U. S. GEOLOGICAL SURVEY

Copper and Zinc Deposits in the Reward Area

Casa Grande Mining District, Pinal County, Arizona

by

J. B. Hadley and H. H. Sullwold, Jr.

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ABSTRACT

The Reward mine, largest copper producer in the Casa Grande mining district, Pinal County, Arizona, produced about 400,000 pounds of copper between 1885 and 1929. Zinc deposits, found nearby in the early exploration of the area, were never worked but have again come to attention because of the current metal shortage. The present geological study was carried on late in 1942 as part of the emergency war minerals program in conjunction with an exploratory project by the U. S. Bureau of Mines on the zinc deposits.

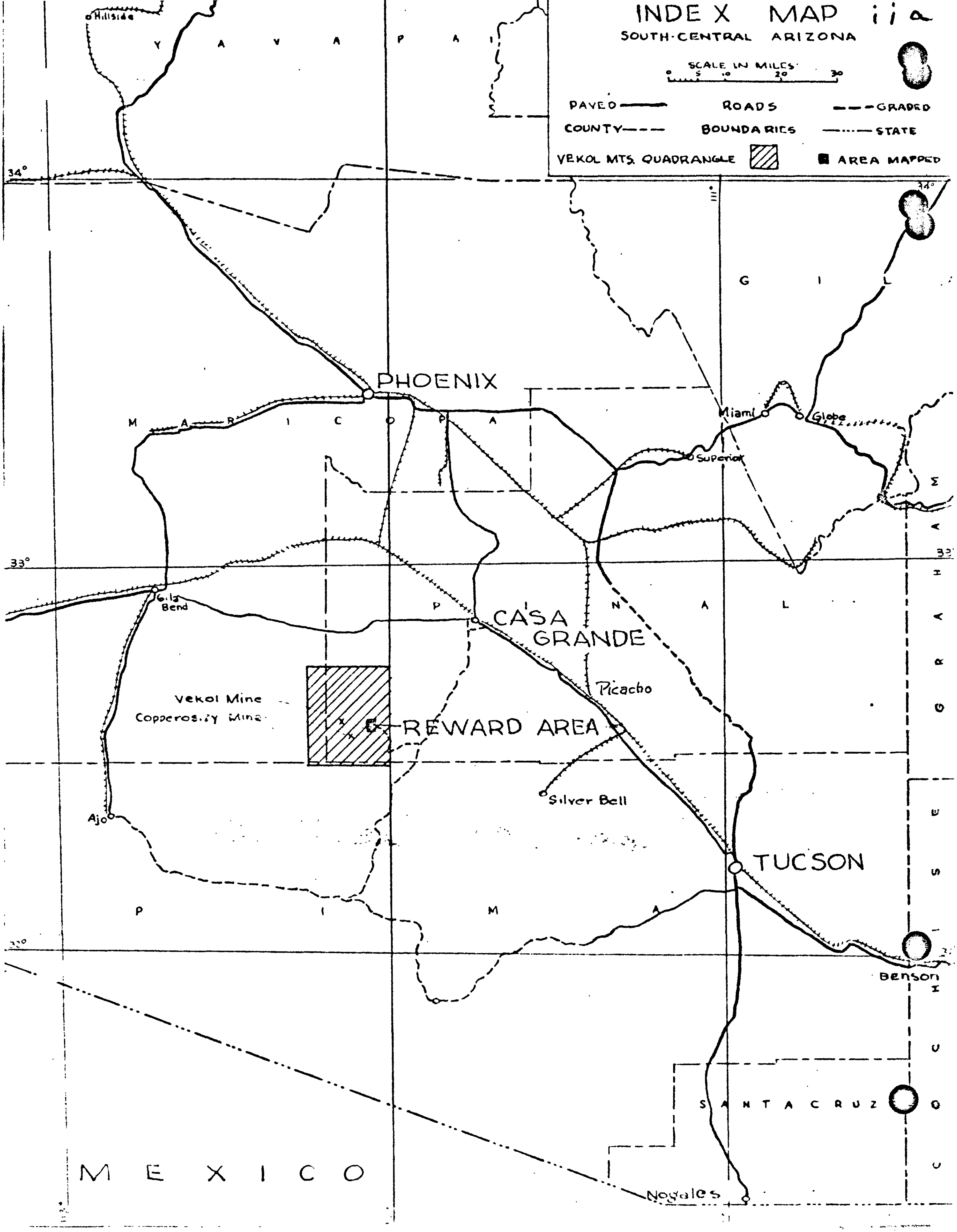
The deposits occur in Paleozoic limestone beds strongly tilted and offset by transverse faults. The deposits are localized along fractures and favorable limestone beds, generally near the principal faults. Copper production came from oxidized material containing abundant hematite and veinlets of malachite. Zinc occurs largely as iron-rich sphalerite with abundant pyrrhotite, pyrite, some chalcopyrite, and lime-magnesia silicates. The mineralogy of the deposits, along with effects of contact metamorphism in the nearby sedimentary rocks, suggests that the deposits are a high-temperature type not far from an unexposed parent igneous body.

