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OPERATIONS AT THE SAN XAVIER MINE

of

THE EAGLE-PICHER MINING AND SMELTING COMPANY

Tucson, Arizona

by

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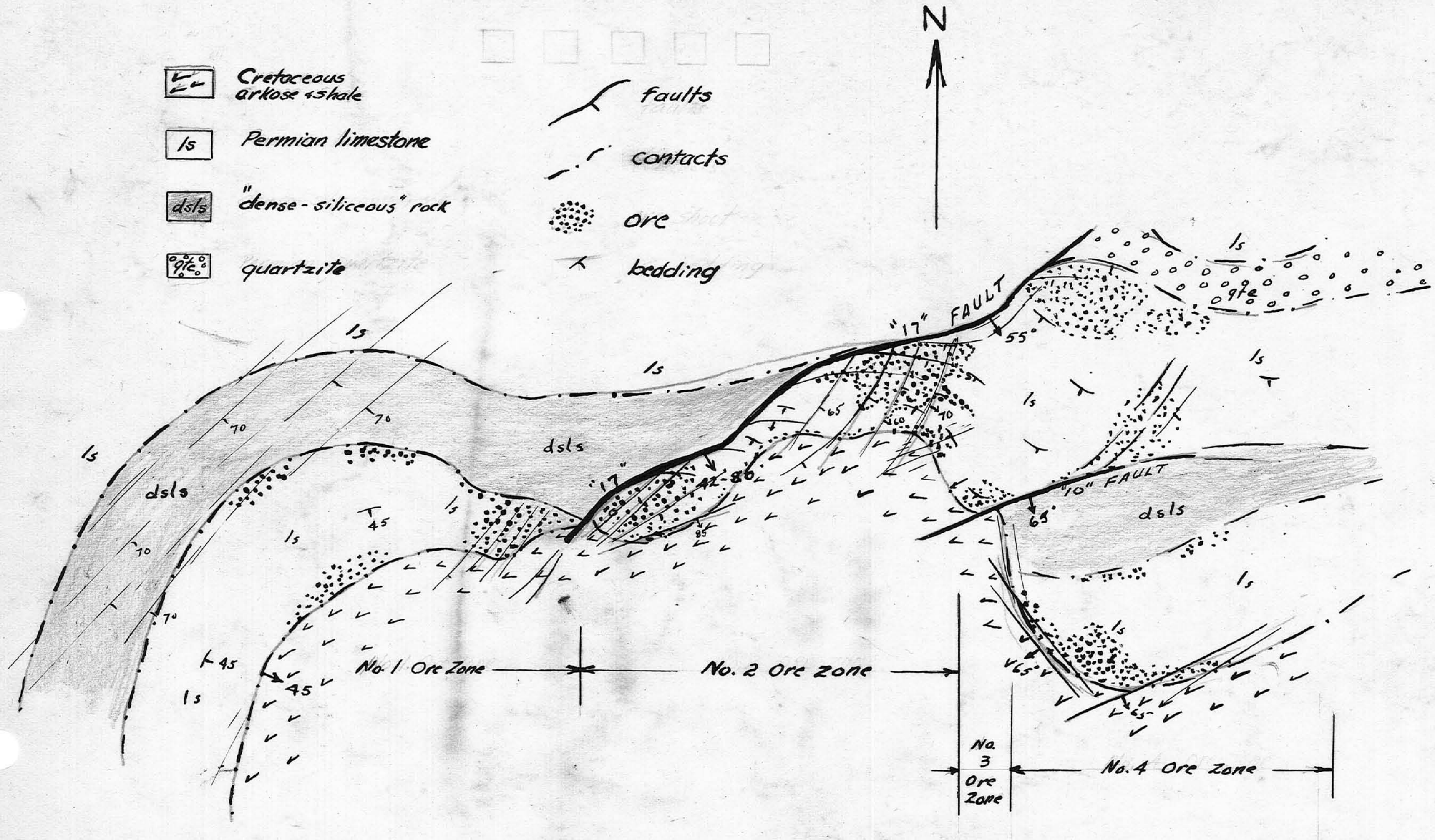

SAN XAVIER MINE

Generalized Sketch Plan

showing

Relation of Ore to Rocks & Structures

in lower levels

LOCATION

The San Xavier Mine of The Eagle-Picher Mining and Smelting Company is located in the Pima Mining District twenty miles southwest of Tucson, Arizona. The mill[1] is located ten miles east of the mine at Sahuarita on the Tucson-Nogales line of the Southern Pacific Railroad.

EARLY OPERATIONS

Before the turn of the century to the end of the first World War, high-grade lead and zinc oxide ores were mined from the upper levels and shipped direct to the smelters. These ores were mined mainly by open stope and shrinkage methods. During this time six shallow shafts were sunk on the property. Five of these shafts are in the eastern part of the mineralized areas. Most of the production was from this area and from the 270-foot level to the surface. The bottom level was 340 feet from the surface but only a small amount of development work had been done here.

The Number 6 shaft in the western part of the mineralized area extended to the 250-foot level and this was operated as a separate unit from the eastern area. The ores from the western area were copper and zinc oxides.

EXTENT OF OPERATIONS

The present mine workings extend horizontally a distance of 2700 feet and vertically 660 feet. At the present time production is obtained from six levels extending from the 200 to the 660. Sinking of the Main shaft

[1] Crabtree & Parker - T. P. No. 2193, July 1947 (Short Cut to Metallurgical Accounting).

has again been resumed below the 660 level. Of seven shafts sunk during the life of the mine, only five are in use at the present time. Of these five shafts, one is used for hoisting and four for emergency exits and ventilation. The hoisting or Main shaft is now equipped with a new 72-foot steel headframe and three steel ore bins. Hoisting is done in counter balance, and this new shaft saves one additional hoisting and tramming which obtained under the old setup. Natural ventilation is aided by the use of one 24,000 CFM exhaust type blower placed on the surface.

PRESENT OPERATIONS

In 1942 The Eagle-Picher Mining and Smelting Company acquired the property and, after rehabilitating the mine, began production on a modest scale. Until 1946 they mined the sulfide ores that had been left above the 340-foot level. In May of 1946 a new vertical shaft was started from the 340-foot level and eventually sunk to the 660 foot level. In January of this year this shaft was brought through to the surface and is the one used for hoisting, as mentioned above. Four levels at intervals of 83 feet were started from this shaft. Although the level interval is 83 feet vertically they are approximately 100 feet apart as measured down the average dip of the ore bodies.

Electric power for the mine is generated on the property by five 2-cycle Fairbanks Morse diesel engines that develop a total of 1200 horsepower. Each engine is directly connected to a 3-phase, 60 cycle, 200 volt generator. At the present time, all of the electric power is supplied and used at 220 volts. In the near future, step-up transformers will be installed to furnish 2300 volts for three new 150 H. P. centrifugal pumps to be located on the 910-foot level.

Approximately fifteen tons of water are pumped for every ton of ore hoisted. For this reason 40 per cent of the power that can be generated is connected to the present pumping plant. The addition of the three new pumps will increase this percentage by a considerable amount.

Compressed air for the mine is supplied by two Ingersoll-Rand Imperial Type 10 compressors.

One-inch round lugged steel is used exclusively for all drilling equipment, so that it is unnecessary to have several kinds of steel underground. All of the steel is threaded for jack-bits.

DEVELOPMENT

After the shaft level stations are completed, a cross-cut is driven from the station through the favorable limestone beds. From this cross-cut, drifts are driven east and west through the ore zones. A considerable portion of the lateral development is in ore. After a reasonable amount of development work has been completed, raises are driven to the level above. As the ore bodies have irregular outlines, the raises are not driven at standard intervals. Wherever possible, they are located near the center and on the footwall side of the ore shoots.

Approximately 1000 feet of size EX Diamond Drill holes are drilled every month underground. This drilling is done for geological information on existing and proposed levels. On the lower levels these holes are used to lower the water table gradually so that lateral development will not cause a sudden inflow of water in quantities too great for the pumps to handle.

DRIFTS AND CROSS-CUTS

Untimbered drifts and cross-cuts are usually driven 6 feet wide and 8 feet high. When blocky or otherwise heavy ground is encountered, they are timbered with 8 by 8 timber as shown in Fig. 1. When it is necessary to timber, the drift dimensions are increased one foot each way.

Seventy-five per cent of the drifting is on a contract basis. This is paid at the rate of $8.00 per foot with the company furnishing all of the supplies. Timber is paid for at the rate of $12.50 per set. Most of the mucking in the drifts is done with Eimco mucking machines. In the contract drifts, the contractor places the track and a company pipeman keeps the pipe near the face.

RAISES

The raises are approximately 7 by 5 feet in section. The chute side is separated from the manway by 3-inch lagging supported on 8 by 8 stulls. As the raises seldom exceed 100 feet in length, supplies are hoisted by hand.

Approximately 50 per cent of the raises are driven on contract at a rate of $10 per foot.

STOPING

The mining methods are not standardized but are adapted to the existing conditions in each ore zone.

Most of the ore comes from flat back cut and fill stopes. After a raise is completed through the ore shoot, the stope is silled off 20 feet above the level. A seven-foot horizontal cut is taken through the entire ore body using drifters mounted on vertical bars.

If the horizontal area of the sill exceeds 1000 square feet, another raise may be driven from the level to the stope floor. This raise will be carried up with the stope. After completion of the sill cut, a floor of 3-inch lagging is laid on 8 by 8 stringers which have been placed on 5-foot centers. Fill material is dumped into the raise from the level above and spread over the floor with small air-powered slushers. After the fill has been leveled off within 2 1/2 to 3 feet from the back, a 2-inch floor is laid. The cycle is then repeated, except that the 2-inch floor is removed before the next filling cycle beings. Whenever necessary, a stull or crib is used to support the back. If the back becomes too heavy, square sets may have to be resorted to. In the smaller stopes the broken muck is shoveled directly into the chutes. In the larger stopes the ore is transported to the chutes either by slushers or in wheelbarrows equipped with pneumatic tires.

Square-set stopes are silled off on the level and are carried up with horizontal cuts the same as the cut and fill stopes. Usually a cut can be completed before it is necessary to fill. If the back becomes too heavy, the sets are tightly filled leaving one row open for access to the working face. Square-set timbers are shown in Fig. 2. The floor pillars under the cut and fill stopes are mined out by square setting after the stope from the level below is completed. Vertical pillars of ore are not left between stopes.

In the Number 1 ore zone 200 feet west of the Main shaft and on the foot wall side of the mineralized limestone area, a few open stopes have been used. In this area the ore occurs as pockets of considerable lateral area and may extend a short distance above or below the level. When one of these areas is encountered, it is silled off on the level with a drifter and the broken ore mucked into cars with a mucking machine. The ore left in the back is then drilled with a stoper and blasted. If a third cut is necessary, it can be drilled from the top of the muck pile. If the ore extends a short distance below the level, it is taken out with jack-hammers. If it should extend several feet below the level, a raise is driven from the level below and the ore mined by cut and fill method.

Stopes are filled mainly with waste material obtained from development headings. When the supply of waste that can be obtained from the development headings is insufficient, a power shovel on the surface loads waste into a dump truck. This is then hauled and dumped into a waste pass extending to all levels with discharge chutes as required.

Occasionally sand from a nearby arroyo has been loaded for filling in the same manner and dumped into an 8-inch churn drill hole. From a chute under this hole the sand is trammed to the places needed. The sand makes the best filling, as it is easy to spread in a stope. However, it must be very dry in order to pass through the drill hole.

TRAMMING

Underground tramming is done here by hand or with two 1 1/2 ton Mancha locomotives. The Main shaft hoisting cages are of sufficient size so that these locomotives are quickly moved from one level to another during the shift. The Eimco mucking machines are readily moved in the same manner. Cars are of 16 cubic feet capacity, turntable mounted, end dump, with roller bearing wheels.

Ore is transported from the mine bins to the mill in 18-ton dump trucks.

WATER CONDITIONS

After the mine was pumped out in 1943, water produced amounted to approximately 35 gallons per minute. As development work was extended on the then lowest level, or 340, additional sources of water were tapped. As new and deeper levels were opened up in the new shaft, a considerable quantity of water was encountered. Some of these sources, when struck with a diamond drill, produced pressures estimated to be as great as 200 p.s.i. At the present time the mine is making approximately 730 G.P.M.

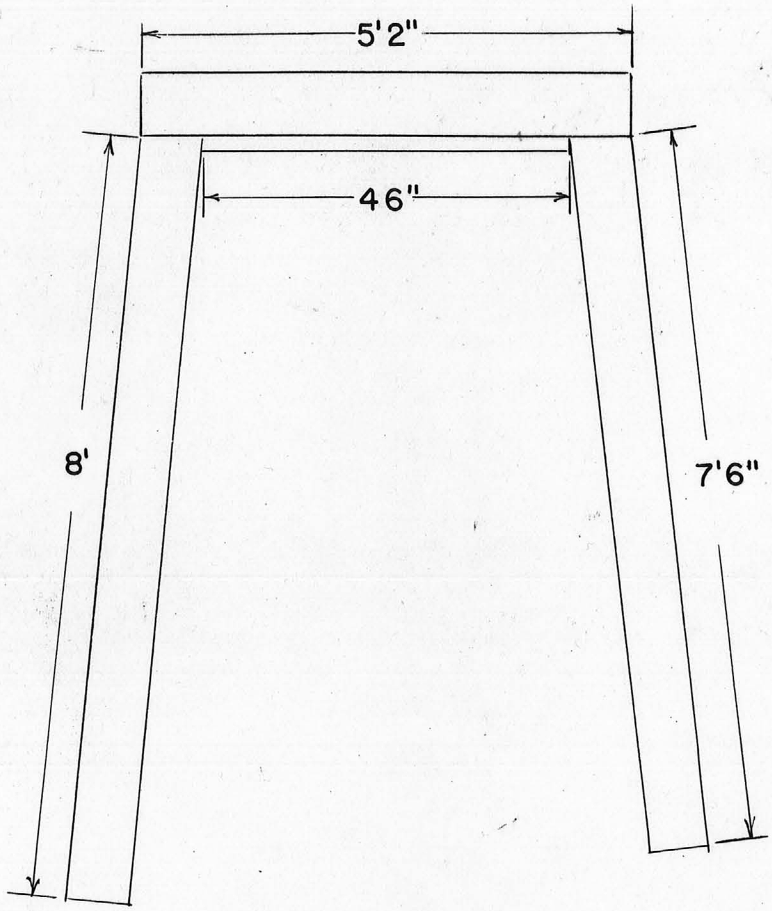

FIG. 1

Standard drift sets made with 8 by 8 timber. The 8 foot post goes on the ditch side of the drift. The 2 by 8 cleat is nailed to the bottom of the cap. Standard batter for the posts is 1¼ inches per foot.

