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ORE DEPOSITS OF THE SIERRITA MOUNTAINS PIMA COUNTY, ARIZONA

BY

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ORE DEPOSITS OF THE SIERRITA MOUNTAINS, PIMA COUNTY, ARIZONA.

By F. L. Ransome.

INTRODUCTION.

The Sierrita Mountains (see fig. 64) constitute one of the smaller of the nearly meridional mountain ranges of southern Arizona. They separate the Santa Cruz Valley on the east from Altar Valley on the west. The range has a length between 13 and 14 miles and a width roughly estimated at 4 miles. The height of the dominating summit, Samaniego Peak, has, so far as known, not been accurately determined. Apparently no part of the range rises more than 2,000 or 3,000 feet above the upper margin of the flanking desert plains or attains an altitude greater than 6,500 feet above sea level. Its slopes carry little or no timber, and in comparison with the Santa Rita Mountains to the east or the Baboquivari Range to the west, the Sierrita Mountains are of minor topographic importance and are scenically unimpressive.

On the west side of the Sierrita Mountains, mainly in a rather definite belt of foothills, is a group of prospects within what is locally known as the Papago district, although they appear to be included within what has also been called the Sierritas district. On the east side of the range lies the Pima district, within which are a number of mines that have produced considerable quantities of copper, zinc, and lead-silver ores. These mines fall into three areal groups—those near Twin Buttes, on the south; those near Mineral Hill, on the north; and those near the abandoned Olive camp, between Twin Buttes and Mineral Hill. The ores near Mineral Hill and Twin Buttes occur in typical contact deposits; those at Olive camp in narrow fissures. The Pima district was organized in 1877.

The Papago district is about 38 miles by road from Tucson. The route from Tucson for the first 24 miles leads in a general southwesterly direction along the excellent Ajo road, a State highway. At the Robles ranch the route branches southward and for about 8 miles follows the road to Sasabe, a settlement on the Mexican border. At King's ranch a branch road turns off to the east and ascends, for about 6 miles, the gentle slope to the foothill belt in which the prospects of the Papago district are situated.

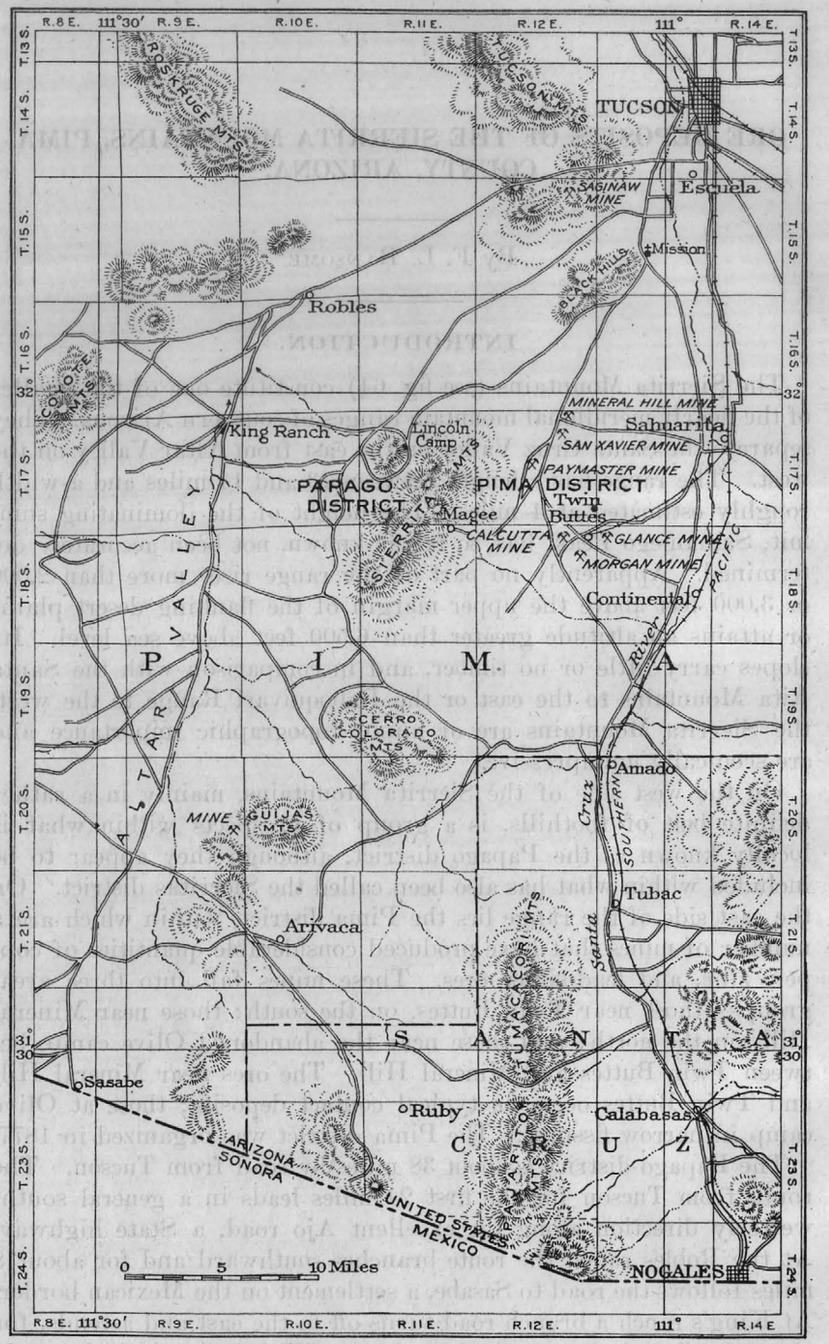


FIGURE 64.—Outline map showing the position of the Pima and Papago districts with reference to the Sierrita Mountains and Tucson, Ariz.

The Pima district is reached by a good road that runs south-southwestward from Tucson for about 18 miles to Mineral Hill. From Mineral Hill a newly constructed highway leads south for about 6 miles to Twin Buttes, which is connected by a branch railway, the Twin Buttes Railroad, 10 miles long, with the Nogales branch of the Southern Pacific. The Twin Buttes Railroad was not in operation at the time of visit, late in 1920.

The present paper is based upon a brief examination extending over 10 days late in November and early in December, 1920. The primary object of this examination was to obtain such general knowledge of the districts as might be useful in planning possible additional geologic work within them.

Although it is impossible to acknowledge individually all the courtesies extended to me during my brief visit, it is a pleasure to mention particularly the hospitality of the Old Pueblo Club, of Tucson, and of Judge S. W. Purcell, of the same city, who accompanied me during most of the time spent in the Papago district. Dean G. M. Butler, of the University of Arizona, director of the State Bureau of Mines, who took keen interest in the investigation, was cordially helpful in many ways. To Mr. John C. Anderson, a mining engineer of Tucson, I am indebted for considerable information of value relating to the mines of the Pima district.

GENERAL GEOLOGY.

The Sierrita Mountains consist essentially of an intrusive granitic core flanked by more or less metamorphosed rocks of sedimentary and eruptive origin. These flanking rocks are notably different in character on the two sides of the range. On the east are rather massive gray limestones, with quartzites, shales, and altered andesitic volcanic rocks. These rocks are folded and faulted, have been invaded by granite, and in places show pronounced contact metamorphism. On the west the rocks are prevailingly schistose, have been more closely compressed, and have been affected by metamorphism of regional character in contrast with the more intense but local contact action on the east. These schists are varied in character and include rocks that were at one time conglomerate, sandstone, shale, limestone, rhyolite, and tuff. They appear to be older than the beds to the east, but no fossils were found in them, and consequently their age is uncertain.

The crest and higher slopes of the range were not closely examined, but distant views and the material in the stream beds indicate that the entire western slope, from the crest down to the foothills, is underlain by a rather fine grained biotite granite which as a rule is more or less decomposed and weathers to comparatively smooth

brown surfaces with few rugged outcrops. The rock resembles quartz monzonite, but thin sections show that it is composed chiefly of alkali feldspar and quartz, with subordinate plagioclase and a little biotite. It is probably to be classed as a granite.

As shown by stream boulders on the east side of the range, that slope also is composed largely of a similar fine-grained granitic rock. A specimen from one of these boulders near Magee's ranch appears to be a rock very close to the dividing line between granite and quartz monzonite. Thin sections show it to contain a slightly more abundant plagioclase than the specimens examined from the west slope and also a little pale-green amphibole. The same streamway from which this was collected contains also boulders of a gray porphyritic rock, apparently andesite.

On the west side of the Sierrita Mountains the descent of the general slope toward the Altar Valley is interrupted by a belt of ridges and isolated hills composed of the schistose rocks, within which are the mines and prospects of the Papago district. This belt is roughly estimated to be from 1 to 2 miles wide and appears to be more prominent along the northern part of the range than in the unexamined country to the south.