At the Reward copper mine, most of the ore came from a single body, 3 to 5 feet thick, 25 to 80 feet wide and 500 feet long, in an extensively garnetized limestone bed. About 2500 tons averaging 8 percent copper is estimated to have been removed, and the mine is now exhausted.

The zinc-bearing area, one-half mile south of the Reward mine, is largely unprospected. Some of the deposits are small, tabular bodies of 2000 tons or less, scattered 100 or more feet apart near a steeply dipping felsite dike. In a 300-foot shaft at one end of this belt, two sulfide bodies carrying 12 to 20 percent zinc were encountered, but little exploratory work has been done on them. In an adjoining area about 300 by 500 feet, bedding veins 3 to 5

feet wide and 100 to 400 feet long at the surface are connected with shorter veins along transverse fractures. Three core-drill holes had been completed by the U. S. Bureau of Mines in this area by February 1, 1943, They indicated that although most of the exposed bedding veins do not extend to the sulfide zone, 250 feet from the surface, smaller, more irregular bodies of iron and copper sulfides are present. Some of these bodies may be bedding veins, and might contain as much as 10,000 tons; most probably contain a few thousand tons or less. The best of the sulfide deposits encountered by drilling contains 17.8 percent zinc and no copper. The maximum copper content was estimated to be 3.5 percent with no zinc. Other sulfide bodies of lower grade contain either zinc alone or both zinc and copper. The oxidized bedding veins that have been sampled contain locally as much as 10 percent zinc; but oxidized fissure deposits show little zinc or copper.

Reserves of copper in the Reward area consist of a few hundred tons of oxidized ore, containing possibly 3 percent copper, left in the Reward mine. Geologic evidence in an adjoining, partially prospected area indicates that another oxidized body might be found comparable to the body already mined. It might contain two thousand tons of 7 percent copper ore. In the zinc-bearing area, 1500 tons of 15-percent zinc-sulfide ore is indicated in the shaft, and 2000 tons of somewhat lower grade may be inferred. Probably not over 50,000 tons of zinc-sulfide deposits exist in the area. It is believed that these deposits are small and widely scattered, and that the costs of exploration and development would be relatively high.


INDEX MAP iia
SOUTH-CENTRAL ARIZONA
SCALE IN MILES
0 5 10 20 30
PAVED ROADS GRADED
COUNTY BOUNDARIES STATE
VEKOL MTS. QUADRANGLE
AREA MAPPED
Hillside
Y A V A P A I
34°
G I L
PHOENIX
M A R I C O P A
Miami
Globe
Superior
33°
Gila Bend
P N A L
CASA GRANDE
Picacho
Vekol Mine
Copperosity Mine
REWARD AREA
Silver Bell
Ajo
TUCSON
P I M A
32°
Benson
S A N T A C R U Z
M E X I C O
Nogales

INTRODUCTION

The Reward area lies in the southwest part of the Casa Grande mining district in southwestern Pinal County, Arizona. It occupies an area somewhat less than a square mile among outlying hills at the edge of a wide alluvial basin bordering the Vekol mountains on the northeast. The topography and culture of the surrounding region is shown on the Vekol mountains quadrangle map of the U. S. Geological Survey (fig. 1). The nearest settlement is the Papago Indian village of Quajote or Kohatk, three miles distant by level, unimproved desert road. The town of Casa Grande, on the Southern Pacific railroad, is 33 miles farther northeast by improved gravel road and is the nearest trading center and shipping point.

