were driven southwesterly from the Union mine, largely in search of possible extensions of the Whitlatch vein. An ore shoot reported to have been both rich and exceptionally wide was mined out of the Whitlach vein early in the history of the camp, but in spite of extensive search, no extensions of this vein have been found. In the crosscuts from the Union, two veins called the Wild Jim and the Snow Flake were found; both are roughly parallel to the Union vein. The Wild Jim has been stoped rather extensively for 75 feet above the 625-foot level of the Union mine. It is a little more than 150 feet into the footwall of the Union vein along a line normal to the Union. The Snow Flake, which is nearly 250 feet farther away from the Union along the same line, does not appear to have been stoped much, perhaps in part because of inadequate ventilation, at a distance from the Union shaft. The Snow Flake vein at the 200-foot level of the Union mine is nearly 1,200 feet from the shaft.

A crosscut has been driven about 1,700 feet northeast from the Union shaft at the 350-foot level. It terminates near the old Bowman incline at an altitude about 160 feet above the Clifton drainage tunnel. The Bowman incline is in the southeastern part of the developed area on Lander Hill, and the crosscut thus serves to prospect the ground between that area and the Union mine. Apparently no veins worthy of prospecting were found in this crosscut.

The Ophir shaft, 270 feet deep, is about 700 feet southeast of the Union shaft and about 150 feet higher up the hill. A crosscut from the bottom of the Ophir shaft connects with a drift on the 125-foot level of the Union mine in an area where considerable stoping has been done.

Numerous caved inclines and tunnels are near the Union and Ophir shafts. Most were shallow, but some may have attained depths of more than 100 feet. Such data as were obtained from them are shown in plate 2.

According to Hague, the Union mine had yielded a total of $293,887.24 before July 22, 1891, when the Austin Mining Co. obtained it.

His data regarding the operations of that company from 1891 to 1898, indicate that during the period the Union mine yielded ore valued at nearly $500,000. About two-thirds of this ore was shipped to smelters and the rest was sent to the mill for concentration. He estimates that the ore may have averaged 50 to 60 ounces of silver to the ton.

LUETGEN TUNNEL

The Luetgen tunnel, on the south side of Pony Canyon close to the large church on the south side of Main Street, is one of the workings that has been reopened and extended by the Austin Silver Mining Co.

In August 1937 the Luetgen tunnel was about 430 feet long, with short drifts on both sides from a point about 320 feet from the portal (pl. 8). The tunnel for most of its length follows a composite dike fully 10 feet wide bordered by quartz lenses. The dike trends about N. 30° E. and dips steeply southeast. A little more than 100 feet from the portal the dike appears to feather out to the northeast into the monzonitic rock, and from surface exposures the dike does not appear to continue northeastward. The drift to the southwest exposes a curved vein on which a little stoping has been done. The strike of the vein ranges from N. 60° W., with a dip of 34° NE. near the tunnel to N. 85° E., with a dip of 41° NW. near the end of the drift.

WORKINGS IN LOWER PONY CANYON

A number of tunnels and inclines are in the general vicinity of the mill of the Austin Silver Mining Co., near the site of the original discovery and some of the earliest development in the district. There has been little activity for many years.

On the south side of the canyon, above the mill tailings dump, tunnels have been driven to prospect for northward extensions of veins that crop out near the Bartlett workings.

The rock on which the mill is built contains quartz veins, some of which are reported to contain silver. An incline a short distance north of the northeastern part of the mill exposes a quartz vein 14 inches wide that strikes N. 32° W. and dips 34° NE. The portal of one of the longest accessible tunnels in this vicinity is a little farther east, near the portal of the Clifton drainage tunnel. This tunnel (fig. 28) is about 758 feet long. About 65 feet from the portal a narrow vein that strikes N. 33° W., and dips 14° NE. is exposed; it contains pyrite, chalcopyrite, and their alteration products. Another vein that strikes east and dips 21° N. is exposed 176 feet from the portal. Still further in calcite veins are cut. A vein that strikes about N. 55° W. and dips 52° NE. was found 531 feet from the portal and was explored by drifts. It has a maximum width of 8 inches, but in the northwestern part of the drift it wedges out.

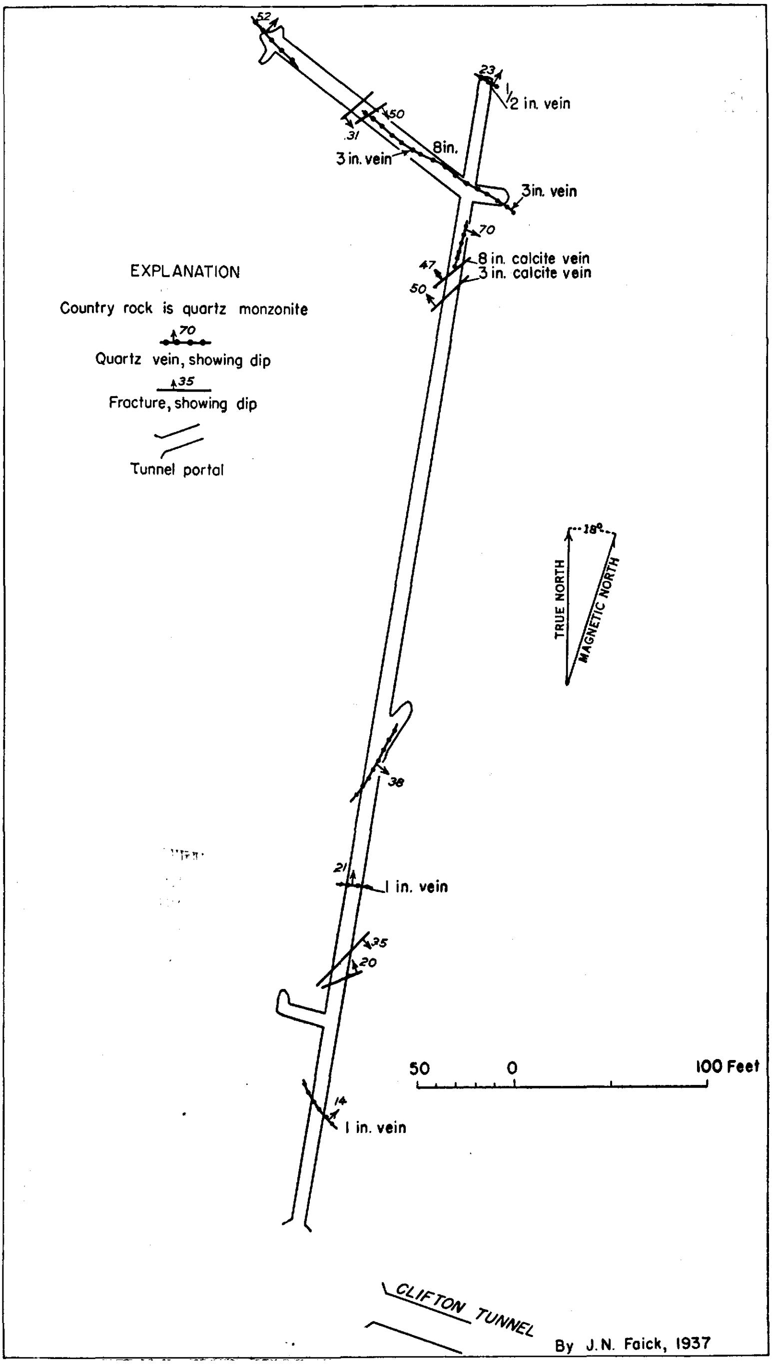


FIGURE 28.—Geologic sketch map of tunnel between the mill and the Clifton tunnel.

Other minor workings are in this general vicinity. Most of them were not accessible in 1937 and have not been studied in detail.

