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POST SKARN BRECCIATION AT THE MISSION DEPOSIT

PIMA MINING DISTRICT, S. E. ARIZONA

ABSTRACT

The Mission copper deposit is a structurally complex allocthanous porphyry skarn deposit. The orebody occurs in overturned Upper Paleozoic strata comprised predominantly of carbonates and quartzites, which in turn is unconformably overlain by a Mesozoic clastic section. Numerous breccia occurrences have been observed in garnet rich skarn. These breccias are clearly post main stage mineralization and post skarn formation in age, but, are associated in both space and time with a late stage hydrothermal event involving veins and fracture filling of sulfates, carbonates, quartz and minor sulfides. One of the breccias is spacially restricted to garnet destructively altered skarn zones that only locally have any fault associations. Two periods of brecciation are interpreted based on observations of fragments occurring within breccia fragments. The earliest period involved tectonic/fault brecciation followed by later strong invading solutions (± vapor phases) that filled fissures, fractures and corroded and modified garnet destructively altered fragments. The matrix consists of a dense, indurated assemblage of gangue minerals consisting of calcite, dolomite, hematite, gypsum, quartz and fluorite and locally produces a "rock flour" texture. The later period of solution invasion masks the earlier tectonic stage, and produces narrow dike and fissure-like solution/replacement breccias with a possible fluidized component. Restoring the allocthanous contiguous Pima-Mission-San Xavier deposits on top of the Twin Buttes deposit, the breccias and late stage hydrothermal activity would then spacially occur in the upper portions of this porphyry copper system.

Paper presented at Conference convened by Univ. of Nevada-Reno at Broadmoor Hotel, Colorado Springs, Colorado. Sept. 18-22, 1983. "Brecciation and Mineralization: Geologic Occurrence and Genesis".

POST SKARN BRECCIATION AT THE MISSION DEPOSIT

PIMA MINING DISTRICT, S.E. ARIZONA

INTRODUCTION & GENERAL GEOLOGY

The Mission deposit located in the Pima Mining District in southeastern Arizona represents a structurally complex allochthonous porphyry copper skarn deposit (figure 1) The geology at Mission consists of an Upper Permian carbonate and clastic section unconformably overlain by Mesozoic arkoses, volcanoclastics and argillite. Both sections are intruded by a 58 m.y. Laramide aged quartz monzonite porphyry emplaced principally along the Mesozoic-Paleozoic unconformity. Resultant alteration and mineralization produced carbonate skarns, hornfels, quartzites and argillites. The altered sedimentary sections form a tabular shaped and folded ore body with major northwest premineral structural trends (figure 2). Superimposed on northwest trending folds is a N80E striking antiformal arch that drapes the units away from the arch. Northwest ore trends are also cut and locally offset by post mineral east-northeast trending faults and fractures. Principle fracture and joint orientations are N25-40E, N70-85E (post mineral), N40W (premineral), N2-N15E (post mineral). The Paleozoic section subsequent to mineralization has been completely overturned resulting in an inverted Permian strategraphic sequence (Jansen 1982). The highest ore grade unit is a garnet skarn of the Permian Concha Limestone (figure 3). The garnet skarn exhibits various garnet and calc-silicate phases that are zoned away from the porphyry.

Significant alteration observed at Mission includes (1) potassic and sericitic alteration developed in the silicate rock assemblages, consisting of porphyry, arkose and argillite; (2) hydrous garnet destructive alteration producing a carbonate, quartz hematite ± green clay and chlorite assemblage in the carbonate units. (Einaudi 1977, 1981, 1982).

The entire Mission-Pima complex lies in upper plate rocks above a post mineral Mid Tertiary north-northwest trending San Xavier thrust fault that is believed to have moved from the top of the Twin Buttes porphyry copper system (figure 1).

BRECCIA OCCURRENCE AT MISSION

Brecciation appears to be an integral phenomena or characteristic in many porphyry copper intrusive phases. Breccias have also been described in a few porphyry skarn occurrences. Among these descriptions in the literature, fault breccias have received the highest billing to date.

Several breccia occurrences have been encountered in the garnet skarn at Mission. Early mining activity encountered a high grade premineral polymetallic intrusive breccia dike composed of garnet skarn, limestone, arkose, argillite and foreign rocks

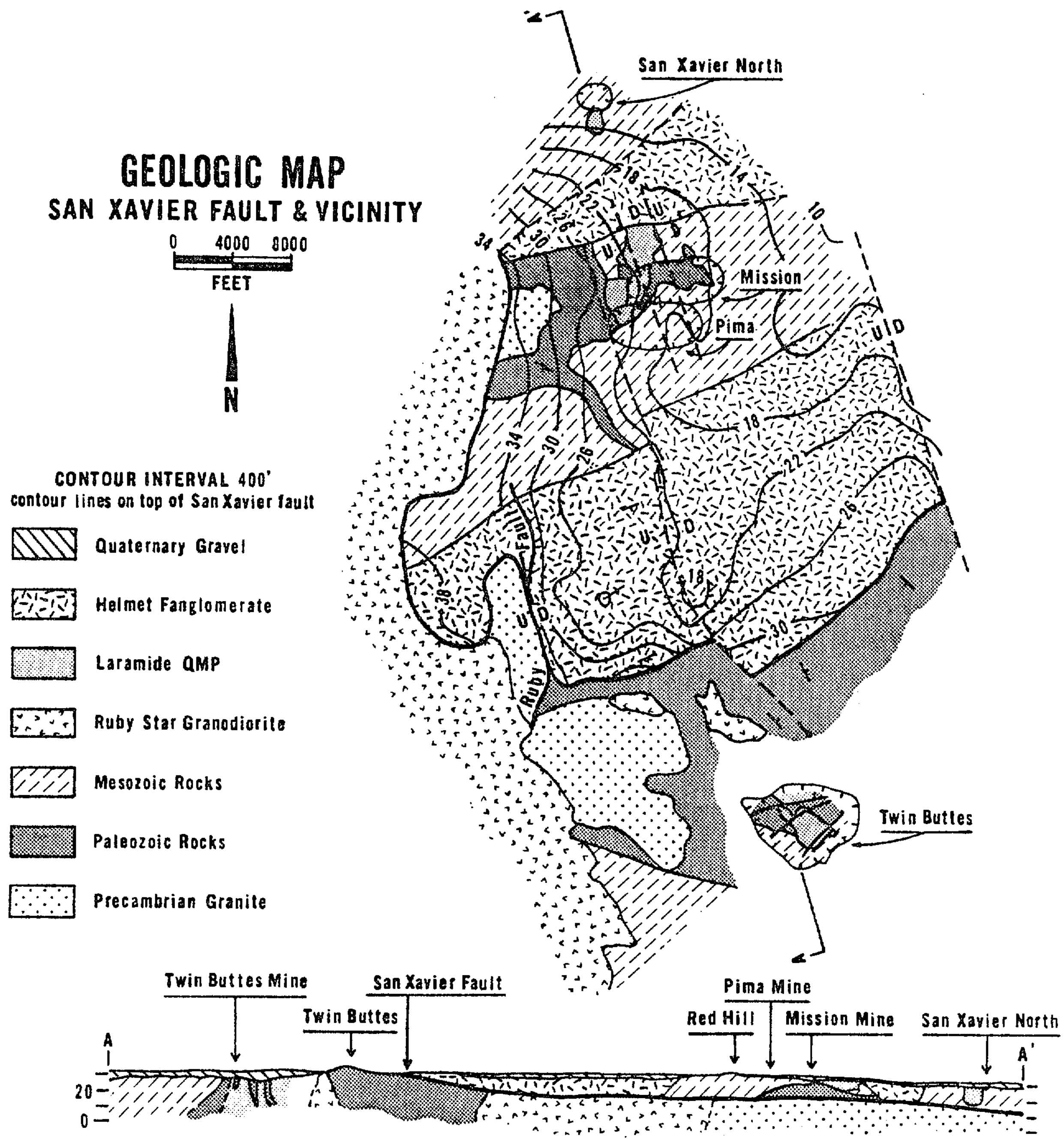

Figure 1. General geology of the Pima mining district. Contour lines represent elevation of the San Xavier fault, as interpreted from diamond drill hole samples and scattered surface exposures.
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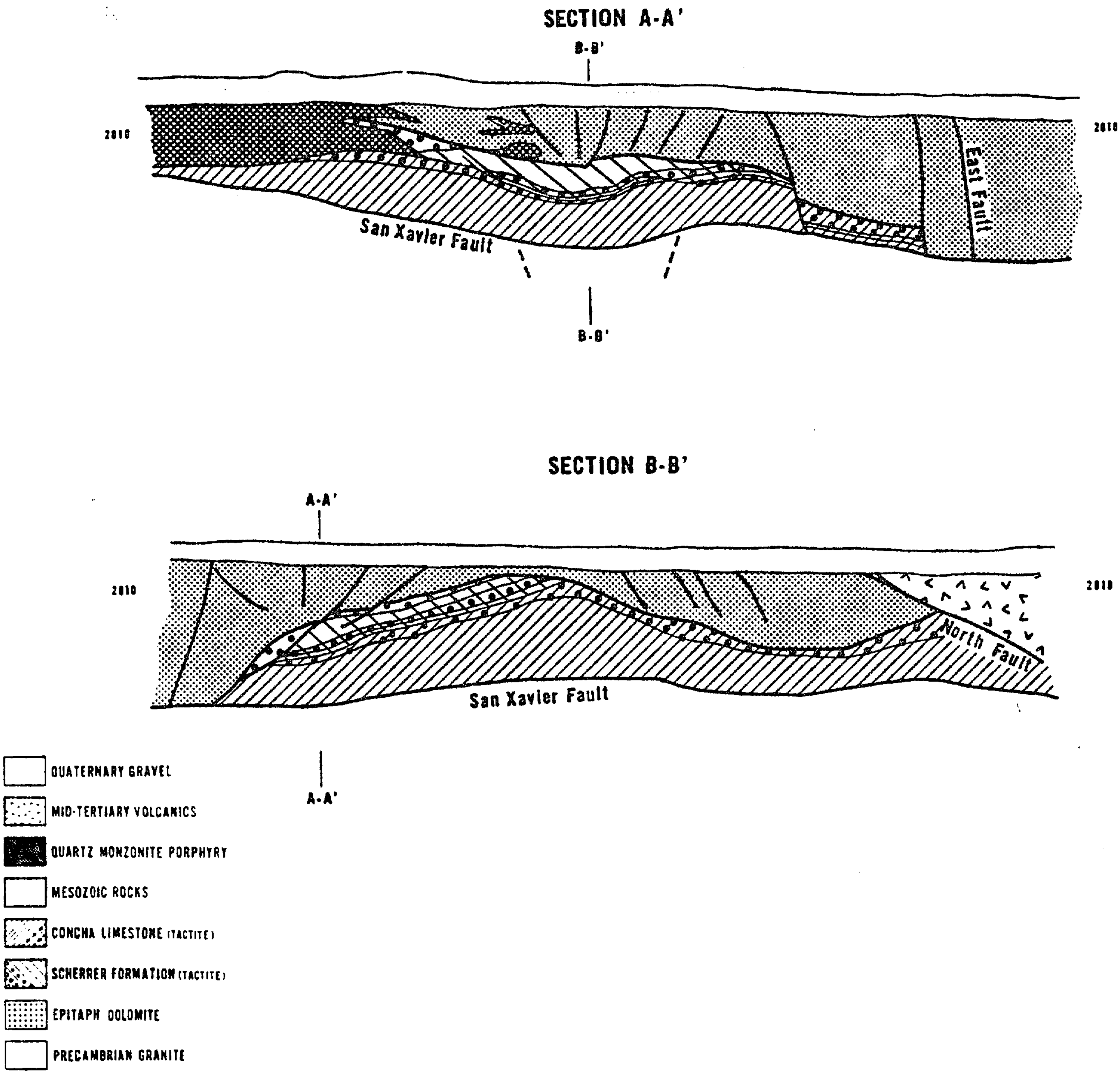


Figure 2. Geologic cross sections through the Mission mine. By permission from Advances in Geology of the Porphyry Copper Deposits: Southwestern North America, Spencer R. Titley, Editor, Tucson: University of Arizona Press, Copyright 1983.