There is no surface water in the area, but a limited amount of water can be obtained from wells 20 to 50 feet deep. A six-inch drilled well at the Reward mine reaches permanent water 350 feet below the surface, but its capacity is not known. The most readily available source of water is the community well at Kohatk.

The principal mine in the area is the abandoned Reward mine. Discovered in the early 1880's, it is reported to have produced, between 1885 and 1929 inclusive, 400,000 pounds of copper valued at $70,000 1/. Between 1885 and 1903 considerable oxidized ore was mined and smelted at the mine; later shipments to 1917 were sent to El Paso, Texas and Hayden, Arizona. The last shipment, in 1929, consisted of one car of ore and 1000 tons of old slag, both from the Reward dump. The mine and several surrounding claims are owned by Kimball Pomeroy and Dr. H. L. Schorneck of Phoenix, Arizona, and Mrs. B. P. Gibson of Mesa, Arizona.

The 300-foot Phonodoree shaft was sunk on the Reward group of claims in the 1880's. It encountered zinc sulfide bodies but no shipments have been made. In the last half of 1942 the shaft was retimbered and exploration carried on at the 300 level by the owners of the Reward mine, under a loan from the Reconstruction Finance Corporation.

The only other productive mine in the vicinity is the Christmas Gift mine (plate I) at which $50,000 in gold and a little lead was produced from shallow workings in 1883-85.

Field work in the area was done in October and November, 1942, by J. B. Hadley and H. H. Sullwold, Jr. under the supervision of N. P. Peterson, all of the Geological Survey, U. S. Department of the Interior. The work included detailed mapping of an area approximately 2000 feet by 5000 feet in the vicinity of the Reward

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1/ Elsing, M. J. and Heineman, R. E. S.: Arizona Metal Production, Arizona Bureau of Mines Bull. 140, 1936, p. 99.

mine and Phonodoree shaft and underground mapping of the principal workings. In November a sampling and core-drilling project by the U. S. Bureau of Mines got under way and to February, 1943 considerable time was spent by the Survey party in cooperation with the Bureau's work. Acknowledgment is made for the use in this report of transit-survey data and assay data generously supplied by the Bureau. The helpful cooperation of Mr. H. K. Grove, superintendent of operations at the Phonodoree shaft, and of Professor A. A. Stoyanow of the University of Arizona who kindly identified several of the fossils collected, was much appreciated.

GEOLOGY

The rocks exposed in the area consist of about a thousand feet of sedimentary rocks, ranging from Cambrian to Mississippian in age, overlain by more than two thousand feet of coarse clastic and volcanic rocks presumably of Cretaceous age. These rocks form a series of hogback ridges trending north-south. Transverse faults, on which the strata are offset by several hundred feet at some places, are largely concealed by alluvial basin deposits surrounding the ridges. The sedimentary rocks are intruded by many dikes and sills of fine-grained igneous rocks, ranging from diorite porphyry to quartz porphyry, and in part of the area the beds have been affected by thermal metamorphism.

Sedimentary and volcanic rocks

The age, thickness, lithological character, and succession of the stratified rocks are summarized in table 1. Their areal distribution is shown on plates I and II.

Although fossils were found at several horizons in the Paleozoic rocks in the vicinity of the mines, they were not sufficient to establish satisfactory correlations of all the beds with the type sections in Arizona. The correlations adopted therefore are based in part on fossil evidence, and in part on lithologic character as compared with descriptions of nearby areas. Formation boundaries shown on the maps were selected principally for convenience in mapping. A group of five beds so used, about 190 feet above the base of the Mississippian, have weathered in distinctive dark gray and tan colors. As these beds are stratigraphic guides in the mineralized area, they are indicated on the geologic map as the "black and tan" beds.

No attempt was made to map most of the coarse clastic and volcanic rocks. Fossils are largely absent, although several unidentified tree trunks were found in sandy conglomerate several hundred feet above the base of the formation. The beds are older than the principal faults in the area. On the basis of their lithology and general stratigraphic relations, these beds are tentatively correlated with rocks held to be of Cretaceous age in southern Arizona.

Intrusive igneous rocks

The oldest and most abundant intrusive rocks in the area are dense-textured, greenish gray or pinkish rocks characterized generally by small hornblende needles and small white or pink feldspar phenocrysts. Well-shaped biotite crystals occur locally. The rock was classed in the field as diorite porphyry or hornblende porphyry. It forms dikes and sills in the Cretaceous beds and dikes in the Paleozoic rocks in the north part of the area. The presence of hornblende porphyry as fragments in volcanic breccia interbedded with the coarse clastics, suggests that these are of contemporary age.

