DEPOSITS OF MANGANESE ORE IN ARIZONA.

By E. L. Jones, Jr., and F. L. Ransome.

INTRODUCTION.

By E. L. Jones, Jr.

FIELD WORK.

Deposits of manganese ore have long been known in some of the old mining districts of Arizona, notably in the Bisbee, Tombstone, Globe, and Patagonia districts, but prior to 1915 the ore had not been mined except as it formed the gangue of silver ores and was needed as a flux for use in local smelters. Manganese ore as such was first shipped from the Tombstone district in 1915, and from the Globe and Bisbee districts in 1916. The high prices that were offered for manganese ore in 1916, 1917, and 1918, and the fact that the opening of the new deposits would render the Government patriotic service greatly stimulated the production of the ore and the search for new deposits. As a result of this search discoveries in many parts of the State have been reported to Government bureaus from time to time.

In order to obtain information concerning these newly discovered deposits, their character and grade of ore, ore reserves, and productive capacity, two geologists of the United States Geological Survey examined manganese deposits in Arizona, E. L. Jones, jr., visiting many scattered deposits throughout the State, and F. L. Ransome those of the Bisbee and Tombstone districts.

The work of Mr. Jones was done in August and September, 1917, and in April, May, and June, 1918. It was geologic reconnaissance work, and generally not more than a few hours could be devoted to the examination of each deposit. Fifty of these scattered deposits were thus examined, but undoubtedly there are many deposits of manganese ore in the more remote parts of the State that have not been reported to the Survey. Since June, 1918, several deposits have been reported that have not been examined. The work of Mr. Ransome was done in the spring of 1918.

DISTRIBUTION OF DEPOSITS.

The manganese deposits described in this report are widely distributed from the eastern to the western border of the State, in Coconino, Cochise, Graham, Greenlee, Maricopa, Mohave, Pinal, Santa Cruz, Yavapai, and Yuma counties. They are all south of the main line of the Atchison, Topeka & Santa Fe Railway, which traverses the northern part of the State. The greater number of these deposits lie in the desert region of Mohave, Maricopa, and Yuma counties. Others are in the Globe, Ash Peak, Patagonia, and Superior districts, and there are several deposits in a small area on the plateau of Arizona, in Coconino County.

PRODUCTION.

The total production to December 31, 1918, in Arizona of manganese ore containing more than 35 per cent of manganese is over 32,000 tons. Of this amount the Tombstone and Bisbee districts have yielded more than 27,000 tons since 1915, and the remainder has been produced since January 1, 1917, from scattered deposits throughout the State. The principal producers of manganese ore in Arizona, except those in the Tombstone and Bisbee districts, are Thurston & Hardy, in the Ash Peak district, Greenlee County; the Manganese Development Co., Wheeler, U. S. group, Gallagher & Flynn, Armour group, and Hatton group, in the Aguila district, Maricopa County; the Arizona Manganese Co., operating the Howard claims, in Mohave County; the Hardshell mine, in Santa Cruz County; the Bunker and Burmeister claims, in Yavapai County; the Dobbins claims, in Yuma County; and the Globe Commercial Copper Co. and Superior & Globe Co., in the Globe district, Tarr & Harper, and the Chamberlain deposit, in Pinal County. The content of iron in these deposits is generally less than 4 per cent. The greater part of the ore contains about 35 per cent of manganese, although several deposits produced small quantities of ore containing 45 per cent or more. Some of the deposits, though large and of fair grade, are so remote from the railroad that the ores can not be mined and shipped at a profit, and others are too small or the material is of too low grade to be commercially valuable. The development work on most of these deposits is small and unsystematic, and it is difficult to estimate the reserve of ore. However, at least 35,000 tons of ore that contain more than 35 per cent manganese could be sorted from these deposits, and a much larger quantity of manganiferous ore containing less than 20 per cent of manganese is available.

The deposits examined are listed on the accompanying base map of Arizona (fig. 30). Where space permits each deposit is shown on

the map by a dot and a number corresponding to that in the list, but where a number of deposits are situated in a mining district of small area the individual deposits can not be shown on the map, although they appear in the list.

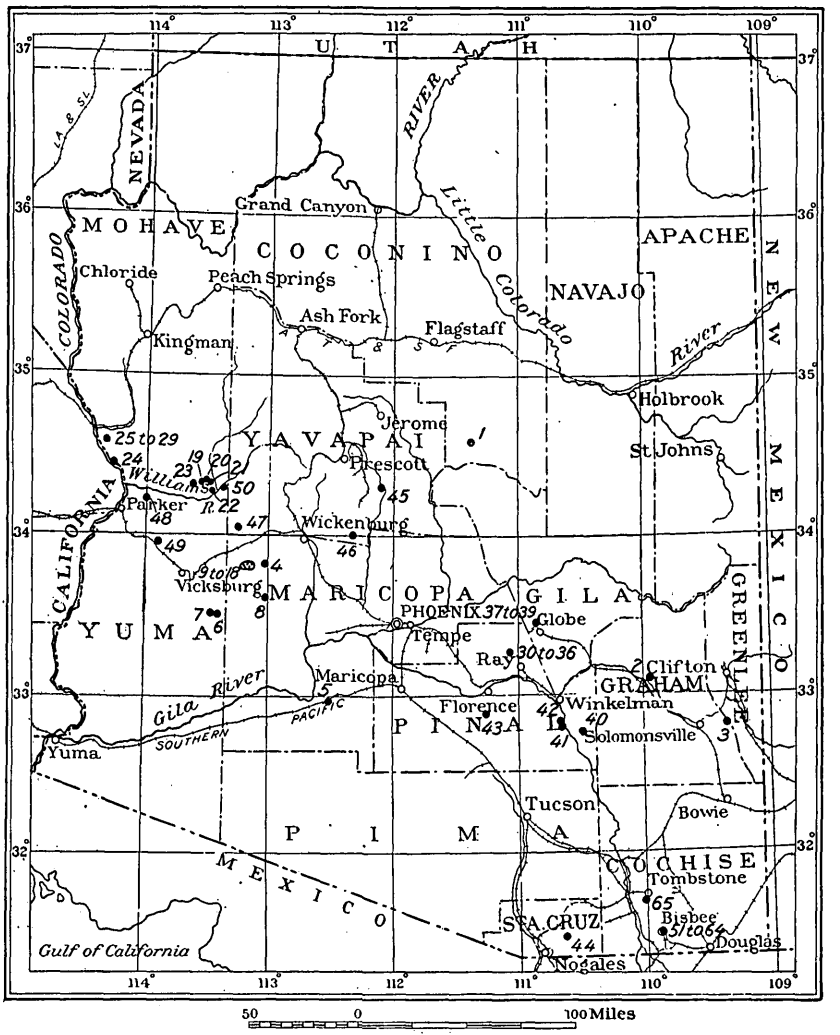


FIGURE 30.—Map of Arizona showing location of manganese deposits.

ECONOMIC FACTORS.

The factors that determine whether the manganese deposits in this region can be profitably worked are prices paid for manganese ores, accessibility to railroads, and transportation and mining costs. Some of the deposits are within a few miles of a railroad, but most of them are more than 15 miles distant, and one in Coconino County

is 56 miles from the railroad. No roads have been built to some of the deposits, and from a few of them the ore is packed on animals to the nearest roads.

The cost of transporting the ore to the railroad by wagon or auto-truck ranges from 35 to 50 cents per ton-mile. Most of the ore is shipped to furnaces in Illinois, Alabama, Tennessee, and Pennsylvania, and some has been shipped to California. The official freight rates, as authorized in August, 1917, from Arizona to Chicago and to points in Alabama and Tennessee are $9 per short ton, and to most smelters in Pennsylvania $10.50 per short ton. Mining costs as reported range from $6 to $20 per long ton. The deposits are mined by means of open cuts, shafts, and tunnels. Most of the drilling is done by hand. Wages are from $3.50 to $4.50 a day. Labor is scarce, and the work is done mostly by Mexicans. Water is available to most of the deposits in the mountainous region in the eastern part of the State, but it must be hauled to many of the camps in the desert, although several operators have obtained a small supply from wells near the deposits.

BISBEE AND TOMBSTONE DISTRICTS, COCHISE COUNTY.

By F. L. Ransome.

GENERAL FEATURES.

The Bisbee or Warren district is in southeastern Arizona, in Cochise County, immediately north of the Mexican boundary, and is traversed by the El Paso & Southwestern Railroad. It is noted as one of the oldest and most productive copper districts in the southwestern United States, and its geology has been fully described in previous reports of the United States Geological Survey and in more recent papers by geologists on the staffs of the principal copper companies operating in the district.[1]

Tombstone, also in Cochise County, lies about 25 miles north-northwest of Bisbee, with which it is connected by an excellent highway. It is the terminus of a branch of the El Paso & Southwestern Railroad which leaves the main line at Fairbank. About 35 years ago, in the late seventies and early eighties, Tombstone was the leading mining district in Arizona and was noted for its large output of rich silver ores. It continued to be highly productive up to 1886, when

[1] See especially Ransome, F. L., The geology and ore deposits of the Bisbee quadrangle, Ariz.: U. S. Geol. Survey Prof. Paper 21, 1904; U. S. Geol. Survey Geol. Atlas, Bisbee folio (No. 112), 1904, reprinted with a supplement in 1914. Notman, Arthur, The Copper Queen mines and works, Arizona, U. S. A., Part II, Geology of the Bisbee ore deposits: Inst. Min. and Met. Trans., vol. 22, pp. 550–562, 1913. Bonillas, Y. S., Tenney, J. B., and Feuchère, Léon, Geology of the Warren mining district: Am. Inst. Min. Eng. Trans., vol. 55, pp. 284–355, 1917.

the known ore bodies above the level of underground water became practically exhausted. For a number of years the district was almost deserted, but about 1902 an ambitious effort was made to lower the abundant water and to explore the district at greater depth. The attempt was costly and the results were disappointing. At present the silver ores are mined only on a small scale by lessees.

The geology and ore deposits of Tombstone have been described in reports by John A. Church[1] and W. P. Blake.[2] These reports, especially that by Church, present excellent accounts of the ore deposits, although at the time they wrote the general stratigraphy of the district was not well understood and a number of statements they made as to the stratigraphic sequence of the formations are now known to be incorrect.

In response to the demand for manganese ore during the war a number of manganiferous deposits not hitherto regarded as of value were exploited in both the Bisbee and Tombstone districts. The present paper is the result of a brief examination of these deposits in March, 1918.

TOPOGRAPHY.

The principal topographic feature of both districts is the Mule Mountains, a compact group of ridges and peaks that attains its greatest elevation, 7,400 feet, about 2½ miles west of Bisbee, and subsides northward to a group of rather low scattered hills near Tombstone. On the south it ends rather abruptly near the Mexican border. The total length of the range is about 30 miles and its greatest width about 12 miles. It lies between the valley of the San Pedro, a southern tributary of the Gila, on the west, and Sulphur Spring Valley, which is tributary to Yaqui River, on the east. Although Mule Mountains form a lower and less imposing mountain mass than the Huachuca Range, immediately west, and the Chiricahua Range, to the northeast, they rise abruptly from the widely sweeping valley plains and near Bisbee are fairly bold and rugged, standing in places nearly 3,000 feet above the adjacent desert lowlands.

GEOLOGY.

As the geology of the Bisbee district has been fully described elsewhere only a brief summary of its salient features need be given here.

[1] Church, J. A., The Tombstone, Arizona, mining district: Am. Inst. Min. Eng. Trans., vol. 33, pp. 3–37, 1903.

[2] Blake, W. P., The geology and veins of Tombstone, Ariz.: Am. Inst. Min. Eng. Trans., vol. 10, pp. 334–345, 1882; Tombstone and its mines, a report upon the past and present conditions of the mines of Tombstone, Cochise County, Ariz., to the Development Co. of America, New York, privately printed, 1902.

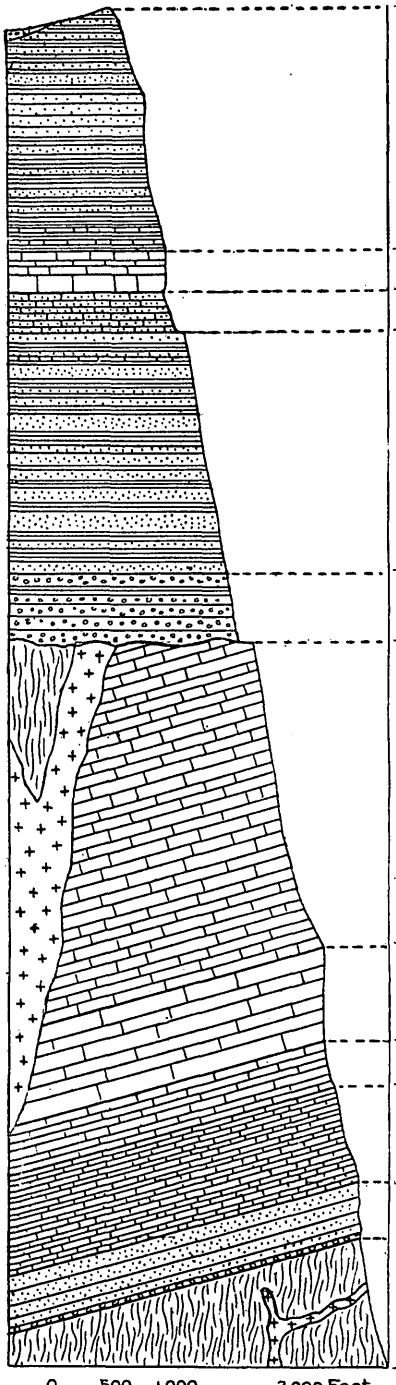
A generalized columnar section of the rocks is shown in Plate III and will aid in understanding the following description:

Resting unconformably on the Pinal schist and pre-Cambrian granitic rocks at Bisbee is the Bolsa quartzite, 430 feet thick, with a bed of conglomerate from 6 inches to a foot in thickness at its base. Most of the pebbles of this basal conglomerate are composed of white quartz and are less than 3 inches in diameter. The conglomerate is overlain, with no definite plane of division, by hard cross-bedded pebbly grits, the individual beds of which are from 10 to 20 feet thick, and above these lie thinner beds of finer-grained quartzite. The general color of the formation is rusty brown.

Conformably overlying the quartzite is the Abrigo limestone, 770 feet thick. This formation consists mainly of rather thin bedded limestones, in part sandy and dolomitic, with some shale. A laminated structure, due to the alternation of layers of gray limestone, generally 2 or 3 inches thick, with still thinner sheets of chert, is a conspicuous feature of the formation. These chert bands are prominent on weathered surfaces. The beds of the Abrigo are generally from 1 to 2 feet in thickness. Their prevailing color, as seen in large exposures, is dark greenish yellow. The upper limit of the Abrigo formation is defined in the Mount Martin section, near Bisbee, by a bed of pure-white quartzite about 8 feet thick. This quartzite is a persistent stratum and immediately underlies the Martin limestone, which carries Devonian fossils. The thickness of the quartzite, however, is variable, and in places it grades downward into the upper sandy limestones of the Abrigo formation.

The oldest marine fossils in this region are found in the Abrigo formation and include trilobites, linguloid brachiopods, pteropods, and other early forms. The fossils collected from this formation have been assigned by Dr. Charles D. Walcott to the Upper Cambrian.

In the Mount Martin section the Martin limestone, carrying a Devonian fauna, overlies the Abrigo in apparent conformity. Its average thickness at Bisbee is about 325 feet. The beds most characteristic of the Martin formation are dark-gray hard, compact limestones which are generally well provided with fossils. Small brachiopods of rounded outline (*Atrypa reticularis* and *Spirifer hungerfordi*) are particularly abundant in some of the beds and give to the weathered surfaces of the limestone a nodular appearance which in the Bisbee quadrangle is peculiar to the Martin formation. A few of the beds are rich in corals, some of which weather out as distinct and in places well-silicified fossils, while others produce rather ill defined white dendritic blotches in the dark limestone. Associated with the preponderant dark limestone here and there are beds of lighter hue and some calcareous shales of a decided pinkish



Red nodular shales with cross-bedded buff, tawny, and red sandstones. A few beds of impure limestone near base. Unconformably overlain by fluviatile Quaternary deposits.	Cintura formation, 1,800 feet plus unknown thickness removed by erosion.	Comanche series.	Cretaceous.
Thick-bedded hard gray fossiliferous limestone.	Mural limestone, 650 feet.		
Thin-bedded arenaceous fossiliferous limestones.			
Buff, tawny, and red sandstones and dark-red shales, with an occasional thin bed of impure limestone near top.	Morita formation, 1,800 feet.		
Bedded conglomerate with rather angular pebbles, chiefly schist and limestone. Rests on irregular surface produced by erosion.	Glance conglomerate, 25 to 500 feet.		
	Great unconformity		
Chiefly light-gray compact limestone in beds of moderate thickness. Contains abundant fossils. Cut by granite porphyry.	Naco limestone, 3,000 feet plus unknown thickness removed by pre-Cretaceous erosion.	Pennsylvanian series.	Carboniferous.
Thick-bedded white and light-gray limestone. Contains abundant crinoid stems. Cut by granite porphyry.	Escabrosa limestone, 700 feet.	Mississippian series.	
Dark-gray fossiliferous limestone in beds of moderate thickness. Cut by granite porphyry.	Martin limestone, 340 feet.		Devonian.
	Unconformity?		
Thin-bedded impure cherty limestones. Cut by granite porphyry.	Abrigo limestone, 770 feet.		Cambrian.
Moderately thick cross-bedded quartzites, with basal conglomerate. Cut by granite porphyry.	Bolsa quartzite, 430 feet.		
	Great unconformity		
Sericite schists. Cut by granite and granite porphyry.	Pinal schist.		Pre-Cambrian.

GENERALIZED COLUMNAR SECTION OF THE ROCKS OF THE BISBEE DISTRICT, ARIZ.

tint. These shales, which flake and crumble on exposure, belong in the lower half of the formation.

The upper limit of the Martin limestone is not everywhere sharply defined. In general it corresponds to the decided change from the dark compact limestones characteristic of this formation to the nearly white granular limestones, made up largely of crinoid stems, which characterize the Escabrosa formation.

Chemically, the typical dark limestone of the Martin formation is a fairly pure calcium carbonate, containing a little silica but practically no magnesia.

Overlying the Martin limestone at Bisbee is the Escabrosa limestone, made up generally of rather thick bedded, nearly white to dark-gray granular limestones, which on close examination are seen to be made up very largely of fragments of crinoid stems. Near the base the individual beds are commonly 10 or 15 feet in thickness, but above the lower 100 feet thicknesses of 1 to 5 feet are the rule, though there are a few more massive beds. The formation as a whole is a pure nonmagnesian limestone, containing practically no arenaceous sediments and only scattered irregular bunches and nodules of chert, usually in its upper part.

Fossils occur at many horizons from the bottom to the top of the formation, but, with the exception of small scattered corals and the abundant fragments of crinoid stems, they are rarely conspicuous and as a rule do not appear on weathered surfaces of the limestone. They probably represent the earlier half of Mississippian time, including the Kinderhook and Osage. In general appearance the Escabrosa formation is white or light gray, but some dark-gray beds occur, particularly near the top. The average thickness of the Escabrosa limestone is taken as 700 feet.

The Naco limestone, which overlies the Escabrosa conformably and with no distinct lithologic change, is made up chiefly of light-colored beds, which consist essentially of calcium carbonate. The beds range in thickness from a few inches to 10 feet but are as a rule thinner than those of the Escabrosa limestone. They differ from the Escabrosa also in texture, the typical Naco limestone being compact and nearly aphanitic, ringing under the hammer, and breaking with a splintery fracture, whereas the Escabrosa limestone is usually more granular and crystalline and crumbles more readily when struck. There are, however, exceptions to this rule, dense aphanitic beds occurring here and there in the Escabrosa formation and granular crinoidal beds being not uncommon in the Naco limestone.

Fossils, particularly brachiopods, are much more abundant in the Naco than in the Escabrosa limestone, and in some places they make up a considerable part of individual beds and weather out conspicuously upon exposed surfaces.

Although the greater part of the 3,000 feet or more of the Naco formation is made up of fairly pure gray limestone, certain thin beds of a faint-pink tint occur at different horizons and are in many places a useful means of distinguishing the Naco from the Escabrosa limestone. These pink rocks, which weathering usually shows to have an inherent lamellar or shaly structure, are very fine grained and compact. Chert is not uncommon in the Naco formation; it occurs as irregular bunches and nodules in beds of otherwise pure limestone or as the result of the silicification of thin fossiliferous beds throughout their thickness. It is also particularly abundant along and near zones of fissuring and faulting.

The fossils from the Naco limestone belong to two groups, one representing early and the other later Pennsylvanian time.

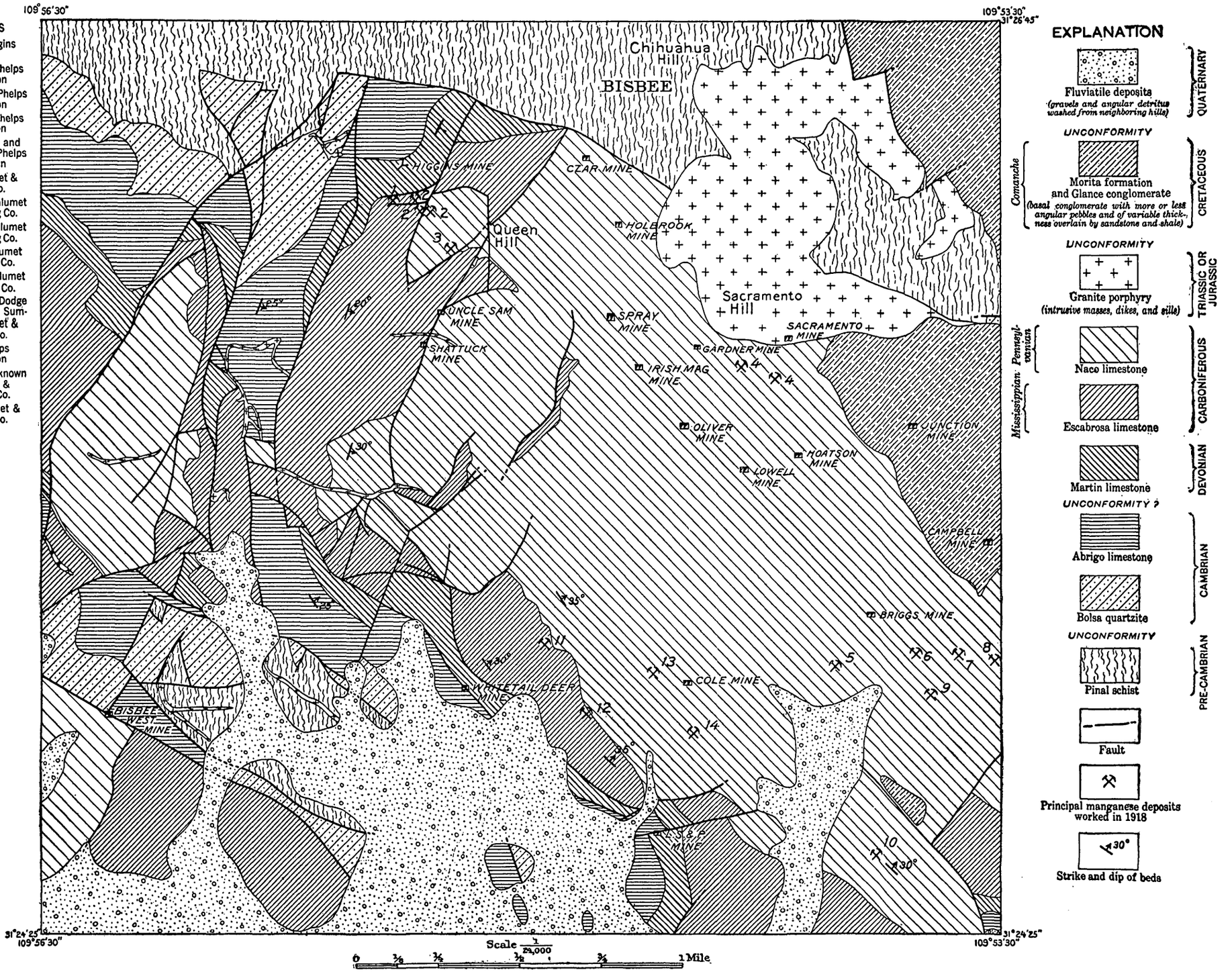
From the preceding descriptions it appears that Paleozoic time is represented in the Bisbee quadrangle by beds having a total thickness of a little over 5,000 feet. Of these the lower beds, 430 feet thick, are quartzites and the remaining 4,570 feet of beds are so predominantly calcareous that they may be collectively designated limestones. The Pennsylvanian series is represented by at least 3,000 feet of strata (the Naco limestone), but only 340 feet (the Martin limestone) can be assigned to the Devonian, and the Silurian and Ordovician appear to be wholly without stratigraphic representation.

All the rocks mentioned have been cut by dikes and more irregular masses of granite porphyry, of which the largest body exposed to view is that forming Sacramento Hill, in the southern outskirts of the town of Bisbee.

The pre-Cambrian and Paleozoic rocks, as well as the porphyry just mentioned, are overlain unconformably by a thick series of Lower Cretaceous beds belonging to the Comanche series. As these beds were deposited after the principal copper deposits were formed and carry only subordinate quantities of manganese ore in the basal formation of the series, the Glance conglomerate, they are sufficiently characterized for the purposes of the present article by the columnar section of Plate III.

The distribution of the rocks in the central part of the Bisbee quadrangle is shown in Plate IV, which is a small-scale generalized reproduction of a colored geologic map published in United States Geological Survey Folio 112 and Professional Paper 21.

The rocks are much faulted, and the structure is complex in detail. The controlling structural element, however, as regards the deposition of the copper ores is a synclinal block of Paleozoic beds south of the town of Bisbee. This block was faulted down in pre-Cretaceous time by the Dividend fault, so that the curved beds composing it dip toward and abut on the north-northeast against the pre-Cambrian Pinal schist and the porphyry of Sacramento Hill,



LIST OF CLAIMS

1. Twilight claim, Higgins Mining Co.
2. Hendricks claim, Phelps Dodge Corporation
3. Golden Gate claim, Phelps Dodge Corporation
4. Mammoth claim, Phelps Dodge Corporation
5. Hanchette Fraction and Danville claims, Phelps Dodge Corporation
6. Nellie claim, Calumet & Arizona Mining Co.
7. Cochise claim, Calumet & Arizona Mining Co.
8. New Era claim, Calumet & Arizona Mining Co.
9. Illinois claim, Calumet & Arizona Mining Co.
10. Waterloo claim, Calumet & Arizona Mining Co.
11. No. 4 claim, Phelps Dodge Corporation, and Summit claim, Calumet & Arizona Mining Co.
12. Boreas claim, Phelps Dodge Corporation
13. Crown King and Unknown claims, Calumet & Arizona Mining Co.
14. Atlas claim, Calumet & Arizona Mining Co.

EXPLANATION

- Fluviatile deposits (gravels and angular detritus washed from neighboring hills) — QUATERNARY
- UNCONFORMITY
- Morita formation and Glance conglomerate (basal conglomerate with more or less angular pebbles and of variable thickness overlain by sandstone and shale) — Comanche — CRETACEOUS
- UNCONFORMITY
- Granite porphyry (intrusive masses, dikes, and sills) — TRIASSIC OR JURASSIC
- Naco limestone — Pennsylvanian — CARBONIFEROUS
- Escabrosa limestone — Mississippian — CARBONIFEROUS
- Martin limestone — DEVONIAN
- UNCONFORMITY ?
- Abrigo limestone — CAMBRIAN
- Bolsa quartzite — CAMBRIAN
- UNCONFORMITY
- Pinal schist — PRE-CAMBRIAN
- Fault
- Principal manganese deposits worked in 1918
- Strike and dip of beds

GENERALIZED GEOLOGIC MAP OF THE CENTRAL PART OF THE BISBEE DISTRICT, ARIZ.

which was intruded into the fault zone. The syncline pitches southeast and passes under the Cretaceous beds, which occupy the eastern part of the district. The deposition of the copper ores closely followed the intrusion of the porphyry. The ore-depositing solutions penetrated fissures that extend from the porphyry southward and westward into the limestone, and the ores replaced parts of the limestones in the down-faulted synclinal block as irregular lenses and as large masses of less definite form. Some of these are closely associated with bodies of porphyry that do not appear at the surface. Most of the ore has been mined in the Martin limestone, although the Carboniferous and Cambrian limestones are also ore bearing, and during the last few years disseminated copper ore has been found in the porphyry of Sacramento Hill. The greater part of the enrichment that has affected the most productive ore bodies of the district is believed to have taken place during a period of erosion that immediately preceded the accumulation of the Cretaceous beds. The chief support to this conclusion comes from the great depth, at least 1,600 feet, to which oxidized ores extend in the Bisbee district, and from the fact that the increasing depth at which oxidized ores have been found as mining development pushed southward corresponds roughly to the tilt of the old pre-Cretaceous surface in the same direction. The depth to the general ground-water level at Bisbee when mining began was probably from 1,000 to 1,100 feet.

