A BRIEF HISTORY OF THE UNITED VERDE OPEN PIT, JEROME, ARIZONA

by

E. M. J. Alenius

THE ARIZONA BUREAU OF MINES

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FOREWORD

This journal, assembled by Col. E. M. J. Alenius, is chiefly an account of the open pit mining and related activities which were done at the United Verde mine, near Jerome, Arizona, from about 1912 to 1940. Prior to this period, the orebody had been worked, for many years, by underground mining methods but, because of various conditions that are described by Colonel Alenius, they could not be economically continued, especially in the upper levels of the mine, and the open pit mining procedures then were established.

Colonel Alenius was closely associated with the venture from 1923 to 1937, during the period of major mining operations, and it is considered that his first-hand description of the problems which were encountered and of the means whereby they were solved, is an historical record which should be preserved. Therefore, the Arizona Bureau of Mines is pleased to have the opportunity to publish Colonel Alenius' treatise as a part of its Bulletin Series.

J. D. FORRESTER, *Director*
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PREFACE

The "Big Hole" was the name miners gave to the United Verde mine, for with its many shafts, raises, large stopes, and miles of drifts and tunnels, it was one of the largest mines in the world near the turn of the present century. Several pictures are included with this presentation so that the interested visitor to Jerome may have a better understanding of how the "Big Hole" was made, and what the problems were. Also, visitors can become familiar with the great extent of the mine by examining the model in the Douglas Memorial Mining Museum at the Jerome State Historic Park. However, only by comparing this with the actual "Big Hole," the United Verde open pit to the north of Jerome, can the magnitude of the early day mining be fully appreciated.

The United Verde open-pit mining operation was unusual in many respects and it presented conditions not commonly found in most mining enterprises. To the best of the writer's knowledge, no other surface mine operation can compare in the variety of situations which were encountered. Whereas development of the pit conformed generally to practices prevalent at the time, many changes and innovations were required as the operations progressed. During its twenty-two year lifetime, from 1918 to 1940, great improvements were made in the methods of drilling, blasting, loading, and hauling and, as a result, technologies first used at the United Verde open pit have contributed to the development of many modern-day surface mining methods.

E. M. J. Alenius

Phoenix, Arizona
November, 1968

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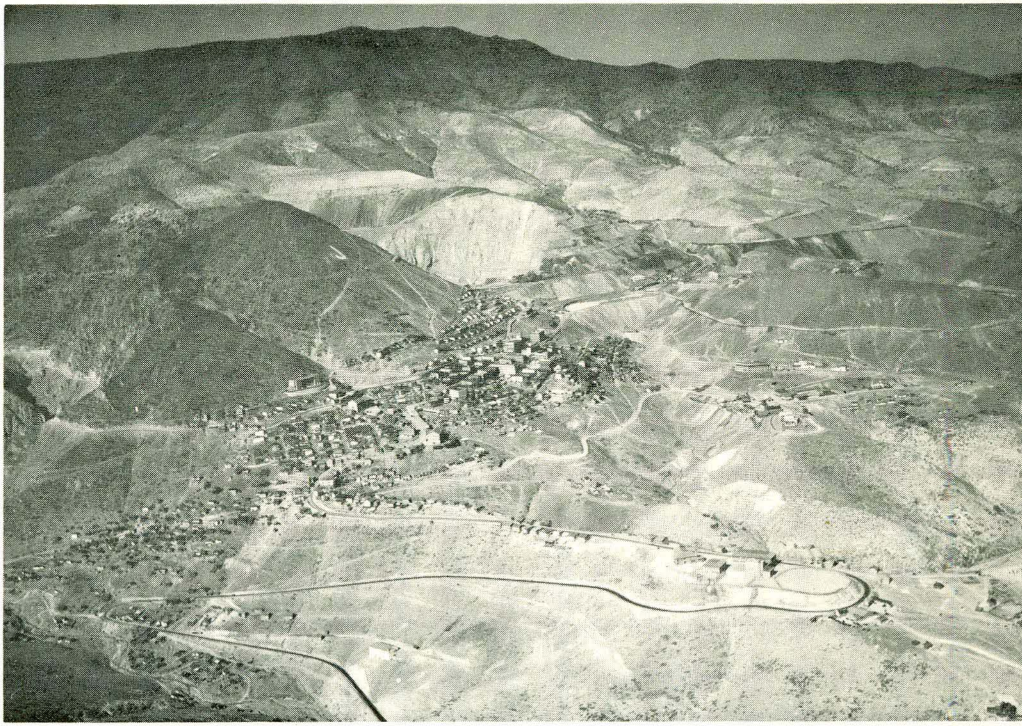

Figure 1. Aerial view of Jerome taken in 1928. The diorite west-wall of the United Verde open pit may be seen in the center with waste dumps to the right. The surface plant of the United Verde Extension Mine and the mansion now occupied by the Douglas Memorial Mining Museum are to the right of Jerome.

INTRODUCTION

The United Verde Copper Company was purchased in 1888 by the late William A. Clark whose original base of operations was in Butte, Montana. During the late 1800's and early 1900's, extensive underground and surface developments were undertaken to work the orebody which was of notable richness in copper, silver, and gold. These developments were along the upper reaches of Bitter Creek Gulch north of the present town of Jerome, Arizona.

As a result of the early mining operations, much of the gulch was filled in and the surface was graded off on the 50 foot level, called the "Slag Level." A smelter was erected on this site which, with the surrounding shops, offices and mine structures, rested on top of the orebody that was roughly 800 feet wide and 1,000 feet long, in surface extent.

Underground and glory-hole mining methods were used originally and considerable production of ore was realized. In 1894, however, a fire started in the upper levels of the mine and eventually it extended as far down as the 900 level. Attempts were made to control the fire by placing concrete bulkheads at strategic localities in the underground workings, but, because of the caving of the ground and the uncontrollable heat which occurred in the orebearing sulfide masses, it became apparent that the orebody could not be fully and economically worked solely by conventional underground and glory-hole mining practices.

Studies were made of the situation and it was decided that the most efficient procedure for further mining, especially of the comparatively high-grade ore remaining in the upper zone of the deposit, would be to develop an open pit. Pursuance of this plan of operation entailed the construction of a new smelter at Clarkdale, Arizona, the erection of a new surface plant on the 500 level elevation, the installation of new underground hoisting facilities and shafts, the development of a tunnel transfer system, known as the "Hopewell Tunnel," on the 1,000 foot level, and the construction of the Verde Tunnel and Smelter Railroad. This railroad connected with a branch line of the Atchison, Topeka and Santa Fe Railroad which ran to Clarkdale. (These Verde Tunnel and Smelter Railroad facilities have been abandoned for many years, but the remains still can be seen from several vantage points in and around Jerome.)

The ore at the United Verde open pit (fig. 1) was high-grade; some sulfides contained as much as 40 percent copper, some siliceous ore assayed more than 200 ounces of silver a ton, and some oxide ore contained more than three ounces of gold a ton. Throughout the life of the pit operation, the ore averaged 3.47 percent copper, 2.07 ounces silver, and 0.071 ounces gold per ton. Economic operation permitted the mining of ore containing as little as 1.00 percent copper, or $4.00 per ton in total value.

The orebody consisted of minerals and rocks with entirely different characteristics. Some ores contained base sulfides with low silica content, others had siliceous sulfides, oxides, or silicates. The host rocks were porphyry and schist. Some of these had been altered by the heat of the underground fire. Selective mining, based on mineral character and grade, was required in order to segregate the ore and rock for treatment either by direct smelting, converting, or concentrating, or stockpiling for leaching and from waste which was used for underground stope filling or placed on dumps. Moreover, by selective mining it was possible to effect greater economy in the smelting process by controlling the silica content of the direct smelting ores to around 23 or 24 percent and the alumina content to about four percent. A noticeable change in types of ore occurred at about the 160 mine level; the ores above were mainly oxides, and those below, mainly sulfides which had been enriched by copper leached and reprecipitated from the oxide zone.

Not only were different minerals and rocks encountered in the orebody and the surrounding waste material, but great differences existed in the degree of hardness and of fracturing in different parts of the orebody. The drilling equipment then available often was inadequate for the requirements, and the explosives which could be obtained frequently were not suited to the conditions. On the other hand, some of the very high-grade sulfides with low silica and iron content, and some of the high silica converter ore in the oxidized zone, required little blasting.