Other intrusive rocks consist of quartz porphyry, felsite and diabase. Quartz porphyry is a dense-textured rock with abundant small, well-shaped crystals of quartz and white feldspar. It appears in the mapped area as a single dike 60 feet thick and 1700 feet long, dipping 60 degrees southeast. At least one other larger body occurs about a mile southwest of the Phonodoree shaft. The quartz porphyry cuts the Cretaceous (?) rocks and the hornblende porphyry sheets, and is considdred to be possibly of Tertiary age.

The Felsite is a dense-textured, greenish gray rock, generally with a few small, indistinct plagioclase phenocrysts. Epidote in small amount and tiny grains of iron sulfide are the only dark minerals visible with a hand lens. The felsite forms an irregularly connected group of steeply inclined dikes extending for a total distance of 1800 feet northeast and southwest from the Phonodoree shaft; it was also encountered in core drill holes below the Bat tunnel and near the George shaft. These dikes cut the Paleozoic limestones and the Cretaceous (?) rocks, but their relations to the other intrusives of the area could not be seen.

Diabase does not outcrop in the Reward area, but it is present with Cambrian quartzite in vertical core drill hole No. III near the George shaft. It is probably related to diabase sills reported intruded into Paleozoic strata in the central and western Vekol Mountains.

Structure

The sedimentary rocks in the Reward area dip west to northwest generally 30 to 45 degrees, although both flatter and steeper dips occur especially where the beds have been affected by faulting. Many high-angle transverse faults are present, most of which are normal faults and offset the beds less than a hundred feet. Three major faults, the Reward, Bat Tunnel, and Phonodoree faults (see pl.2) have stratigraphic displacements of several hundred feet. Movement on the Bat Tunnel fault produced much steepening and horizontal drag as well as fracturing and subsidiary faulting in the adjacent beds. One short strike-fault with displacement of about 30 feet is followed by a felsite dike northeast of the Phonodoree shaft.

At least two distinct periods of faulting occurred, for some northerly trending faults are offset by faults of westerly trend. Both westerly and northerly faults displace the Cretaceous (?) beds in several places.

Apparently a slight angular unconformity exists at the base of the Cretaceous (?) in the area, for these beds dip generally 5 or 10 degrees less than the Paleozoic beds. This unconformity is also shown by the fact that about 130 feet of Mississippian beds, present a mile north of the Reward mine, are absent due to erosion in the vicinity of the mine.

Metamorphism

Thermal metamorphism of the calcareous rocks is conspicuous on the hillside north of the Phonodoree shaft (plate II). Nearly all the limestone fragments in the conglomerate on this hill have been altered to garnet, chlorite, and coarse calcite, and much of the sandy matrix is replaced by epidote or garnet. The alteration has made the conglomerate here relatively resistant to erosion, for elsewhere it is generally eroded lower than the limestone beds. In addition, the uppermost 5 to 20 feet of the Mississippian limestone is continuously replaced by coarse yellow garnet, chlorite, specularite and quartz for half a mile north of the Phonodoree shaft. Limestone is also commonly altered to garnet or other lime silicates at or near the felsite dike. Because core drilling in limestone beds east of the north end of the quartz porphyry dike showed increased metamorphic effects as the dike was approached, it may be that the metamorphism is related to the quartz porphyry as well as the felsite.

Ore Deposits

The ore deposits of the area are located principally in the vicinity of the Reward mine and George shaft and in an area about 300 feet wide and about 2000 feet long between the Bat tunnel and the Phonodoree shaft. The deposits are localized along faults and fissures in limestone and along favorable beds in Mississippian and Devonian(?) limestone (see footnote to table 1). Three kinds of deposits are present: zinc-copper sulfide deposits in the Bat tunnel - Phonodoree area, oxidized copper deposits in the vicinity of the Reward mine, and oxidized zinc deposits in the vicinity of the Bat tunnel.