In the Tombstone district (Pl. V) the oldest pre-Cambrian rock is fine-grained schist into which is intruded a gneissoidal granite. These rocks occupy a rather small area in the vicinity of Ajax Hill, south of the area that contains the principal mines. The unconformably overlying Paleozoic beds closely resemble those at Bisbee. The Bolsa quartzite has about the same thickness and character in both districts. The Abrigo limestone is 70 feet thinner here than at Bisbee, and the bed of quartzite at its top also appears to be a little thinner than it is in the region to the south. The Martin limestone has a larger proportion of shale at Tombstone than at Bisbee, but it contains similar coral-bearing beds, and the fauna is the same as that of the Martin limestone at the type locality. The beds of the Martin at Tombstone maintain the same total thickness, 340 feet, as at Bisbee.

The Mississippian series (Escabrosa limestone) of the Carboniferous is approximately 500 feet thick at Tombstone, as against 700 feet at Bisbee, but owing to the lack of any plane of lithologic distinction between the Mississippian and the Pennsylvanian in this region these figures are not very reliable.

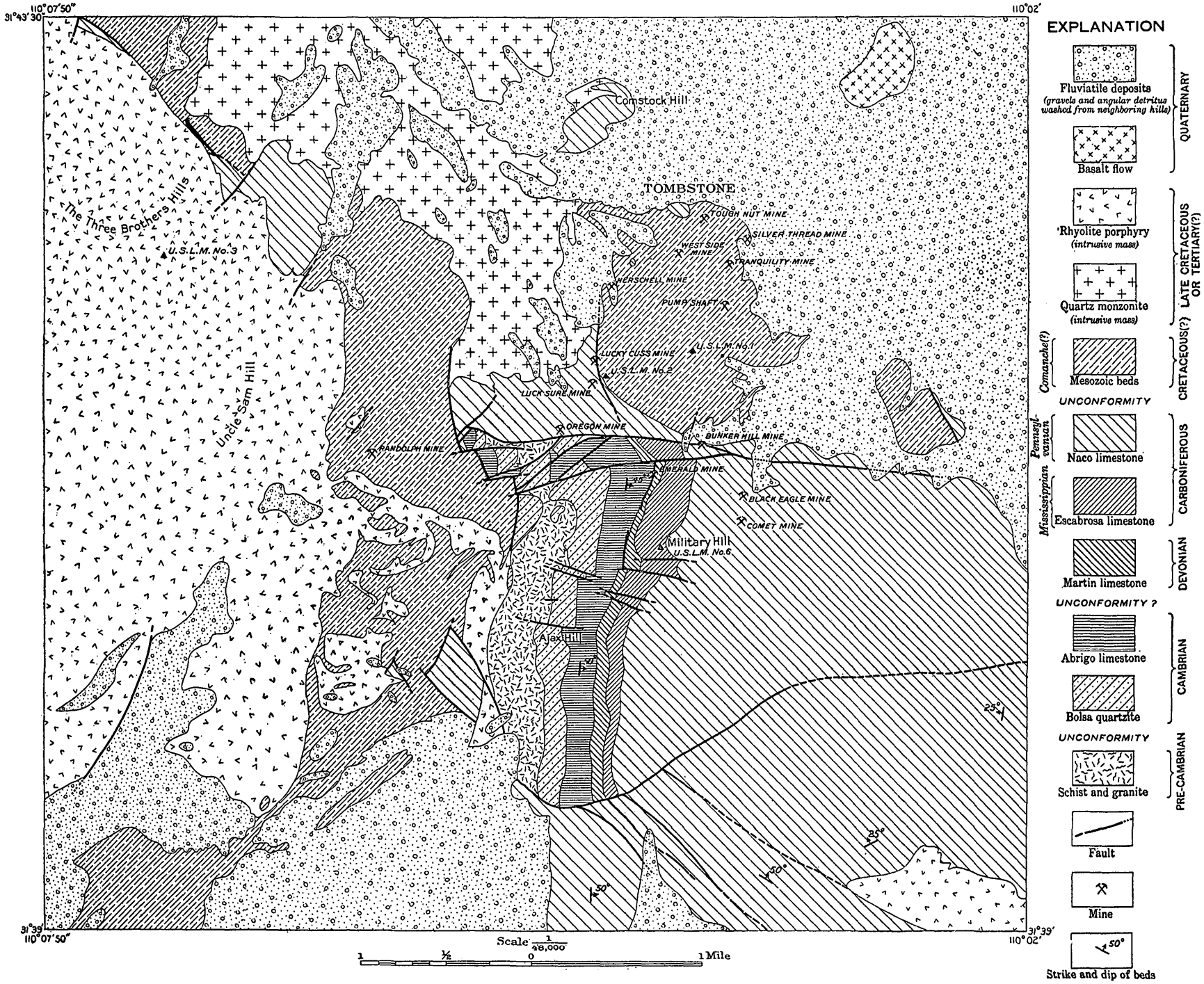
The Pennsylvanian (Naco limestone) is well represented at Tombstone and consists almost wholly of limestone.

Unconformably overlying the Naco limestone is a series of conglomerates, shales, quartzites, and thin limestones whose age has not been ascertained. These beds may possibly be the equivalent of the Comanche series of the Cretaceous at Bisbee, but they are decidedly different in lithologic and stratigraphic constitution. Certain beds of dark-bluish limestone within this group of strata are richly fossiliferous, but the fossils are poorly preserved and the paleontologists have as yet been unable to reach any more definite conclusion than that they are probably of Comanche age. These beds include the Herschell quartzite, white lime, blue lime, Contention shale series, and Randolph limestone of Church, although he supposed the last-named limestone to underlie the Bolsa quartzite (his "Ajax quartzite"). No name will be given to this assemblage of strata in the present report. They will be referred to merely as the Mesozoic beds.

Intrusive into all the sedimentary formations mentioned and undoubtedly also into the underlying pre-Cambrian is a body of granodiorite or quartz monzonite whose exposures cover an area of about 2 square miles west of Tombstone and extend for an unknown distance northward beyond the area shown in Plate V. Contacts show that this mass extends south and east under the sedimentary beds, and its exposed area would undoubtedly be much larger were the surface of the district lowered a few hundred feet by erosion. The intrusion of the monzonite rock was accompanied and followed by intense local metamorphism of the sedimentary rocks. A number of porphyry dikes in the sedimentary rocks are probably offshoots from the same irruptive mass.

The western part of the district is occupied by a large body of porphyry that is similar in chemical composition to the quartz monzonite but is more siliceous. This also is intrusive into the Paleozoic and Mesozoic sediments but is nowhere, so far as known, in contact with the quartz monzonite. It may be a differentiate from the same magma reservoir and owe its difference in texture to solidification under a thinner cover of superjacent rock than the monzonite porphyry.

The rocks of the Tombstone district, like those at Bisbee, have been intensely faulted, and only a brief outline of the geologic structure can be presented here. It will be seen from Plate V that the fault block south of Tombstone which is surmounted by Military and Ajax hills shows, from west to east, an ascending sequence of eastwardly dipping beds from the pre-Cambrian rocks to the Naco limestone of the Pennsylvanian series of the Carboniferous. With relation to this block all other parts of the district have been faulted down. Both to the north and south generally east-west faults or



PRELIMINARY GEOLOGIC MAP OF THE TOMBSTONE DISTRICT, ARIZ.

fault zones have brought the Naco limestone across the north-south belt of pre-Cambrian, Cambrian, Devonian, and lower Carboniferous (Mississippian) beds and have cut off their surface exposures. On the west of this block a complex, irregular zone of faulting, which apparently existed before the principal igneous intrusions, extends from the vicinity of Ajax Hill to and beyond the northwest corner of the area mapped in Plate V. The effect of this faulting has been to depress the Paleozoic formations west of the fault zone and to make the Mesozoic beds and the monzonitic porphyry the prevailing surface rocks in the southwestern part of the district.

By far the greater part of the silver ore that has been mined at Tombstone was taken from the Mesozoic beds, where it occurred partly in altered porphyry dikes, partly in large flat bodies that had replaced beds of limestone, and partly in fissures. The Mesozoic beds of the area just south of Tombstone are cut by a number of nearly north-south porphyry dikes and are sharply folded. The large replacement ore bodies were generally found along the anticlines in the vicinity of dikes or fissures.

BISBEE DISTRICT.

GENERAL CHARACTER AND DISTRIBUTION OF DEPOSITS.

Deposits of manganese ore, as indicated by black streaks or patches in the generally well-exposed Paleozoic limestones, are widely distributed over the southwestern part of the Bisbee quadrangle. Most of those deposits which have been opened to supply war needs lie, however, close to the towns of Bisbee and Warren, in the vicinity of the large copper mines. (See Pls. IV and VI.) The ore, principally psilomelane, occurs in irregular bodies, generally in close association with fissures in the Escabrosa and Naco limestones. Some deposits follow the fissures and are lodelike in form; others extend laterally from the fissures along certain beds of limestone that have been more susceptible than others to the process of replacement. Most of the deposits are superficial, few of them descending to a greater depth than 50 feet, and they are worked by open cuts and shallow shafts or inclines.

The largest and most productive deposit that had been opened in March, 1918, was that on the Twilight claim of the Higgins copper mine, about half a mile west-southwest from the center of Bisbee. Among the scattered bodies that were being worked by the Phelps Dodge Corporation in 1918 or from which this company or its lessees had recently taken ore may be mentioned that on the Golden Gate claim, half a mile southwest of Bisbee and 700 feet west-southwest of the summit of Queen Hill; two deposits on the

Mammoth claim, on a low spur just south of Sacramento Hill; a deposit on the Danville and Hanchette Fraction claims, about 1,000 feet south-southwest of the Briggs shaft; one on the No. 4 claim, about a quarter of a mile northeast of the Whitetail Deer mine; and one on the Boreas claim, about 2,000 feet east-southeast of the same mine. Small lots of ore had been taken also from a few other localities, and at the time of visit work was being started alongside of the railway near Lowell station, apparently on the Virginia claim.

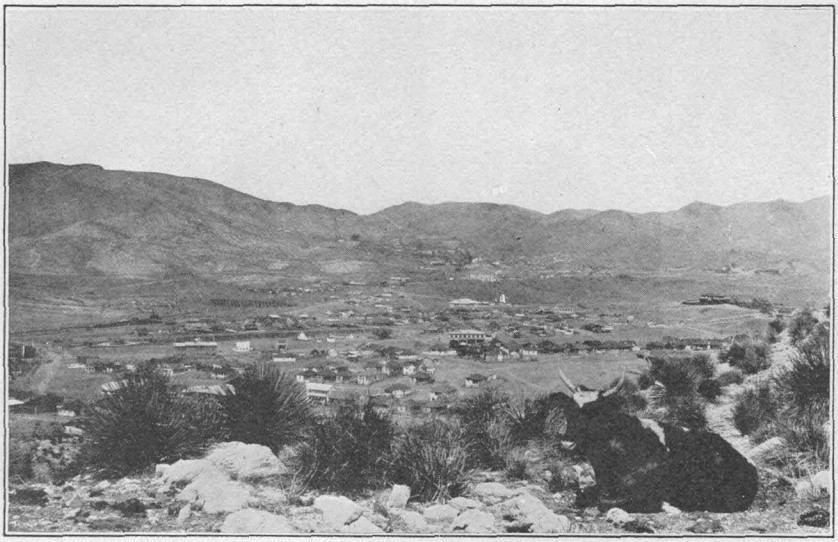
The Calumet & Arizona Mining Co. was also, in 1918, mining manganese ore at a number of places, especially on the limestone hill southeast of the Briggs shaft, on the Nellie, Cochise, New Era, Topgallant, St. Louis, and Illinois claims, where there were about six active openings. Ore had also been taken by this company from the Waterloo claim, on a hilltop three-quarters of a mile south of the Briggs shaft; from the Atlas or an adjacent claim, about 1,000 feet south of the Cole shaft; and from the Crown King and Unknown claims, just west of the Cole shaft. In all, this company has probably made from twenty to thirty openings in its search for manganese ore.

A small quantity of manganese ore was shipped in 1917 by the Shattuck-Arizona Copper Co. This was collected from several places on the company's ground, partly from small open cuts and partly from the 200-foot level of the main line. It required too much sorting, and the attempt to mine manganese ore was abandoned.

Small lots of manganese ore were shipped in 1917 or 1918 from a deposit on the south slope of Gold Hill, 5 miles southeast of Bisbee (and therefore outside of the area mapped in Pl. IV), on ground owned by the Houghton Development Co. and from shallow pits and trenches on the ground of the Marquette & Arizona Copper Co., about 9 miles southeast of Bisbee and a little more than a mile north of the Mexican line. The Marquette deposit is of special interest as occurring in the Glance conglomerate, the basal formation of the local Cretaceous.

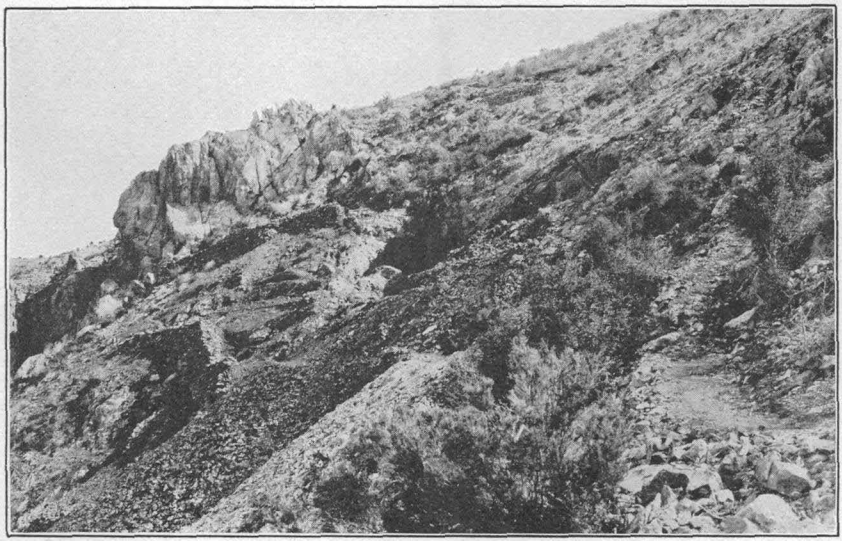
In addition to the deposits mentioned, all of which are apparently of superficial character, a body of manganese ore had been cut by the Calumet & Arizona Mining Co. in March, 1918, on the 1,300-foot level of the Junction shaft, about 800 feet northwest of the Briggs shaft. No shipments had been made from this body at the time of examination.

None of these deposits are far from the railroad, and most of them are probably within half a mile of it. Owing, however, to the situation of some and the comparatively temporary character of the operations on all, it has not proved practicable to build roads



A. GENERAL VIEW OF THE CENTRAL PART OF THE BISBEE DISTRICT, ARIZ., FROM THE SOUTHEAST, SHOWING THE CHARACTER OF THE LIMESTONE HILLS IN WHICH THE MANGANESE DEPOSITS OCCUR.

The town in the foreground is Warren. Sacramento Hill is the sharp-topped eminence outlined rather faintly against the hills in the middle distance. Bisbee lies in a canyon behind it.



B. OPEN-CUT WORKINGS ON THE TWILIGHT CLAIM OF THE HIGGINS MINING CO., BISBEE, ARIZ., FROM THE NORTHWEST.

All the rock in the view is Escabrosa limestone, and the prominent outcrop on the left shows some of the minor fissuring found in the vicinity of fault zones. Only a small part of the manganese pit can be seen in this view.

to them, and a considerable part of the ore is brought down to the nearest wagon road or railway siding on pack animals.

INDIVIDUAL DEPOSITS.

TWILIGHT CLAIM.

The deposit on the Twilight claim of the Higgins Mining Co. is half a mile west-southwest of the center of Bisbee, at about 6,100 feet above sea level, in the steep limestone bluff directly south of the buildings and main adit of the Higgins copper mine (Pl. VI, *B*). The bluff is composed of the Escabrosa limestone, here occupying its normal stratigraphic position above the Martin limestone, which crops out on the steep lower slope of the hill. The Escabrosa, however, is traversed by a zone of nearly east-west fissuring along which there has been some minor faulting followed by considerable silicification. In consequence of this silicification and of the deposition of the manganese ore along the fault zone, the limestone has resisted erosion and presents a rugged front to the lower country on the north.

Along the zone of fissuring manganese deposits extend for a distance of over 1,000 feet, partly within the boundaries of the Hendricks claim of the Phelps Dodge Corporation and partly within those of the Twilight claim. These ore bodies are irregular replacement masses whose longest dimension is not invariably parallel with the fissure zone as a whole. The individual ore bodies may follow subsidiary divergent fissures. The largest mass of ore mined on the Twilight claim, although very irregular, coincides with a series of nearly vertical fissures that strike as a whole about N. 60° W. This body appears to be about 200 feet long and as much as 30 feet wide and has been mined by open cuts to a depth of about 40 feet. It probably does not extend, with anything like these dimensions, for more than 10 to 20 feet below the floor of the principal open cut from which ore was being taken in 1918. The deposit has no definite walls but shows all gradations from solid black ore to gray limestone in which thousands of minute reticulating fractures are accentuated by the deposition of manganese oxide. Many of these fractures are so minute as to show no actual filling and yet by the deposition of manganese oxide within their walls they appear as dark feathery lines of appreciable width.

The best ore is hard, compact, nearly black psilomelane. In places the psilomelane contains small sheaves and irregular bunches of barite, with which are commonly associated aggregates of a bright yellow-green crystalline mineral which is being studied by Prof. Charles Palache, of Harvard University, and W. T. Schaller, of this

Survey. It is a copper-arsenic compound and is probably a new mineral species.

A soft black manganese mineral, probably pyrolusite, occurs sparingly.

The material mined probably contains about 30 per cent of manganese, but it is sorted for shipment so as to yield a product containing about 40 per cent. Screenings containing about 37 per cent of manganese are shipped as second-class ore.

The general composition of the ore is shown by the following 10 smelter analyses:

Smelter analyses of manganese ore from Twilight claim.

Mn	46.78	42.27	41.98	40.84	40.39	40.01	39.59	39.20	37.32	37.28
Fe	7.21	8.80	8.98	10.33	8.69	9.90	9.37	9.40	9.89	9.90
SiO_2	13.34	14.95	11.78	11.66	15.47	11.99	11.31	18.44	11.85	15.33
P	.047	.059	.022	.062	.043	.057	.061	.051	.043	.055

The smelters exact a penalty for silica in excess of 8 per cent.

The ore is carried on pack animals a short distance down to the Higgins mine and thence is hauled in motor trucks over a good road to the El Paso & Southwestern Railroad at Bisbee. At the beginning of March, 1918, there had been shipped from the Twilight claim 6,087 tons of ore from a total of fully 30,000 tons of material mined. The ore was consigned to the Miami Metals Co. and the Southeastern Iron Corporation, Chicago.

No close calculation of the quantity of ore remaining in the deposit could be made, but it was roughly estimated on March 4, 1918, at 10,000 tons of shipping ore.

HENDRICKS CLAIM.

The deposits on the Hendricks claim of the Copper Queen division of the Phelps Dodge Corporation are in part an eastward continuation of those on the Twilight claim and in part lie a little south of that zone of deposits, in the Naco and Escabrosa limestones. Comparatively little mining has been done on the Hendricks manganese deposits. The total shipments from several small openings amounted on March 1, 1918, to about 350 tons. About half of this ore was of good grade and went to the Tennessee Coal, Iron & Railway Co., Bessemer, Ala. The lower grade material was shipped to the Miami Metals Co. (Iroquois Iron Works), Chicago. The Hendricks ore contains a little copper and lead, according to Mr. David H. White, in charge of manganese mining for the Phelps Dodge Corporation, whose assistance in the investigation is here gratefully acknowledged.

GOLDEN GATE CLAIM.

The Golden Gate deposit is situated half a mile southwest of the center of Bisbee, on a spur of Escabrosa Ridge, just west of Queen Hill. It is an irregular lode along a fissure zone which strikes N. 80° W. and dips 80° N. The country rock is apparently Naco limestone, but the deposit is close to the rather indefinite boundary between the Naco and Escabrosa limestones, and may be partly in the Escabrosa. The average width of the lode is about 5 feet. The ore is chiefly psilomelane with some barite and occurs partly as the filling of fissures and partly as a replacement deposit after limestone. It has been mined by shallow open cuts from which about 300 tons has been extracted. The general character of the ore is shown by the following chemical analyses made in the laboratory of the Copper Queen division of the Phelps Dodge Corporation. As in nearly all analyses made in this laboratory, the manganese content is considerably lower than that given in smelter analyses of the same material. The SiO_2 is supposed to include any BaO present.

Analyses of manganese ore from Golden Gate claim.

Mn.....per cent..	38.0	39.3	S.....per cent..	Trace.	Trace5
SiO_2.....do....	21.1	19.6	Cu.....do....	1.65	2.1.
Al_2O_3.....do....	3.4	2.0	Au.....ounces per ton..	None.	None.
CaO.....do....	5.0	0.5	Ag.....do....	.32	Trace.
Fe.....do....	4.2	5.6			

The ore from the Golden Gate claim, from 800 to 900 tons, was carried by pack animals to the railroad near Bisbee, and most of it was shipped to Bessemer, Ala.

MAMMOTH CLAIM.

The deposits on the Mammoth claim are on a low spur that extends eastward from the Gardner shaft, just south of Sacramento Hill. They are irregular replacement bodies in fractured Naco limestone close to the contact with the altered porphyry of Sacramento Hill. In the porphyry are perhaps some included masses of altered Pinal schist.

Mining has been conducted at two places. At the northwesterly pit about 500 tons of ore had been obtained at the time of visit, and it was roughly estimated that about as much more was available. From 600 to 700 feet southeast of this pit another pit had been recently opened from which it was expected to obtain at least 1,500 tons of ore. The ore shows no definite walls and does not follow any persistent zone of fissuring.

The ore is psilomelane with nests of barite and small bunches of a green copper-arsenic mineral which is probably the same as that ob-

served in the Twilight ore. Occasionally a little chalcocite is found. The following analyses, made in the Phelps Dodge laboratory at Bisbee, exhibit the general character of the ore:

Analyses of manganese ore from Mammoth claims.

Mn.....per cent..	41.3	38.4	42.3	43.7	S.....per cent..	0.5	Trace.	0.5	Trace
SiO_2..... .do....	6.8	14.3	10.2	10.2	Cu.....do....	1.11	.5	1.05	1.6
Al_2O_3.....do....	3.1	2.9	2.8	2.0	Au...ounces per ton..	None.	Trace.	None.	None.
CaO.....do....	5.1	7.1	5.4	4.3	Ag.....do....	.18	.14	.12	.08
Fe.....do....	3.6	7.3	3.4	6.9					

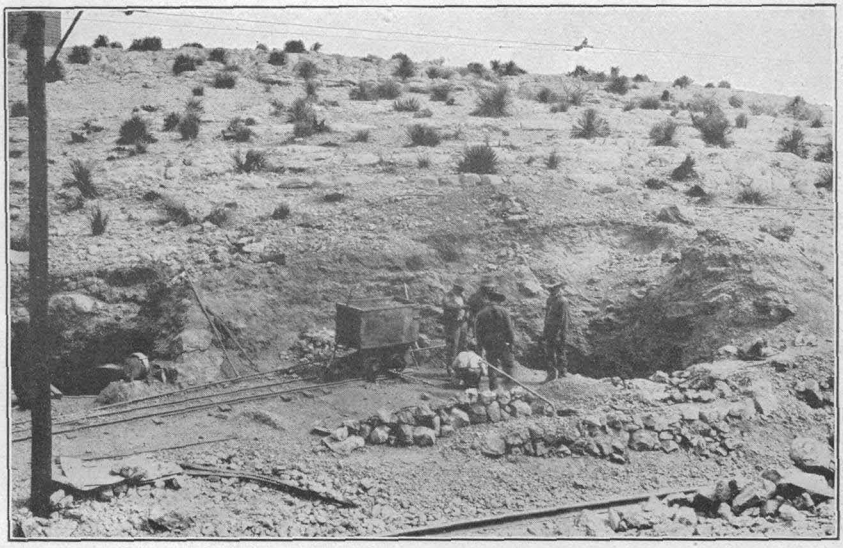
NEW ERA, COCHISE, TOPGALLANT, NELLIE, ILLINOIS, AND ST. LOUIS CLAIMS.

On the group of claims belonging to the Calumet & Arizona Mining Co., southeast of the Briggs shaft, the most active work in progress at the time of visit was apparently on the New Era claim, on both sides of the electric line between Bisbee and Lowell. These deposits are all in the Naco limestone, and most of them are closely associated with nearly north-south fissures. Whether these fissures are identical with the fissures of like direction with which the deep-lying copper ores of this part of the district are genetically connected is not known, but they at least belong to the same system. At the two places close to the car line where the most ore had been obtained these north-south fissures are crossed by some nearly east-west fissures, and the fracturing of the limestone in the vicinity of this intersection evidently furnished the conditions favorable for the deposition of ore. The workings on the east side of the track are shown in Plate VII, *A*. The limestone beds dip to the east, away from the observer, and the ore occurs mainly as a replacement of a single bed. It is variable in thickness up to a maximum of 4 feet. An inclined underhand stope had been carried down for about 25 feet from the surface at the time of visit. On the west side of the track the beds, as shown in Plate VII, *B*, are more nearly horizontal. In addition to the two openings shown in Plate VII there are probably within an area 200 yards square (40,000 square yards) half a dozen other smaller pits from which some ore had been taken.

About 700 feet west of these openings some good ore had been taken from an irregular replacement mass along a north-south fissure. Here a shaft 20 feet deep had been sunk and a drift run for about 35 feet to the south. The ore apparently was of low grade at this depth.

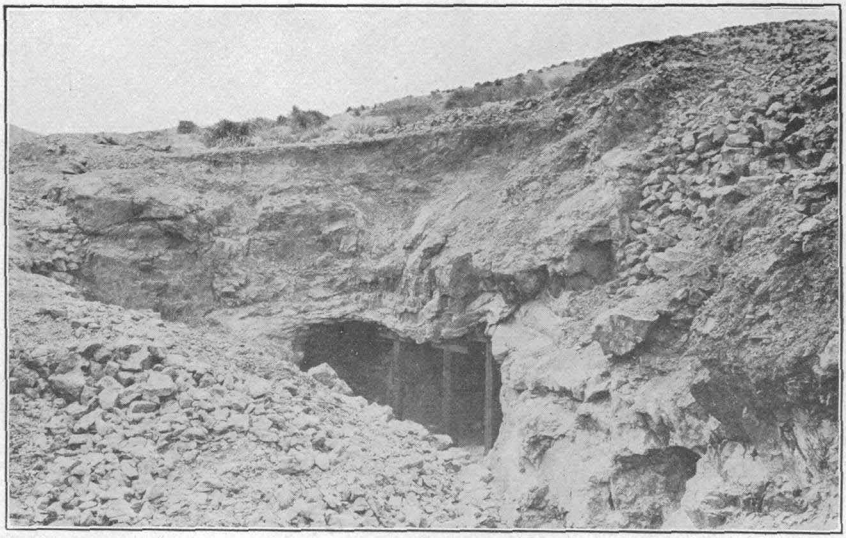
The ore from all the openings in this group is of the usual character—hard, compact psilomelane, which requires sorting to free it from limestone.

Smelter determinations on about twenty lots of sorted ore from this group of claims show from 40 to 54 per cent of manganese, and from 9 to 24 per cent of combined silica and alumina.



A. OPEN CUTS IN MANGANESE ORE ON THE EAST SIDE OF THE BISBEE-WARREN ELECTRIC LINE, OPENED BY THE CALUMET & ARIZONA MINING CO., BISBEE, ARIZ., LOOKING EAST.

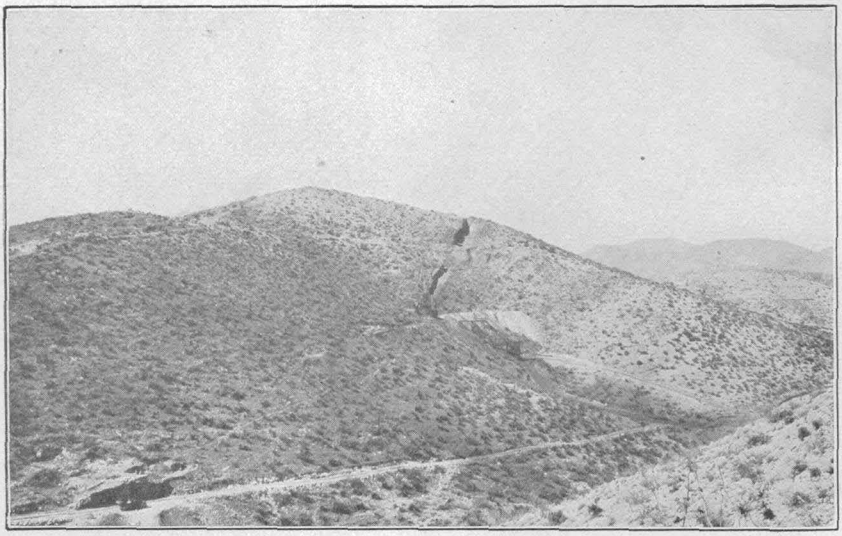
This view shows a characteristic exposure of Naco limestone beyond the cuts.