Not enough work was done to determine the exact character, the relative abundance, and the relations of the various rocks that compose this schistose series. Forming a considerable part of the belt, particularly along its eastern margin, near the granite previously described, are pale lilac-gray rocks that, although plainly squeezed and schistose, have not been recrystallized as a whole and still show very clearly their original clastic texture. They appear to have been deposited as sand and gravel, in which, together with the preponderant quartz grains, there was much feldspar, mainly plagioclase, with rock and mineral fragments of various kinds. Rock composed of such material has sometimes been called graywacke. Sediments of this heterogeneous character must have been derived from areas in which igneous rocks were undergoing disintegration and erosion so rapidly that grains of feldspar, not as a rule a very resistant mineral, were carried away and deposited in some adjacent water body before they could decompose. The granules of ordinary sandstone are almost all quartz, a mineral that is much more stable than feldspar. It is possible also that these sediments represent a mingling of ordinary rock detritus with volcanic tuff.

Associated with these sedimentary rocks and like them now schistose are elongated masses of rhyolite with abundant small quartz phenocrysts. These are presumably flows that were erupted during the deposition of the sediments and have been folded and compressed with the sedimentary rocks. There has been no general recrystallization, but the quartz phenocrysts, as seen under the microscope,

have been cracked, and the fragments have been more or less displaced. The original material of the groundmass has been squeezed around them and now contains considerable sericite and calcite. Some of the schistose rhyolitic material may have been rhyolite tuff.

Limestone also forms a considerable part of the schistose series, and as it has been locally silicified and is generally more resistant to weathering than most of the associated rocks it crops out conspicuously along the ridge tops of the foothills. There are many distinct bodies of limestone in the schistose series. Some are only a few feet wide or thick; others measure 100 feet or more. Some continue for a mile or two; others are 100 feet or less in length. They apparently are folded, upturned, and squeezed lenticular beds that were deposited as members of the sedimentary and volcanic series within which they lie. Most of the mines and prospects in the Papago district are in these limestone beds.

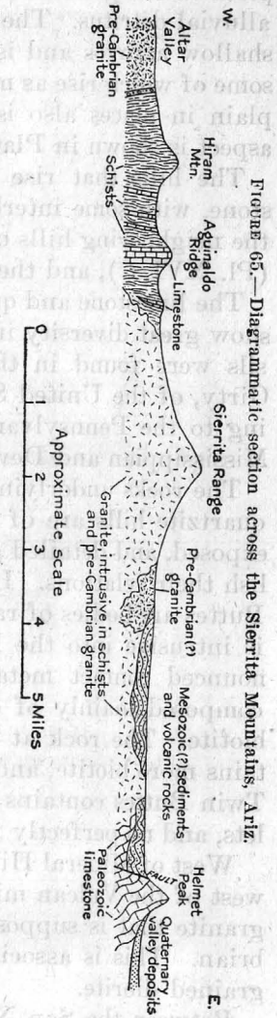


FIGURE 65.—Diagrammatic section across the Sierrita Mountains, Ariz.

Lying generally west of the rocks just described is a belt, perhaps half a mile to a mile wide, of blue-gray slaty schists, within which are a few thin beds of dark quartzite. This belt obviously consists of metamorphosed shale and sandstone, the metamorphism, as generally in the district, being more a direct mechanical result of pressure than a chemical and mineralogical reconstitution of the rocks. These slaty schists make up the foothill ridge known as Hiram Mountain.

West of the slates and underlying the upper margin of the plain that slopes gently westward from Hiram Mountain to the alluvial bottom of Altar Valley is a fairly coarse porphyritic granite with phenocrysts of reddish orthoclase. This is probably pre-Cambrian. A rather unsatisfactory exposure of conglomerate, probably a basal conglomerate, was seen at one place between this granite and the slates or schists of Hiram Mountain.

A rough diagrammatic section across the Sierrita Mountains, not drawn closely to scale and not intended to be accurate in detail, is shown as figure 65 and will help to make clear the apparent general relations of the rocks so far as could be determined in a brief reconnaissance examination.

On the east side of the range the younger, fine-grained intrusive granitic rocks extend from the crest down to the foot of the main range, whence a very gently sloping plain extends eastward to Santa Cruz River. For at least 5 or 6 miles from the mountain front this plain has in general a rock surface thinly covered here and there by alluvial detritus. The plain is not perfectly even but is trenched by shallow arroyos and is surmounted by clusters of conspicuous hills, some of which rise as much as 700 feet above its general surface. The plain in places also is more or less rolling and hilly. Its general aspect is shown in Plate XVI.

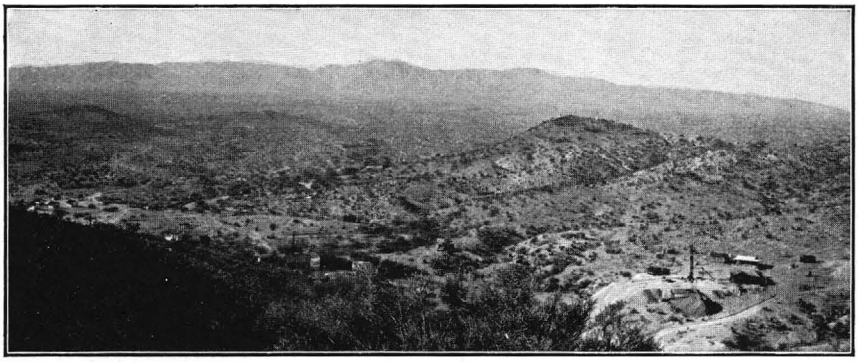
The hills that rise sharply above this surface are mainly limestone, with some interbedded quartzite. Such are Mineral Hill and the neighboring hills of the same group (Pl. XIX, *A*), Helmet Peak (Pl. XVI, *C*), and the group of hills in the vicinity of Twin Buttes.

The limestone and quartzite of the hills are folded and faulted and show great diversity in strike and dip. A few poorly preserved fossils were found in the limestone and were determined by G. H. Girty, of the United States Geological Survey, as probably belonging to the Pennsylvanian division of the Carboniferous. Possibly Mississippian and Devonian beds are also present.

The rocks underlying the plain between and around the limestone-quartzite hills are of varied character. They are not continuously exposed, and detailed geologic mapping would be necessary to establish their relations. In the neighborhood of Mineral Hill and Twin Buttes are bodies of rather coarse porphyritic light-gray granite that is intrusive into the limestone and quartzite and has effected pronounced contact metamorphism. At Mineral Hill this granite is composed mainly of orthoclase, microcline, quartz, and chloritized biotite. The rock at Twin Buttes is generally a little darker, contains more biotite, and shows little or no microcline. The granite at Twin Buttes contains considerable pyrite, disseminated and in veinlets, and no perfectly fresh and unaltered specimens were obtained.

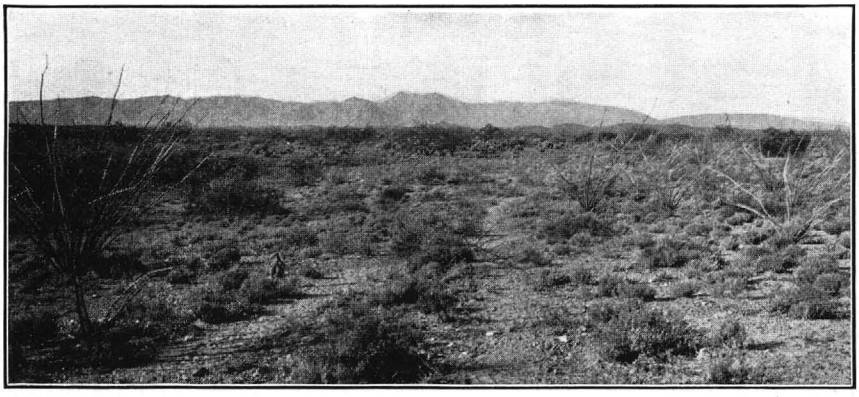
West of Mineral Hill and extending up on the north spur of the hill west of the Vulcan mine is an exposure of coarse-grained crumbling granite that is supposed from its general character to be pre-Cambrian. This is associated with and apparently cut by a dark fine-grained diorite.

Between the San Xavier mine and Helmet Peak the plain is cut mainly on red and green shales with some thin-bedded quartzitic sandstone. These beds are variable in strike and dip from place to place and in some localities stand nearly vertical. Presumably they are younger than the gray limestone of the neighboring hills and may be of Mesozoic age. Along the west side of Helmet Peak they appear to have been faulted down against the limestone, and the

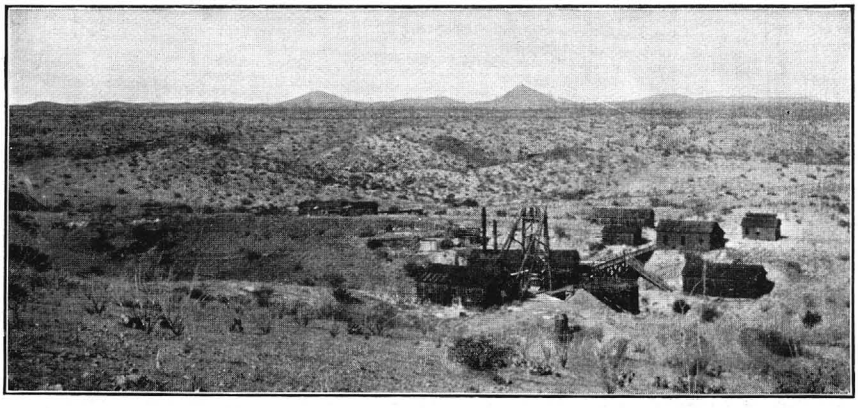


A. VIEW SOUTHWEST TOWARD THE SIERRITA MOUNTAINS, ARIZ., FROM A POINT NEAR THE SAN XAVIER MINE.

The hills in the foreground are mainly Paleozoic limestone Beyond them and to the left is the rock-floored plain described on page 412. The old Olive camp mines are in the vicinity of the two low hills that interrupt the generally even surface of the plain in the left-hand part of the view.