BARTLETT WORKINGS

The group of workings containing the Bartlett tunnel along the gulch south of Pony Canyon near the mill and north of the Castle are described together. The Castle, a landmark in the area, is built of blocks of monzonite and resembles a medieval fortalice. It was intended as a residence, but apparently was never completed for occupancy.

The principal workings are the Bartlett and Hanchett tunnels, the Tripod shaft and a nearby tunnel, a vertical shaft on a subsidiary ridge above the gulch, and cuts and shallow tunnels on the north slope of the gulch, below the road. These are shown in plate 9. Recent work by the Austin Silver Mining Co. in this vicinity has been confined to the Bartlett tunnel. Some of the vein matter found here was sufficiently high in grade to encourage further work. At the time that field work for the present report ceased the northerly branch of this tunnel was being extended near the Tripod shaft, and the results of this later work are incorporated in plate 9, on the basis of a map furnished by J. P. Hart.

The Bartlett tunnel extends 250 feet into the hill in a S. 21° E. direction and then branches. In the straight part several narrow silicified ribs and quartz veinlets are exposed. The aggregate length of the different branches on September 20, 1937, was about 435 feet. Close to the point where the branches begin, a zone of fracture and alteration 10 feet wide is exposed. The zone trends about N. 40° E. and dips steeply northwest. The quartz monzonite in the zone is much sheared and chloritized and contains silicified ribs parallel to the shear planes. A few feet farther east the tunnel passes through a dark, somewhat altered dike for a distance of nearly 15 feet. The contacts, especially on the east side, are so irregular that the attitude cannot be accurately determined, but it trends east of north and is steep. Between the dike and the fault zone a segment of a narrow quartz vein of northwesterly trend is exposed in the roof of the tunnel. Exposures on the surface and in the Hanchett tunnel suggest that the dike may continue as much as 250 feet northeast. It has not been found to the southwest, although surface exposures of similar rock, either another dike or a faulted segment are near and northwest of the portal of the Bartlett tunnel. The first branch to the right from the main tunnel is near the northwest side of the fault zone and cuts a comparatively wide quartz vein about 60 feet southwest of the main tunnel. A drift has been run for 55 feet along this vein, which strikes N. 75° W. and dips 56° to 65° NE. This vein in places is as much as 3 feet wide and contains pyrite. Some assays of the vein are reported to show enough silver to encourage further development. A crosscut to the south from the main tunnel a short distance southeast of the dike exposes several quartz veinlets, two trending N. 70° to 75° W. and dipping 75° SW. In the main tunnel a narrow, poorly defined vein has been traced for about 40 feet from the crosscut. It trends about N. 50° E. and dips 76° NW. This vein is crossed by another that trends nearly east and dips north the angles of 45° to 80°; at the intersection no displacement of either vein was noted. The cross vein is of variable width and grades into irregularly silicified quartz monzonite containing disseminated pyrite. The quartz of the vein contains pyrite and, locally, chalcopyrite, galena, sphalerite, and bornite. The bornite is probably supergene. In places it is reported to contain considerable silver. Locally, bands of vein quartz and silicified rock occupy much of the width of the drift. Several cross slips interrupt and slightly offset the vein. Some contain quartz veinlets; others show silicification of the country rock along them. Conspicuous outcrops of white quartz on the surface are probably the same vein, although the trend is a little more to the north than in the drift.

Another prominent vein crops out almost continuously for 370 feet from the Castle to the vertical shaft (pl. 9). It strikes a little east of north and dips 65°–70° E. On the north slope of the gulch, a series of cuts expose a double vein that is almost in the line of strike of the one near the Castle but dips 80° to 85° W. The principal exposure is at the altitude of 6,575 feet, and is the only one that is shown in the northeast part of plate 9. The inaccessible Tripod shaft is close to the gulch and nearly on the line between the vein exposures. A short tunnel nearby contains a quartz seam that strikes N. 58° W. and dips 27° NE. One object of the drift to the east in the Bartlett workings was to determine whether the double vein and the one near the Castle are parts of the same vein. The drift failed to expose any connecting link between the two. As can be seen from plate 2, small openings expose other veins of different trends in the general vicinity of the gulch containing the Bartlett workings.

BYERS INCLINE

The Byers incline is a short distance south of the Castle (pl. 9). Much of the work on the incline was done by the Austin Gold Mining Co. about 1905. At that time the property was known as the Last Chance mine. There have been other periods of activity, but neither available records nor the appearance of the workings indicate that much ore was ever mined.

The Byers incline follows a vein all the way down. Drifts to the east at depths of 122 and 222 feet in the incline show that the vein is irregular and interrupted by several cross fractures, some containing quartz. At the portal of the incline a cross fracture of this type has been offset by the main vein and contains vein quartz which curves and merges with that of the main vein. In several places in the mine postmineral movement along cross fractures has disturbed and slightly displaced the vein, but it is clear that these fractures originated prior to the time that the vein quartz was deposited. Some of those familiar with the area believe that the vein in the Byers incline is the same as one of the veins in the Bartlett tunnel. This seems possible, provided the dip in the intervening ground is less than in the workings. Minor openings near and east of the Byers incline (see pl. 2) expose veins with roughly similar trends, but development is insufficient to establish correlations.

The vein in the Byers incline is composed of white quartz with locally abundant pyrite, chalcopyrite, galena, and sphalerite. The Reveille of July 1, 1905, reports that a sample 7 inches wide from this mine assayed 2.3 ounces in gold and 311 ounces in silver to the ton, and another 18 inches wide assayed 1.3 ounces in gold and 160 ounces in silver.

MINOR WORKINGS SOUTHWEST OF THE CASTLE

A number of cuts and short tunnels exist along the front of the range from the Castle southward as far as the Jackpot mine. The data disclosed by these are, for the most part, sufficiently summarized in plate 2, but a few of the tunnels are described separately.

A lode about 1,000 feet southwest of the Castle and 1,500 feet north of the Jackpot mine has been traced a longer distance than most others in this part of the Austin area (pl. 2). It trends east, dips steeply north and is known to be over 300 feet long. A crosscut tunnel near the west end of the vein is open for 225 feet in a S. 13° E. direction. A short drift 10 feet from the portal exposes the vein, which consists of two parallel lenses, one 18 inches, the other 12 inches wide. In the drift both lenses terminate against a nearly flat, rolling fracture which is itself filled with 2 or 3 inches of quartz. Near the west wall of the crosscut tunnel the more northerly of the two steep lenses dips northward into the floor. The crosscut has caved at a place where another nearly flat, iron-stained slip is exposed. The rock here contains disseminated pyrite and slips lined with chlorite.

Near the east end of the known part of the steep vein another vein trending nearly east and dipping nearly vertically is exposed near the portal of a short tunnel. This eastward-trending vein terminates against a slip that strikes about N. 15° W. and dips 25° NE. and is therefore not exposed in the tunnel.

The portal of the Cummings tunnel (pl. 10) is a little more than 1,000 feet west of the Jackpot mine. This should not be confused with the Cummings Lease on Lander Hill. The Cummings tunnel and its irregular branches expose two lamprophyre dikes and 12 veins.

JACKPOT MINE

The Jackpot mine is a little more than a mile and a half by road southwest of Austin. It was known in the early days, when ore is reported to have been mined from it. The present mine was worked mainly from 1905 to 1911 with later reopenings. A note on a map in the files of the Austin Silver Mining Co. indicates a production, mainly in 1911, of 2,300 tons of ore assaying 0.3 ounce in gold and 29 ounces in silver to the ton and 497 tons assaying 1.12 ounces in gold and 112 ounces in silver. Some mining was also done here about 1920. In 1936 and 1937 much of the activity of the Austin Silver Mining Co. was concentrated here and some ore was milled. Some ore from this mine was also shipped directly to smelters. The production through 1937, exclusive of early unrecorded production, is roughly $100,000. The material recently milled and shipped was mainly oxidized. On the other hand, much of that mined in 1911 came from between the 100- and 300-foot levels and was doubtless mainly unoxidized.