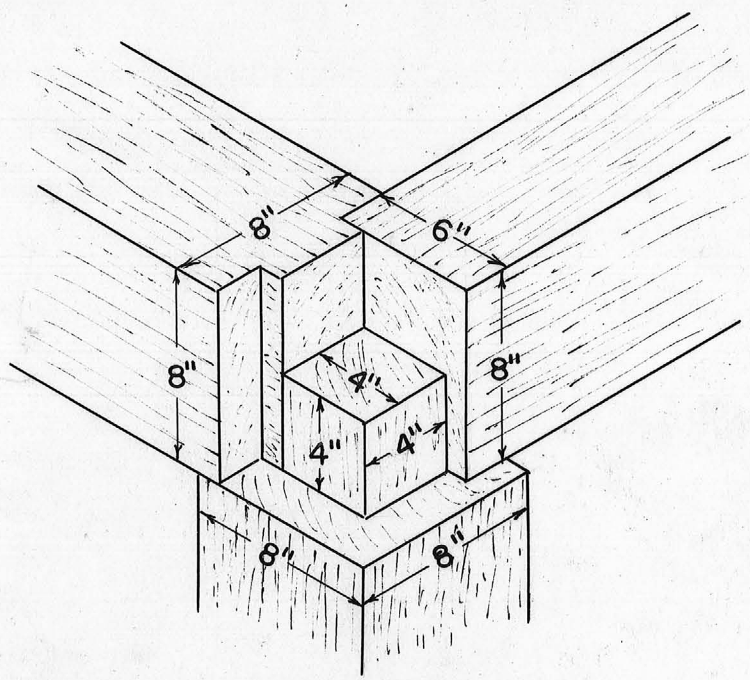

FIG. 2

Standard timber framing with post butting cap. The sets are 5 feet center to center horizontally. The stope posts are 6 feet long between the horns or 6 feet 8 inches over all. Sill posts for square set timbering are 7 feet long between the horns.

CROSS-SECTION TYPICAL FOOTWALL CUT & FILL STOPE

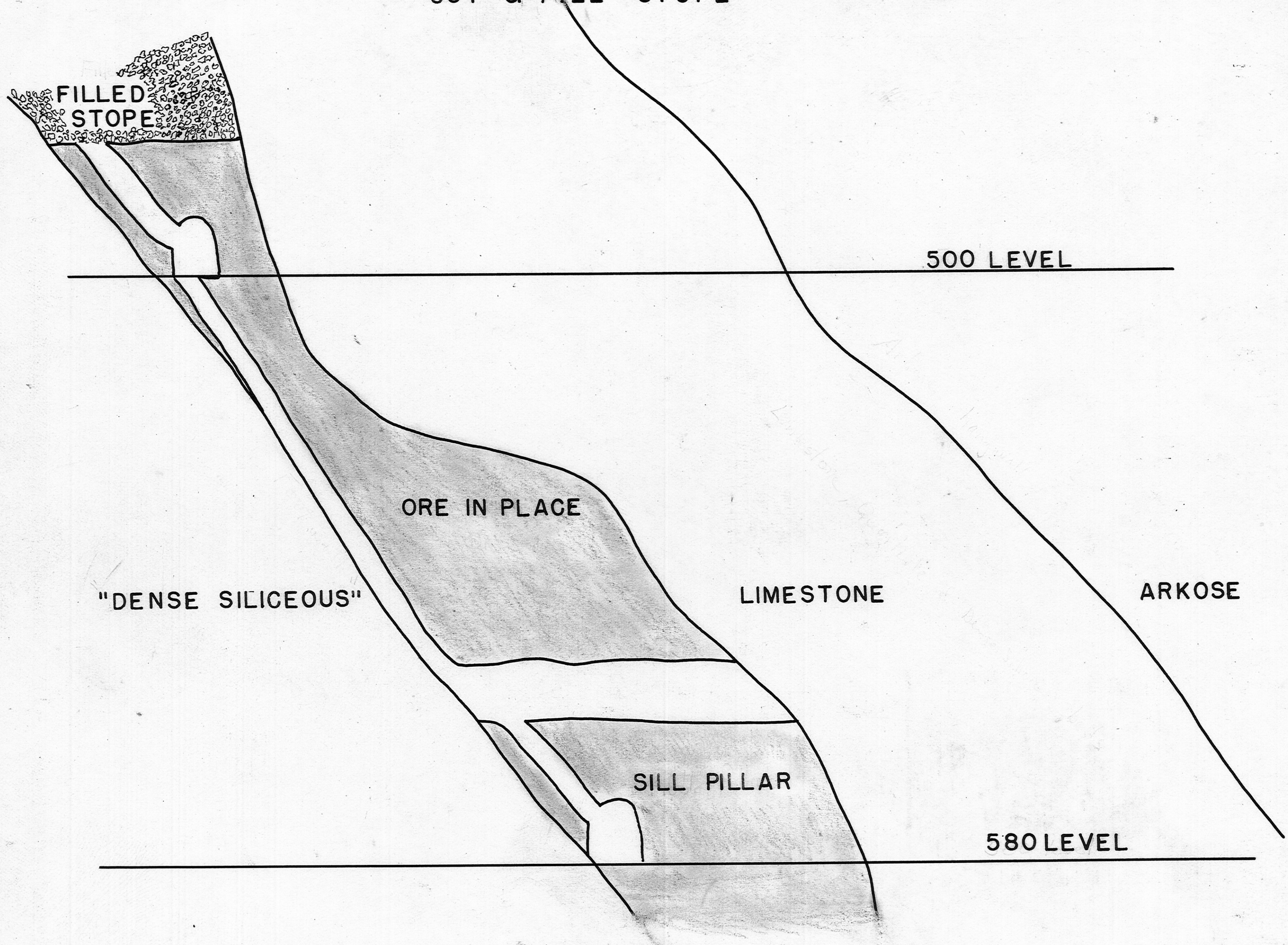

FIG. 3

CROSS-SECTION TYPICAL HANGINGWALL

SQUARE-SET STOPE

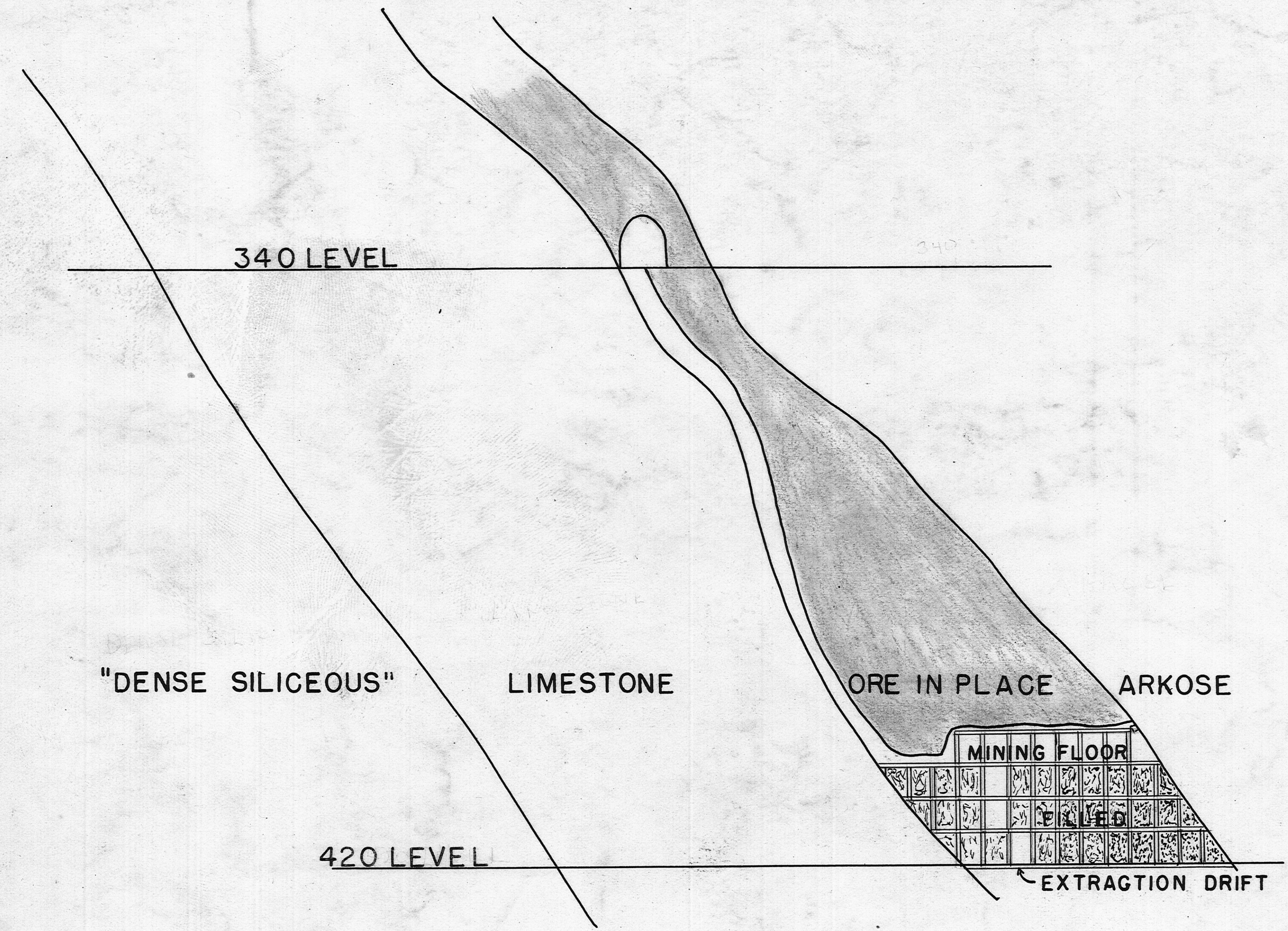

FIG. 4

VAN SMITH

LATERAL DEVELOPMENT AT THE SAN XAVIER MINE

There are three classes of lateral development work, 1) Timbered drifts, 2) Untimbered drifts, 3) Sub-level drifts. This report deals with the first two and is concerned with those headings driven during the period June 1, 1951, to February 1, 1952, on the 500 Level and below. Sufficient information was not recorded for all drifts driven on the 340 and 420 levels but two headings have been chosen for comparative purposes.

This analysis of development work has been made to determine the reason for the excessive costs and to suggest what steps should be taken to reduce them.

As a rule drift sizes are as follows:

Untimbered	6 ft. wide	7½ ft. high
Timbered	7½ ft. wide	8½ ft. high

For the purpose of this report, the rock has been classified in four categories relating to hardness for drilling purposes as well as breaking qualities. Listed opposite is the average number of holes usually required per round.

ROCK	UNTIMBERED	TIMBERED
Very soft	---	9-12
Soft	13	15
Medium	16-19	18
Hard	22	

DRILLING:

The hammer-cut round is used in most cases but occasionally a V-cut or burn cut is used when difficulty in breaking the ground is encountered. Rounds are drilled to obtain an advance of five feet.

For the past year both leyners and jackleg combinations have been used for drilling, but the jacklegs have not proved completely satisfactory in hard rock. When used in the softer types, and operated by a miner experienced in their use, they have proved to be both popular and efficient. In the latter part of 1951, hot-milled bits averaging 1-5/8" diameter were provided for use with jacklegs, which increased their efficiency. These bits were the criterion in deciding which of the two drilling methods should be used. If one of these bits will not drill a 7 ft. hole in a reasonable time or has to be discarded before the hole is completed, the jackleg combination is replaced by a leyner.

Up to June 1950 drill steel was provided in lengths of 2½, 4, 5½ ft. which provides the 18" change required for a stoper. At that time, 7' steel was introduced for use in drilling burn-cut rounds and has been available ever since. In December 1951 at the request of the shift bosses, drill steel in 4½ and 6½ ft. lengths were supplied for use with leyners, and by taking full advantage of the leyners' 24" change, a 6-ft. hole could be drilled with three lengths of steel. Bits are supplied in racks of 18 bits in three sizes, starting at 1-7/8" or 2" and decreasing by 1/8" gauge.

In soft and very soft ground no difficulty has been experienced in breaking the ground and a certain amount of overbreak is invariably achieved. In these cases it is of little consequence whether cut holes, breast holes, lifters, etc. are the same length since no bootlegging occurs. However, in the harder types of rock it is essential that cut holes be drilled at -45° and that they be 1.4X the length of the flat holes. Therefore, if a five-foot round is desired, the cut holes must have a minimum length of 7'. This is not possible since about 6" of the 7' steel is lost in the chuck and four bit sizes are required. Therefore, with bits and steel available in the sizes mentioned, the logical round would consist of flat holes 4' long with 6½' cut holes. This is not at all satisfactory in a timbered drift where medium ground is encountered, since drift sets are spaced at 5' intervals.