Sulfide deposits

The most common sulfide deposits contain zinc and iron sulfides in a ratio of about 1 to 2, generally with small amounts of chalcopyrite. The zinc sulfide is black, iron-rich sphalerite (Marmatite) estimated to contain about 50 percent zinc and 12 percent iron. Iron sulfides include pyrrhotite and generally a smaller amount of pyrite. These minerals occur in grains 1 to 5 millimeters across, either massive or coarsely disseminated in gangue. Chalcopyrite, sparingly present at the Phonodoree shaft, is more abundant in samples from core drill holes below the Bat tunnel, where it appears either with sphalerite and iron sulfides or without other sulfides. Magnetite, largely without sulfides, is locally associated with the deposits; it occurs with serpentine in irregular lenticular masses and narrow bedding veins in dolomitic limestone.

Gangue minerals consist largely of lime and magnesia silicates derived from the limestone host rock. In most of the deposits, diopside, tremolite, and talc abound. In the larger, richer bodies the gangue consists of fine-grained, dark green mixtures of chlorite and serpentine. Granular, honey-yellow garnet is abundant in some mineralized beds, but it is not common in fissure deposits.

The deposits range from more or less regular veins to erratic bodies with irregular outlines. Replacement seems to have been the dominant mode of deposition, controlled by faults and associated fractures, joint systems, and bedding. The most regular bodies are those deposited in favorable beds; one such body in the Reward mine maintained a more or less uniform thickness of 3 to 5 feet for a length of 500 feet, and another near the Bat Tunnel could be traced for 400 feet. Most bedding veins extend probably less than 200 feet. Bodies along fractures are less regular, the width varying markedly with changes in the wall rock; in unfavorable wall rock, well-mineralized veins commonly become abruptly tight and barren. The most extensive of the known deposits occur in fractured and faulted ground near the Bat Tunnel and Reward faults. The Reward fault is mineralized locally, though no important deposits are known along it. In the Bat tunnel - Phonodoree area the structural control seems to have been steeply dipping faults and fractures either parallel to the felsite dike or located near the hanging wall of the Bat Tunnel fault.

Origin of sulfide deposits

The presence of garnet, diopside, magnetite, specularite, and pyrrhotite with the deposits suggests that they were formed at relatively high temperatures, not far from a parent igneous body. If this is true, the sulfide deposits may be genetically associated with quartz porphyry bodies in the area.

Effects of Oxidation

The upper parts of the deposits have been thoroughly oxidized. Iron sulfides have been converted to earthy hematite and subordinate limonite. Hematite is commonly soft and porous, although it may be compact and fairly hard. Limonite is generally soft and abundant in some of the disseminated zinc deposits in lime-silicate rock south of the Bat tunnel. Gangue minerals are generally masked by iron oxides, but garnet, fibrous silicates, and clay minerals derived from weathering and leaching can be recognized. The oxidized bodies are generally cavernous due to solution and leaching, and secondary gypsum and drusy calcite are commonly present.

Copper in the oxidized deposits is present principally as malachite, with subordinate amounts of chrysocolla. In the Reward mine, malachite generally fills narrow veins and forms crusts in leached material. Chrysocolla occurs as conformable lenses or discontinuous layers less than a foot thick within the leached zone. Nearly all of the original zinc has been leached from most of the oxidized veins. At several places, however, in the Bat tunnel and its vicinity, considerable amounts of zinc carbonate (hydrozincite, smithsonite, aurichalcite) and silicate (hemimorphite(?) have been redeposited on the limestone walls or have replaced limestone remnants in the veins. Lesser deposits of oxidized zinc minerals may occur in lime-silicate gangue.

The depth of oxidation varies greatly in different parts of the area. In the Reward mine and George shaft, complete oxidation extends an unknown distance below the present water table, which is 300 feet below the adjacent valley floor. In the Phonodoree shaft, complete oxidation extends only 45 feet below the collar, and the deposits are practically unoxidized below 65 feet. The bottom of the shaft, 300 feet below the collar, is dry. At the Bat tunnel, information from drill holes indicates that the deposits are oxidized generally as much as 250 feet from the surface, but that fresh sulfides occur 250 feet or more above the present water level.

LOCAL DESCRIPTIONS

The known copper ore bodies at the Reward mine have long since been mined out, and geological information about them is based on what can be seen in the walls and pillars of old stopes. In the zinc-bearing area between the Bat tunnel and the Phonodoree shaft, development has not progressed beyond the prospect stage, hence information about size, shape and distribution of the deposits comes largely from surface exposures.