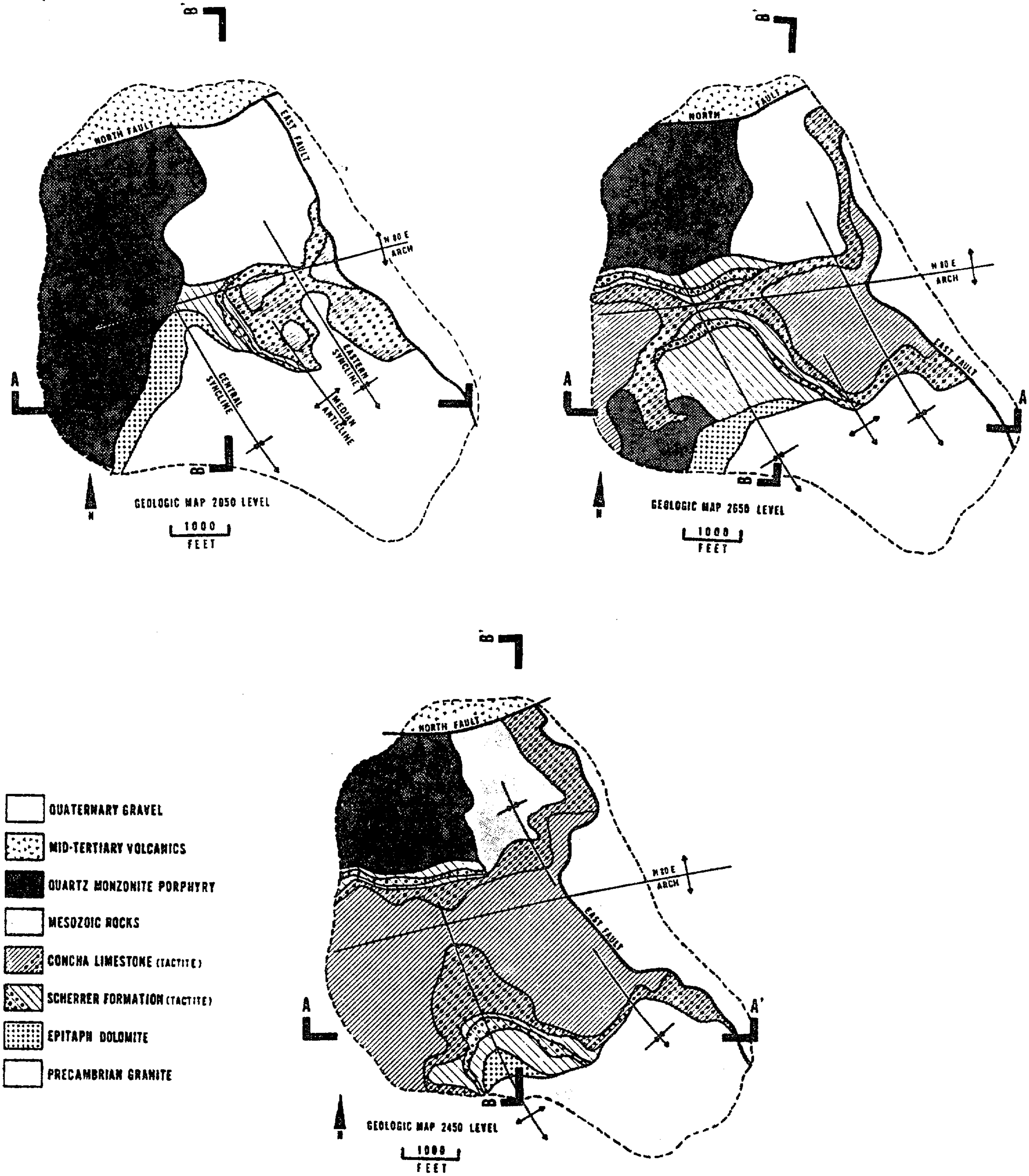


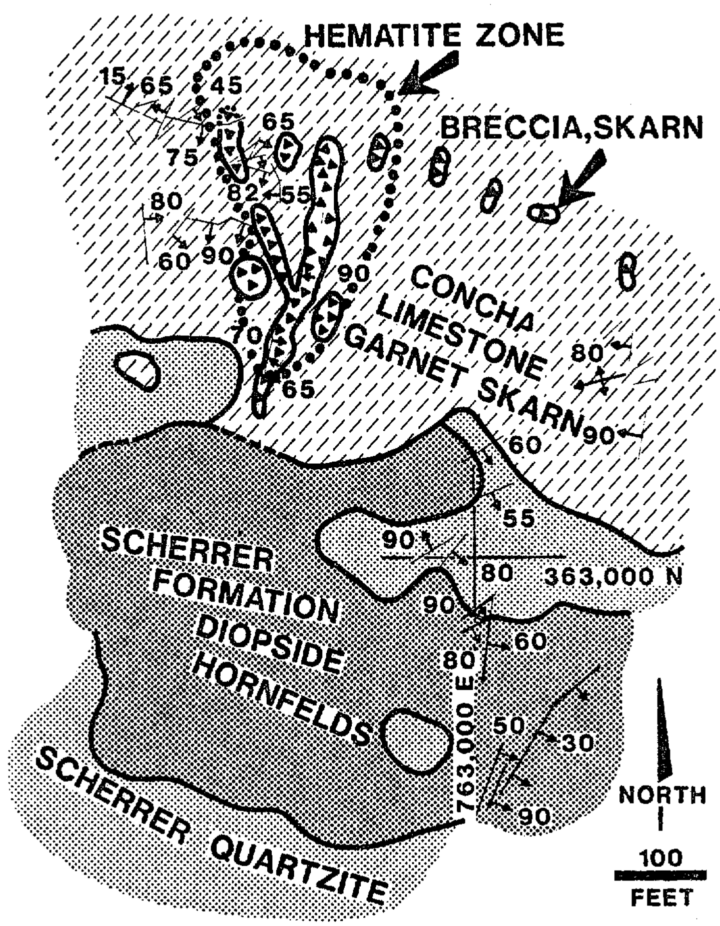
Figure 3. Geologic bench maps of selected levels in the Mission mine and vicinity. Refer to Figure 2 for cross sections and stratigraphic section. By permission from Advances in Geology of the Porphyry Copper Deposits: Southwestern North America, Spencer R. Titley, Editor, Tucson: University of Arizona Press, Copyright 1982.

cemented by a clastic matrix. The breccia dike had a 1,500 ft. locally offset strike length, 5-10 ft. width and, subsequently, has been mined out for over 10 years (Gale 1965).

More recent mining has encountered two (2) breccia types located in the western and central portions of the pit occurring in the garnet skarn unit.

Q BRECCIA

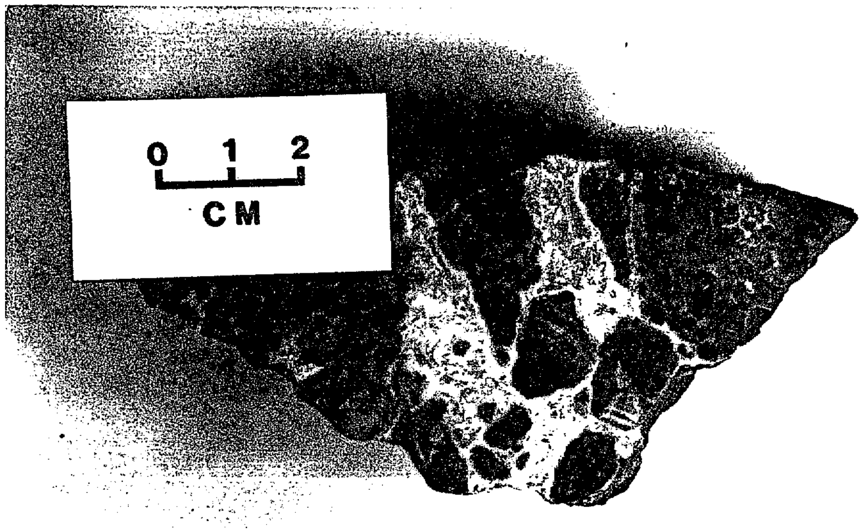
The first breccia occurs in the western pit area, 100-200 ft. east of the quartz monzonite porphyry sill. The breccia forms north-northeast trending linear dikes to irregular thin discontinuous masses and fissure zones. The breccia is spacially associated with pervasive hematitic zones and garnet destructively altered skarn that encompasses a 200 ft. diameter zone locally (figure 4). One bench face exposure shows that the breccia locally was narrow and "V" shaped and bounded by 2 N22-N25E oppositely dipping faults with possible minor strike slip movement. However, no appreciable offsets were observed and jointing and bedding could be traced through the breccia zone without displacement. The breccia was 2 ft. to 8 ft. wide from toe to crest of bench, respectively. The host wall rock consists of massive garnet and wollastonite cut by hematite veinlets and exhibits strong mineralization.



GEOLOGIC BENCH MAP
2650 ELEVATION

Figure 4

The Q breccia consists of rounded to angular fragments of altered skarn and possible quartzite (the latter from superjacent Scherrer Formation), that contain weak to strong veinlets and disseminated chalcopyrite, pyrite and minor sphalerite. Quartz sulfide veinlets cut several fragments and terminate at the fragment boundaries. The fragments commonly exhibit a shattered to fragmental almost disintegrated texture locally, and "float" in a dense gray siliceous calcareous and locally gypsiferous fine grained matrix (with rare open spaces). The matrix contains weakly disseminated pyrite and minor chalcopyrite and rare quartz - quartz calcite sulfide veinlets. In slab and thin section, the matrix exhibits iron rich and bleached zones in sharp contact. Both zones contain minor flow structures and a fine grained rock flour texture (figure 5). In slab specimen, the bleached zone is about 6 inches wide and commonly is separated from the rose colored hematitic matrix by a 1 inch siliceous zone composed of micrographic quartz and carbonate material. Electron microprobe data indicates the very fine grained rock flour texture is composed of dolomite/ankerite, iron oxides, minor quartz and chlorite. Altered garnet and quartz fragments locally display rounding, with 1/8 inch corrosive halos, which on earlier exposures gave the impression the breccia was some type of pebble pipe or dike. However, further mining revealed the breccia contained much more angular fragments than rounded. Many fragments are



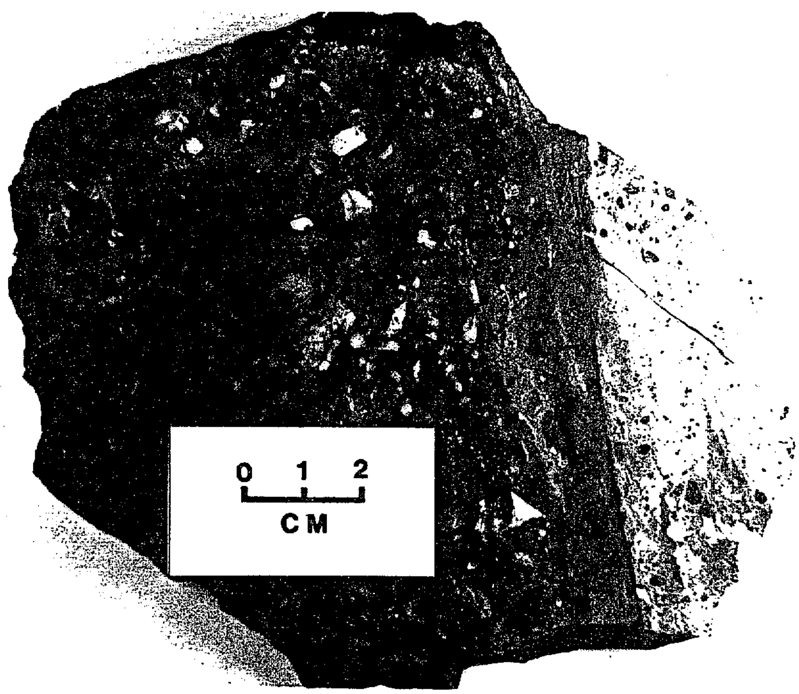


FIGURE 5 Q breccia slabs exhibiting bleached and iron oxide stained zones in sharp contact. Flow structures are evident adjacent to the color contact. Both the red (dark) and white bleached zones are composed of fine grained dolomite/ankerite, iron oxides, calcite and minor quartz.

cut and veined by the hematitic siliceous-carbonate matrix. One interesting exposure, gypsum cemented and veined fragments; extended into the surrounding skarn wall rocks, pervasively frosting fractures and producing gypsum-carbonate vein swarms. Gypsum and calcite veining has occurred in other areas of the skarn and diopside hornfels units, usually in close proximity to the quartz monzonite porphyry and appears to reflect a late stage hydrothermal event involving the addition of sulfates and carbonates (the latter the result of recarbonation of skarn, Einaudi 1981, 1982). The above veins were oriented predominantly east-northeast. Two arcuate N35-55W faults also contained gypsum coatings. The Q breccia overall exhibits a low fragment to matrix ratio and fragment percent varies from 40 to 60 percent by volume. A prominent east-west north dipping fault was mapped in earlier exposures and appeared to form a hanging wall boundary to the breccia (at least locally). A N2E vertical fault, that is clearly post breccia in age, cuts the breccia and forms an intensely sheared friable zone.