The open pit operations were conducted above the earlier underground workings and, consequently, every drilling, blasting, loading, and hauling operation required careful examination of old maps to avoid encountering concealed raises, drifts and open stopes. In some cases, the extent to which caving had occurred, as a result of the underground fire, was not accurately known. Moreover, as may be noted in figure 2, extensive underground workings had been driven beneath the diorite hanging

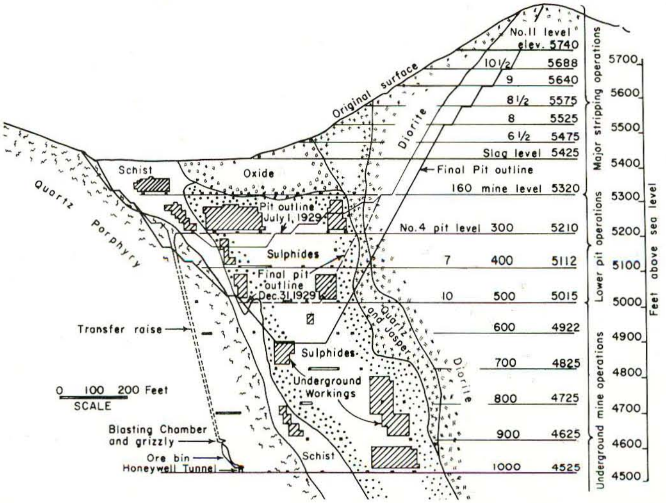

Figure 2. Typical section of the United Verde Open Pit as of July 1, 1929; note the relationship of the complex orebody to the porphyry foot-wall and the diorite hanging wall. This section shows the underground workings as far down as the 1000 foot level to which material from the pit was dropped through transfer raises for disposal via the Hopewell Tunnel system. The hanging wall pit slope was moved back during the depression years because the support for this wall had been weakened by underground caving above the 1200 level; the resulting pit outline (as of 1940) is shown.

wall on the northwest side of the orebody and these had weakened the support of the overlying mass of diorite. These factors induced considerable sloughing of the diorite and, as a result, the removal of abnormal quantities of waste rock was required during the mid-1930's. Thereafter, constant vigilance with attendant scaling and trimming was required to avoid injury to workmen and damage to equipment below the waste banks. At the termination of mining operations in the pit in 1940, the diorite wall along the northwest side was more than 600 feet high without a protective bench (fig. 1). (This high diorite wall is readily visible when the pit is approached from Jerome, or when viewed from the Douglas Memorial Mining Museum.)

In 1915, the new smelter was "blown in," and in 1918, stripping, or waste removal, for the open pit was started. A Marion 300, 8-cubic yard, full-revolving steam shovel began cutting into the slag dump in the 160 level (fig. 3), and an Osgood Model 120, 4-cubic yard, railroad-type steam shovel was used on the 300 level (figs. 4 and 5). Switchbacks for a standard gauge haulage railroad were constructed on the north side of the diorite hill to provide access to the south side where benches, 50 feet in height, were to be cut to establish a safe slope above the open pit.

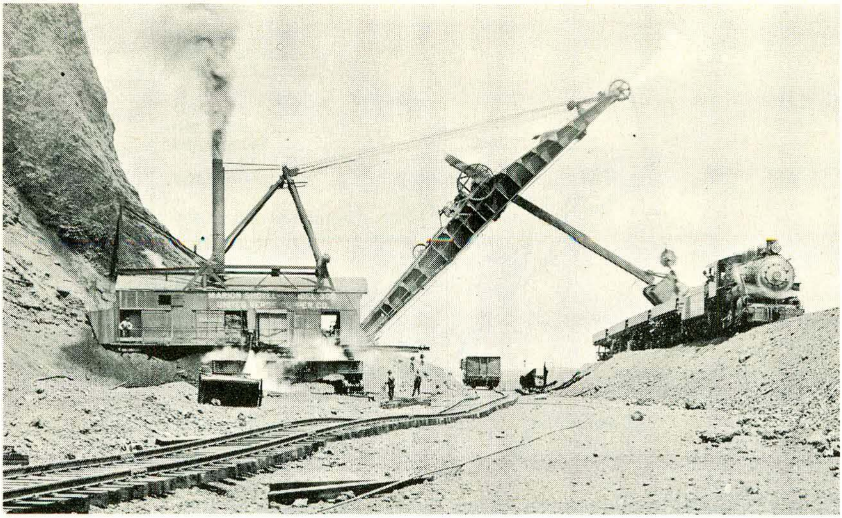

Figure 3. The Marion 300, 8-cubic yard, coal-fired steam shovel loading slag in 1920, into 25 cubic yard dump cars with a six wheel, switcher-type, steam locomotive. This full revolving shovel was procured on a priority basis during World War I, having been built for work at the Panama Canal. The shovel was mounted on four rail-type, heavy-duty trucks which enabled it to move on very heavy sections of track laid by a four-man ground crew. The shovel crew consisted of an engineer, craneman, oiler, and fireman, a far cry from the one man operated shovels of today. The shovel was equipped with two boilers and was later modified to use fuel oil.

In 1923, after some waste rock was removed on intermediate benches, stripping was started on the top bench at the 5725 elevation. By this time, old surface structures on the slag level (fig. 6) were being demolished, and the Marion shovel had been cutting rapidly into the orebody. The rich oxide and siliceous ores mined were mainly stockpiled on nearby dumps, as the smelter could not treat them in the quantities produced. Some waste was disposed of through glory holes and connecting raises for use in filling mined-out underground stopes, but most of the waste material was loaded into 25-cubic yard, railroad dump cars and hauled by switcher-type, steam locomotives to dumps (fig. 7). (These waste dumps and switchbacks can be seen from the road to Perkinsville, a short distance north of Jerome.)

It became evident in the Autumn of 1924, that the hard, unaltered diorite being encountered on the upper benches was causing stripping operations to fall behind the schedule needed to keep up with the rapid advance of the Marion 300 shovel in the orebody (fig. 8). Consequently, when the diorite was exposed on the 160 level, six large tunnels during a two year period were driven into the diorite wall and then blasted in order to expose more of the orebody. This produced an unbroken bank above the 160 level (fig. 9) which in some places was more than 500 feet high by the time major stripping operations were terminated in 1927. A total of 803,000 cubic yards of ore and 7,274,000 cubic yards of waste had been removed from above the 160 level.

It was originally contemplated that mining below the 160 level would be done by glory hole methods, and that the underground workings would be designed in such manner as to permit the broken material to be dropped through transfer raises to the 1,000 foot level, where it then could be moved to the surface via the Hopewell Tunnel system. However, it was found that transfer raises could not be strategically located for most economical operation because of old mine workings and caved areas resulting from the fire, and also, that it was not possible to mine selectively by glory hole methods. Consequently, in 1925, it was decided to mine the orebody below the 160 level with small shovels working on benches about 30 feet high. Ore and waste materials could be selectively mined by careful drilling and blasting and then loaded into dump trucks

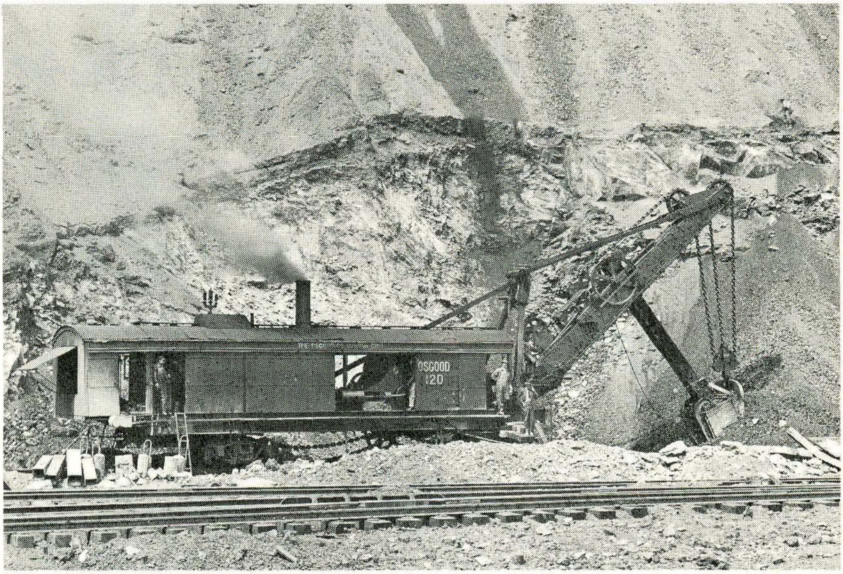

Figure 4. The Osgood 120, 4-cubic yard, railroad-type steam shovel loading slag on the 300 level in 1920. This was the largest shovel of its type then built. The shovel moved along on track with a swinging boom and dipper and with the front end supported on jacks when digging. These shovels were later modified to use fuel oil, and equipped with caterpiller trucks for independent moving, one truck at the rear and one each at the end of each supporting jack arm. Carbide lights for night operation are stacked on the ground behind the shovel.

