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EXPLORATION AND DEVELOPMENT OF THE SAN MANUEL ORE BODY*

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The early history of the San Manuel mine, the principal geologic features of the deposit, the methods of drilling and sampling, and some of the results of the drilling and sampling have been ably described in previous reports, namely Bureau of Mines Report of Investigations 4108; a paper entitled "San Manuel Prospect" by H. J. Steele and G. R. Rubly given before the Arizona Section, A.I.M.E. at Tucson, Arizona, October, 1946; and a talk given by Philip Kraft at a meeting of the New York Section, A.I.M.E. in March, 1948.

The San Manuel property is in the Old Hat mining district about 45 miles north of Tucson, Arizona. The town of Mammoth about 3 miles further north is one of the oldest towns in Arizona and has been the center of mining activity off and on for over 75 years. The old stage road from Tucson to Globe, as well as the present State highway 77, crosses the property over the ore body.

A prominent hill of monzonite, stained red with iron oxide, attracted early prospectors to the property but shallow prospecting and two churn drill holes put down in 1915 failed to discover anything of economic interest. Most of the area surrounding the red hill is covered with a layer of conglomerate. Two small outcrops of copper silicate stained monzonite lie at the base of the hill. The largest of these outcrops covers less than two acres in a triangular shaped patch.

J. M. Douglas, R. B. Giffin, V. Erickson and H. W. Nichols were owners of a group of claims covering the San Manuel property. In 1942 they applied to the R.F.C. for a development loan and the U.S.G.S. was requested to examine the property, which they did. The Survey recommended that the United States Bureau of Mines test the ground and early in 1943 the Bureau decided to put down some churn drill holes in the outcrop and through the surrounding conglomerate to determine the value and extent of the copper mineralization. I believe that Dr. B. S. Butler of the United States Geological Survey who was then head of the Department of Geology at the University of Arizona, was instrumental in convincing the Bureau that an important and valuable body of copper ore might exist under the conglomerate cover.

The U.S.G.S. mapped the area and the Bureau of Mines drilled a few shallow holes starting in November, 1943. A coordinate grid system was laid out on 200-foot centers to conform to the estimated axis of the ore body. The preliminary drilling showed that the ore body did extend under the conglomerate and that it continued in depth beyond 350 feet which was the deepest hole drilled. The Bureau secured additional funds and continued drilling.

The Magma Copper Company became interested in the property and upon the recommendation of Dr. John Gustafson, who was engaged in geological work for the

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Magma Copper Company at the time, Magma secured an option to purchase the property in August, 1944. Magma also took options on some adjacent claims and located other claims on surrounding open ground. In September, 1945, Magma exercised its option and formed the San Manuel Copper Corporation to carry on exploration and development of the property.

The Bureau of Mines Engineers decided before they started exploration that churn drilling was the most practical method of obtaining samples in this area. They did not think diamond drills would core unless a large diameter core such as 3 inches or more was cut. This would have been very expensive sampling. When we took over the property our engineers agreed with the Bureau that diamond drilling was impractical so churn drilling was continued. Later on one of our neighbors, who was drilling in search of an extension of our ore body, introduced diamond drills. Our observation of their drilling convinced us that churn drilling was better suited for sampling this particular formation. Core samples would have been very desirable to have so we attempted to cut core with a rotary rig brought in from California. It was a good rig and was operated by an efficient crew. The hole was put down 1000 feet before coring was started. The hole was continued to 1650 feet with core cutting bits but less than 10% core was recovered. The hole was 9" in diameter and the core 3 5/8" in diameter. The ore is interlaced with numerous fractures in all directions. The core broke on these fracture planes while in the core barrel and then it was ground to powder by the rotation of the drill and little or nothing remained in the barrel. After this attempt we gave up trying to obtain a core.

Drilling started in the shallower part of the ore body where only a few holes were drilled deeper than 1500 feet. Most of these holes were collared with an 8-inch bit and finished with a 6-inch bit. Both the conglomerate and the monzonite proved to be tight, compact rock so that casing was seldom needed. When drilling was extended over an area where the over-burden and ore was deeper only a few holes were less than 2000 feet and several were over 2700 feet with the deepest 2850 feet. These deeper holes were started with 12½-inch diameter bits and casing was generally necessary. Most of the casing was recovered for re-use and I believe the loss did not average quite 10%.