B. OPEN CUT IN MANGANESE ORE ON THE WEST SIDE OF THE BISBEE-WARREN ELECTRIC LINE, OPENED BY THE CALUMET & ARIZONA MINING CO., BISBEE, ARIZ., LOOKING SOUTHWEST.

This view shows how ore makes out in certain beds of the Naco limestone.

A. SHALLOW WORKINGS FOR MANGANESE ORE ON THE DANVILLE AND HANCHETTE FRACTION CLAIM OF THE PHELPS DODGE CORPORATION, SOUTHEAST OF BISBEE, ARIZ.



B. PROMPTER MINE, TOMBSTONE DISTRICT, ARIZ., FROM THE EAST.

The open cuts are on the Prompter fault fissure, which is crossed by the road just to the left of the view. The Oregon shaft is on the other side of the hill, west of these cuts. The rock in the foreground and on the slope to the right of the fault fissure is Naco limestone; that on the left of the fissure is chiefly Abrigo limestone with a little Bolsa quartzite on the top of the hill. The distant hills are rhyolite porphyry.

WATERLOO CLAIM.

The deposits on the Waterloo claim of the Calumet & Arizona Mining Co. crop out on a hilltop three-quarters of a mile south of the Briggs shaft and a quarter of a mile east of the main line of the Bisbee branch of the El Paso & Southwestern Railroad. Here three or four open cuts have been made along at least two nearly north-south fissures in the Naco limestone, and from these cuts 1,200 to 1,500 tons of ore has been shipped. The pits are all shallow.

Smelter determinations on twenty lots of Waterloo ore show a range from 34 to 53 per cent of manganese and from 8 to 18 per cent of silica and alumina. The earlier shipments in 1916 averaged about 50 per cent of manganese and 13 per cent of silica and alumina.

DANVILLE AND HANCHETTE FRACTION CLAIMS.

On the Danville and Hanchette Fraction claims of the Phelps Dodge Corporation the deposit, which is about 1,000 feet south-southwest of the Briggs shaft, consists of irregular replacement masses along a N. 10° W. zone of fissuring in the Naco limestone. Ore has been taken out from a number of shallow cuts and pits along a distance of about 500 feet. The principal and deepest excavation, which is close to the railway spur to the Cole mine, is shown in Plate VIII, *A*. This ore is of good grade. It consists of compact psilomelane and the principal impurities are residual inclusions of limestone and some vein calcite. Analyses also show as much as 2 per cent of copper. The total product at the time of visit was about 600 tons, most of which was shipped to Bessemer, Ala.

A few typical analyses of the Danville-Hanchette ore, made in the Copper Queen laboratory at Bisbee, are given below. The manganese determinations made at Bessemer, Ala., given for comparison, are generally higher than the Bisbee results.

Analyses of manganese ore from Danville-Hanchette claims.

Mn (Bessemer) ..... per cent..	49.2	49.7	47.5	49.4	46.4	47.9	47.5
Mn (Bisbee) ..... do....	42.3	43.8	38.9	45.0	36.3	41.4	45.6
SiO_2 ..... do....	10.2	8.4	6.9	7.4	8.4	6.6	7.6
Al_2O_3 ..... do....	1.4	1.3	1.8	1.3	1.9	1.8	1.7
CaO ..... do....	8.1	3.5	10.5	5.2	15.6	4.6	7.4
Fe ..... do....	2.8	2.1	3.2	3.4	3.8	2.7	2.5
S ..... do....	None.	None.	Trace.	Trace.	Trace.	Trace.	0.5
Cu ..... do....	2.09	1.93	1.90	1.72	.95	.44	1.62
Au ..... ounces per ton..	None.	None.	None.	None.	None.	None.	None.
Ag ..... do....	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	0.10

ATLAS CLAIM.[1]

The deposit on the Atlas claim of the Calumet & Arizona Mining Co. lies about 900 feet south of the Cole shaft and, like most of the other deposits in this part of the district, is on a north-south fissure zone in Naco limestone. It is similar in general character to the deposits on the Waterloo and Danville claims and like them has been worked by cuts or trenches along the fissure zone. About 800 tons had been shipped from the Atlas at the time of visit. The earlier shipments contained about 45 per cent of manganese with 14 to 20 per cent of silica and alumina. Later shipments were of lower grade.

CROWN KING AND UNKNOWN CLAIMS.

Along the east face of Escabrosa Ridge west of the Cole mine manganese ore has been mined at a number of places along a series of three or more fissure zones that strike a little east of north. This strike is almost coincident with the strike of the beds of Naco limestone, but the beds dip 25°–35° E., whereas the fissures are nearly vertical. From 600 to 700 tons of ore, ranging from 38 to 49 per cent of manganese and from 5 to 20 per cent of silica and alumina, had been mined by the Calumet & Arizona Co. from these fissure zones prior to March, 1918, but no work was in progress at the time of visit.

BOREAS CLAIM.

The deposits on the Boreas claim[2] are situated on the south end of Escabrosa Ridge, about 2,000 feet west-southwest of the Cole shaft. They are on one of the zones of fissuring just described as passing west of that shaft, but the psilomelane is very bunchy and is not everywhere closely associated with recognizable fissures. Some irregular replacement masses are in solid crystalline limestone, apparently the Escabrosa limestone. A little prospecting had been done on this claim, and some ore had been found at the time of visit, but, so far as known, no shipments had been made. A carload of "float" ore, supposed to have been derived from the Boreas claim, was gathered up on the Irish and Hygiene claims, south of the Boreas.

NO. 4 AND SUMMIT CLAIMS.

The deposit worked in 1918 by the Phelps Dodge Corporation on the No. 4 claim is on the southwest slope of Escabrosa Ridge, a

[1] Although the deposit here described is recorded by the Calumet & Arizona Mining Co. as being on the Atlas claim, it appears from a comparison of the topographic map of the district with a claim map to be in part at least on the W. M. A., Bay State, and John D., jr., claims, which adjoin the Atlas on the west.—F. L. R.

[2] The name is spelled Boras on some claim maps, and that may be the recorded designation.

quarter of a mile northeast of the Whitetail Deer mine. Here, at the time of visit, a cut had been made about 15 feet wide, 125 feet long, and 45 feet high at its face, which was then practically at the north boundary of the No. 4 claim. The deposit continues northward into the Summit claim of the Calumet & Arizona Mining Co. but had not then been worked by that company.

The ore occurs along a nearly north-south fissure zone, which here traverses the upper part of the Escabrosa limestone, and has replaced the limestone irregularly on both sides of the zone, as shown diagrammatically in figure 31.

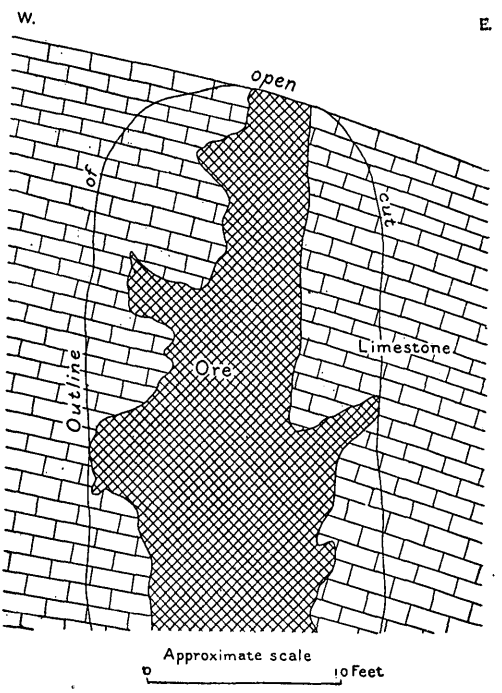


FIGURE 31.—Sketch showing general mode of occurrence of manganese ore on No. 4 claim, Bisbee district, Ariz.

The ore is psilomelane and requires less sorting than that from any other deposit worked by the Phelps Dodge Corporation. About 1,500 tons had been shipped early in March, 1918, and the deposit showed no indication of exhaustion. All but two carloads had been sent to Bessemer, Ala.

A few typical analyses of No. 4 ore, made in the Copper Queen laboratory at Bisbee, are given below, with the Bessemer determinations of the manganese contents for comparison.

Analyses of manganese ore from No. 4 claim.

Mn (Bessemer)	per cent	45.84	48.03	47.60	47.88	47.94	48.53
Mn (Bisbee)	do	42.0	43.8	42.3	43.8	42.4	40.5
SiO_2	do	16.0	14.8	17.8	14.6	15.6	14.6
Al_2O_3	do	.3	1.0	1.2	1.3	1.3	1.5
CaO	do	5.5	4.0	1.3	2.4	5.4	5.5
Fe	do	6.7	7.0	5.8	6.4	7.0	6.9
S	do	None.	Trace.	.5	.8	Trace.	.5
Cu	do	.38	.26	.71	.47	.75	.....

Most of the analyses show a little silver, the maximum half an ounce per ton.

GOLD HILL.

The deposit owned by the Houghton Development Co. on the south slope of Gold Hill has yielded 1 carload of ore. The psilomelane, associated with iron oxide, barite, and calcite, occurs in small irregular replacement masses in the Naco limestone in the vicinity of a northwest-southeast fissure.

The analysis of the single shipment of about 50 tons made in the Copper Queen laboratory, with the Bessemer determination of the manganese, is as follows:

Analysis of manganese ore from Gold Hill.

Mn (Bessemer)	per cent	47.65	CaO	per cent	5.0
Mn (Bisbee)	do	36.6	Fe	do	15.0
SiO_2	do	9.8	S	do	Trace.
Al_2O_3	do	1.0	Cu	do	.30

So much sorting was necessary to obtain ore of shipping grade that work was abandoned.

MARQUETTE GROUP.

On claims belonging to the Marquette & Arizona Copper Co., in the southeastern corner of the Bisbee quadrangle, manganese ore is rather widely distributed in the Cretaceous Glance conglomerate. The deposit on which most work has been done is a vein that strikes N. 23° E. and dips 80° W. At the time of visit it had been superficially trenched for a distance of 350 feet. This work exposed a vein of nearly pure psilomelane as much as 9 inches wide accompanied on both sides by conglomerate in which the finer interstitial material had been largely replaced by psilomelane. In places the ore, including the metallized conglomerate, was 4 feet wide. A shipment is reported to have been made, but at the time of visit work had been abandoned. The ore is evidently more siliceous than that in the limestone contains considerable disseminated pyrite, sphalerite, and it up to shipping grade.

In the vicinity of this vein, particularly west of it, for a distance of 500 feet or more, the Glance conglomerate contains small irregular bunches of psilomelane, and similar occurrences in the Glance conglomerate were reported south of the locality examined.

JUNCTION MINE.

The exceptional body of manganese ore in the Junction mine of the Calumet & Arizona Mining Co. was found on the 1,300-foot level, about 800 feet northwest of the Briggs shaft, in the Martin limestone, along a north-south fissure. It appeared to be from 12 to 15 feet thick and at least 40 feet long from north to south and to extend for 75 or 100 feet above the level. Not enough work had been done at that time, however, to determine the size and shape of the deposit, and no shipments had been made. East of the manganese the limestone contains considerable disseminated pyrite, sphalerite, and galena.

The ore is chiefly psilomelane but is more cavernous or spongy than most of the surface ores. Sixteen partial analyses, made in the laboratory of the Calumet & Arizona Mining Co., show from 35 to 53 per cent of manganese and from 6 to 34 per cent of silica. The average of these determinations is 49.8 per cent of manganese and 6.2 per cent of silica.

PRODUCTION.

In the early part of 1918 the Bisbee district was yielding from 1,500 to 1,600 tons of manganese ore a month. All of this was sorted shipping ore, but the amount of sorting necessary to obtain a 40 per cent product differed considerably at different workings.

The annual production of manganese ore in the Bisbee district to the end of 1918 was as follows:

Manganese ore produced at Bisbee, 1916–1918, in gross tons.

Year.	Over 35 per cent Mn.	10 to 35 per cent Mn.
1916	703	.....
1917	8,618	.....
1918	10,643	927
	19,964	927

TOMBSTONE DISTRICT.

GENERAL CHARACTER AND DISTRIBUTION OF DEPOSITS.

In the Comet, Bunker Hill, Lucky Cuss, Lucksure, and Oregon mines in the Tombstone district (see Pl. V) much of the oxidized

silver ore is highly manganiferous, and on this account, even when the silver content was too low to give them value purely as silver ores, they have been in demand as flux at the Douglas smelters. From these ores only silver, gold, lead, and copper have been extracted; the manganese, having served its purpose as flux, has been lost in the slag. There is no sharp line between such ores and those that have been mined for manganese. The chief source of manganese ore in the Tombstone district has been the Oregon mine, about 1½ miles southwest of Tombstone, operated by the Bunker Hill Mines Co., a subsidiary of the Phelps Dodge Corporation, although small quantities have been obtained from the Lucky Cuss and other mines.

The manganese ores of this district are chiefly psilomelane and occur in irregular pipelike masses or "chimneys" in limestone, distributed along zones of fissuring.

OREGON MINE.

The Oregon and Prompter workings, here described as one mine, are on the Prompter fault fissure, a branch of the strong east-west fault which passes north of Military Hill and has previously been referred to as one of the most conspicuous structural features of the district. In the vicinity of the mine the fault brings the Naco limestone on the north against the Abrigo limestone, Bolsa quartzite, and pre-Cambrian granite on the south. Deposits of manganese ore and of manganiferous silver ore occur at many places along this fault, mainly in the Naco limestone. Manganiferous silver ores chiefly have been mined in the Bunker Hill mine, and argentiferous manganese ores chiefly in the Oregon mine. The Prompter fault fissure (see Pl. VIII, *B*) dips 65°–70° S., and the fault is thus of the reverse type. The fissure is occupied for at least a part of its length by a decomposed porphyry dike.

The Prompter workings (Pl. VIII, *B*) constitute the eastern part of the Oregon mine. They consist of an inclined shaft on the fissure 300 feet deep, with two levels. On the upper or 160-foot level the main ore shoot is at least 300 feet long and as much as 18 feet wide. The bottom level had not been driven to the ore body at the time of visit. West of this ore shoot and also in the main fault zone is a shorter ore body which has been stoped in places to a width of 25 feet. These ore bodies are mainly replacement masses in the Naco limestone on the footwall side of the porphyry dike.

From a point near the collar of the Prompter incline a tunnel has been run through the hill, under the open cuts shown in Plate VIII, *B*, to the Oregon shaft, on the other side. This shaft is 300 feet deep and is vertical. It is not on the main fault fissure but on a close

fissure, known locally as the Oregon slip, which branches in a N. 60° W. direction from the Prompter fault fissure and is entirely in the Naco limestone. The Oregon slip dips 70°–85° NE., and as a rule is accompanied by no gouge or breccia. From the 300-foot level of the Oregon an inclined winze goes down on a body of ore to an additional depth of 300 feet.

The ore bodies in the Oregon workings occur as irregular, more or less tortuous pipes of rudely circular cross section. At least eight of these bodies are known. The average diameter appeared to be about 10 feet, and some of them have been mined from the surface to the level of underground water, which stands 630 feet below the collar of the shaft. They occur generally along lines of intersection of the Oregon slip with less conspicuous cross fissures. In the angle between the Oregon slip and the Prompter fault fissure there are at least two other fissures approximately parallel with the Oregon slip. Some small bodies of ore have been mined on these. All the Oregon ore bodies are mainly replacement deposits in the Naco limestone. They occur some on one side, some on the other side, and some on both sides of the Oregon slip. They have no definite walls save where they happen to be bounded on one side by a wall of the main fissure.

At the time of visit, early in March, 1918, the Oregon mine was yielding about 2,000 tons of ore a month. It had been in operation about two years and had produced about 50,000 tons in all. The material from the higher-grade bodies is sorted, and the hard lumps of comparatively pure psilomelane are shipped for the manufacture of ferromanganese. The residue from this sorting and the material from the lower-grade bodies is run over grizzlies, and the oversize lumps are again sorted. The rejected material from this sorting with the fines is sent through the concentrating mill near Tombstone. Here the material is concentrated about 8 to 1. The higher-grade concentrates, running from 70 to 85 per cent of MnO_2, are shipped as "chemical manganese," of which three grades are made. The lower-grade concentrates, generally running from 40 to 43 per cent of manganese, are shipped as furnace ore to steel works in Pennsylvania. The tailings and slimes are partly dried and are shipped to Douglas, Ariz., where they are used for their silver contents and fluxing value. Only such ore is mined as will give tailings that are sufficiently argentiferous to pay for shipment. In other words, the manganese ores of the Oregon mine could not be profitably exploited or even mined without loss if they were not argentiferous. In 1917 these ores contained, on an average, 7.78 ounces of silver to the ton.

No analyses of the "chemical manganese" concentrates were available at Tombstone. Below, however, are given a few typical analyses

of the lower-grade concentrates that were shipped as furnace ore in 1917:

Chemical analyses of concentrates shipped from Tombstone as furnace manganese ore.

[From records of the Bunker Hill Mines Co. Analyst unknown.]

Mn.....per cent..	−41.80	49.90	44.11	43.96	41.87
SiO_2.....do....	−14.61	4.84	9.82	71.16	9.48
P_2O_5.....do....	− .024	.014	.020	.028	.024
H_2O.....do....	−10.10	3.45	6.3	6.60	10.20

An analysis of manganiferous silver ore shipped from the Oregon mine to the Douglas smelter of the Phelps Dodge Corporation, presumably made at the smelter, shows the following composition:

Analysis of manganiferous silver ore from the Oregon mine.

Au.....ounces per ton..	0.013	CaO.....per cent..	10.1
Ag.....do....	21.10	SiO_2.....do....	20.0
Cu.....per cent..	.99	Al_2O_3.....do....	2.0
Fe.....do....	2.8	AgCl.....do....	.3
Mn.....do....	27.3		

PRODUCTION.

The production from Tombstone, exclusive of manganiferous silver ores which were used as flux and from which no manganese compounds were obtained, was as follows:

Manganese ore and concentrates produced at Tombstone, 1915–1918, in gross tons.

Year.	Over 35 per cent Mn.	10 to 35 per cent Mn.
1915	380	.....
1916	2,355	5,544
1917	3,776	.....
1918	843	37
	7,354	5,581

ORIGIN OF THE DEPOSITS.

The field investigation of the Bisbee and Tombstone manganese deposits was directed to immediate practical ends in connection with the estimation of the quantity of domestic manganese ores available under war conditions. The examination was brief, and the collection of data bearing on the origin of the deposits was incidental to the main purpose of the visit. Consequently the discussion of genesis that follows is suggestive rather than conclusive.

That the manganese deposits of the Bisbee district are in some way connected in their origin with the copper deposits appears probable from the fact that they occur most abundantly in the particular part of the district in which copper ores have been found. Many of them, moreover, are directly above deep-lying copper deposits and occur along fissure zones that, at greater depth, have influenced the deposition of copper ores. Most of them also contain a little copper. The manganese ores, however, are not directly connected with the bodies of copper ore and do not hold with respect to them the relation of gossan. They are, however, unquestionably supergene (formed from above) and accumulated during one or more periods of erosion and oxidation. No deposits of particularly manganiferous unoxidized material have been found in the course of the very extensive underground exploration of the district, and the unoxidized copper ores are apparently no more manganiferous than the inclosing limestones. No chemical analyses, however, have been made to determine this point. Many of the manganese ores, moreover, contain considerable barite, and barium minerals, so far as known, are absent from the unoxidized copper deposits.

Manganese ores have been deposited in the Bisbee district during at least two periods, as shown by the occurrence of boulders or fragments of psilomelane in the Glance conglomerate and by the presence within the conglomerate of deposits such as those on the Marquette group of claims, southeast of Bisbee. (See p. 112.) Most of the deposits in the Paleozoic limestones are believed to have accumulated during the extensive erosion that prepared the surface on which the Glance conglomerate was laid down. It would be very difficult to prove, however, that some of them or parts of them were not deposited during the erosion that stripped that conglomerate from portions of the district.

In a narrow sense they can not be classed as residual deposits—that is, they do not represent the residuum left, with more or less downward concentration, from preexisting bodies of unoxidized manganiferous material that occupied substantially their present positions. The manganese apparently has been transported by supergene waters and has been concentrated during the general process of erosion.

Under the microscope, in thin section, the psilomelane in limestone that has not been wholly replaced by it shows clearly that its deposition was conditioned by fissuring. It follows microscopic cracks and zones of crushing. The psilomelane is not, however, confined to the actual openings of these fissures but occurs on both sides of them in unfissured grains of calcite, as minute black specks, generally less than 0.01 millimeter in diameter, and as irregular aggregates of feathery or mosslike outline. In one thin section many of the black parti-

cles show angular outlines suggestive of cubic or octahedral form. No evidence was found, however, of the derivation of the manganese oxide from some other manganiferous mineral, such as the carbonate, rhodochrosite. There is nothing in the generally irregular outlines of the mineral to suggest that it is pseudomorphic, and the mode of occurrence indicates that if manganese oxide was not deposited directly from solution the mineral originally deposited must have changed rapidly to psilomelane while the process of deposition was still in operation.

If the deposits were not derived directly from the copper deposits and are not of hypogene origin—that is, deposited by ascending solutions from deep sources—what can be their genetic relation to the copper ores? Two points of connection are suggested. In the first place, it appears probable that the oxidation of the sulphides of the original copper deposits, particularly of the pyrite, supplied sulphate solutions and that the manganese, gathered partly from the limestones themselves and partly perhaps from earlier concentrations, was transported as manganese sulphate. As Dunnington[1] has shown, manganese sulphate in solution is not readily acted upon by limestone unless there is free access of air and might be carried for considerable distances through underground channels in a limestone country. In the presence of both air and calcium carbonate, however, the manganese is precipitated as oxide.

In the second place, the same set of fissures that at an earlier period provided channels for the movement of hypogene copper-bearing solutions probably continued to be planes of weakness in the rocks and to be penetrable to some extent by waters of superficial origin. They would thus be the places where manganese-bearing solutions would begin the replacement of limestone.

The association of the manganese ores with silver ores in the Tombstone district is much closer than that of the manganese ores with copper ores at Bisbee. In fact, as already pointed out, no real distinction is recognizable between the manganiferous silver ores and the argentiferous manganese ores. Moreover, their relations as regards position are more intimate, and in some places one kind of ore passes into the other. There is apparently some ground for regarding the manganese ores of Tombstone, in part at least, as the oxidized upper portions of silver deposits, from which some materials have been leached or abstracted and in which some of the manganese from formerly existent higher parts of the deposit has been concentrated.

Not all the Tombstone silver deposits are associated directly with manganese ores or with manganiferous silver ores, and few of the

[1] Dunnington, F. P., On the formation of deposits of oxides of manganese: Am. Jour. Sci., 3d ser., vol. 36, pp. 175–178, 1888.

unoxidized silver ores contain any recognizable manganiferous mineral. In the Lucky Cuss mine, however, one ore body was found which contained abundant albandite, the manganese sulphide. The oxidation of such a body would undoubtedly yield an argentiferous manganese ore.

The manganese ores of Tombstone are probably not entirely residual. Some of the manganese, as at Bisbee, has probably gone into solution as sulphate, has migrated into the adjacent limestone, and has been deposited in fissures and solution channels and by replacement of the limestone. A part of the manganese is believed to have been derived, as at Bisbee, from the Carboniferous limestones and not from bodies of silver ore.

ORE RESERVES.

The large number of the deposits in the Bisbee district, their irregular form, the lack of systematic development, and the methods of mining and handling the ore make any reliable estimate of available tonnage utterly impossible. In normal times it probably will not pay to work deposits of the character here described. Under necessity, however, or with unusually high prices for manganese ore, perhaps 50,000 tons of 40 per cent ore would be available. This estimate, which is admittedly rough, is believed to be more nearly a minimum than a maximum. Considerably more material might be obtained by concentration, but it is difficult to see how any profit could be made under ordinary conditions by concentrating the manganese ore.

In the Tombstone district there appears to be less manganese ore available than at Bisbee. It is doubtful whether the district could be relied upon to yield more than 5,000 to 10,000 tons of shipping ore and concentrates, in addition to what was produced to the end of 1918. In 1918 operations were said to be barely paying expenses, and under normal conditions the manganiferous ores of Tombstone can probably not be mined and treated profitably for their manganese contents.

COCONINO, GRAHAM, GREENLEE, MARICOPA, MOHAVE, PINAL, SANTA CRUZ, YAVAPAI, AND YUMA COUNTIES.

By E. L. Jones, Jr.

TYPES OF DEPOSITS.

The types of deposits of manganese ore that were noted in this investigation are veins and brecciated zones, bedded deposits, and irregular deposits associated with travertine. These types of deposits are contained in both igneous and sedimentary rocks which

range in age from pre-Cambrian to Quaternary. The igneous rocks are pre-Cambrian granite and gneiss; Tertiary rhyolite, andesite, and dacite; and Quaternary basalt. The sedimentary rocks are limestone and quartzite of Paleozoic age; sandstone of Tertiary age; and sandstone, conglomerate, sand, and gravel of probable Quaternary age.

VEINS AND BRECCIATED ZONES.

The veins and brecciated zones are contained in both igneous and sedimentary rocks, but they may be divided into two classes—those associated with silver-bearing minerals and those free from silver.

MANGANIFEROUS SILVER DEPOSITS.

Manganiferous silver deposits occur in the Hardshell mine, in the Patagonia district; in the Globe district; in the deposit owned by the Consolidated Holding & Trust Co., and perhaps in a few other deposits, in the Superior district, though assays of the ore were not available.

The deposit in the Hardshell mine occurs in a shear zone in Paleozoic quartzite and limestone and Tertiary rhyolite and felsite. The deposits of the Globe district occur in quartzite of Cambrian age and in diabase which intrudes the quartzite. The deposits in the Superior district occur both in fissures or shear zones in Paleozoic limestone and quartzite, and as replacement deposits along the bedding planes of limestone adjacent to the fissures.

The ore shoots vary greatly in size. In the Hardshell mine manganese ore occurs in a shear zone about 300 feet long and 30 feet wide, and the oxides are reported to extend to a vertical depth of 200 feet. In the Globe district the ore shoots are less than 200 feet long and about 3 feet wide, and the ore generally extends to depths less than 50 feet. Some of the low-grade deposits in the Superior district are several hundred feet long and a few feet wide and are known to be oxidized to a vertical depth of 400 feet, but the shoots of high-grade material do not extend far along the strike, although they have been found to a depth of more than 100 feet.

The manganese oxides of the silver-bearing deposits are psilomelane, pyrolusite, braunite, manganite, and wad. Psilomelane and braunite in complex intergrowth are the chief manganese oxides in the Hardshell mine, associated with pyrolusite, manganite, and wad. They form part of the gangue of silver-bearing lead minerals, principally cerusite, with some galena. Quartz is abundant, but the percentage of iron oxide is low. In the Globe district the manganese ores are soft and consist of an intimate mixture of manganese and iron oxides, in which scattered nests of manganite or pyrolusite

crystals occur. Braunite is the chief manganese oxide in several small ore shoots in the Consolidated Holding & Trust Co. group, in the Superior district. It is associated with cerusite (lead carbonate), vanadinite (the vanadate of lead), and wulfenite (the molybdate of lead). In other deposits in this district pyrolusite, wad, and psilomelane are the dominant manganese oxides.

NON SILVER-BEARING DEPOSITS.

Manganese deposits in veins and brecciated zones that are valuable for their manganese content only are widely scattered throughout the southern part of the State, and they include the largest number of deposits examined by the writer. They occur in igneous and sedimentary rocks ranging in age from pre-Cambrian to Quaternary, but most of them are in lava flows of Tertiary age. Among the deposits of this type are the Thurston & Hardy mine, in the Ash Peak district, Greenlee County; the Harper & Tarr mine and the Norton property, near Feldman; the Chamberlain deposit, south of Florence; numerous deposits in the Aguila district, near Bouse; the Arizona Manganese Co.'s mine on Colorado River, 40 miles north of Parker; and deposits in the Needles Mountains, southeast of Topock.

The ore shoots vary greatly in size, like those in the silver deposits. Some are veinlets less than 100 feet long, with a maximum width of 1 foot; others occur in persistent fissures as masses less than 100 feet long but 3 feet or more wide; and still others are contained in shear zones which have a maximum width of 40 feet. In these shear zones the manganese oxides are in ramifying veinlets which in places inclose and partly replace the rock fragments of the breccia. In the Aguila district some of the workable deposits of this type are about 50 feet long and 10 feet wide.

