1916

Mining methods of the Calumet and Arizona Mining Company, Warren District, Cochise County, Arizona

James Lawrence Head

Department: Mining Engineering

MISSOURI SCHOOL OF MINES

MINING METHODS OF THE CALUMET AND ARIZONA MINING COMPANY, WARREN DISTRICT, COCHISE COUNTY, ARIZONA

BY

JAMES LAWRENCE HEAD

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THESIS

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MINING METHODS

of the

CALUMET & ARIZONA MINING COMPANY

Chapter I

LOCATION

The mines of the Calumet & Arizona Mining Company are located at Bisbee, Ajo, Courtland, and Superior Arizona. Only the workings at Bisbee in Cochise County will be discussed in this report. Bisbee is in the Warren District on the eastern slope of the Mule Mountains in the southeastern part of Arizona, about six or seven miles north of the Mexican border.

Chapter II

HISTORY

The Calumet & Arizona Mining Company was organized March 1901 under the laws of Arizona. It entered upon its career in the district at the Irish Mag shaft, more than a mile east and south of the original discovery in the camp. The existence of the Irish Mag orebody was inferred from under-ground work in the adjoining shafts of the Copper Queen Consolidated Mining Company, after a careful study of the general geological

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conditions of the district. Nevertheless, work was started amid much doubt. Indeed, it required a great deal of determination and sturdy application of conviction to enable Captain Tom Hoatson and his associates to proceed against the equally firm conviction of most everybody in the Warren District at that time that the Irish Mag location was off the zone of enrichment on the limestone side of the porphyyy intrusion.

The discovery of the Briggs orebody greatly extended the proved ore area of the district, particularly east along the Dividend fault. When first opened, the Briggs shaft was sunk 900 ft. and various levels explored but without profitable result. Accordingly the Briggs shaft was closed down. Meantime the Junction shaft was developing one of its big orebodies on the lower levels around the 1200-1300 and found that its ore was running off towards the Briggs. It was deemed worth while to reopen the latter shaft and continue sinking to a greater depth. They did this and on the 1300-ft. 1400-ft., and 1500-ft., levels they opened up an orebody of an area from 1000 to 1500 ft. wide and more than 4,200 ft., long.

The Briggs and Junction orebodies were the property of the Superior and Pittsburg Copper Company which had been

HISTORY

organized June 30, 1907 under the laws of Minnesota. In 1911 a merger between the two companies was effected and the name of the Calumet and Arizona Mining Company retained. Although under the same management the books were kept separate, involving double clerical work and duplication of taxes. On Jan. 1, 1916, the S. & P. was finally absorbed by the C.& A. The C. & A. paid the stockholders of the S. & P. $21.50 per share, or exchanged one share of C. & A. for three and a half shares of S. & P., giving a bonus of $1.00 per share for speedy transfer.

Chapter III

PRODUCTION

The following table shows the production in pounds copper together with the net earnings, price received per pound, and cost per pound since the starting of operations in 1902. The figures for 1915, while approximate only, show the breaking of all previous records.

PRODUCTION

Production of the Calumet & Arizona Mining Co.

Year	Pounds Copper	Earnings	Received	Cost
1902	1,200,000			
1903	25,535,857	$1,341,474	11.558¢	6.89¢
1904	31,638,660	1,682,518	12.562	7.86
1905	31,772,896	2,314,268	14.932	8.21
1906	37,470,284	4,827,872	17.960	5.71
1907	30,689,448	2,114,047	18.102	11.22
1908	28,029,506	857,700	12.948	11.00
1909	27,630,050	1,214,495	13.531	10.38
1910	28,029,506	1,119,848	12.932	9.72
1911*	49,945,905	* includes Superior and Pittsburg		7.65
1912*	53,108,628			7.02
1913*	52,897,383	4,074,637		
1914*	52,667,929	3,085,536		8.19
1915*	62,500,000	6,400,000		8.00

Chapter IV

ORES AND ORE DEPOSITS

Pre-Cambrian crystalline schists are overlain by about 5,000 ft., of Paleozoic limestones with quartzite at the base. After their deposition they were deformed by folding and faulting and were cut by intrusions of granitic porphyry which is intimately connected with the origin of the copper deposits as indicated by the presence of garnet, tremolite, diopside, and other silicates associated with the ore minerals. After a period of erosion a transgression of the Cretaceous sea

ORES AND ORE DEPOSITS

deposited a thick series of beds on the older series. The two most pronounced features of the folding and faulting in the district are the Dividend fault, roughly east and west, with a dip to the south, throwing the pre-Cambrian schists on the north against the Paleozoic limestones on the south, and the Sacramento Hill porphyry stock, close to Bisbee, intruded into the Dividend fault, and extending into both the schist and limestones. This stock is about 1 mile long and about 1½ miles wide.

The copper deposits lie in the limestones, particularly the Carboniferous and Upper Devonian, mainly on the east side of the intrusive mass on the downthrown side of the fault, and appear as large, irregular and ill-defined or rudely tabular masses, sometimes following the stratification. The ore-bodies give little clue to their whereabouts prior to development. They are almost entirely oxidized, even down to depths of 1,400 ft. below the surface.

The primary ores consist mainly of pyrite and chalcopyrite. The oxidized ore, containing copper carbonates, cuprite, and sometimes also chalcocite, with much limonite, passes gradually on its peripheries into "ledge matter" or limonitic clays, which in turn grade into altered and contact-metamorphosed

ORES AND ORE DEPOSITS

limestones. The ore is remarkable for its variableness of character, some of it being very soft, requiring a large amount of timber, and other portions consisting of extremely hard sulphides. They are of high uniform richness and self-fluxing.

Heretofore, as already explained, the operations have been confined almost exclusively to the ore deposits in the lower Carboniferous rocks. There is no probability of the limestones of older or lesser age carrying copper in anything like the abundance of the Naco and Escarbrosa beds, but it is equally certain that the porphyries, which geologists assume to have been the source or the carrying media of the copper in the limestone, contains disseminated secondary ores of sufficient value to be worked, and that orebodies of notable size and of very good grade, have been discovered in limestone of Devonian and Cambrian age, which may give longer life to the district than is at present assigned to it.

Chapter V.