The mine has two vertical shafts; the Jackpot was sunk to a little below the 400-foot level in 1911. The short drifts on this level were not accessible in 1937 because the water had not been pumped, but the vein matter in them is reported to be rather low in grade. The Buffalo shaft, the northern of the two, extends only to the 200-foot level, and much of the recent work has been done above this level. The stopes that were active in 1937 are indicated on plate 11, which also shows the principal drifts above the 400-foot level as they were early in September 1937. The workings north of the Jackpot shaft from the stopes above the 100-foot level down to the 400-foot level follow an essentially continuous lode. The workings in the southern part of the mine from the 300-foot level to the surface are mainly along a similar lode. On the upper levels this lode lies approximately 50 feet west of the lode first mentioned. The lode exposed on the 300-foot level has a general northeasterly trend and that is much interrupted; it is probably the downward continuation of the vein on the 200-foot level, which bends to unite with the lode in the northern part of the mine. In the extreme southern part of the 300-foot level quartz is only intermittently exposed, mainly because it was not continuous when originally deposited but the interruptions are accentuated by postmineral movements.

The lodes consist of a zone of shearing, brecciation, and alteration with lenses of vein quartz at intervals within them. The zone of disturbance is commonly several feet wide and the quartz lenses are from a fraction of an inch to a couple of feet wide. In many places two adjacent large lenses lie within the shear zone. The country rock is much jointed and in places thin quartz seams extend along the principal set of joints transverse to the lode.

Most of the postmineral adjustments appear to have taken place approximately in the plane of the lode. Such movements are shown by the fact that here and there the vein quartz is shattered and disturbed. In places rolled fragments of quartz lie along fissures within the shear zones, but nothing indicates that the displacements are large. As plate 11 shows, quartz is far from continuous within the explored portions of the lodes, but this is thought to result mainly from irregularities in original deposition. Some minor movement has taken place along fissures transverse to the lodes. Most transverse fissures are bordered or filled with vein minerals and it is evident that they are therefore of premineral origin, even though postmineral movements may have occurred.

The principal sulfide is pyrite, although others are reported locally. The pyrite is most abundant as aggregates within the quartz lenses, but in numerous places is sparsely disseminated in the wall rock, especially in the vicinity of cross fractures that are silicified or lined with vein quartz. Chlorite is conspicuous, especially along the more prominent fracture planes that are free or nearly free from vein quartz. A few calcite seams are present.

This mine is one of the few that contains enough gold to be of commercial interest. Commonly the proportion is roughly 1 ounce of gold to 100 ounces of silver, although in many assays the amount of gold is less. Available assays, most of which were made in 1910 and 1911, suggest that the grade of the ore is lower than in the mines on Lander Hill. Assays showing much more than 100 ounces of silver to the ton are rare. Many comparatively large lots contained less than 50 ounces of silver to the ton. The richest available assay, quoted in the Reveille of November 30, 1907, showed 2.48 ounces of gold and 365 ounces of silver to the ton.

VEINS SOUTH OF THE JACKPOT MINE

The mineralized zone explored in the Jackpot mine can be traced with confidence for a distance of nearly 1,200 feet, and it may well be over 1,500 feet long (pl. 2). Development beyond the limits of the Jackpot mine has not been sufficient to trace individual veins with precision, but the quartz lenses in workings south of the mine probably correspond to the lode in the south part of the Jackpot mine.

Farther south, in and near the Dudley B shaft, another vein lies 200 feet east of the projected line of the Jackpot vein and trends nearly due north, with a steep west dip. As plate 2 shows, this vein is probably at least 500 feet long, but it has not been exposed continuously for this distance. The Dudley B shaft is about 90 feet deep with short drifts exploring the vein on either side. A little production was reported from this shaft, which has long been idle. In the shaft and nearby cuts the vein quartz is as much as 15 inches wide. The Reveille of March 21, 1908, notes that 25 pounds from the Dudley B shaft assayed 2.17 ounces of gold and 500 ounces of silver.

Cuts, shallow inclines, and tunnels about 600 feet west of the line of the Jackpot vein, expose other veins on the True Fissure, Tommy, and neighboring claims. As plate 2 shows, the principal veins are closely associated with lamprophyre dikes that differ in attitude from place to place, but in general trend nearly north and are vertical or dip steeply west. The veins are on or close to the borders of the dikes. The quartz lenses are similar to others in the general vicinity but, in addition, the quartz monzonite is so silicified that it forms resistant ribs over a foot wide.

THE OK MINE

The OK mine is close to Marshall Canyon and southeast of the Dudley B shaft. It is one of the earliest of those opened by the Austin-Dakota Development Co. but has long been idle; the lower workings are full of water. According to notes in the Reveille in 1914 and 1915 when much of the work was done, the OK incline was driven 300 feet on the dip of the vein. In 1937 this incline was filled with water to a level 6 feet below the drifts shown on figure 29. As plate 2 shows, the vein in this mine can be traced in surface cuts for nearly 600 feet. Judging by comments in the Reveille, the vein in the OK mine is partly oxidized down to the 200-foot level on the incline (not shown in figure 29) and contains some native silver, according to reports. The Reveille of February 20, 1915, notes an assay from "the hanging wall ledge" on the 300-foot level that indicates a content of 0.13 ounces gold and about 750 ounces silver to the ton.

X-RAY MINE AND NEIGHBORING WORKINGS

The X-Ray mine is a little more than 1,000 feet northeast of the OK mine. The Austin-Dakota Development Co. did most of its development work at the X-Ray mine, which has been idle since about 1920 and was inaccessible in 1937. Drifts and crosscuts that totaled several thousand feet in length were driven at different levels from the shaft, which was 400 feet deep. Apparently these workings disclosed a vein that trends about N. 60° E. and another that trends nearly N. 30° E.

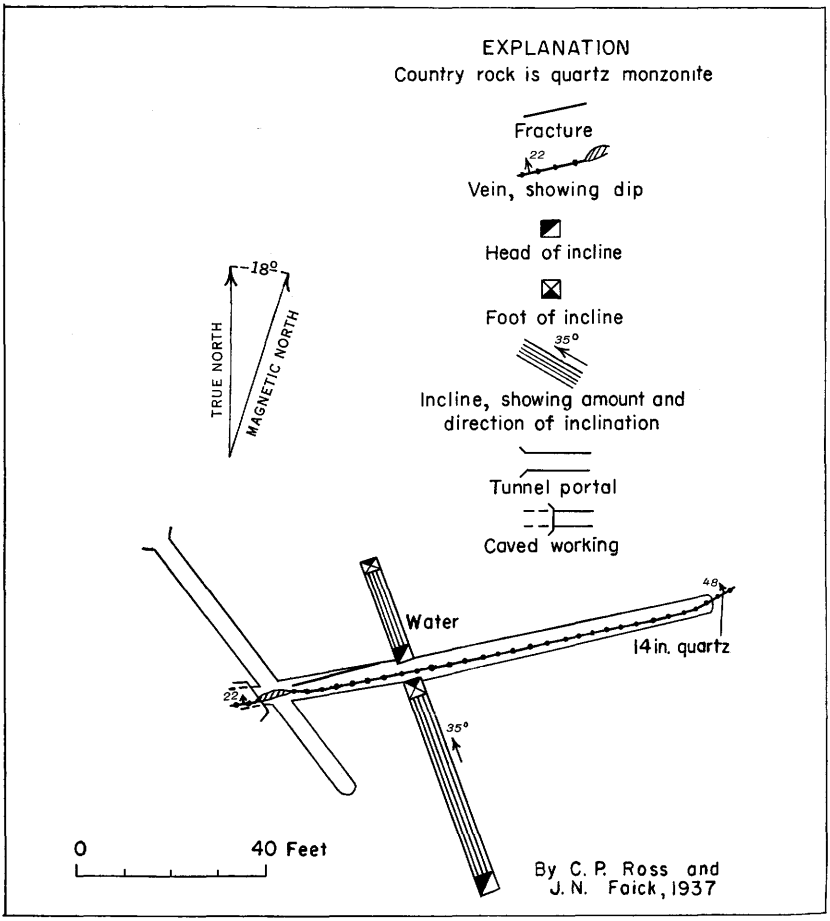


FIGURE 29.—Geologic sketch map of the OK mine.