As the ore consists of the oxides derived from the weathering of the vein material, the depth to which it extends in the veins and brecciated zones is determined by the permeability of the deposits to circulating waters, which is, in part, dependent on the size and nature of the fractures. In a large simple fissure with well-defined walls oxidation generally extends deeper than in a number of small, nonpersistent fissures in a zone of fracturing. Manganese oxides are reported to extend to a depth of 100 feet in the Tarr & Harper vein, which is essentially a simple fracture in limestone and quartzite. In the Aguila district the principal work has been done on the Armour and U. S. groups, where the deposits are contained in shear zones in andesite, 50 feet long and 10 feet wide, and the ore extends to a maximum depth of 50 feet, though in other deposits exploited in the district the ore goes to depths of 10 feet only. Deposits

worked by the Arizona Manganese Co. near Colorado River north of Parker are veins and shear zones in basalt, and in most of them the ore extended to depths of less than 10 feet.

Psilomelane, pyrolusite, and manganite have been recognized in the veins and brecciated zones, and they occur in all the deposits. Psilomelane is most abundant at the outcrops and extends only to shallow depths in the deposits. In the Thurston & Hardy mine it has been found at a depth of 60 feet from the surface, but this is most exceptional. Psilomelane occurs in the common mammillary and botryoidal shapes and has been deposited in thin concentric layers on the walls of the veins or about fragments of wall rock as a nucleus. Commonly layers of pyrolusite or manganite are interlaminated with the psilomelane, and in some veins where it was deposited about small, closely spaced rock fragments the pattern is very intricate. The pattern is brought out in specimens that have been sawed and polished; the hard psilomelane stands out in steel-gray bands, while the soft pyrolusite gives a dull pitted surface, and manganite, though much softer than psilomelane, is in bright prismatic crystals. In the Flynn property, northwest of Bouse, manganite is well developed in intergrown bundles of needle-like crystals. Not only do the manganese oxides occupy the open fissures in the rocks, but they replace the associated rock. Thus in the Pittsburgh group of the Aguila district fragments of granite are replaced by manganese oxides, and in the Armour group fragments of andesite are also replaced. All gradations from partial to complete replacement of the rock fragments were noted, but in most of the specimens collected from brecciated zones rock fragments form the nuclei about which the manganese oxides were deposited.

The minerals that accompany the manganese oxides in the non silver-bearing veins and brecciated zones are calcite, iron oxides, and barite. Calcite is abundant and is universally present in veins and brecciated zones that are contained in Tertiary lava flows, but quartz does not occur except as it may be contained in wall rocks included in the vein or composing the breccia. The calcite is both of primary and secondary origin. The primary calcite is dark colored and contains microscopic filaments of manganese oxides. It is not definitely known from the specimens collected whether the manganese oxides resulted from the decomposition of some manganese carbonate in chemical combination with calcite, whether they were deposited from solutions contemporaneously with calcite, or whether they were introduced into the cleavage cracks of the calcite. The writer believes that in some of the deposits the manganese oxides were deposited contemporaneously with calcite by surface waters.

In most of the deposits in Tertiary lava flows the iron oxides are sparse and where they occur are usually separate from the manganese oxides. They are more abundant in basalt than in rhyolite and andesite.

Barite occurs abundantly in a vein that cuts sandstone on the Hatton claims, north of Aguila. It is associated with manganese oxides and calcite. In the Flynn deposit northwest of Bouse, barite occurs in flat, tabular crystals associated with manganite crystals. Barite was not observed in deposits in Tertiary lava flow.

BEDDED DEPOSITS.

Bedded deposits occur in the Needle Mountains, southeast of Topock; in the Artillery Mountains, north of Williams River; on Santa Maria River 6 miles from its junction with Big Sandy River; in the Superior district; and in Long Valley, Coconino County. The character of these deposits and the rocks with which they are associated are different in each locality. In the Topock district the replacement deposits are contained in tuff beds associated with Tertiary lavas. The deposits near the Artillery Mountains have been formed by the replacement of sandstone of late Tertiary or Quaternary age that is overlain by flows of Quaternary basalt. On Santa Maria River clays and loosely consolidated sands are partly replaced by manganese oxides. Many low-grade manganese deposits in the Superior district are due to the replacement of Paleozoic limestones along bedding planes adjacent to fissures.

The age of the bedded deposits in the Topock district and near Artillery Mountains is known to be Tertiary or later. The deposit on Santa Maria River occurs in bench-land sediments that are of Quaternary age. In the Superior district the manganiferous deposits are of the same age as the copper and lead-silver deposits, which are probably Tertiary. In Long Valley the deposits occur in Carboniferous limestone which has been eroded to a base-level and is overlain by Tertiary lava flows.

Only a few of the deposits that have been formed by replacement near the surface and are entirely isolated by erosion could be measured. The development work on these deposits is very superficial. In the Topock district a tuff bed 5 feet thick, mineralized with manganese oxides, crops out for several hundred feet, but its horizontal extent is known at one point only, where a tunnel 30 feet long was driven into it. At other places in the Topock district shallow holes dug through detrital material have disclosed a partial replacement of the underlying tuff by manganese oxides.

Bedded deposits on the south flanks of the Artillery Mountains are distributed over an area of several square miles. They replace strata

of sandstone, and those that are commercially valuable have been long exposed to weathering and now occupy the caps of low hills or are the topmost stratum of the rocks in basins or along the mesas. One deposit in a claim group located by W. J. Graham and his associates is exposed over an area approximately 1,000 feet long and from 50 to 400 feet wide. The stratum ranges from a few inches to 3 feet in thickness, with a probable average of 1 foot. Within 2 miles of this deposit are two other deposits, each of which replaces a sandstone stratum that is now the topmost member of a series of sandstone and clay beds. One of the deposits is exposed along the bank of an arroyo for 375 feet, and the other is similarly exposed for 600 feet. Each contains more than 7,000 tons of manganiferous ore, assays of which indicate an average content of about 25 per cent of manganese. In the bench land along Santa Maria River a manganese deposit is indicated by its outcrop for 1,200 feet. It has been formed by the partial replacement of a sandstone bed in a layer about 6 inches thick and includes also seams and nodules of manganese oxides in an underlying clay bed through a distance of 6 feet. There has been no development to determine how far back from the face of the bluff these oxides extend. The Superior district contains many low-grade manganiferous deposits that occur in the bedding planes of limestone. Some of the deposits are several feet wide and may be traced for several hundred feet along their strike, but the material is very siliceous, and no attempt has been made to mine it.

At Long Valley, in Coconino County, deposits of manganese ore are disclosed by a number of shallow shafts and open cuts which have been sunk through the alluvium. The horizontal extent of these deposits is not known.

The manganese minerals of the bedded deposits are the oxides psilomelane, pyrolusite, manganite, and subordinately braunite. Psilomelane occurs in all the deposits and is particularly abundant in the surface ore of the deposits near the Artillery Mountains, on Santa Maria River, and in Long Valley. In these deposits granular pyrolusite also occurs in the less weathered or exposed parts of the deposits, and in masses of mammillary and botryoidal ore from the Artillery Mountains manganese or pyrolusite in short crystals is deposited between layers of psilomelane. Wad and pyrolusite are the dominant oxides in the replacement deposits in tuff beds in the Topock district. In the Superior district the manganese oxides are generally mixed with iron oxides, but some small deposits of psilomelane, pyrolusite, and braunite are relatively pure.

The minerals associated with these deposits are largely the unreplaced minerals of the beds and those of secondary origin. In the tuff beds of the Topock district quartz and feldspar grains are found

in the ore together with secondary calcite. Near the Artillery Mountains manganese oxides have partly replaced and surrounded quartz and feldspar grains, and in some of the deposits secondary calcite is also abundant.

Iron oxides accompany the manganese oxides in the Superior district, together with secondary quartz and minor amounts of calcite. In a bedded deposit adjacent to a large fault on the Consolidated Holding & Trust Co.'s property cerusite, vanadinite, and wulfenite are associated with manganese oxides. At Long Valley iron oxides are associated with manganese oxides, and secondary calcite occurs in minor amounts. Much of the ore is siliceous, owing to the inclusion of fragments of sandstone and unreplaced sand grains.

DEPOSITS IN TRAVERTINE.

Manganese ore associated with travertine was noted at only one locality, about 12 miles southeast of Mayor, near the junction of Sycamore Creek with Agua Fria River. The manganese deposits occur about the brink of a bench which rises about 75 feet above the river. A thin basalt flow overlies the travertine and clay beds containing the manganese deposits. The ore occurs in seams and irregular masses in clay and sandstone, associated with chert and travertine. It does not crop out but has been disclosed at a number of places by open cuts and shallow holes to a maximum depth of 10 feet. The manganese oxides are principally botryoidal and vesicular psilomelane. With them a little secondary silica occurs, but iron oxides are noticeably absent.

MINES AND CLAIMS.

COCONINO COUNTY.

1.[1] *Black Diamond and adjacent claims.*—Manganese deposits occur about 1½ miles west of Clints Well, in Long Valley, Coconino County. They are included in the Verde quadrangle, mapped topographically by the United States Geological Survey, and are reported to be in the western part of T. 14 N., R. 10 E., the township survey of which was made recently. The manganese deposits are known to occur in an area 1½ miles long and a mile wide, and a number of claim groups and claims have been located over them. They are accessible by automobile from Flagstaff and were visited by the writer in June, 1918. In a direct line the deposits are 47 miles from Winslow, to the northeast, or from Flagstaff, to the northwest, both towns on the Atchison, Topeka & Santa Fe Railway, but the roads to them from Winslow and Flagstaff are 56 and 60 miles long, respectively.

[1] Numbers in black face refer to corresponding number on accompanying maps.

These roads are rocky and steep in places and are said to be almost impassable after heavy rains.

These deposits of manganese ore have long been known, for some old shafts and holes on them are at least 20 years old, and it was said that a small quantity of ore had been mined years ago and used as flux in a smelter on Verde River. Recently these old workings have been relocated, and claims have been staked over some of the adjacent ground. Development work was begun late in 1917 and continued to May, 1918, but at the time of visit no work was being done. No ore has been shipped from the claims, although there is 100 tons of ore on the dumps containing about 40 per cent of manganese. The cost of hauling the ore to the railroad is prohibitive at the present time.

The principal groups and claims on these deposits are the Black Diamond group of three claims, owned by Geo. W. Grimes, L. A. Hough, and J. J. Chiles, of Pine; the Star, Long Valley, and May Queen claims, owned by J. J. Chiles and L. A. Hough; and a group of three claims, owned by Charles Thurer.

The country surrounding the manganese deposits is a high plateau known as the Plateau of Arizona and locally as Mogollon Mesa. South of Flagstaff several mountains rise to altitudes of 8,500 feet above the sea level, but the general altitude of the plateau is about 7,000 feet and near the manganese deposits about 7,100 feet. The plateau south of Flagstaff is dissected by streams draining east to Little Colorado River and west to Verde River. In the upper parts of these streams the valleys are relatively broad and shallow and have low gradients, but within a few miles of their sources, particularly those draining westward, the streams erode deep, narrow canyons to a depth of 1,000 feet or more below the plateau. Long Valley, a tributary of Clear Creek, which flows to Verde River, lies about 100 feet below the general surface near the manganese deposits. It contains no permanent stream, but water stands in places along its course and the water level is only a few feet below the surface.

The climate of Mogollon Mesa is about the same as that of Flagstaff, where the average annual precipitation is about 24 inches and the mean annual temperature is 44.7°. The soil is residual and deep and owing to the abundant rainfall supports a heavy growth of merchantable timber, most of which is yellow pine. All the timber growth of the Plateau of Arizona is embraced in national forests, and much of the plateau south of Flagstaff is in the Coconino National Forest.

The Plateau of Arizona is underlain by a series of flat or gently dipping beds of sandstone and limestone of Carboniferous age. The Kaibab limestone is the topmost sedimentary rock over much of the plateau, and it contains the manganese deposits. No igneous

rocks were observed near the claims, but several miles farther north lava flows are the dominant rocks nearly to Flagstaff. Many of the mountains and hills that rise above the plateau are composed of these lava flows, which are of Tertiary age. The Kaibab limestone, where noted in a few exposures near the manganese deposits, is flat bedded. An inspection of the surface gives no evidence of faulting, but in the workings on a number of the deposits the ore is a breccia of limestone and sandstone fragments cemented by iron and manganese oxides. The prospects in which such breccia is found are nearly in alinement along a northeast-southwest course, and this indicates that they may be on a fault.

The deposits of manganese ore occur near the surface as replacement bodies in decomposed limestone and sandstone and in breccias of the same formations. The greatest developments are on the Black Diamond group, where there are ten or more shafts and open cuts recently worked, in addition to the old workings. The deepest shaft is 25 feet deep. On the Thurer group and the Star and Long Valley claims the developments consist only of shallow discovery holes. As shown in a number of shafts and open cuts the limestone and sandstone are decomposed several feet below the surface and stained in shades of yellow, red, brown, and black from iron and manganese oxides.

Manganese oxides occur in nodules and masses in the decomposed rock, replace the limestone and sandstone in varying degrees, and form the cementing substance of breccias. Nodules and masses of manganese oxides composed largely of psilomelane are scattered over the surface and are found in decomposed rock to a depth of a few feet. Some of the masses are 2 feet in diameter and weigh hundreds of pounds. The psilomelane has a peculiar structure; most of the specimens that were collected are vesicular and ropy in appearance but when broken open are found to be composed of columnar rods 1 or 2 inches long deposited in concentric crusts. Brown iron oxide has been deposited in the interstices of this ore.

Below the bunches and masses of the purer psilomelane ore found near the surface are masses of manganese and iron oxides which partly replace limestone and sandstone along the bedding planes. In some places the manganese and iron oxides are mixed, but generally the manganese oxides are in streaks and masses incased by iron oxides. In one deposit the ore appears to be a black granular homogeneous mass, but on close examination it is found to replace sandstone. Numerous small rounded quartz grains are embedded in psilomelane and pyrolusite which have replaced the cementing substance of the sandstone. In most of the workings the streaks and masses of ore in replacement deposits extend only a few feet from the surface.

The breccia consists of fragments of sandstone and chert cemented by manganese and iron oxides. Some of the rock fragments are very small, and in some specimens the matrix itself is granular and suggests sandstone largely replaced by oxides. Breccia was found in three of the workings which are in alinement in a northeasterly direction on the Black Diamond group; on the Star claim, a quarter of a mile northeast of the Black Diamond group; and on the Long Valley claim, 1½ miles N. 30° E. from the Black Diamond group. The depth to which the ore extends in the zone of brecciation has not been determined, but a shaft 25 feet deep is still in ore. Psilomelane and pyrolusite are the manganese oxides.

Except for a little calcite of secondary origin no minerals accompany the manganese and iron oxides.

The developments are insufficient to permit an estimate of ore reserves in the several claims, but on the dumps of the Black Diamond group there is about 100 tons of ore containing 40 per cent of manganese in addition to a large tonnage of lower-grade material.

The ore on the whole is siliceous, though a considerable quantity of psilomelane could be sorted from the dumps of the Black Diamond group, assays of which are reported to have yielded from 43 to 48 per cent of manganese, 3 per cent of iron, and 8 to 12 per cent of silica. According to J. M. McIver, of Oatman, Ariz., general samples from these dumps yielded 23 to 35 per cent of manganese, 3 to 7 per cent of iron, and 25 to 40 per cent of silica.

The source of the manganese oxides can not be established until more development work has been done on the deposits, particularly in the brecciated zones. Two hypotheses, however, seem plausible—(1) that the manganese oxides have been deposited in their present position as oxides from the solution of manganese minerals originally disseminated in overlying rocks that have since been eroded, and (2) that the oxides are residual from weathered manganese minerals originally deposited in a fault or brecciated zone, solutions from which permeated the adjacent sediments and replaced them. The evidence of the origin of these deposits, however, seems to favor residual origin rather than vein filling. No minerals were observed in the breccia other than the iron and manganese oxides and secondary calcite, and the fact that the oxides extend deeper in the brecciated zones than elsewhere is, of course, due to the more ready circulation of surface water in such zones. Some of the workings are more than 1,000 feet from the known zone of fracturing, and replacement by manganese oxides shows a decided decrease from the surface downward.

GRAHAM COUNTY.

2. *Voelckel claims.*—A deposit of manganese minerals 4½ miles northeast of Fort Thomas was located in 1914 by Louis Voelckel, of Fort Thomas. No output has been made from the property, and the amount of ore in the deposit as indicated by the development work is so small that further development is not warranted. However, as one of a type of deposits of geologic interest the deposit deserves mention.

A trail 4½ miles long is the most direct route from Fort Thomas to the deposit, but it is accessible by a wagon road 6 miles long, reported to be in poor condition. Transportation from the deposit to the railroad station at Fort Thomas would be impracticable in the spring, when Gila River is in flood and its sandy channel, a quarter of a mile wide near Fort Thomas, is impassable to vehicles.

The climate is arid, and the probable average yearly rainfall is less than 10 inches. Along Gila River are scattered groups of cottonwood trees and a general growth of mesquite, which also is found along the arroyos. The rocky hill slopes support several varieties of cactus and thorny shrubs, the most prominent being the giant cactus, which attains heights of 25 feet.

The deposit lies at an altitude of 3,800 feet above sea level, whereas the altitude of Fort Thomas is about 2,700 feet, approximately that of Gila River. Hills between the deposit and Fort Thomas are several hundred feet higher than the deposit. The region is drained by Gila River, in which there is flowing surface water at all seasons of the year; arroyos draining toward Gila River from its north side are dry except for springs in a few places where the arroyos cut through bench lands.

The trail from Fort Thomas northeastward to the deposit crosses the broad sandy channel of Gila River and then enters bench lands that extend from the north bank of the river northward for about a mile to some low hills. The bench lands attain an elevation of several hundred feet above the river. An arroyo has carved a canyon through the hills beyond the bench land and exposed an excellent section of eruptive rocks of Tertiary age composed of rhyolite, andesite, obsidian, and interbedded yellow tuffs. The lava flows in this canyon, which is 1½ miles long, are horizontal or gently inclined. Beyond the box canyon are the low-lying hills in which the manganese deposit occurs. These hills are likewise composed of lavas, but the lavas have been faulted and stand at steep angles. A red porphyritic andesite incloses the manganese veins.

The deposit consists of narrow and irregular veins that traverse sheared andesite in a northeasterly direction and narrow seams that

cement andesite breccia. The veins are short; the longest one can be traced only 30 feet, and it splits into branches which dip at low angles. A tunnel 30 feet long across the shear zone gains a depth of 20 feet, but manganese-bearing veins are exposed only near its portal.

The veins are composed mainly of calcite, with which the manganese oxides are associated generally as concentric crusts of psilomelane and short prismatic crystals of manganite. Some of the calcite is brown and is probably manganiferous, but most of it in the veins on the surface is white. The manganese oxides were probably derived from the decomposition of the brown calcite.

Assays of specimens of ore indicate a content of 18 to 20 per cent of manganese and as much as 6 per cent each of iron and silica. Calcite is abundant in the ore and may supply most of the remainder of its constituents.

GREENLEE COUNTY.

3. *Thurston & Hardy mine.*—A group of six manganese claims owned by R. V. Thurston and Joseph Hardy is in the Ash Peak district, Greenlee County, a short distance north of Ash Peak. The claims were visited May 16, 1918. The nearest shipping point is Sheldon, on the Arizona Eastern Railroad, 8 miles east of the deposit, and it is accessible by a good wagon road. Production from these deposits was begun in 1917, and to August 31, 1918, over 500 tons of ore containing more than 40 per cent of manganese had been shipped to smelters east of Mississippi River.

The deposits are in a moderately dissected area near the summit of the Peloncillo Mountains, at an altitude of 4,500 feet above sea level. The hill at the base of which lie the manganese deposits rises about 200 feet above them, and the higher peaks in the vicinity, one of which is Ash Peak, may reach 5,000 feet. Eastward the hills slope to Gila River, and westward the mountainous area gives way to a gently sloping detritus-filled valley. None of the gulches or arroyos that head in the Peloncillo Mountains contain flowing water except after heavy rains, and only a few springs are known in the range. The climate is arid, and the vegetation is very sparse, though the higher mountains support grasses sufficient for the subsistence of cattle.

The country rocks in the vicinity of the manganese deposits consist of Tertiary lava flows—a gray to brownish-red vesicular basalt overlain by white to pink rhyolite which forms the capping of the small hill above the manganese deposits. The basalt is much decomposed and contains a white mineral of secondary origin which fills the cavities and vesicles, and in the shear zones it is altered to a crumbly and clayey material from which the manganese oxides can be readily separated by washing.

The manganese deposits are contained in two shear zones about 1,200 feet apart, which cut the basalt and perhaps the rhyolite also, but no ore has been found in the rhyolite. The north shear zone trends N. 70° W. and dips steeply to the south. It has been traced for about 1,500 feet, and shallow, open cuts 1,200 feet apart show the character of its mineralization. Between these workings manganese float occurs sparsely, but the length of the ore shoots has not been determined. At the east end of this zone an open cut shows the sheared rock to cover a width of 30 feet, in which six principal stringers of manganese oxides as much as 3 inches wide are distributed. The open cut near the west end of the zone shows 10 feet of sheared basalt, with a few seams of manganese oxides, the largest of which is 6 inches wide.

The south shear zone, which has been the source of the manganese ore so far recovered, is explored by shafts and open cuts through a distance of 900 feet, but the ore shoots are not continuous for this distance. At the east end the zone strikes N. 55° W. and dips 70° NE.; at the west end it strikes N. 80° W. and dips 70° N. Two shafts 30 feet and 84 feet deep have been sunk on the east end of the shear zone, and in addition open cuts and drifts have explored the zone and proved it to be ore bearing for 200 feet. Here the shear zone is about 10 feet wide, and the ore is found in discontinuous or lenslike veinlets, which in places are 2 feet wide. At the west end of this shear zone there is a shaft 60 feet deep, and open cuts and drifts aggregating 200 feet. Here the ore is contained in a fairly distinct vein about 14 inches wide.

The manganese minerals consist of the oxides psilomelane and pyrolusite. Psilomelane predominates, and it occurs in the veinlets inclosed in soft altered basalt. Nodules of pyrolusite are found here and there in the shear zone, and from one pocket 7 tons of pyrolusite is said to have been mined and shipped for use as chemical ore. The manganese oxides are generally free from association with iron oxides, but at the west end of the shear zone limonite became so abundant that the mining of manganese ore was suspended there, because the grade of ore was lowered to the point where little or no profit could be made. Calcite is abundant, particularly in the west end of the south zone, where it makes up a large part of a vein of coarse crystals about 1 foot wide.

The maximum depth to which the manganese oxides extend has not been determined, although the ore was found in the bottom of the 80-foot shaft. Work in this shaft was suspended because the vein material could not be hoisted by hand from this depth and treated at a profit.

In mining these deposits a large amount of material must be handled. A partial separation of ore and waste is made on the mine

dumps, where the material is screened, and the larger chunks of ore and waste material are removed. The finer material is then hauled to a well a quarter of a mile distant, where three hand jigs have been set up and a further separation is made. Each jig consists merely of a 16-mesh screen about 2 by 4 feet, operated by hand power. The ore is thrown on the screen and on being worked or jigged in water the clayey substance is washed off, leaving the manganese concentrates. About 1,000 pounds of manganese concentrates per man per day can be produced in these jigs. The concentrates contain about 45 per cent of manganese, 2 per cent of iron, and 4 per cent of silica.

MARICOPA COUNTY.

4. *Manganese Nos. 1 and 2 claims.*—Two claims owned by J. C. Reed and Simon Rodriguez are on the northeast slope of Black Butte, about 20 miles in an air line S. 70° W. from Wickenburg. The deposit is best reached by the road that goes to the Vulture mine, southwest of Wickenburg. Westward from the Vulture mine a poorly defined road can be traversed within 2 miles of the deposit. The ore body is small and does not warrant any expenditure in road making. The claims were located in March, 1918. On May 27, when they were visited, no development work had been done on them except for a shallow discovery hole.

Black Butte is an isolated hill in a detrital plain. The deposit is at an altitude of 2,950 feet, about 600 feet below the summit of the butte and 700 feet above the surrounding plain. Several arroyos drain from the butte to the plain, but none of them contain water. The rainfall is very scanty, and the vegetation consists of desert shrubs and cactus.

Black Butte is composed entirely of volcanic rocks. Near its base and extending within a few hundred feet of the summit are thick-bedded white rhyolite tuffs and pink flow-banded rhyolite, some of which are glassy or felsitic. The rocks that overlie the rhyolite and extend to the summit are black basalt and probably some andesite.

The deposit consists of small seams of manganese oxides in a shear zone in rhyolite which strikes apparently N. 30° E. The seams are widely distributed through a distance of 20 feet, and they range from a fraction of an inch to 3 inches in width. They are not abundant enough to be profitably mined, and the mineralized zone has been traced only a few feet north and south from the discovery hole. The manganese oxides are soft black fine-grained crystals that are probably pyrolusite. They occur for the most part as fissure fillings, but they also replace the wall rocks and included fragments of tuff in the veins. No iron oxides were observed with the manganese oxides, but calcite is commonly found in the seams.

5. *Bosque group.*—The Bosque group of manganese claims, owned by T. H. Farley, is about a quarter of a mile south of the Southern Pacific Railroad, 12 miles east of Gila, the junction of a branch line running south to Ajo. The group comprises three claims, but manganese minerals have been found on one of them only. The developments consist of a few shallow holes, and no ore had been shipped to the time of visit, September 18, 1917. The deposits exposed at that time were small and discontinuous, and only a few tons of ore was in sight.

The climate is extremely arid, but the area supports a sparse growth of desert shrubs and cactus.

The deposit is on a small circular knoll about 50 feet high, at an altitude of 1,100 feet above sea level. The knoll is an outlier of the Maricopa Mountains, some of whose summits rise 1,000 feet or more above the detrital plains that flank them. Gila River, which flows around the south end of the Gila Bend Mountains, about 10 miles west of the deposit, is the only stream of the region. There are no wells in the vicinity of the deposit, and the depth to water level is not known.

A coarse-grained biotite granite composes the hill on which the manganese deposit lies, and it is apparently the dominant rock of the Maricopa Mountains. No sedimentary rocks were noted in the vicinity of the claims.

The deposit has been formed by the replacement of the granite along a poorly defined zone of fissuring. As exposed by open cuts the deposit is small. The replacement or impregnation of the granite by manganese oxides was irregular and incomplete, and the deposit is generally but a few inches wide. In one place, however, it is 20 inches wide in the center of a lens which tapers within a distance of 5 feet to a mere seam at each end. The granite is clearly replaced by the manganese solutions, for all gradations were observed from ore in which, though it is granular in texture, none of the original component minerals of the granite are apparent to ore which shows numerous crystals of feldspar, quartz, and biotite in a groundmass of manganese oxides. The replacement of the granite minerals apparently proceeded selectively, feldspars being attacked first, followed by biotite and quartz. In the process of replacement abundant secondary calcite was formed and it occurs in veinlets and bunches in the ore.

The manganese oxides are psilomelane, pyrolusite, and manganite, all intimately mixed. Psilomelane is the most abundant and occurs in small nodules in the ore. Manganite occurs as microscopic crystals in the interstices of psilomelane, associated with the soft amorphous pyrolusite. The material is hard, granular, and very siliceous for

the most part, because of the presence of the unreplaced minerals of the granite.

The origin of the manganese oxides is not apparent.

6. *Derby claims.*—Two claims owned by T. G. Derby and associates are about 32 miles southeast of Salome, in the Ellsworth mining district, Maricopa County. The deposit lies in a detrital plain sloping to the south about 2 miles east of Road Tanks. It is accessible from Salome, on the Atchison, Topeka, & Santa Fe Railway, by a fair road that goes by the Harquahala mine. The claims were located in May, 1918, a few weeks before they were visited by the writer, and very little development work had been done on them.

The deposit lies in a detrital plain at an altitude of 1,300 feet above sea level. Some low hills said to be outlines of the Eagle Tail Mountains rise above the plain about a mile north of the deposit. Shallow arroyos drain southward through the detrital plain, but none of them contain water except that which remains for a short time after heavy rains and that which collects in "tanks," or natural rock reservoirs. Two of these reservoirs, known as Road Tanks, worn in rhyolite bedrock, are said to be about 30 feet deep each, but they are now filled with sand. The rainfall is about 5 inches a year, and it supports only the typical desert vegetation of cactus, mesquite, greasewood, paloverde, ironwood, and a few other shrubs.

The low hills north of the deposit are composed of lava flows, principally rhyolite, and these flows appear in patches scattered about the detrital plain where they have become exposed by erosion. The deposit occurs in one of these patches 100 feet in diameter. Dense fine-grained banded rhyolite about 2 feet thick is stained with manganese oxides, with here and there some softer material, but an assay of selected material is said to have yielded only 28 per cent of manganese. There is but a small quantity of this low-grade material, and the chief interest in connection with the deposit lies in the association of manganese oxides with a siliceous phase of rhyolite.

7. *Howard claims.*—About 2 miles west of the Derby claims is a group of claims owned by W. W. Howard and associates. The deposit occurs in a small area of vesicular lava, which is surrounded and partly overlain by detrital material. It is exposed for 75 feet in an open cut, is about 6 inches thick, and dips about 10° N. The manganese oxides are small crystals of manganite in minute seams or crevices in black siliceous material, which is partly replaced by fine-grained amorphous manganese oxides. The siliceous material looks like chert, but it is probably a phase of the lava flow, and apparently the manganese oxides are closely associated with it. A few tons of this material has been mined from the open cut, and there is about 40 tons in sight. Selected material contains 30 per cent or more of manganese, but most of it is high in silica.