Einaudi (1982) refers to post skarn fault breccias in the Palo Verde property (northwest area of the Mission deposit). He reports that the fault breccias are cemented by calcite-hematite-siderite and skarn fragments in the breccia are pervasively altered to carbonate-hematite. Alteration extends up to a meter away from major faults and into the skarn along fractures. The Q breccia is associated with faulting locally but most exposures have no obvious fault associations and the hematitic zone mentioned above extends well beyond the breccias and seems to form a 200-300 ft. diameter zone of very pervasive hematite. Numerous slab samples were examined and a number of different textural varieties were observed. One breccia slab exhibited a gross alignment of lathlike garnet fragments in sharp contact with unbrecciated garnet and wollastonite skarn. The breccia and wall rock were separated by a 1/8 inch quartz hematite veinlet. Numerous other small fissures in the breccia group exhibited a breccia fragment texture often with aligned fragments cemented and cut by carbonate and quartz, with no apparent movement. These observations suggest solution/replacement styles of formation. Breccias similar to the Q breccia have been observed in other areas of the pit, all in the garnet skarn and are usually small narrow linear dike-like or fissure-like in form.

N BRECCIA

The second breccia type is quite limited in exposure and size and currently is visable only as float in a blasted muck pile in close proximity to the marble (and locally extends into the marble). The N breccia was observed on 2 benches (along 2770 and 2730 elevations). Bench heel and crest outcrop

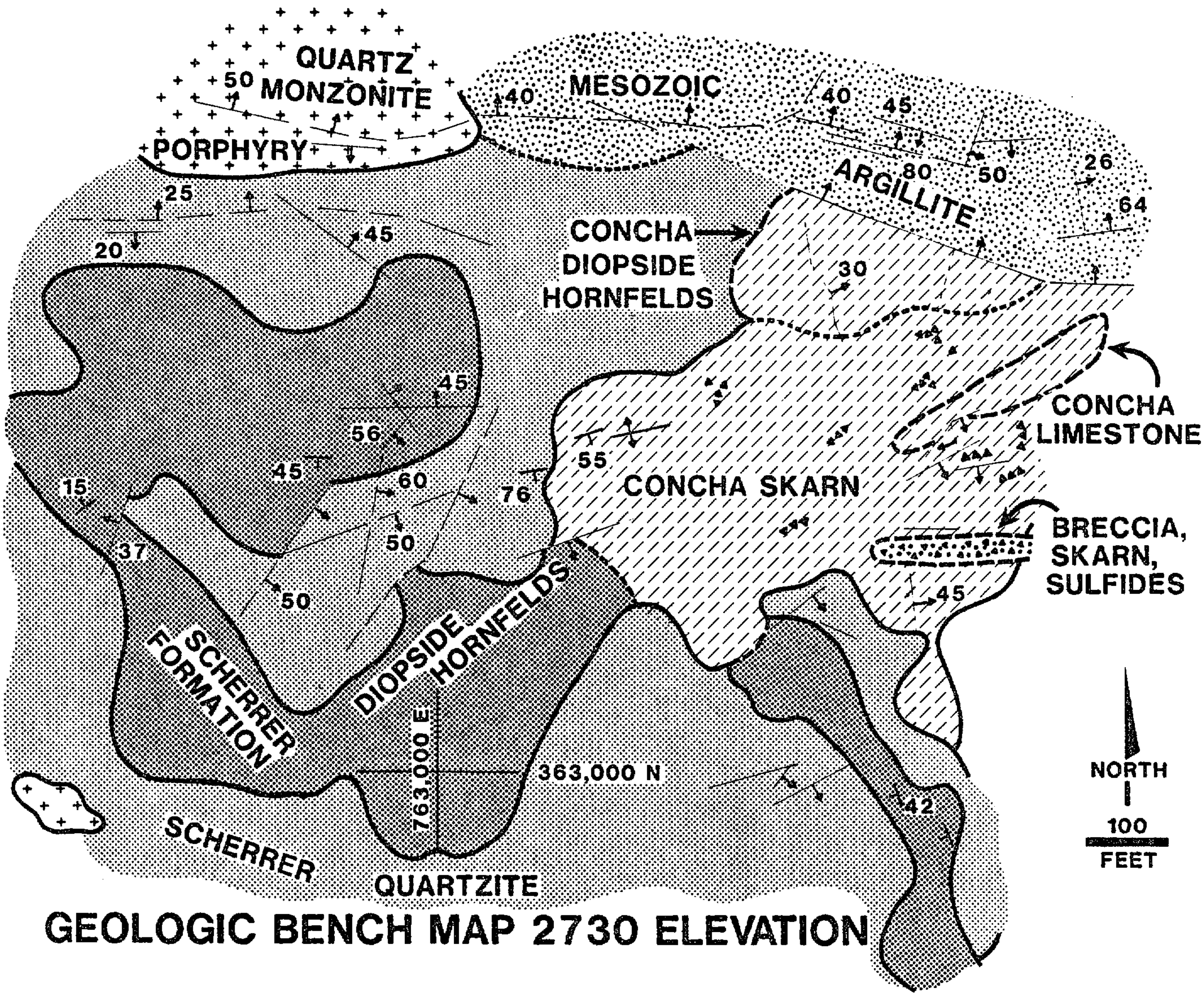
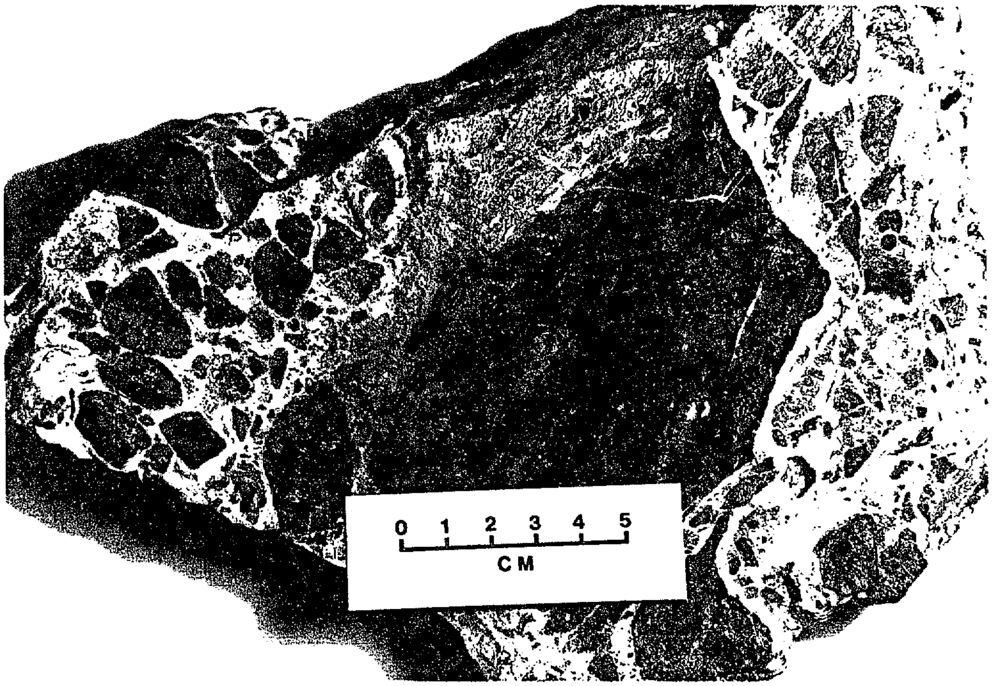
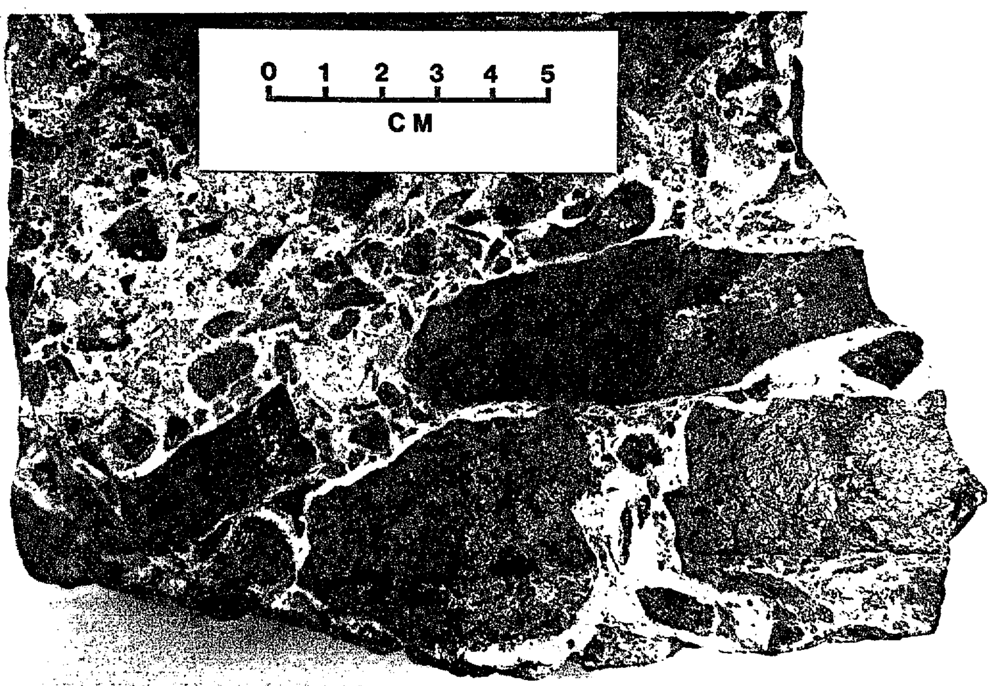

QUARTZ MONZONITE PORPHYRY
MESOZOIC ARGILLITE
CONCHA DIOPSIDE HORNFELDS
CONCHA LIMESTONE
CONCHA SKARN
BRECCIA, SKARN, SULFIDES
SCHERRER FORMATION
DIOPSIDE HORNFELDS
763,000 E
363,000 N
SCHERRER QUARTZITE
NORTH
100 FEET
50
40
45
80
26
64
25
20
30
56
60
15
37
55
76
42
GEOLOGIC BENCH MAP 2730 ELEVATION