Reward mine and George shaft

At the Reward mine, the principal deposits occurred in a limestone bed, 6 to 8 feet thick, which dips 18 to 30 degrees northwest. Copper ore bodies 3 to 5 feet thick and 25 to 80 feet wide occupied a zone 650 feet long. The long axis of the zone is nearly parallel to the Reward fault, which lies 100 feet north of the ore bodies. At its west end the fault splits into several branches, one of which cuts off the ore bed 650 feet down dip from the outcrop. (See fig. 3 and section D-D', plate IV). The ore bed could not be recognized beyond this fault. South of the ore bodies, the bed consists of coarsely crystalline garnet rock, in which hematite formed by the oxidation of iron sulfides is present in amounts which decrease away from the ore bodies. Copper minerals cease rather abruptly for the transition from minable ore to practically barren garnet rock generally occurs in 10 or 20 feet. On the north, the ore bodies are bounded sharply by limestone which has not been altered beyond being uniformly recrystallized and stained reddish brown. Downward the ore bed is strongly mineralized as far as the terminating fault.

In the mine, the ore bed is overlain by ten feet of magnesian limestone, characterized by dense texture, thin bedding, and gray color mottled with red, brown, or green. Immediately below the bed is 20 feet more or less of hard, white quartzite and calcareous sandstone, underlain by magnesian limestone interbedded with similar quartzite. Copper deposits occur locally in the limestone immediately below the 20-foot quartzite bed, but not in commercial amount.

Steeply-dipping fractures and faults cut the ore bed in various directions but do not displace the bed more than a few feet. Many smaller fractures that are barren in the overlying limestone are nearly obliterated in the ore bodies and may have helped to localize the ore. Stronger faults are generally barren, although they are locally mineralized at some distance from the ore bodies. Deposits in these steeply-dipping faults carry much hematite, but important copper deposits are lacking, possibly because the faults presented more favorable channels for leaching by ground water than the more gently dipping ore bed.

Primary copper deposition probably took place shortly after replacement of the favorable bed by garnet. The solutions which fed the main ore bodies probably came up along the southernmost branch of the Reward fault, near its intersection with a minor, north-trending fault exposed in the lower levels of the mine (fig. 3). They then traveled more or less up the dip of the bed, depositing copper and iron sulfides at the edge of the garnet rock. During oxidation of the sulfides most of the iron and a large part of the copper remained in the ore bodies.

The George shaft (plate II) is in a wedge between the east-west Reward fault and an older fault trending north-northwest. In this wedge the beds exposed in the Reward mine are present in much the same relation to the Reward fault and intersecting faults as in the mine, thus suggesting the presence of another ore body similar to that in the Reward mine. The vertical George shaft, said to be 400 feet deep, is without firm timber, although it can be reached at the 160 level by way of lateral workings connected with the bottom of an inclined shaft, 70 feet west-southwest of the George shaft (see section D-D', plate IV). Although at the surface the favorable bed is concealed by basin deposits in this area, it is exposed in the inclined shaft, where it dips 25 degrees northwest, and was followed by drifts for 50 feet southwest and northeast from the subsidiary shaft. The bed is mineralized and oxidized much as in the Reward mine for a thickness of 5 feet. A small amount of copper is present here and there but little ore was taken out, if any, and no further work was done in the bed. In the vicinity of the main shaft at the 160 level a little work was done on oxidized bodies as much as ten feet wide along steeply dipping faults, but almost no copper was found. The Reward fault, mineralized at the surface not far from the shaft, was not encountered in the workings, all of which are south of the fault.

It is estimated that stopes in the Reward mine yielded approximately 2500 tons of ore, from which about 400,000 pounds of copper is reported to have been recovered. On the basis of this figure, material stoped is calculated to have contained about 8 percent copper. Material now in place in the walls is estimated to contain generally less than 5 percent copper across 3 feet or more of the bed.

Bat Tunnel - Phonodoree area

Fifteen hundred feet south of the Reward mine both oxidized deposits and sulfide deposits are known, and zinc rather than copper is the dominant metal. The deposits lie in a belt 100 to 300 feet wide extending 2000 feet southwest from the Bat Tunnel fault almost to the Phonodoree fault (plate II). Deposits exposed at the surface are scattered throughout the belt, but decrease in number and size from north to south. Aside from a few short adits, the only underground workings are the Bat tunnel, 560 feet long (fig. 6 and plate II) at the north end of the belt, and the Phonodoree shaft, 300 feet deep (fig.4 and plate III, section C-C') at the south end.