8. *Hatton claims.*—Two claims located by J. Hatton are in the Big Horn Mountains about 30 miles southeast of Aguila. They are accessible from Aguila or Wickenburg by a road that extends within 2 miles of the deposit. The claims are under lease to the Noble Electric Steel Co., of San Francisco, which in June, 1918, had a force of eight men engaged in the development of the deposit. No ore had been shipped at that time.

The deposit lies in some low hills at an altitude of 2,000 feet above sea level. The local relief is only a few hundred feet. Several arroyos drain to the detrital plain east of the Big Horn Mountains, but they contain no permanent water supply except that which accumulates in the natural rock reservoirs. One of these, known as Wood Chopper Tank, is about 5 miles east of the deposit. The rainfall is very light, and it supports only the desert shrubs and cactus common to the region.

The hills in the vicinity of the manganese deposit are composed of lava flows, and the rock which incloses the deposit is fine-grained rhyolite.

The manganese deposit occurs in a vein that strikes N. 20° E. and dips 75° W. It has been trenched for 300 feet along its strike and is shown to be about 2 feet wide. A shaft 14 feet deep at the time of visit was being sunk on the vein. Another vein 200 feet east of the shaft cuts the rhyolite, but it contains no ore. The vein material on the surface is composed of manganese and iron oxides with some secondary calcite. The manganese oxide, pyrolusite, is intimately mixed with the iron oxides. In the shaft the carbonate vein matter is much more abundant than in the surface ore, and it is evident that the oxidized ore will not extend much deeper. Selected samples of the surface ore are said by Mr. Schoonover, the superintendent of the property, to assay from 35 to 40 per cent of manganese, 10 per cent of iron, and less than 1 per cent of silica. The material from the shaft probably does not contain more than 25 per cent of manganese, and only a few hundred tons is indicated by the development work.

AGUILA DISTRICT.

GENERAL FEATURES.

Manganese deposits occur in the Aguila district at the north end of the Big Horn Mountains, in Maricopa County and in an outlying spur of the Harcuvar Mountains in Yavapai County, a few miles north of the Maricopa County line. The deposits in the Big Horn Mountains, extending east and west for several miles, are from 12 to 16 miles south of Aguila; that in Yavapai County is 9 miles north of Aguila. Some of these deposits were examined by the writer on

September 11 and 12, 1917, but after that time several other deposits were discovered, and the district was revisited in May, 1918. The deposits are readily accessible by wagon road to Aguila, the nearest shipping point on the Atchison, Topeka & Santa Fe Railway. Motor trucks are generally used in transporting the ore to the railroad, but owing to the softness of the road material, which allows "chuck holes" to form, the maintenance of the roads is a considerable expense.

In the Big Horn Mountains from east to west the deposits are the J. M. Meadows, Manganese Development Co., Wheeler, U. S. group, Giblin, Gallagher & Flynn, Sissons & Pegram, Armour, and Pittsburg claims. The deposit north of Aguila, known as the Hatton, was under lease to Woods, Huddart & Gunn, of San Francisco. It is specifically described on pages 180–181 under Yavapai County. The first shipment of manganese ore from the Aguila district was made by Genung & García in 1916, from the deposit now operated by the Manganese Development Co. In April, 1917, Jack Marden began shipments from the Armour group, but later in the same year this group was operated by the Noble Electric Steel Co., of San Francisco. Woods, Huddart & Gunn, the Manganese Development Co., and several lessees of other deposits produced ore in 1918. To May, 1918, about 2,500 tons of ore containing about 35 per cent of manganese, 2 per cent of iron, and 15 per cent of silica had been shipped from the Aguila district.

GEOGRAPHY.

The desert region west of Wickenburg, traversed by the Atchison, Topeka & Santa Fe Railway, consists of broad detrital plains above which rise isolated mountain ranges. Among these ranges are the Harcuvar, Harquahala, Big Horn, and Vulture mountains. The Harcuvar and Harquahala Mountains rise to heights of several thousand feet above the surrounding plains; the Big Horn Mountains have a relief of only a few hundred feet. Most of the manganese deposits in the Big Horn Mountains are at altitudes of 2,000 to 2,500 feet above sea level. West of Hassayampa River at Wickenburg there are no permanent streams along the railway route, but the mountains are drained by numerous arroyos and washes, which flow to the plains. Where the broad valleys become constricted between mountains, water may generally be obtained from wells at shallow depths. Near the manganese deposits in the Big Horn Mountains water is developed in a well on the Rogers ranch, and other though unreliable sources of water supply are the "tanks" or natural reservoirs worn in the bedrock in some of the arroyos.

The climate is arid, with a rainfall of only a few inches a year, and in consequence mining conditions are rendered unfavorable by

the lack of wood and water and the intense heat of the summer. Mesquite, greasewood, paloverde, and ironwood grow abundantly in the arroyos and valleys, and several varieties of cactus grow on the hills.

GEOLOGY.

This part of western Arizona has been examined by Bancroft,[1] and according to his descriptions the main masses of the Harcuvar and Harquahala mountains are composed of a granite, gneiss, and schist complex and metamorphosed sediments of pre-Cambrian age. Masses of granite of probable Mesozoic age also occur in the Harcuvar Mountains. The Big Horn Mountains are composed of pre-Cambrian granite, gneiss, and schist overlain by Tertiary lava flows, which in the northern part of the mountains are dominantly red biotite andesite. Most of the manganese deposits of the Big Horn Mountains are found in the lava flows, but on the Pittsburgh group and the Flynn & Gallagher property the veins occur in granite and schist. The deposit of the outlying spur of the Harcuvar Mountains north of Aguila is contained in red sandstone, in which there are in places scattered pebbles of granitic rocks. The sandstone covers only a small area, for a group of hills a short distance northwest of the deposit is composed of lava. The sandstone, which is probably of late Tertiary age, strikes northwest and dips southwest, and the beds disappear beneath detrital material.

ORE DEPOSITS.

The manganese deposits of the Aguila district are in veins and brecciated zones. Those in the Big Horn Mountains cut both andesite and the granite and schist, and the vein north of Aguila cuts sandstone. The veins and brecciated zones in the Big Horn Mountains were formed during two periods of fracturing. Most of the veins are of one period, and most of these strike nearly north, but a few strike N. 45° W. The veins of the other period strike nearly east, but they may vary either way by 20°. They are later than the northerly veins, some of which have been faulted 50 feet or more by easterly fissures. Some of the zones of northerly fissures can be traced for 2 miles or more, but rarely can a single fissure be traced for more than a few hundred feet, and the ore shoots of these fissures are even shorter. A few of the ore shoots are 100 feet long, but most of them are less than 50 feet; they range in width from 1 foot to 10 feet.

[1] Bancroft, Howland, Reconnaissance of the ore deposits in northern Yuma County, Ariz.: U. S. Geol. Survey Bull. 451, 1911.

The deposit north of Aguila is a well-defined fissure which strikes N. 60° W. and is vertical. The fissure has been traced for 400 feet, but the largest ore body in it is 50 feet long and 3 feet wide.

These deposits are developed by shafts, open cuts, and tunnels, but in no place is the development work extensive, and the greatest depth attained on any deposit is 50 feet. The development work is confined to the ore bodies, and in most of the deposits the oxidized ores extend to depths of less than 50 feet and as little as 10 feet.

The manganese oxides are manganite, psilomelane, and pyrolusite. In the brecciated zones in andesite and the older rocks the oxides are accompanied principally by calcite, but in the vein in sandstone, barite and calcite are associated with the manganese oxides. In the Big Horn Mountains the oxides are deposited in veinlets and in concentric layers about the fragmental material which has been more or less replaced by them. The andesite and granite fragments range from less than a quarter of an inch to 1 foot or more in diameter. The layers of manganese oxides consist of crystalline grains separated by bands of steel-gray oxides, which are harder than the crystalline material and give a brilliant polished surface. These hard bands are composed mainly of psilomelane, but they are not entirely homogeneous, for when these bands were etched with dilute hydrochloric acid microscopic layers of crystalline and amorphous oxides were revealed. Vugs in the ore are generally lined with prismatic crystals of manganite, from a sixteenth to a quarter of an inch long. The manganite crystals are striated at right angles to their longest axis. The crystals are arranged in closely compressed bundles, and no well-formed individual crystals were observed.

The ore is believed to have been derived from the decomposition of calcite containing manganese oxides. This is strongly suggested by the abundance of veinlets of secondary calcite throughout the ore, and the appearance of the ore from the deeper workings. At the bottom of a 30-foot shaft on the Armour group the ore is a soft amorphous dark-brown aggregate in which, in places, the crystal structure of the original carbonate is imperfectly preserved. On further weathering, as typified on the surface, this aggregate changes to crystalline manganite and hard psilomelane which are deposited in alternate crusts. It is not known, however, whether the calcite is a hypogene mineral of the veins or whether it was deposited in the fissures by meteoric waters.

MINES AND CLAIMS.

9. *J. M. Meadows group.*—The Meadows group of seven claims is at the northeast end of the Big Horn Mountains, at an altitude

of approximately 2,400 feet above sea level. The claims were located in 1916, but no ore has been shipped, and the development work consists only of a number of discovery shafts, each 10 feet deep.

The manganese deposits occur in some low hills composed of reddish biotite andesite with a little dacite. The deposits are found in a number of veins and brecciated zones that strike from N. 70° W. to due west and are vertical. Most of the veins are less than 1 foot wide, and the ore shoots are only a few feet long. The largest ore shoot observed on the surface is 25 feet long and 2 feet wide, but at a depth of 6 feet the deposit is only 6 inches wide. The manganese oxides are manganite and pyrolusite, deposited about fragments of country rock or as fissure fillings. Calcite generally accompanies the ore, but the manganese oxides are commonly free from admixture with iron oxides.

The deposit is capable of producing a few hundred tons of material from which, it is estimated, 100 tons of ore containing 40 per cent of manganese could be sorted.

10. *Manganese Development Co.*—The Manganese Development Co.'s claims lie west of the Meadows group and 16 miles southeast of Aguila. The deposit has been worked by several operators, and at the time of visit was operated by E. C. Lane and J. Genung. Several carloads of ore were shipped in 1917, and a car was being loaded in May, 1918. The claims lie across a north-south ridge composed of red biotite andesite. The summit of the ridge is about 200 feet above its base, at a point where the manganese deposits cross it. Two fissures that strike nearly due east and dip steeply south contain the manganese deposits. They can be traced for about 1,000 feet, and are limited on the west near the base of the ridge by a strong northward-trending fissure. Several ore shoots have been opened on these veins, the largest of which was mined for 125 feet on the strike of the vein to a maximum depth of 10 feet. The veins are narrow, showing a maximum width of 2 feet of solid ore. The material is hand sorted and screened to obtain a marketable product. The manganese oxides are manganite, pyrolusite, and psilomelane. Manganite occurs in short prismatic crystals deposited in layers locally intercalated with psilomelane about fragments of andesite. The andesite is in part replaced by the manganese oxides. Calcite is abundant in the ore, but very little iron oxide occurs. Shipments of ore are said to have assayed 46 per cent of manganese with low silica and iron.

11. *Wheeler claims.*—The Wheeler claims adjoin those of the Manganese Association on the south. A small quantity of ore was produced in 1917, but no work was being done at the time of visit. The deposit consists of a narrow east-west fissure which has been explored to a shallow depth for 40 feet along its strike, and prac-

tically all the ore has been removed. The geologic relations and the ore are similar to those at the deposit of the Manganese Development Co.

12. *Claude Fugatt claims.*—Two claims owned by Claude Fugatt lie about 1 mile S. 70° W. from the property of the Manganese Development Co., and a short distance south of an abandoned gold mine. The deposit occurs in some low hills at an altitude of 2,500 feet above sea level. The country rock is biotite andesite, which overlies the older granite and schist. A large shear zone that trends N. 20° W. contains the manganese deposits. It is from 200 to 500 feet wide, and in it small veins and breccias containing manganese oxides can be found for more than 1,000 feet along the strike of the zone. The development work consists of two 10-foot discovery holes. Apparently the veins are too small and too widely distributed to be mined profitably. Manganite and pyrolusite are the dominant manganese oxides, and associated with them are considerable limonite and calcite.

13. *U. S. group.*—The U. S. group of seven claims, owned by John Rogers, of Aguila, is in the north end of the Big Horn Mountains, about 15 miles S. 15° W. from Aguila. In 1918 the property was under lease to Woods, Huddart & Gunn, who shipped nine carloads of ore during the first quarter of the year, but work had been suspended at the time of visit in May, 1918. The country rock composing the small hills in which these claims lie is red biotite andesite. Four veins and brecciated zones from 1 foot to 6 feet wide have been found on the property, but only two of them have been prospected. They strike from north to N. 45° W. and dip east or west. The zone in which these veins occur is about 600 feet wide, and in it manganese-bearing fissures can be found for at least 2 miles south of the U. S. group. Two of the veins have been displaced to the west about 30 feet by east-west faults. Development work has been done on two of the veins only; from one vein ore was removed from a deposit 40 feet long and 20 feet deep, and on the other a shaft was sunk 50 feet. The lengths of the ore shoots have not been fully determined. It seems quite probable, however, that several thousand tons of ore containing 40 per cent of manganese could be won from the veins, but in order to obtain this grade of ore, sorting and screening of the vein material would be necessary. The dominant manganese oxides are manganite and pyrolusite. Calcite is very common in the ore, but iron oxides are generally absent. The depth to which the oxides extend has not been fully proved, but probably little ore will be found below 50 feet.

14. *Giblin claims.*—The Giblin claims lie about a mile south of the U. S. group, at an altitude of 2,400 feet above sea level. About 23 tons of ore was shipped from the deposit in 1917. No work was

being done in May, 1918, and there are no ore reserves on the property. The deposit is a brecciated zone in red andesite, which trends northwest. An open cut 40 feet long, 15 feet wide, and 6 feet deep marks the place from which the ore came. The ore is a black earthy oxide, pyrolusite, with a few crusts of hard psilomelane, associated with fragments of andesite and calcite veinlets.

15. *Gallagher & Flynn claims.*—Four claims owned by Gallagher & Flynn lie about a mile S. 20° E. from the end line of the U. S. group, and they evidently cover part of the same vein zone as that of the U. S. group. In 1918 about 70 tons of ore containing over 40 per cent of manganese was shipped from the property. When it was visited in May, 1918, lessees were mining a small quantity of ore. The claims lie in low hills composed of granite, though patches of the Tertiary lava flows are found here and there on the claims and completely overlie the granite a short distance to the north. The principal workings are at an altitude of about 2,400 feet, and the maximum relief is 200 feet. The known deposits on this group consist of three veins or brecciated zones. The two outer veins are 850 feet apart, strike from N. 5° E. to N. 10° W., and dip steeply west. Very little development work has been done, and the length of the ore shoots is not known, but the brecciated zones are about 10 feet wide. One vein is explored by two holes 20 feet apart, each 12 feet deep, and another vein by a shaft 30 feet deep sunk below an open cut. The veins or breccias are contained in granite and schist. Rarely the ore consists of manganese oxides as much as 6 inches wide, but most of it is in narrow seams of oxides that cement together and partly replace fragments of granite from 1 inch to 1 foot in diameter. The manganese oxides are manganite as stubby prismatic crystals, pyrolusite as a soft powder, and psilomelane in hard crusts showing concentric deposition with some intercalated narrow layers of manganite crystals. The maximum depth to which the manganese oxides extend has not been determined, but they are found in the bottom of the 30-foot shaft, and they probably extend 30 feet or more deeper, for the brecciated zone is wide and affords a good circulating medium for the meteoric waters to effect oxidation. Calcite accompanies the manganese oxides, but iron oxides are very scarce.

16. *Sisson & Pegram claims.*—A group of claims owned by Sisson & Pegram lies south of the Gallagher & Flynn group. No work has been done on them except for shallow discovery holes. Granite and fine-grained red andesite and dacite, which overlie the granite, are the rocks on these claims. The manganese deposit is contained in a vein that strikes N. 10° W. and dips 75° E. The vein can be traced for several hundred feet, but apparently the ore is restricted to small

shoots in it. At one place in the vein a breccia 10 feet wide has been uncovered, in which narrow seams of manganese oxides cement the rock fragments, and at another point on the vein 6 inches of manganese ore is exposed. The manganese oxides are manganite, pyrolusite, and psilomelane.

17. *Armour group.*—The Armour group of claims lies in the northwest end of the Big Horn Mountains, about 15 miles S. 15° W. from Aguila, at an altitude of approximately 2,100 feet above sea level. The claims have been leased to several operators. In April, 1917, Jack Marden shipped five carloads of ore; in August, 1917, the claims were leased to the Noble Electric Steel Co., of San Francisco, which shipped 26 carloads of ore. In May, 1918, the deposit was being worked by T. H. Rosenberger, of Los Angeles. The country rock is dominantly red biotite andesite, but a short distance south of the workings hornblende schist, gneiss, and granite are exposed. The deposit is a brecciated zone about 10 feet wide, which strikes north and dips steeply west. As shown by the workings the zone is about 800 feet long, but it does not lie in a continuous course, for a segment of the vein 200 feet long is displaced 70 feet to the east by two east-west faults. Several shafts have been sunk on the vein, the deepest of which is 50 feet deep, and ore has been removed from numerous open cuts. Although the zone is mineralized as far as exploited, the commercial bodies of ore occur in lenses to a maximum length of 50 feet. The manganese oxides are dominantly manganite and pyrolusite, but a little psilomelane occurs near the surface. Most of the ore is a breccia (fig. 32), and in order to obtain a product containing 32 per cent or more of manganese it is necessary to sort the ore by hand and screen it. The finer particles that go through the screen are retained; the coarser material, consisting of andesite fragments with adhering crusts of manganese oxides, is rejected. The process is very wasteful and makes only a small increase of manganese from that in the vein material. The concentrates assay from 32 to 40 per cent of manganese, and the reject screenings are said to assay 28 per cent of manganese. There is approximately 1,200 tons of

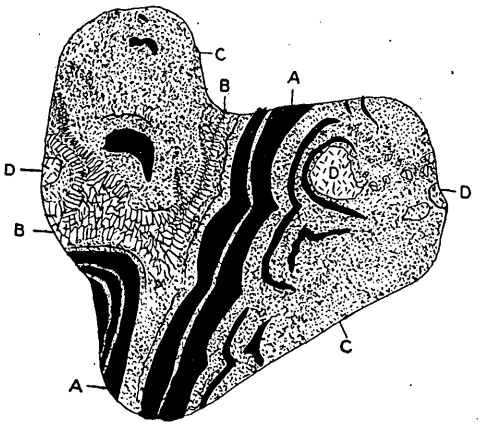


FIGURE 32.—Polished section of manganese ore from the Armour group, Aguila district, Maricopa County, Ariz. A, Psilomelane; B, manganite; C, finely crystalline pyrolusite; D, unreplaced andesite fragments.

reject screenings on the dumps, and the managers intend to install a Stebbins dry concentrator in an endeavor to concentrate this material. In addition, probably several thousand tons of ore remains in the deposit.

18. *Pittsburgh group.*—The Pittsburgh group of seven claims is about 2 miles south of the Armour group, from which a road must be made in order to market the ore. The claims lie in some low hills carved in granite and schists of pre-Cambrian age. The deposits are owned by Uhlik, Cuendet & Irish. They were discovered several years ago, but the development work is small and scattered. T. H. Rosenberger now has a lease on the claims. The manganese deposits consist of a number of veins and brecciated zones that vary widely in strike and dip. One vein strikes N. 20° W. and dips 60°–75° SW.; another strikes N. 50° W. and is vertical; another strikes east and dips 70° S.; and another strikes N. 50° W. and dips 40° NE. Some of these veins may be traced more or less continuously for 2,000 feet along their strike; the ore shoots, however, so far explored are not over 100 feet long. The material of the brecciated zones is composed of fragments of granite and schist a foot or more in maximum diameter, cemented together and partly replaced by manganese oxides. In places veins of solid ore are 6 inches or more wide, and such ore can be readily hand sorted from waste, but in most of the ore the seams of manganese oxides adhere tightly to the rock fragments, making it necessary to crush the ore. Psilomelane, pyrolusite, and manganite are the manganese oxides. Psilomelane is relatively more abundant than in other deposits in the Big Horn Mountains, and on one of the veins it has been found to a depth of 30 feet. Calcite, as a secondary mineral, generally accompanies the manganese oxides, but iron oxides occur only in a few of the ore shoots. It is impossible to estimate the quantity of ore from the little development work that has been done on the veins, but a minimum of several thousand tons of ore is indicated by the open cuts and shafts on the assumption that the ore extends to a depth of 25 feet.

MOHAVE COUNTY.

ARTILLERY PEAK AND WILLIAMS RIVER REGION.

GENERAL FEATURES.

Manganese deposits occur in Mohave County in the southern part of the Artillery Mountains, north of Williams River. In these mountains deposits of economic importance have been found in an area about 6 miles long and 2 miles wide, but slight mineralization by manganese solutions was noted over a much larger area, principally in the mesa that lies between the mountains and Williams River. The largest of these deposits is about 51 miles west of Con-

gress Junction, the nearest accessible railroad point. About 45 miles of this distance, between the crossing of Williams River at Alamo and Congress Junction, is traversed by a fair road with good grade, but between the river and most of the deposits several miles of road must be built in order to transport the ore. A reconnaissance was made of some of these deposits by the writer September 7, 1917, and this work was extended in May, 1918, by means of a traverse from Alamo to the known deposits in the area.

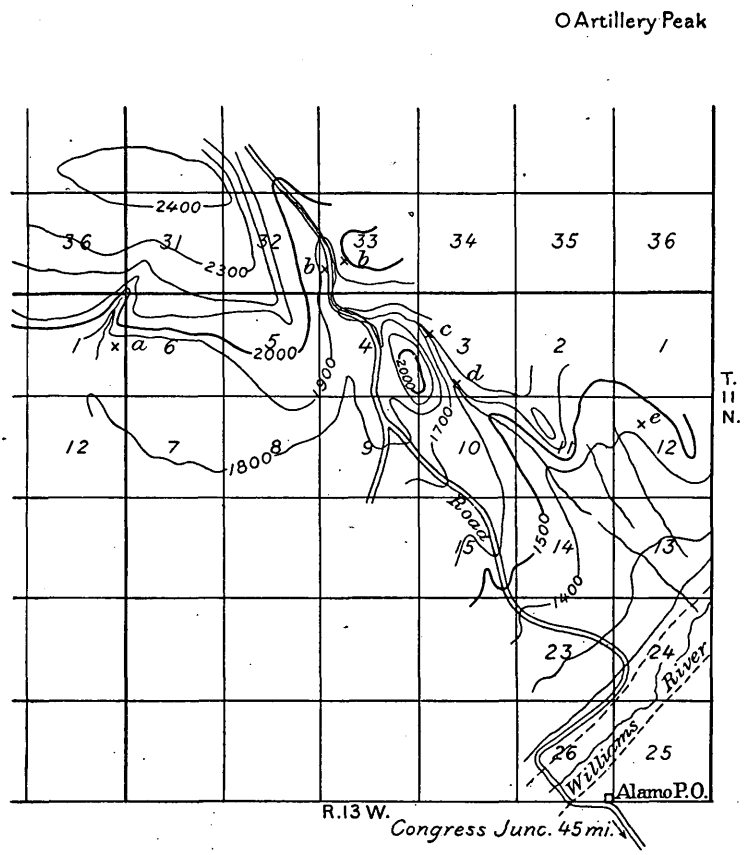


FIGURE 33.—Sketch topographic map of area near Artillery Peak, Mohave County, Ariz., showing location of manganese deposits.

The manganese deposits of this region were discovered many years ago, and they have been located from time to time, although little or no development work was done to make the locations valid. In view of the present value and importance of manganese ores several of the deposits are claimed by two or more locators. The recent locators of these deposits are W. J. Graham and associates, T. R. McComas, Jeremiah Shanahan, S. K. Barbee, and John Carr. The deposits are shown on the sketch map (fig. 33).

Up to May, 1918, no ore had been produced from any of these deposits, but at that time W. J. Graham and associates were repairing the road and establishing a camp preparatory to the shipment of ore.

GEOGRAPHY.

The main mass of the Artillery Mountains north of the deposits is greatly eroded and is marked by sharply defined peaks, the most prominent of which is Artillery Peak. The dissected mountain area is flanked on the southwest and south by lava-capped mesas that slope southwestward and merge into a detrital plain several miles wide extending to Williams River. The highest point of the mesa northwest of the Graham deposit is about 2,400 feet in altitude, and a barometric reading at Alamo, on Williams River, gave about 1,200 feet. The manganese deposits range in altitude from 1,500 to 2,000 feet. The lava-capped mesas and the detrital plain are cut by numerous arroyos that drain southward to Williams River. The local relief between the bottoms of the arroyos and the summit of the mesa may be as much as 400 feet, but in the detrital plain the channels are generally less than 100 feet deep. Williams River contains water throughout the year, though in places the flow is underground. None of the arroyos in the vicinity of the manganese deposits contain water except for a short time after rains. The average annual rainfall is probably less than 5 inches, and it is distributed mainly through the winter, but a part of it occurs in the midsummer. A few groves of cottonwood and abundant mesquite and paloverde grow along Williams River, but the mesa supports only shrubs and several varieties of cactus.

GEOLOGY.

No detailed geologic work has been done in the vicinity of the Artillery Mountains, but in 1903 W. T. Lee, in the course of a reconnaissance of a part of western Arizona, traveled through Signal Canyon of Big Sandy River, on the east side of these mountains. According to Lee the main rock mass of the Artillery Mountains is a coarse-grained granite, but Artillery Peak is composed of effusive rocks which extend to Signal Canyon. As shown by the present reconnaissance work the lava-capped mesas and the detrital plain are underlain by sandstone, clay, and conglomerate. The sandstone beds have been disturbed by folding, but the work was not sufficiently detailed to determine the structure. Dips as steep as 35° were observed, both to the northeast and southwest. The capping of the mesas is made up of basalt flows, which overlie conglomerate or sandstone beds. Some of the flows are over 100 feet thick, but others

are only 5 feet thick. The sandstone overlies the granite in the canyon near the Graham deposit, but in most of the area its lower contact is concealed. Its age has not been determined, but it is not earlier than Tertiary, and it may be Quaternary. The basalt flows that cap the mesas are believed to be of Quaternary age.

The sandstone has been considerably faulted and folded, and that the basalt also may have been faulted is strongly suggested by the abrupt termination of basalt against older granitic rocks and the tilting of the flows to the west.

ORE DEPOSITS.

The manganese ore deposits occur as replacement bodies in the sandstone and clay beds and as filling in fissures or brecciated zones that cut both the sandstone and the overlying basalt. The Graham, McComas, and Shanahan deposits replace sandstone, the Carr deposit is a brecciated zone in sandstone, and the Barbee deposit is a fissure filling in basalt. It is very probable that other deposits will be found in this region in similar rocks when search is made for them.

The manganese minerals of the replacement deposits and fissure veins are psilomelane, manganite, and pyrolusite. No carbonate or silicate manganese minerals were observed, although calcite occurs in fissure veins in basalt and in replacement deposits.

BEDDED DEPOSITS.

General character.—A thickness of several hundred feet of slightly indurated sandstone and clay is exposed below the basalt capping of the mesa. Massive beds of gray, red, and brown sandstone are intercalated with clay beds. In places the sandstone beds are 25 feet thick. The sandstone is replaced to various degrees by manganese oxides, and all gradations were observed from deposits containing a small percentage of manganese to deposits containing over 40 per cent. The richest of these deposits lie on the surface or are partly concealed by angular débris; the lower-grade deposits are those which have not long been exposed to weathering or are overlain by other beds. As shown by thin sections of specimens from several deposits, the cementing substance of the sandstone is first replaced by manganese oxides, then the feldspar grains or clayey substances, and last, the quartz grains. The ore is hard though granular. Some specimens show abundant subangular or rounded quartz grains embedded in a matrix of black psilomelane; in others the sand grains are apparently replaced completely by manganese oxides, but the specimens glisten from calcite, which has also been

deposited as crystals in vugs in the ore. The most weathered masses of ore are botryoidal and crusted forms composed mainly of psilomelane, but at shallow depths pyrolusite predominates. The botryoidal masses, however, are composed of concentric layers of psilomelane in alternation with short prismatic crystals of manganite. The outer layer is psilomelane.

A thin section from a specimen of low-grade ore on the Graham deposit was examined under the microscope. The sandstone is composed of quartz and feldspar grains, which occupy about one-half the volume of the section, and they are embedded in the manganese oxides. Quartz is the predominant mineral of the grains, but feldspars are also abundant, and they consist of orthoclase, microcline, and plagioclase. Some of the plagioclase grains have undergone decomposition to sericite and calcite, and in these grains manganese oxides have been deposited along cleavage cracks. Most of the grains are angular to subangular and prismatic, although a few are irregularly rounded. The continued angularity of the grains as they are diminished in volume by replacement must mean that the replacement proceeded largely along the cleavage and crystal planes. Calcite occurs interstitially in the grains, and numerous minute prisms of manganese oxides extend into the secondary calcite.