We made no attempt to specify the type of drilling rig or equipment to be used. We described the work to be done and the contractors brought in whatever machine they had suitable for the job. Six different models of Bucyrus-Erie machines were used at various times. The Bucyrus-36-L and the latest model Bucyrus 28-L were the most satisfactory rigs tried, especially on holes over 1500 feet deep. Four different models of Fort Worth Spudders were also used; they were the Super D, Model F, Jumbo H, and Super J. The Fort Worth machines did well on deep holes but they were heavy and cumbersome to move, they took more time than the Bucyrus machines to set up, and required a larger site on which to work. Gasoline, diesel oil and butane were used as fuel depending on the engine. The water table lay from 300 to 700 feet below the surface so the contractors had to haul the water needed for drilling until they had reached the ground water. They used tank trucks and obtained the water from the Mammoth-St. Anthony mine about a mile from our drilling area. No living quarters were provided for the drillers by the company. They took care of themselves and families. Some stayed in the town of Oracle about nine miles away but most of them lived in trailers close to their work.

The coordinate system for drilling started by the Bureau of Mines was adopted and extended. At first we drilled on centers 200 feet apart along the supposed strike or long axis and on 400 foot centers across the short axis. As the body began to take shape and we realized to some extent its area we drilled on

400 foot centers in both directions. The Bureau of Mines drilled 17 holes having a total of 15,844 feet; San Manuel deepened several of these holes and put down 88 new holes drilling 180,092 feet in total.

Samples were taken every 20 feet while drilling in conglomerate except where copper minerals were visible in the sludge and 5 foot samples were taken. After the hole penetrated the monzonite below the conglomerate samples were taken every 5 feet until the hole was finished. Drilling was continued in each hole for a considerable distance, in material assaying less than .4% copper, below the projected bottom of the ore body, before the hole was abandoned. Where the information from adjacent holes permitted us to make a reasonable estimate of the depth to the bottom of the ore we seldom drilled over 120 feet in low grade below the estimated bottom position. Where we were not reasonably sure of the thickness of the ore body we occasionally drilled up to 500 feet in low grade material below the last assay of .5% or better.

Samples were taken every 5 feet from the bottom of the conglomerate to the bottom of the hole. After a five-foot run the operator was required to bail the hole until it was clean. All of the material bailed was run through a series of splitters and the cut taken for sampling was drawn off in a 5 gallon milk can. A portion of the reject was taken from each run to provide material for classifying the rock and for panning a concentrate. The entire contents of the milk can containing 15 to 20 pounds of solids were dried on a steam table. All of the water was evaporated and no attempt was made to settle and decant before drying. After drying the sample was quartered and one of the quarters was pulverized for assay pulps. The three quarters were bagged separately and stored for future reference. Each sample representing 5 feet of hole was assayed separately. When a hole was completed composite samples, representing about 100 feet of drilling, were made up covering the entire ore column in each hole. These composites were assayed in our laboratory and spot checks made with assays run by outside custom assayers. Finally a composite was made for the total sulphide column in each hole and each of these composites was assayed by ourselves and an independent custom assayer. The average of the 5 foot samples checked with the composite samples within a few hundredths of one percent copper. I don't believe there was over .02 percent copper difference between the average of the 5 foot samples, our composite assays, and the custom assays, for the entire ore body and many individual holes checked exactly.

One of the characteristics of the San Manuel Ore body is the uniform distribution of copper values throughout the body in both horizontal and vertical direction. The percentage of copper in each ore column cut by the large majority of holes is very close to the percentage of copper in the entire ore body. In an individual hole the top of the ore body is usually marked by a change in copper content from .3% or less to .8% copper in a single 5 foot run. The succeeding samples would seldom assay over .9% or below .7% copper until the bottom was reached. The bottom would be marked by an immediate drop from .8% copper to say .4% in the next sample and within a few more runs the assays would be below .3% copper. Below this it was not unusual to have several hundred feet of .25% copper before the grade fell to .1% or less. In general the footwall material was pyritic with chalcopyrite giving way to pyrite and very little change in the total sulphide content.

The size, shape and extent of the ore body was established by systematic drilling. From the beginning numerous theories were advanced regarding the trend and location of the values beyond completed holes. Very little weight was given to these theories in practice for we followed the ore along the coordinate system as long as it persisted in a given direction. The full extent of the ore body is not yet known because, having developed 460,000,000 tons, we stopped drilling. A series of holes along the southwest perimeter of the drilling show good columns of ore. The best of these has a column 1780 feet thick averaging better than .7% copper; the bottom 500 feet of this column assayed .9% copper. We have no idea as to how far the ore body extends beyond these holes.