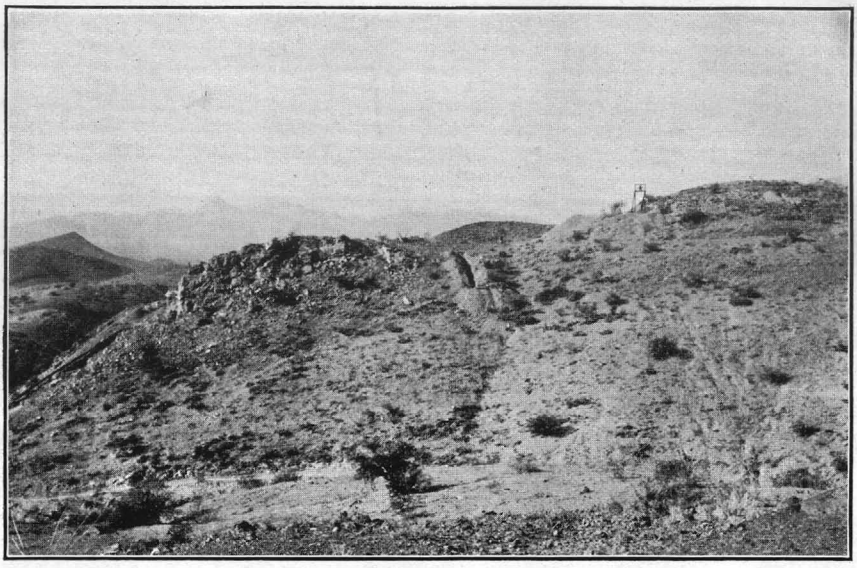


B. VIEW WEST OVER THE PIEDMONT PLAIN TO THE SIERRITA MOUNTAINS FROM THE WELLINGTON MINE, ABOUT 2 MILES SOUTH OF HELMET PEAK.



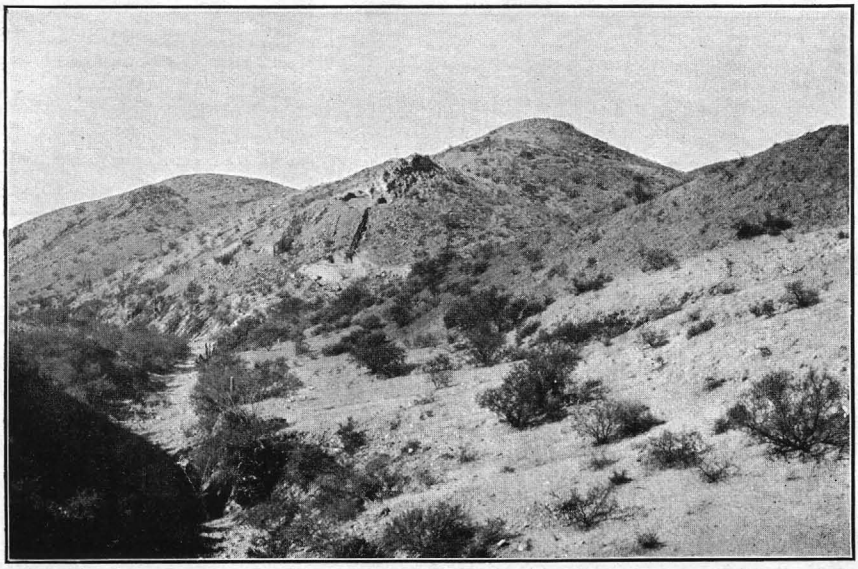
C. SENATOR MORGAN MINE, SIERRITA MOUNTAINS, FROM THE SOUTH.

The ore zone crops out along the low ridge to which a trestle bridge extends from the shaft. On the extreme left is part of the dump of the old shaft. Beyond the mine is the dissected surface of the piedmont plain, surmounted in the distance by Helmet Peak and the neighboring limestone hills near the San Xavier and Mineral Hill mines.



A. WORKINGS ON THE SUNSHINE CLAIM, PAPAGO DISTRICT, ARIZ., FROM THE EAST.

To the right is the main shaft. To the left of it is an open cut across the ore-bearing limestone. In the end of the ridge, to the left, is another open cut. In the distance are the Baboquivari Range and Baboquivari Peak.



B. WORKINGS ON THE SUNSHINE CLAIM, PAPAGO DISTRICT, FROM THE SOUTHEAST, LOOKING DOWN THE DRY BED OF ASH CREEK.

precipitous western front of the peak is interpreted as a slightly eroded stripped fault surface. The Reiniger-Freeman shaft, 376 feet deep, appears to be wholly within these shales and thin quartzites.

West of the above-described sedimentary rocks and extending from the South San Xavier mine southward past Olive camp is a generally decomposed and altered rock that has been locally called rhyolite. As exposed at the surface the rock is suggestive of a kaolinized or sericitized granite porphry within which is considerable secondary quartz. In many places the weathered surfaces of the rock are black with a thin coating of manganese oxide. An unoxidized specimen from the dump of a shaft near the old Olive mine shows abundant disseminated pyrite, and it is to the oxidation of this mineral that the general alteration and decomposition of the rock, as exposed at the surface, are evidently due.

Thin sections, examined microscopically, show that the rock is mainly quartz, with considerable sericite. The quartz is in irregular grains. Some of these are in close interlocking contact, as in typical quartzite; others are separated from one another by sericite in very fine grained aggregates. No trace of igneous texture is apparent, and the rock has evidently undergone complete recrystallization. Whether it was originally an arkosic sandstone or a very siliceous porphyry can not be definitely determined from the specimens collected.

About a quarter of a mile south of the Olive mine, in the vicinity of the Prosperity group of claims, the country rock is andesitic. It is altered and is, in part at least, an andesite breccia. The same rock extends for more than a mile to the southwest and is the general country rock of the Paymaster mine, where it is underlain at a depth of about 300 feet by a moderately coarse gray granite, which becomes the surface rock a short distance west of the mine and extends up to the east base of the Sierrita Mountains. The relations of this rock to the granitic rocks of the Sierrita Mountains and to the granite that is intrusive into the Paleozoic limestone and associated sedimentary rocks near Twin Buttes were not ascertained. The granite near the Paymaster mine may be pre-Cambrian.

In the vicinity of Twin Buttes gray limestone, presumably of Carboniferous age, with associated quartzite and shale, is cut by a moderately coarse gray granite with phenocrysts of orthoclase and rather abundant biotite in irregularly bounded aggregates of small scales. Near the mines the granite contains much pyrite as veinlets and disseminated crystals and the feldspars are more altered than might be supposed from the inspection of hand specimens. The contact metamorphism is more intense in this part of the district

than elsewhere. Garnet rock is abundant in outcrops and on the dumps of the various mines. Certain beds of the limestone are more susceptible to garnetization than others, but bunches of garnet are distributed irregularly through all the beds. In places, particularly at the Senator Morgan mine, as shown by material on the dump, there has been very active development of magnetite, green fibrous amphibole, and chlorite, intimately associated with pyrite, chalcopyrite, and zinc blende. In the quartzite near the same mine there is abundant epidote. In some parts of the quartzite the epidote is nearly or quite as abundant as the quartz, the two minerals together forming an aggregate of closely interlocking grains of apparently contemporaneous crystallization. It occurs also in larger crystals on joint surfaces.

ORE DEPOSITS OF THE PAPAGO DISTRICT.

In the Papago district no work was actually in progress at the time of visit (December, 1920). So far as could be learned there is no general claim map of the district in existence, and in the time available only a very general impression could be gained of the outlines and relative positions of the groups of claims to be described.

The most southerly of the principal groups examined is the Sunshine-Sunrise group, comprising about seventeen claims and two mill sites and owned principally by Judge S. W. Purcell, of Tucson. This group has a length of 6,500 feet and an average width of 2,200 feet. The principal exploratory work has been done on the Sunshine No. 1 claim and includes a shaft 140 feet deep with a short drift and crosscut at the 100-foot level. (See Pl. XVII, *A*.) South of the shaft, as the illustration shows, is an open crosscut, and south of this, at the south end of the ridge in which the workings are situated, is another open cut and under it a tunnel run in a northerly direction into the hill, from Ash Creek. The ore occurs in beds of limestone, apparently about 50 feet in total thickness, which strike N. 20° W. and dip about 65° W. This limestone, which does not appear to cross Ash Creek to the south, is apparently a lenticular member of the schistose series. On Sunshine Hill it lies about 800 feet west of the granite, from which it is separated by a belt of the gray schist described on page 410. West of the limestone are alternations of similar schistose and slaty rocks with belts of schistose rhyolite. The ore consists mainly of galena with a little chalcocite and occurs partly as a filling of irregular fractures in the limestone and partly as a replacement of their walls. At the slight depth attained the galena is generally accompanied by cerusite, anglesite, cerargyrite, and other products of oxidation. Surface cuts and pits along the outcrop of the limestone show the presence of more or less galena for a length of 500 to 700 feet, but not enough work has been done

to prove the existence of a continuous ore body along the line of these openings. Judge Purcell informed me that samples that assayed high in lead and silver, with some gold, had been taken at several places, and the appearance of some of the material bore out his statements. The deposit as a whole, however, appears to be of comparatively low grade, and it would be impossible without considerable additional development to make any close estimate of the quantity and average tenor of ore present in any considerable and definite mass of the limestone. An engineer whose results are regarded as reliable and whose sampling was done for a prospective purchaser informed me that a sample taken vertically across the face of the open cut at the south end of the ridge (see Pl. XVII, *B*), where at present may be seen what is probably the most promising face of ore, yielded on assay from 6 to 7 per cent of lead and 4 ounces of silver to the ton. Such material could probably be concentrated at a profit if enough of it—some hundreds of thousands of tons—were available.