A specimen of ore in which to the eye the sandstone grains were wholly replaced but in which secondary calcite was abundant was examined in thin section. In the predominant groundmass of manganese oxides numerous fragments of quartz and feldspar grains are scattered, and they apparently compose about 25 per cent of the volume of the section. The fragments are angular or prismatic and show conclusively that the grains have been replaced along cleavage cracks. Secondary calcite occupies cavities in the section and fills small fissures extending through the ore.

19. *Graham claims.*—The manganese deposits under the control of Graham, Craig & Creighton, of Phoenix, are in the west-central part of sec. 33, T. 17 N., R. 13 W., about 6 miles northwest of Alamo, in an arroyo draining to Williams River. The deposits have been known for many years and located from time to time. In 1917 Graham and his associates acquired the rights to three claims of Carr, Rider & Bendervald, and in 1918 they had established a camp and were attempting to mine and ship the ore.

There are two deposits in the group; one lies on a small hill at an altitude of 2,100 feet, about 250 feet above the arroyo and a quarter of a mile east of it; the other deposit is cut by the arroyo, but the greater part extends west of it to the base of the mesa and is partly covered by basalt talus. Both deposits replace sandstone beds and are now completely exposed except for surface débris. The deposit on the small hill is exposed for about 250 feet on its strike,

with an average width of 50 feet, and is 3 feet thick. A block of ore has been faulted down for a few feet from the main mass, and indeed the whole deposit appears to lie along a major fault which brings schist and granitic rocks adjacent to the younger sandstone and basalt. East of the deposit and about 75 feet above it a breccia composed of fragments of quartzite and schist is stained and in places cemented by iron and manganese oxides. The rocks underlying this breccia are probably similar to those of the breccia, but east of the deposit occur the younger sandstones and lava flows. Red and brown, slightly indurated sandstones underlie the manganese bed and dip about 15° SW. This ore body is the highest-grade deposit of this type in the region, and it contains from 35 to 44 per cent of manganese with a probable average of 38 per cent. This deposit was estimated to contain about 3,500 tons of ore of this grade.

The deposit on the west side of the arroyo can be traced for 1,000 feet and is from 50 to 400 feet wide. It lies on the surface as a shell from 1 foot to 3 feet thick. Float ore is difficult to distinguish from fragments of the basalt talus which extends over part of the deposit. The ore contains about 25 per cent of manganese and is high in silica. About 20,000 tons of ore of this grade is in sight.

A short distance north of this deposit, on the west bank of the arroyo, is exposed a bed of sandstone that is slightly impregnated with manganese oxides but is thought to contain not more than 15 per cent of manganese. Analyses by the Southern Manganese Corporation, of Anniston, Ala., of three specimens of ore from the Graham deposit are given below. Nos. 1 and 2 are samples from the small hill and No. 3 from the deposit in the arroyo.

Analyses of manganese ore from Graham claims.

	1	2	3		1	2	3
Mn	44.45	43.13	27.78	Lime	1.20	0.00	14.61
Fe	1.00	1.40	1.60	MgO	.07	.72	.12
SiO_2	8.60	10.50	22.30	BaO	4.07	3.41	4.27
Al_2O_3	2.97	4.70	4.78	P	.05	.05	.03

20. *McComas claims.*—The deposit located by T. R. McComas is in sec. 3, T. 11 N., R. 13 W., about 1½ miles southeast of the Graham deposit, and it is dissected by the same arroyo. It is about 1½ miles from the road. The manganese-bearing bed, from 2 to 6 feet thick, is the topmost layer of a series of red sandstone and shale which strike N. 20° W. and dip 25° SW. The ore body is exposed for 375 feet, but on the west side of the arroyo it is covered with detritus a few feet back from its outcrop, and the depth to which the ore extends is not known. There is some high-grade ore in the form of psilomelane float, but the deposit as a whole contains about 25 per

cent of manganese. The ore is identical with that of the larger deposit of the Graham claims. The deposit is estimated to contain about 7,500 tons of ore.

21. *Shanahan claims.*—The manganese deposit located by J. Shanahan is also in sec. 3, about a quarter of a mile south of the McComas deposit and in the same arroyo. Like the McComas deposit it is the topmost stratum of red sandstone that is partly replaced by manganese oxides. This bed is 3 feet thick and is exposed on the west bank of the arroyo for 600 feet, and for a short distance it forms a dip slope into a tributary gulch. The sandstone beds strike N. 25° W. and dip 25° W. The ore bed is displaced a few feet in several places by northerly faults that dip steeply east. Little development work has been done on the property, and the depth to which the beds are replaced by oxides is not known, but the deposit probably includes 9,000 tons of material that contains 25 per cent of manganese.

Other replacement deposits.—Manganiferous sandstones were noted in several places, but the deposits have no commercial value. In sec. 12, T. 11 N., R. 13 W., an arroyo has cut a channel 50 feet deep in the bench land and exposes vertical sandstone walls. Here a manganiferous gray sandstone about 8 feet thick is overlain and underlain by red sandstones. The beds dip slightly to the west. The sandstone contains about 3 or 4 per cent of manganese, which has partly replaced its cementing substance, and in places there are small seams of manganite or pyrolusite. In sec. 23, T. 11 N., R. 3 W., red and brown sandstones that dip 30° E. contain streaks of low-grade manganiferous material as much as 6 inches thick. Another low-grade deposit is exposed in an arroyo north of Williams River, near a road that goes to the Cactus Queen copper camp.

VEINS AND BRECCIATED ZONES.

22. *John Carr claims.*—The manganese claims owned by John Carr are in the western part of sec. 12, T. 11 N., R. 13 W. The deposit is contained in a shear zone in red sandstones. The sandstones are brecciated through a length of 600 feet in a northerly direction, along the strike, and a width of about 50 feet, forming a network of seams in which manganese and iron oxides have been deposited. Psilomelane is the dominant manganese oxide, and limonite is the dominant iron oxide. These seams rarely are more than 2 inches wide, and they are so sparsely distributed that it does not appear possible to mine and concentrate the material profitably. Little development work has been done, and the depth to which the manganese oxides extend is not known.

23. *Nigger Boy claims.*—The Nigger Boy group of two claims, owned by S. K. Barbee, is in sec. 1, T. 11 N., R. 14 W. The claims

were located in April, 1918, but when they were visited in May little work had been done on them. The property lies near the mouth of a canyon, on a bench and a projecting spur below the west side of a basalt-capped mesa. The Graham property (p. 147) is on the east side of this mesa. The mesa rises steeply about 200 feet above the bench at the mouth of the canyon. Two flows are exposed on its slope, and another about 5 feet thick overlies conglomerate of the bench land.

The deposits consist of a brecciated zone in basalt, 75 feet long and 25 feet wide, on the low outlying spur from the mesa, and a vein that cuts the basalt of the bench land about 1,500 feet south of the brecciated zone.

The basalt is a fine-grained brown to red vesicular rock most of whose constituent minerals are altered in part to iron oxides, chlorite, calcite, and kaolin. Small phenocrysts of undecomposed plagioclase feldspar and olivine were noted, however, in one of the specimens. The most conspicuous feature of the rock is the abundance of amygdules ranging from some the size of a pinhead to some an inch long, most of which are filled with coarsely crystalline brown to black calcite. On weathered surfaces the calcite has been dissolved from some of these amygdules, leaving behind thin films of manganese oxides and a greenish mineral believed to be chlorite. The dark color of the calcite is due to arborescent growths of manganese oxides, which are present even in very small fragments. The manganese oxides are believed not to have been deposited along cleavage cracks in the calcite but to have been deposited in their present form contemporaneously with the calcite. Weathering of the dark calcite in the brecciated zones and veins has concentrated and enriched the manganese oxides in the ore bodies, most of the calcium carbonate going off in solution. The depth to which the ores extend in these deposits, therefore, depends on the conditions that promote circulation of the ground waters, such as the size and continuity of the fissures. As a rule ore will be found at greater depth in wide fissures than in narrow ones, but probably in none of them will ore be found below a depth of 25 feet.

In the brecciated zone the veinlets range from a fractional part of an inch to 8 inches in width, but they are rather too widely spaced to be profitably mined. The oxides are manganite and psilomelane. Manganite in well-developed stubby crystals lines cavities in the ore and may compose the whole veinlet, but commonly the veinlet contains ribs of hard psilomelane.

The vein strikes N. 20° W. and is nearly vertical. It was traced for 250 feet and is about 2 feet wide. A hole 6 feet deep was dug on the vein into the underlying conglomerate and sandstone. Mr. Barbee has reported that he was unable to find the vein in the con-

glomerate and sandstone. As shown in a polished specimen, the ore is an intergrowth of manganite, pyrolusite, and subordinate psilomelane, arranged in a most intricate pattern. Some of the oxides, probably pyrolusite and psilomelane, show concentric deposition in laminae of minute thickness in parts of the specimen, and merging into this structure in another part pyrolusite is intergrown with calcite in long spindles. In places narrow seams in the ore are lined with stubby manganite crystals. A partial analysis of the ore in this vein as reported by Mr. Barbee yielded Mn 47.3 per cent, SiO_2 1.80 per cent, Fe 1.7 per cent, and P 0.01 per cent. This deposit is of particular interest in that it clearly proves that the manganese veins cut the youngest basalt flows, which are regarded as of Quaternary age.

NEAR COLORADO RIVER.

24. *Arizona Manganese Co.*—The Arizona Manganese group of 11 claims is in Little Chemehuevis Valley, about half a mile from Colorado River, in Mohave County. The property was visited by the writer May 24, 1918. It is difficultly accessible by a wagon road about 35 miles long from Franconia and Powell, stations on the main line of the Atchison, Topeka & Santa Fe Railway, but it is best reached by boat from Parker, the distance along the river being about 40 miles. The claims were located by George Howard, from whom, in 1917, E. C. Humphreys obtained an option, established a camp, and began mining the deposit. The ore was hauled by wagon half a mile to the loading platform and there transferred to a gasoline launch and transported to the landing at Parker, where again it was transferred to wagons and hauled to railroad cars for shipment. The deposit was not being worked at the time of visit, but probably 150 tons of ore had been transported to Parker and about 300 tons on the dumps awaited shipment.

Little Chemehuevis Valley is a narrow area of bottom lands and low-lying hills along Colorado River. It lies mostly in California, extending for a few miles on either side of the mouth of Whipple Wash. The altitude of the bottom lands is about 400 feet above sea level, and that of the manganese deposit in the adjacent low hills is about 600 feet. The low hills on the Arizona side of Colorado River are cut by numerous shallow arroyos that drain to the river, but near the manganese deposit none of them contain water except after heavy rains. The rainfall is less than 5 inches a year, and in consequence only a few desert shrubs and cactuses are found on the hillside, but in the bottom lands of Colorado River mesquite, willow, and a few cottonwood trees grow.

The rocks of the small hills consist of an older series of gneiss, diorite, and granitic rocks, of pre-Cambrian age, and a younger series

of basalt and sandstone, of Quaternary or late Tertiary age. The relation of the basalt to the sandstone has not been studied in detail, but near the manganese deposit the basalt is seemingly intruded into the sandstone. The basalt is similar to that on the Barbee claims, described on pages 150–151, but it is more decomposed, and the abundant amygdules are filled with black calcite that is more highly manganiferous than the calcite in the basalt on the Barbee claims. Fragments of the black calcite were studied under the microscope and found to inclose minute rods and growths of manganese oxides that were apparently deposited contemporaneously with the calcite.

The manganese deposits consist of several veins and brecciated zones that cut the basalt or lie on the contact of basalt and sandstone. Most of these veins lie in a zone which trends west-northwest and dips steeply northeast, but one vein was observed which strikes

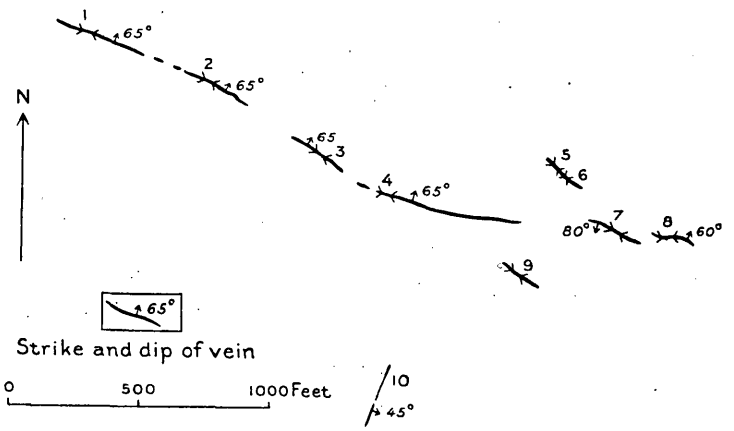


FIGURE 34.—Sketch map showing workings on Arizona Manganese Co.'s claim, Mohave County, Ariz.

a little east of north and dips southeast. They have been prospected by ten or more open cuts through a distance of 3,000 feet, and the development shows that the ore occurs in small shoots in the fissures. The open cuts are from 20 to 80 feet long and have a maximum depth of 10 feet. The principal cuts are shown on the accompanying map (fig. 34). From most of the shoots the ore has been mined, but one shoot 45 feet long and 4 feet wide remains in one open cut. The veins and brecciated zones range from a few inches to 5 feet in width. In places the ore and associated minerals are wholly fissure fillings, but most of the deposits are breccias.

The manganese minerals are psilomelane and pyrolusite, associated with calcite and iron oxides. The iron content varies; in some of the ore shoots the manganese oxides are quite free from iron, but in others it is abundant and intimately mixed with the manganese oxides. Psilomelane occurs near the surface and forms concentric crusts

about fragments of basalt. At shallow depths it gives way to the soft oxides of manganese. Calcite is everywhere abundant in these manganese deposits; in places it forms well-defined veins in the ore body. In one of the open cuts a vein of calcite in coarse crystals is 1 foot thick, but where exposed in most of the workings the calcite is intimately mixed with the ore and underlies it. Some of the calcite is white, but most of it is in coarse brown to black crystals, its color being due to filaments and fernlike growths of manganese oxides.

The manganese of the ore bodies may have been derived from two sources, but the evidence for either is not conclusive. One hypothesis is that the oxides are the residual products from the weathering of manganiferous calcite deposited by ascending hot solutions in the veins, and the other is that the oxides were deposited with calcite by meteoric waters which derived the minerals from the decomposition of the basalt. The altered basalt adjacent to the fissures is in favor of the first hypothesis, but the facts that no manganese minerals other than the oxides were found and that the oxides appear to have been deposited contemporaneously with the calcite lend support to the second hypothesis.

The oxides are very superficial, and as shown in the numerous open cuts little ore is found below a depth of 10 feet. The ore that was shipped and that now stacked on the dumps is judged to contain about 35 per cent of manganese and about 8 per cent of iron. Little care was exercised in sorting it, and the silica content is high owing to included fragments of basalt. Several thousand tons of this material remains in the deposits, but it is doubtful if it can be profitably mined, even under the high prices for manganese ores that prevailed in the summer of 1918.

TOPOCK DISTRICT.

GENERAL FEATURES.

The Topock manganese district is 8 miles in a direct line southeast of Topock, on the southeast side of a group of pinnacled peaks known as the Needles. It is included in the area mapped by the United States Geological Survey as the Needles special quadrangle. The area in which manganese deposits have been found covers 3 square miles, and in it many claim groups have been located. Two days in June, 1918, were spent by the writer in the examination of this district. The nearest shipping point to the district is Powell, a station on the Atchison, Topeka & Santa Fe Railway, 8 miles to the north. Between this point and the deposits a newly made wagon road follows a wash, but the ground is soft, and there is a considerable grade for most of the distance. Probably a few thousand dollars would be required to put this road in good repair. Another road

passes 2 miles east of the southern part of the district, and a connection could readily be made with it, but the haul to the railroad is 5 miles farther than by the new road.

Most of the claim locations on the manganese deposits of the Topock district were made in the fall of 1917, but up to June, 1918, no ore had been shipped and the development work consisted principally of shallow surface cuts.

GEOGRAPHY.

The Needles are flanked north of the manganese district by a sloping detrital plain which extends to Sacramento Wash, a valley traversed by the Atchison, Topeka & Santa Fe Railway. South and east of the deposits detrital material flanks the south end of the Needles and extends around them westward to Colorado River, to the north end of Chemehuevis Valley. In these detrital deposits are flat-topped areas called mesas. The manganese deposits are at altitudes ranging from 1,100 to 1,200 feet above the sea level, about 200 feet lower than the summits of adjacent hills. About 2 miles north of the district is a prominent peak 2,347 feet in altitude, used as a triangulation station by the United States Geological Survey. Numerous shallow washes or arroyos drain from the Needles to Colorado River or to the surrounding detrital plains, but none of them contain water, and the nearest source of supply to the manganese district is Colorado River. The region is arid, and the rainfall is probably nearly the same as at Needles, Calif., where the mean annual precipitation since 1892 is 2.47 inches. The soil supports a few desert shrubs.

GEOLOGY.

The rocks range in age from pre-Cambrian to Quaternary. The Needles are composed chiefly of lava flows and volcanic ash and breccias of Tertiary age, but in places these effusive rocks have been eroded and the underlying pre-Cambrian granite and gneiss have been exposed. One such area of pre-Cambrian rocks is north of the manganese district, on both sides of the road that goes to Powell. The manganese deposits occur in Tertiary lava flows. The mesas and detrital plains that partly surround the low hills in the manganese district are underlain by sandstone beds, exposed where arroyos have cut through the overlying rock débris. They are composed of loosely coherent sand grains, with some fragments of rocks eroded from the adjacent hills. Some of these beds dip about 25° SW., and others lie flat. They are younger than the lavas and evidently were deposited during a stage of aggradation in Colorado River. This formation is probably the same as that which occurs extensively

along Colorado River and to which Lee[1] has given the name Temple Bar conglomerate. The Temple Bar conglomerate is considered to be of Quaternary age.

Extensive faulting has occurred in the manganese area. The faults are difficult to trace but are indicated by the tilted lava flows and sandstone beds and the isolated hills of lava surrounded by detritus and sandstone. Some of the faulting occurred after the deposition of the Temple Bar conglomerate and hence is of Quaternary age.

ORE DEPOSITS.

The manganese deposits are contained in brecciated zones in volcanic flows and breccias and in bodies that replace tuff beds. The brecciated zones strike about N. 70° W. They are wide zones of fracturing without well-defined walls and are not very persistent. The most clearly defined shear zone is that on the Verdun group, which is about 400 feet long and 30 feet wide. In these zones the manganese oxides occur generally as small, widely spaced ramifying veinlets, but in places the breccia is composed of fragments of rhyolite a quarter of an inch or less in diameter, about which the manganese oxides have been deposited in concentric crusts. A vein of calcite occurs in the shear zone on the Stewart & Garriott claims. On the Verdun group a tuff bed 5 feet thick crops out for about 600 feet and has been replaced by manganese oxides, as shown in several workings on the deposit, and in the Topock group tuff beds have been replaced, but the extent of the replacement has not been determined.

The manganese oxides are psilomelane, pyrolusite, and wad. Psilomelane is the dominant oxide in the brecciated zones, where it has been deposited in concentric crusts about fragments of breccia or as fissure fillings. Boulders of float psilomelane which weigh 50 pounds or more were found on the Verdun group. Iron oxide is in places abundantly associated with the psilomelane, and calcite persistently accompanies all the manganese oxides. Psilomelane is known to extend to a depth of 10 feet on the Verdun group, but its maximum extent in depth is not known. The deposits that replace tuff beds consist of a soft brownish-black mixture of iron oxides, wad, and pyrolusite. The largest working in deposits of this character is a tunnel 30 feet long in the Verdun group.

Deposits of manganese minerals have been found on the Topock, Verdun, and Powell groups and the Stewart & Garriott and Gates & Brown claims. There are other claims in the vicinity that have no valid location.

[1] Lee, W. T., Geologic reconnaissance of a part of western Arizona: U. S. Geol. Survey Bull. 352, 1908.

MINES AND CLAIMS.

25. *Topock group.*—The Topock group of five claims in the northern part of the field is owned by Frank Tursick, Jack H. Smith, Frank Seibert, R. E. Donaldson, and S. A. Brown. The claims lie in low hills and across a wide detritus-filled wash. At three points discovery holes disclose small bodies of manganese minerals. Two of these bodies are in a poorly defined zone of shearing in volcanic breccia and show masses of material, some 2 feet in diameter, composed of granular pyrolusite, which replaces reddish breccia that contains abundant brown carbonate crystals. At another point a hole was dug through the detrital material of the wash into a tuff bed with associated black siliceous material resembling chert. Here the tuff is replaced by manganese oxides in a layer 6 inches thick. At no other point has this deposit been uncovered.

26. *Verdun group.*—The Verdun group of five claims is owned by Frank Tursick and Jack H. Smith. The claims cover a hill that rises about 100 feet above the detritus-covered plain. Manganese ore occurs in wide zones of shearing in volcanic breccia and in a tuff bed. The developments at the time of visit consisted of an open cut 40 feet long, which attained a maximum depth of 10 feet beneath the outcrop of manganese ore in one of the shear zones, and a tunnel 30 feet long driven on the dip of the tuff bed, which is partly replaced by manganese oxides.

One shear zone cuts agglomerate composed of fragments of basalt, andesite, and rhyolite. It follows the crest of a small hill for 400 feet, striking N. 70° W. and dipping steeply northeast. On the south side of the shear zone and extending parallel with it for a few hundred feet is a basaltic dike. At the east end of this shear zone another zone of shearing extends southward for 200 feet, and opposite it on the north the tuff bed containing the replacement deposit crops out for about 600 feet. The shear zone first mentioned contains the more valuable deposit. Psilomelane forms in ramifying veinlets through the brecciated zone, which in places is 40 feet wide. Most of these veinlets are generally less than 1 inch wide, but locally at the intersections of veinlets bodies of ore 6 inches in diameter may be formed, and some boulders of psilomelane float weigh 50 pounds or more. The highest grade ore is most weathered and is found in botryoidal and mammillary masses. Float psilomelane is said to have yielded an assay of 53 per cent of manganese, 2 per cent of iron, 6 per cent of silica, and a trace of phosphorus. Psilomelane in the veins and breccias is incrusted with iron oxide, and calcite is abundantly associated with it. Ore taken a few feet beneath the surface is said to have yielded as much as 10 per cent of iron, but the manganese content is less than in surface ores. The

amount of ore in this deposit is very difficult to estimate, but probably 200 tons of high-grade float is scattered over the surface, and several thousand tons of lower-grade material remains underground. The treatment of the material as mined from the deposit presents a problem, for only locally within the shear zone are the veins abundant enough and of sufficient width to permit profitable hand sorting. Most of the material would have to be crushed and concentrated in order to make a marketable product, but because of the small percentage of ore in the rock and the lack of water it is doubtful if concentration would pay.

The replacement deposit occurs in a bed of white volcanic ash or tuff which is overlain by volcanic breccia. The bed strikes N. 70° E. and dips N. 20° W. It crops out for about 600 feet on the north side of the shear zone. At the point where the tunnel is driven the partly replaced bed is about 5 feet thick. The deposit consists of soft, porous brownish-black material, with here and there narrow streaks of crystalline pyrolusite and bands of unreplaced volcanic ash a few inches thick. Analyses of this material are said to have yielded an average content of 28 per cent of manganese, 8 per cent of iron, and about 10 per cent of silica. The ore is of low specific gravity, and it was judged to weigh about 100 pounds to the cubic foot. On the assumption that the replacement of the bed by manganese oxides extends 30 feet from its outcrop there is more than 4,000 tons of low-grade ore in the deposit. It is evident that the material can not be improved in grade by mechanical concentration because of the softness of the manganese oxides.

27. *Powell group.*—The Powell group of four claims adjoins the Verdun group on the east. It is owned by Frank Tursick, Jack H. Smith, Frank Seibert, R. E. Donaldson, and S. A. Brown, of Needles, Calif. The group lies across a reentrant mesa between the volcanic hills and includes a knoll at its east end. A few shallow discovery holes have been dug on the claims, but the only deposit thus far disclosed is a zone of brecciation that crosses the knoll, strikes east, and is apparently the continuation of the zone on the Verdun group, as it is in alinement with that zone. The deposit is contained in rhyolite breccia several feet wide, but the limits of the zone are poorly defined. Psilomelane is the dominant manganese oxide, and it cements fragments of the breccia together and traverses the fractured rock in small irregular seams. Small masses of the breccia consist of fine fragments of rhyolite a quarter of an inch or less in diameter, cemented together with psilomelane. The volume of the rhyolite fragments is much greater than the volume of manganese oxides in these masses, and to separate the manganese oxides from the rhyolite country rock would require crushing and mechani-

cal concentration. The deposit is too low in grade to work, but there is several tons of float ore that could be readily gathered. Calcite accompanies the manganese oxides and partly fills the interstices as a thin coating on psilomelane. Very little iron occurs in the deposit. The depth to which the manganese oxides extend has not been determined, but it is believed that in most places they do not persist more than 25 feet beneath the surface.

28. *Gates & Brown group.*—Southwest of the Verdun and Powell groups is a group of five claims owned by Gates & Brown. The group extends across a small hill which rises 200 feet above the surrounding detrital plain. The hill is composed of rhyolite. An arroyo at the northwest end of the hill has exposed in its bed some flat-bedded gray sandstone overlain by detrital material. Manganese oxides occur in a brecciated zone in rhyolite, which strikes about N. 60° W. and extends across the hill near its summit. The zone is poorly defined, and in it are widely spaced stringers of psilomelane that are too lean to mine. However, probably a carload of psilomelane in botryoidal and mammillary masses as much as 6 inches in diameter could be gathered from the surface.

29. *Stewart & Garriott group.*—A group of five claims owned by Stewart & Garriott lies between the Verdun and Topock groups. It overlies some small hills on both sides of an arroyo. The rocks composing the hills are volcanic breccia, rhyolite, volcanic ash, and banded reddish jasper. The jasper is about 40 feet thick in one place, where it is associated with the rhyolite flows. At the time of visit the development work consisted of an open cut 30 feet long and a shallow discovery hole on a vein that strikes N. 70° W. and dips 70° N. The vein is in a shear zone in decomposed volcanic breccia stained with iron oxides. In the discovery hole a few feet west of the open cut small bunches of psilomelane and pyrolusite occur near the surface. The vein in the open cut is 2 feet wide, and consists of coarse-grained calcite with comb structure. The calcite is gray to greenish black, with here and there a small nest of soft brown oxides. This vein material is exposed to a depth of 6 feet in the cut. The dark color of the calcite is due to minute filaments of oxides that appear to permeate the smallest fragments to which the material can be crushed. Some of this dark calcite was tested in a borax bead, and gave a greenish color, changing to brown and faint lavender when cold, showing that it contains both iron and manganese oxides. It could not be determined from the material whether the iron and manganese oxides were introduced into the cleavage cracks of the calcite or whether they result from the decomposition of some iron and manganese mineral in the form of carbonate. An alternate hypothesis is that the manganese oxides

were deposited as such with the calcite, both minerals having been derived from the decomposition of minerals in the lavas.

PINAL COUNTY.

SUPERIOR DISTRICT.

GENERAL FEATURES.

The reported occurrence of large bodies of low-grade manganese ores in the Superior or Pioneer district was the basis for a reconnaissance examination of three days in September, 1917, and a revisit to the district in June, 1918. The copper deposits and stratigraphy of the district were described in 1913 by Ransome.[1]

The manganiferous deposits are in a zone 4 miles long, extending about the same distance north and south from Superior, on the westerly slope of a group of unnamed hills. A prominent cliff near the town is known as Apache Leap. Most of the deposits within this zone were examined, but the lack of development on them precluded any systematic or thorough study.

Among the mining groups containing manganiferous ores, named from north to south, are the Magma Chief, Magma, Superior & Arizona, Queen Creek Copper, Magmatic Copper Co., Consolidated Holding & Trust Co., and Grand Pacific.

HISTORY.

The history of the Superior district dates from the location of the Silver King and Silver Queen mines in 1875. The Silver King mine, credited with a production of $8,000,000 or more in silver, is about 3 miles north of Superior. It has lain idle for many years, but recently attempts have been made to unwater the shafts and resume operations.

The Silver Queen mine, now owned by the Magma Copper Co., and generally known as the Magma mine, is a large producer of copper, and to its operation the existence of Superior is largely due. The Superior & Arizona also produces some copper ore, and there are many prospects in search of copper that have not reached the productive stage. Attention has recently been directed to deposits of manganiferous iron ores which outcrop prominently in the district, but no bodies of ore that could be profitably mined have yet been found.

ACCESSIBILITY.

Superior is accessible by the Arizona & Magma Railroad, a narrow-gage line that connects with the Arizona Eastern Railroad at

[1] Ransome, F. L., Copper deposits near Superior, Ariz.: U. S. Geol. Surv. Bull. 540, pp. 139–158, 1913.

Magma. Most of the mining properties are accessible to Superior by wagon roads from 1 to 4 miles long.