along a dike that is conspicuous at the surface in this vicinity. The dike was followed for more than 1,000 feet on the 200-foot level. Figure 30 is adapted from the only available map, which shows the principal workings but is probably incomplete. Accounts in the Reveille indicate that the veins contained ruby silver and that some of the vein matter was high grade. On November 6, 1918, a shipment of less than a ton of ore from this mine was reported to contain 1,072 ounces of silver. Apparently this came from the vein that trends N. 60° E. The Reveille of January 10, 1920, notes that the drift along the dike revealed occasional kidneys of rich ore. Assays of the ore indicated values of $100 to $500 a ton, mainly in silver. One of these assays is reported to total $322.20, of which $2.40 was in gold and the remainder in silver.

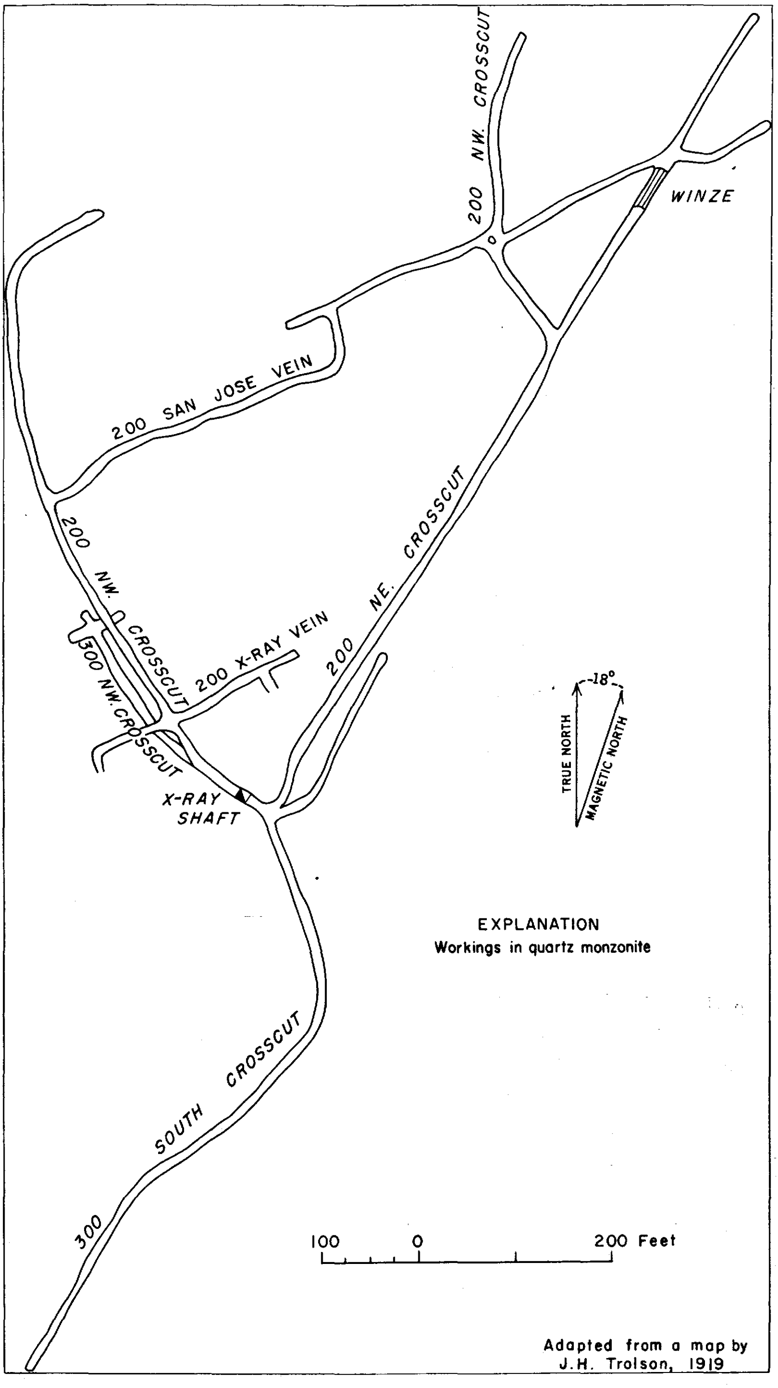


FIGURE 30.—Map of X-Ray mine.

A prominent dike extends from the X-Ray shaft to the Luetgen tunnel (pl. 2). This dike is compound, with branches and parallel subsidiary dikes. Although exposures are not continuous, a quartz vein is adjacent to the dike for most, if not all, of its length of more than 3,000 feet.

Plate 2 also shows that in a broad area on both sides of the dike numerous veins of diverse trends are exposed in the many workings of this area. Cuts and inclines are closely spaced, in part in search for extensions of the rich ore shoot that was mined in the early days in the Whitlatch mine, some distance to the east.

The Silver Chamber incline is nearly 1,200 feet north of the X-Ray shaft. Although long idle, most of it is still open (see fig. 31). In the upper stopes about 60 feet from the collar, the sulfides have been thoroughly oxidized and the quartz is stained by iron and manganese oxides. At greater depth, pyrite is the only identifiable sulfide, but the quartz in places is darkened by finely disseminated material that is in part pyrite but may include other minerals.

The Austin Silver Mining Co. has prospected extensively in the area east of the long dike between the X-Ray shaft and the road through the saddle between Central and Union Hills. Much of this was done by removing the thin cover of granitic sand that conceals the veins. A promising vein named the Littrell was discovered on the X-Ray Extension claim nearly 1,100 feet east of the X-Ray shaft. The prospecting of this vein had just begun when the field work for the present report came to an end. Shortly afterwards the Camargo incline was started and some stoping was done. During this work old stopes are reported to have been encountered. A number of old cuts and inclines are south of the X-Ray and east of the OK workings. Such data as are available are summarized on plate 2.

DALTON AND NEIGHBORING WORKINGS

Several workings are situated on the sides of Dalton Gulch, a north-trending tributary of Marshall Canyon near the middle of the southern border of the area shown in plate 2, which also shows the distribution of the veins and dikes. Most of the veins trend north or northeast. One wide vein, which trends almost due north and dips steeply west, can be traced in workings and outcrops for more than 1,000 feet. Near its north end quartz lenses are not conspicuous but ribs of silicified rock crop out above the general level of the hill sides. On the west side of the gulch about 300 feet from this vein, bulldozer operations have uncovered a segment of a parallel vein.