The Sunrise claims lie generally east of the Sunshine claims. On the Sunrise No. 6 claim, about 800 feet east of the Sunshine workings, is the contact between the granite on the east and the schist on the west. No very conspicuous contact metamorphism was noted at the main contact, but a short distance east of this contact a narrow mass of limestone is included within the eruptive rock. This has been changed in part into a hard, tough greenish-yellow rock consisting largely of garnet with some green amphibole. In places it contains a little pyrite and sphalerite and on the surface shows some copper carbonates, doubtless derived from chalcopyrite. A little oxidized copper ore is reported to have been shipped from a shallow opening on the outcrop. A 200-foot crosscut tunnel driven east under the outcrop fails to show any ore. The same limestone inclusion can be traced through the granite for some distance, possibly half a mile, north of the tunnel.

About 1½ miles northwest of the Sunshine workings and close to the main road is the Banner mine, which was worked intermittently from the eighties up to 1904. The Banner shaft is reported to be about 200 feet deep but is filled with water to within less than 100 feet from the surface. This shaft and a tunnel on the adjoining McKinley claim, to the south, are on a zone of fissuring and silicification in limestone, within the generally schistose series. The geologic relations are broadly similar to those on the Sunshine claim, the limestone being separated from the intrusive granite of the main range by a belt of gray slaty schist with some schistose rhyolite. The zone of fissuring strikes about N. 20° W. and dips 45°–50° E. It is generally less than 2 feet wide. Quartz, which is partly fissure filling and has in part replaced the limestone, is abundant but bunchy and does not

follow continuously any one fissure. The veins also are displaced by numerous cross faults of small throw. The ore, which was treated in a small mill, now dismantled, appears from material on the dump to have consisted of quartz with partly oxidized pyrite, galena, sphalerite, chalcopyrite, and some chalcocite, probably derived from chalcopyrite. It was valuable chiefly for its silver content. The Banner and McKinley claims are said to be owned by the Lehigh Valley Bank, of South Bethlehem, Pa.

About a mile north of the Banner is the Olympia shaft (Pl. XVIII), apparently about 200 feet deep. This is on the Olympia group of 14 claims, which adjoins the Banner on the north and is reported to be owned by the Olympia Mining Co., of Chicago. No work was in progress at the time of visit. The Olympia is on the same belt of partly silicified limestone as the Banner and McKinley mines, which here determines the crest of a rather prominent ridge. No persistent vein could be seen, but the limestone has been irregularly fissured, contains bunchy quartz veins, and is itself more or less silicified.

The Clark group of 10 claims lies north of the Olympia, partly on the same limestone ridge. Most of the work on this group, however, has been done to the east of the ridge and close to the granite. Here a little isolated hill (Pl. XVIII) composed mainly of limestone contains bunches of vein quartz and more or less thoroughly silicified limestone. No regular or persistent vein was recognized, but a few tons of partly oxidized silver ore has been shipped from scattered shallow pits and trenches. Supergene enrichment has probably been active here, and the appearance of the surface is not indicative of the presence of large or deep ore bodies. The Clark No. 2 and Clark No. 3 claims lie west of the Clark No. 1, on the same limestone ridge as the Olympia. They show a few small, irregular streaks of copper-stained, oxidized silver ore in silicified limestone, but the metallization has apparently been feeble, and the prospects for finding an ore body of considerable size can not be considered encouraging.

North of the Clark group is the Aguinaldo group of nine claims, owned by S. W. & E. M. Purcell. Most of the work on these claims has been done at a point about 2 miles north-northwest of the Sunshine camp, on the same limestone ridge on which are the Banner and Olympia mines. The beds strike northwest and dip 85° NE. They are in part fractured and silicified and crop out boldly. Near the Aguinaldo workings the limestone has been intruded by a decomposed dioritic offshoot that projects to the northwest from the main granite mass previously described. Near this tongue, which is regarded as a calcic border variety of the granite, the limestone shows contact metamorphism. It contains layers or streaks of tremo-

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but it is believed that the work of the Federal geologists and their associates did much to encourage miners to patriotic efforts to develop domestic deposits of war-important minerals. It was demonstrated that the United States has reserve deposits of chrome ore adequate to supply a war demand for several years. Now that the war is over the country is conserving its domestic supplies by employing higher-grade and cheaper ore from foreign countries. The first paper in this bulletin, by J. S. Diller, "Chromite in the Klamath Mountains, California and Oregon," discusses in detail the occurrence and origin of chromite and in this respect serves as an introduction to the five papers that follow. The presentation of theoretical matter in these other papers is therefore reduced to a minimum.

lite in radial fibrous aggregates, associated with galena. There are also lenticular or bunchy masses of dark-weathering material that consists of calcite, limonite, psilomelane, and pyrolusite or manganite, with galena in small stringers and bunches. Associated with these minerals are a little azurite and malachite and some wulfenite. There is no vein. The Aguinaldo is essentially a low-grade contact deposit in limestone, formed as a result of the granitic intrusion. A little wulfenite is reported to have been sorted out and shipped from surface cuts and short tunnels, and some of the ore is stated to have assayed as high as 300 ounces of silver to the ton. None of the material seen in 1920, however, looked like ore, and it is very doubtful whether the information obtainable from the surface and from the few existing openings warrants the conclusion that deeper exploration would uncover an ore body. Just north of the place where most of the exploratory work has been done on the Aguinaldo a ravine with drainage from east to west cuts through the ridge. This ravine seems to coincide with a fault that appears to have offset the beds north of it to the east. Not enough study was given to the locality to demonstrate this offset, however. A shaft about 200 feet deep intended to develop the Aguinaldo ground at greater depth than is possible by tunnels has been sunk in the ravine. This shaft is apparently north of the fault.

North of the Aguinaldo is the Wheeler & Perry group of two claims, on which the geologic conditions are similar to those on the Aguinaldo. Some manganiferous silver ore is said to have been shipped from shallow workings on these claims. Still farther north, according to Judge Purcell, and on the same zone is the Little Johnnie claim, from which also some silver ore has been shipped. This was not visited.

West of the ridge that contains the Olympia and Aguinaldo prospects is a valley, probably from half a mile to a mile wide, that separates this ridge from Hiram Mountain. This valley is floored generally by truncated, nearly vertical thin beds of limestone separated by slates and slaty schists. The limestone beds have been fractured and silicified and at a number of places have been prospected or worked for silver ore. This is particularly true on the Cunningham group of five claims, just south of the old Stevens ranch, where five or six parallel belts of limestone have been prospected. Two old and abandoned shafts appeared to be at least 100 feet deep. Material on the dumps shows a little malachite and azurite and dark, obscure sulphides, probably in part argentite. A small quantity of silver ore has been shipped from the Cunningham group, which is reported to be owned by C. J. Cunningham, of Tucson.

In this same valley, perhaps half a mile north of the Cunningham group and nearly west of the Aguinaldo workings, is Lincoln camp and the Yellow Bird shaft, about 150 feet deep. The Lincoln or Yellow Bird group comprises 15 claims and a mill site and is owned by S. W. & E. M. Purcell. The shaft is in one of the numerous limestone members within the prevalent slaty rocks and is a few feet west of a belt of schistose rhyolite. The beds strike N. 5° W. and dip about 85° W. The Yellow Bird is reported to have made some shipments of argentiferous galena and cerusite. The best ore seems to have been soft, earthy yellowish material, partly cerusite, found in crevices in the fractured limestone.