The ore body we have outlined is covered with several hundred feet of Gila conglomerate for the greater part. Most of the tonnage is so far below the surface and covered with so much over-burden that stripping and open cut mining is out of the question. The structure of the monzonite we have been able to observe on the surface and the experience obtained in drilling leads us to believe that the ore will cave readily and that block caving will prove to be the most economical method of mining. We plan to adopt that method.

The drilling and sampling we have done has provided us with proof of a definite tonnage of ore, the metal content thereof, and the partial boundaries of the ore body. We still need adequate representative samples for metallurgical testing so we will be able to design a reduction and concentration plant. We need accurate knowledge of the physical characteristics of the rock in place, and broken, in order to plan development and extraction methods and to estimate mining costs. To get this information we have started a program of underground exploration. Two shafts will be sunk--one 7' by 26½' outside of steel, with four compartments, will be 2140 feet deep and the other 7' by 20' outside of timber, with three compartments, will be 1960 feet deep. About 14,000 feet of drifting and crosscutting is planned on two levels.

The prelininary exploration program has been laid out so that the openings may be used for development or extraction when production is started. In order to obtain the information we desire as quickly as possible we would have preferred to locate the first shaft near the center of the ore body. If we thought that a conventional timbered shaft with three compartments four or five feet in cross section could be sunk 2000 feet deep near the center of the ore body that would have been our first shaft, even though it would eventually be lost. We anticipate that a large quantity of water will be encountered in the ore body. Our neighbor, the St. Anthony Mining and Development Company, a few thousand feet north of us is pumping over 2000 gallons per minute from their 1050 foot level. They pumped over 3000 G.P.M. for many months after opening this level and the water came from a single 6' x 8' face. We may have a comparable amount of water in our shaft and if this proves true a large shaft section will be necessary to accommodate the pumping equipment. In addition, expensive stationary pumps with sumps and accessory equipment will be required. We didn't think it wise to locate such an expensive shaft in a position where it will be destroyed by mining operations. Consequently, a site was chosen in the footwall of the ore body outside of the line of subsidence and about midway between the extremities of the body. Due consideration was given to faults, surface topography, and accessibility in choosing the site. The yard and surface plant have been arranged so that a twin shaft may be located close by. Two shafts will be needed to hoist the anticipated production of 25,000 to 30,000 tons per day. The first shaft has been started and is being sunk as a permanent shaft which will be capable of handling up to 15,000 tons of ore per day when provided with suitable skips and hoisting equipment. Steel sets, with concrete outside the steel where needed, will be used for lining.

The second shaft will be sunk in the ore body and will be started soon. This will be a timbered three-compartment shaft which will eventually be lost. If we are fortunate and do not encounter excessive water we will be into the ore and obtaining needed information in a short time. If the water is excessive we will delay sinking this shaft until the large footwall shaft is down and the ground around the second shaft is dewatered. This second shaft is located in the part of the ore body which will probably be mined first. It will be used for access to exploratory levels in the immediate area and later will be used to service the development work required to prepare the body for extraction.

The surface plant required for the sinking and exploration program is rapidly nearing completion. We have constructed a power plant containing three G. E. 1000 K.W. generators driven by Cooper-Bessemer gas diesel engines, and two C.P. air compressors; one of 1600 and one of 1800 cubic feet per minute capacity. Natural gas is supplied at 500 lbs. pressure through 20 miles of 4-inch pipe which was installed recently by the El Paso Natural Gas Company to serve our property. A machine shop, steel shop, hoist house, warehouse, change room, and office are either finished or nearly so. We have constructed twenty-one 3, 4, and 5-room dwellings, two 24-bed dormitories and a mess hall.

Some months ago we had Fairchild Aerial Surveys photograph the property and prepare a topographic map of the area. They did an excellent job and we now have contour maps on a scale of 200 feet to the inch with 10 foot contour intervals covering our entire group of claims. These maps will provide the base for laying out plans for plant, townsite, transportation system, tailings disposal and other surface construction. We are presently planning for production at a rate of 25,000 tons per day. A concentrating plant will be built as near to the ore body as property and topographic limitations will allow. It must of course be outside the ultimate limit of subsidence. A smelter may or may not be built depending upon economic considerations. There are already several copper smelters operating in Arizona, for instance the A. S. and R. Smelter at Hayden is twenty-five miles down the San Pedro river from our property. Magma Copper Company, who controls San Manuel, has a smelter at Superior about seventy-five miles north of San Manuel. The transportation of concentrates plus the charge for smelting will have to be compared with the amortization of the cost of a new smelter plus the cost of smelting, before a decision is made.