BLASTING

Blasting is usually carried out at lunch time and quitting time but in some cases, may be carried out earlier at the discretion of th e shift boss when conditions allow. The procedure is as follows: Primers are prepared first and placed in the holes. The remaining powder is often split with a knife, loaded and tamped, one or two sticks at a time, using a wooden tamping stick. Fuses are cut and spit in the order of firing. Wooden spacers $\frac{3}{4}$x8 are used to distribute the powder for maximum effect and economy in burn-cut rounds but are not used in the hammer-cut round since a concentration of powder is required where the burden is greatest, i.e., at the bottom of the hole. The rock produced by this method of blasting frequently contains a large percentage of boulders and occasionally of such size that they must be broken with a hammer before loading.

In general, the order of firing the holes is such that the lifters are fired last. In the hand mucking era this was highly desirable in order that as much muck as possible be thrown back on the mucking floor for easier shovelling. This is not at all satisfactory when a mucking machine is used for the following reasons:

1) The muck is scattered for a distance of 15-25' at a sloping angle, with a maximum height of 3-4' at the face.
2) Excessive time is required to muck out this flat shallow pile.
3) It is difficult to fill the dipper on the mucking machine.
4) Due to the excessive crowding action required, compressed air consumption is high.

In some cases, shift bosses have changed the order of firing so that the lifters are blasted as soon as possible after the cut h oles. This curtails the scattering of muck and produces a muck pile 5-6' high and about 12 ft. long.

MUCKING and TRAMMING:

All mucking is done with mucking machines. Motors are used exclusively on 340, 500 and 660 levels, occasionally on 420 and 580, and infrequently on other levels. The loaded cars are usually trammed to the station but in some cases, the cars may be dumped at raises for transfer or for filling a stope. The procedure when using a motor is as follows: The motor crew delivers empty cars to the mucking machine and remove them when loaded until a train load has been filled. The number of cars comprising a train load will vary from three to eight cars depending on the condition of the battery, track grade over which the load must be hauled (if dumping for fill the grade may be adverse) and the availability of empty cars. While the motor is gone, the drift crew trams the cars from the nearest switch to the mucking machine and back.

The hand tramming procedure is as follows: The mucking machine operator trams the empty and loaded car between the mucking machine and the nearest switch. His partner trams from the switch to the station. Where raises are the final destination of the muck, an extra man is generally provided since cars are side dumped and one man may not be capable of handling the job. Occasionally the car may be trammed to the raise by both the mucking machine operator and his partner when an extra man has not been provided. Two cars are in constant use, one at the mucking machine while the other is being dumped. Where excessive tramming distances are involved, an extra mucker is usually provided and each trammer covers half of the total distance between the switch nearest the mucking machine and the station. Three cars are in constant use.

Tramming delays, whether by hand or motor, are frequent and caused by:

1) Excessive tramming distance from the nearest switch to the mucking machine.
2) Insufficient number of cars on the level.
3) No empty cars on the station.
4) Breaking boulders on the grizzly when dumping in a raise.
5) Poor track conditions, such as defective switches, sharp curves, and varying track grade.
6) Excessive tramming distances when hand tramming.

The biggest time loss involves 1) and 3) and the reasons for the latter are as follows:

a) Cars may have been left loaded on the station by the previous shift and there is a hoisting delay of one to three hours on all shifts depending on the amount of tools or timber to be lowered.

b) Failure of the shift boss in arranging to have the cars pulled from the particular level on which a drift crew is mucking. (The tendency occasionally has been to hoist ore in preference to development waste.)

c) Trammers pulling chutes on the same level where a round is being mucked.

d) Failure of the trammer to notify the cager before all the cars have been pulled.

e) Practice of the cagers: hoisting all loaded cars from one level before moving to the next one.

f) Two or more drifts being mucked at the same time on different levels.

g) When development waste is being transferred within the mine for backfill, the time to dump the cars may exceed that required to fill and tram the cars from the drift heading.

h) Occasionally on graveyard, the waste bin has been filled and there is no other provision for dumping the muck.

The time required to fill an 18 cu. ft. car with a mucking machine varies from 1½ to 3 minutes when operated by an experienced man. The time required to fill the car depends on the size of the muck (the smaller the better), the height of the muck pile, whether the round is being mucked on a curve and the clearance between the timber and the track in a timbered drift.

<u>TRACK</u>

The mucking machine advances towards the face on slide rails which are laid on edge so that the ball of the slide rail lies against the web and between the ball and flange of the upright rail. The slide rails are held in place by track spikes driven into the tie against the flange. 4 x 6 track ties are laid at 30" center as the slide rails are advanced.

Most of the drifts are not driven on line but curve to follow geological formations which present several drawbacks to the above method of advancing track. Rails are now provided in 15 ft. lengths but at one time they were in various lengths from 12 to 20 ft. The drawbacks and common delays resulting are as follows:

1) Lack of proper length slide rails. Depending on where the permanent track ends and the degree of curvature of the heading, the length of slide rails required will vary from 5-15 ft. and these sizes are not always available. When slide rails are curved and used temporarily in an upright position, and then later replaced by permanent track, much time is consumed in straightening them for satisfactory use as slide rails again.

2) Failure to fix track properly before blasting.

3) Mucking machines frequently derailed when operating on sharp curves as the slide rails may be easily pushed out of position.

4) Failure by the mucking crew to place track ties as required before advancing the slide rails.

5) Shortage of track supplies, fishplates, track spikes, nuts and bolts.

6) Use of salvaged rail which must be straightened and the attempt to use track of different sizes.

In the early part of this year, track sections for use in curved drifts were made up in the machine shop. A set of these sections consists of six 2½ ft. sections of track and wedges of varying sizes which give the curvature required. A mucking machine can clean up 2½ ft. ahead and when this has been cleaned up, a track section is laid and bolted into place. This system was adopted as a result of discussions held at a Safety Meeting in December '51, and has proved both safer and more efficient than that used formerly.

<u>TIMBERING:</u>

Drift sets are made from 8x8 timber and consist of three pieces; a cap 62" long with a scab 2x8x46 centered on the under side, one post 8' long and the other post 8½' long which is placed on the ditch side. This combination is used exclusively on the 660 level and below but two 8' posts are used on the upper levels where a large ditch is not necessary since water is not encountered. Dimensions for placing the timber are as follows:

Distance from top of rail to under side of cap-------------7'
Spread between posts across the top of rails----------------70"
Distance on ditch side outside of rail to post--------------30"
Distance other side outside rail to post--------------------20"

When starting a new timbered drift from ano ther timbered drift, the procedure is generally the same. The turnout consists o f three sets, one with a 9 or 10' cap, one with a 7 or 8' cap and a V-set in which the caps are not standard and are cut to fit. Three slab rounds are taken out to provide room for this timber and in blasting them, drift posts are often knocked out or broken which causes the collapse of one or more drift sets. Frequently when this has occur red booms must be used to re-timber this section. Since the switch is not put in until the V-set has been completed, some hand mucking is necessary.

Once the turnout has been completed, the dr ift is driven on instructions from the mine foreman. An order to change the drift bearing may be given in one of two ways: a) turn a specified number of degrees or b) reduce the length of a particular collar brace. The method of drilling the round is left to the discretion of the shift boss who in turn may leave the decision to the miner. It is dou btful whether any two shift bosses would give the same instructions for drilling the round. Consequently, when the round has been drilled, blasted and mucked out, there may not be sufficient clearance for the timber, necessitating additional drilling, blasting or moiling.

Frequently when driving a timbered drift it is necessary to plug the bottom for the post hitches and when this occurs, approximately 2-4 hours lost time may be involved. For example:

A round blasted by graveyard is mucked out by day shift. Afternoon shift will start off their shift by digging the hitches for the timber and may find that they cannot dig them deep enough without drilling and blasting. If the drift is being drilled with a jackleg combination, a jackhammer is readily available and the 2-4 holes required are drilled and prepared for blasting in ½-1 hr. Similarly, if the back or wall clearance is insufficient, additional holes must be drilled. However, if this drift is being driven with a leyner, three machines are required and it is not u ncommon to find three machines in a heading, leyner, stoper and jackhammer. If they are not in the heading, considerable time is lost in looking for and bringing this equipment to the face. Since these holes cannot be blasted until lunch time, there may be a considerable amount of lost time. Rarely will the set be completed by the end of the shift. Thus graveyard crew must complete the set and drill the next round. With the reduced amount of time available for drilling, it is unlikely that they will blast at the end of the shift. The round will be completed by day shift and there will probably be a further delay when they must wait until lunch time to blast. The men are instructed that when there is a delay in normal working procedure, they are to clean track, ditch, and scrap timber, and this time is charged on the time cards to cleanup.

A great deal of this trouble is due to the inexperience, lack of sound judgement on the part of both shift bosses and miners. In timbered drifts, overbreak is the rule rather than the exception, and it is common belief among drift crews that this overbreak will result in giving the required clearance regardless of how the drill holes may be drilled or spaced. Occasionally, excessive overbreak may occur requiring back cribbing, spiling or the use of booms.

METHOD OF CHANGING DIRECTION IN AN UNTIMBERED DRIFT.

When changing the drift bearing, there is n o standard method used. The reason for changing may be one of two reasons; to follow a contact or reach a predetermined objective. The usual practice is to drill all holes parall el with respect to the newly desired bearing which does not produce sufficient clearance, especially when turning to the left, for the mucking machine operator. Thus it is necessary to drop back and take out one or more slab rounds which are charged to stoping.

ENGINEERING AND GEOLOGY.

At most mining properties, the Engineering Department produces on paper the details of all proposed development work and this is discussed among the departmental heads concerned so that all the factors involved and alternate methods to accomplish the objective can be considered before a final decision is reached. This requires cooperation and advanced planning. Once the work has been commenced, a frequent and constant check on progress is maintained by the Engineering Department personnel and such services as lines, timber details and track gradients checks are provided.

It is not uncommon here for a member of the Engineering Department to give instructions regarding changes to either the drift crew or the shift boss. Very frequently this information is not completely understood and the work is not carried out as desired, resulting in unnecessary work, delays and expenditures.

The Engineering Department has not been set up or administered to achieve its main function as a service department for production, and the quality of service provided is poor. Consequently, there is very little cooperation and a great deal of friction between this department and the production department.

COSTS AND ACCOUNTING.

The cost per foot of development as determined by the present system does not give a true picture of the actual costs for several reasons:

a) Development footage as listed in the monthly report covers both drifts and sub-drifts, yet labor charges in nearly all sub-drifts are charged to stoping.
b) When starting a new drift, slab rounds are charged to stoping and timbering turnouts are charged against drift repair.
c) Any slab round required for a change in direction or for a diamond drill station is charged to stoping although footage may be credited to the drift.
d) Timbering charges entailed when a set has been blasted out are made against drift repair.
e) Short headings which may be driven off a main heading but where no track is laid, is frequently charged to stoping although the footage is credited to development.
f) Track labor charges are not made against development.
g) The time involved in delays and waiting to blast a round are made against cleanup while other delays due to faulty equipment, lack of cars, etc., are charged to development.
h) Tramming charges, where a motor crew or an extra trammer is used, are made against stoping.
i) Timbering charges involved in timbering a drift that has been driven and completed as an untimbered drift are made against drift repair.

SUMMARY:

The information listed has been obtained from shift and daily development reports. The time in hours as listed refers to crew hours, a crew consisting of one miner and one mucker. Since the development reports account for only the seven working hours, the total crew hours were divided by seven to obtain the number of crew shifts.

In determining the costs as listed, consideration was taken of the existing pay rate, shift differential, and also included overtime based on a 48-hr. week. Thus the average crew shift wages amount to $28.60.

Powder consumption has been based on the assumption that 180 sticks weigh 50 lbs.

The advance per round in most cases is less than five feet due to the inclusion of slab rounds. However, in the case of 660 23-1 Dr. an advance exceeding five ft. per round was obtained by drilling seven foot rounds. The ground was of medium hardness but because of the excessive burden on the cut holes, three extra holes, four feet long and drilled at -60, were used.

In the case of 660 10-3 Dr. unusual conditions were encountered. The ground was hard and difficult to break. The presence of water hindered loading and blasting. Ventilation was poor, causing excessive delays for smoke and gas. The presence of water courses reduced blasting efficiency and required drift sets and cribbing. These sets were frequently knocked out when a round was blasted which required an excessive amount of timbering time.

900 2-1 Dr. was driven in an erratic manner, the drift bearing being frequently changed. This fact, plus the use of poor drift crews, resulted in higher costs, particularly on track work. The cost of this drift is in contrast with that of 740 A-1 Dr. which was driven by the best drift crews available.

DELAYS:

The cost of delays for the drifts listed averaged $1.32/ft. 500 2-1 Dr. when driven on contract had the lowest delay cost amounting to $0.35/ft. This was due to the fact that the drift crews requested and received the complete cooperation of the shift bosses in providing the best possible equipment and service.

The following, in order of importance, are the most common delays:

a) Lack of/or faulty equipment.
b) Lack of cars when mucking.
c) Smoke.
d) Low air pressure.
e) Waiting to blast. (When not charged to cleanup)
f) Pipework.
g) No crew. (Occurs when crews are shifted due to absenteeism)
h) Engineers surveying.

CONCLUSIONS AND RECOMMENDATIONS:

From the figures obtained, the average times required for the various operations for a five-foot round are:

Drilling	7.10	hrs.
Mucking	5.70	
Timbering	7.60	
Delays	1.19	
Track	1.63	
Total	23.22	hrs.

The reason for these excessive times is partly due to the current practice of substituting another miner or mucker in a heading when the regular miner is absent. This is done for one of two reasons; to get the muck and to attempt to obtain development footage. Frequently these are not experienced in the type of work involved and are slower in all phases of the work. The fact that it is not their usual working place and that they are not expected to put out as much work as the regular crew, may result in the accomplishment of much less work than they are able to do.