Figure 6

patterns delineated a near vertical 5 ft. wide 60-100 ft. long "intrusive breccia" dike or fissure occurring in the garnet skarn (figure 6). The breccia is comprised of rounded to subangular massive chalcopyrite fragments and angular to rounded fragments of moderately to intensely altered garnet skarn. The fragments vary in size from less than 1 mm to 6 inches in diameter. Rounded silica fragments also occur in the breccia. The fragments float in a texturally zoned medium to coarse grained calcite and quartz matrix, locally containing numerous vugs lined with bladed calcite, dolomite and purple fluorite cubes (figures 8 & 9). Numerous chalcopyrite and skarn fragments exhibit gray corrosive hydrothermal halos (figure 10). A few skarn fragments are rounded without any noticeable corrosive effects. The fragments contain moderate to strong disseminated chalcopyrite $\pm$ pyrite and sphalerite mineralization. Another post mineral observation is quartz sulfide and quartz calcite veinlets terminated along fragment margins. The calcite rich matrix cuts many of the fragments and contains only trace amounts of sulfide (figure 11). In thin section the grayish halos appear to be a chilled margin comprised of fine to medium (½ mm) anhedral calcite grains with minor quartz, grading outwards to coarse grained (2-3 mm) locked calcite rhombohedrens. The halos contain moderate disseminated chalcopyrite contrasted to sparse sulfide occurrences in the

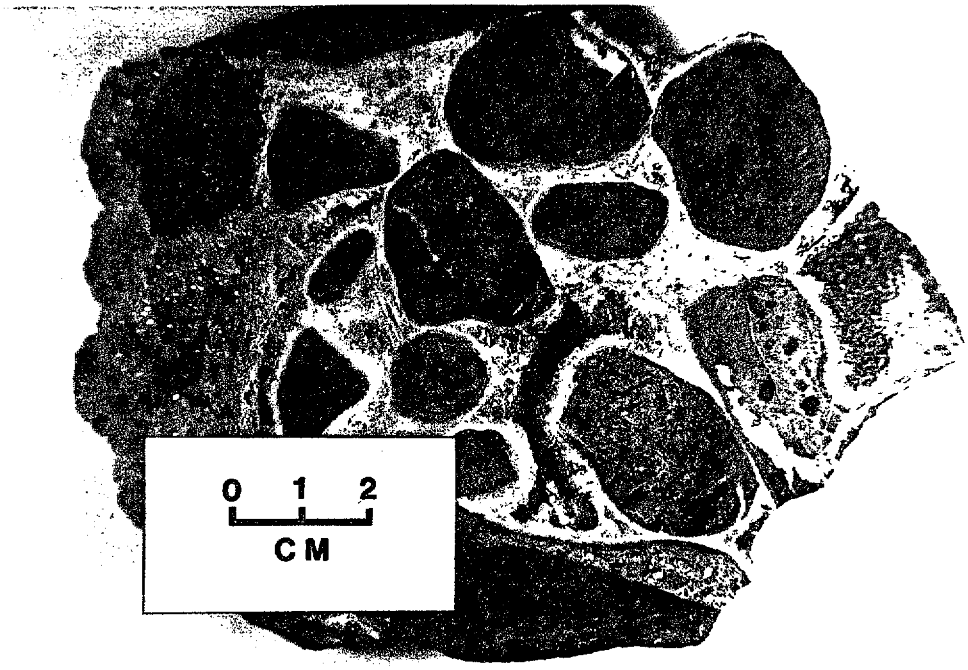


N breccia with various sized fragments of garnet skarn fragments (dark) and chalcopyrite (gray). Lower right hand corner of photograph contains a cavity with flourite cubes.

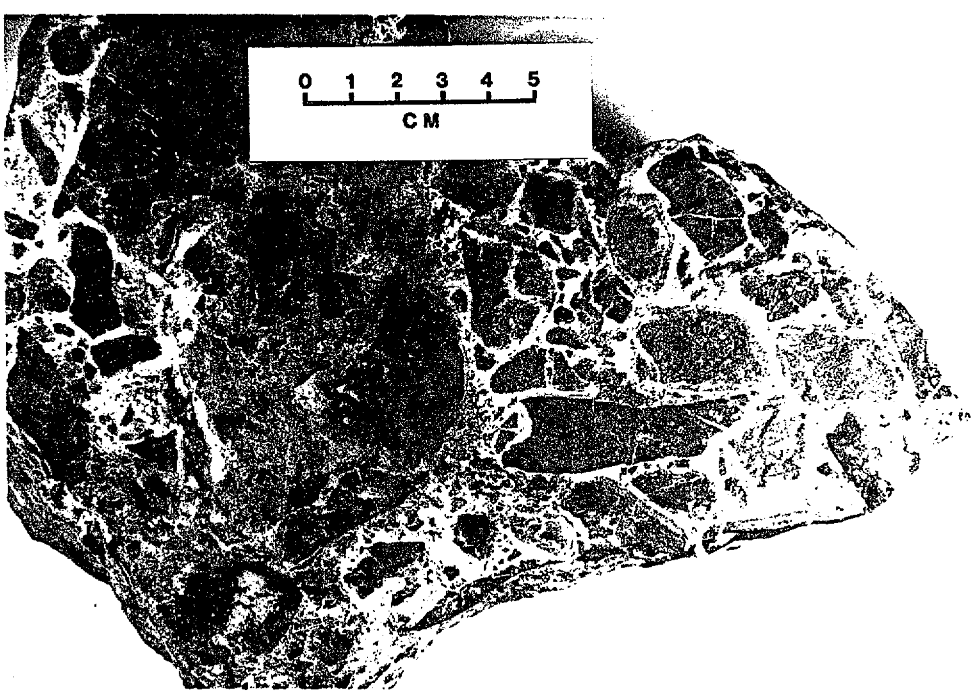


White matrix consists of calcite $\pm$ minor quartz. Note chalcopyrite fragments (gray) in lower right hand corner that has been broken apart and displaced. N breccia.

FIGURE 8



N breccia exhibiting fine grained halos (gray) around various fragments.



N breccia. Note gray halos around chalcopyrite fragments at right portion of photograph.

FIGURE 9

coarse grained matrix. Similar to the Q breccia the garnet fragments here have been altered to a garnet, destructive assemblage of strong hematite carbonate and quartz. In addition to a general matrix grain size zoning there appears to be a faint fragment size zoning developed in a few of the samples. The greatest rounding of larger fragments occurs towards the center of the breccia walls (figure 10). In these same samples, a linear "stream" of aligned oblong shaped fragments occur close to breccia walls, and appear to be aligned with their long axis transverse to the strike of the breccia dike.

Smaller, rounded fragments commonly occur close to the breccia wall and are enclosed in a light gray moderately siliceous matrix (figure 11). The above observations may be the result of fluidization. No shearing structures were observed in slab samples, thin section or in the bench face.

The N breccia grades downward from a dike/fissure occurrence to thin branching microbreccia fissure ¼-½ inches wide, with calcite cemented, skarn fragments.

DISCUSSION

The above observations suggests that the N breccia at the latest period of hydrothermal activity developed by a fluidized mode of

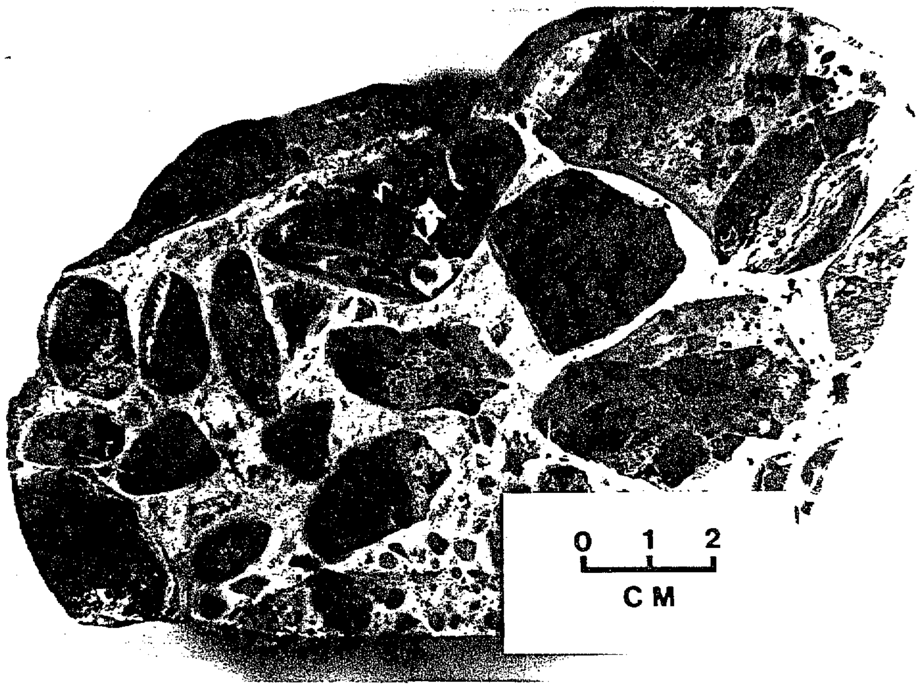
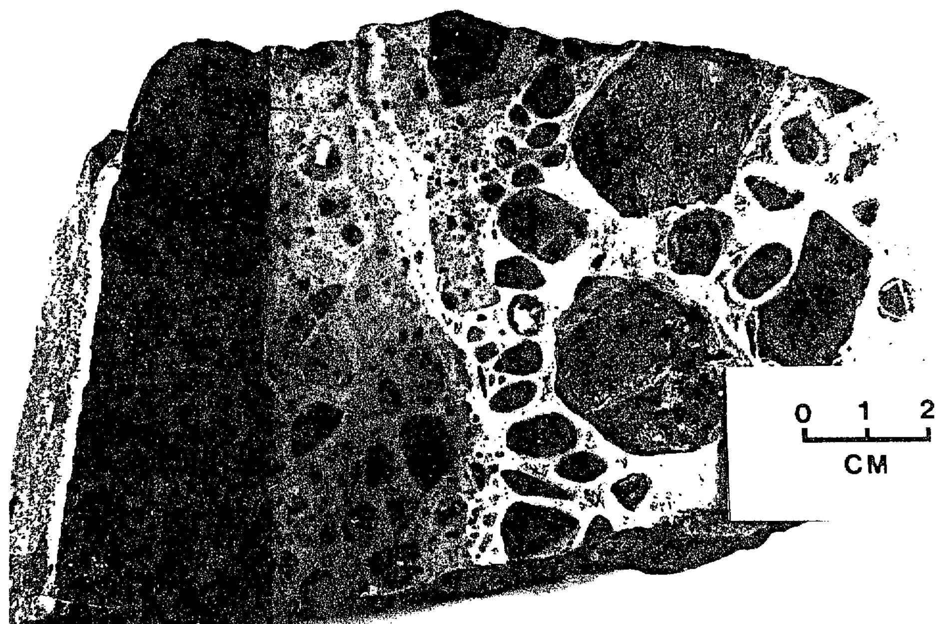


FIGURE 10

Note carbonate and quartz veinlets (white) cutting fragments and commonly terminated at fragment margin.