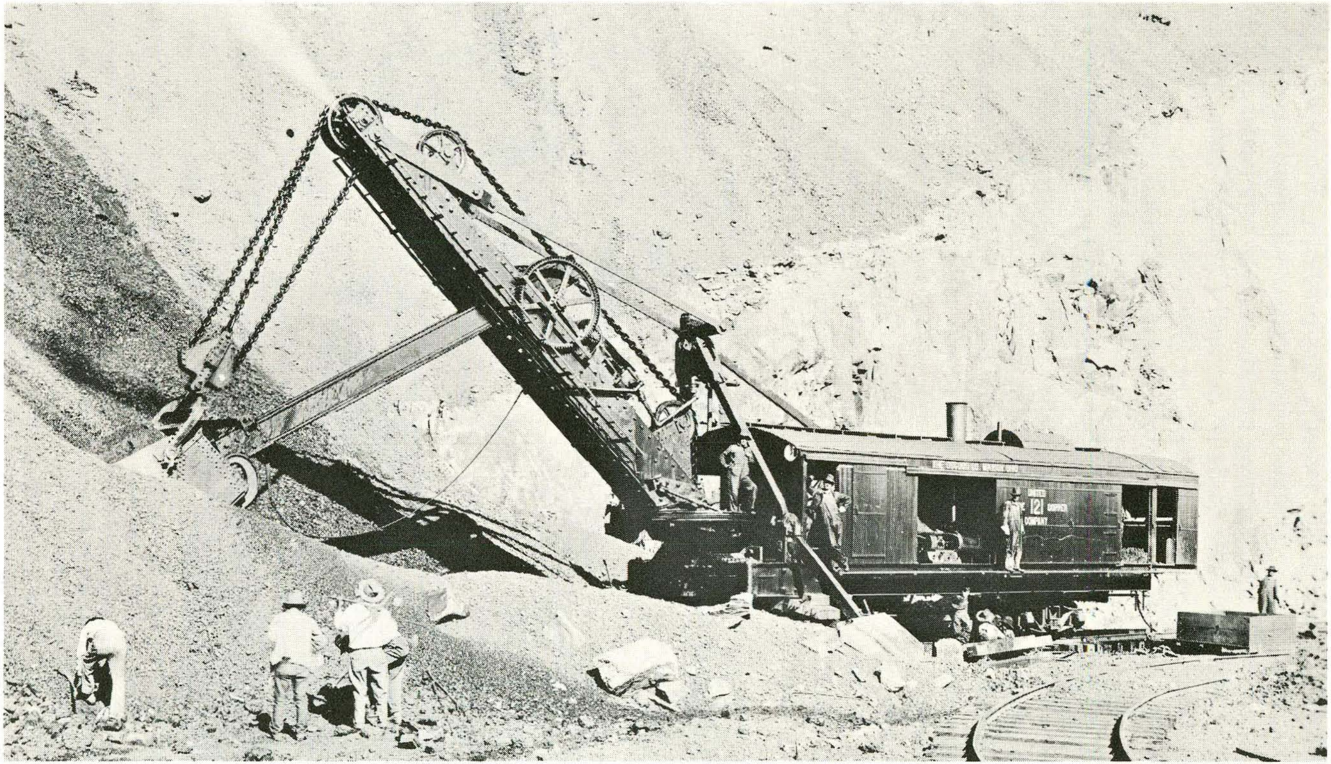

Figure 5. United Verde Copper Company's Steam Shovel No. 121, a model 120 Osgood, on the 300 level.

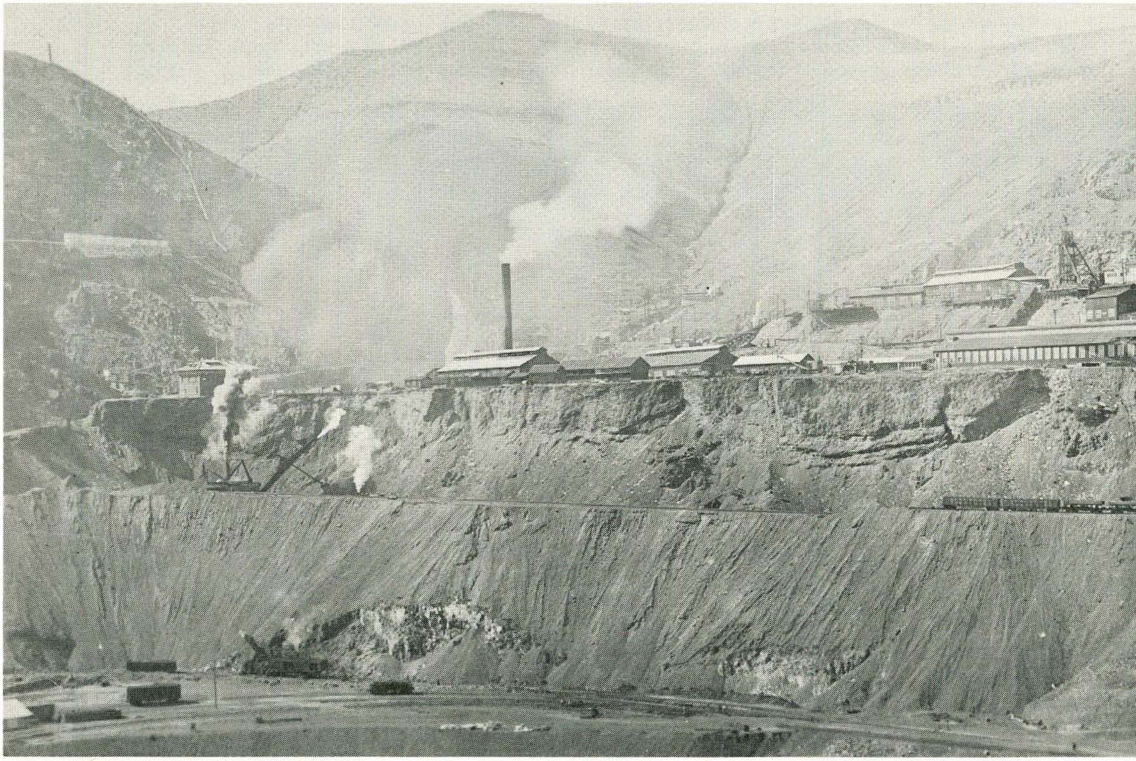

Figure 6. An early 1920 view of the surface plant on the 50 foot or slag level and the pit operations below, showing the Marion 300 shovel cutting across the slag dump on the 160 level and the Osgood 120 shovel on the 300 level. Number 3 shaft headframe is seen in the upper right.

Figure 7. Recent aerial view of Jerome. The United Verde open pit and waste dump switchbacks are at the upper right. The surface plant of the United Verde Extension mine is to the lower right center, with the mansion now occupied by the Douglas Memorial Mining Museum.

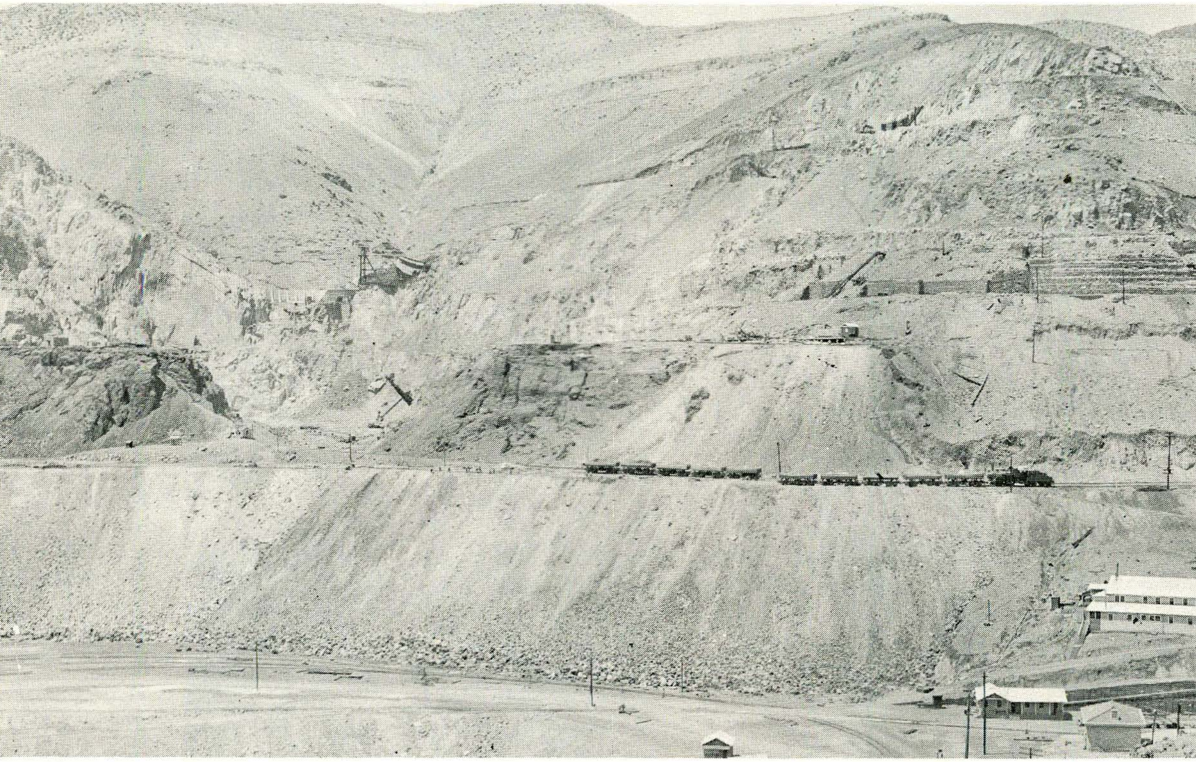

Figure 8. View taken in 1924, showing the cut into the orebody on the 160 level. The boom and dipper of the Marion 300 shovel are seen below the No. 4 shaft headframe. An Osgood 120 shovel is seen on the 5475 bench above and to right.