The major factor contributing to the high costs is the lack of incentive pay. There is no way to enforce the completion of a certa in amount of work on predetermined schedule, and no pride in personal accomplishment. This is strikingly shown by comparison of the figures on the Summary Sheet. 500 2-1 Dr., the only heading on contract during the period under review, was driven at approximately half the cost of the average.

	No. of holes Drilled	Drilling Time - hrs.	Drill speed Holes/hr.	Average No. Holes per Rd. Blasted	Holes Blasted	No. of cars Mucked	Mucking Time/hrs.	Mucking Cars/hr.	Cars/Round	Hrs. Delay	Timbering Time/hrs.	No. of Sets	Hrs./set	Powder used No. sticks
340 6 DR.	440	183	2:40	14.6	408	704	138.0	5.10	25.0	33.5	---	--	--	2260
T 420 5-4 DR.	*	*	-	14.3	774	1452	*	*	27.0	*	*	38	*	3698
T 500 2-1 cont.	381	115.5	3.30	14.4	375	815	95.5	8.53	31.35	11.0	70.0	25	2.8	2046
T 500 2-1	395	152.5	2.59	17.5	349	560	117.5	4.76	28.0	9.5	172.5	14	12.3	1918
500 12-4	634	293.0	2.16	19.7	631	662	184.0	3.60	20.7	45.5	---	--	--	2341
PT 580 4-1	184	68.5	2.69	16.30	179	282	65.5	4.31	25.6	49.5	60.5	8	7.6	890
580 10-2	276	120.0	2.30	16.9	270	338	101.0	3.35	21.1	24.0	---	--	--	1485
T 660 2-1	891	401.0	2.22	15.5	945	1564	301.0	5.20	25.6	53.0	288.0	50	5.8	4580
PT 10-3	685	387.5	1.77	26.0	909	577	139.5	4.14	16.5	77.0	80.0	3	26.6	4618
T 19-2	768	325.0	2.36	16.3	699	1710	333.0	5.14	39.8	64.0	374.0	44	8.5	4044
T 23-1	256	107.5	2.38	19.6	236	425	90.5	4.70	35.4	16.0	112.5	14	8.0	998
T 740 2-1	276	118.0	2.34	14.7	265	616	122.0	5.05	34.2	42.0	158.0	19	8.3	1265
PT A-1	495	191.0	2.59	15.0	421	851	149.0	5.70	30.4	24.0	69.0	11	6.3	2083
PT 10-4	1051	445.0	2.36	17.2	1050	1146	238.0	4.82	18.8	90.0	157.5	11	14.3	5897
900 2-1	296	140.0	2.11	16.0	272	342	89.5	3.82	20.1	24.0	---	--	--	1414
T 6-3	665	265.5	2.51	15.0	601	1283	329.5	3.89	32.1	52.5	286.0	34	8.4	2869
6-3-1	240	87.5	2.74	14.8	207	348	105.5	3.30	24.8	11.0	10.0a	--	--	1170
PT 12-1	678	260.0	2.61	16.0	690	771	263.0	2.93	17.9	37.5	48.0	7	6.8	3566
	8,611	3,660.5	2.35	16.6	9,281	14446	2,862.0	4.54	25.8	664.0b	1796.0b	237b	7.6	47142

* NO INFORMATION AVAILABLE
Drilling time includes setting up and blasting.
Mucking time includes scaling and wetting down muck pile.
ack work includes bending rail, laying ties, advancing slide rails.
ering time includes tramming timber to face, drilling or moiling hitches.
Delays: Major - B.O. Equipment, lack of cars, smoke.
Minor - Pipework, surveying, low air pressure.

a) Replacing timber in adjacent drift, knocked out by blasting.
b) 660 10-3 DR. not included-unusual conditions.
c) 420 5-4 DR. not included.

Powder Lbs./ft.	Advance in Feet	Advance per Rd. Blasted	Total Crew Shifts excl. Track	Total Cost excl. Track (LABOUR ONLY)	Cost per ft. excl. Track (LABOUR ONLY)	Total Crew Shifts incl. Track	Total Cost incl. Track (LABOUR ONLY)	Cost per ft. incl. track (LABOUR ONLY)	Cost per ft. of track (LABOUR ONLY)	No. of Rds. Blasted	Tramming dist. switch to face	Tramming dist. switch to station	AVERAGE TRAM SWITCH TO FACE	Total Tram
4.98	126	4.50	50.64	$1420.00	$11.28	55.43	$1560.00	$12.39	$1.11	28	90-216	*	151	
5.25	194	3.60	——	*	*	197.75	5402.00	27.90	*	54	0-190	*	95	
4.45	128	4.92	41.70	1192.00	9.32	44.20	1263.00	9.88	0.56	26	0-120	120	60	180
5.72	93	4.65	64.60	1847.00	19.85	69.40	1980.00	21.30	1.45	20	0-90	215	45	260
5.95	109	3.40	75.00	2145.00	19.70	85.50	2440.00	22.40	2.70	32	0-105	735	53	810
4.50	55	5.00	34.90	996.00	18.10	37.85	1082.00	19.70	1.60	11	0-55	540	28	570
7.00	59	3.69	49.30	1410.00	23.85	54.40	1553.00	26.35	2.50	16	0-45	578	2[illegible]	600
5.22	244	4.00	149.00	4260.00	17.50	164.0	4680.00	19.18	1.70	61	0-210	360	105	465
14.20	90	2.57	97.60	2790.00	31.00	105.00	3000.00	33.40	2.40	35	0-255	750	128	875
5.64	199	4.63	156.50	4480.00	22.40	168.70	4815.00	24.20	1.80	43	0-195	1530	98	1630
3.80	73	6.10	46.60	1333.00	18.30	49.00	1400.00	19.18	0.90	12	0-60	1680	30	1710
4.12	85	4.72	63.00	1800.00	21.20	68.70	1915.00	23.10	1.90	18	0-85	125	43	165
4.12	141	5.04	61.90	1770.00	12.55	67.50	1930.00	13.70	1.15	28	0-155	240	73	315
9.31	176	2.88	133.10	3800.00	21.60	145.50	4170.00	23.60	2.00	61	0-175	610	88	700
7.73	51	3.00	35.40	1035.00	20.30	44.50	1273.00	25.00	4.70	17	0-50	280	[illegible]	305
4.00	200	5.00	133.40	3820.00	19.10	142.80	4080.00	20.40	1.30	40	0-200	540	100	640
5.00	65	4.64	30.60	875.00	13.45	34.35	955.00	14.70	1.25	14	0-65	630	33	665
7.23	137	3.19	86.90	2482.00	18.10	96.20	2750.00	20.50	2.40	43	0-135	900	68	970
5.88	2,225	3.98	1,309.93	37455.00c	18.44c	1630.78	46248.00	20.79	1.67	559				

Note on Rock Identifications at the Sa n Xavier Mine, Arizona

by

William R. Jones

<u>Cretaceous Beds</u>: <u>Arkose, argillite, etc.</u>

The Cretaceous deposits of southeastern Arizona may be 25,000 feet thick and are composed of red and purple shales, white to reddish-brown arkose, dark greenish graywa oke, volcanic flows, thin, lenticular dark gray to black very fine grained limestones, and limestone conglomerates, also coarse quartzite conglomerates usually with abundant red inter-cobble material: argillites of all colors, and quartzites. In short, nearly every type of sedimentary rock. It is important to realize this and not to depend on always having a hanging-wa ll formation at the mine of arkose. True, it usually is, but it is also quite often a dense, soft, greenish-gray mudstone or argillite. In the central part of the mineand in the hanging waall at the #4 ore zone, argillite has been noted most frequently. It is usually ravelly ground, prbably because it has been crushed in the bending of the syncline and anticline. It is soft and scratches easily which probably means it contains clay.

Within the mine area, especially near the ore shoots the contact between the limestone(which may have been altered to garnet or other silicates) and the arkose or argillite is often marked by a 6-12 inch band of high grade ore. Upon passing throughthis band, the arkose may not be recognized for 10 of 15 feet. Whether due to alteration or to original deposition irregularities, the intervening ground may be a fine-grained, light greenish "quartzite?" or the soft ravelly argillite. It is often necessary to examine a face with great care in order to find one spot, 1-2 inches in diameter, which you can definitely say is arkose. I usually look first for a pink or salmon colored spot, then examine this spot for the typical arkose "look", which bears some resemblance to fine-grained tapioca pudding. The pink matrix surrounding the dull gray quartz grains is orthoclase or microcline feldspar. If the quartz grains are less than 0.5 mm, I call it fine or very fine grained, if greater than 0.5 mm but less than 1.5 mm,I call it medium grained. Anything coarser than 1.5 mm I have called coarse grained, but this is rarely observed. For the most part , a nine power hand lens is necessary to see the texture and to make sure the interstitial material is feldspar and not just crushed or finer grained quartz. Unfortunately, not all pink spots are definitely arkose, but may be altered limestone. These pink spots resulting from the alteration of limestone are dense and no grains are visible. The presence of garnet or limestone in or near these dense pink-colored altered areas will help establish this material as altered limestone. The 10-15 feet of light green quartzite? found before entering true arkose (as in diamon-drill holes on the 420 level) may well be a silicated limestone into which hydrothermal quartz has been introduced. The edges of these blebs of quartz are serrate and they look somewhat like sand grains which have been stretched out and corroded. A microscopic examination of this material has not been done, but should be in the future.

Kuhn described numerous sections of arkose and concluded that epidote commonly replaces the interstitial feldspars and to a much lesser degree, the quartz grains. In a specimen which shows quartz grains imbedded in an epidote matrix, one cannot be sure that he is not dealing with just an ordinary poorly sorted quartzite, the matrix of which has been converted to epidote. In case of doubt, it would be advisable to take another round out ahead. This would not be necessary if quartzite beds did not occur within the favorable limestone, at least in the limestone under the "17" fault on the west half of the mine. Quartzite beds also occur in the so called dense silicious beds. The danger is in stopping a crosscut headed for the arkose in an altered quartzite member of the favorable limestone or the even lower dense silicious strata.

The resemblance between the dense silicious beds and the Cretaceous argillite is unfortunate. The argillite usually will give way to arkose within 10 feet in some direction, at least temporarily, or a band of arkose will be observed in the argillite.

In the vicinity of the #6 shaft workings, both at the surface and underground, the arkose has a different look. It is lighter in color and coarser grained. Megascopically it often resembles an alaskite granite. It is not however, for at the sufrace, bedding has been observed in it, and underground, close to the limestone contact, numerous large egg-shaped pebbles have been observed.

Beware of the resemblance between poorly sorted grits found in the lower Permian beds and the arkose of the Cretaceous series.

The Limestones of Permian Age:

A ll the limestones within the immediate mine area are undoubtedly of Permian age. The lower Permian limestones are softer, usually white and dense, and form part of a series made up of marls, hornfels (impure altered limestones), shales, and gypsum beds. Above these, there are three younger Permian limestone beds separated by two quartzite beds. The upper quartzite is about 20-100 feet thick and the lower about 400 feet thick. The best exposure of this section that I know of is in the Santa Rita Mountains, in the cliff about 2000 feet east of the Copper World Mine, Helvetia district. An exposure closer to the mine can be studied in the "Helmet Peak" area 4000 feet east of the San Xavier Mine.

Formerly only the top limestone member was called theSnyder Hill formation, but the tendency at the University of Arizona is to use the name so as to include all the beds, i.e. the three limestones and the two quartzites. The upper limestone is by far the most fossiliferous, in fact in certain beds they)mostly corals and brachiopods) are abundant. In the Helvetia area, at least, the only fossil beds I ever found in the two lower limestone beds were practically microscopic in siz e, and if I recall correctly, the assemblage was dominated by delicate coiled gastropods and crenoid plates. Chert nodules are abundant in certain layers of the upper limestone member.

All three limestone beds are dark blue-gray to black. In places, thin white and black beds alternate. Under certain conditions the limestones are bleached and recrystallized.

A detailed study of each limestone member might reveal interbedded lenses of sandy or clayey limestone beds. Eldred Wilson, Arizona Bureau of Mines geologist, states that the presence of impure sandy beds in the Snyder Hill is typical.

Hernon and others(Kuhn and Jones) believe that the limestone beneath the Cretaceous (arkose) and avove the "17" fault in the San Xavier Mine is the top limestone member--the Snyder Hill as origionally defined by A. A. Stoyanow. Thisconclusion is supported by the abundance of fossils, the presences of layers of chert nodules, and by the fact that at the surface and underground in the east half of the mine, the limestone rests on a thin bed of quartzite, which is never over 100 feet thick and usually much less. It might be argued that the limestone is the middle limestone (as I believe Ma yuga held) and that the quartzite is the lower thick (400 feet) quartzite more that 3/4 of which has been cut out of the section by faulting.

The question is academic. Pretty surely the limestone is either the top or middle member. Fossil evidence is unreliable as evolution between the ages of the twolimestones progressed imperceptibly.

The limestone found within the mine, above the "17" fault and the brownish-gray, medium grained quartzite, and below the Cretaceous beds is both thick and a nd thin bedded, and nearly black in the lower part. An irregularly thick bed of greenish-gray "dense silicious" rock is found in about the middle of this limestone. Kuhn made a study of severa l thin-sections and classified the rock a s a very fine grained shaly quartzite. There has always been the feeling that this layer may be nothing more than an alteration of the limestone. The presence of the "10" fault zone along its lower contact provided the necessary channelway for the solutions capable of the metamorphism--if that is what it is. Personally I favor the idea that it was deposited as a muddy silt during an interruption of the lime deposition. Naturally it has been metamorphosed by heat and magmatic solutions, and has suffered deformation along with the other beds above and below it.