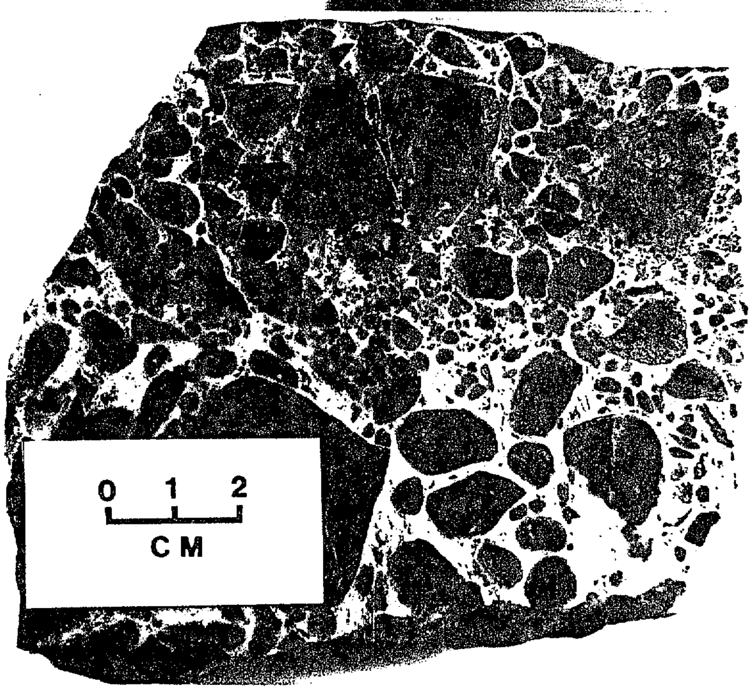


FIGURE 11

Middle photograph shows size zoning of fragments away from breccia wall (left side). Thin black zone along contact of large red (dark) fragment consists of fine grained quartz. Note oblong shaped fragments in middle of photograph. Photograph at left shows strong rounding and rotation (?) of breccia fragments. Dark fragments consist of [illegible] iron and manganese [illegible] carbonate.

transport. One point must be considered in discussing possible mechanisms of formation. The Paleozoic section is completely overturned and restoring the Mission deposit on top of the Twin Buttes system places the attitude of the Paleozoic section to vertical (present attitude of the Paleozoic rocks at Twin Buttes) at the time of mineralization and alteration. This would place the attitude of the N breccia to near horizontal. The breccia would then have been sill or lense like in shape. With the above in mind, the breccia formed or mobilized as a breccia slurry moving through a prefractured and brecciated zone. This style of formation may account for the apparent sorting and abrasion effects such as fragment zoning adjacent to the breccia wall exhibiting smaller sizes, and a narrow micrographic quartz zone separating interfragmental material and wall rock. There is no evidence to suggest this breccia slurry penetrated the rock forcefully. The recrystallized carbonate matrix masks any prior comminution effects.

Solution channels occurring in the marble adjacent to the marble garnet line exhibit strong solution cavities and vugs lined with calcite, dolomite and fluorite. These solution channels are very similar to open spaces in the N breccia and possibly formed at the same space time interval as brecciation. One interesting feature is the lack of occurrence of similar breccias and solution channels at the Twin Buttes deposit (pers. comm. C. F. Barter), the probable roots of the Mission-Pima deposits.

Q BRECCIA DISCUSSION

Similar to N breccia, the Q breccia group contains fragments within breccia fragments, although pervasive hematite flooding obscures the evidence, so that replacement processes could create the illusion of fragments. Overall, the breccia group exhibits a prominence of small to medium (3 mm - 7 mm) sized angular garnet and quartz fragments; an interfragmental ratio of 1.5:1 to 1:1; dense well indurated finely comminuted rock flour texture and close space-time association with pervasive hematitic alteration (with or without fault association). The observations suggests that the Q breccia group also formed by fluidization processes. The Q breccia group similar to the N breccia, was largely developed along prefractured and/or brecciated zones. Possibly some open spaces were formed by earlier solution collapse. The fluidized mode of transport is not envisioned as forcefully creating open spaces but instead mobilizing fragments and interfragmental material developing the rounding, corrosion and comminuted texture during transport and emplacement. The very narrow breccia fissures with a greater percent of carbonate matrix probably achieved much of their fragment aligned texture by corrosion/replacement of fragments by invading solutions presumably at disequilibrium with the wall rocks.

SUMMARY

Preliminary investigations indicate that intrusive-like breccia and tectonic breccias were invaded and superseded by late stage hydrothermal fluids (± vapor phases), creating narrow discontinuous but locally, widespread replacement and fluidized breccias in skarn rocks at the Mission deposit. The hydrothermal solutions responsible for the interfragmental material appear to be related to late gypsum veining and recarbonation events. The time of breccia formation occurred syn to post garnet destructive alteration, and breccias are spacially associated and restricted to these alteration zones. Breccias and solution cavities have not been observed in unaltered green garnet zones.

If one assumes that the Pima-Mission-San Xavier contiguous ore bodies represent the top of the Twin Buttes deposit, then the post-skarn breccias and solution channels are a manifestation of activity uniquely occurring in the upper portion of this porphyry copper system.

ASARCO

Southwestern Mining Department
S.W. Mining Dept.

March 26, 1979

TUCSON

Memo To: T. E. Scartaccini

Subject: MISSION/PIMA JOINT POTENTIAL

Several studies covering a joint operation of the Pima-Mission reserves have been accomplished with the best available information and are summarized below:

CASE I - Mill the current Pima reserves and the "Super Pit" reserves together with the Mission reserves through the Pima mills. The Mission Mill will be used for the Eisenhower and San Xavier ores with some Pima Super Pit ore used to fill capacity after Year 19. Fulfill Eisenhower ore delivery to Anamax.

TOTAL OPERATION 28 YEARS

CASE II - Mill the Mission, San Xavier and any Eisenhower ores through the existing Mission Mill in conjunction with the Eisenhower Agreement (current operating plan).

TOTAL OPERATION 33 YEARS

CASE III - Mission-Pima-San Xavier-Eisenhower reserves are unitized and milled through the Pima and Mission Mills.

TOTAL OPERATION 30 YEARS

CASE IV - Pima projected operation, milling 18,000 tpd of high grade low stripping available ore (= 52 million tons @ 0.66% cu -- included in existing reserves).

TOTAL OPERATION 8 YEARS

CASE V - Pima Mill Super Pit through their Mills - relocating one Mill and some other plant facilities.

TOTAL OPERATION 17 YEARS

Enclosure 1 is a summary of the ore reserves.

Enclosure 2 summarizes the after tax cash flows generated for the various studies.

There appears sufficient incentive to take a more detailed look at these possibilities, but time is of the essence due to the Pima projected operation - mining the high grade ore. The potential of a 700+ million ton reserve from the this area could only be realized by a joint operation.

Mission and Eisenhower can offer better grade ore and the land required for dumps and tailings while Pima has mill capacity and water. Pima would be saved the cost of re-locating one of their mills and other plant facilities while Mission would also benefit by not having to proceed with the San Xavier mill expansion.

The after tax cash flows would be somewhat larger once remaining plant depreciation were utilized thereby also increasing the depletion deduction allowed.

David F. Skidmore
Assistant to Manager

DFS/mc
encls.

Ore Reserves - All Ownerships
January 1, 1979
M Tons

	All Mat'ls	Waste: Gravel	Waste: Rock	Waste: Total Waste	Ore: Sulfide Ore	Ore: Cu %	Waste/Ore Ratio
MISSION							
Asarco	122,190.0	19,120.1	75,357.6	94,477.7	27,712.3	0.78	3.41
Leasehold	177,246.7	11,520.6	95,223.5	106,744.1	70,502.6	.75	1.51
Total	299,436.7	30,640.7	170,581.1	201,221.8	98,214.9	.76	2.05
Eisenhower							
Golden West	71,791.0	4,233.3	36,442.5	40,675.8	31,115.2	.71	1.31
Palo Verde	368,886.5	53,756.9	189,628.5	243,385.4	125,028.5	.61	1.95
Total	440,205.5	57,990.2	226,071.0	284,061.2	156,143.7	.63	1.81
San Xavier South							
Tract 2	355,732.4	64,447.3	196,128.7	260,576.0	95,156.4	.52	2.74
San Xavier North							
Tract 1	117,325.8	7,170.2	56,432.7	73,602.9	43,722.9	.55	1.68
Tract 2	77,370.8	15,869.1	33,801.5	49,670.6	27,700.2	.44	1.79
Total	194,696.6	23,039.3	100,234.2	123,273.5	71,423.1	.51	1.73
Pima							
1) Existing	560,000			420,000	140,000	0.45	
Sub-Total				1,289,133	560,938	0.57	2.30
2) Super Pit	560,000			420,000	140,000	0.45	
Grand Total	2,410,071			1,709,133	700,938	0.55	2.44

Enclosure 1

Enclosure 2

CASE	OPERATING YEARS	ORE USED	CAPITAL REQUIRED (x 1000)	AFTER TAX CASH FLOW (x 1000)
I	28	Pima-Super Mission SX (Mission Portion (of Eisenhower	$36,000	$420,385
II	33	Mission SX (Mission Portion (of Eisenhower	$18,000	$299,201
III	30	Mission Pima-Super SX Eisenhower	$56,000	$600,387
IV	8	Pima (High Grade)	$ 5,000	$143,105
V	17	Pima-Super	$200,000	$ 21,238

PIMA MINING COMPANY

History

The Pima orebody was discovered in 1950; extensive underground development was begun in 1952. In August 1954 the parent company, Union Oil Company of California, granted Cyprus Mines Corporation an option to examine the property, and Utah Construction Company was engaged to study the economic possibilities of mining by open pit.

After sampling and drilling to check the work completed under the original Pima management, Cyprus purchased a three-quarter interest in the property, Union Oil retaining one quarter. Cyprus later sold a one-quarter interest to Utah Construction Company, retaining half interest and management responsibility.

The first ore was reached by stripping October 1956, and the first concentrate was produced in December.

The mine lies about 20 miles southwest of Tucson, Arizona. Some 250 people are now employed, all of whom live in Tucson and commute daily.

The Pit

The Pima pit is a 1700 x 1400-foot oval, the long axis parallel to the strike of the orebody. The north side of the pit is carried as a final pit slope that coincides with the footwall of the orebody. The south side and east and west ends of the pit are working slopes continually being stripped back toward the final slopes.

An inclined roadway extending from the natural ground surface on a 5 percent grade down to the northeast corner provides access to the pit. This road enters the pit 130 feet below the natural surface and continues as a pit ramp on a 5 percent grade to the 3150-foot bench (roughly the base of the alluvial cover). At this point the ramp system is steepened to a 12 percent grade and continues to the pit bottom. The 5 percent grade is maintained in the alluvial section to facilitate scraper haulage out of the pit. In addition to this main access ramp, temporary working ramps in the alluvial areas allow shorter routes to dumps. These are left on top of working benches and do not change the overall working slopes.

Below the base of the alluvium, haulage is by truck down to the skip loading point or up from the bottom to the skip loading point.

The final pit slopes in the alluvium are laid out at 1.2:1 overall with 50-foot bank heights, 0.6:1 bank slopes, and 30-foot benches except at the base of the alluvium, where a 50-foot bench was left as protection against excessive sloughing. Final slopes in the rock are laid out at 1:1 with 40-foot bank heights, 0.375:1 bank slopes, and alternate 10 and 40-foot bench widths.

Working slopes in the alluvium are maintained at 1.35:1 with alternate 25 and 50-foot benches. Bank slopes and heights are the same as final slopes. Working slopes in the rock are usually held at 2:1 overall with 50 to 60-foot benches, 40-foot bank heights, and approximately 0.5:1 bank slopes.

An incline for the skip hoist trackage was left on the center of the north (final) slope. Slotting into the pit slope on the upper benches and allowing a slight protrusion on the lower benches permitted a 38° skipway incline -- somewhat flatter than the overall final slope.

Utah Construction Company, which had been awarded the pre-stripping contract on the basis of low bid, started actual stripping in November 1955. MRS tractor units and Wooldridge 34-cubic yard scrapers were used in conjunction with one Marion 151-M shovel and four LLD Euclid trucks. Utah stripped approximately 6 million cubic yards during its contract (November 1 to October 1, 1956). Pima commenced stripping operations alongside the contractor in April 1956 and by the end of that year had moved about 3 million cubic yards. During stripping, Pima trained a competent group of employees to operate the pit after Utah completed its contract.

Total pre-mine stripping amounted to a little more than 9 million cubic yards. About 1 million cubic yards of this was rock and the remainder alluvium.

At the present time stripping rate is about 3.0 cubic yards of waste per ton of ore. Rate for the remaining life of the mine will be about 2.6 cubic yards of waste per ton of ore.

Production

Daily mine production is set at approximately 4000 tons of ore on the basis of a 6-day week. Ore is mined on one shift and rock stripped on the other two shifts. Alluvium is stripped on all three. Normal payroll for the pit is 114, including supervision. Daily production averages 12,000 cubic yards -- 1700 cubic yards of ore (4000 tons), 4500 cubic yards of waste rock, and 6000 cubic yards of alluvium. Output is therefore approximately 107 cubic yards per manshift.