SHAFTS AND MINE PLANTS

The Irish Mag was the first shaft sunk. It is 1,350 ft. deep and has four compartments. The shaft was sunk through hard limestone, except where occasional orebodies were cut. Levels were driven at depths of 440 ft., 550 ft., 750 ft., 850 ft., 950 ft., 1050 ft., and 1150 ft. The main body in the Mag was the immense orebody north of the shaft. It was the largest orebody in the district and for years produced an immense tonnage. The ore has now practically been worked out and no hoisting is done at the shaft. The shaft was equipped with a 78-ft. steel headgear, a 114-ft. ore bin and a 250-hp. electric hoist, raising 3-decked cages.

The Oliver shaft is a 4-compartment shaft and is 1600 ft. deep. It cut ore at 710 ft. below the surface. The upper workings showed high-grade oxidized ores and the lower workings carried rich sulphides, having large bodies of oxide and sulphide ores from the 950 to 1350 levels. The orebodies have been practically exhausted and the mine was shut down during the slump in 1914, but operations were resumed on a small scale during the summer of 1915. The shaft is equipped with a 600-gal. Nordberg electric pump, and a Nordberg electric hoist.

The Powell shaft southwest of the Irish Mag was started

SHAFTS AND MINE PLANTS

Nov.,1908, and sunk 600 ft.,but no ore was encountered.

It is from the shafts of the Superior and Pittsburg Copper Company that most of the ore has been and is now being produced.

The Hoatson shaft was one of the first of this group. It is sunk on an isolated claim, the Del Norte, separated from the Junction property by one claim belonging to the Copper Queen Company. The shaft is 1,575 ft. deep and has four compartments, and is equipped with a steel head-frame. Its orebodies,which were among the largest in the district,have been almost entirely worked out and no hoisting is done at the shaft. Any ore mined in the Hoatson is hauled by motors to the Junction shaft.

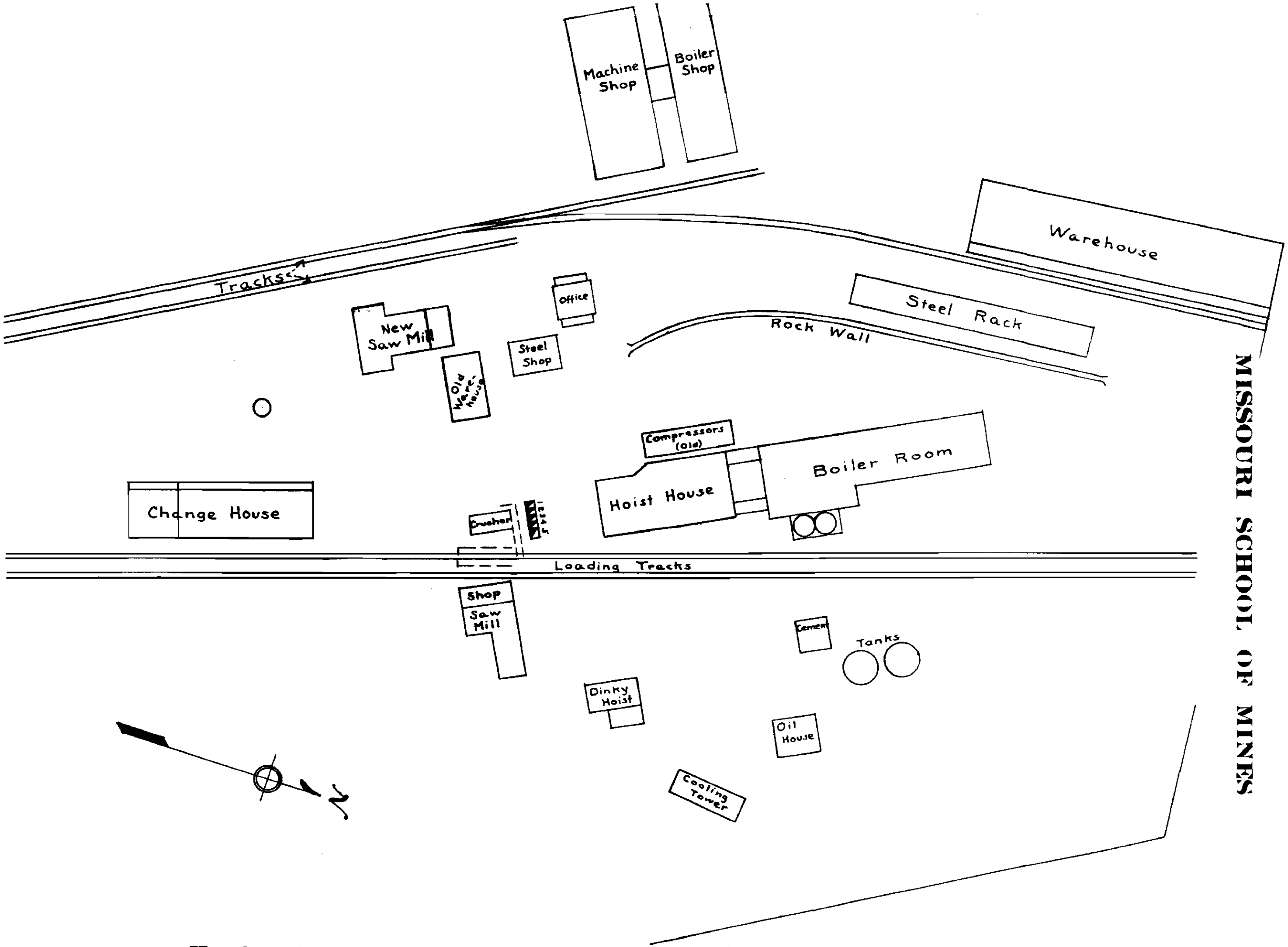
The 3-compartment Cole shaft lies considerably west of the main ore belt, the ore there being apparently due to an outlying intrusion in that part of the country. The shaft is 1,450 ft. deep, and has been a steady producer for a number of years.

The Briggs shaft was one of the last to be sunk. It has 3-compartments and is 1,530 ft. deep. At the present time, little ore is being hoisted through this shaft, the ore from the large orebodies of this mine being hauled to the Junction and there hoisted. The Briggs shaft

SHAFTS AND MINE PLANTS

is used mainly for lowering timber and supplies.