Where the plant and townsite will be located has not been decided nor will it be decided for some time. We anticipate 1000 to 1200 men will be employed and according to the experience in southwest mining camps that will mean a new town of 5 to 6 thousand population will come into being. During the next two years we will be making plans for the mine and permanent plant, but many details will have to wait until the information from underground is obtained.

The ore body is low grade and deeply situated; on the other hand the tonnage is large and the ore column is thick. We have a virgin, untouched deposit whose size, shape and location have been accurately determined for our planning engineers information. The best practices and most efficient devices developed in caving operations to date can be adopted. The combined and accumulated knowledge of many mines having years of experience will be drawn upon in laying out our plans for exploitation.

It is too soon for an exposition on our plans for exploitation of the ore body as these plans are in a very early and formative stage and they consist mainly of detached ideas rather than a consolidated program.

We expect to be able to develop caving blocks or panels 700 feet long, 160 feet wide and 600 feet high where the thickness of the ore will allow. Few blocks of this height have been caved and drawn before. The plans for development will be made flexible so that the height of the block can be reduced or increased if early experience indicates a change desirable. The opportunity is present for making this the most efficient block caving operation in existence.

We have given considerable thought to the possibility of raising the ore to the surface by means of long, inclined conveyor belts in series, rather than by conventional vertical hoisting. This is quite practical from an engineering point of view. Modern conveyor belt systems afford a cheap method of transportation. The inclined conveyor could be pointed in the direction of the surface plant and thus greatly reduce the length of surface transportation which will be required to reach the reduction plant if vertical hoisting is adopted. The decision on this point will of course be one of overall economy and flexibility. Our present conclusions are that belt life would be too short and the consequent maintenance cost too high for a conveyor to compete with hoisting. However, great strides are being made by belt manufacturers for this type of service and before we must commit outselves the picture may change. In this connection the permanent footwall shaft now being sunk has been so designed that it can be used as an ore hoisting shaft or if we do not hoist ore it can be used either as a supply shaft or as a ventilation shaft, both of which will eventually be required.

I mentioned the fact that we expected to find considerable water in the ore body. The footwall shaft was located in an area which is unbroken by known faults and which a careful geological study indicated was the least likely to encounter a large flow of water while sinking. We hope this will prove to be true but we are providing for a disappointment. When the top of the ground water table is reached a pump station and sump will be cut on the 820 foot level. Two 700 G.P.M. centrifugal pumps will be installed immediately and provision made for additional pumps if they are required. Sinking pumps with a combined capacity of 600 G.P.M. have been provided and more may be installed if necessary. Air driven, large capacity, low head sump pumps will be used in the bottom. They will discharge into a steel tank hanging in the shaft. Motor driven centrifugal pumps will relay the water from this tank to the sump above. The platform holding the centrifugal pumps is under and an integral part of the hanging tank. When the head capacity of the hanging pumps has been reached booster pumps will be installed in series in the discharge pipe line. Two 8-inch pump lines will be carried down the shaft.

Even though we are fortunate enough to finish sinking without encountering more water than we can handle easily, a large sump and pump station will be immediately installed on the bottom level before we crosscut to the ore body. We think it inevitable that a large flow of water will be encountered in the ore body so water doors will be installed and long holes will be carried ahead of the face of the crosscut towards the ore body.

If we run into an excessive quantity of water, say 1,500 to 3,000 G.P.M. in sinking, we will probably sink one or more churn drill holes outside the shaft and install deepwell pumps to lower the water table below the sinking operations.

Many phases of this operation have been discussed very briefly and incompletely. I am sure that the experience gained in bringing the property into production will provide subjects for reports which will be of interest and value to the mining industry. It is often said the geologist can make an accurate picture of the ore body after it has been mined out. We will be able to tell how to exploit the San Manuel ore body after we have done it and our mistakes are behind us.