The deposits occur in Mississippian limestone beds, which dip 38 to 45 degrees northwest. These beds are cut by a dozen or more minor normal transverse faults, most of which are older than the deposits. The deposits have followed different sets of structures, according to which the belt can be divided into two parts.

In the central and southern part of the belt, ten or twelve deposits, poorly exposed, occur in altered limestone within 50 feet of the felsite dike and are distributed along 1000 feet of its length. The largest of the bodies measures 10 feet wide, 60 feet long and 30 feet vertically; but some shown on the map in this region are less than two feet wide. All have steep dips either with or against the bedding, and most are elongated parallel with the dike. They appear to be replacement deposits controlled by the same set of fractures that governed the emplacement of the dike. Surface showings are nearly all oxidized. Exposures in one shallow shaft, 1100 feet northeast of the Phonodoree shaft, show small masses of zinc and iron sulfides distributed through lime silicate rock and otherwise altered limestone.

In the Phonodoree shaft, two sulfide bodies were encountered in addition to the oxidized body at the collar, and two smaller bodies were found in lateral workings at the "300" level (fig.4). These bodies have been explored to a very limited extent at the 190 and "300" levels by means of drifts and cross cuts with a total length of 250 feet. The larger bodies appear to be more or less tabular, dipping more steeply than the bedding in the enclosing limestone. The lowest body found in the shaft has conformable upper and lower contacts for the short distance seen, but it ends abruptly against barren limestone in the northeast face of the shaft. In general the contacts of the bodies follow faults, shear zones, and joints in limestone, or ramify irregularly. Two prominent faults exposed in the shaft and on the "300" level adjacent to the larger bodies may have served as feeders.

In the vicinity of the Bat tunnel, oxidized deposits occur in four favorable beds 50 to 70 feet apart (plate II). These beds are cut by several transverse faults dipping steeply toward the Bat Tunnel fault, and the faults are also mineralized for as much as 80 feet from their intersections with favorable beds. The most extensive bedding vein is mineralized 4 to 6 feet wide for 400 feet at the surface, and was cut in the Bat tunnel 110 down-dip from the outcrop. The two holes thus far drilled have shown that this vein may extend 300 feet and possibly 400 feet down dip. The downward extent of the other bedding-veins has not been demonstrated, but it is certainly not as great, especially at some distance from the transverse veins. The vertical extent of the mineralized ground, as shown by the drilling to February 1943, is at least 350 feet. Several sulfide bodies, found by the drilling to that time, are 250 feet or more below the surface in this area, but as yet their shapes and sizes are unknown. The host bed of the deposits in the Reward mine, if present in the Bat Tunnel area, might well be mineralized. This bed can be traced from the Reward mine southward to a point 1000 feet north of the Bat tunnel, where it passes under alluvium. Although the bed probably extends considerably south of the tunnel, it is not exposed and core drill holes completed to date did not go deep enough to reach it.

Sample data obtained by the U. S. Bureau of Mines and the Reconstruction Finance Corporation in the Bat Tunnel-Phonodoree area indicate that the better sulfide bodies carry between 12 and 20 percent zinc, and probably average 15 percent. A bulk sample across 7 feet of the sulfide body at the 20_ level in the Phonodoree shaft, taken and assayed by the Bureau, gave: zinc 11.7%, iron 26%, magnesia 12.6%, silica 9.7%, lime 4.9%, alumina 1.2%, traces of copper and silver and no lead or gold.

At the Bat tunnel, one iron-zinc sulfide body encountered in hole No. 1 gave 17.8 percent zinc for 6.8 feet. Another body composed of limesilicate rock with disseminated chalcopyrite, encountered with a width of 6 feet in hole No. 3, is estimated to contain 3.5 percent copper and no zinc. Other sulfide bodies range in width from 1 to 16 feet as cut in the holes, and contain a visually estimated maximum of 1.5 percent copper and 10 percent zinc over widths of 3 feet or more. Oxidized deposits in the Bat Tunnel area containing abundant iron oxides carry generally less than 1 percent zinc according to Bureau sampling, although some high-grade oxidized zinc ore may occur on the vein walls. Some oxidized bedding veins composed largely of lime-silicate minerals may contain as much as 10% zinc for widths of ten feet.