While the C. & A. has no shaft which could be called a main hoisting-shaft, yet the Junction shaft closely approximates one. Nearly all the ore mined in the Briggs and Hoatson is hauled by motor trains on the 1400-ft. level to the Junction shaft and there hoisted. The shaft is 200 ft. deeper than any shaft in the district, it having a depth of 1837 ft. It has five compartments and is lined with concrete. The Junction shaft drains the C. & A., properties and the Copper Queen workings, raising upwards of 1,500,000,000 gals. per annum. A pump station is located on the 1,000-ft. level. A new pump station has been cut on the 1800-ft. level. The water is utilized largely in the irrigation of formerly desert lands in the flat towards Naco, south of the mine. The shaft is equipped with a 75 ft. steel headgear. The power plant has a 16 X 42" Nordberg 4-cylinder hoist, a Nordberg 4-cylinder triple-expansion air compressor, having capacity to compress 5,975 cu.ft. of air per minute to a pressure of 70 lbs. per sq. inch, and twelve 250-hp. marine boilers. There is a large machine shop on the grounds. Fig. I shows the surface arrangement at the Junction.



-FIG. 1.-JUNCTION-SURFACE-PLANT, LOWELL, ARIZ.-

SHAFTS AND MINE PLANTS

About two years ago the Calumet & Arizona replaced the timbers of its Junction shaft with concrete. The particular object of concreting the shaft was the elimination of extreme fire risk at that point, inasmuch as the cessation of pumping through the shaft for one hour would mean the loss of all operating levels at the Junction, Briggs and Hoatson mines.

The shaft which is 27 ft. 3 in. by 6 ft. wide, was concreted to the surface from a point 1535 ft. below. This was accomplished in eight months and 24 days and required 8374 cu. yd. of concrete. Since that time the shaft has been deepened 200 ft. and also lined with concrete. All figures given here deal with only the concreting of the 1535 ft. The shaft has five compartments; compartments 1 and 5 are pipe compartments; 3 and 4, the main hoisting compartments; and 2, the dinky cage compartment. The walls were placed solid to the ground where the thickness did not exceed 24 in. Where it did exceed this figure, a dry wall was built of coarse rock and was filled in behind with mine waste, thus serving the purpose of a back form. The size of compartments 3 and 4, the main hoisting compartments, is 4 ft. 6 in. by 6 ft. The compartments were separated by three curtain walls of reinforced concrete, $\frac{3}{4}$-in. rods with a tensile strength of 50,000 lb. per sq. in., being used as reinforcement. At 10-ft. intervals, 2 X 5-ft. windows

SHAFTS AND MINE PLANTS

or air vents were left in the curtain walls to obviate the suction which would be created by the cage moving in so long a tube.

Considerable preliminary work such as the erecting of overhead storage bins and the equipping of a limestone quarry ½ mile away, was done previous to starting concreting. From the overhead bins the materials in the proportion of one part cement, three parts sand, and five parts rock, were fed to the concrete mixer. From here it was dumped through vertical pipes for delivery to the point where used.

Chapter VI

STOPING

In practically all cases, stoping is started from the sill upward. A raise is sent through to the next level to admit of the lowering of timber, the proper ventilation of the stope, and the dumping of filling. In the stopes in the oxide ores, the filling is carried within about two floors of the back pf the stope and immediately below where men are working.

In supporting the excavations, square-setting is used

STOPING

almost exclusively. The system, as a whole, has been very suwcessful. The means of supporting excavations by this method is too familar to need further description here.

The Camp of Bisbee has long been noted for the extremely expensive methods necessary to extract the ore in spite of the large size of the mines. The causes of this lie in the irregular nature of the deposits and in the treacherous ground; and the square-set and filling methods mentioned above are no reflection on the management of the companies. Nevertheless, it is now being discovered that some of the deposits at least are susceptible to extraction by more economical methods.

One of these methods is used at the Cole shaft where the grade of ore will not permit the expense of square-setting. It is known as the Mitchell Top-slice and Caving System and was developed by Mr. M. W. Mitchell, the mine foreman, after much experimenting. Before discussing the method it is necessary to dwell for a moment on the nature of the deposit amendable to this type of stoping. At the Cole shaft the orebodies consist of a series of roughly tabular lenses that are found in breaks cutting through the limestone. The material in these breaks consist of

FORM 8a
109 10-14-2500-F. P. & S. Co.

STOPING

leached limestone, broken limestone and a limonitic clayey material, parts of which are impregnated with sufficient oxides and carbonates of copper to make ore. In size, these lenses may be as much as several hundred feet long, 50 ft. wide and 50 ft. high. They vary in copper contents from 4 % to 10 %.

In mining, the extent of the orebody is first determined by running cross-cuts and raises. It is then cut into a series of sections by rows of square-sets a single set in width, extending across the orebody at 45 ft. centers. This timbering is carried vertically to the top of the orebody and is known as the gangway sets. In order to have an even floor under which to start mining, the top of each section is then mined by the square-set method, one set high or more. Usually one floor of square-sets is sufficient. The posts of the square-sets are set directly on the ground. After the ore has been taken out of the square-sets, long sills of 4 X 10 in. timber are laid across the stopes from one gangway to the other between each row of posts. A 2-in. plank floor is laid on these sills and serves to keep the capping from mixing with the ore during slicing. Then, if possible, the sets are filled with waste on top of this floor. This is to serve as a cushion for any ground to fall on in case the back does not immediately follow the caved timber after slicing has started below.

After the square-sets have been filled, or the timbers shot down in case there is no filling, a drift is started from one gangway to another at the edge of the orebody just below the caved or square-set ground. The first 11 ft. of this drift is driven as an inclined raise on a 45-degree pitch and then driven horizontally until it reaches a point halfway across the 45-ft. section. A similar drift is driven at the same time from the opposite gangway, and these two hole together in the center of the section. This 11ft. of incline at the start of the drift serves as a slide for ore to run into the gangway sets and thus minimizes the amount of shoveling in the stope. Contiguous parallel drifts are then run across the orebody in the same manner until all the ore in the slice is finally taken out. The sills above and any loose ground are caught up by props consisting of 8 or 10-in. round timber. These props rest on the ground, so that should they take weight, they will not crush, but be driven into the ground. The timber is cheaper than that usually used in the mine and, wherever possible, is taken out and used again. The ground is allowed to cave to within 15 to 20 ft. of the working face as it moves across the slice from one side to the other. Just enough

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STOPING

props are used to keep the back safe for this distance from the face. When the whole slice has been taken out across one section, the props are shot down, in case they have not already come down, and the capping is allowed to cave.

After the ground above has settled, a slice is taken out in the same manner as before, except that the slice slide in this case is 15 ft. long, and the slice 9 ft. high. On the completion of each slide the back is caved and a new one is started until the bottom of the ore is reached. Slicing is not carried below a haulage level, any ore extending below being attacked from the level below, in the same manner.