Between November 1, 1955 and January 1, 1958, 12.8 million cubic yards of alluvium, rock, and ore were moved from the pit. Of this total excavation, 5.9 million cubic yards were moved by a contractor as pre-mine stripping. A total of 1.1 million tons of sulfide ore averaging 1.74 percent copper has been handled by the concentrator. In addition, 659,668 tons of mixed sulfide and oxide ore have been stockpiled.

Geology

Bedrock is overlain by 200 feet of alluvial wash, which has a regular eastward slope, and there are no outcroppings within a 1500-foot radius of the mine. Lying immediately above bedrock is an irregular conglomerate zone (0 to 25 feet thick) of medium to coarse texture, composed of igneous and sedimentary rocks cemented by siliceous and calcareous material.

The Pima orebody is a pyrometasomatic (contact metamorphic) deposit. The main ore zone has an average dip of 45° to the south and trends east-west, curving from a northwesterly bearing on the west to a slightly northeasterly direction on the east. The ore zone is variable in thickness, probably averaging 200 feet, and this zone has been developed over a lateral span of 1600 feet in the main part of the mine. It extends into a neighboring property on the west, but to the east geology and mineralization are obscure. The lower limits of the zone have not been determined, but it has been intersected by drillholes at about 800 feet vertical depth. Paralleling the main ore zone on its footwall side is a persistent breccia zone, which extends to the northeast beyond the present known main orebody.

Determination of age and identification of rock types has been complicated, since most of the rocks are moderately to highly altered or metamorphosed. Many of the less altered rocks are fine-grained; consequently field determinations have often been uncertain, and even petrographic studies have not been definite. The rocks fall into three broad classes: 1) carbonate, 2) clastic, and 3) igneous.

<u>The carbonate rocks</u>, grouped under the term "hornfels", constitute the main high grade ore zone. These rocks are garnet (Grossularite) hornfels, diopside hornfels, and tremolite hornfels. Dolomite and limestone are present in varying amounts. The main ore sulfide is chalcopyrite, with minor amounts of chalcocite, native copper, chrysocolla, tenorite, bornite, and cuprite.

The zone of oxidation extends erratically 40 to 50 feet below top of bedrock. The chalcopyrite forms local and highly irregular concentrations, and shows a tendency to favor one type of hornfels more than another.

The clastic rocks, occurring in both hanging and footwalls of the carbonate formation, are extremely fine-grained with a quartzitic appearance. They are composed of quartz, feldspar, and sericite, and texture is definitely clastic. In some places it is almost sedimentary; in other it has an igneous appearance. On the basis of petrographic work and visual examination of drill core, those at Pima believe that some of the clastic rocks formerly called "arkosite" may be better classified as pyroclastics. Even though they cannot be decisively proven petrographically, these pyroclastics may contain local accumulations of sediments, clastic and otherwise. In the hanging wall clastic rocks, pyrite is widely disseminated and there are zones of low grade disseminated chalcopyrite mineralizations, which makes an open pit operation feasible.

The igneous rocks found at the mine are of intrusive nature and consist of rhyolite, syenite, and quartz monzonite porphyry. The rhyolites and syenites are unmineralized and occur in and above the hanging wall of the carbonate series. The bulk of the quartz monzonite porphyry is found in the footwall clastics and is slightly mineralized by pyrite and chalcopyrite.

Engineering

The engineering department works in close cooperation with the production departments and is responsible for operating layouts, estimates, pit schedules, and uniformity of mill feed. Present personnel consists of a chief mining engineer, pit engineer, ore control engineer, and draftsman and a field survey crew of three -- an instrument man and two rodmen.

Mine operating layouts are prepared on the basis of a series of pit expansions. Each expansion is scheduled for completion of alluvium and waste rock stripping before the ore is exhausted in the previous expansion. Layouts are made on current pit maps on a scale of 1 inch to 50 feet. Volume estimates of ore and stripping are made on horizontal level maps on which the ore blocks are outlined. Cross sections on a scale of 1 inch to 50 feet are used in planning the layouts, although currently these are not used for estimating. Owing to the size and shape of the present pit, a more accurate estimate can be obtained from horizontal level maps.

Volume estimates of material removed from the pit are made quarterly on specially prepared section. To keep the pit map and ore control maps up to date the pit is surveyed each month, with a more accurate survey when a volume estimate is made.

For ore control, each blasthole drilled is sampled and assayed. From the established grade cutoffs, the material in each pit blast is classified and where necessary is segregated. Where two or more types of material are encountered in one blast, the cutoffs are flagged in the bank for the operators' guidance. From the assays of the ore material, a blend is established between various working faces for a constant grade of mill feed. Close cooperation is maintained between the ore control engineer and the mine operating staff.

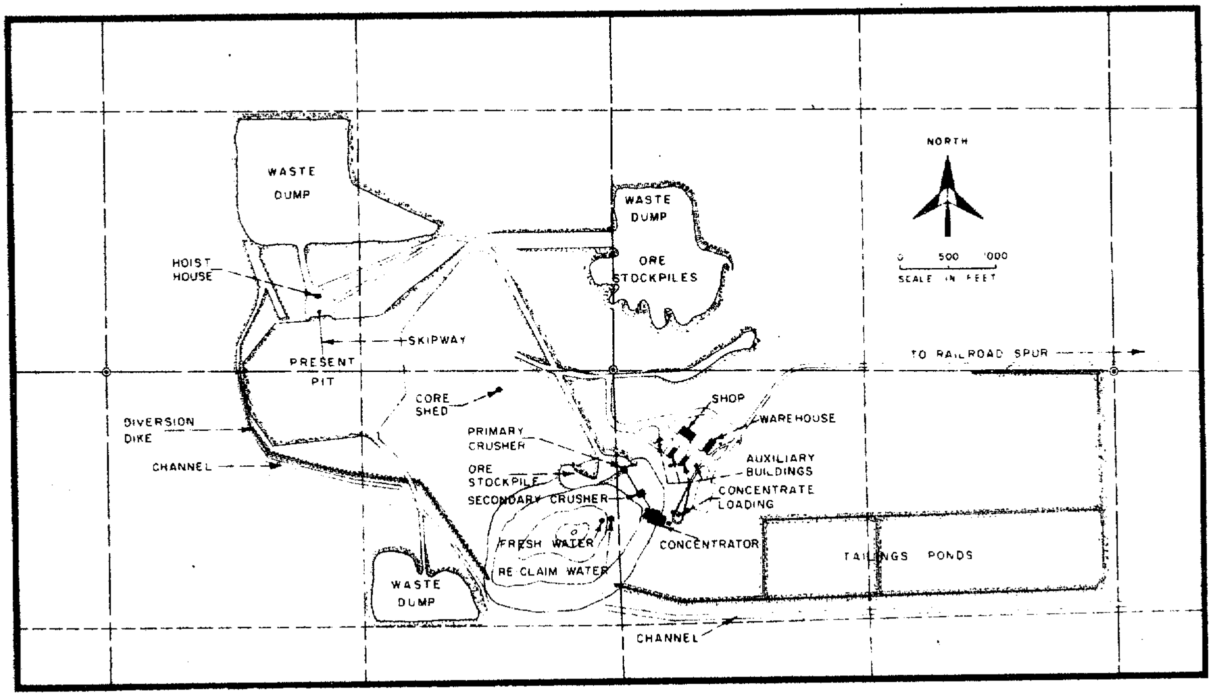
A certain amount of mechanical drafting, construction design, and detailing is done by this department for all other departments in connection with repair and alterations of facilities and small construction work. Cost estimates are also prepared and specifications set up.

The engineering department makes claim surveys, conducts time studies on equipment, maintains records on material stockpiled from the pit, provides line and grade control for pit operations, and does sampling. Because the orebody now being worked is split between a state mineral lease and federal patented claims, careful estimates are made of ore volumes of the other material removed from each section of the property, and records are kept up regularly on these volumes.

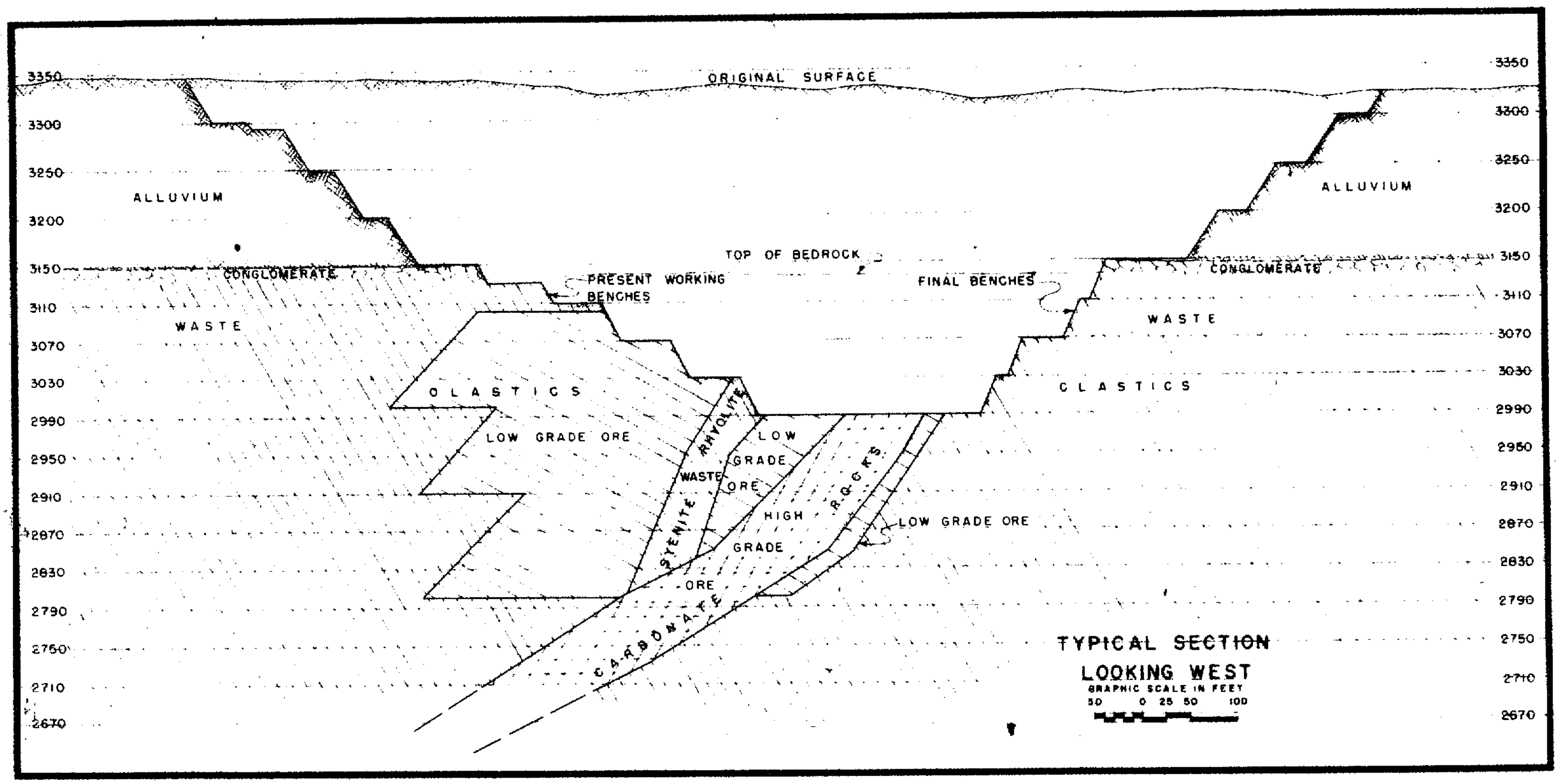
PIMA MINING COMPANY

PIMA MINE

TUCSON, ARIZONA



GENERAL AREA MAP



TYPICAL SECTION
LOOKING WEST
GRAPHIC SCALE IN FEET
50 0 25 50 100

PIMA MINING COMPANY CONCENTRATOR

TUCSON, ARIZONA

by

George A. Komadina, Mill Superintendent

The open pit mine and concentrator of the Pima Mining Company is located approximately twenty miles south of Tucson, Arizona in the Mineral Hill area. The Pima ore body was discovered in 1950 and after an extensive underground development program it was decided that the deposit could be more profitably worked as an open pit mine. The concentrator was completed late in 1956, regularly scheduled operation was started on January 1, 1957. Through October, 1958 the concentrator has treated 2,010,548 dry tons of ore.