RESERVES AND FUTURE POSSIBILITIES

Known ore bodies in the vicinity of the Reward mine are virtually exhausted, so that any further production would have to come from undiscovered deposits. The geologic evidence points to the fault wedge between the mine and the George shaft as the possible location of an oxidized copper deposit comparable to that at the Reward mine. Such a deposit, if present, would lie near the fault in the same favorable bed, but the dip of the bed might be steeper, possibly increasing the chances of leaching of the copper. The deposit would not extend much, if any, below the oxidized zone, and might contain 2000 tons.

Primary copper sulfides are undoubtedly present in the vicinity of the Reward mine at some distance below the present water level. Prospects for important sulfide deposits in this area, however, seem poor.

In the Phonodoree workings, about 1500 tons of 15% zinc sulfide ore is indicated, and 2000 tons more of somewhat lower grade may be inferred. Indications are that any undiscovered bodies in the vicinity of the shaft are small, a few thousand tons or less, and that the average horizontal distance between them is likely to be 150 or 200 feet. The cost of finding and developing such bodies would thus be relatively high. It is improbable that as much as 30,000 tons of sulfide bodies are present within 300 feet of the surface in the central and southern parts of the zinc-bearing area.

In the vicinity of the Bat tunnel, no reserves of sulfide ore can be determined at present. The core-drilling project of the Bureau in this area is designed to find downward continuations of the oxidized bedding-veins into the sulfide zone. To February 1, 1943, at which time three holes had been completed, this effort had not succeeded. Further closely spaced drilling in this area stands a small chance of locating one or two sulfide bodies of 5,000, possibly 10,000 tons, with highly variable zinc and low copper content. Most of the bodies found by this means will be much smaller, and all will lie 200 feet or more from the surface. Probably not more than 30 or 40 thousand tons exists in the area; and, as at the Phonodoree shaft, considerable underground development would be required to prove up any appreciable tonnage.

The grade and distribution of oxidized zinc deposits in the Bat Tunnel - Phonodoree area are likely to be so erratic that no estimate of reserves of oxidized ore can be made from the data available.

TABLE I. SEDIMENTARY AND VOLCANIC ROCKS IN THE REWARD AREA

Age	Formation	Thickness	Character
Quaternary			Desert basin deposits.
Cretaceous (?)		2000 +	Upper part mostly conglomerate, (arkose,) and volcanic breccia. Lower part mostly conglomerate with abundant well-rounded fragments of Paleozoic limestone and quartzite, and some fragments of dense-textured felsic porphyry, and granite. Beds of red sandstone, volcanic breccia, arkose, quartzite and quartz-conglomerate locally near base.
Lower Mississippian	Escabrosa	300-450	Upper part interbedded light and dark gray limestone 140 to 300 feet thick; thickness increases northward due to unconformity with overlying beds. Carries early Mississippian fossils. Lower part massive gray magnesian limestone 95 to 120 feet thick; weathers dark brownish gray; underlain by 20 to 30 feet of dense limestone with 5 to 10 feet of light greenish shale or shaly limestone at base.
Upper Devonian	Martin (?)	75	Light brownish gray, massive magnesian limestone, weathers tan or buff. Few fossils.
	Picacho de Calera(?) a/	175-210	Well-bedded gray magnesian limestone and dolomite interbedded with white calcareous sandstone or quartzite. Carbonate beds are one to three feet thick, generally dark gray, weathering to tan, olive brown, or black. Calcareous sandstone more abundant in upper part; massive cross-bedded sandstone 10 to 20 feet thick at top; Distinctive rusty beds of dolomitic edgewise conglomerate are widespread at the base. In the vicinity of the Reward mine, the lower 80 feet consist of thin bedded limestone and calcareous shale.

a/ Mapped with Cambrian rocks.

Middle Cambrian	Santa Catalina	175	Thin-bedded, slabby calcareous sandstone and shale; generally dark brown or purplish gray, weathering dark. Thick-bedded, cross-bedded sandstone locally present at top. Fucoid markings abundant in shaly beds. Carries middle Cambrian fossils in the south part of the Vekol mountains.
	Troy	250 +	Thick-bedded white quartzite. Locally uneven grained and bluish to reddish. Exposed along east side of area, and encounterd 800 feet vertically below the surface in a core-drill hole at George shaft. Base not exposed.