All drilling is done with $2\frac{1}{4}$ -in. piston machines on a vertical column. In working each 45-ft. section, it is divided into two equal parts, one-half being worked from the gangway on one side by the day shift and the other from the gangway on the opposite side by the night shift.

The distinguishing features of this system are the slides and gangways. The slides are formed by placing 2-in. timber in the gangway,—sets so that all the ore of the slice from any part of the slide, will run into a chute without any mucking. The system has been found to permit a saving in labor, timber, powder and air.

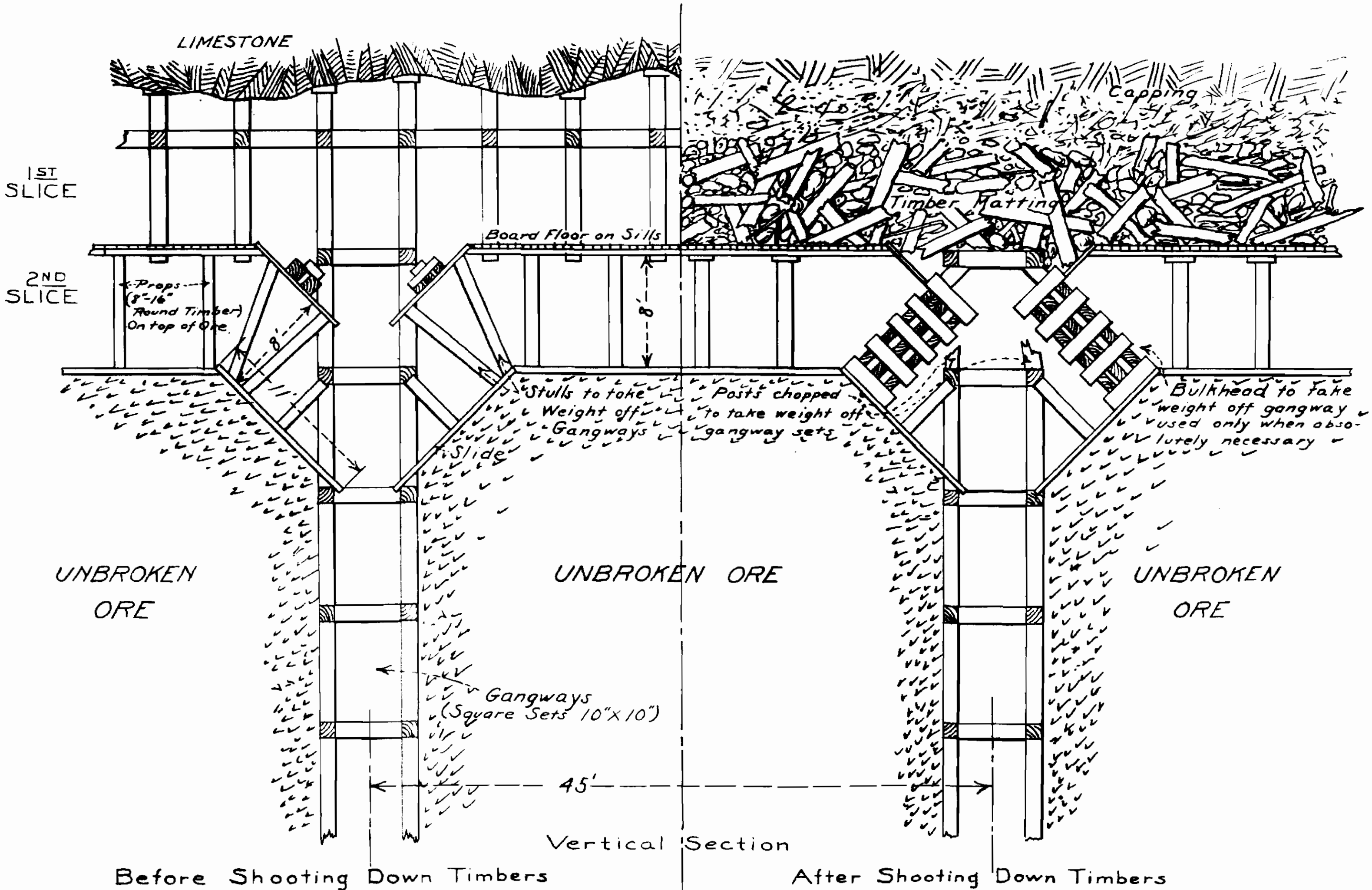


FIG. 2 - MITCHELL TOP-SLICE SYSTEM AS APPLIED IN COLE MINE

STOPING

The Mitchell system finds a slightly different application at the Briggs mine. At this mine orebodies consist of a series of lenticular masses of iron and copper sulphides, averaging from 3 to 15 % copper. The physical character of the ore in the lenses will not permit open stopes, but parts of them are favorable for the top-slicing. The ore is of a fairly uniform grade, containing no horses of waste, and the back of the stope will stand for a short time with the timbers used.

In applying the method (see Fig. 3) the orebody first is blocked out by chute-crosscuts, driven at right angles to a main crosscut and spaced at an interval of 40 ft. These chute-crosscuts are driven to the edge of the orebody and later serve as haulageways from the stopes. Two-compartment timbered raises are put up off the main crosscut at 20-ft. intervals to the top of the orebody. Usually every second raise is carried up to the level above, to permit timbers being lowered into the stope, and also so that waste can be introduced as filling after the pillars have been mined out.