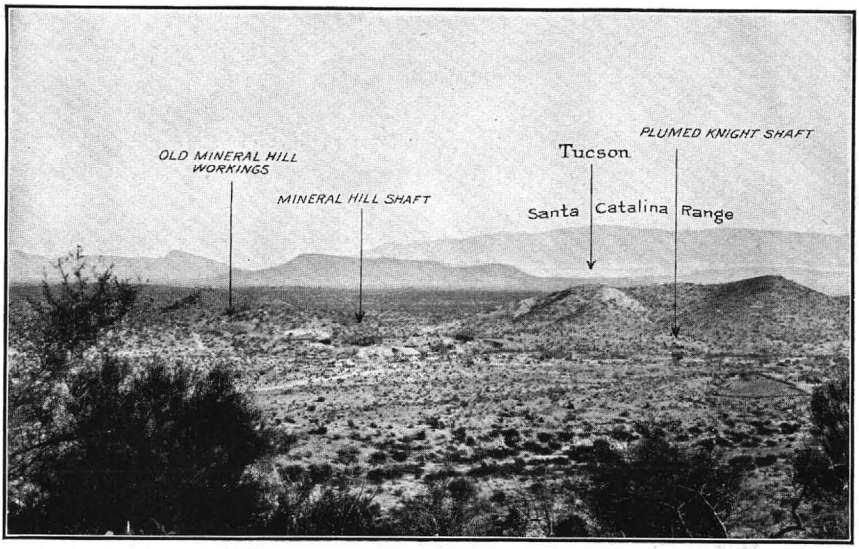
From half a mile to a mile west of the Yellow Bird shaft, well up on the east slope of the ridge of Hiram Mountain, at an elevation of about 4,200 feet, are the workings on the Providencia claim of the Yellow Bird group. This deposit is of different character from any of those previously described. The ridge is composed mainly of blue-gray slaty schists which are mainly squeezed sedimentary rocks and which in general strike about N. 20° W. and dip 75°–80° W. The Providencia is on a bed of quartzite, 4 to 5 feet thick, that has been shattered and has the resulting irregular network of cracks filled with argentiferous chalcocite. The chalcocite, as seen in the open cut and in the small tunnels run into the deposit, has been partly altered to covellite and malachite. Some ore is reported to have been shipped from the Providencia, but all the work done is close to the surface. Presumably the chalcocite will give place at depth to chalcopyrite or bornite, but it is not possible to predict the depth at which the change will occur. The Providencia deposit is not large but appears to be more promising and better worth additional exploration than some of the silver-lead deposits in the limestone beds previously described.

About half a mile west of the Hiram Mountain ridge, on the edge of Altar Valley, is the Leahy group of claims, in pre-Cambrian granite. No persistent vein was seen, but the granite contains some small irregular fissures that contain partly oxidized chalcopyrite and pyrite with some free gold.

Close to the road, a mile or two north of Lincoln camp, is an inclined shaft on a quartz lode in slate. This, I was informed, is on the Critic group. The dump shows much quartz, stained in part with carbonates of copper, but no ore.

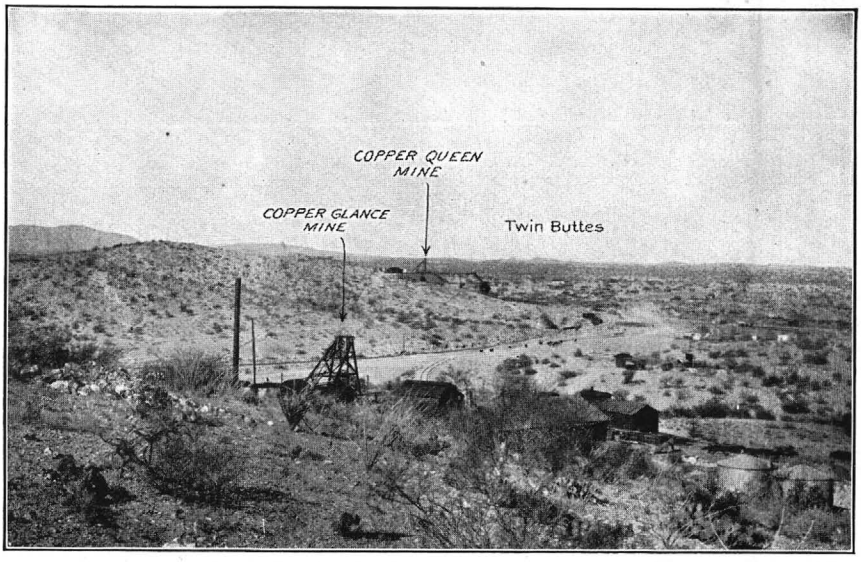
A deposit of fluorite at the north end of the Sierrita Mountains, on the Neptune group, was not visited.

South of the section of the range examined, on its western slope, are the San Juan, McIntyre, and other groups of claims, which were not visited. Some silver ore is reported to have been shipped from the San Juan.



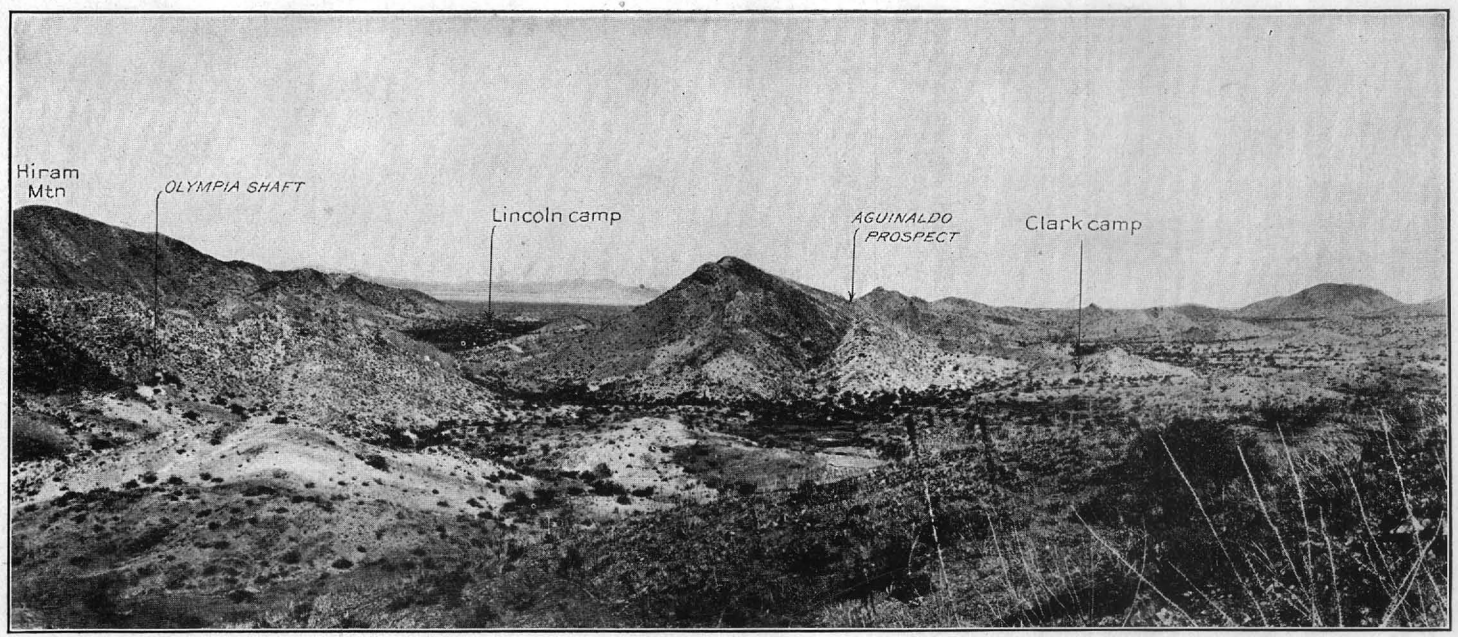
A. MINERAL HILL MINE, PIMA DISTRICT, ARIZ., FROM THE SOUTH.

The flat-topped hill in the distance is a part of the Black Mountains. (See fig. 64.)



B. VIEW NORTHWEST TOWARD THE COPPER QUEEN MINE AND THE SETTLEMENT OF TWIN BUTTES, PIMA DISTRICT, FROM A POINT NEAR THE COPPER GLANCE MINE.

The Sierrita Mountains appear in the distance, to the left.



GENERAL VIEW TO THE NORTHWEST IN THE FOOTHILL BELT OF THE SIERRITA MOUNTAINS, PAPAGO DISTRICT, ARIZ.

The slope in the foreground is on granite and descends to a little valley beyond which is the limestone containing the Olympia and Aguinaldo prospects. Through a gap in this ridge may be seen Lincoln camp, and beyond it, to the left, is the schist mass of Hiram Mountain.

and (3) preliminary reports on economic investigations the results of which are to be published later in more detailed form.

Although these papers set forth mainly the practical results of economic investigations they include brief theoretical discussions and summary statements of conclusions if these appear to require prompt publication.

Beginning in the spring of 1917 and continuing throughout the period of the war the United States Geological Survey made special field explorations, surveys, and laboratory studies of deposits of ores of metals used in the manufacture of ferroalloys, pig iron, and steel, including manganese, chromium, tungsten, molybdenum, titanium, uranium, vanadium, zirconium, and iron. More than 2,500 deposits were examined in 27 States, Cuba, Porto Rico, Santo Domingo, Costa Rica, and Panama. As soon as the field examination of a group of deposits could be completed systematic notes giving estimates of tonnage of ores were sent to Washington for the information of the Shipping, War Industries, and War Trade boards and other Government organizations that were interested in the question of what domestic supplies were available for substitution for foreign ores.