I have never seen any bedding planes in the limestone above this shaly quartzite. Either it has been destroyed by intense folding and recrystallization or it was originally very thick bedded.

On the west side of the mine, beneath the arkose and the "17" fault, the strata consist of alternating beds of white and dark gray limestone and "dense silicious" rocks. The individual beds range in thickness from 35 to 100 feet. To date only the topmost limestone member has been productive, although marrow zinc sulphide mineralization has been penetrated in several places in the next lower limestone. The so called "dense silicious" beds are in places definitely quartzite, but for the most part, no grains can be seen. Kuhn found them to consist of subangular grains of quartz with interstitial clay. The rock is various shades of green, from light to dark; it is bleached to light brown, and ~~is~~ pink along fractures; it is scratched easily with a pick because of the interstitia l clay; it breaks in a rather unique manner; characteristically it contains minute grains of pyrite disseminated throughout. (This pyrite has most probably been crystallized from iron-rich sediment depostited simultaneously with the mud and sand.) In some cores, the contact of a similar appearing rock with the limestone is undeniably typical of replacement alteration. The bulk of the evidence at present suggests that alteration is od minor importance, however.

Without going into any detailed reasoning, I will mention that I am not convinced that the productive limestone member in the rock series found in the west part of the mine, beneath the "17" fault is identical with the productive limestone in the hanging-wall block of the "17" fault.

The recent penetra tion of a gypsum bed in Diamond-drill hole 238(660 level west side) is almost positive proof that the beds directly above and below it are older than Snyder Hill--what has been called the Yeso formation, also Permian. At this time the presence of a major fault is not evident to explain the a ppearance of the Yeso so close to the productive limestone which has been considered in the past to be Snyder Hill.

The Yeso formation in nearby areas is about 1500 to 2000 feet thick and it ispredominately made up of incompetent beds. There has been a marked tendency wherever thrust faulting is in evidence, for the competent upper Permian beds (the Snyder Hill limestones and quartzites) to override the incompetent beds of the Yeso. This apparently happened in the San Savier area.

Alteration of the Limestone:

W here the limestone is altered, the origional character of the bed is usually obliterated. Generalizations on the type of alteration and a description thereof has been previously written up, and should be easily obtained from Mr. Duff's file.

GEOLOGY AND HISTORY

of

THE SAN XAVIER MINE, ARIZONA

by

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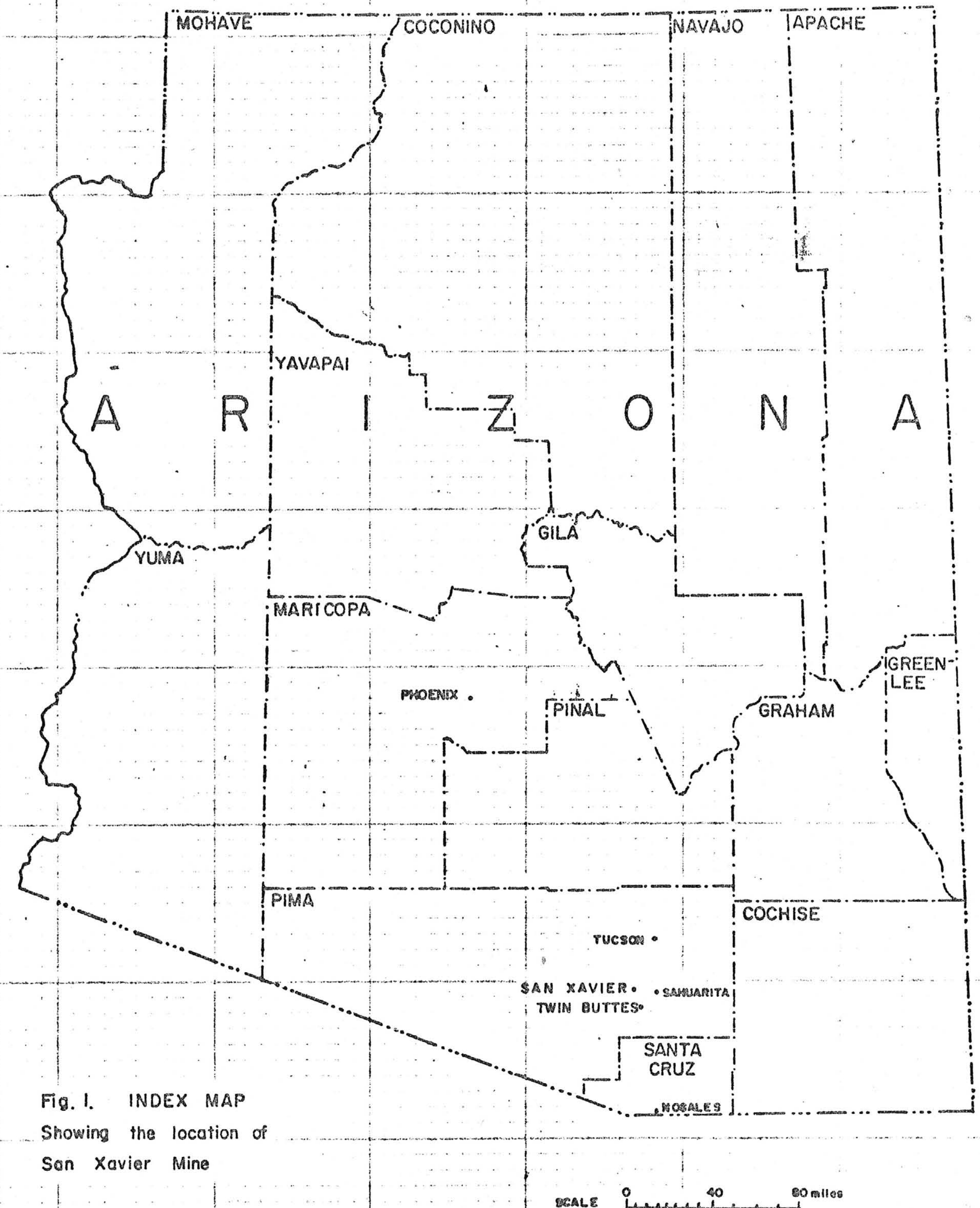

Fig. I. INDEX MAP
Showing the location of
San Xavier Mine

ABSTRACT:

The San Xavier Mine is located in the Pima Mining District approximately 18 miles south of Tucson. It is reported that this mine was worked for lead and silver by the Spaniards and the Mexicans in the 1700's.

The original San Xavier Claim is the first recorded surveyed claim in Arizona according to the Surveyor General's files. This was in the year 1872. At the time of patenting in 1882 five diamond drill holes had been drilled on the property.

Although production was ceased in 1959, this mine has been one of Arizona's large zinc and lead producers.

The San Xavier lead-zinc-copper-silver ores are within sediments in the upper part of the Andrada formation of Permian age. These rocks have been folded, broken by faulting and fracturing, and intruded by narrow dikes and irregular apophyses of quartz diorite porphyry or granodiorite. Metasomatic alteration apparently was later than igneous intrusion, accompanying ore deposition.

The principal ore deposits are situated near the axis of a major synclinal structure along the crests of smaller synclinal folds. The most important ore shoots occur as pipe-like to locally tabular bodies which plunge with the bedding and generally follow an arcuate contour around the folding.

Dominant ore controls appear to be steeply plunging folds with zones of fracturing and shearing, cross folding and flat shearing which locally deform the steeply plunging folds, metamorphism and alteration of favorable limestone beds prior to ore deposition, and selective replacement of garnet and hedenbergite along favorable beds and structures by metallic minerals.

INTRODUCTION:

The data included in this paper are based mainly on a study of the San Xavier Mine which was made during 1958 for the Anaconda Company. At that time, prior to the final closedown of the mine, a geological mapping program was carried out on the 660, the 770, and the 820 levels, and mine records including maps and drill logs, were examined and studied in detail.

The purpose of this paper is to bring together information from the above study and to supplement this with information that is available from other publications, unpublished data from theses, mine company reports, and personal communications. It should be stressed that the conclusions derived in this paper are the result of a detailed study of only a small portion of a large complexly faulted and mineralized district. It is hoped, however, that the data as presented will contribute to the general knowledge of the geology of the area.

HISTORY AND PRODUCTION:

The San Xavier mine is located within Sections 2, 3, 10, and 11, Township 17 South, Range 12 East in the Pima Mining District, about 18 miles to the south of Tucson, Arizona. The mine was first discovered by Spanish soldiers and Jesuit priests and is reported to have been worked by the Spaniards and Mexicans during the early 1700's.

According to an unpublished history of the pioneer Contzen family, the San Xavier claim was first located in 1856 by Fred Contzen and his brother, Julius, shortly after they had established the Punta de Agua Ranch on the Santa Cruz River about three miles to the south of the San

Xavier Mission.

The original survey of the San Xavier claim was made in March of 1872 by S. W. Foreman, a U.S. Deputy Mineral Surveyor. Two claims called the San Xavier were surveyed at this time. One measured 1200 feet by 396 feet, and the other measured 3000 feet by 396 feet with the larger completely overlapping the smaller one. Apparently in anticipation of a change in the mining law, the mineral surveyor recorded both surveys. These are for Lot No. 38, and both were accorded General Land Office Number 1 for the first mining claim to be registered in the Arizona territory. The claimants were M. B. Duffield and I. Q. Dickason.

Neither of the above claims were patented. In September of 1882, six claims in the San Xavier mine area were surveyed for patent by Solon M. Allis, Deputy U.S. Mineral Surveyor. These included the San Xavier claim (No. 415) and the Western Extension San Xavier claim (No. 412) which covered the approximate area of the original 3000 foot long San Xavier claim, together with the Patterson claim (No. 411), the Arizona King claim (No. 414), the Arizona Queen claim (No. 416), and the Democrat claim (No. 417). All six of these claims were patented to the Santa Rita Land and Mining Company, the claimant of record.

The patent survey for the Western Extension San Xavier listed three shafts with depths of 145, 275, and 75 feet with unmeasured drifts and winzes, and two diamond drill holes of 280 and 275 foot depths. On the San Xavier claim, shafts of 90 feet and 10 feet are listed along with three diamond drill holes with depths of 75, 100, and 150 feet. It might be of interest to note that underground workings intersected one of these holes which appeared to be about four inches in diameter. No record is available of the type of drilling machine used or the drilling results.

In 1877, Colonel C. P. Sykes purchased the San Xavier property and organized the San Xavier Mining and Smelting Company, which operated intermittently until 1893. From 1877 to 1882, the mine produced mainly argentiferous lead carbonates and sulfates which were estimated to average $65 in silver and from 40 to 65 percent lead per ton of ore. Reports list that over $100,000 in silver was taken from the mine up to 1882 when the near surface silver ores became exhausted.

After 1893, the Manning, Goldsmith, and Zepeda Mining Partnership operated the mine on an intermittent basis. In 1897, General L. H. Manning reopened the mine, successfully utilizing Wilfley tables for concentrating purposes.

From 1899 to 1906, a Wisconsin-Minnesota group formed the Meyer-Clark-Rowe Mines Company and performed extensive development work. By 1903, they were reported to have shipped 50,000 tons of oxide ores to the El Pase smelter for treatment.

The Empire Zinc Company purchased the property in 1912 and continued production through 1917, closing down in December of that year. In 1916, the No. 6 shaft was started and sunk to a depth of 250 feet with levels at the 100, 150, and 250 foot depths. These are the workings that have recently been donated by the Anamax Mining Company to the University of Arizona for use of the College of Mines as a mining laboratory.

No authentic production records are available until after 1912. During the operation by the Empire Zinc Company, information published by the Arizona Bureau of Mines (4) indicates that the San Xavier mine produced 6,000,000 pounds of lead and $200,000 in silver. No figures are given for copper and zinc. According to Ransome (13), the ore shipped in 1917 assayed up to 6 percent copper and 6 ounces of silver, but the average was lower in grade.

The mine remained idle from 1918 to 1942 when the Eagle-Picher Company took a lease and option on the property. Eagle-Picher exercised its option in 1943 and constructed a 175 ton per day concentration mill near Sahuarita at the site of the old Pioneer Smelter. In 1944, the capacity of the mill was doubled and later increased to 400 tons per day to handle custom ore along with mine production. During Eagle-Picher's operation, the No. 7 shaft was completed from the surface to 924 feet vertically in depth with stations cut at the 340, 420, 500, 580, 660, 740, 820, and 900 foot levels. Development and mining was carried out on all levels with the 340 and 660 levels being driven westerly to a point under the No. 6 shaft where a connection via raises and stopes was made to the 250 foot level from the No. 6 shaft.

The San Xavier mine from 1943 to 1949, was one of Arizona's important producers of lead and zinc with its output ranking third in the state in 1948. Production figures for 1948 and 1949 (Duff and Kumke, 3) were reported at 450,901 ounces of silver, 18,255,006 pounds of lead, 32,125,070 pounds of zinc, and 1,708,481 pounds of copper. Eagle-Picher ceased operation in 1953 with only a skeleton crew being retained for repair and maintenance work.

McFarland and Hullinger of Toole, Utah, leased the mine and concentrator in 1955, and later in 1956 negotiated an option agreement covering the property and facilities. From 1955 to the closedown in 1959, mining and milling operations were conducted at a rate of approximately 100 tons per day. During this time the mill heads reportedly averaged about 8 percent lead, 10 percent zinc, and 1 percent copper along with some values in silver and gold.

The property was later sold to the Banner Mining Company. It is now part of the Anamax Mining Company holdings.