Figure 9. Stripping operations in 1925. One Osgood shovel is working on the 5425 elevation bench to the right and a Marion 300 shovel is working on the 160 level in the center foreground. The top of the diorite bank at this time was at elevation 5860.

Figure 10. View of pit in June, 1928, looking northeast. The pit surface plant and the idle Marion 300 shovel are on the 160 level with Sunshine Hill in the background. Smoke from the Clarkdale smelter can be seen in the upper right. Below the smoke, at the edge of the pit, is a tank for mill tailings which were initially used for choking off the underground fire. Electric, 1¾ cubic yard shovels, an electric churn drill, and rocker-type, side-dump trucks may be seen in the pit; the lower ones are on the third bench below the 160 level, at elevation 5240. One truck has just dumped a load into No. 8 transfer raise.

for transportation to transfer raises driven up from below wherever possible in and around the orebody. During the course of these lower level operations, nine transfer raises were available at one time or another, and these permitted complete segregation of the various types of ore and waste materials.

Within a few years, four 50-B, 1¾-cubic yard, Bucyrus-Erie alternating current electric shovels were put into operation (fig. 10). At first, a few World-War I Liberty trucks having a 3-cubic yard side-dump body were used. Later, however, 10-ton capacity, custom assembled trucks which at the time were the largest units available, were obtained. From this initial use of trucks in mining operations, large haulage trucks have been developed and in many cases have completely eliminated rail haulage.

With the increasing demand for copper that developed in the late 20's, the mining rate was increased, and 1,055,684 tons of ore was mined from the pit during 1929. The break in the market late in 1929 caused mining operations to be sharply curtailed in 1930 and shortly later to be suspended entirely until January, 1935. Up to this time (1930), a total of 8,500,000 cubic yards of waste had been removed and 5,660,000 tons of ore averaging 3.22 percent copper, 2.51 ounces silver, and 0.086 ounces gold per ton had been mined.

Figure 11. Drilling vertical holes in diorite with Leyner 248 drifter suspended by block and tackle arrangement from a tripod. Note Keystone steam operated churn drills in background.

No serious problems occurred during the first years of operation in breaking the waste rock and ore for removal. The steam-powered Keystone churn drills which were used had no difficulty in putting down vertical holes in the oxidized ores and in the altered stripping material. As a result, the cut into the orebody on the 160 foot level moved rapidly ahead. However, trouble developed when the fresh diorite was exposed on the upper benches. The drills could penetrate the diorite only at the rate of three to five feet per hole per shift and this was possible only by frequent, periodic enlargement or "springing" of the bottom sections of each hole by blasting as the hole was being sunk.

Faced with this inability to effectively drill and break the diorite overburden, so as to keep ahead of the advance of ore mining on the 160 foot level, air drilling was tried. Leyner drifter drills suspended from tripods were used to drill 30 foot vertical holes into the top of the bench (fig. 11) and jackhammer-drilled holes, up to 20 feet in length, were driven into the toe of the bench (fig. 12). As detachable bits were not available, the handling of many sets of drill steel was required. In

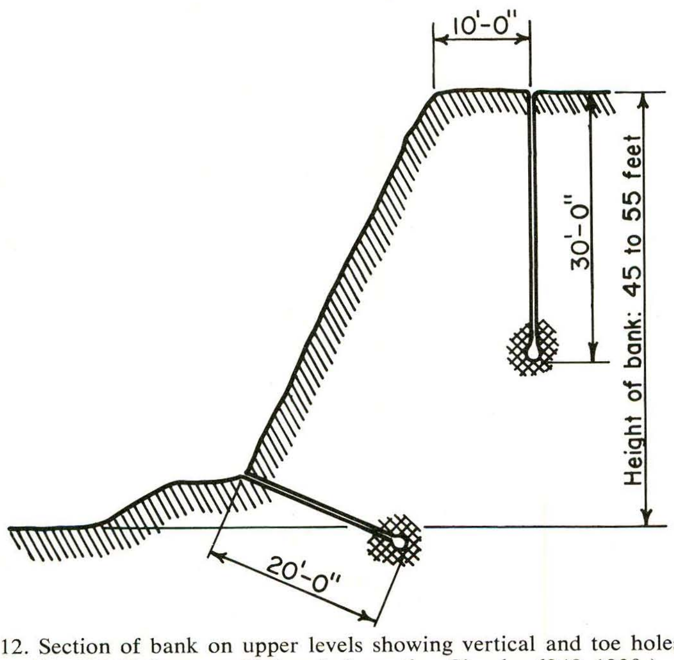

Figure 12. Section of bank on upper levels showing vertical and toe holes. (From Fig. 5, U.S. Bureau of Mines Information Circular 6248, 1930.)

drilling the 30 foot vertical holes, no less than 19 changes of drill steel were required under the most favorable conditions. Even using the best available steel sharpening and tempering practices, an average advance of only 3.7 feet an hour could be obtained with the drifters and 3.5 feet an hour with the jackhammers.

All holes were chambered by successive charges of 60 percent stick dynamite so that enough space could be developed to hold the amount of explosives required to break-out the burden of rock. On the 160 foot level more than 5,000 pounds of explosives were placed in many of the 120-foot deep, churn drill holes in order to break the 110-foot high bank. The explosive charge required for air drilled holes varied from 75 to 250 pounds. Fifty percent strength dynamite generally was used for blasting and the charges were primed with 50 to 60 percent strength dynamite and detonated by No. 8 instantaneous electric blasting caps. On the upper benches, the hard diorite shattered poorly and extensive secondary drilling and blasting was required to break the larger fragments and the hard toes which commonly remained unbroken at the foot of the benches.

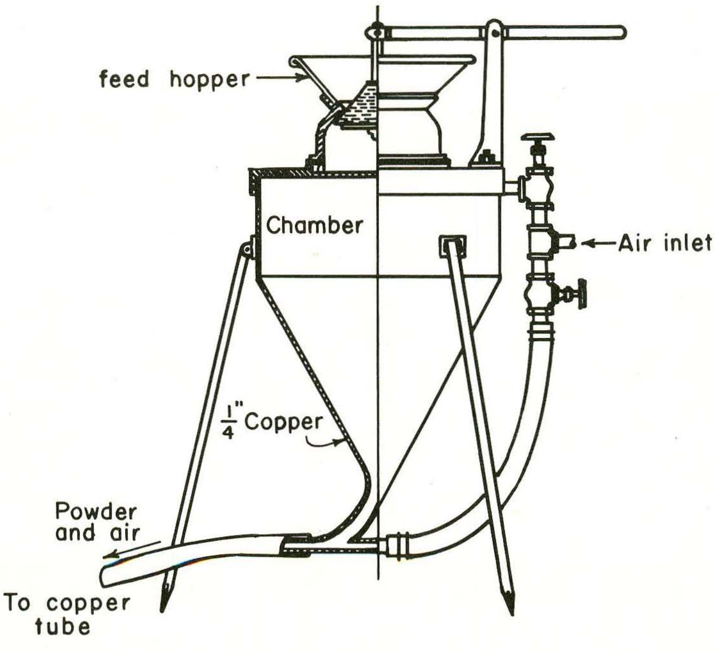

Figure 13. United Verde powder loading machine. (From Fig. 6, U.S. Bureau of Mines Information Circular 6248, 1930.)