Summaries of the data were promptly published by the Geological Survey in the form of press bulletins, and several longer papers on these subjects have been published by the American Institute of Mining and Metallurgical Engineers.[1] Other papers prepared largely by Federal Survey geologists have been published by several State surveys.[2] The papers on chromite and manganese ore in this bulletin are some of the results of this war work; other papers were published in "Contributions to economic geology" for 1919 and 1920. In the field work the United States Geological Survey enjoyed the cooperation of the California State Council of Defense and the State geological surveys of Colorado, Georgia, Minnesota, Tennessee, and Virginia, the University of Nevada, the New Mexico State School of Mines, and the United States Bureau of Mines.

During the war period there were large increases in the domestic production of manganese, chrome, tungsten, and other ores of this steel-hardening group and of the ferroalloys. To war prices is doubtless due part of the stimulation for this increased production,

[1] Harder, E. C., and Hewett, D. F., Recent studies of domestic manganese deposits: Am. Inst. Min. and Met. Eng. Trans., September, 1919, 48 pp. Diller, J. S., Recent studies of domestic chromite deposits: Idem, 44 pp. Burchard, E. F., Manganese-ore deposits in Cuba: Idem, 52 pp. Burchard, E. F., Chrome-ore deposits in Cuba: Idem, 23 pp.

[2] Stose, G. W., and Schrader, F. C., Manganese deposits of east Tennessee: Resources of Tennessee, vol. 8, Nos. 3 and 4, 531 pp., Tennessee State Geol. Survey, 1919. Stose, G. W., Miser, H. D., Katz, F. J., and Hewett, D. F., Manganese deposits of the west foot of the Blue Ridge, Va.: Virginia Geol. Survey Bull. 17, 166 pp., 1919. Hull, J. P. D., LaForge, Laurence, and Crane, W. R., Manganese deposits of Georgia: Georgia Geol. Survey Bull. 35, 295 pp., 1919.

It must of course be recognized that any conclusion as to the future of the Papago district that can be drawn from so brief an examination as that made in 1920 is tentative and may be changed by future development. The general impression gained, however, is that the metallization has not been strong and that large deposits of ore probably do not exist, although additional prospecting may disclose bodies of comparatively small size. Good ore has undoubtedly been found at many places, but it has come from relatively small deposits and from shallow workings. It is highly probable that the small quantity of silver ore shipped or milled is material that has been enriched by the chemical action of descending solutions and is not representative of what may fairly be expected at depths of several hundred feet.

ORE DEPOSITS OF THE PIMA DISTRICT.

At the north end of the Pima district, about 18 miles from Tucson, is the Mineral Hill mine (Pl. XIX, *A*), which belongs to the Mineral Hill Consolidated Copper Co., of Pittsburgh, Pa. This company, incorporated in 1904, is the successor to the Azurite Copper & Gold Mining Co. It owns or controls between 50 and 60 claims in the vicinity of Mineral Hill, including the Azurite, Plumed Knight, and Sunrise groups.

The mine now in operation is developed through a vertical shaft about 700 feet deep, with the principal levels at 500, 600, and 700 feet below the collar. No ore has been shipped from these workings, and the efforts of the company are confined entirely to prospecting and to blocking out such ore as has been found. Formerly, however, considerable oxidized copper ore was shipped from the now abandoned Azurite workings, in the upper part of the Mineral Hill deposit. The Azurite company is reported to have had two 30-ton water-jacket copper furnaces in operation prior to 1904 and to have produced ore to the value of over $500,000. In 1916 the Pima district is credited with the production of 6,683,094 pounds of copper, of which "most" is stated to have come from the Azurite workings of the Mineral Hill Consolidated Copper Co.[1]

About a quarter of a mile east-southeast of the Mineral Hill shaft is the Plumed Knight mine, formerly owned by the Pioneer Mining & Smelting Co. but now belonging to the Mineral Hill company. The workings of this mine are reported to be 350 feet deep and produced considerable oxidized copper ore above the 150-foot level, especially between 1907 and 1918.

The general geologic features in the vicinity of Mineral Hill are very roughly indicated in the accompanying diagrammatic sketch

[1] U. S. Geol. Survey Mineral Resources, 1916, pt. 1, p. 310, 1917.

(fig. 66), which is not drawn to scale. Mineral Hill is composed mainly of rather thin bedded quartzite which strikes generally northwest and dips steeply southwest. Traversing the south slope of the

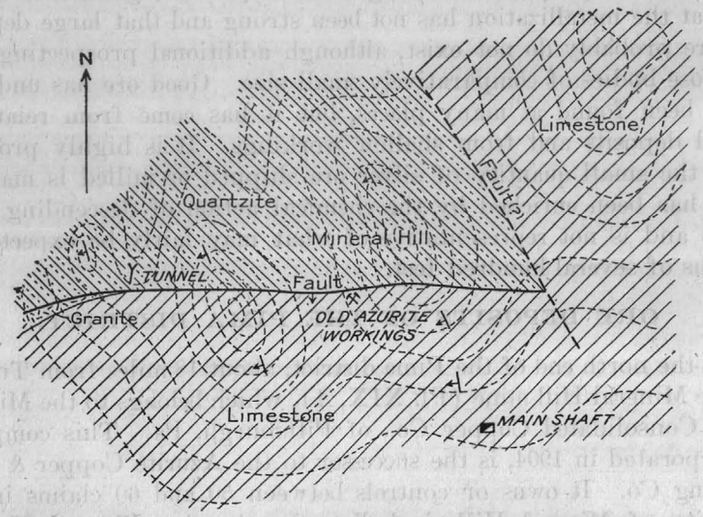


FIGURE 66.—Diagrammatic plan showing general geologic relations at Mineral Hill, Pima district, Ariz.

hill and passing just north of the summit of a smaller hill to the west is a nearly east-west fault with a dip to the south of 55° or more. The rock on the south or hanging-wall side of the fault is more or less

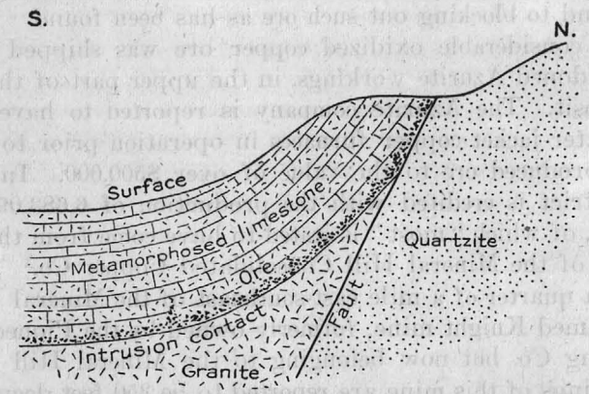


FIGURE 67.—Diagrammatic section showing probable general relations of the ore to the inclosing rocks at Mineral Hill, Pima district, Ariz.

metamorphosed limestone with approximately the same strike and dip as the quartzite. The workings of the Mineral Hill mine show that this limestone is underlain by granite that is apparently intrusive into it, the relations being something like those diagrammatically

CONTRIBUTIONS TO ECONOMIC GEOLOGY, 1921.

PART I. METALS AND NONMETALS EXCEPT FUELS.

F. L. RANSOME and E. F. BURCHARD, *Geologists in charge.*

INTRODUCTION.

The Survey's "Contributions to economic geology" have been published annually since 1902. In 1906 the increase in the number of papers coming under this classification made it necessary to divide the contributions into two parts, one including papers on metals and nonmetals except fuels and the other including papers on mineral fuels. In 1915 the year included in the title was changed from the year in which the field work reported in these papers was done to the year of publication, and in consequence there was no volume entitled "Contributions to economic geology, 1914." The subjoined table gives a summary of these bulletins.

United States Geological Survey "Contributions to economic geology."

Date in title.	Date of publication.[a]	Bulletin No.	Date in title.	Date of publication.[a]	Bulletin No.
1902	1903	213	1912, Part I	1914	540
1903	1904	225	Part II	1914	541
1904	1905	260	1913, Part I	1915	580
1905	1906	285	Part II	1915	581
1906, Part I	1907	315	1915, Part I	1916	620
Part II	1907	316	Part II	1916	621
1907, Part I	1908	340	1916, Part I	1917	640
Part II	1909	341	Part II	1917	641
1908, Part I	1909	380	1917, Part I	1918	660
Part II	1910	381	Part II	1918	661
1909, Part I	1910	430	1918, Part I	1919	690
Part II	1911	431	Part II	1919	691
1910, Part I	1911	470	1919, Part I	1920	710
Part II	1912	471	Part II	1920	711
1911, Part I	1913	530	1920, Part I	1921	715
Part II	1913	531	Part II	1921	716

[a] The date given is that of the complete volume; beginning with Bulletin 285, the papers have been issued as advance chapters as soon as they were ready.

As the subtitle indicates, most of the papers in these volumes are of three classes—(1) short papers describing as thoroughly as conditions will permit areas or deposits on which no other report is likely to be prepared; (2) brief notes on mining districts or economic deposits whose examination has been merely incidental to other work;

represented in figure 67. A little of the granite is exposed on the surface just south of the fault, west of Mineral Hill. The granite is probably a sill and may be underlain by the same quartzite as that against which it is faulted. The thickness of the granite, however, is unknown.

The ore bodies in the Mineral Hill mine occur in the limestone close to the granite. They are irregular in form, particularly as regards the limestone hanging wall, into which they extend much farther along certain north-south fissures than elsewhere. Most of these fissures dip steeply east. Their relation to the bedding planes of the limestone is not clear and was not ascertained in the short time spent in the mine. As shown in the diagram, the ore body as a whole has a fairly steep dip to the south near the surface but becomes more nearly horizontal on the lower levels.