SURFACE FEATURES.

Superior lies at an altitude of 3,000 feet above sea level, at the base of the steep westerly slope of a northward-trending ridge on the north bank of Queen Creek, where it emerges from its canyon. The canyon is carved across the structure of the ridge. The summit of Apache Leap is about 4,700 feet above sea level, Kings Crown Peak, a few miles northwest of Superior, attains an altitude of 5,530 feet. Eastward from the summit of Apache Leap extends a gently sloping surface that represents a flow of Tertiary eruptive rocks.

Queen Creek, an intermittent stream, drains westward toward Gila River. Springs are found in the gulches near the base of the steep westerly mountain slope, and most of them are probably situated along strong northerly faults. A few trees grow along Queen Creek, and the hills support only a sparse growth of desert vegetation. The original water level of the Magma mine is reported to have been about 400 feet below the surface, but the old shafts of the Silver King mine, at an altitude of approximately 3,500 feet, are said to have filled with water.

GEOLOGY.

The steep hillside immediately west of Superior gives an excellent exposure of the rocks of the district. As outlined by Ransome these formations are, in ascending order, (1) an intrusive sheet of diabase, (2) the upper of the two pre-Devonian quartzites, (3) the Devonian limestone, (4) the Carboniferous limestone, and (5) a flow of dacite which forms the crest of Apache Leap and is the prevailing rock over a desolate country for 5 or 6 miles to the east. The general dip of these rocks is 35° E. South of Superior near the shaft on the Magmatic Copper Co.'s property diabase intrusions occur also in Devonian limestone.

A prominent structural feature of the district is a strong fault that strikes a little west of north and passes at the base of the steep west front of Apache Leap. It is concealed by alluvium south of Superior, but north of Superior the fault can be plainly traced, passing a short distance west of the Magma shaft and through a pronounced gap in two mountain blocks toward the Silver King mine. The fault dips west, and the mountain block west of it has been normally displaced, bringing Carboniferous limestone west of the fault adjacent to diabase and quartzite east of the fault. Other northward-trending faults were observed south of Superior. East-

ward-trending faults, though of moderate or small displacement, are important because of their relation to the ore deposits. The one of greatest displacement is probably that along which the ore body of the Magma mine was deposited, in conjunction with an intrusion of granitic rock. The vertical displacement of this fault is about 150 feet. Smaller faults are visible on the steep westerly hill slope east of Superior. The eastward-trending faults are probably older than the northward-trending faults, for the Magma fault and dike are reported to end abruptly against the major northerly faults.

MANGANESE DEPOSITS.

The manganiferous ore bodies occur in the fault planes of the two systems and in bedding planes of limestone adjacent to the faults. The Devonian limestone immediately above the quartzite presents a horizon especially favorable for the occurrence of deposits in the bedding planes. The deposits vary greatly in size; some can be traced for several hundred feet along their strike, but others are lenses whose outcrops are only a few feet in length. These ore bodies have a vertical range in occurrence of 1,000 feet from the base of the west slope of Apache Leap, approximately 3,000 feet above the sea, to altitudes of 4,000 feet.

The manganese minerals of the surficial deposits consist of the oxides, associated generally with limonite, quartz, and calcite, but in a deposit on the Daggs group the oxides are associated with cerusite, wulfenite, and vanadinite. The oxides are principally wad with a few seams of pyrolusite or manganite and subordinate psilomelane. Braunite occurs also on the Consolidated Holding & Trust Co.'s group. Rhodochrosite was reported from the unoxidized copper ores in the Magma mine but was not observed elsewhere in the district. This mineral may be the source of the manganiferous ores of the district, although it is suspected that manganiferous calcite or siderite may have been the source of some of the oxides. Limonite is an abundant though variable constituent of the deposits. Calcite as a secondary mineral of the veins is abundant. The siliceous character of most of the deposits is due to masses of jasper and fine-grained silicified limestone inclosed in the oxides. South of Superior, at the shaft of the Magmatic Copper Co., the ore is soft and granular, and its color ranges from brown to brownish black, according to the amount of iron oxide it contains.

The quantity of low-grade ores in the district is large, though no single deposit may be expected to yield more than a few thousand tons, and many deposits contain only a few hundred tons. No deposit has been sufficiently developed to afford data for an accurate estimate of tonnage.

MINES AND CLAIMS.

30. *Magma Chief.*—The Magma Chief mine is about 2 miles north of Superior. On the Baltimore claim of the Magma Chief group an inclined shaft 35 feet deep shows 2 to 3 feet of manganiferous ore in the bedding planes of massive limestone. The limestone strikes N. 70° E. and dips 50° S. A tunnel 175 feet below the outcrop is being driven to intersect the deposit but at the time of examination had not reached it. Assays of material from the inclined shaft are reported to contain from 23 to 39 per cent of manganese, 4 to 14 per cent of iron, and 40 per cent or more of silica. Bodies of manganese ore crop out also in the bedding planes of limestone on either side of an eastward-trending fault at an altitude of 3,800 feet. A tunnel that forms the principal development of the Magma Chief mine is directed eastward along this fault, and in June, 1918, it had intersected the manganiferous ore bodies at a depth of 400 feet. One of these ore bodies is about 5 feet wide on the surface and can be traced for several hundred feet along the strike of the beds, but the material is very siliceous. On the tunnel level the sheared vein matter is about 20 feet wide, and it consists of iron and manganese oxides, jasper, and silicified limestone, but it is judged to contain not more than 10 per cent of manganese, about 15 per cent of iron, and more than 50 per cent of silica. This material is not adapted to mechanical concentration.

31. *Magma group.*—In the Magma mine small bodies of manganiferous ores occur in the bedding planes of limestone, but they are regarded by the managers of the mine as not being of commercial grade.

On the Monarch claim of the Magma Consolidated Mining Co. an old tunnel driven from the level of Queen Creek follows a fissure which trends S. 25° E. and dips 60° S. and cuts massive limestone. The limestone strikes N. 10° W. and dips 35° E. Along the fissure for 320 feet are lenses and masses of iron and manganese oxides as much as 3 feet wide. Some of the material is of fair grade and may contain 30 per cent of manganese, but much of it is highly siliceous. There is approximately 500 tons of ore containing 25 per cent of manganese above the tunnel level, but the depth to which the oxides extend has not been determined.

Manganiferous ore crops out on the hillside a short distance east of the Magma mill. It occurs in a fault or shear zone in massive gray limestone, which strikes N. 50° E. and dips 45° NE. The deposit is silicified material stained and impregnated with manganese and iron oxides. It is exposed for 250 feet and is from 1 to 4 feet wide. The manganese content of the deposit is judged to be not over 15 per cent, the iron content about 10 per cent, and the silica content over 50 per cent. The manganese and iron oxides

are fine grained and intimately mixed, and their mechanical separation does not appear possible.

32. *Lake Superior & Arizona.*—The Lake Superior & Arizona mine, near the mouth of the Queen Creek canyon, is a producer of copper ore. The ore body is said to replace limestone near the contact with the underlying Cambrian quartzite. At this horizon bodies of siliceous manganese ore crop out on the surface from the creek level to the crest of the ridge. Northward from the ridge toward the Magma mine there is little manganese in the limestone beds except where eastward-trending fissures cut the bedding. Here small lenses of highly siliceous manganiferous material occur along the bedding planes and in the fissures.

33. *Queen Creek Copper Mining Co.*—The Queen Creek Copper Mining Co.'s property is developed by an inclined shaft 275 feet deep, driven on the contact of limestone with quartzite. The limestone at the contact is highly silicified and contains iron and manganese oxides in a body several feet wide.

34. *Magmatic Copper Co.*—The Magmatic Copper Co.'s group of seven claims is about 2 miles south of Superior, in low-lying hills at the base of the westerly slope of Apache Leap, at an average altitude of 3,000 feet above sea level. The developments consist of a working shaft 130 feet deep, several old shafts from 50 to 80 feet deep, and a tunnel 100 feet long. The rocks exposed on these claims are quartzite, limestone, diabase, and dacite. The quartzite forms the base of the series, and it is overlain by several hundred feet of massive limestone. Intrusive into the limestone on the east side of the claim group is a large mass of diabase. South of the working shaft, between two faults, is an area of dacite identical with the rock forming the crest of Apache Leap. The dacite was probably brought to its present position by faulting. The sedimentary rocks strike about north and dip 35° E. A prominent northward-trending fault can be traced for several thousand feet on the claims. It cuts the limestone and south of the shaft brings dacite into contact with the limestone. A fault that strikes northwest probably joins the northward-trending fault a short distance north of the shaft. Other faults or fissures of small displacement trend about east.

The manganese deposits occur in the fault fissures or along bedding planes of limestone adjacent to the faults. No persistent body crops out, but lenses of manganiferous iron ore a few feet long occur along the faults, associated with silicified limestone and jasper. The largest body occurs in the block of ground covered by the dacite flow between the northwesterly and northerly faults. At a depth of 93 feet the working shaft encountered a body of manganiferous material in limestone which persists to a depth of 107 feet. This body apparently dips about 40° W., so its thickness is about 10 feet,

but no work has been done to determine the length of the shoot or its persistence in depth. An old shaft 500 feet southeast of the working shaft on the northwesterly fault shows about 5 feet of manganiferous material a few feet below the collar, but whether this material is continuous between the two shafts has not been determined.

The material from the working shaft is granular and dark brown. On exposure to the air it crumbles to a powder. Fresh pieces show specks and narrow seams of manganese oxides in the predominant reddish-brown iron oxides. Many pieces show partly decomposed coarse crystals of a brownish spar, which may be manganiferous siderite. The material is comparatively free from silica. An analysis is said to have shown 18 per cent of manganese, 34 per cent of iron, and 4 per cent of silica.

35. *Consolidated Holding & Trust Co.*—The Consolidated Holding & Trust Co. owns a group of numerous claims, commonly known as the Daggs group, on the westerly slope of Apache Leap. There are some extensive workings on the property driven in a search for copper ore, chief among which are a shaft 700 feet deep and a tunnel that connects with the shaft at a depth of 150 feet. Very little work has been done here in recent years. In June, 1918, lessees were mining an ore body in the tunnel. This body is valuable chiefly for its lead content, but it also contains manganese oxides and two rare minerals—wulfenite, the molybdate of lead; and vanadinite, the vanadate of lead.

The ore body, which was encountered about 800 feet from the portal of the tunnel, occurs in limestone just above the contact with the underlying quartzite near a prominent fault that strikes N. 70° W. and dips steeply southwest. The ore body has been explored for 100 feet on the dip of the bed and 15 feet on its strike and is from 1 to 3 feet thick. It consists of manganese and iron oxides with variable amounts of cerusite, wulfenite, and vanadinite crystals. The cerusite and rare lead minerals are more abundant next the quartzite; vanadinite in short tabular hexagonal crystals is commonly found adhering to the quartzite or in fissures in the quartzite; then follows a porous mass of yellow wulfenite, white cerusite, and calcite crystals a few inches thick, more or less stained with manganese and iron oxides. The upper and larger part of the deposit consists of an intergrowth of psilomelane, manganite, and perhaps some braunite with minor amounts of iron oxides and crystals of wulfenite and cerusite, in cavities in the ore. Some of the manganite is in bundles of fine fibers that somewhat resemble asbestos in texture. A partial assay of selected manganese ore by the Colorado Fuel & Iron Co. is said to have yielded 34 per cent of manganese, but the ore is said to be objectionable because of its lead content.

About a quarter of a mile east of the main tunnel of the Daggs group, at an altitude of 4,000 feet above sea level, an old tunnel was driven on a vertical fissure that strikes N. 20° W. and cuts massive limestone. Some copper ore was stoped from the vein, but the workings are now caved, and the size and nature of the deposit could not be determined from an examination of the surface. In addition to some copper-stained rock the dump contains 10 tons of manganese-bearing material. Specimens consist dominantly of a massive aggregate of coarse platy black crystals with a little psilomelane and minute seams of manganite which cut the other oxides. The platy crystals are hard and give a dark-brown streak. Small particles of the mineral are attracted by the magnet, and a chemical test reveals some gelatinous silica and iron. The mineral is probably braunite.

On the Daggs group northward from the principal workings small irregular masses of manganiferous iron oxide occur here and there in the limestone. Half a mile north of the shaft there is a deposit 30 feet long and 10 feet wide, consisting of a mixture of iron and manganese oxides high in iron but probably containing not more than 15 per cent of manganese.

36. *Grand Pacific.*—The Grand Pacific Copper Co.'s property comprises a group of 35 claims which lie mostly south of the Consolidated Holding & Trust Co.'s group. The mine is about 3 miles south of Superior, and the altitude of its lower tunnel is about 3,650 feet. The mine produces copper ore, but in the course of development some low-grade bodies of manganiferous material were encountered. Three tunnels are directed in a course about N. 75° E. along the ore-bearing fissure or shear zone, which cuts massive gray limestone. The limestone strikes north and dips 20°–40° E. The vertical distance between the upper and lower tunnels is 264 feet.

The material of the shear zone on the lower tunnel level consists of brecciated limestone, clay gouge, iron and manganese oxides, and in places a coarse-grained brown calcite. The zone is about 10 feet wide on this level. The manganese and iron oxides are intimately mixed, and no crystalline oxides were noted. No commercial bodies of manganese ore occur on the lower tunnel level, and it is doubtful if the vein matter as a whole contains more than 5 per cent of manganese. A selected sample of manganiferous material from tunnel No. 2, 234 feet above the lower tunnel, is said to have yielded 15 per cent of manganese and 45 per cent of ferric oxide (Fe_2O_3).

GLOBE DISTRICT.

DISTRIBUTION OF DEPOSITS.

The manganese deposits of the Globe district are grouped in a small area in the Globe Hills about 4 miles north of Globe. They

are principally covered by claims of the Globe Commercial Copper Co. (California), Superior & Globe, and Mineral Farm groups. The date of location of these claims was not ascertained, but as the region is famous for its production of copper and as veins having a heavy gossan crop out on the claims they were doubtless located many years ago. Some silver ore is said to have been produced from an old shaft on the Globe Commercial Copper Co.'s property. The deposits are readily accessible to Amster, the nearest shipping point on the Arizona Eastern Railroad.

GEOGRAPHY.

The Globe Hills in the immediate vicinity of the manganese deposits have low relief, though south of Globe the Pinal Mountains are high and are deeply dissected. The manganese deposits are at altitudes of 4,100 feet above sea level, at the base of hills which rise a few hundred feet above them. Pinal Peak, 10 miles south of Globe, has an altitude of 7,850 feet. Pinal Creek, an intermittent stream a few miles west of the manganese deposits, drains northward. Gulches on the east side of the deposits drain to the east and south, but they contain water only after periods of storms.

The climate is arid, and the average rainfall is probably not more than 10 inches a year. The hills support a sparse growth of shrubs typical of the desert areas.

GEOLOGY.

The rocks in the vicinity of the manganese deposits consist of quartzite belonging to the Apache group,[1] which is probably of Cambrian age, intruded by masses of diabase. Exposures are poor, and the formations are cut by numerous faults, which in places bring quartzite and diabase into juxtaposition. Along several of these faults, which strike east-northeast, the ore bodies are formed chiefly by the replacement of diabase, and to a minor extent they fill fissures and replace the quartzite.

ORE DEPOSITS.

The manganese oxides are associated with limonite, calcite, and unreplaced minerals of the diabase, principally quartz and feldspar, and fragments of quartzite. The manganese oxides are wad and needle-like crystals of manganite; the manganite occurs as narrow seams and lines small cavities in the ore. The ore is black, dark brown, and reddish, and in most of it that lies on the dumps the

[1] Ransome, F. L., Geology of the Globe copper district, Ariz.: U. S. Geol. Survey Prof. Paper 12, 1903.

presence of manganese minerals is little suspected because they are enveloped by the soft limonite, which breaks to a powder. When the ore is freshly broken the manganese oxides are apparent as seams or as finely crystalline aggregates that line cavities. The best ore was obtained from the surface.

Water level has nowhere been reached in the extraction of manganese ores; the deepest work is about 45 feet below the surface. There are some deeper shafts in the vicinity, but no information was to be had with regard to the depth of the water level.

As explored, the ore shoots of the deposits are lenticular masses with a maximum length of 200 feet and a maximum depth of 45 feet. The ore at the point where this depth was attained, however, was of poor grade, and it is probable that the ore will not persist much below this depth in any of these veins.

The replaced rock of the manganese deposits is greatly altered, so that its original character is difficult to recognize, but it appears probable that the diabase was replaced to a greater extent than the quartzite, as the texture of most of the replaced rock more nearly resembles that of the diabase than of the quartzite.

MINES AND CLAIMS.

37. *Globe Commercial Copper Co. (California group).*—The California group of the Globe Commercial Copper Co. lies in the southeastern part of the manganese-bearing area north of Globe. The property is said to have produced some silver ore many years ago, but it is only recently that attention has been turned to manganese ore. In 1916 the claims were leased to Buckingham & Wright, who shipped 24 cars of manganese ore from September, 1916, to February, 1917. Later the claims were worked by Jamison & Bailey, who shipped nine cars of ore to June, 1917, but since then work has been suspended. In all about 1,500 tons of ore was shipped to the Miami Metals Co., of Chicago, and to the Seaboard Steel & Manganese Corporation, of Temple, Pa., for use probably in alloys. Assays of the best and poorest carload shipments from this property are as follows: Manganese, 35.52 and 16.70 per cent; iron, 11.31 and 8.77 per cent; silica, 8.47 and 38.55 per cent; phosphorus, 0.031 and 0.204 per cent; and moisture, 6.04 per cent in one sample only. The best ore was obtained near the surface, and the poorest is said to have come from the bottom of a shaft 45 feet deep, the greatest depth to which the ore was mined. The ore is said to contain about 2 ounces of silver to the ton. Most of the ore of better grade has been mined from the veins in this property, but on the assumption that ore extends to a depth of 50 feet, there is in reserve probably 1,000 tons of ore with a content of 20 to 30 per cent of manganese.

Several manganiferous veins are inclosed by the California group. They strike about east and dip 30°–60° N. The vein that has yielded most of the manganese ore strikes N. 75° E. and dips 60°N. 15° W. In general it lies at the contact of quartzite and diabase, but at the east end of the workings it is inclosed by diabase. The average width of the vein is 18 inches, and it has been exploited to shallow depths for 200 feet along its strike. The greatest depth attained was in a shaft 45 feet deep, but there the ore was of low grade, being high in silica. The ore is soft black to dark-brown material. The manganese oxides are mostly in the form of wad, pyrolusite, and manganite. The cavities which occur sparsely in the ore are lined with short crystals that are probably manganite.

38. *Superior & Globe.*—The Superior & Globe group adjoins the California group on the northwest. One shipment of 47 tons of ore was reported to have been made from this group in June, 1917, and it gave the following assay: Manganese, 25.7 per cent; iron, 10.62 per cent; silica, 11.44 per cent; phosphorus, 0.67 per cent; moisture, 1.45 per cent. From the meager developments there is estimated to be in reserve from 1,000 to 5,000 tons of ore with a content of 20 per cent of manganese. Several veins are exposed on both banks of an arroyo that drains westward. They have been explored by several short tunnels, open cuts, and shallow shafts. Two men were at work on the property in August, 1917. North of the arroyo an old shaft of the Superior & Globe Copper Co. was sunk in diabase to a depth of 900 feet in search of copper ore. The manganese-bearing veins strike northeast and dip 20°–60° NW. They are contained in diabase and quartzite or occur at the contact of these rocks. They can not be traced on the surface beyond the banks of the arroyo, but where exposed by the workings the manganese-bearing shear zones are from 2 to 10 feet wide. The greatest depth attained on these veins was 20 feet, and at that depth the ores are very siliceous and the manganese content much lower than at the surface. The ore is dark brown to reddish brown but on fresh fractures shows the seams of black manganese oxides traversing it, with here and there a vug lined with small crystals of manganite. The red and brown colors are due to limonite or hematite. The ore for the most part replaces the diabase, and the silica content varies according to the degree of replacement. Secondary calcite is a common mineral of the ore.

39. *Mineral Farm group.*—The Mineral Farm group of 21 claims lies east of the Superior & Globe Commercial Copper Co.'s properties, in a small basin at the head of a gulch draining southward to Pinal Creek. No manganese ore has been produced from this property except for a small quantity said to have been used as a flux in

the Old Dominion smelter at Globe. The manganese deposits are unexplored, so there is little on which to base an estimate of the ore reserves. The outcrops, however, indicate several thousand tons of manganiferous iron ore containing probably 20 per cent of manganese. Numerous veins occur in this group, and they strike from north to northeast. They cut diabase and quartzite, and their courses are marked by outcrops of gossan and by abundant float of iron and manganese oxides, which can be traced for several hundred feet. The veins range in width from 2 to 10 feet. The iron is in the form of limonite and specular hematite containing bunches and stringers of pyrolusite. Quartz is abundant in the croppings.

VICINITY OF SAN PEDRO RIVER

40. *Clayshulte deposit.*—The manganese deposit owned by John Clayshulte is about 10 miles northeast of Mammoth, on the southeastern slope of Table Mountain. A poor road traverses an arroyo from the main road along San Pedro River to a point within 2 miles of the deposit, but the building of a new road for the remaining distance and repair of the old one would entail considerable expense. Winkelman, the nearest railroad point, is about 22 miles north of Mammoth.

Little development work has been done on the deposit, and no ore has been shipped.

The manganese deposit is contained in massive limestone and is apparently a replacement deposit along a fissure that strikes northeast. The ore body can be traced for 150 feet, and at the point where a shaft was sunk it is 16 feet wide. The shaft is 30 feet deep and is the only development work on the deposit. The ore is a mixture of iron and manganese oxides and would probably be classified as wad. It is soft, brownish black, and generally homogeneous, though in places it shows nests and veinlets of small manganite crystals. Assays are said to yield uniformly about 22 per cent of manganese. The iron content of the ore may equal or exceed the manganese content, but it has not been determined. The depth to which the ore extends below the 30-foot shaft is not known. Under present conditions this deposit has no value.

41. *Mogul group.*—The Mogul group of five claims, owned by J. W. Norton, is in the Black Hills 3 miles west of San Pedro River, at a point 15 miles south of Winkelman. In order to ship ore it would be necessary to build a road from the deposit to San Pedro Valley, but this could be accomplished at little expense by following an arroyo for most of the way.

The claims were located early in 1918, but to the time of visit only a small amount of development work had been done, and no ore had been shipped.

The principal workings are in an upland surface of moderate relief, at an altitude of 3,300 feet. The hills and bench land slope gradually eastward to San Pedro Valley, which at a point east of the deposit is about 2,200 feet above sea level. Numerous arroyos drain to San Pedro Valley, but none of them contain water. The climate is arid, and the rainfall probably is not more than 5 inches a year. A few desert shrubs, grasses, and cactus grow on the hills and in the arroyos.

The bench land, which extends about 2 miles back from San Pedro Valley along the arroyo at the head of which the manganese deposit is situated, is composed of gravels and poorly sorted rock fragments at least 200 feet thick. These gravels flank quartzite, conglomerate, and diabase sill, which aggregate about 200 feet in thickness where they are cut by the arroyo, and these rocks in turn rest on a coarse-grained reddish biotite granite that is the dominant rock in the north end of the Black Hills.

The manganese deposit is contained in a vein of coarse-grained calcite which projects in places a foot or two above the decomposed granite country rock. The vein strikes N. 45° SW. and dips 45° SW. It can be traced continuously for 350 feet, and its greatest width is 10 feet. The ore occurs principally in the hanging-wall side of the vein, and the ore shoot is about 250 feet long and 2 feet wide. Two holes have been dug on the deposit, the largest of which is 25 feet long and 6 feet deep.

The manganese oxides on the surface are principally masses of psilomelane, showing concentric structure. At depths of a few feet softer manganese oxides appear, which in places merge into dark-colored calcite. Calcite is the dominant gangue mineral, and no quartz was observed, although analyses of the ore are said to yield about 4 per cent of silica. By careful hand sorting an ore containing 40 per cent of manganese may be obtained, but most of the vein matter as mined is judged to contain about 25 per cent of manganese. Very little iron occurs in this deposit. The abundance of calcite in the deposit and its dark color in parts of the vein suggests very strongly that the manganese oxides were derived from the decomposition of manganiferous calcite.

42. *Tarr & Harper mine.*—The Tarr & Harper group of five claims is in Camp Grant Wash, about a mile west of its junction with San Pedro River. It is accessible by a good wagon road 13 miles long from Winkelman, on the Arizona Eastern Railroad. This property was visited on April 24, 1918, by the writer, who mapped the geology of the formations in the immediate vicinity of the deposit, as shown in figure 35. The deposit was first worked by the Arizona Rare Metals Co., which produced 408 tons of ore in 1917. In 1918 R. D. Harper resumed operations and from February to April had

shipped four carloads of ore; the fifth car was being placed on April 24.

The mine is at the mouth of a draw tributary to Camp Grant Wash, at an altitude of 2,300 feet above sea level. The hills in the immediate vicinity of the mine rise about 300 feet above it. San Pedro River is an intermittent stream, and Camp Grant Wash contains water only in Putnam Springs, about 3 miles from its mouth, and for a short time after rains. The climate is arid, and the average rainfall is about 5 inches a year. A few cottonwood trees grow along

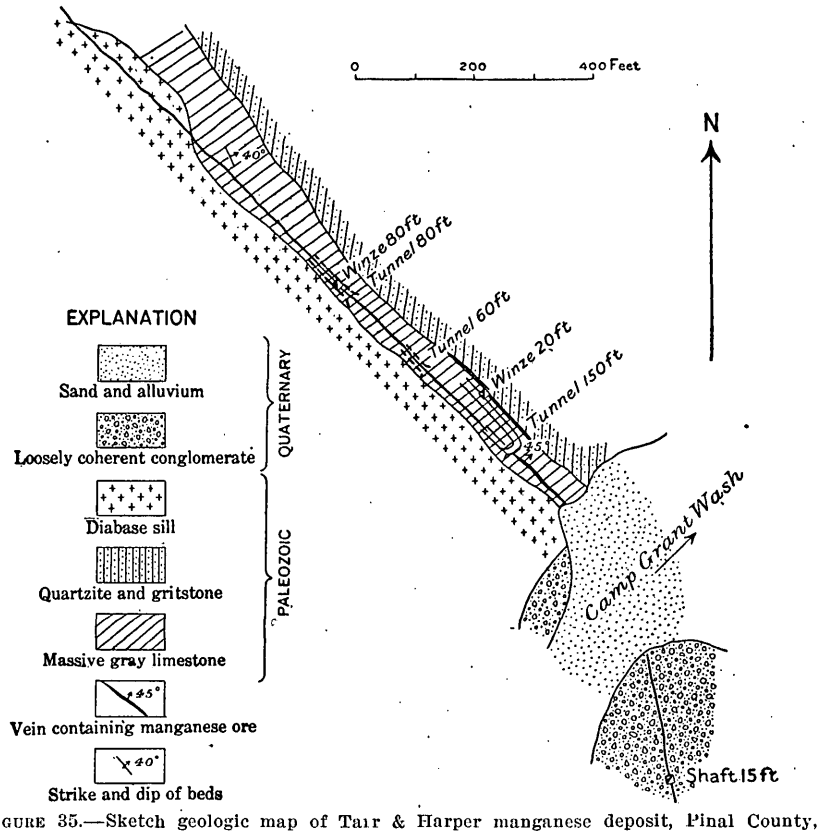


FIGURE 35.—Sketch geologic map of Tair & Harper manganese deposit, Pinal County, Ariz.

San Pedro River, and desert shrubs and several varieties of cactus grow in the arroyos and on the hillsides.

San Pedro River flows northward in a broad valley disproportionate in width to the size of the present stream. On each side of the stream are bottom lands as much as a mile wide. Bench lands rise abruptly from the bottom lands and extend eastward and westward with a gently rising surface to outlying spurs from the mountainous areas. In parts of the valley the bench lands are several miles wide.

The bench lands are composed of slightly indurated and poorly stratified sand, pebbles, and angular rock fragments. These sediments are at least 200 feet thick and may be much thicker. They are probably of Quaternary age, and in the vicinity of the manganese property they flank Paleozoic or older rocks. Both sedimentary and igneous rocks are cut by the manganese-bearing veins. They consist of limestone at the base, intruded by a diabase sill, overlain by conglomerate, which grades into gritstone and hard white quartzite. The formations strike northwest and dip northeast. They are flanked on the east by the flat-lying sand and conglomerate beds, and west of the mine they overlie granite of pre-Cambrian age.

The manganese deposits are contained in fissure veins which cut both the older sedimentary rocks and the younger sands and conglomerate. The fissure in the older rocks trends N. 45° W. and dips 45° NE., and lies in the bedding or cuts the beds at an acute angle; the fissure in the gravel beds strikes about N. 10° W. and is nearly vertical. Whether these fissures were produced by the same dynamic forces is not known, but the occurrence of the manganese deposit in a fissure in Quaternary gravels is of particular interest.