The Dalton mine is near the head of the gulch on the east side. A boiler explosion in 1917 is said to have put a stop to operations which have not been resumed since. The incline was not safely accessible but the crosscut tunnel leads to drifts that are open (fig. 32). A little

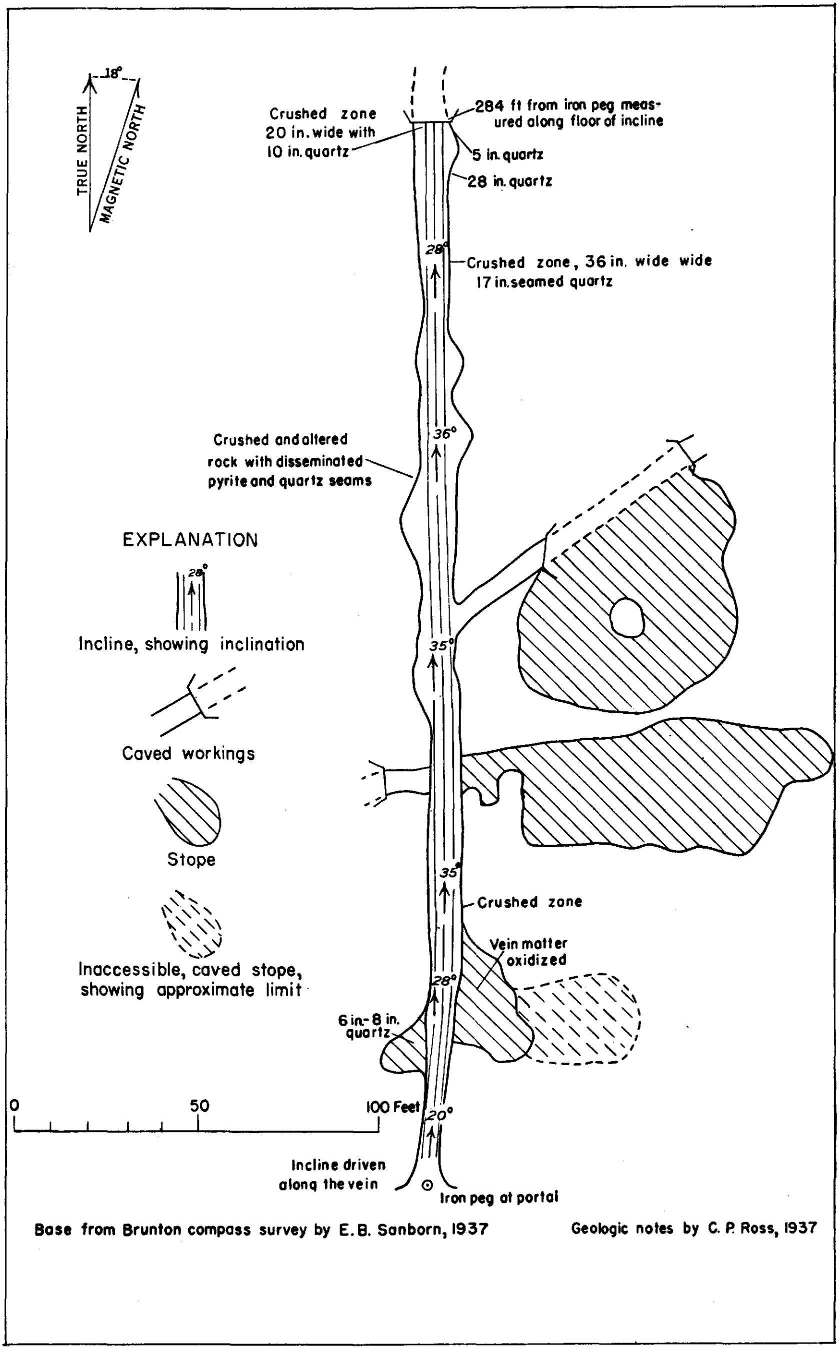


FIGURE 31.—Geologic map of the Silver Chamber incline.

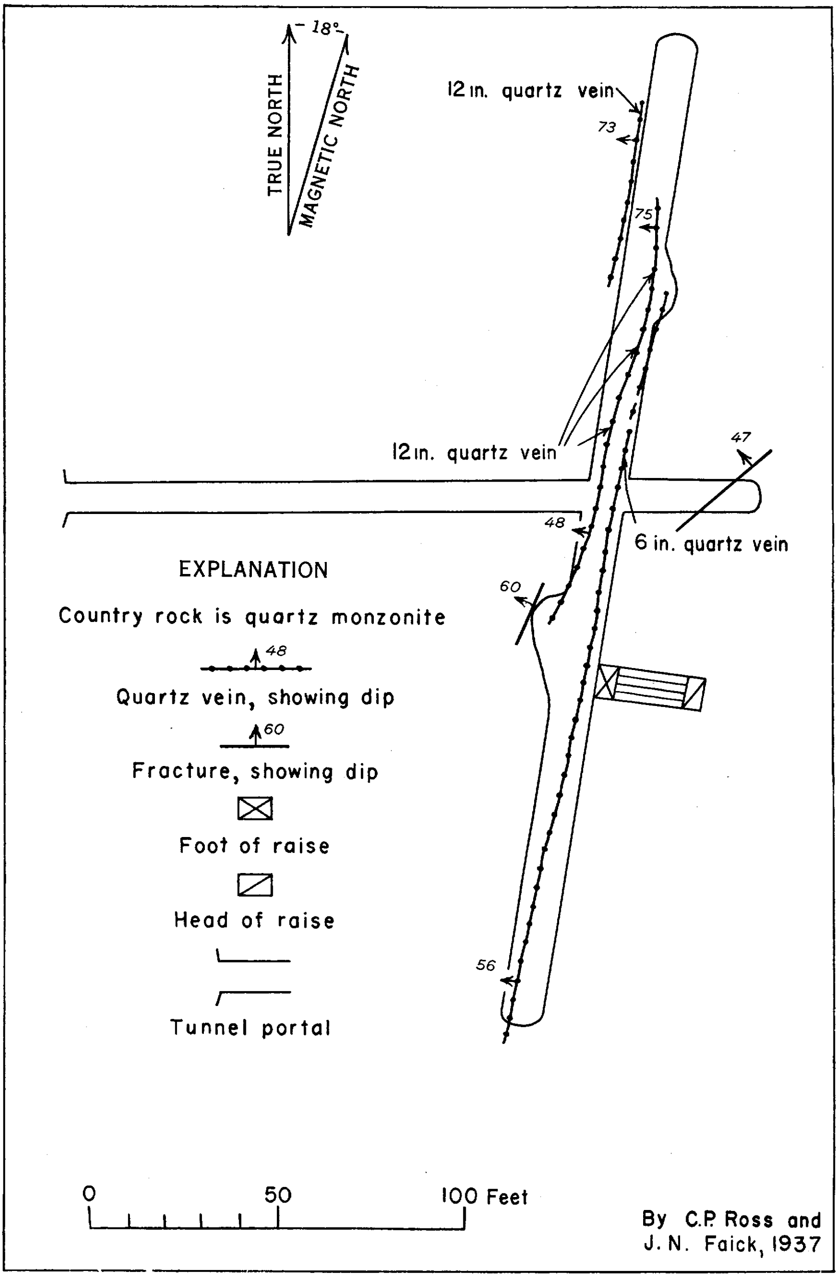


FIGURE 32.—Geologic sketch map of the Dalton mine.

ore has been taken from small stopes on the vein, which consists of a series of subparallel quartz-filled fissures that pinch and swell, attaining a maximum thickness of 1 foot.

MIZPAH MINE

The Mizpah mine includes a group of small workings in the southwest part of the area shown in plate 2. Little has been done here since 1911, but the principal workings are still open. One tunnel in the footwall of a large lamprophyre dike is 290 feet long and trends about S. 55° E. It cuts two very narrow veins that strike about N. 35° E. and dip about 70° NW. A short distance to the north a tunnel driven 60 feet in a S. 77° E. direction reveals a vein on its northeast side for half of its length. This northeast dipping vein is curved and is followed by the tunnel. Lamprophyre is exposed on its hanging wall. A small incline from the surface intersects the tunnel about 30 feet from the portal and continues downward about 60 feet on an inclination of about 60° to the northwest. At the bottom of the incline 100 feet of irregular, interconnected drifts explore a rolling vein with only slight change in dip. The small amount of material that has been taken from the Mizpah mine apparently came from this lower level.