The ore, of which the principal valuable constituent is copper, is mainly pyrite that is intimately associated with chalcopyrite, magnetite, and apparently a little pyrrhotite. There are all gradations from massive sulphides and magnetite to metamorphosed limestone containing, together with these same minerals, quartz, garnet, pale monoclinic pyroxene, tremolite, green monoclinic amphibole, and probably other metamorphic silicates. The Mineral Hill ore is thus clearly of contact-metamorphic origin.

In the Plumed Knight workings the ore formerly stoped above the 150-foot level was all oxidized and occurred as irregular lenses in the limestone. The general strike of these lenses appeared to be N. 50°–60° W., with dip to the southwest. The limestone is considerably fissured, but the lenses apparently lie approximately parallel with the bedding planes.

Adjoining the ground of the Mineral Hill Co. on the west, and lying for the most part west of the main road from Tucson to Twin Buttes, is the Vulcan group of seven claims, owned by the Vulcan Consolidated Mining Co., of Tucson, but understood to be bonded to Chicago people. The ground has been developed by a 560-foot inclined shaft, from which considerable work was evidently done. Ore shipped from these workings in 1916 and 1917 is said to have yielded nearly 1,200,000 pounds of copper and over 11,000 ounces of silver and to have averaged between 6 and 7 per cent of copper. Abundant water is reported to have entered the bottom of the incline, and these workings were finally abandoned. A new vertical shaft was started a short distance south of the old incline but has not yet reached the ore zone. No work was in progress at the time of visit. The geologic conditions at the Vulcan are similar to those at Mineral Hill, and the ore deposit is apparently of the same general character.

70616°—22——3

About half a mile a little west of south from the Vulcan shafts and also on the west side of the road is the shaft of the San Xavier Extension Copper Co., 500 feet deep. This is on the Red Oxide claim of the Red Oxide group of five claims. From this mine had been shipped up to September, 1919, about 900 tons of ore that averaged about 4 per cent of copper and 2 ounces of silver to the ton. No work was in progress during December, 1920, and the mine was not examined. According to Mr. John C. Anderson the principal levels are at 227 and 313 feet below the collar, and the drifts extend for about 300 feet west of the shaft. All the workings are said to be in limestone, the beds of which strike northwest and dip about 40° SW. These beds are reported to be cut by a number of northeast-southwest faults. The ore apparently occurs as small lenticular masses that lie approximately with the bedding of the limestone. Piled on the dump at the time of visit was a few tons of zinc ore, chiefly sphalerite with some chalcopyrite. This is said to have come from a small stope above the 227-foot level. The copper ore was shipped from some of the upper levels.

South of the Red Oxide group are the San Xavier and South San Xavier groups, comprising about 13 claims, owned by the Empire Zinc Co. The principal shaft is 380 feet deep, with levels at about 50, 100, 150, 200, and 380 feet below the collar. At the time of visit the mine was idle and was filled with water to about 40 feet below the 150-foot level. The San Xavier mine was purchased by the Empire Zinc Co. in 1912 and produced in 1913 about 1,500 tons of copper-silver-lead ore, which was hauled by motor trucks to Sahuarita, 7 miles away, and thence shipped to the El Paso smelter. Considerable oxidized zinc ore was also developed during that year, and the mine continued productive up to December, 1917. The ore shipped in 1917 carried as much as 6 per cent of copper and 6 ounces of silver to the ton, but the average was considerably lower. Some zinc carbonate ore was also produced from 1913 to 1917, mainly from open cuts. The condition of the mine in 1920 did not permit satisfactory examination in the short time available, and the following description is far from complete.

The workings lie on the south side of a hill 300 to 400 feet high, composed of gray limestone, probably of Carboniferous age. The beds strike N. 80° E. and dip 50° S. The south slope of the hill is very nearly a dip slope. East of this hill, separated from it by a saddle through which a fault runs, is another hill composed of folded and faulted gray limestone, within which is a layer of brittle, fractured quartzite from 75 to 100 feet thick. The only fossil remains seen in the limestone were crinoid stems, echinoid spines, and a few fragments of brachiopods. The ore, so far as could be ascertained, occurs wholly in limestone, which is much fractured

but within which was seen no dominant or master fissure. The limestone shows no recognizable metamorphism. The ore bodies mined above the water level were very irregular masses composed of smithsonite, copper carbonates, probably cerusite, earthy yellow jarosite, limonite, and other products of oxidation. The 150-foot level, on which comparatively little work has been done, shows pyrite, sphalerite, and chalcopyrite. No galena was noted, but presumably this mineral was present in some of the similar masses that, by oxidation and enrichment, were changed into the ore bodies formerly mined on the upper levels.

About half a mile a little south of west of the main San Xavier shaft is the West San Xavier shaft and a quarter of a mile farther west the South San Xavier shaft. These were idle at the end of 1920 and were not examined. Some ore was shipped from the South San Xavier in 1906, before it was acquired by the Empire Zinc Co. The approximate alinement of these three shafts suggests the existence of a nearly east-west zone of fissuring that may have been a controlling factor in ore deposition.

The San Xavier deposit is regarded as a metasomatic replacement of limestone closely related in origin to the intrusion of the granitic masses exposed at Mineral Hill and Twin Buttes. It does not appear to be a typical contact deposit like those at Mineral Hill and Twin Buttes.

Southeast of the San Xavier mine, occupying chiefly the lowland between San Xavier Hill and the prominent limestone hill known as Helmet Peak, is the San Xavier Extension or Wakefield group, owned by the Reiniger-Freeman Mining Co., of Tucson, incorporated in 1918. The company has sunk a 376-foot vertical shaft from one-eighth to one-fourth mile southeast of the San Xavier shaft. No work was in progress at this shaft at the time of visit. The dump consists of brittle fine-grained shale and thin-bedded sandstone, with some epidotized andesite and other volcanic rocks. There is no indication of ore, and the reasons for sinking a shaft at this place are not evident.

A short distance southwest of this shaft, on the San Carlos claim, a shaft about 100 feet deep has been sunk on a stringer of chalcopyrite, which in places is 6 inches wide. Southwest of this shaft, on the same claim but supposedly on a different vein, some prospecting was being done in December, 1920, on a stringer of galena that in places was several inches wide. Some good shipping ore had been sorted out, but the deposit appeared to be too small to be of much importance. The country rock of the San Carlos claim is the same thin-bedded, predominantly shaly formation as near the Reiniger-Freeman shaft.

In the vicinity of the former Olive camp, west and southwest of Helmet Peak, are the Olive (or Olivette), Annette, Swastika, Schu-

macher, Prosperity, and Alpha mines. With the exception of some modern work on the Prosperity group, these mines have been idle for many years. The Olive claim (now known as the Olivette) is said to have been located in 1886 and to have yielded about $750,000 in silver. In 1913 the Tucson Mining Co. built a 100-ton concentrator at the Olive mine, but nothing was learned about its operation. The ore of this and other near-by mines, according to Mr. Anderson, was mainly argentiferous tetrahedrite and galena, with probably some silver chloride near the surface. It occurred in at least two sets of intersecting fissures, which apparently are narrow and contain very little quartz. The veins do not crop out prominently and as a rule are rather obscure at the surface. As the deepest work is reported to be at 300 feet, the veins presumably were not profitable below that level. In the vicinity of Olive camp fissures of the same general character as those that have been worked are fairly numerous, and some of them apparently have never been prospected. The general country rock of these mines has been described on page 413.

The Prosperity group of eight claims lies immediately south of the Olive mine and has been worked through two shafts, probably about 300 feet deep. One of these is on the Contention claim, and the other, about 300 feet west-southwest of it, on the Tit for Tat claim. The vein strikes about N. 65° E. and dips very steeply to the southeast. The country rock is somewhat altered andesite breccia. Water stands in the old shafts at 80 feet below the surface, but H. M. Hebble, who has a bond and lease on the group, was doing some work at the time of visit above the 80-foot level. He had found some good lead-silver ore, about 15 inches in maximum width, which he reported to contain about 50 per cent of lead and 15 ounces to the ton in silver. The ore consists of galena, pyrite, chalcopyrite, tetrahedrite, and quartz. The highest assays in silver are obtained where tetrahedrite is abundant.

About a mile southwest of the Prosperity workings and about 3 miles in the same direction from the San Xavier mine is the Paymaster mine. This is now idle, but considerable underground work has been done here, and some ore is understood to have been shipped about 15 years ago. The surface rock at the mine is andesite breccia, apparently the same as at the Prosperity. This is underlain, at 300 feet in the main shaft, by rather coarse granite, possibly pre-Cambrian granite. The present workings consist of a vertical shaft 340 feet deep, in which the water stands at less than 300 feet. Only the 205-foot level was examined. This crosscuts northeast for 120 feet from the shaft and cuts what is known as the Lead vein, which strikes about north-northwest and has a rather variable dip, the average being about 70° W. About 50 feet farther northeast is a

ILLUSTRATIONS.

second, nearly parallel vein known as the Iron vein. No ore was seen on this level, but the Lead vein is reported to contain mainly galena and the Iron vein mainly pyrite with a little chalcopyrite and tetrahedrite. As seen on the 205-foot level, the "veins" appear as strong fissure zones with much soft, crushed andesite and gouge. The veins proper are apparently small and have been broken by vigorous postmineral faulting in the general plane of the vein.