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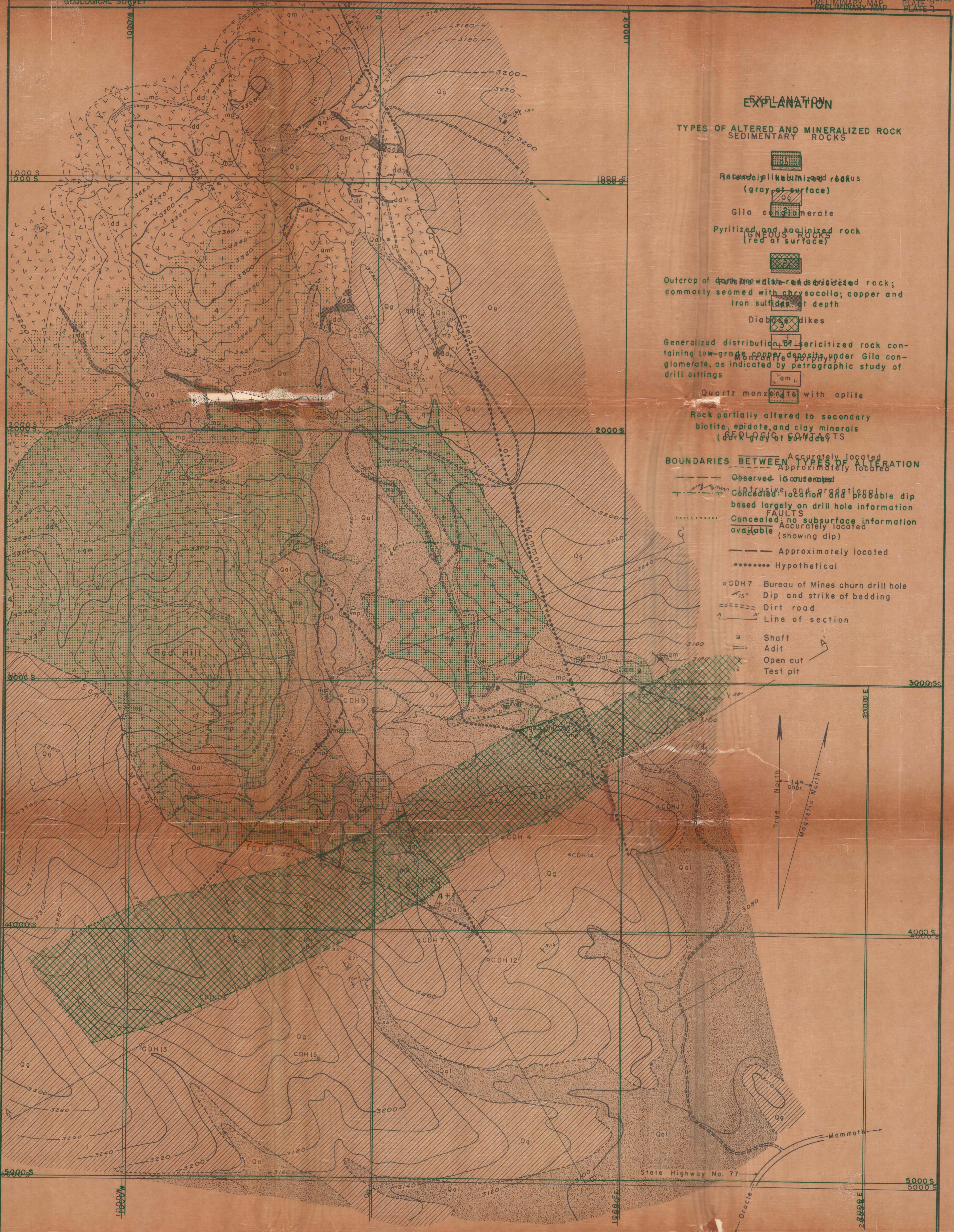
STRATEGIC MINERALS INVESTIGATIONS
PRELIMINARY MAP PLATE 2

STRATEGIC MINERALS INVESTIGATIONS
PRELIMINARY MAP PLATE 1



UNITED STATES DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY

AREAL DISTRIBUTION OF ALTERED AND MINERALIZED ROCK

SAN MANUEL COPPER DEPOSIT AND VICINITY

OLD HAT MINING DISTRICT PINAL COUNTY, ARIZONA

1945

0' 100' 200' 400' 600' 800' 1000'