HARDY MINE

The Hardy mine is near the head of Crow Canyon, a short distance south of the area included in plate 2. According to Humes' manuscript report, the Austin-Manhattan Consolidated Mining Co. ran 692 feet of drifts and crosscuts on the tunnel level, about 125 feet on the dip below the highest outcrop of the vein. He also says that workings sunk for a depth of about 30 feet on this outcrop disclosed ore, some assaying as much as $200 to the ton. When visited in September 1937 only about 125 feet of the tunnel could be entered. The tunnel branches 80 feet from the portal where several quartz veinlets come together. None of these seems to correspond to the vein that trends N. 33°–38° E. and crops out 125 feet or more up the hillside. The vein has been stoped to the surface for a distance of 100 feet, with a maximum depth of 50 feet. Near the upper end of the vein the dip is 75° NW. but a short distance down the hill the dip becomes 71° SE. The vein consists of silicified quartz monzonite with quartz lenses whose maximum width is at least 10 inches.

OTHER WORKINGS IN THE AUSTIN AREA

Although the workings controlled in 1937 by the Austin Silver Mining Co. include almost all of the productive mines in the Austin area, a number of other properties are known. Claims in the vicinity of Slaughterhouse Gulch were not studied in as much detail as the central part of the district, but old workings are scattered over the slopes bordering the gulch, especially near its head. Most of the workings are caved. Some of the other outlying workings like those on Union Hill also yielded so little information when visited that the known facts can be summarized adequately on plate 2.

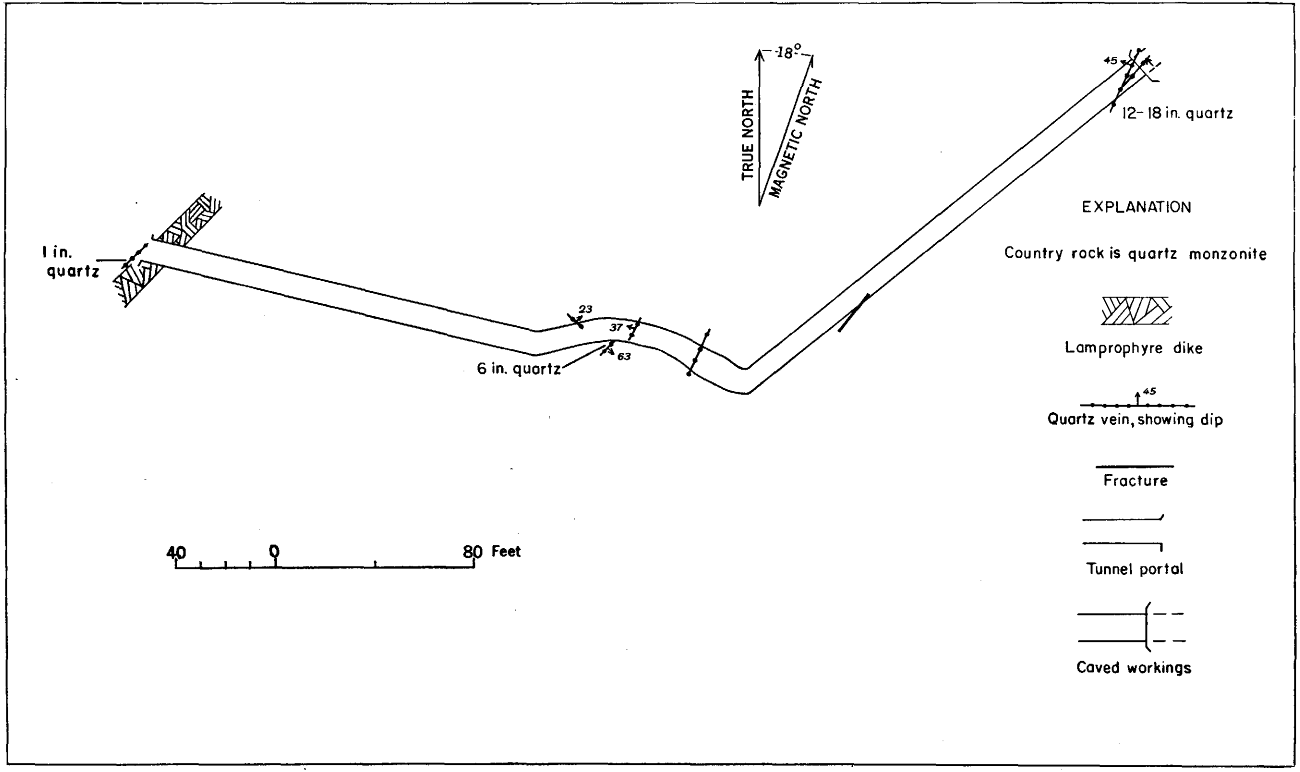
KILBORN GROUP OF CLAIMS

The Kilborn group of claims lies on both sides of the northwestern part of Austin. Available data indicate about 20 claims in these two areas, formerly held by the Nevada Equity Mines Co. The Moss tunnel was started in Slaughterhouse Gulch (pl. 1) in the hope of cutting the northwestern extensions of the veins of Lander Hill. Perhaps this is the tunnel that has recently been reopened by the Nevada Equity Mines Co. This tunnel was driven several hundred feet into the hill, intersecting several veins according to reports. Judging from the dump, these veins carried galena, sphalerite, pyrite, and chalcopyrite in considerable abundance. The tunnel was caved in 1937 where the first vein was encountered. Most of the numerous, shallow workings on the Kilborn group of claims south of the Moss tunnel are shown on plate 2. The veins of this group north of Austin contain, in places, sulfides similar to those in the Moss tunnel.

ESCOBAR PROPERTY

Mrs. M. J. Escobar holds two groups of claims in the Austin area. One group of seven overlapping claims lies between the northern part of the Kilborn property and the mill of the Austin Silver Mining Co. The principal recent work here has been on the Silver Eagle claim. The veins have been prospected at intervals since early in the history of the district. Some ore is reported to have been mined in 1937, but details are lacking. The second group consists of two claims south of the southern Kilborn claims and east of the Jackpot mine.

The principal working on the Silver Eagle ground is a tunnel (fig. 33) originally about 900 feet long, but in 1937 it was caved about 395 feet from the portal. At the portal a vertical lamprophyre dike is exposed. At intervals further in, a number of quartz veinlets of diverse trends are exposed. The vein consists of quartz with sparsely disseminated grains of the common sulfides and streaks of impure calcite. Ore worth $80 a ton is reported to have been found somewhere in this tunnel. A short distance uphill from the portal of the tunnel a shallow incline was being deepened in August 1937. The incline is on a vein that strikes N. 70° W. and dips 23° NE. Nearby are irregular old workings, including a small stope on a vein that strikes N. 50° W. and dips 33° NE.



By C. P. Ross and J. N. Faick, 1937

FIGURE 33.—Geologic sketch map of the Silver Eagle tunnel.

The two Escobar claims in the southern part of the Austin area were being developed in 1937 near the Sunset No. 2 tunnel in the hope of finding a vein that is exposed in a shallow incline and cuts on the hillside above. This vein strikes N. 60° W. and dips 50° NE. The portal of the tunnel is southwest of and 60 feet lower than the outcrop of the vein. The tunnel is 145 feet long; its face is probably near the vein that is being sought, if its dip of 50° is maintained at depth. The last 30 feet of the tunnel cuts several lenses of quartz containing ankerite. Pyrite crystals are scattered through the quartz and the altered wall rock. The quartz lenses range in strike from N. 88° W. to N. 53° W. and in dip from 25° to 62°NE. They probably represent branches of the larger vein exposed in the incline. The quartz lenses in the tunnel are traversed by fractures that strike N. 8° E. and stand vertical. These show evidence of crushing but have scarcely displaced the quartz lenses. The fractures are lined by a thin film of vein quartz.