GENERAL GEOLOGY:

The general geology of the Pima Mining District has been described previously by several papers and only a brief summary is included here. This district is underlain by rocks which range in age from Paleozoic through Mesozoic to Tertiary. The San Xavier mine is in the upper Paleozoic within a thick series of Permian sediments. Older formations including Cambrian, Devonian, Mississippian, and Pennsylvanian strata outcrop to the north of the San Xavier area. To the south, younger Permian rocks and Cretaceous sediments and volcanic extrusives are exposed. The stratigraphic sequence for the district is summarized below:

Upper Cretaceous
- Arkose, shale, and thin limestone
- Shales, sandstones, and conglomerates
- Undifferentiated volcanics, arkose, sandstone, and conglomerate

Permian
- Naco Group
  - Rain Valley formation; dolomite, dolomitic and cherty limestone with local narrow limy sandstone layers near the bottom.......... 470 ft.
  - Concha limestone; cherty limestone, some fossils.................. 350 ft.
  - Scherrer formation; sandstone and quartzite, dolomite, alternating thin beds of quartzite and dolomite, quartzite and sandstone 150 feet thick at base................................. 369 ft.
  - Andrada formation; dolomitic limestone, and a heterogeneous sequence of limestone, sandstone, siltstone, and marly beds with at least two beds of gypsum in the upper part..............1500 ft.

Pennsylvanian
- Horquilla formation; thin bedded, cherty limestone and shale..... ....750-900 ft.

Mississippian
- Escabrosa limestone; massive, granular limestone, local chert nodules.. 350 ft.

Devonian
- Martin limestone; limestone with thin calcerous shale near the bottom...100-350 ft.

Cambrian

Abrigo formation; fine to medium grained quartzite in the upper part of the formation with alternating limestone and shale in the lower part.. 350 ft.

Bolsa quartzite; subangular to rounded, fine to coarse grained quartzite.. 600 ft.

Bryant (1) divides the Permian into four formations which he named, from oldest to youngest, the Andrada, the Scherrer, the Concha, and the Rain Valley. In the San Xavier mine the lowest strata exposed are correlative to the middle and upper part of the Andrada formation. Rocks lying unconformably above the Andrada, previously referred to in previous publications as the Cretaceous, are believed by the writers to be equivalent to the lower part of the Scherrer formation of Permian age.

The Andrada formation is typically a variable series of quartzose siltstones, sandy shales and claystones, and quartzites with interbedded limestones and some gypsum. The close similarity of many of the rocks, the lack of any definite marker bed, the deformation and metamorphism of the strata, and the numerous faults and shears make correlations difficult within the formation. Consequently, interpretation of the structure is sometimes puzzling and determination of a stratigraphic sequence with definite thicknesses is virtually impossible.

Sediments unconformably above the Andrada consist chiefly of argillaceous quartzites with some intrastratified maroon to green sandy shales and siltstones. Locally, some coarsely granular quartzites are noted at the base. Above the argillaceous quartzite member, interbedded limestones, quartzites, and dolomites are reported in diamond drill hole intersections. Comparisons of these rocks with Bryant's (1) description of the Scherrer formation show a close similarity.

Intrusive rocks are largely confined to the area west and northwest of the mine. Here an igneous body, commonly referred to as the "Sierrita granite" outcrops at the surface at a radius of 2000 to 3000 feet from the San Xavier No. 7 shaft. This body widens and extends below the 900 level to the east under the mine area and has been encountered beneath the sediments in drill holes as far east as the Mission pit (Lacy, 10). This rock is generally light gray in color, consisting of coarse-grained quartz, plagioclase, and microcline feldspar cemented in fine-grained matrix of the same minerals. Mafic minerals are rare, seldom exceeding three percent of the rock constituents. The microcline phenocrysts vary in size from 5 to 25 mm averaging about 10 mm. The grain size of the rest of the rock ranges from 2 to 0.2 mm.

It should be emphasized that this rock is not a typical "porphyry" and that the porphyritic texture is caused by the late growth of microcline. Alteration is slight and the rock is quite fresh appearing on a broken surface. Thin sections prepared from drill core below the 900 level, indicate no evidence of introduction of hydrothermal fluids of an ore stage.

The age of the Sierrita granite has been the subject of some controversy. Mayuga (10) regarded the granitic body to be Post-Cretaceous in age, probably early Tertiary, but later work dates the intrusion as Precambrian, with the overlying sediments representing a thrust block.

Underground in the western workings of the 660 level, several small dike-like to sill-like apophyses of quartz diorite porphyry or granodiorite are exposed, also cropping out at the surface in several places to the south and southwest of the mine. These porphyritic rocks definitely intrude both Permian and Cretaceous rocks, and are regarded as late Cretaceous or early Tertiary in age.

Generally these rock types have porphyritic texture with euhedral phenocrysts of plagioclase, biotite, and hornblende set in a fine grained matrix composed of plagioclase, quartz and orthoclase. Ratio of phenocrysts to the ground mass average about 76:24 with the grain size of the phenocrysts ranging from 4 to 0.4 mm. These rocks have been hydrothermally altered, evidently by the same processes which altered the surrounding sedimentary rocks, and where observed underground contain minor amounts of pyrite and chalcopyrite.

STRUCTURE:

The granite-sedimentary contact to the west and northwest of the mine is marked at the surface by a strong fault, named the San Xavier Thrust, which strikes about N10°E and dips flatly to the east. This fault zone apparently forms the contact between the granite and sedimentary rocks below the 900 level, extending eastward under the San Xavier mine area.

Cooper (2) regards this fault as a large thrust having a displacement of about 6½ miles with the sediments above representing a thrust block or klippe over the underlying granite. Age of this faulting is indicated to be of post-mineral age.

The strata in the mine area generally dip steeply southward, averaging about 60 degrees. The beds are folded, faulted, and locally intensely deformed. The numerous folds occur usually as broad to locally tight rolls and crenulations along a larger, southerly plunging synclinal structure. These individual folds also plunge southward with trends ranging from S50° - 60° E in the western part of the mine to S 0° - 20° W in the eastern part. Thinning of the beds usually is apparent on the limbs and thickening is common on the crests and troughs.

Along many of these steeply plunging folds, flat rolls with generally east-west trending axes locally deform the steeply-dippling axial planes, possibly indicating later deformation. Many bedding plane slips and weak shears are associated with the folding, probably produced by the same compressive stresses. These follow the limbs of the folds parallel to the bedding and sometimes cross the beds at low angles. These structures are pre-mineral in age. Other pre-ore fractures and fissures, with little apparent displacement, strike between N10°W to N30°E.

Numerous faults occur throughout the mine area. The most prominent of these structures, named the 17 fault, is well-exposed on the 660 level south and east of No. 7 shaft where it strikes S70° - 80°W and dips 35° - 70° southeast. To the west, the probable extension of this fault swings to S10° - 45°W, dipping from 35° - 60° southeast. Further east, this fault zone joins or terminates against a N35° - 45°W trending structure that dips to the southwest. A N-S section through No. 7 shaft indicates, if the 900 level geology is correct, an approximate throw of about 300 feet with the hanging wall moving up to the north. Movement is expressed by a 2 to 4 foot sheared zone with development of serpentine, gouge, breccia, and ½ to 2 inches of black to brown clays.

Other smaller thrust and reverse faults, trending generally east-west to southwest, occur as either splits from the 17 fault or as parallel to sub-parallel structures. One of these faults, called the No. 10 fault, shows little apparent offset. Displacements along many of these structures and particularly along the 17 fault zone, appear to be post-mineral, but may reflect later movement along pre-mineral shear and fracture zones.

Local brecciation and crushing of the incompetent beds, as a result of the folding and deformation, are common occurences. Other breccias occur as irregular, steeply-dipping zones with a heterogeneous assortment of angular to sub-angular fragments of the different sedimentary rocks in a soft clayey and limy matrix. Many contain fragments of mineralized limestone and quartz, indicating a post-mineral age.

MINERALIZATION:

The mineral deposits occur as replacements of metamorphosed limestones of the upper part of the Permian Andrada formation lying between clastic beds and along zones of folding and shearing that roughly parallel the bedding. The principal ore bodies lie to the southeast of No. 7 shaft and are situated near the axis of the major synclinal structure along the crests and troughs of the smaller folds. To the west, other mineralized bodies are exposed on similar folds along the westerly limb of the synclinal structure. The ore shoots occur as pipe-like to locally tabular bodies, plunging with the bedding and generally following an arcuate contour around the folds. Along the plunge of the ore shoot, mineralization is often limited by flat cross folds and flat-dipping shears (see Figure 4). Commonly, along these structures where the bedding flattens, the ore shoot thins, becoming either a narrow seam or pinching out altogether. Above or below these "flats" the ore shoot usually again thickens. The deposits are generally small averaging 15 to 20 feet wide with local widths up to 50 feet. In plan, the lengths are quite variable.

A few narrow vein-like replacements occur along steep N10°W to N30°E trending fractures in both the Andrada and Scherrer(?) formations, becoming pyritic in the clastic sediments.

The sedimentary rocks surrounding the mineralized zones are highly altered and metamorphosed. In the limestones, garnet, hedenbergite, and calcite are the chief metamorphic products with lesser amounts of epidote, wollastonite, serpentine, and tremolite. In the clastics, development of serpentine, sericite, and epidote along with other lime silicates is noted; and chondordite, kaolin and orthoclase have been identified in thin section studies of various specimens.

The principal sulfide minerals are sphalerite, galena, chalcopyrite, and pyrite. Small amounts of hematite, magnetite, and bornite are sometimes present. Silver is an important accessory, probably occurring in solid solution with galena and sphalerite. Generally galena is more abundant in the ore deposits to the east of the No. 7 shaft becoming a minor constituent in the ore zones to the west. In the western part of the mine, sphalerite is most prevalent together with spotty concentrations of chalcopyrite and minor bornite.

The metallic minerals occur usually as massive replacements in the metamorphosed limestones, replacing the garnet and hedenbergite; however, locally the mineralization makes out into the crystalline limestone as irregular pods, blebs, and thin seams. In certain areas, glassy quartz with good blebs of sulfide minerals occurs as irregular small pods and narrow steep dipping stringers.

At the surface, a conspicuous iron-stained gossan marks the outcrop of the ore deposit. The lower limit of oxidation is irregular, extending locally to as deep as the 420 level, but generally the most extensive development of the oxidized portion is above the 200 level. Here the ore minerals consist mainly of cerussite and smithsonite, usually associated with limonite, jarosite, and goethite. Local occurences of wulfenite, hemimorphite, copper carbonates, and native copper together with some chalcocite are also reported (Jones, 6).

PARAGENESIS:

The paragenesis for the hypogene minerals have been determined by Mayuga (11) as follows:

garnet, epidote, and other silicates
primary magnetite
hematite
pseudomorphic magnetite (after hematite)
hedenbergite
quartz
quartz
pyrite
sphalerite
chalcopyrite
galena

His report lists in some instances that quartz was deposited later than galena which may reflect a later quartz stage.

SUMMARY AND CONCLUSIONS:

The San Xavier mineral deposits are considered to be within sediments that are equivalent to the Andrada formation; the mineralized bodies, however, are not limited to one stratigraphic horizon but occur in several different limestone beds. Rocks above the Andrada are believed to be the Scherrer formation, also of Permian age.

Major loci for ore deposition appear to be as follows: favorable limestone beds; steeply-plunging folds with zones of fracturing and shearing; cross folding and flat-shearing which deform the steeply-plunging folds; metamorphism of favorable beds prior to ore deposition; and selective replacement of garnet and hedenbergite along favorable beds and structures by the metallic minerals.

The selective replacements of garnet and hedenbergite by lead-zinc-copper sulfides in the San Xavier deposit are suggestive of a contact metasomatic or pyrometasomatic type. However, when the deposit is viewed in relationship to other nearby mines in the district, its alteration and metallization sequence is reflective of the zonal arrangements characteristic of many other major porphyry copper deposits of the southwest. Alteration and mineralization must be considered district-wide with the San Xavier deposit being peripheral to the extensive copper deposition which forms the Pima, Mission, and Palo Verde mines. Richards and Courtright (14) consider the mineralization processes within the district to be hydrothermal-metasomatic rather than pyrometasomatic. Diffusion evidently played a part of major importance with the hydrothermal solutions moving outward from the loci of mineralization along faults and fractures, selectively replacing favorable wall rocks away from the feeder channels.

ACKNOWLEDGEMENTS:

The authors wish to express their appreciation to the Anamax Mining Company and to James L. Kelly, Chief Geologist, for their cooperation in the preparation of this paper. In particular, we wish to acknowledge contributions made by Calvin C. Brown, who participated in the underground mapping, and by Pierce D. Parker and D. P. Cox, who made the petrographic studies. We especially wish to acknowledge and thank H. W. Olmstead, J. G. Kuhn, and J. D. Sell for their critical review of the manuscript, Tina King for her assistance in preparing the illustrations, and R. Radabaugh and John Teet for their cooperation in providing certain historical information from the records of the New Jersey Zinc Company.