The Alpha, another early producer of the Olive camp group, now idle, is about a mile south of the Prosperity. It was not examined.

A mile or two south of Helmet Peak, close to the main road to Twin Buttes, is the Wellington prospect, where, at the time of visit, work was in progress in a 122-foot shaft, with a drift on the 100-foot level. The shaft is on a fault that strikes N. 70° W. and brings the supposedly Mesozoic rocks of the Olive camp area on the north against gray Paleozoic limestone on the south. The material on the dump showed some copper stains.

Near Twin Buttes, a small settlement inhabited chiefly by Mexicans, the principal production has come from the Copper Glance, Copper Queen (Pl. XIX, *B*), Minnie, and Senator Morgan (Pl. XVI, *C*) mines. The Copper Glance mine is a little over half a mile east-southeast of the railway station at Twin Buttes, the Copper Queen is about halfway between the settlement and the Copper Glance, the Minnie is half a mile west of the station, and the Senator Morgan is at the end of the railway, about a mile southwest of Twin Buttes. These mines have yielded for the most part a pyritic copper ore of shipping grade carrying considerable gold and silver.

The first extensive development in this part of the Pima district was undertaken by the Twin Buttes Mining & Smelting Co. about 1903. In 1905 26 miles of standard railway was built from Tucson to Twin Buttes. About 1910 18 miles of this road was sold to the Southern Pacific Co. and became part of its branch into Mexico by way of Nogales. By 1913 the company was shipping about 1,500 tons a month of copper-silver-lead ore to El Paso. This company operated the Glance (Copper Glance), Queen (Copper Queen), and Senator Morgan mines. In 1913 E. G. Bush and associates, who as the Bush-Baxter Mining Co. had been successfully working the Minnie mine, leased the Senator Morgan mine. They also took a lease and gave a bond on the Glance mine, which, as the Glance Mining Co., they developed profitably and finally purchased. Similarly, as the Midland Copper Co., they acquired the Queen mine. The Glance and Queen mines were in operation up to the later part of 1920 but were idle at the time of visit and were not examined. Mr. Bush, who was recovering from a serious illness and was unable to accompany me to the mines, stated that there is good ore in the lower levels and that work would be resumed. The contents of the ore bin at the Glance

supported his statement. The Morgan and Minnie mines have been idle for three or four years.

The Glance vertical shaft, 625 feet deep, is on the north slope of a low limestone hill, close to the contact of the limestone with the granite that underlies the plain to the north of the hill. On the 535-foot level a crosscut connects through a raise with the bottom level of the 500-foot Queen inclined shaft, which is similarly situated with reference to another low limestone hill and to the granite-limestone contact. Inspection of maps of the underground workings showed that the ore bodies occur rather irregularly in the limestone near the granite. The limestone in the vicinity of the shaft at the surface is partly altered to garnet rock and partly recrystallized as marble. The garnet is of a yellow-brown variety and is associated with magnetite. Certain beds of the limestone were evidently more susceptible to garnetization than others, but bunches of garnet and magnetite are also irregularly distributed through the less completely metamorphosed limestone. The ore, as seen in the bins, consists of chalcopyrite, pyrite, sphalerite, magnetite, chlorite, garnet, and actinolite, all intimately intergrown. The general strike of the limestone beds is N. 50°–60° W., and the dip is nearly vertical. The ore bodies appear to lie generally with the bedding. Presumably, from the record of past shipments, some galena occurs in these deposits, but none was seen in 1920. The dumps of the Glance and Queen mines show abundant granite, through which is much pyrite and chalcopyrite disseminated and in small veinlets.

The Senator Morgan mine lies along the northeast base of a low ridge composed chiefly of epidotized quartzite. The beds strike with the ridge, N. 50° W., and dip about 45° SW. The rock shows varying degrees of epidotization from films of epidote on joints to a rock in which epidote and quartz in nearly equal proportions form a closely interlocking aggregate. Exposures in prospect pits indicate that the formation is generally thin bedded and contains some shale. Presumably the epidote-quartz rock was at one time a calcareous sandstone. Northeast of the quartzite is a belt of calcareous shale, and northeast of this a belt of gray limestone, probably of Carboniferous age. This rock is conspicuously altered and contains masses of garnet rock with bunches of epidote. The ore zone crops out strongly in this belt of metamorphosed limestone, striking about N. 80° W. A number of openings have been made along this zone, including what was at one time the main shaft, the dump of which can be seen at the left in Plate XVI, *C*. Later a new shaft was made by raising from one of the levels through the belt of shale that crops out south of the ore zone. The Senator Morgan workings are reported to have attained a depth of 900 feet.

CONTENTS.

[The letters in parentheses preceding the titles are those used to designate the papers for advance publication.]

The dump of the older shaft is made up of materials that are clearly the products of vigorous contact metamorphism. Pyrite and chalcopyrite are associated with abundant magnetite, garnet, and green amphibole in coarsely crystalline radial aggregates. Little or no granite appears on the dump, and none is exposed at the surface at the shaft. Granite is visible, however, in a shallow ravine a few hundred yards northeast of the mine buildings, and some of this rock is reported to have been reached in the underground workings. The deposit has the characteristics typical of a contact-metamorphic deposit, and its formation was clearly a consequence of the intrusion of the granite into the limestone. On the lower levels of the Senator Morgan mine the ore is reported to have been of low grade, with pyrite and magnetite very abundant.

The Esperanza mine, worked at different times by the Chesterfield Copper Co. and the Blanche Rose Mining Co., lies 3 or 4 miles west-southwest of the Senator Morgan mine and was said to be about 800 feet deep. It has been idle for years and was not visited.

Complete figures of production of the Pima district are not available, but the following table, compiled from the volumes of Mineral Resources published by the United States Geological Survey, gives some idea of the scale of operations during the later years of activity in the district:

Metals produced in the Pima district, Ariz., 1907–1919.

Year.	Copper (pounds).	Lead (pounds).	Zinc (pounds).	Gold (dollars).	Silver (fine ounces).
1907	98,791	.....	.....	.....	20,342
1908	1,078,390	111,586	.....	421	12,619
1909	1,696,166	282,150	.....	786	53,493
1910	303,522	278,746	.....	1,777	27,098
1911	685,879	17,616	.....	103	10,771
1912	1,787,971	56,199	111,737	1,155	34,475
1913	1,217,188	997,813	1,891,451	305	51,765
1914	872,699	767,960	.....	1,091	43,128
1915	3,164,358	28,013	47,762	2,283	43,726
1916	6,683,094	544,877	84,650	270	100,439
1917	4,440,864	263,872	175,440	145	57,639
1918	3,032,095	114,622	.....	159	55,154
1919	1,004,851	50,194	.....	432	14,986

It will be noted that the yield has shown unusual fluctuations in all five of the metals reported. This is in large measure accounted for by the irregular and variable character of contact-metamorphic deposits.

As regards the future of the Pima district only a few rather general impressions can be recorded on the basis of so brief an examination as was made, with so few opportunities for underground study as were found at the time of visit. There has apparently been much more intense metallization on the east side of the Sierrita

Mountains than on the west side, particularly in copper ores of the contact-metamorphic type. Probably there are considerable bodies of such ore as yet undiscovered, with perhaps still larger quantities of low-grade material that will require concentration before smelting. The outlook for finding additional bodies of sphaleritic zinc ore likewise appears to be fairly good. Undoubtedly, also, bodies of argentiferous galena will from time to time be found, but it is not expected that these will be large or will extend to great depth. There is some basis, also, for expecting that additional underground exploration may bring to light other small high-grade silver-bearing shoots, such as were formerly worked at Olive camp.

DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

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CONTRIBUTIONS TO ECONOMIC GEOLOGY

(SHORT PAPERS AND PRELIMINARY REPORTS)

1921

PART I.—METALS AND NONMETALS EXCEPT FUELS

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GEOLOGISTS IN CHARGE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1922

E side of pit · High grade

High grade

Looking S

E Side of pit

8/3/60 Pima

Mine. Rex Spaulding

C-M. 360 TPD

2 men per shift in mill. 125 men produce 25m TPD. including waste stripping

Present mill heads about 1.35%. Will be 1.5% shortly.

Cyprus Mines 50%

Union Oil 25%

Plan to expand to 72M @ 8000 TPD.

FW = marl, ls., barren. Breccia zone along E-W, S-dipping, fit. is post ore & post oxidation (? chrysocolla frags in breccia).

Hi grade ore seems to be in hornfels? Not dissemin. Coats fracture faces. to W, toward Banner line, associated with ZnS - looks marmatitic.

Small squirts of porphyry -
I saw some in Fw of
Main thrust (?) while
breccia along thrust
looks post-mineral.

No reason why thrust
itself should not be
premineral & main
ore control.
Hw rock called ~~porphyry~~
pyroclastic. Everything

I saw was very highly
altered.
Bench holes plotted,
logged & assayed.

M.O.S. present. Magnetite