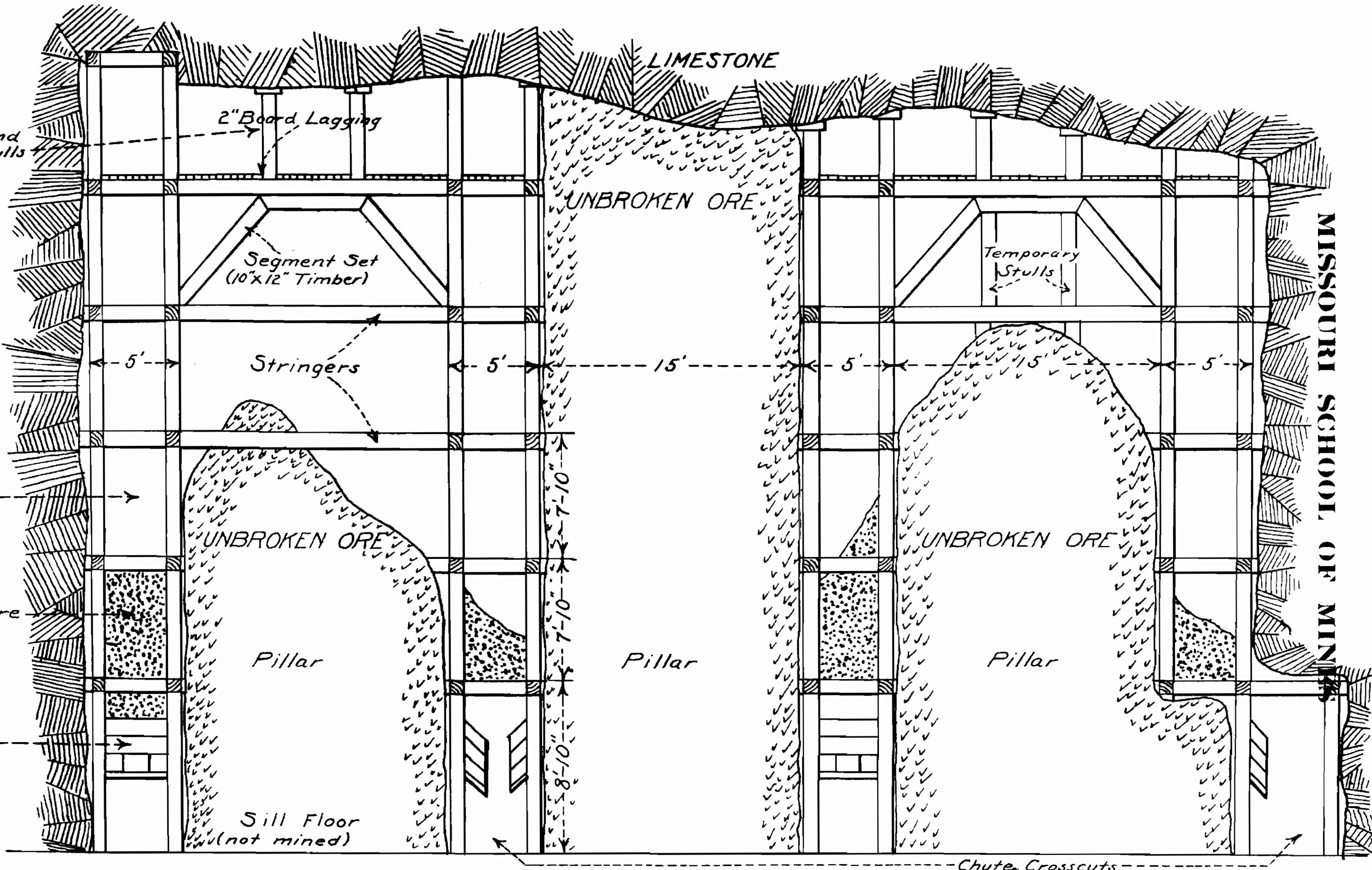
The orebody then is cut into a series of pillars 15 ft. thick, by running single rows of gangway sets from the first floor of the raises to the edge of the orebody. These are carried upward either directly over, or at the side of the

STOPING

top of the chute-crosscuts to the top of the orebody. In driving the gangways, regular square-set stoping is used. In case of friable ores it may be necessary to lag the sides of sets. Chutes are arranged in the gangways so that the ore mined above may fall out without mucking.

The pillars then are mined by first catching up the back with long stringers and then removing the ore in horizontal sections beginning at the top of the pillar. Only ore down to the top of the first floor (8 ft. above the sill) is mined; the ore below being left for mining at a later time. As mining progresses, long stringers are placed between the two adjacent rows of gangway-sets to keep up the back and hold the square-sets in position. No mucking is necessary, as the ore runs out by gravity into the gangway-sets, and thence into the chutes. As seen in the figure, segment sets consisting of two angles and a spreader are used in the second slice. They are used only at the top of the stope and are for the purpose of keeping up the back while the ore is being taken out of the pillar below.

After the ore has been mined out of the pillar, lagging is placed over the ore on the first floor, and the space occupied by the pillar is lagged off and filled with waste



Vertical Section

-FIG. 3 -MITCHELL-TOP-SLICE-SYSTEM-AS-APPLIED-IN-BRIGGS-MINE-from the level above. The gangway-sets are preserved, as they are used in mining the pillars on the opposite side to the one just mined. The adjoining section is then mined out in the same manner.

It is estimated that by using this method, the cost of labor, was 65 %, timber 72 %, and air 57 % of the costs of labor, timber and air in square-setting. Besides being cheaper, this method has the advantage that a small block of ground can be made to produce a large tonnage in a short time after slicing has been started. The "plugger" drill is used as nearly all the holes are down holes. There is practically no mucking except at the last stages.

In mining the large sulphides orebodies of the Junction and Briggs' shaft, an entirely different system is employed. At first in order to replace square-setting, shrinkage stoping was used, but this was found to be rather unsafe. To replace it Mr. Oscar Gilman, the mine foreman, devised what is known as the Gilman Cut-and-Fill System. The various stages in this system are shown in figure 4. The following is a brief description of the method, the details of which may be obtained from inspection of the figure.

The ground is blocked out by running, from a main cross-cut, parallel crosscuts at 40-ft. centers to the limits of