Fifty percent strength dynamite generally was used for the blockhole and mud-cap blasting of the large boulders, with fire fuse and No. 6 blasting caps used for detonating. Free flowing, quarry powders were used for loading vertical holes, when such explosives became available, and were used also in toe holes, being emplaced with the aid of a pnuematic, powder-loading machine. Low strength, quarry powders were tried, but the higher strength No. 1 quarry powder, manufactured by the Apache Powder Company, generally was used when conditions permitted. Most holes were sand tamped after loading and priming.

Loading of air-drilled, toe holes with stick dynamite was a slow and tedious task, requiring under the most favorable conditions a minimum of 20 minutes to load 50 pounds of the explosive into a hole. In many instances, fractures and seams in the diorite caused bridging or blocking of the hole during loading, and this necessitated hazardous reopening of the hole. A pnuematic, powder-loading machine was developed in 1924 with which quarry powder, placed in a container, could be forced by low air pressure through a connecting hose into a copper tube inserted into the hole (fig. 13). With this device, 50 pounds of quarry powder could be deposited in the chamber of a hole in less than one minute. The primer was inserted before loading, thus eliminating in a large degree the possible danger of reopening a blocked hole (fig. 14).

Figure 14. Loading jackhammer-drilled toe holes with the pnuematic powder loading machine. Powderman at left is inserting one inch copper tube into hole. Two men with a long tamping stick are inserting primer into another hole. Osgood 120 steam shovel with 4-cubic yard bucket may be seen in background.

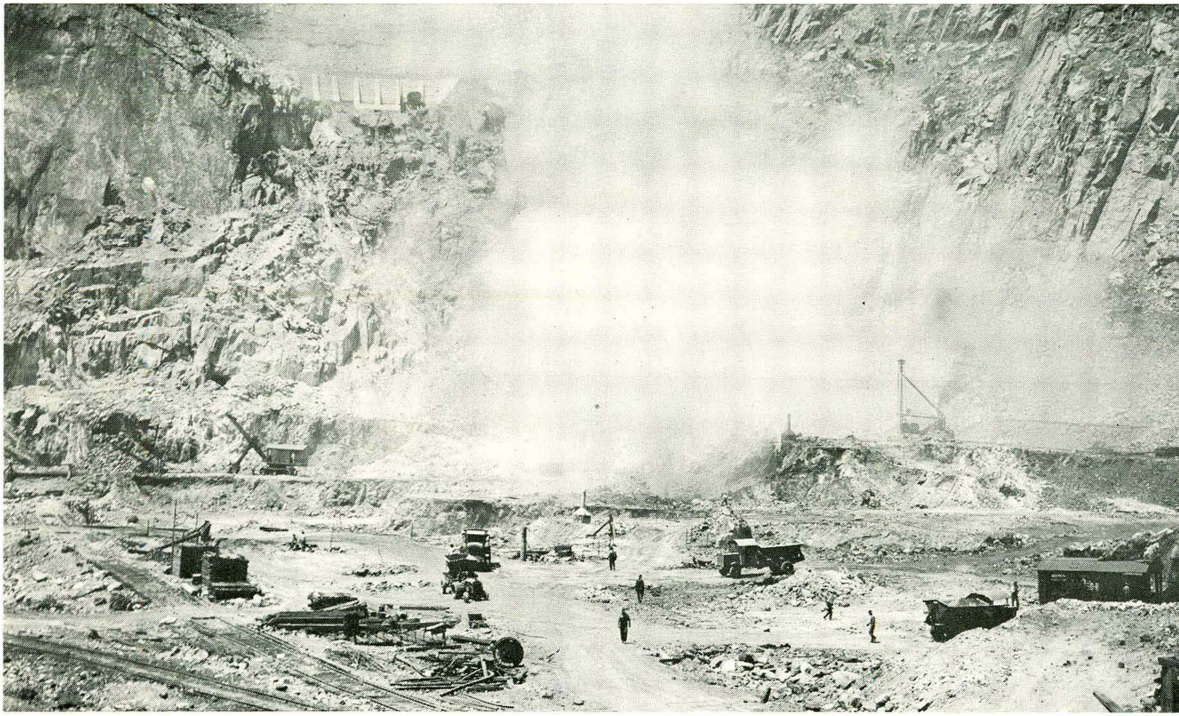

Figure 15. View taken during the early stages of mining operations below the 5320 bench (160 foot level). Smoke from the underground fire may be seen emanating in the vicinity of No. 2 shaft. Noted in the picture may be seen two Bucyrus, Model 50-B, 1¾ cubic yard, alternating current electric shovels; a Keystone, steam powered churn drill; and several of the early side-dump trucks.

Figure 16. A potentiometer with an iron-constantan thermocouple being used to measure temperature in a churn drill hole. An attempt is being made to cool several holes by blowing air into them. The highest temperature measured in any hole was 780° F. Two 1¾ yard shovels, trucks and an electric churn drill are seen operating in the background.

Forcing an explosive powder under pressure into a drill hole chamber is hazardous under the best of conditions, and requires careful consideration of such factors as shock and heat which might cause uncontrolled detonation. The energy resulting from shock or impact is dependent upon the mass and impact velocity of the detonation device and, under normal conditions of temperature, a particle of powdered dynamite requires tremendous impact-velocity to cause detonation. However, the sensitivity to impact of explosive materials increases rapidly with increasing temperatures particularly above 125°F. It was realized that under high ambient temperatures the potential hazard increased so much that the use of the loading device developed in 1924 should be restricted to areas of relatively low temperature, generally in the cooler diorite waste material. Safe practice also required that the loading machine, hose, and tube be washed and cleaned with a neutralizing solution after each use. Even with these precautions, one serious mishap occurred in the use of the powder loading device. In this instance, air temperature was above 100° F. and an explosion was initiated in the exposed hose while an attempt was being made to relieve a stoppage in the passage of the powder into a hole.

Between 1924 and 1927, when the 160 bench level was being extended into the orebody, hot ground was encountered and the pit was filled with smoke from the burning ore and old timbers in the underground workings (fig. 15). At times, when there was no breeze, visibility was limited to 300 feet. On some occasions during night operations, the heat of the burning ore caused shovel dippers and truck bodies to glow a dull cherry red. The hot burning ore presented several problems, not the least of which was in blasting.

Additional procedures were developed for controlling the blasting of hot ground after a mishap occurred in 1924 when attempting to load a hole in hot ground by conventional methods. Ground temperature was measured in all holes where heat was apparent and attempts were made to cool the hot holes before they were loaded. This was done by running water or air into them, or by placing wet sand in the enlarged chambers. The extreme heat did not permit measurement by mercury thermometers and it was necessary to use a potentiometer with an iron-constantan thermocouple to measure the temperature (fig. 16). When the temperature could be reduced below 120°F. for a substantial time, it was considered safe for loading. Many holes could not be cooled, however, particularly when the burning sulphide mass was encountered below the 160 level. Preloaded insulated paper tube cartridges were developed for use in both air and churn drilled holes (fig. 17).

Figure 17. Connecting electric detonators in preloaded paper tube cartridges for blasting air-drilled toe holes in very hot ground. One hole is being cooled down by blowing air into it. Note that tubes are supported off of the hot ground in order to keep them from heating.

Not only did the burning ore present problems for the surface operation, but it presented problems in the underground handling of ore through the transfer raises, and in its ultimate disposal via the Hopewell Tunnel system. (See figs. 18, 19, and 20.) In order to protect the transfer raises, only a small amount of burning ore was placed in a transfer raise at any one time and then it was mixed with material not on fire.

The underground fire was finally brought under control beginning in 1927, when tailings from the concentrator at Clarkdale were brought to the mine and pumped into the fire area through the bulkheads which sealed off the underground levels. The effectiveness of this procedure was so great that, in 1928, a plant was constructed adjacent to the pit for producing finely-ground sand suspended in water, similar to the concentrator tailings.

As noted previously, stripping on the upper benches could not keep ahead of mining operations on the 160 foot level. To speed up the stripping, a series of six tunnel blasts was carried out in the diorite wall on the 160 level. The first of these was in the Autumn of 1924. For the first three of the tunnel blasts, the bank height was 200 feet or more and the rock was hard diorite (fig. 21). Black powder was used as the main explosive charge in these three original blasts, and in the first the ground temperature varied from 112° to 152°F. Poor fragmentation and fracturing of the hanging wall resulted. The bank height was lower for the last three blasts, being only 110 feet for the sixth. Quarry powders were used as the main explosive charge in the last three blasts, and excellent fragmentation resulted. In all of the six tunnel blasts, the main explosive charge was primed with from three to seventeen percent of stick dynamite, generally of 50 percent strength. The total quantities of explosives in the tunnel blasts varied from 54,000 pounds to almost 260,000 pounds.