ROOSEVELT MINE

The Roosevelt mine is in the northeastern part of Austin. Two claims, the Roosevelt and the N. R. A. (fig. 27), are both managed by L. L. Moore although the former is the property of the W. H. Whiteburn estate. Small shipments have been made at intervals since 1911 or earlier. Smelter returns dated August 31, 1927, show that 10,714 pounds of ore (dry weight) from old workings on this property contained 0.015 ounce gold and 44.3 ounces silver to the ton, 18.7 percent lead, 2.2 percent copper, 3 percent zinc, 12.4 percent iron, 9.0 percent sulfur, and 41.2 percent insoluble matter. The vein minerals include quartz, rhodochrosite, calcite, galena, tetrahedrite, chalcopyrite, sphalerite, and pyrite. The shaft is vertical to a depth of 42 feet, where it continues on an incline of 62° NE. for an additional 67 feet. Short drifts were driven at the 42-foot level as well as from the bottom of the incline. They explore a vein that trends about N. 45° W. near the shaft but swings to N. 78° W. farther northwest. The dip is from 67° to 74° NE. Near the shaft on the 42-foot level the vein is 2 feet wide but within 50 feet to the northwest it has pinched out. At the bottom of the incline there are two quartz lenses, one 8 inches in width and the other 4 inches. A second incline has been sunk 51 feet on a vein that trends N. 40° W. and dips 67° NE.

CLAIMS OF THE LANDER HILL MINING COMPANY

The slopes around upper Pony Canyon east of the developed area on Lander Hill contain few workings and most of these were inaccessible in 1937. The Lander Hill Mining Co. acquired 13 claims in this vicinity. In 1937, a caved crosscut tunnel, 800 feet southeast of the old Curtis shaft and trending N. 60° E., was being reopened; by September 215 feet was accessible. A narrow, rolling, nearly flat vein 45 feet from the portal and narrow veinlets striking N. 35° W. and dipping 45° to 70° NE. about 200 feet from the portal are exposed. One of these veinlets contains rhodochrosite.

RUNDBERG PROPERTY

In 1937 Rudolph and Lars Rundberg had four claims with the principal workings about 2,000 feet west of the Jackpot mine. At the surface near the cabin a stope has been opened on a vein that strikes N. 28° E. Five tons of ore, valued at $97 a ton, is reported to have been shipped from here. The vein has been followed downward by an incline 134 feet long whose slope is 44° NW. in the upper part and decreases to 15° near the bottom. In the lower part of the incline the vein is pinched and near the face is broken and indistinct. Masses of a highly altered dike rock are in the broken part.

About 300 feet southwest of the incline an irregular, branching tunnel has been driven into the side of a tributary of Marshall Canyon. The incline trends a little east of north and has an aggregate length of about 470 feet. It explores several discontinuous veins that cross each other with slight offsets. Some are roughly parallel to the vein in the incline while others trend northeast at different angles.

Two conspicuous veins have been prospected by shallow workings southeast of those mentioned above. One of these trends northeast and dips 50° to 75° SE. This vein has a maximum width of at least 2 feet, but most of it is narrower; it crops out at intervals for 1,000 feet. On its hanging wall is a large lamprophyre dike. The other prominent vein trends northwest and is thought to be essentially continuous for 800 feet although in the central part, dashed on plate 2, the vein has not been definitely traced.

LAURENT PROPERTY

Gus Laurent and his associates hold claims near the southwest corner of the area shown in plate 2. In 1937 they worked in an incline that was 48 feet deep with an average inclination of 50° NW, a little more than 60 feet of drifts were driven from the bottom and a short drift farther up the incline. These workings are on a vein that strikes about N. 60° E. and dips 60° NW. and less. The vein in places breaks up into irregular veinlets and is less than 8 inches wide. Several roughly parallel veins are exposed in nearby cuts and short inclines. In addition quartz lenses are exposed at intervals along a dike whose average trend is N. 30° E.

POWELL AND SCHLEMMER PROPERTY

On the south side of Crow Canyon opposite the Hardy workings three claims have been located by F. B. Powell and Harry Schlemmer. The location was made in 1926, but only a little work has been done. The workings consist of an incline on a spur about 150 feet above the stream in Crow Canyon, except for the upper 20 feet, the incline was filled with water at the time of visit, but quartz on the dump shows that a vein was found in the incline. Down the slope northwest of the incline is a silicified zone that trends N. 18° W.

YANKEE BLADE AND NEIGHBORING AREAS

MIDAS FLAT

Numerous shallow workings have been dug in the dissected pediment on either side of Midas Flat in the lower part of Yankee Blade Canyon. The locations of the more conspicuous workings and the trends of the few observed veins are shown on plate 1. Most of the veins trend northeast but some trend northwest. It is reported that some contain noteworthy amounts of gold. The Reveille of May 29, 1907, notes that a 2-foot vein in the Peerless mine contained $430 in silver and $8 in gold to the ton at a depth of 92 feet. The Breen mine in the southern part of the flat is one of the best known and deepest in the area. It attained a depth of 150 feet in the late seventies and early eighties when most of the work was done. The Austin Silver Mining Co. owns the two Yellow Dog claims south of the Breen but by 1937 it had done little work on them.

SILVER CLIFF MINE

The Silver Cliff mine is on the northwest side of San Francisco Canyon at the north end of the area shown in plate 1. The deposit was discovered about 1870. The three claims that cover it were relocated by W. C. Francis in 1933. The incline is reported to be 240 feet deep but in 1937 the air was so poor that carbide lights would not burn at a distance of 70 feet below the collar. In its upper part the incline trends N. 25° E. on a slope of 31°. The quartzite close to the incline strikes N. 78° W. and dips 25° NE. The vein cuts the bedding of the thin-bedded carbonaceous quartzite at a slight angle. The vein is reported to have a maximum width of about 20 inches with the richer sulfide layers having a maximum width of 6 inches. According to Mr. Francis, assays of this vein ranged in value from $200 to $960 a ton, mainly in silver. The gold content is very small. The sacked material on the dump contains abundant stibnite and small amounts of other sulfides, which are slightly oxidized; ruby silver minerals are reported.

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WATT MINE

The Watt mine is on the northwest slope of New York Canyon, roughly half way between the canyon head and the mountain border. This mine, once called the Cambrian, was first opened by David Todd about 1869. The records of the county assessor credit David Todd with a total production of 27 tons and 74 pounds, valued at $3,515.89 from 1869 through 1876. His largest recorded output in any one quarter was 6 tons, 1,200 pounds, valued at $682.61 in the quarter ending December 31, 1874. In September 1903, according to the Reveille of December 7, 1904, it passed into the hands of Isabel and Robert Watt and Victor Roacheville. In 1903 and 1904 it yielded 6 carloads of ore valued at $300 a ton, of which $2 to $15 was in gold. In January 15, 1908, the Reveille estimated that the total production to that time had been $100,000. The mine was worked intermittently until 1937. R. W. Lemaire, the holder at that time, stated that the mine is supposed to have produced over $150,000.

The main Watt incline was driven N. 38° E. for 350 feet (fig. 13) and is inclined at angles that range from 14° to 45°; most of it slopes a little more than 30°. Levels have been opened at distances of 85, 179, and 253 feet on the slope from the collar. The 85-foot level, more extensively caved in 1937 than the others, was also originally connected to the surface by a tunnel and two short inclines. This level has about 240 feet of accessible drifts, the 179-foot level has 425 feet, and the 253-foot level has 445 feet of drifts. Stopes have been carried upward from each level. They are partly filled but appear to be largest near the main incline between the first and second levels. Northwest of the Watt mine a winding tunnel has been driven toward the mine, presumably in search of an extension of the Watt vein. The irregular zones of crushing and mineralizations exposed in it may well be related to the Watt vein.