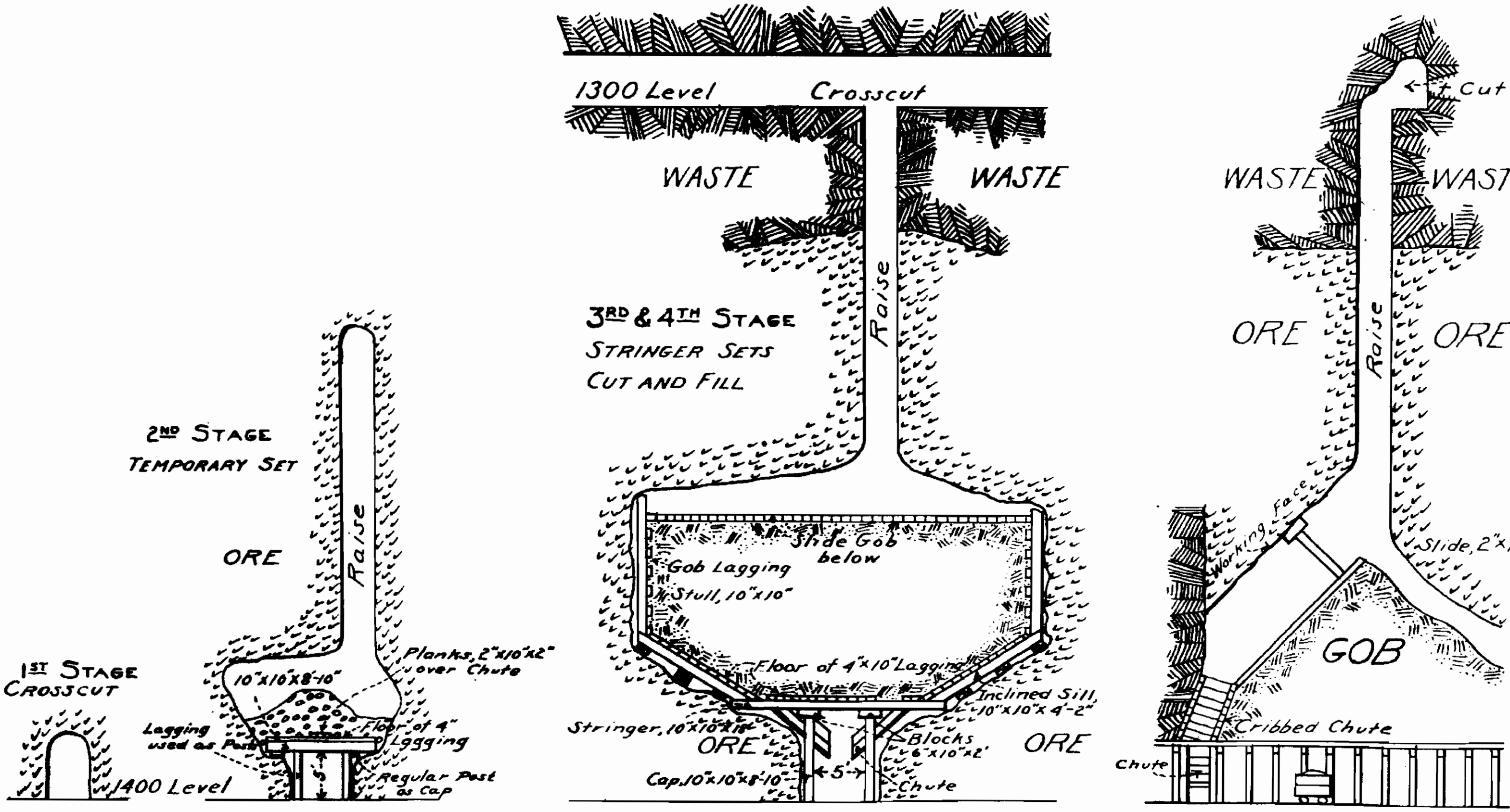
STOPING

of the orebody. Vertical raises are driven off these cross-cuts, near the intersections of the main crosscut, or at some multiple of 50 ft. from it, usually. These raises are run up to the level above, where they hole into a crosscut and provide a means of filling the stope later on.

Temporary sets shown in the 2nd. stage of the figure then are placed at 5-ft. intervals along the crosscut. They are set in place to catch the ore that is broken in placing the regular stringer sets (3rd stage) and thus lessen the amount of shoveling as the ore can run through a chute in the flooring between the sets into a car beneath.

When sufficient ground is broken, the temporary sets are removed and the stringer sets placed in position. To block the stringer to the next one in place 4 X 6 -in. spreaders are used. The stringers are floored over with lagging. Chutes are placed in every other set on each side of the crosscut. Ore is then broken on both sides of the stope to make room for inclined sills which are set on a little over a 30-degree incline. A 4-in. plank floor is laid on these sills and serves as a slide for the broken ore to run into the chutes.

We now have the bottom of the whole width of a 40-ft. section timbered and we are ready to start stoping which is done by the cut-and-fill system. The drilling is done



Vertical Section through Stope

Lengthwise of Stope

- FIG. 4 - GILMAN - CUT-AND-FILL - SYSTEM -

STOPING

by stoping machines with water attachment. The ore is to be mined in 10-ft. inclined slices. The first cut is taken from the back across the whole width of the section, from 30 to 40-ft. on both sides of the raise. All the ore broken runs from the slides into the chutes without mucking.

When the ore is all withdrawn after the first cut, waste is run in from above through the raise until it forms a cone reaching to the back of the stope. The gob pile is then evened off on the sides so as to have a triangular cross-section, instead of a cone, as shown in Fig. 4. Two slides stoping on a 40-degree incline from the center of the raise are made by laying sills of 2 X 10 -in. plank horizontally across both sides of the pile and laying a 2-in. floor on this.

The 10-ft. slicing is then repeated, all subsequent cuts being taken off the back, parallel to the slides. The ore is all withdrawn after each cut, and the floor, together with the sills, is taken up preparatory to a second fill. As the waste gets higher in the stope, it is kept away from the ore in the next section by sills and gob lagging as shown in the figure. Cribbed chutes of 4 X 10 -in. lagging are carried up through the gob to the bottom of the inclined slides to permit the removal of the ore.

Chapter VII

VENTILATION

Ventilation in the mines is natural as far as possible. Most of the shafts are connected on the different levels, and usually the levels are cool enough for comfort, and the air is good. Levels are connected in many places by raises which are put up for prospecting purposes as well as to help the ventilation. Where a raise does not ventilate, the stope naturally, special methods of ventilation are used. One way is to cover over with plank the manway set of a raise on the working floor of the stope and to remove the floor in one of the sets in the far corner of the stope, thus forcing the air to travel across the working floor, down into the far corner and back to the raise in the ~~in the~~ floor below. In this way two floors of a stope can be ventilated if there is a current of air in the raise. When there is not a current of fresh cool air in the raise, small centrifugal blowers run by electric motors are used to blow air from a main passageway to the stope. Six-or eight-inch galvanized pipe is used to conduct the air. Natural ventilation is sometimes aided by the exhaust from drill machines and compressed air.

The relative humidity in most places exceeds 90 per cent, making the mine air somewhat oppressive.