Most of the ore has been obtained from the deposit in the older rocks on the north side of Camp Grant Wash, where a shaft 80 feet deep was sunk and about 275 feet of tunnels driven. On the south side of the wash only a few shallow holes have been dug. On the north side of the wash the fissure is known to contain manganese ore for 1,500 feet or more along its strike, but the ore has been mined only between points 500 feet apart, where the fissure is contained in limestone and quartzite above a diabase sill. The vein is from a few inches to 4 feet wide. In places there are two ore-bearing streaks a few feet apart, separated by brecciated material of the fault zone. The footwall of the zone in the present working tunnel is a slickensided plane with well-defined striae, the direction of movement being northeast but at a small angle from the dip of the fissure. Above 500 feet northwest of the workings the vein is inclosed in diabase where the ore is mixed with iron oxides and is of much lower grade than in the limestone and quartzite. Ore is reported to extend to the bottom of the 80-foot shaft, but it is believed not to extend to that depth in most places in the fissure.

The manganese oxides are pyrolusite, manganite, and psilomelane. They have been deposited in the open spaces of the fissure and have also replaced the crushed wall rocks to some extent. Iron oxides occur sparsely in that part of the vein that is being worked, but they are abundant where diabase is the inclosing rock of the fissure and are intimately mixed with manganese oxides. Calcite is an abundant mineral of the ore, and it likewise is of secondary origin. The original manganese minerals of the fissure were not noted, but the

abundance of secondary calcite makes it appear probable that manganiferous calcite was present. The ore is sorted by hand and screened in order to obtain a product carrying 40 per cent of manganese. Much of the material of the dumps contains 30 per cent of manganese, but it is high in silica. The meager development indicates that several thousand tons of ore containing 40 per cent of manganese could be recovered from the deposit in the older rocks on the north side of the wash.

The deposit in the gravels on the south side of the wash is indicated for 300 feet along the strike of the vein or shear zone, but its average width and the depth to which the manganese oxides extend have not been determined. A small quantity of ore was mined from a hole about 10 feet deep. At the surface where this hole was dug the vein material was about 1 foot wide, but the walls diverge downward and at the bottom of the hole it is at least 6 feet wide. The deposit consists of small pebbles and angular rock fragments of the gravel beds cemented together and partly replaced by pyrolusite, manganite, and subordinate psilomelane. Apparently there is no clean ore in masses large enough to pay to sort, and in order to make a marketable product the material would require concentration.

FLORENCE DISTRICT.

43. *Chamberlain mine.*—The Chamberlain mine is in a desolate region 12 miles southeast of Florence. The deposit is small, and only a short time was spent in its examination on September 5, 1917. The deposit was recently discovered, and development work on it consists only of shallow open cuts. Two carloads of ore amounting to 74 tons were shipped from the property early in 1917, but in September no work was being done. Florence, the nearest railroad station, on the Arizona Eastern Railroad, is readily accessible by a good wagon road. The climate is arid and supports only desert shrubs and several varieties of cactus. Shallow channels that contain water only for short periods during storms drain toward Gila River to the north. The depth to water level is not known.

The surface features consist of a broad detrital plain sloping gently to the north, above which rise a few isolated low hills. The manganese deposits occur on one of these hills that is about 500 feet in diameter and stands at an altitude of 2,000 feet above sea level, or 50 feet above the plain.

The hill is composed of a coarse-grained hornblende granite with small remnant patches of red andesite. Several small fissure veins in the granite, which strike N. 20° W. and dip 70° SW., contain the manganese ore. The veins are from a few inches to 1 foot wide, and

the longest ore shoot as shown by an open cut is 125 feet in length. In places along the veins the granite is brecciated, and the fragments are cemented by manganese oxides.

The manganese oxides are principally hard crusts of psilomelane, but softer oxides occur as the decomposition product of black calcite. Detrital material about the hill contains numerous fragments of psilomelane which under the action of the elements are polished and rounded and look not unlike weathered fragments of dark volcanic glass. Some of the psilomelane is botryoidal, with concentric layers. For the most part it was deposited in the fissure as crusts, but it also partly replaced fragments of granite inclosed in the veins. Calcite is abundant in the veins, and it occurs as two generations; the primary calcite is a dark-colored variety which on decomposition apparently yields manganese oxides and masses of sparkling white crystals and small veinlets of secondary calcite. Barite also occurs as visible crystals in the ore, and as shown in the analysis barium is a considerable constituent of the ore and in part probably is in chemical combination in the psilomelane.

The depth of oxidation is not known, as the deepest workings are but 6 feet beneath the surface. It is apparently shallow, for in places the black calcite, the source of the manganese oxides, is only partly decomposed.

The ore is sorted by hand. Analyses of the ore shipped supplied by Mr. Chamberlain gave the following results: Manganese, 40.75 per cent; iron, 0.82 per cent; silica, 3.37 per cent; phosphorus, 0.37 per cent. A more complete analysis, also obtained from Mr. Chamberlain, gave in addition $CaCO_3$, 15.12 per cent; $MgCO_3$, 2.75 per cent; and BaO, 13.14 per cent.

The veins are small, and they pinch and swell. Whether they persist beyond the limits of the hill in which they crop out has not been determined, for a deep detrital plain surrounds the hill. The ore shoots range from a few feet to 125 feet in length and have an average width of 6 inches. On the assumption that the oxidized ores extend to a depth of 25 feet about 250 tons of ore containing 40 per cent of manganese could be won from these deposits.

SANTA CRUZ COUNTY.

44. *Hardshell mine.*—The Hardshell group, comprising 42 claims, is on the easterly slope of the Patagonia Mountains, about 1 mile southwest of Harshaw. The ore deposit was discovered in 1879, and it has produced a large amount of lead-silver ore. Within late years the deposit had not been worked for its lead and silver, but the occurrence of manganese oxides in the Hardshell mine and in outcrops on several of the claims has induced the managers to reopen the mine.

On April 30 and May 1, 1918, the writer made a brief examination of the outcrops and such of the workings in the Hardshell mine as were accessible.

The deposit lies at an altitude of 4,350 feet, at the foot of the steep southerly slope from Table Mountain, the summit of which is 6,145 feet above sea level. From the foot of Table Mountain southward for several miles an area of dissected igneous rocks of moderate relief is succeeded by gently sloping bench land to San Pedro Valley, whose altitude at Mammoth is 2,348 feet. None of the arroyos draining to San Pedro Valley contain permanent streams, but near the manganese deposit a spring issues from the quartzite and flows for a short distance down the arroyo.

The climate is arid, and the average rainfall is probably less than 10 inches a year. A few trees and shrubs grow in the arroyos, and the hill slopes support several varieties of cactus and grasses.

Gravel, clay, and angular detritus compose the gently sloping bench. These deposits are succeeded by granite, diorite, and schists to the base of Table Mountain. Quartzite, limestone, and metamorphosed igneous rocks compose the lower part of the southerly slope of Table Mountain and are overlain by dark-colored horizontal lava flows that are probably of Tertiary age. The older igneous and sedimentary rocks are intimately folded and faulted, and no detailed geologic mapping of them was attempted.

The Hardshell mine is in a gulch at an altitude of 5,150 feet. The hills in the immediate vicinity of the mine rise from 300 to 400 feet above it, but a mile to the south American Peak stands at an altitude of about 6,200 feet. Manganese minerals crop out in several places on the claim group between the mine and the summit of a hill half a mile south of the mine.

Hardshell Gulch contains no permanent stream, although at its mouth water stands 10 feet below the surface. No records of the rainfall are available, but it is probably not less than 10 inches a year, and it is sufficient to support a good growth of oak, juniper, and walnut trees and several varieties of grasses.

The mine is accessible by a good wagon road 9 miles long, which leads to Patagonia, on the El Paso & Southwestern Railroad.

The geology and ore deposits of the Santa Rita and Patagonia mountains have been described by Schrader and Hill.[1] The rocks which underlie the Hardshell group of claims are limestone, quartzite, conglomerate, and intrusive rhyolite and felsite.

The boundaries of the different types of rock are most irregular, owing to faulting and the manner in which felsite and rhyolite are intruded in the beds of quartzite and limestone. In the Hardshell

[1] Schrader, F. C., and Hill, J. M., Mineral deposits of the Santa Rita and Patagonia mountains, Ariz.: U. S. Geol. Survey Bull. 582, 1915.

mine rhyolite and felsite are the dominant rocks, but there are also beds of quartzite and limestone. In the field it is difficult to distinguish quartzite from felsite. On the hill south of the mine a body of massive blue limestone is sharply delimited on two sides by masses of quartzite, conglomerate, and rhyolite. The limestone is of Devonian age, and the quartzite is probably of Paleozoic age but can not be definitely assigned to any period. The rhyolite and felsites are Tertiary.

The Hardshell mine explores a shear zone which strikes northeast and dips northwest at angles varying from a few degrees to 35°. The developments consist of an inclined shaft 600 feet deep on the dip of the ore body and drifts on several levels which extend about 200 feet east of the incline and about 75 feet west of it. The workings attain a vertical depth of 250 feet. Water now stands in the shaft to the 325-foot level, or 160 feet from the surface, and most of the workings were inaccessible at the time of visit.

The shear zone ranges from a few feet to 60 feet or more in width, and the ore deposits occur rather irregularly in it but with a persistent vein along its footwall. The material of the shear zone is greatly crushed quartzite, rhyolite, felsite, a persistent band of kaolinized material, and the ore, consisting of lead carbonate and subordinate galena associated with iron and manganese oxides. The iron and manganese oxides are generally separate. In some places the manganiferous ore is 6 feet wide and is fairly persistent, but elsewhere it occurs in irregular bunches and stringers and in nodular masses disseminated in kaolinized material. Oxidized lead ore is intimately associated with the manganese deposits, and near the surface some pyromorphite occurs also. The manganese oxides are pyrolusite, psilomelane, and braunite. Most of the ore is hard, and it can be separated, though rather imperfectly, from the gangue minerals by mechanical means. An analysis of the manganese concentrates is said to yield about 42 per cent of manganese, 15 per cent of silica, and a little iron and phosphorus, but the ore contains also about 15 ounces of silver to the ton, from 10 to 15 per cent of lead, and about 2 per cent of copper. The silver and lead are lost when the ore is smelted for its manganese content.

Manganese oxides occur as the cementing substance of quartzite and felsite breccias in several places in Hardshell Gulch south of the Hardshell mine. In places the solid ore is 6 inches wide, but most of it is in narrow seams in the fractured rock. Braunite and psilomelane are the most prominent oxides. A few shallow holes have been driven on these outcrops.

The manganese deposit on the crest of a small hill half a mile south of the mine is developed by four shafts from 6 to 50 feet deep.

These shafts roughly mark the outline of a brecciated zone in limestone 300 feet long and from 50 to 100 feet wide. The rocks are greatly brecciated and contain numerous seams of manganese oxides where pits have been sunk, but it is not known how generally the mineralization extends across the brecciated zone. Samples from these shafts are said to have yielded from 22 to 38 per cent of manganese and 8 ounces of silver to the ton. Most of this material would have to be concentrated in order to make a shipping product.

The depth to which manganese oxides extend is not known, but they have been reported in the deepest workings of the Hardshell mine, which are 250 feet below the surface. Water now stands at a vertical depth of 165 feet, so the manganese oxides extend a considerable distance below the water level. It is believed that the manganese oxides do not extend as deep below the numerous outcrops on the Hardshell group as in the Hardshell mine, because they are in poorly defined shear zones that do not offer a medium for circulating waters like the Hardshell fissure.

The total reserves of manganiferous material indicated in the Hardshell fissure and in deposits that crop out at several points on the claim group aggregate many thousand tons, but the utilization of this material will be dependent on the continuity of the high prices for manganese ores that prevailed during the summer of 1918 and its adaptability to some form of concentration or other process of beneficiation.

YAVAPAI COUNTY.

45. *Bunker & Burmeister claims.*—The manganese claims owned by Bunker & Burmeister are near the junction of Sycamore Creek with Agua Fria River, 12 miles southeast of Mayer, the nearest shipping point, on a branch line of the Atchison, Topeka & Santa Fe Railway. The claims are readily accessible by wagon road. In 1917 30 tons of ore was shipped, the returns of which were as follows: Manganese, 44.56 per cent; iron, 0.92 per cent; silica, 6.77 per cent; phosphorus, 1.23 per cent. Work was being done in a number of shallow holes on the claims at the time of examination in September, 1917, and several tons of ore was stacked on the dumps. The nature of the deposit makes any estimate of ore reserves uncertain, but the quantity is believed not to exceed a few hundred tons.

The deposits lie in a bench that rises 75 feet above the river, whose altitude at this point is 3,500 feet above sea level. The dominant rocks of the region are schists and intrusive igneous rocks, but the low-lying country through which Agua Fria River flows is largely covered with basalt. The deposits occur as nodules in sand asso-

ciated with magnesian travertine in which there are bands and nodules of a waxy white and yellow chert. The travertine[1] is said to merge horizontally into a volcanic agglomerate with calcareous cement, which is overlain by the basalt. The nodules and small masses of manganese ore so far extracted have come from depths of not more than 6 feet. There are few surface indications of the occurrence of ore except for an occasional piece of float, and the ore bodies are found by digging shallow holes indiscriminately in the sand and chert formation. Some of the ore is attached to the travertine or occurs as nodules in weathered cavities of the travertine. The ore is psilomelane in vesicular or botryoidal form. It generally lies in horizontal lenses, the largest of which was reported to be 2 feet thick. One body 6 feet long and 1 foot thick was exposed in a pit at the time of examination, and leading into it above and below were several stringers or feeders of manganese ore, some of which were vertical and some slightly inclined. The manganese oxides are not associated with iron oxides, and the ore is readily sorted to a high-grade product.

The source of the manganese is not known, although its association with the travertine suggests that it was deposited by the same agencies, namely, from springs. The only other source of the ore that appears probable is water which percolated through overlying rocks and collected manganese from the decomposition of manganese-bearing minerals which they may have contained. The basalt may contain minerals carrying small quantities of manganese to fulfill these conditions, but no analyses of it are available.

About a mile west of the Bunker & Burmeister claims, on the opposite side of Agua Fria River, two claims owned by E. V. Bunker and E. S. Rogers are situated similarly to those above described, on the bench land overlooking the river and associated with travertine in sand and clay beds. No ore had been shipped from the property to the time of visit, but several tons were on the dumps of the several shallow holes. Assays of the ore are said to have yielded 55 per cent of manganese, with little or no impurities.

46. *Castle Creek deposit.*—The Castle Creek manganese deposit, owned by J. B. Girand and R. A. Craig, of Phoenix, Ariz., and C. E. Champie, is about 23 miles northeast of Hot Springs Junction, a station on the Atchison, Topeka & Santa Fe Railway. The deposit was recently discovered, and the development work on it consists of a few open cuts and short tunnels. No ore had been shipped from the deposit to the time of visit, September 13, 1917, but there was about 40 tons of high-grade ore on the dumps and loading platform. A wagon road, formerly in good repair but now badly washed in

[1] Jaggar, T. A., jr., and Palache, Charles, U. S. Geol. Survey Geol. Atlas, Bradshaw Mountains folio (No. 126), p. 3, 1905.

places, goes from Hot Springs Junction to Castle Hot Springs, on Castle Creek, a short distance southeast of the deposit. From the road a trail 1 mile long leads to the manganese deposit, which is at an altitude of 2,800 feet, or 600 feet above the road at the point where the trail begins.

Granite and granite gneiss are the rocks that inclose the deposit. Pegmatite veins and masses in which large, well-developed hornblende crystals are conspicuous are abundant along the trail. Lava flows which overlie granitic and metamorphic rocks are prominent along Castle Creek.

The manganese ore occurs in fissure veins in the granite and granite gneiss. Two veins are developed on the property. One strikes N. 70° W. and is vertical, and the other strikes N. 20° W. and dips 70° W. Each vein averages about 1 foot in width, and as exposed by the developments the ore shoots are respectively 50 and 75 feet long. A short tunnel driven on one of the fissures below an open cut gains a depth of 40 feet, but at the face the ore is a mere stringer inclosed in sheared granite.

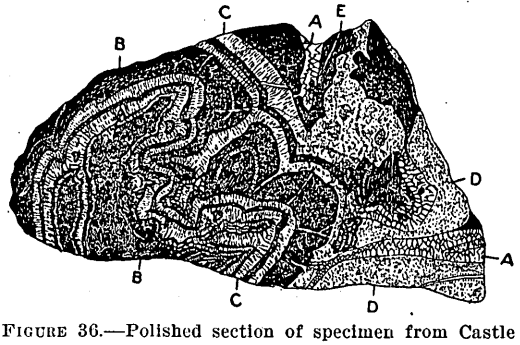


FIGURE 36.—Polished section of specimen from Castle Creek mine, Yavapai County, Ariz. A, Calcite; B, psilomelane; C, manganite; D, finely crystalline pyrolusite; E, Expansion crack.

The ore consists of psilomelane, manganite, and pyrolusite deposited in nodular and botryoidal crusts and masses. Calcite is very abundant in the ore, and nodular masses composed of concentric layers of manganese oxides are commonly incrusted with sparkling calcite crystals. Along parts of the vein on the surface botryoidal crusts of psilomelane are on the walls of the fissure. A polished section of a part of the nodule of ore (fig. 36) shows some very interesting structure. The nodule is apparently made up of many composite bands of the oxides about different nuclei. Bands from one nucleus may coalesce with bands from another, resulting in an extremely irregular pattern with deep indentations. Some concentric growths of manganese oxide appear to have been interrupted by fracturing and the deposition of calcite. The bands are irregular in thickness, and in the polished specimen a band composed mainly of psilomelane is from one-sixteenth to one-third inch in thickness. This band is bordered by bands of manganite in small fibers about one-eighth of an inch thick and in part of the specimen by finely granular material believed to be pyrolusite, which may result from

the alteration of manganite. In the psilomelane band are discontinuous films of pyrolusite in microscopic grains. In the broader parts of the psilomelane band several minute fractures extend through the band but stop at the bordering bands of manganite and pyrolusite. These fractures have subsequently been filled with calcite, and calcite has also been deposited in the interstitial spaces between concentric growths about different nuclei. The fractures in the psilomelane bands are believed to have been produced by contraction of the bands of psilomelane possibly before the succeeding deposition of manganite. Other fractures extend through thin bands of psilomelane into bordering bands of manganite, but the fracture in the crystalline material is sharply deflected from its course in the psilomelane and indeed may extend nearly parallel with the manganite bend but not go through to the opposite wall of the next psilomelane band. The chemical and physical conditions which caused the deposition in alternating bands of manganite, pyrolusite, conditions will cause a change in deposition from one mineral to and psilomelane are not known, but apparently a slight change in another. The original source of the manganese oxides is not apparent in the veins as far as the workings extend, but the abundance of calcite deposited in and about nodules of ore indicates that manganese oxides were derived from manganiferous calcite or were deposited with calcite.

Probably not more than 500 tons of ore could be produced from the two ore shoots thus far discovered on this property. The ore is, however; of high grade, containing about 50 per cent of manganese and very little iron.

47. *Hatton group.*—The Hatton group of manganese claims, 9 miles northwest of Aguila, is in the Aguila district (see pp. 135–143), though it lies in Yavapai County, whereas the other manganese deposits of the district are in Maricopa County. The principal workings of the Hatton claims are near the base of a small outlying hill of the Harcuvar Mountains, at an altitude of 2,500 feet above sea level. The hill is composed of red sandstone which strikes northwest and dips about 30° SW. The deposit occurs in a well-defined fault fissure which strikes N. 60° W. and is generally vertical. The fissure is explored through a distance of 400 feet by a number of open cuts and at one point by a shaft 40 feet deep, from which at a depth of 20 feet are short drifts. The largest ore body thus far exposed is 50 feet long and 3 feet wide. The ore is for the most part composed of soft amorphous manganese oxides inclosing small bunches of short prismatic crystals of manganite. Small cavities in the ore are lined with minute filaments of a soft black lustrous manganese oxide which may also be manganite. The ore is apparently a decomposition product of black calcite with its contained manganese oxides. In parts of the vein black calcite and barite show banded

structure. Barite predominates in the vein near the bottom of the shaft. A few stains of copper salts were noted in the vein material. The best ore was obtained near the surface, and the limit of commercial ore in depth as shown in the shaft is about 35 feet. The ore is screened and hand sorted in order to obtain a product said to contain 38 per cent of manganese. Between August, 1917, when production began, and April, 1918, when operations ceased, the mine produced about 600 tons of ore. It was reported that the greater part of the ore has been mined from the deposit.

YUMA COUNTY.

48. *Iron King group.*—The Iron King group of 4 manganese claims is in Yuma County about 26 miles north of Bouse and 4 miles from the Planet mine. The nearest shipping point is Midway, 12 miles to the southeast, on the Arizona & Swansea Railroad, which is accessible by a good wagon road. The deposit has been known and located for several years. It is said to be owned by Harry Hanna, from whom Charles Flynn secured an option. One carload of ore is said to have been shipped in 1916, but none has been shipped since that time, and the property was idle at the time of visit, May 19, 1918.

The deposit occurs in an area of moderate relief marked by ridges and isolated peaks that rise a few hundred feet above the plain sloping to the south and the detritus-filled washes or arroyos between the hills. The principal shaft is at an altitude of 1,350 feet, on the slope of a hill whose summit is about 200 feet higher. The mountainous area is drained by washes which flow to Williams River, about 4 miles to the north, and to Cactus Plain, on the south. None of the washes contain water except after heavy rains, and the nearest source of supply is Williams River. The rainfall is probably not more than 5 inches a year in this region, and the vegetation is very scanty except along Williams River, where cottonwood trees and abundant mesquite grow.

The rocks in the vicinity of the deposit consist of an older series of granite gneiss overlain by bands of limestone and amphibolite, massive limestone, quartzite, and metamorphosed shales; and a younger series of sandstone, calcareous sandstone, and detritus and wash material. The older rocks are probably pre-Cambrian; the younger rocks range from late Tertiary to Pleistocene. The manganese deposit is contained in sheared rocks along a fault zone, which strikes N. 45° W. and apparently dips southwest. The fault marks the contact between conglomerate and wash material on the northeast or footwall side and silicified and serpentinized limestone and quartzite breccia on the hanging wall, in which the manganese

minerals occur. Overlying these rocks on the hanging-wall side a short distance to the southwest is red sandstone, in part calcareous, which strikes N. 60° W. and dips 30° SW. It is much younger than the underlying rocks and is very similar to rocks noted along the bench or mesa lands north of Williams River in the vicinity of Alamo. The zone of brecciation along this fault is 100 feet wide in places, and for a distance of 1,000 feet the rocks are generally iron stained, but the occurrence of manganese minerals is limited to a few so-called "blowouts," the largest of which is about 50 feet long and 20 feet wide. The deposits have been explored by short tunnels and a shallow shaft, in all about 125 feet of development work. The mineralized material of the "blow-outs" or chimneys is silicified limestone and quartzite, impregnated with iron and manganese oxides and cut by seams an inch or less in width of long fibrous manganite crystals. In some of these seams barite crystals are developed about projecting needles of manganite. Barite veins several inches wide are numerous, and hematite, calcite, and quartz are other accompanying minerals of the deposit. The deposit as a whole probably contains 15 per cent of manganese, 15 per cent of iron, and at least 40 per cent of silica. It was stated that a carload of sorted ore shipped in 1916 contained about 30 per cent of manganese and was high in silica. The material is not amenable to mechanical concentration except as it might be possible to separate the manganite crystals. The depth to which oxidation extended in this deposit has not been determined, and none of the original manganese minerals that gave rise to the manganese oxides were observed. The deposit has no value under present conditions.

49. *Dobbins claims.*—Two claims owned by J. M. Dobbins are in the Granite Wash Hills 6 miles east of Bouse. A poorly defined road follows an arroyo to a point within half a mile of the deposit and could be made serviceable with little expenditure. The claims were located in April, 1918, and at the time of visit (May 19) the deposit was being worked and about 30 tons of ore was stacked on the dump.

The deposit lies in low hills at an altitude of 1,350 feet above sea level, and the local relief is not more than 100 feet. There are no streams or springs in the vicinity. The region is drained to Bouse Wash by arroyos that carry off the infrequent flood waters following heavy storms. The rainfall is probably the same as at Parker, where the average is about 5 inches a year. Ironwood, paloverde, and mesquite grow along the arroyos, and several varieties of cactus are found abundantly in the hills.

Tertiary lava flows composed principally of a red biotite andesite are the dominant rocks in the vicinity of the manganese deposit. They are flanked or more or less covered by angular débris. A shear

zone in andesite which trends S. 65° W. and dips steeply northwest contains the manganese deposit. This zone can be traced for 1,000 feet or more, but the manganese deposits in it are apparently local, and only one ore body of importance has been discovered. A hole 10 feet deep was dug at a point where manganese float was abundant, and an ore body 25 feet long and 2 feet wide was disclosed. The manganese oxides are psilomelane and pyrolusite, which occur as the cementing material of breccia and which replace in part the andesite fragments. Psilomelane is more abundant at the surface, but at depths of a few feet pyrolusite predominates. There is much secondary calcite in the ore, but no quartz except that contained in included fragments of country rock. The limit of the ore is apparently reached at a depth of 6 feet, where there are small quantities of soft pyrolusite in abundant calcite, some of which is dark colored from the inclusion of manganese oxides.

50. *Kaiserdoom claims.*—The Kaiserdoom claims, which were located May 2, 1918, by W. M. Whipple and L. M. Watson, are in the NW. ¼ sec. 21, T. 11 N., R. 11 W., in the bench land on the south side of Santa Maria River. Congress Junction on the Atchison, Topeka & Santa Fe Railway, 33 miles to the east, is the nearest shipping point, but at least 3 miles of new road must be built before ore can be shipped.

The bench land on the south side of Santa Maria River rises from 100 to 250 feet above the bottom lands. It is composed (see fig. 37)

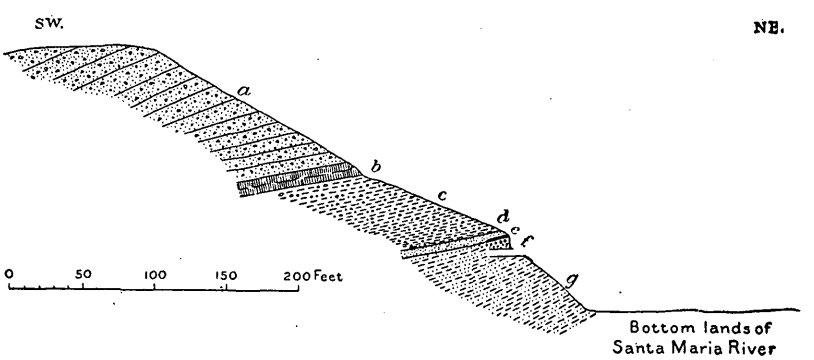


FIGURE 37.—Section of bench land along south side of Santa Maria River, Yuma County, Ariz.: *a*, Loose gravel and conglomerate; *b*, basalt flow; *c*, volcanic ash; *d*, grit; *e*, manganese ore; *f*, manganiferous clay; *g*, shale.

at the base of greenish and yellow shale, which may grade horizontally and vertically into red and reddish-brown sandstone, red clay, grit, and conglomerate. Above this series are white volcanic ash beds, a basalt flow, and then loose gravel and conglomerate beds to the top. At the top of the lower series a spring issues and a considerable stream of water flows in a waterfall 15 feet high over the grit capping of the underlying clay beds. In the lower series the

members show remarkable variations within short distances on their strike; in places the clay and shale beds grade into sandstone and arenaceous limestone. The formations strike in general northwest and dip about 10° SW.

The manganese ore occurs at the top of the lower series, in the grit member and in the clay bed which underlies it. The grit member is from 1 to 5 feet thick and the clay bed about 10 feet thick. The ore occurs for about 1,200 feet following the sinuosities of the outcrop of the grit.

The ore replaces the cement of the sand or grit by psilomelane and occurs also in layers of pure psilomelane as much as 6 inches thick in the clay below the grit and in disseminated nodules and thin sheets in the clay beds. Where explored by a short tunnel near the waterfall, the clay beds contain these nodules and sheets through a distance of 6 feet. On the top and bottom surfaces of these flat tabular masses of ore are little ridges of psilomelane that probably represent little fissures or channels in the clay beds along which the manganese solutions flowed. Limonite also occurs in these clay beds in forms similar to the manganese oxides, but it is not mixed with the manganese oxides. How far back from the outcrop the ore extends is not known, as only two small tunnels each 10 feet long have been driven in the clay bed. The source of the manganese has not been determined, but it is evident that the oxides were deposited from solutions percolating through the sandstone member into the underlying clay bed. These solutions replaced the sandstone in part, first attacking the cementing substance of the grains and then the quartz grains, but rarely was the replacement by manganese oxides complete.

In the hard psilomelane are little nests of finely fibrous and prismatic crystals that are probably manganite.

The grit that is partly replaced is much too siliceous to be smelted, but possibly a marketable product might be made by crushing and concentrating the material. The nodular and tabular ore masses in the clay are of good quality, and they contain about 45 per cent of manganese. The quantity of ore that the deposit contains can not be estimated in advance of development, but there is probably 200 tons of float ore on the property.