CRUSHING: Run-of-mine ore is fed by truck from the pit or dozer from a stockpile to the primary crusher chute. A Ross chain feeder draws ore over a 7-in. grizzly to feed a 66 x 84-in. Birdsboro jaw crusher set to produce -7-in. material. The crushed ore is transported to the secondary crushing and screening building by a 54-in. conveyor. The ore is screened over two double-deck Tyler F-900 Tyrock screens dressed with 1½ x 18-in. rod grizzlies on the top deck and 3/4 x 2-in. slotted woven wire on the lower deck. Oversize from the top decks passes to a 7-ft. standard Symons crusher and oversize from lower decks to a 7-ft. shorthead Symons crusher. The screens and crushers are so located that cross conveyors are not necessary -- the screens feed their respective products by gravity into the crushers or onto the fine ore conveyor.

A Link-Belt automatic tripper distributes the -3/4-in. ore to two fine ore bins. These bins were designed to hold 6000 live tons, but experience has proved that the unexpectedly high angle of repose (up to 70°) reduces capacity to 4000 live tons. This relatively small bin capacity for the plant, which grinds up to 3600 tons per 24 hr. has required operation of the crushing and screening plant seven days a week rather than the expected six days. It is planned to increase bin capacity enough to permit operating the mill seven days a week with the crushing and screening plant running six days.

GRINDING: Ore is removed from each bin by means of a pair of tapered slots onto gathering feeder belts. Mill feed at rates up to 3600 tpd is drawn from any combination of two of the four belt feeders. The feeders, integrated with a weightometer provide uniform flow rates, discharge onto a conveyor that flows into the spout feeder of a 10 x 13 ft. Allis-Chalmers rod mill operating in open circuit. The rod mill discharge is split between two primary cyclone feed sumps. One side utilizes a 10-in. type T Amsco dredge pump, while the parallel unit is a type CT Barrett-Haentjens solids handling pump. Each unit delivers rod mill discharge at 50-57 percent solids to two 20-in. model D-20-B Krebs cyclones operated with a feed inlet pressure of 8-10 lb. At the present time 6-3/4-in. vortex finders and 3-1/2-in. ceramic apex pieces are used.

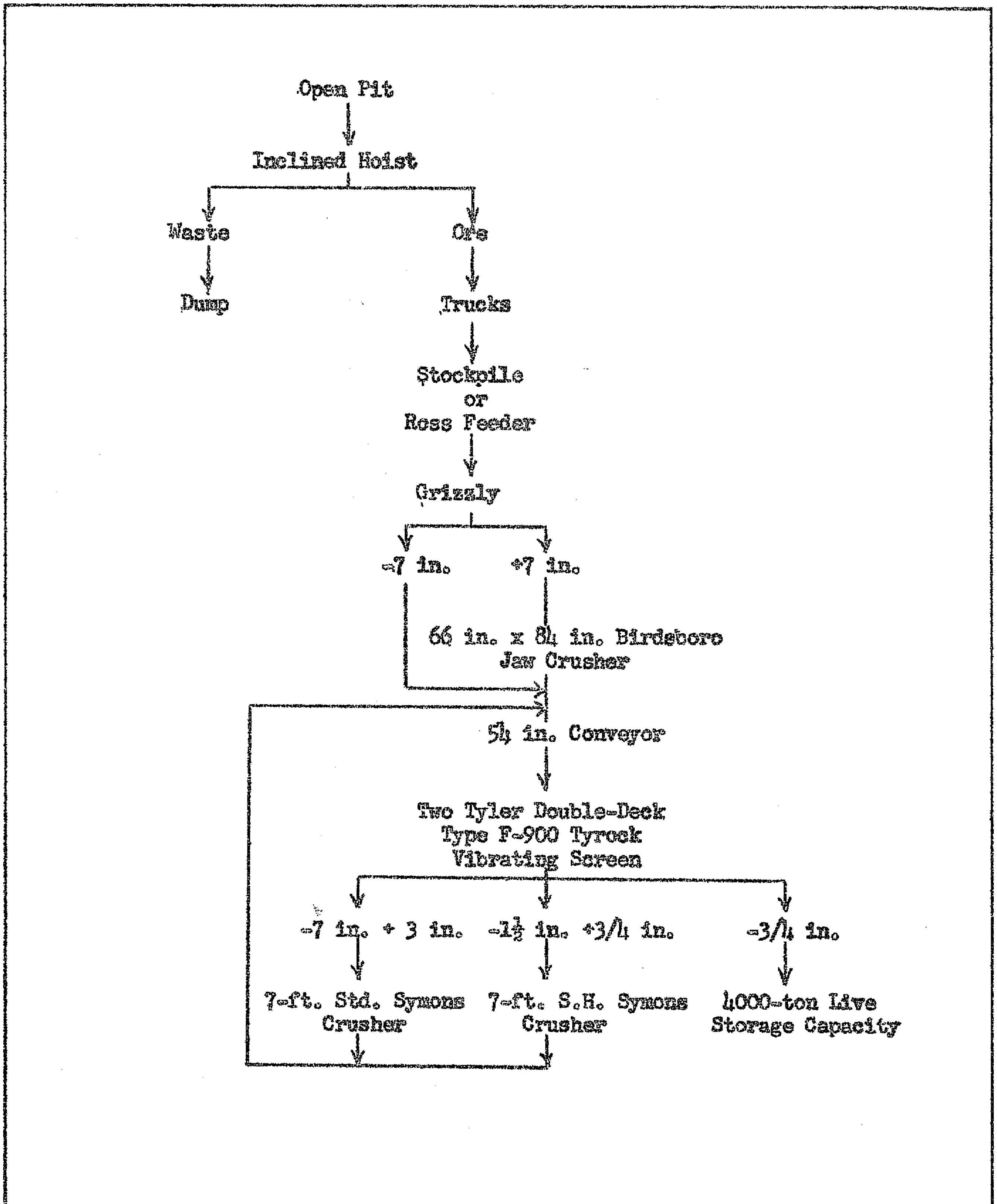
CYCLONE SEPARATION: The cyclones are able to take a fairly wide range of feed rates and still maintain overflows of 27 to 31 percent solids. The underflow, at 80 to 85 percent solids, is delivered by a spout to a 10-1/2 x 13-ft. Allis-Chalmers overflow ball mill. The ball mill discharge, at 76 to 82 percent solids, returns to the cyclone feed sumps. A portion of the cyclone overflow is bled off to maintain constant levels in the sump boxes. The remainder is reduced to 27 to 28 percent solids prior to flotation.

The regrind circuit consists of a 7 x 12-ft. Allis-Chalmers overflow ball mill operating in closed circuit with six 10-in. model D-10-B Krebs cyclones. The cyclone overflow is used as dilution water in the primary grinding circuit. The use of the regrind circuit has been deferred until a change in character of ore requires finer grinding of either the middling fraction or the rougher concentrates. During the first 10 months of 1958, 88 percent by weight of the middling product was -200 mesh and contained 89 percent of the total copper in this product.

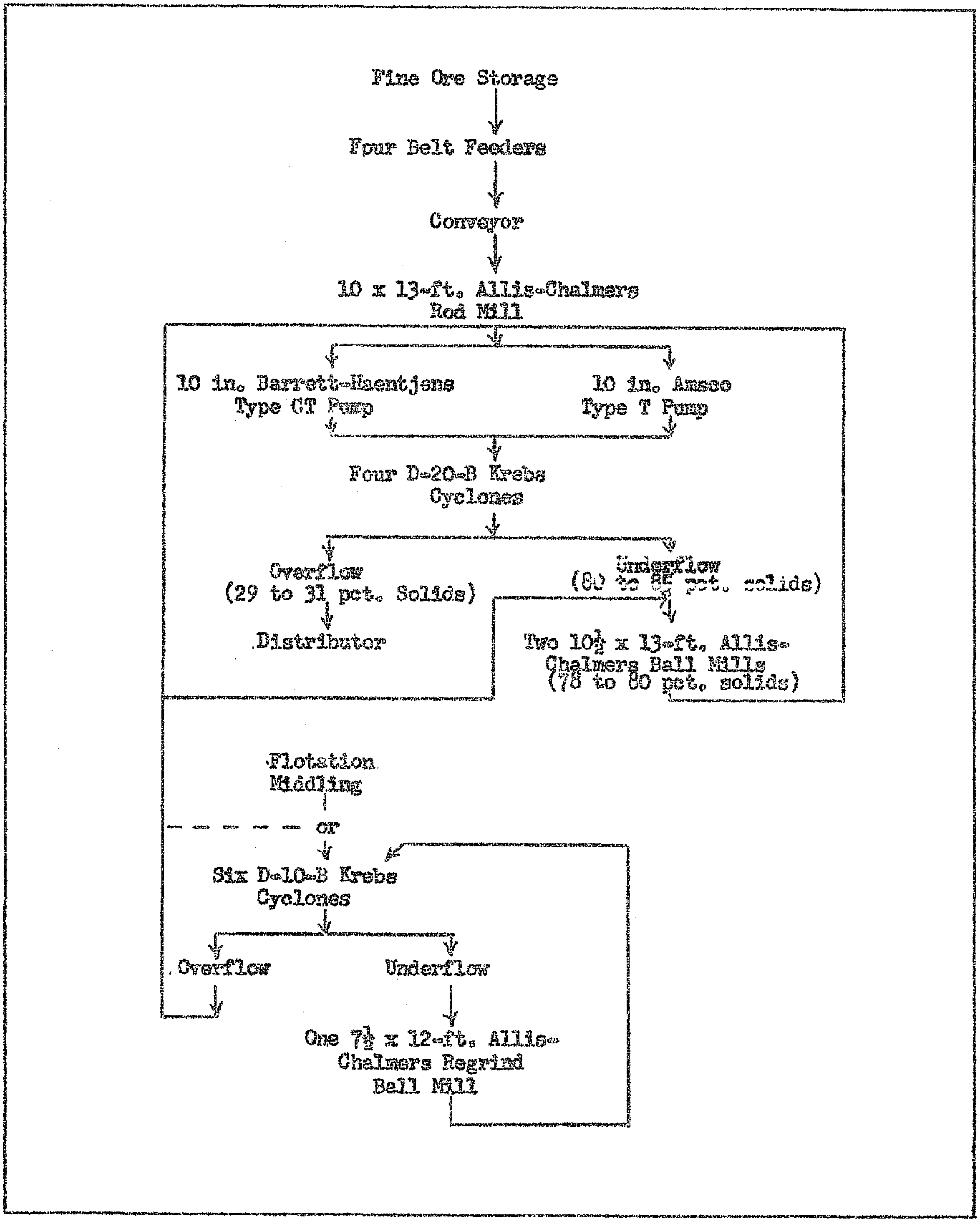
The rod mill, operating at 15.55 rpm, was charged with 3-1/2-in. and 4-in. rods at a rate of 0.572 lb. per ton for the first ten months of 1958, the October rate was 0.712. It now appears that 4-in. rods will be the standard makeup. Single wave chrome-moly steel liners are used. The initial set of shell liners treated 1,719,002 dry tons of ore.

One of the ball mills is now operating at 16.85 rpm or 70% of critical while the other one is scheduled to go to 18.6 rpm or 77.5% of critical at an early date. Considerable increase in ore hardness has necessitated the speedup of the mills. Ball consumption for the first ten months of this year was 1.079 lb. per ton, in October the rate was 1.215. Starting late in October ball rationing was resumed using one-third

CRUSHING FLOWSHEET



GRINDING FLOWSHEET



three inch, balance two inch. Double wave chrome-moly steel liners are used in the ball mills. All of the original liners are still in the ball mills, in the very near future the feed end liners will have to be replaced.