Mining below the 160 foot level was highly selective. Not only was the ore separated from the waste, but the various types of ore were mined separately so that they could be segregated for proper processing. At first, jackhammer-drilled holes were used exclusively. Later, however, more efficient, Armstrong electric-powered churn drills and tripod-mounted drifters were used to supplement the jackhammers which then were used mainly for drilling along contacts and in the areas where changes in the characteristics of the ore occurred. In hot ground, preference was given

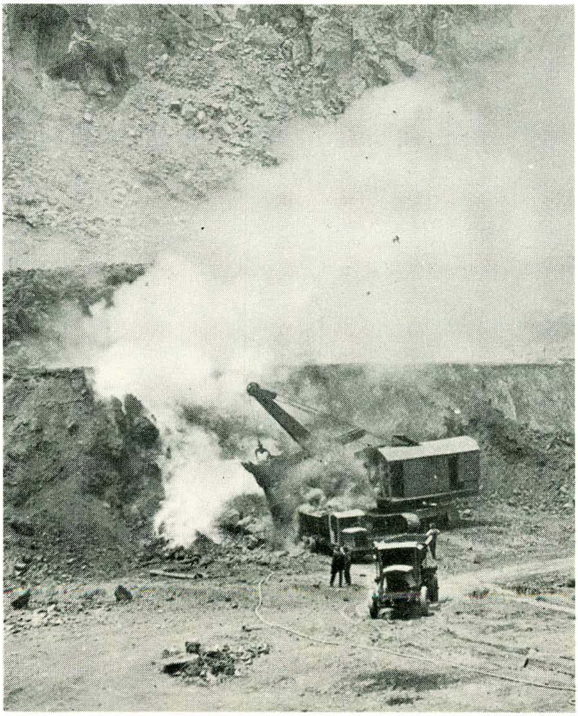
Figure 18. Loading burning ore with 50-B shovel on 5240 level in 1926.

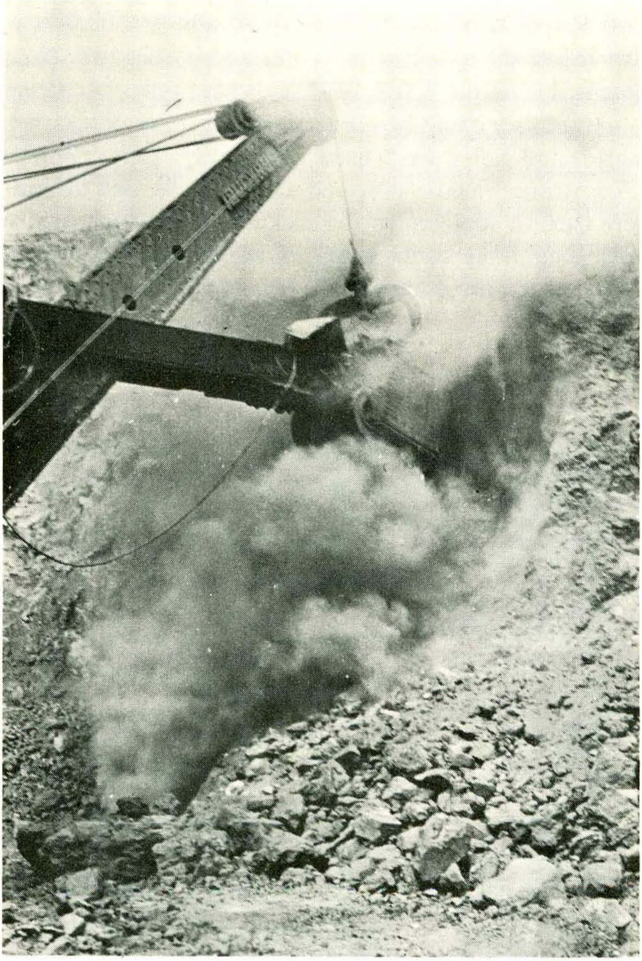

Figure 19. Close up of shovel digging into burning sulfide ore.

to the use of churn drills for drilling blast holes. Since only a small amount of explosive, insulated from the heat, could be placed into each hole, these holes were closely spaced and only 35 percent strength dynamite was used.

Drilling problems, even more difficult than those in the fresh diorite, were encountered in the dense, siliceous sulfide ore uncovered below the oxidized zone. Churn drill holes could be advanced only with extensive and repeated chambering, and even with the more modern churn drills, the advance averaged only about six feet a shift. Air drilling was also a problem but with the introduction in the middle thirties, of detachable bits, modern mounted drifters, and automatic feed devices, more effective drilling was made possible. However, failure to obtain good fragmentation in the harder materials continued to make extensive secondary drilling and blasting necessary in order that the ore and waste would pass through the transfer bins on the 1,000 foot level, or empty out of the bottom dump railroad cars when direct loading was possible.

An experiment in the use of liquid oxygen (LOX) for blasting was made about 1928. Cartridges of carbon black, 4 x 12 inches in size, were saturated with liquid oxygen and used in churn drill holes. Detonation was by means of an electric squib. The shattering effects in the hard siliceous sulfide ore were excellent and LOX blasting was estimated to be twice as effective as that obtained by the use of 60 percent strength dynamite. For the experiment, liquid oxygen was delivered nightly from Phoenix in Dewar flasks. However, the possible danger of its use in hot ground and certain economic considerations ruled against its continued use.

Figure 20. View after dumping load of burning ore into a transfer raise.

Figure 21. No. 3 tunnel blast, shortly after the moment of rupture, showing toe being blown out and high bank of shattered diorite dropping down. In this blast, almost 260,000 pounds of explosives was detonated, the broken bank extending from the 160 foot level, elevation 5320, upward to the 5575 level, a height of 255 feet.

Figure 22. View of fractured area at the surface, showing displacement of the diorite hanging wall, 650 feet above the 330 level, where mining operations were then being conducted. The Sunshine Hill and 500 level townsites are at the upper center and right, respectively. Tracks of the Verde Tunnel and Smelter Railroad may be seen extending as far as the Hopewell Tunnel in the distance.

In June, 1929, mining operations in the pit had progressed to below the 300 level, and were being conducted on a 24-hour, 3-shift basis. At about 4:00 a.m. on June 30th, workmen in the pit were alarmed by very sharp noises, resembling explosions, during which time the bottom of the pit, in the center section adjacent to the diorite wall, gave way and dropped as much as four feet. At the same time, rupturing of the diorite wall occurred, and the break extended across a width of more than 300 feet, and upward to beyond the upper edge of the pit wall, which at that time was more than 650 feet above the lowest pit level (fig. 22). The ruptured section dropped more or less as one mass, with only a relatively small amount of rock rubble, about 25,000 tons, falling into the pit. Workmen were evacuated from the fractured area immediately, and all possible equipment was moved from the affected areas as rapidly as possible. With mining operations thus essentially discontinued, a survey was initiated to determine the extent of the caving and its effect on continued pit development.

The investigation disclosed that early on the morning of the previous day, June 29, men working in the upper levels of the underground mine had reported that the ground above the 1,200 level had caved. As most of the workings above this level had been sealed off to control the fire in the upper orebody, the great extent of the caving, and thus the potential danger, was not recognized, and no warning was given to those in charge of pit operations.

Close examination of the fractured area on top of the hill disclosed that a displacement of about three feet had occurred and that there were more than 12 distinct fractures at the surface (fig. 22). No further movement of the pit floor was evident. The cause of this subsidence was attributed in part to the heavy surface blasting in previous years, partly to weakening of the underground support by the slimes which had been pumped into the underground fire area for choking-off the fire, and partly to weakening of support by the continued burning of the underground fire in certain areas. It was concluded that the caved material had filled the open spaces in the underground working, thus providing support for the loosened mass, and that the mass probably had dropped as far as it would go.

In a few days, it became evident that no large slide into the pit would occur immediately. However, broken rock continued to ravel and fall from the fractured bank, and, although not in great quantity, it was enough to make operations in the pit hazardous. Scaling and trimming

Figure 23. View of the caved material from the big slide of March, 1931. The pile of broken diorite rock was about 600 feet wide, covering the lowest working bench at the 5175 level and the crest extended upward about 350 feet. More than 1,000,000 tons of rock slid down the hanging wall, and some of the fragments were as big as a house.

of the bank then was initiated and this permitted mining in the pit to be resumed on the far side, away from the fractured diorite. Further rockfalls ceased in a few days, but the broken slope was placed under constant surveillance, and on Sundays, all equipment was moved away from the fractured slope so that scaling and trimming could be conducted.