FORM B8
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Chapter VIII

TIMBERING

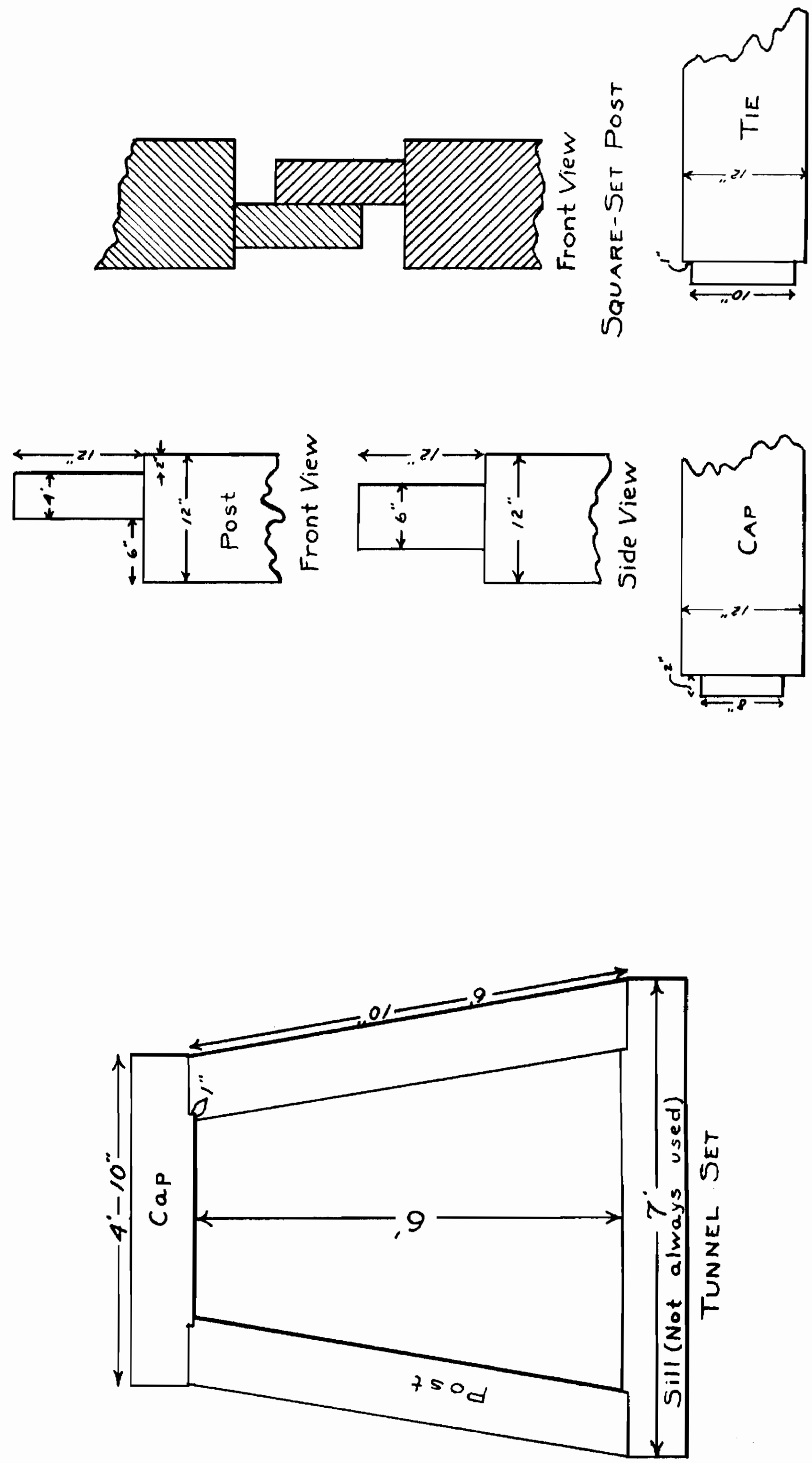
As would be inferred from the above discussion of stoping, a large amount of timbering is used in the mines. The timber used is chiefly Oregon white pine, there being little or no timber in the immediate district. All vegetation in the district was destroyed by the sulphurous fumes of the matte process employed by the old Copper Queen smelter.

This large amount of timber, (over one million feet per month) is, of course, due to the square-setting methods. The timber used is all framed stock, with few exceptions. In very heavy ground, round timber is sometimes used.

Fig. 5, shows the framing of the square-set timbers as is generally employed by the C. & A. All timbers are 12" X 12". The cap is 4' 10" long with a 2" shoulder and an 8" X 12" face. For the tie a 10" X 12" timber is used, or a 12" X 12" timber framed so as to have a 1" shoulder with a 10" X 12" face. The tie is 4' 10" long.

The post is 5' 10" long, having a 12" horn with a 6" X 4" face so framed that it will fit side by side with the horn from the host above. See fig. 5.

MISSOURI SCHOOL OF MINES



- FIG. 5 - TIMBER FRAMING -

TIMBERING

Fig. 5, also shows a tunnel set which is used in the timber drifts. The usual size of drifts is 5' X 7'.. All timber is 12" X 12" .

Under stoping has been mentioned several special methods of timbering, such as bulkheading, etc.

Chapter IX

MISCELLANEOUS

A few miscellaneous points from the author's notes which are not mentioned above are enumerated here.

a. Labor is of all nationalities. No Mexican labor is employed underground.

b. The law of Apex has been waived, and the common law adopted by which the side and end line carried down vertically define the ownership of the minerals in depth.

c. The company is paying special attention to the "Safety First" work. This work is in charge of Mr. Thos. Gowperthwaite, M.S.M. '05.

d. Intermediate tramming to haulage chutes is done, in general, by mules and hand. Electric haulage is employed on the 1400 level of the Junction, Briggs and

MISCELLANEOUS

Hoatson mines. It is also being installed on the 1600 level of the Junction.

e. The sliding wage scale is employed.