by

D. H. Kupfer and G. M. Schwartz

Geological Survey

GEOLOGIC AND TOPOGRAPHIC MAP OF THE SAN MANUEL COPPER DEPOSIT AND VICINITY

OLD HAT MINING DISTRICT PINAL COUNTY, ARIZONA

1944

Contour interval: 20 feet Datum is mean sea level

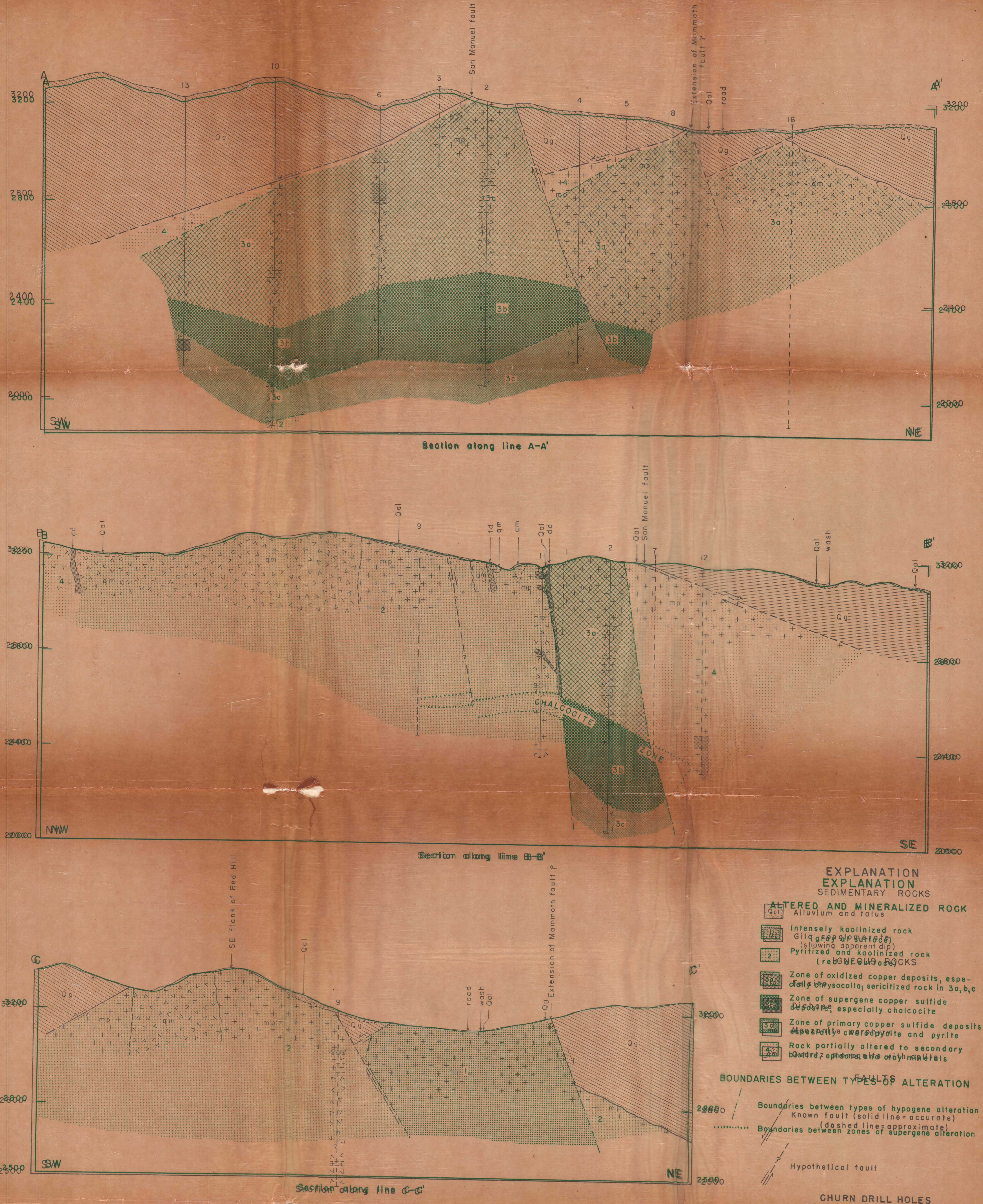
0' 100' 200' 400' 600' 800' 1000'

United States Bureau of Mines (Project-1466)

Geology by

N.P. Peterson, D.H. Kupfer, G.M. Schwartz, and E.E. Gould

Geological Survey



DISTRIBUTION OF ROCK ALTERATION AND COPPER MINERALIZATION

DISTRIBUTION AND STRUCTURE OF ROCK FORMATIONS

VERTICAL SECTIONS THROUGH THE SAN MANUEL COPPER DEPOSIT AND VICINITY

VERTICAL SECTIONS THROUGH THE SAN MANUEL COPPER DEPOSIT AND VICINITY

0' 100' 200' 400' 600' 800' 1000'

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San Manuel

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