As an additional safety measure, a program of monitoring the fractured area was undertaken to detect further movement. Twenty or more monuments were set in concrete in the vicinity of the fractured area on top of the hill, and periodic surveys were made to ascertain the vertical and horizontal displacement that had occurred. From these measurements the total movement was determined. This information was recorded on a time-movement graph, which indicated the rate of total movement. A uniform rate of movement was recorded for eighteen months but then an increase was noted. Projecting the curve, it was predicted that the mass would give away in the twentieth month, and so it did. Sloughing of rock from the fractured area began a week before the predicted date and increased at an accelerating rate until the rock mass gave way in March, 1931, with a tremendous roar and clouds of dust. It was estimated that more than 1,000,000 tons of waste rock fell into the pit (fig. 23). Fortunately, practically all operations in the pit had been suspended because of the advance notice provided by the rate-of-movement studies, and no injury to personnel or damage to equipment resulted.

This method of predicting when a fractured wall would fail, by plotting the time and movement, also was successfully employed to predict another fall of rock in March, 1936, when about 400,000 tons fell into the pit from the wall on the southwest side of the pit.

DEPRESSION YEARS AND ADDITIONAL STRIPPING

By the start of 1931, pit operations had been drastically curtailed. Most mining work was confined to supplying a small amount of waste for filling stopes in the underground mine which was continued in operation until the summer of that year. However, the cracking and caving of the diorite hanging wall in March resulted in a resumption of waste stripping that summer, and so provided employment for many workers during the depression years. The overall cost of this stripping was much lower than it would have been in previous years as costs for labor, materials and supplies were at rock-bottom during the depression. This additional stripping also made it possible to extend pit operations down to the 630 level, instead of stopping at the 500 level as had been previously con-

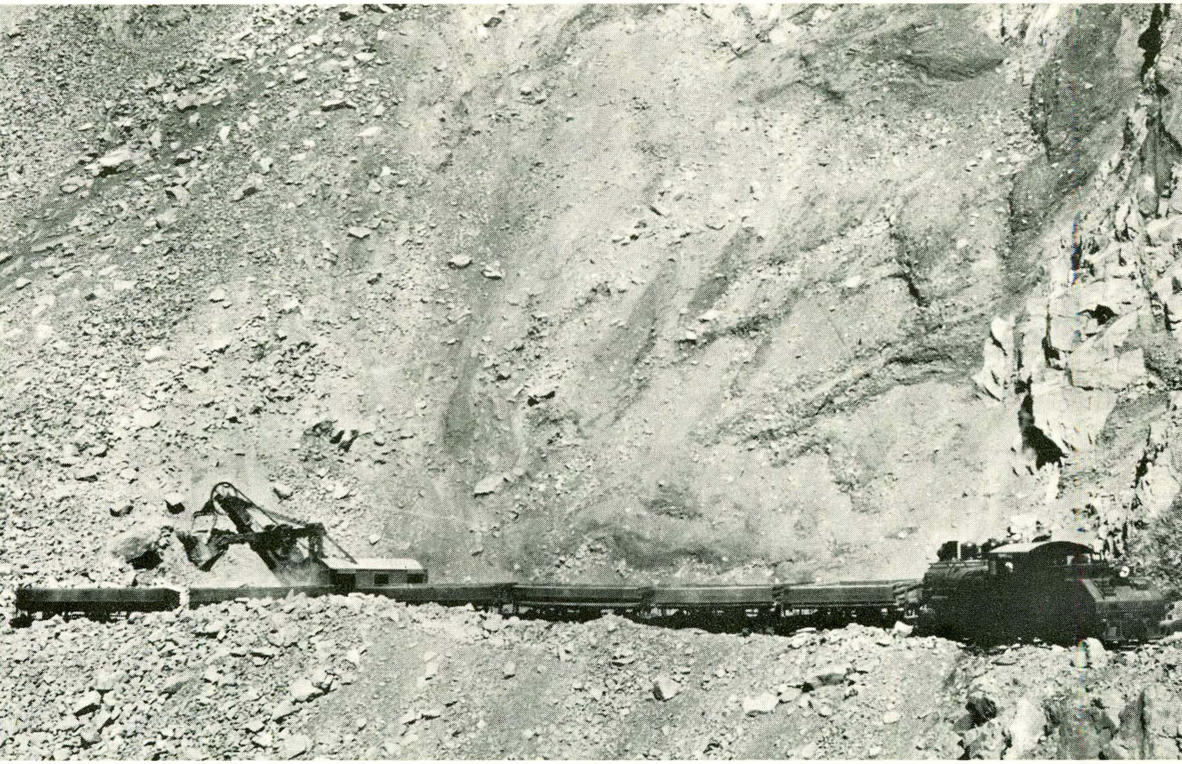

Figure 24. View taken in December, 1931, showing the Bucyrus-Erie 120-B, 4-cubic yard electric shovel on the 160 level cutting into the rock slide debris.

templated. During the following years, and continuing several years after the resumption of open pit mining in January, 1935, more than 6,000,000 cubic yards of waste was removed from the surrounding pit walls.

Stripping operations were resumed at a point 100 feet above the previously uppermost bench in order that all the fractured ground which had resulted from the caving of the diorite hanging wall might be removed. Thus, the hanging wall slope was cut back and the edge of the pit cut the surface at an elevation of 6,000 feet above sea level, as compared with the previous high mark of 5,820 feet. This also resulted in some overlying sandstone and limestone units being removed.

Stripping operations were carried down progressively on 50-foot high benches to the 5525 foot level, to remove weight from the fractured hanging wall. Below the 5525 level, however, stripping was confined mostly to removal of the fractured and caved material in the slide mass that had entered the pit (fig. 24). This caved material was not uniform, and many large fragments, some as big as a house, had to be dislodged and broken before loading. This had to be done beneath a 200-foot-high bank, under extremely hazardous conditions, and the slope required constant scaling and trimming. An unusual situation was noted in the lower part of the slide mass. Here, the caved material had been recemented, presumably by the action of precipitates derived from fumes rising from the underground fire area. These fumes invaded the fractured rock and the precipitated solids cemented the fractures. The cemented material was difficult to break mechanically. However, it was soon discovered that a generous amount of water would loosen the cementing agent.

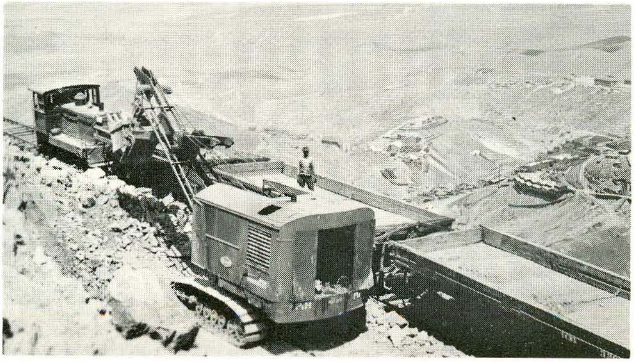

Figure 25. View showing the ¾-cubic yard P & H gasoline shovel, the gasoline locomotive, and 10 yard dump cars used on the upper two benches when stripping was resumed in 1931. The Douglas Memorial Mining Museum can be seen below, in the right center.