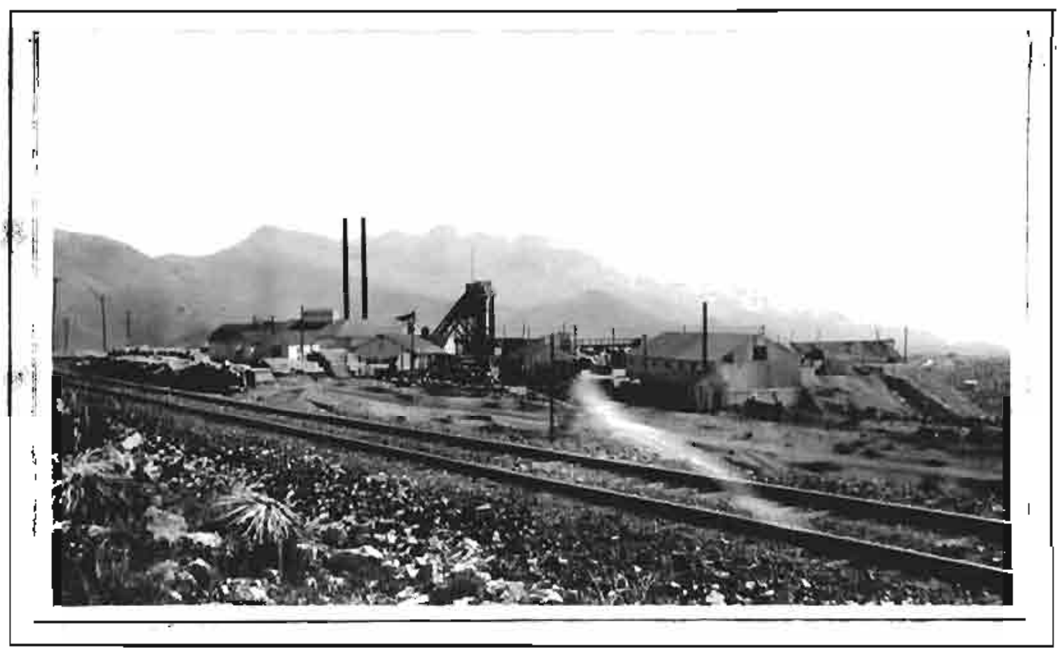
d. All main haulage ways, stations, powder houses, etc., are lighted by electricity. Carbide lamps are used by the workmen.

e. The Junction shaft is equipped with concrete ore pockets at the 1400 and 1600 levels. These pockets are 17 X 17 X 28 ft. They discharge into skips, the discharge doors being operated by compressed air.

-SACRAMENTO HILL FROM THE SOUTHEAST-
Oliver Dump in Foreground

-HILLS CARVED FROM CRETACEOUS BEDS EAST OF BISBEE-
The prominent white band is the upper member of the Mural limestone

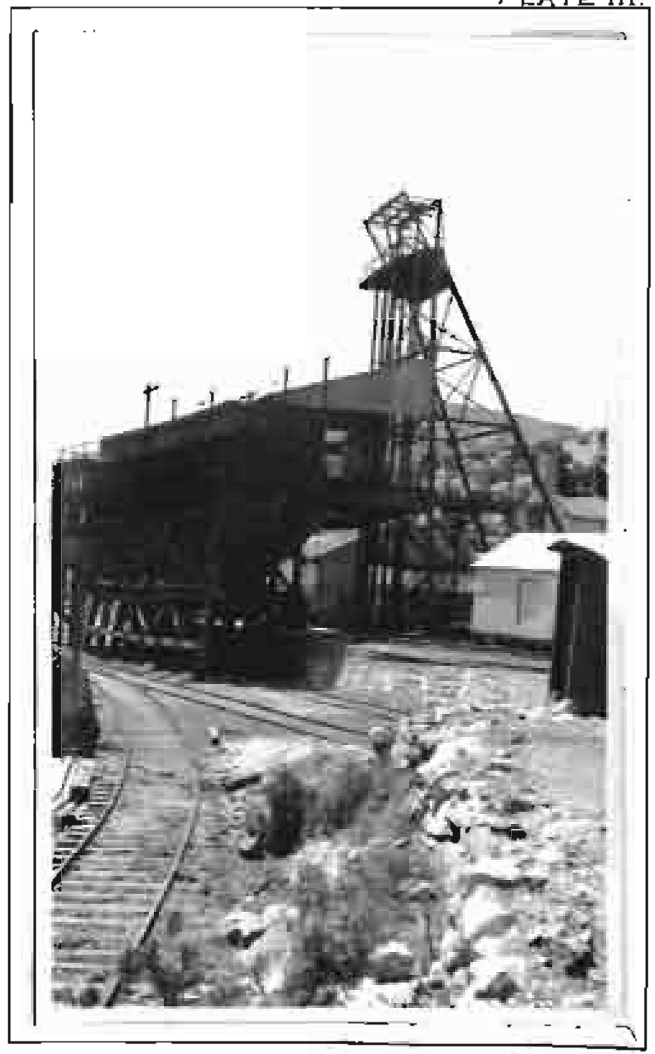
·GENERAL OFFICES, WARREN, ARIZ.·



·THE BRIGGS·

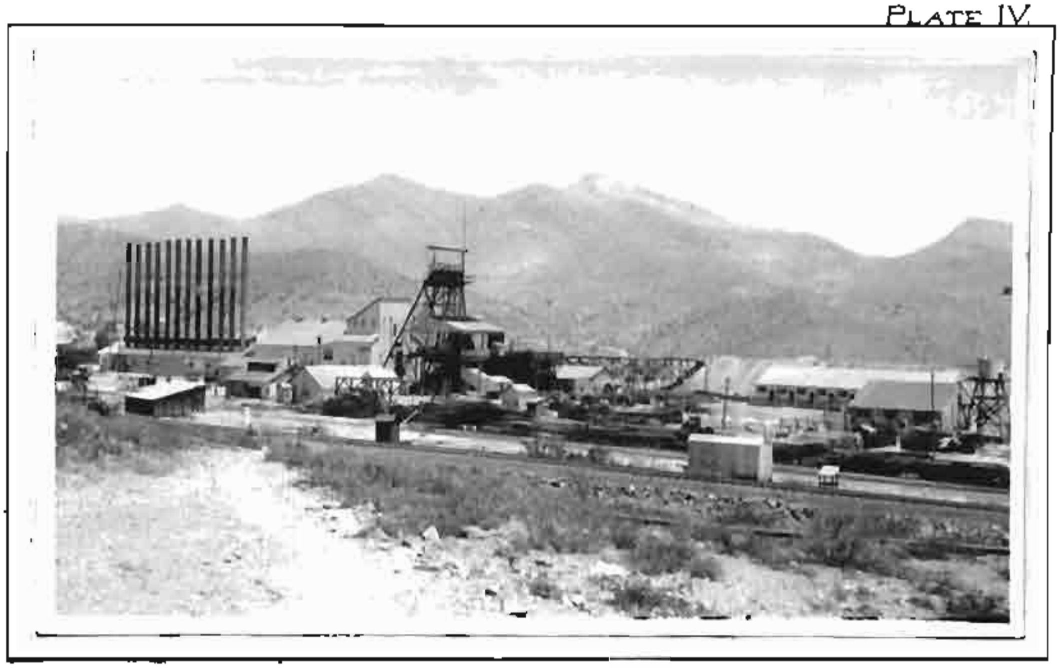
PLATE III.

- THE COLE HEADFRAME -



- THE HOATSON HEADFRAME -

PLATE IV.



·THE JUNCTION·

·THE BRIGGS·