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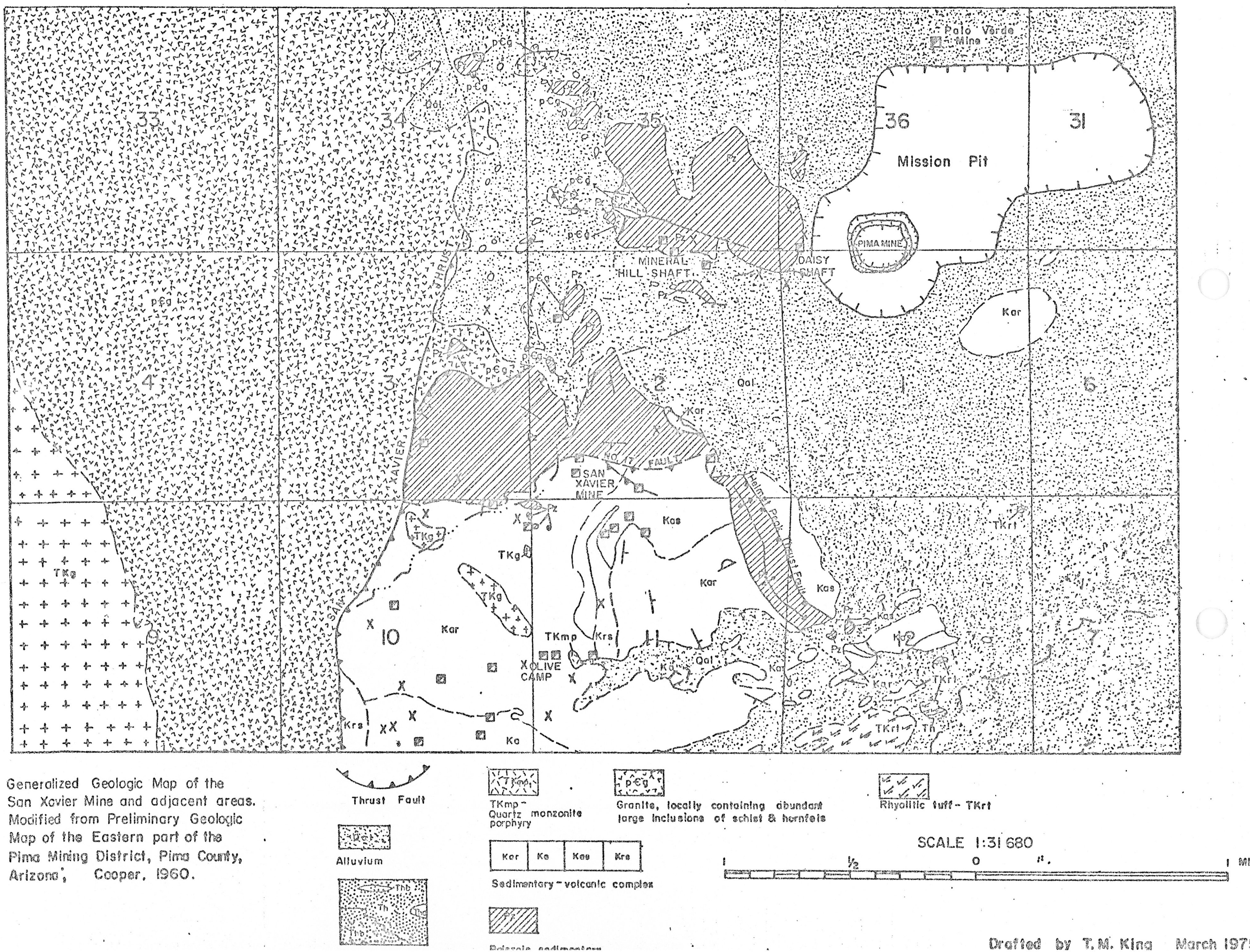


Fig. 2. Generalized Geologic Map of the San Xavier Mine and adjacent areas. Modified from Preliminary Geologic Map of the Eastern part of the Pima Mining District, Pima County, Arizona, Cooper, 1960.

Drafted by T.M. King March 1975

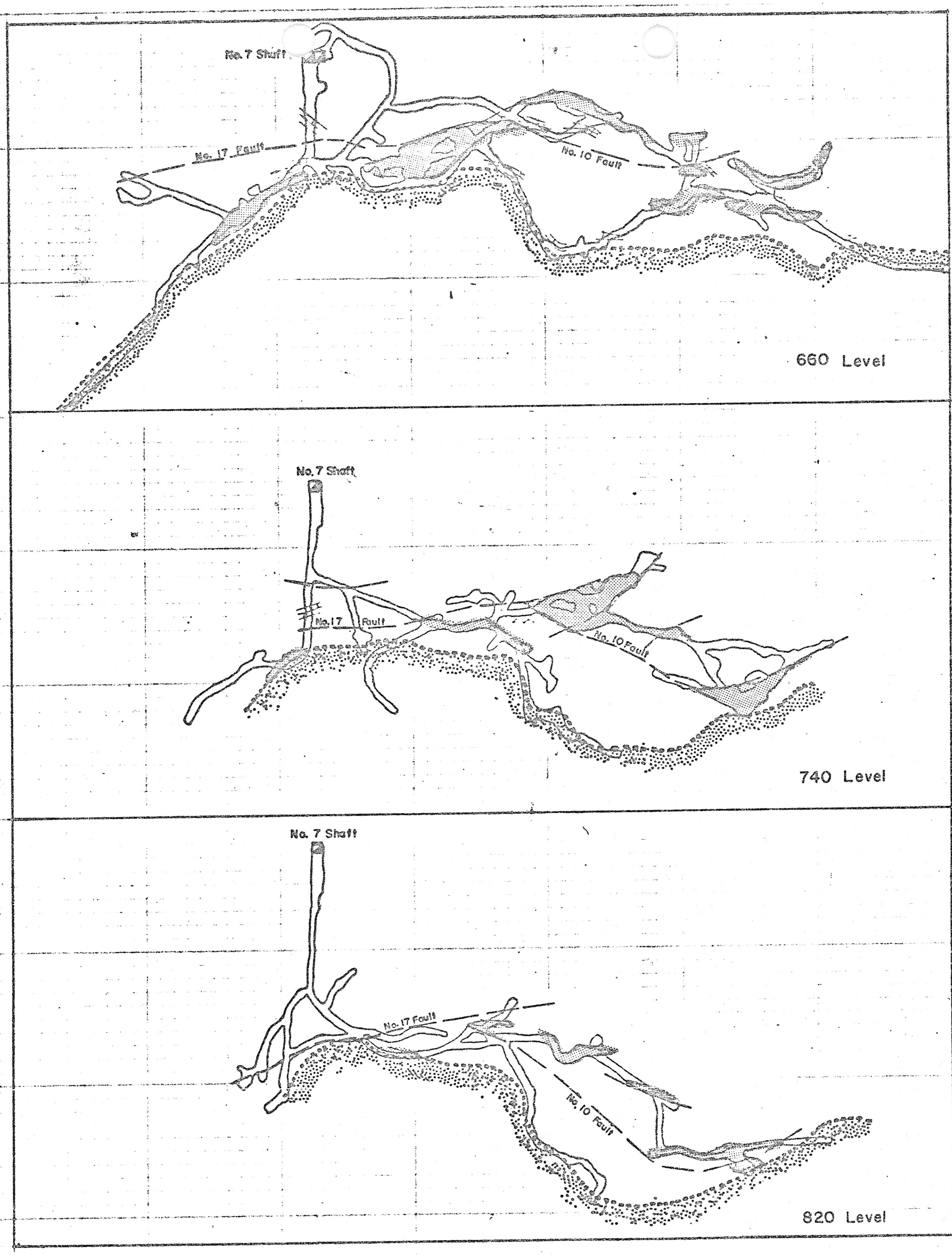
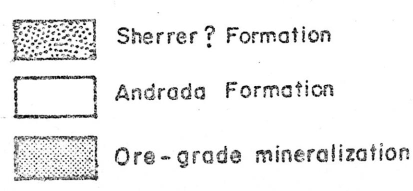


Fig. 3

Generalized geologic maps of the 660, 740, and 820 Levels, San Xavier Mine



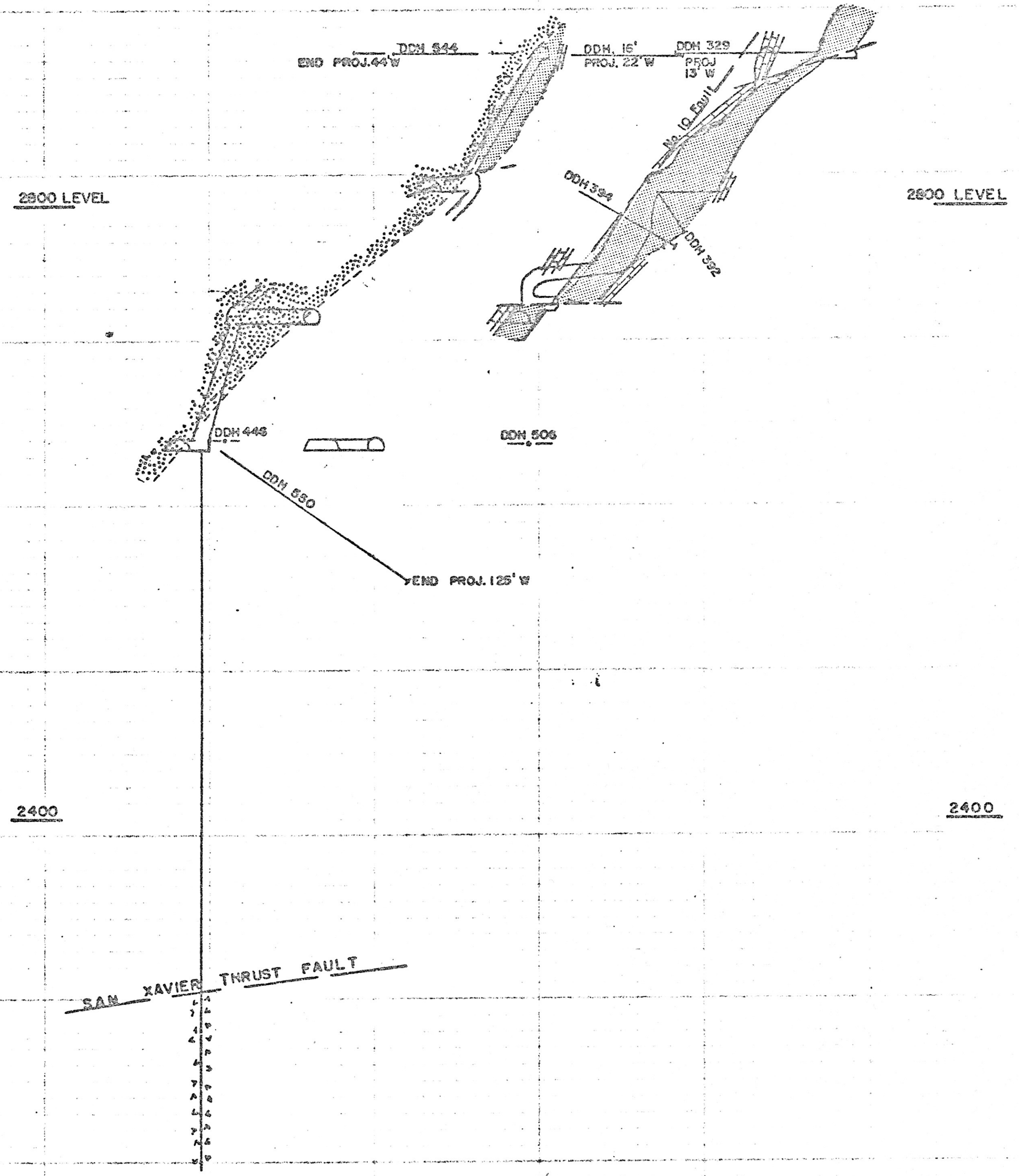


Fig. 4

North - South section through San Xavier Mine showing the ore relationships along the plunge of folds.

Fault

Contact

SAN XAVIER MINE

Ore-grade mineralization

Andrada Formation

Sherrer Formation

San Xavier Granite

X 1086 8OM 7-39

Gilman, Colorado
May 4, 1940

MEMORANDUM

COPY

SAN XAVIER

MINE

BY

MR. T. H. GARNETT

I went to the San Xavier Mine in March 1916, and remained there until March, 1917. Mining was started with the intention of taking advantage of the favorable market for lead and copper.

Water in the mine stood a short distance above the 200 foot level. The old boiler at No. 1 shaft was fired and a small Cameron pump using steam for power removed the water in 10 days to two weeks. After uncovering the 200 foot level no attempt was made to unwater deeper workings. A small deep well pump operated at short intervals each day served to keep water off the 200' level.

Drinking water was obtained from a small inflow in an unused drift on the 200' level. This water was hoisted in kegs. Drinking water was also brought from the Pioneer Smelter by ore trucks.

It is reported that the 380' level of No. 1 shaft produces much more water and the flow while sinking No. 6 shaft was probably 50 to 60 gals per minute at 100' depth.

Mining operations were confined to oxidized lead and lead-copper ores. Production was 20 to 30 tons per day. The greater portion of this ore came from the area east of No. 2 shaft on the 100' level, from the surface between No. 1 and No. 2, some very good lead carbonate near No. 3 shaft on the 100 foot level, and later quite a lot of copper ore from the surface in the vicinity of No. 6 shaft. An attempt was made to get some production from No. 4 shaft but I don't think more than one truck load was hoisted.

While I was there No. 6 shaft was started and a drift extended on the 100' (?) level to the west for probably 80'. This drift encountered 20 or 30 feet of low grade zinc sulphide. The rock was more or less broken but did not appear very favorable for ore.

No attempt was made to mine or develope the sulphide ore bodies and no comments I could make would add to information given by others who have made a thorough geological study of the mine and vicinity.

T.H. Garnett/AM

BOM 7-39

Gilman, Colo.
June 18, 1940.

MEMORANDUM

COPY

SAN XAVIER MINE

BY

F. J. MALOIT

__WATER:__ When the mine was in operation in 1917, the water at #2 Shaft was kept just below the 220 level. To hold the water there we pumped about 10 gallons of water per minute.

At #6 Shaft while sinking we encountered water at about 180 ft. below the shaft collar and the flow increased gradually with depth. On the 250 level the flow of water was between 50 to 60 gallons per minute up to the time the Southeast heading hit the limestone-granite contact, when the flow increased to well over 100 gallons per minute. However, this flow may decrease rapidly once the surrounding country is drained. Also the flow may vary considerable as the lime-granite contact runs down the arroyo bed.

The churn drill hole put down for domestic water, proved to be a "duster."