As yet there is no information to show the effect of feed rates, pressures, and other variables on classification performance of the cyclones.

THE FLOTATION SECTION: The flotation feed passes through a distributor that divides the pulp to six parallel banks of 66-in. single overflow Fagergren flotation machines. The rougher concentrate from the first four cells goes to the 10-cell No. 24 Denver cleaner and recleaner machine. The cleaner tailings are combined with the scavenger concentrate produced on the last six cells of the rougher bank. At present this middling pulp is being pumped to the head of the primary grinding circuit for use as dilution water. The alternate flow is to send the middlings to the regrind circuit.

Recleaner concentrate flows to a 50-ft. Dorr thickener, the underflow is moved by centrifugal pump to a 6-ft. diameter 7-disc Eimco filter, and overflow is returned to the middling sump for use as dilution water in the grinding circuit. Experience has shown that the pump can be directly connected to the underflow discharge spigot. Currently the thickener is also used for storage to permit filtering for 2 hours and then an idle storage period for 10 hours. This cycle is repeated twice every 24 hours. The filtered concentrate (containing 10 to 11 percent water) is conveyed to storage and then scraped by a Joy slusher into 25-

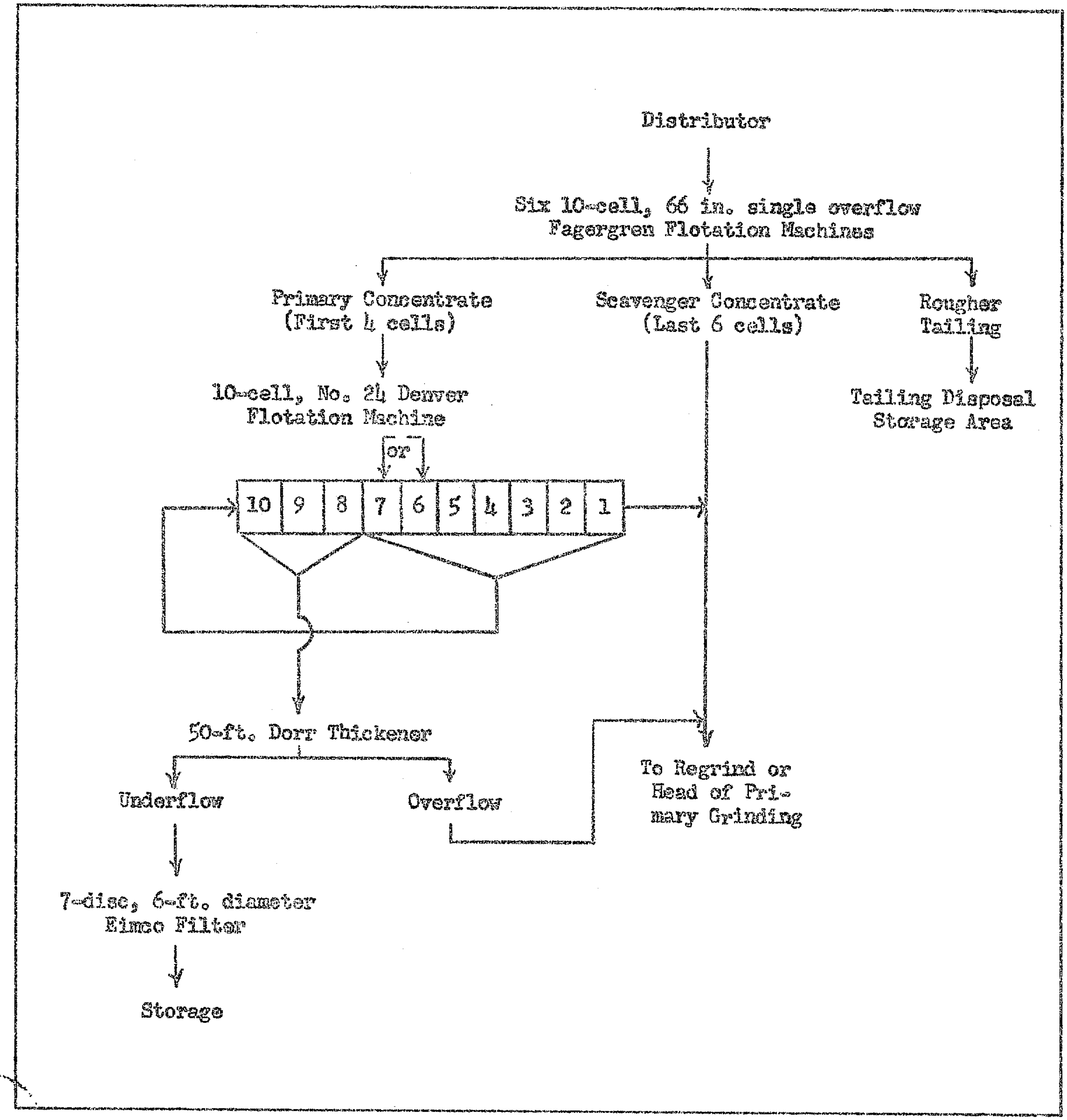
ton Kenworth dump trucks. The concentrate is weighed and sampled for moisture at the mill and then hauled seven miles to the railroad. After the car is loaded and leveled, it is pipe-sampled in a grid pattern for copper analysis. Concentrate is shipped to the copper smelter at Hayden.

Tailing from the concentrator flows by gravity unthickened to slime disposal ponds 5000 ft. from the mill. This pulp is cycloned to remove the sand fraction for berm building while the slimes flow to the central portion of the storage pond. Reclaimed water passes through six inch drain holes in a decant line placed at each six inch rise in elevation. At a later date a decant tower will be constructed at the end of the present decant line. Water passes through the decant line to a gathering sump from which it is pumped to a 250,000 gallon water storage tank above the mill. The mill water is treated with phosphate to minimize lime scaling in the various mill water lines.

Fresh water is pumped six miles from wells along the Santa Cruz river to a 50,000 gallon storage tank. This is the potable water supply as well as make-up for the mill. The mill requires 240 gallons of make-up water per ton of ore treated.

REAGENTS: Mill reagents are mixed on day shift and pumped to day storage tanks. Pebble lime is purchased and slaked in a Dorr lime slaker. The lime slurry is pumped throughout the mill and is withdrawn as needed. Nearly all the lime being added is used in the grinding circuit. A pH of 11.3 to 11.5 has been found optimum for current ores when using the following reagent combination which was standard for the first six months of this year. Lime, Z-6 and/or Z-11 xanthate and methyl isobutyl carbinol

FLOTATION FLOWSHEET



(MIBC) are added to the rod mill. Z-6, Z-11 and MIBC are added to the distributor, the second, fourth, sixth and eighth cells. Sodium sulfide, when needed, is added to the fourth, sixth and eighth cells.

After laboratory investigation showed promise a mill test employing Z-200 as one of the reagents was tried during July and a portion of August. The results were encouraging so during September a repeat test was scheduled. More operating details were clarified so that an optimum condition could be determined. During October the plant used this anticipated optimum condition and came up with results that compared with the better to date. The change from the standard previously described was that Z-200 was substituted for the Z-11 in all points of addition, Z-6 was reduced in quantity, a pH of 10.2 maintained on the grinding circuit. Dowfroth 250 or MIBC was found to be approximately equal in the laboratory -- mill testing of this condition is currently being carried on.

The average reagent consumption in pounds per ton of ore milled for the various periods follows.

	First Six Months, 1958	October, 1958
Lime	6.849	3.104
Z-6, Xanthate	0.086	0.039
Z-11, Xanthate	0.043	----
MIBC	0.094	0.012
Dowfroth 250	----	0.045
Sodium cyanide	0.019	0.004
Sodium sulfide	0.429	0.032
Phosphate	0.014	0.010
Z-200	----	0.040

The concentrator is laid out to utilize the natural slope for gravity flows through the plant. The entire plant is designed to use minimum labor. The crushing crew, working on single shift under a foreman, consists of one primary and one secondary operator and one or two laborers who clean up spills and remove wood and steel from the ore. Steel is removed by hand -- a tramp steel detector will not work because of the magnetite content of the ore.

The plant operates on a seven-day basis, relief operators are employed to maintain a five-day work week for all hourly employees. The concentrator is handled by a shift foreman, a grinding operator, flotation operator and a tailing laborer. On day shift a concentrate loader and a reagent man are also available. Maintenance of the mill and crusher is handled by nine repairmen, one oiler, and three laborers under the direction of the repair foreman. The total mill manpower of 50 includes supervision, operation, maintenance, metallurgy, sampling, assaying and clerical employees.

Electrical power purchased from the Tucson Gas, Electric Light & Power Company is delivered to the Pima substation at 44,000 v. Power is stepped down to 4160 v for distribution to the mine and mill. Power consumption for the first 10 months per tone is as follows:

Crushing	1.087
Concentrator	16.312
Fresh water	2.288
Reclaim water	0.593
Total mill	20.280 KWH per ton milled

APPENDIX

ROD MILL SCREEN ANALYSIS, JANUARY-OCTOBER, 1958

FEED

Size	Percent Retained	Cum. Pct. Retained
+ 1 inch	0.04	
-1 +½ inch	19.10	19.14
-½ in. +4 mesh	37.76	56.90
-4 mesh	43.10	100.00
Total	100.00	

DISCHARGE

Size	Retained	Retained
+ 8	3.02	
+ 10	3.97	6.99
+ 28	26.22	33.21
+ 48	15.09	48.30
+ 65	5.23	53.53
+ 100	6.03	59.56
+ 150	5.18	64.74
+ 200	4.10	68.84
+ 325	7.15	75.99
- 325	24.01	100.00
Total	100.00	

FLOTATION CONCENTRATE ASSAYED SCREEN ANALYSIS
JANUARY THROUGH SEPTEMBER, 1958

Size	Percent Retained	Cum. Pct. Retained	Assay Pct. Total Cu	Distribution Percent	Distribution Cum. Pct.
+ 100	0.82		16.77	0.60	
+ 150	3.54	4.36	20.09	2.74	3.34
+ 200	7.70	12.06	23.56	6.91	10.25
+ 270	13.82	25.88	25.34	13.21	23.46
+ 325	8.73	34.61	25.65	8.46	31.92
- 325	65.39	100.00	27.57	68.08	100.00
Total	100.00		26.56	100.00	

APPENDIX

FLOTATION TAILING ASSAYED SCREEN ANALYSIS
JANUARY THROUGH SEPTEMBER, 1958

Size	Percent Retained	Cum. Pct. Retained	Assay Pct. Total Cu	Distribution Percent	Distribution Cum. Pct.
+ 65	1.91		0.49	3.36	
+ 100	6.74	8.65	0.34	8.63	11.99
+ 150	10.23	18.88	0.28	12.26	24.25
+ 200	9.72	28.60	0.24	9.91	34.16
+ 270	11.38	39.98	0.21	10.16	44.32
+ 325	6.39	46.37	0.19	5.24	49.56
- 325	53.63	100.00	0.22	50.44	100.00
Total	100.00		0.236*	100.00	

* Of this 0.089 percent is oxide and 0.147 percent is non-oxide copper.

SUMMARY OF OPERATING DATA
JANUARY THROUGH OCTOBER, 1958

Flotation feed pH	11.3
Rod consumption	0.572 lb. per ton
Ball consumption	1.079 lb. per ton
Crusher operated (single shift basis)	86.17 percent
Mill operated (3 shift, 7-day basis)	96.23 percent
Ore, Specific Gravity	2.937

PERCENT SOLIDS IN MILL PULPS

Rod mill discharge		70.57	
Cyclone feed	No. 1 - 54.05		No. 2 - 54.85
Cyclone Underflow	No. 1 - 82.94		No. 2 - 81.61
Cyclone overflow	No. 1 - 29.13		No. 2 - 30.10
Ball mill discharge	No. 1 - 79.78		No. 2 - 79.10
Rougher flotation feed		27.01	
Cleaner flotation feed		17.30	
Recleaner flotation feed		16.00	
Concentrate Thickener Underflow		53.80	