The Watt vein follows a crushed zone that has a maximum width of 3 feet and is nearly parallel to the bedding of the impure quartzite. Irregular veinlets and lenses of quartz are distributed through the zone. Pyrite is the only sulfide definitely recognized, but abundant crystals of copper sulfate suggest the presence of tetrahedrite. The sulfates were formed at least in part after the mine was opened. Along the lower 100 feet of the main incline the vein is so poorly defined that no drifts explore it. Altered aplite dikes of different attitudes are exposed at several places on the first level.

MORRIS AND CABLE TUNNEL

The portal of the Morris and Cable tunnel is close to the bottom of New York Canyon opposite the Watt mine (fig. 13). This property has been operated intermittently since 1868 or before. The tax records indicate that from 1868 to the middle of 1880 it produced 217 tons 962 pounds valued at $59,986.04. These figures show that the average tenor was high. This mine shared in the activity in New York Canyon early in the present century but no record of its production at that time is available. Total production of the Morris and Cable mine [10] is reputed to be $2,200,000. Even though this estimate presumably includes the yield of the old Tuolumne mine in Yankee Blade Canyon, whose workings were once connected with the Morris and Cable tunnel, the figure is probably high.

In 1937 only about 550 feet of interconnected workings along a strike length of 200 feet were accessible near the portal of the Morris and Cable tunnel. As figure 13 shows, the vein has been followed for over 1,000 feet on the tunnel level and at the Tuolumne incline it has also been opened both above and below the tunnel. The average trend is N. 60° W. and the dip is 30° NE. or less. In the accessible workings part of the vein has been removed by stoping and the visible portions consist of a rather poorly defined crush zone in quartzite with irregular quartz veinlets. Pyrite is the only metallic mineral noted. An assay map of the main drift prepared by Francis J. Peck and Co. for the Maricopa Mines Co. in 1911, when most of the workings were open, shows that as much as 272.46 ounces of silver to the ton is present at one place but the content of most samples ranges from about an ounce to somewhat more than 30 ounces of silver to the ton with negligible amount of gold.

CHASE MINE

The old Chase mine, inactive for a number of years, has been worked intermittently since 1865. The tax records show that at least 118 tons valued at $22,020.67 were obtained from this mine prior to 1881. The later production, which may have been considerable, is not known. The total is reputed to be $800,000, but no data are at hand to confirm this. The mine, like the True Blue described below, was operated about 1911 by the Maricopa Mines Co. and is now held by the Austin Syndicate.

Figure 13 shows the principal workings, but most of them were inaccessible in 1937. A short incline near the channel in New York Canyon below the portal of the main tunnel gave access to part of the vein but the incline is now caved. A large winze has been sunk on the vein below this drift but could not be descended safely in 1937. Near the winze the vein strikes N. 71° W. and dips 36° NE. The quartzite is intricately brecciated and is seamed and cemented with vein quartz for widths somewhat over 2 feet.

[10] An alternate spelling for this mine is "Morris and Caple."

TRUE BLUE TUNNEL

The portal of the True Blue tunnel is near the mouth of New York Canyon on the northwest side. The vein explored by this tunnel and by a still older tunnel and incline a little farther upstream has been known since 1875 or before and, according to some accounts, has yielded as much as $250,000. A small production is shown by the tax records for 1875 and 1876, but most of the activity was from 1900 to 1913. In 1912 and the early part of 1913 the Maricopa Mines Co. held the property and erected a mill which operated only a short time. In 1937 this company's successor, the Austin Syndicate, was engaged in reopening the main tunnel but had not progressed far enough to expose the main vein at the time that field work for the present report came to an end.

The first part of the True Blue tunnel is a crosscut somewhat more than 850 feet long. Judging by available maps (fig. 13) a vein was revealed about 665 feet from the portal, and was followed. An incline from the hillside above was driven down this vein to the tunnel. This incline, which has an inclination of 23° to the northeast, was mapped in part during the present study. About 150 feet farther along the crosscut another set of drifts has been opened along a vein, but the relation to the main vein is not clear. Drifts and crosscuts explore the intervening ground; the dip of the main vein is so gentle that all these workings might be on the one vein. Where the second vein is reached in the main tunnel, the drift to the northwest is only 100 feet long, but the winding drift to the southeast is 985 feet long. The southeast drift has a stope above it near the crosscut and several raises farther in. At two places such raises connect with workings that reach the surface. One, the old True Blue tunnel, was visited during the present study. The other is apparently the incline on Chase ground. If this interpretation of available maps is correct, the main vein in the True Blue is the same as that in the Chase. This vein may continue southeast through the Morris and Cable and Patriot workings.

Only the first 470 feet of the main True Blue tunnel could be entered at the time of visit. This portion is entirely in granitic rock and discloses only a few narrow quartz veinlets. Other accessible True Blue workings are in the quartzite; the part of the main tunnel that follows the principal vein is also reported to be in that rock. The old True Blue tunnel, which has two portals, winds into the hill for 200 feet to the collar of the winze that connects with the main tunnel. It follows a vein in a crush zone in quartzite that trends from N. 10° W. to N. 45° W. The dip is from 10° to 45° NE. Pyrite is the principal visible sulfide but arsenopyrite, galena, sphalerite, tetrahedrite, molybdenite, and proustite are also present. In the outer part of the tunnel stringers of altered aplitic rock cut the quartzite close to the vein.

PATRIOT MINE

The Patriot mine, near the head of Yankee Blade Canyon, is one of the oldest and best known in this part of the district. Its workings are probably more extensive than those of any other mine in the district outside of the Austin area. This is attested both by such maps as are available (fig. 13) and by its comparatively large dumps.

The tax records show that from the middle of 1868 to the middle of 1883 the Patriot produced 416 tons, 528 pounds valued at $129,742.06. Doubtless considerable additional ore credited in the records to individuals came from this mine. The Patriot was one of the mines reopened by the Maricopa Mines Co. about 1910. It was productive at intervals from 1883 to 1910, but there is no reliable record of total production. According to some estimates the total production of the Patriot was $3,000,000. With all due allowance for the incompleteness of the record, this figure seems high.

The main incline at the Patriot is over 700 feet long, judging by figure 13, and has drifts at seven levels. The upper part of the incline slopes 31° NE. In 1937 about 65 feet below the first level the incline was full of water so that the lower levels could not be examined. The first level is also reached by a tunnel whose portal is close to the channel of the gulch and nearly 70 feet vertically below the collar of the incline. This tunnel winds northeast for about 336 feet and reaches the first level close to the incline. Drifts on this level extend on both sides of the incline for an aggregate distance of 412 feet. The vein follows an irregular crushed zone in quartzite. The strike ranges from N. 60° to 75°W. and the dip from 15° to 44° NE. The ore in small stopes above the 100-foot level is oxidized, but sulfides were found below the level.

OTHER WORKINGS IN THE YANKEE BLADE AREA

Several short tunnels and other workings have been opened along and near New York Canyon. The locations of the principal ones are shown on plate 1. Where veins are visible, they are essentially similar to those described above. The scattered workings and outcrops in this part of the area are, in places, sparsely speckled and streaked with copper sulfates, chrysocolla, and iron oxides, indicating that mineralizing solutions were not confined to the crushed zones in which the ore shoots are localized.

In Yankee Blade Canyon, especially in its upper reaches, dumps that mark the site of old workings are numerous. Some are large enough to show that hundreds of feet of work must have been done but all the workings are extensively caved and few can be entered at all. A few were worked about 1910 but most became inactive 10 to 30 years earlier. Most mining men now in the district do not even know which of the dumps correspond to mines whose names were once famous. Such names as were learned and the trends of the veins that could be seen are shown on plate 1. The Prosperity shaft and neighboring inclines are on a group of eight claims held by Mr. and Mrs. W. C. Francis, who state that the principal incline is 130 feet deep and contains a total of 400 feet of work. Assays obtained here are reported to be as high as 2,000 ounces of silver to the ton. The vein is said to be 6 to 8 inches wide and to contain arsenopyrite and ruby silver.

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