According to hearsay the flow of water on the 380 ft. level was about 75 gallons per minute.

__ORE DEPOSITS:__ All the known oxidized ores that could be mined at a profit from the present mine workings were shipped.

The mineralized surface showing on the Patterson Claim looks encouraging for an orebody to exist there.

With the exception of the #1 shaft orebody the ore shoots are small and erratic with a decrease in cross section with depth.

The #1 and #4 orebodies will need to be mined at least in part, by a method requiring ground support. These orebodies have a number of slips and faults running through them and also a weak hanging wall in places.

The other orebodies can be mined by open stope methods, possibly using some stulls at times.

__No. 6 SHAFT:__ There was no ore found on the 250 ft level. The headings were in limestone and were driven under known ore on the 100 and 150 ft levels. In fact the ore went just about 6 ft. below the 150 ft. level, also the ore cross section was much smaller on the 150 ft level than on the 100 ft level. There were some showings of zinc sulphide on the 100 and 150 ft levels, but these showings, are rather weak and one would not expect much tonnage to come from them.

In Southeast heading, which encountered the large flow of water on the 250 ft level #6 shaft, the contact where the flow came from looked like a limestone-granite contact and not the so-called igneous complex or arkose. However, I was waist deep in water and in a hurry to get out, so my observations may have been faulty.

(2)

Gilman, Colo.
June 18, 1940

6 8OM 7-39

SAN XAVIER MINE Cont'd. BY F. J. MALOIT.

COPY

ADJACENT PROPERTY: If the ore does not go below 380 ft level on the company property, I believe there is no advantage in acquiring additional adjacent claims. The extension of ore with depth should be determined as soon as possible, as this will determine whether San Xavier Mine can become a paying mine for the Company and whether adjacent property should be acquired.

The history of the surrounding camps seems to point out that the ore bodies are cut off by granite at a depth of about 400 ft.

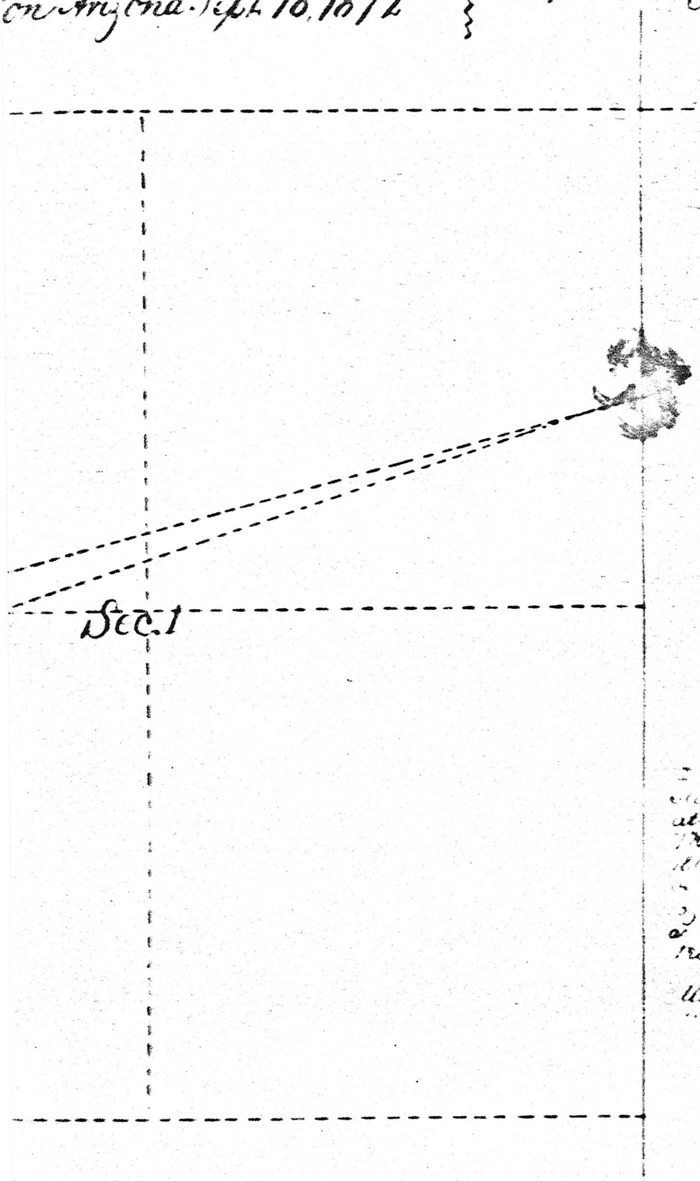
Frank J Malois

FJM/AM

Note Pioneer Smelter at Corwin Mine located at Zinc [illegible] field notes of the survey of the San Xavier Mining Claim [illegible] this Plat has been made, have been examined and ap[proved] [and] are on file in this Office; and I hereby certify that the [illegible] [be]ars silver, and the value of the labor and improvements thereon [illegible] thousand Dollars, as shown by the report of the Deputy Surveyor [and the test]imony of two witnesses, and I further certify that this claim is [not includ]ed within the exterior lines of any other claim.

[U.S.] Surveyor Generals Office
[Tucs]on Arizona Sept. 18, 1872

John Wasson
Sur. Gen!



I certify that this is a true & correct copy [illegible] San Xavier Mining Claim [illegible] ation.
The [illegible] [illegible] [illegible] of the U.S. Land Office [illegible] the Register and Receiver of the Land Office at Prescott A.T. dated [illegible] 1873,
The plat has been altered accordingly.

U.S. Surveyor Gen'ls Office
Tucson [illegible] 1873

[illegible]
Sur. Gen!

1

Lot No. 38

Mineral District No. 3.

PLAT of the SAN XAVIER MINING CLAIM

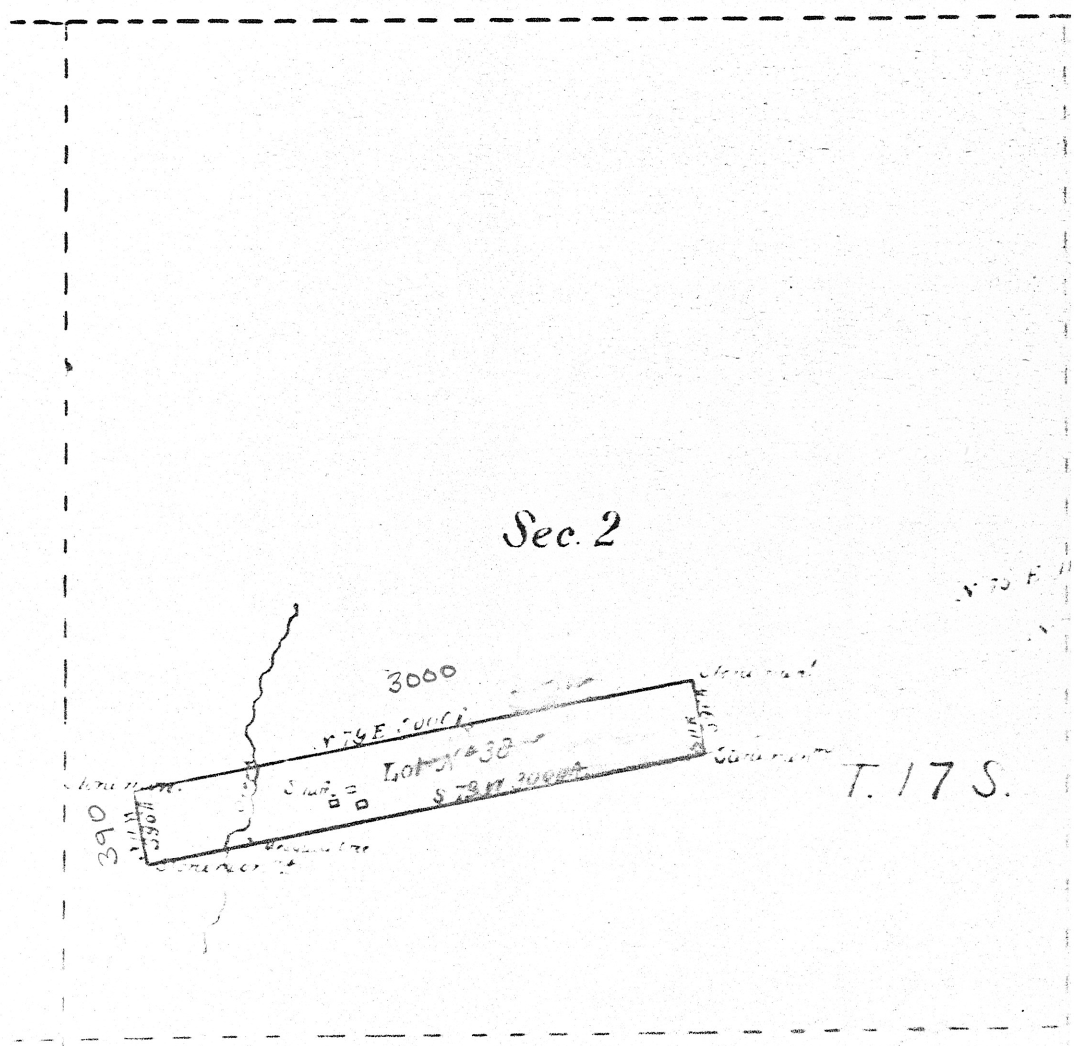
Pima Mining District Pima County Arizona

Claimed by M. B. Duffield & I. Q. Dickason

Surveyed by S. W. Foreman U. S. Dep. Surveyor
March 3, 1872

Containing 27.65 Acres

Scale 990 ft. to 1 inch.



Lot No 38 (3)

Mineral District No 8

PLAT of the SAN XAVIER MINING CLAIM

Pima Mining District, Pima County, Arizona

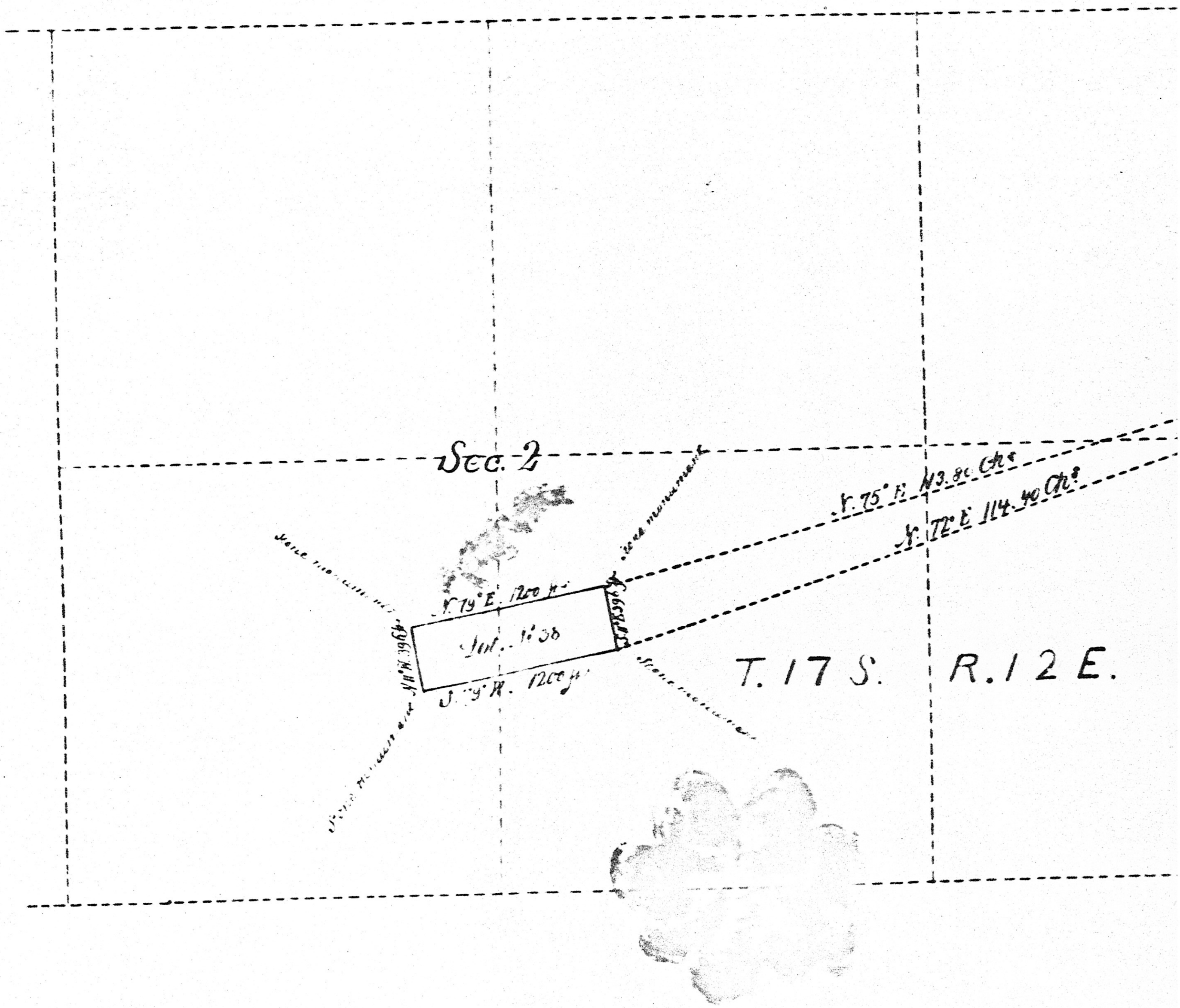
Claimed by M. B. Duffield & I. Q. Dickason

Surveyed by S. W. Foreman, U.S. Dep. Surveyor

March 2d 1872

Containing $10\frac{91}{100}$ Acres

Scale 990 ft. to 1 inch



Scale 2" = 1 mi.

THE INTERIOR