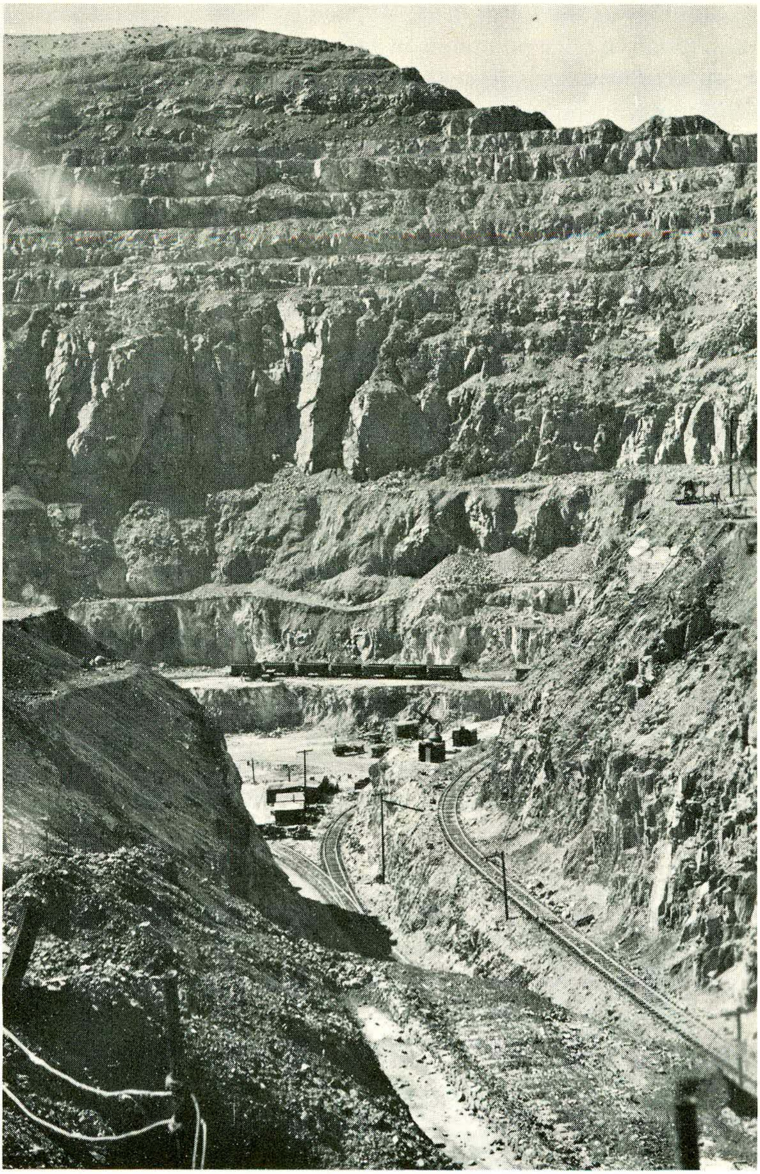

Figure 26. October, 1935, view of the diorite wall from the cut on the 300 level. The top of the bank is at elevation 6,000. A series of benches, 50 feet high, extends down to the 5525 elevation bench. Below that, a bank 200 feet high rises above the 160 level bench, which in turn, is about 150 feet above the ore cars waiting to be loaded on the 5178 elevation bench. The difference in elevation from the top of the cut to the lowest working bench is about 820 feet.

Figure 27. View of pit in October, 1935. With the construction of the cut into the pit in the 300 level, the pit surface plant was moved down to that level. Track was laid into the pit on two grades, one line to the third bench (elevation 5240), the other to the fifth bench (elevation 5178). On the extreme left, a 120-B, 4-cubic yard, shovel can be seen waiting for a waste train to come in. Below it, another 120-B shovel is loading ore into 100 ton V. T. & S. R. R. cars for direct shipment to the smelter which can be seen in the upper right. (Compare with Figure 10 which views the same area in 1928.)

Track was relaid on the old, previously constructed switchbacks and waste dumps, and the old steam locomotives and dump cars were put back into service. The old steam shovels, however, were not used since many improvements had been made in power shovels during the previous years. Two Bucyrus-Erie 120-B, 4-cubic yard, electric shovels with Ward-Leonard controls were obtained. This type of shovel operated at less than one-third the cost of the old steam shovels. These modern shovels were the first of their type to be used in Arizona. Since construction of switchbacks to the two upper levels was impracticable, a small gasoline-powered shovel, a gasoline locomotive and several 10-yard railroad dump cars with the necessary track were moved up to those levels on a road constructed for that purpose (fig. 25).

In 1934, a cut was made into the pit from the 300 level to facilitate the removal by direct rail haulage of waste below the 160 level (fig. 26). Also, this would permit direct loading of ore from two benches and eliminate the necessity of transfer through raises and the Hopewell Tunnel system, when mining was resumed (fig. 27). This cut was later widened since the bedded sediments on this side of the orebody provided desirable waste for filling underground stopes. The extent of the "Big Hole" can be seen to the best advantage from the 300 level, which is bordered by the road leading from Jerome to the old Mine Office buildings. Standing at

Figure 28. 1938 view of the United Verde open pit mining operations, the end of which occurred early in 1940. At this time mining was being conducted on the 600 foot mine level. Note the roadway on the south-east pit wall for providing access to operations. (Compare with figures 10 and 27.)

the west edge of this bench, one can look down into the pit, the bottom of which is about 300 feet below (fig. 28). The full depth of the pit is not now apparent, however, for although operations were terminated at the 630 mine level (330 feet below the 300 level), the hole has been partially filled by subsequent caving and by waste from more recent leasing operations.

RESUMPTION OF PIT MINING OPERATIONS

The removal of waste during the depression years and an improved price for copper permitted resumption of mining in January, 1935. The extreme heat encountered in previous years was never a problem when mining was resumed. The burnt schist ores, however, required special metallurgical treatment and milling procedures had to be devised to handle them. On February 18, 1935, control of the United Verde Copper Company passed to the Phelps Dodge Corporation and shortly thereafter a decision was made to forego further underground mining until pit operations were well towards completion. Thus, the danger of more fracturing and caving of the diorite hanging wall would be lessened. Pit mining proceeded at an accelerated rate for two and one-half years. Practically all ore processed was mined from the pit, amounting to more than 2,500,000 tons having an average grade of 3.92 percent copper, 1.44 ounces of silver, and 0.046 ounces of gold per ton. Copper prices were low and fluctuated widely during this period but by conservative estimate, the value of the ore produced from the pit in these first 30 months of ownership by the Phelps Dodge Corporation was more than $25,000,000.

Production in the pit declined rapidly after 1937 because the working benches became more and more restricted in depth by the merging pit walls. (See fig. 28.) Pit mining had been carried downward to the 630 level, or more than 1,100 feet below the highest point at the rim of the pit, when operations were terminated in April, 1940. A total of more than 4,050,000 tons of ore were removed from the pit during the period 1935–1940, and it averaged 3.83 percent copper, 1.45 ounces of silver, and 0.050 ounces gold per ton.

Not all of the ore above the 630 level could be recovered by pit mining since the pit slopes, by necessity, could not encompass the entire ore zone. Underground mining began again on a small scale in April, 1937, and was terminated in 1953. A few years later, leasers started mining some of the ore remaining above the 630 level outside the pit limits and, at the present time (1968), they are mining ore from the upper regions of the south wall.

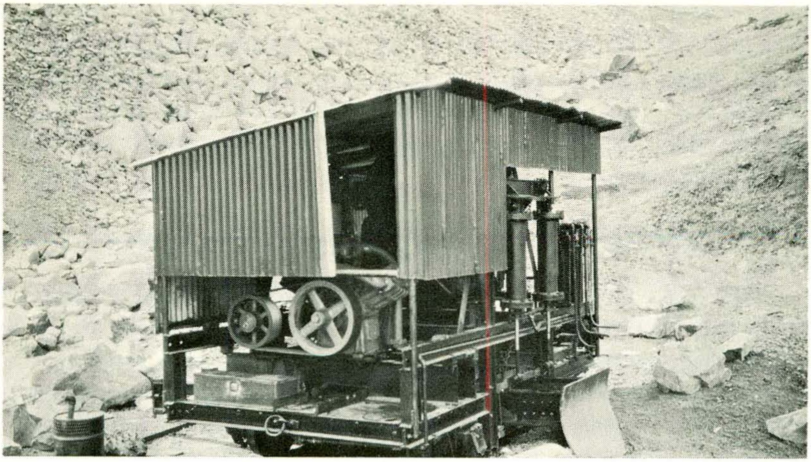

Figure 29. One of the innovations at the United Verde Pit. The pneumatically operated, traveling dozer, designed and constructed by the U. V. Mechanical Department, was used for smoothing out material on the edges of the track dumps so that the track could be shifted expeditiously as the dumps advanced.

Figure 30. One of the then modern pneumatic-tired, hydraulic-operated, side-dump, drop-door 20-ton dump trucks placed in operation in 1935.

SUMMARY OF OPERATIONS

During the life span of the United Verde Open Pit, from 1918 to 1940, many changes occurred, not only in the operating methods and equipment used in the Jerome operation (e.g. see figs. 29 and 30), but in surface mining operations, in general. Although unique as a surface operation, the United Verde open pit procedures contributed to these changes. Uncertain conditions prevailed in developing and operating the United Verde pit for many years but when mining resumed in 1935, the work progressed smoothly under the firm management and systematic mining procedures that had been established.

The life of the United Verde pit coincided with a period of "feast or famine" for the copper industry. The fluctuating price of copper was reflected in the alternate speeding up and shutting down of operations. For example, all work stopped beginning in 1921, for a year and a half, and all ore mining ceased for four and a half years during the Great Depression. Thus, actual pit mining of ore was carried out during a total period of not more than fifteen years.

It has been noted that 9,708,923 tons of ore were mined from the pit. In addition, several million tons of very low grade material was placed on designated dumps for leaching. Disregarding copper produced by leaching, production from the pit roughly amounted to 674,000,000 pounds copper, 20,000,000 ounces silver, and 689,000 ounces gold which can be valued conservatively at more than $100,000,000. This was indeed a sizeable value to come from a hole in the ground.

The story of the United Verde Open Pit operation is not complete without paying tribute to the loyalty and skill of the men who made it possible. From the scaler, dangling at the end of a rope on the high bank, to the drillers, powdermen, shovel crews, truck drivers, and other workmen, a fine spirit of cooperation and accomplishment existed. No task was ever too difficult, in spite of the unusual and often hazardous conditions under which these men worked.

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