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GEOLOGICAL INTERPRETATION OF THE PALO VERDE MINE
BASED UPON DIAMOND DRILL CORE

By

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INTRODUCTION

The Palo Verde Mine, owned and operated by the Banner Mining Company, Tucson, Arizona, is located in the Pima Mining District, Pima County, Arizona, approximately 20 miles south of Tucson along the Twin Buttes road. The mine is bounded on the north by the San Xavier Papago Indian Reservation and on the west by Banner's Mineral Hill-Daisy area. The general locale of this mining area is on the gentle sloping alluvium covered pediments on the northeast flank of the Sierrita Mountains. The alluvial covering averages 200 feet in the vicinity of the shaft with the closest bedrock outcropping approximately 4200 feet to the southwest. The elevation above sea level at the Palo Verde Shaft collar is 3242 feet. This mine is relatively new with only a meager amount of underground workings to use for geological study. This paper was written almost entirely on the strength of the geologic interpretation based upon diamond drill holes spaced 250 feet apart in an equilateral triangular grid system.

During September, 1959, a five compartment steel and concrete shaft was started. Prior to the shaft sinking a churn drill hole was drilled 35 feet to the south of the shaft and no water was hit until the hole reached below the 1100 foot level. Shaft sinking progressed fairly rapidly in relatively dry ground until a large flow of water was tapped at the 960 foot level. Stations have been cut at the 700, 800 and 900 foot levels with plans for future expansion below these.

Plans for a thousand ton-per-day production have been made and work is now in progress underground on all levels according to schedule. Diamond drilling is still in progress as the outer limits of the Palo Verde ore body have not yet been delineated in all directions. Approximately 40,000 feet of diamond drilling plus several thousand feet of churn drilling have constituted the exploration and development program in this area.

ROCKS

The basement complex in this area is presumably the Precambrian? "Sierrita" granite which is an unmineralized and slightly chloritized light greenish gray, medium to coarse grained granite. It is exposed on the surface 1½ miles to the west of the Palo Verde shaft and in the bottom of several diamond drill holes in the vicinity of the shaft. The surface of the granite dips uniformly at a low angle to the north and east in the area.

In addition to the Sierrita granite we have other intrusives such as quartz monzonite porphyry and andesite dikes. The intruded host rocks are limestones and quartzites of Paleozoic age and arkose, graywacke and argillite of Cretaceous age.

The quartz monzonite porphyry consists of quartz, feldspar and biotite mica, mineralized with ranging amounts of pyrite, chalcopyrite and molybdenite. The size of the feldspar phenocrysts range from microscopic to ¼ inch, with an occasional pink phenocryst up to 3/4 inch in length. The feldspar phenocrysts comprise approximately 60% of the porphyry. The biotite mica flakes are small and sparsely disseminated through the porphyry. Gypsum is prevalent throughout as small veinlets and coatings on the exposed surfaces in the fractures. The porphyry has been extensively crisscrossed with small 1/16 to ½" veinlets of late quartz containing pyrite and molybdenite as a rule. The porphyry forms a massive sill-like body somewhat anticlinal in nature with its axis dipping to the west at a low angle. This sill is very extensive in areal coverage with the outer limits extending beyond the scope of this paper. A major portion of the top of the porphyry sill and related ore bodies have been removed by erosion. Numerous small fingerlike apophyses protrude from the mass into the sedimentary host rocks.

The andesite is in the form of relatively thin dikes intruding the limestone and arkose east of the shaft but have not as yet been found in the quartz monzonite porphyry. The dikes are no doubt post mineralization in age but their respective age with the thrusting is unknown as yet.

The sedimentary rocks have been recrystallized and hydrothermally altered so that the original character is fairly uncertain. It appears that only the Paleozoic and Cretaceous (?) rocks are represented in the immediate area of the Palo Verde Mine.

The Paleozoic rocks are limestones, quartzite, marl, gypsum and hornfels. The limestone is grey to blue, fine-grained, impure and recrystallized in part. Associated with the limestone are lenses of relatively pure quartzite suggestive of the Permian Scherrer formation. The topmost portion of the limestone has been largely altered to tactite, whereas the lower portion has been recrystallized to marble. Underlying the limestones and quartzite are faulted slivers of the Pennsylvanian hornfels and the Permian marl and gypsum beds. Gypsum from these lower beds has been dissolved and carried both laterally and upward into overlying formations. The reason for stating that the gypsum came almost entirely from the underlying gypsiferous sedimentary beds rather than from the oxidation of pyrite are as follows: (1) an abundant supply of gypsum is present below, (2) the water has a hydrostatic head (3) the gypsum is prevalent in all rocks below a certain undulating horizon and almost entirely absent above. It is assumed that the large amounts of extremely hard water tapped in the Palo

Verde shaft and drill holes followed extensive water courses in the gypsiferous beds and limestones.

Resting unconformably on the Paleozoic formations are units of presumably Cretaceous arkose, greywacke and argillite with thin lenses of tactite and conglomerate interbedded. All these units have been acceptable to mineralization with the exception of the dense compact siltstone.

STRUCTURE

The true structural conditions prevailing at the Palo Verde Mine area are not entirely decipherable from the limited amount of information revealed by drill holes. Certain indisputable structural relationships, however do exist and from these a reasonable geologic picture can be pieced together.

A low angle thrust fault separates the Precambrian (?) Sierrita granite from the overlying porphyry and sedimentary formations. Typical of most thrusts, a gouge and brecciated zone up to 16 feet in thickness has been found whenever drilling penetrated the fault. The gouge is usually gray to green gray, containing small subangular to rounded fragments with no discernible mineralization. The overlying competent rocks are intensely fractured up to 50 feet above the fault surface.

There are reasons to believe that this major thrust fault is the same one that Cooper (1) has named the "San Xavier" thrust, and which he predicts has lateral movement up to 6½ miles. If Cooper's hypothesis is correct, then the roots of the Palo Verde and adjoining ore bodies are in the Twin Buttes Area. There are corresponding similarities which leads the writer of this paper to agree with Cooper. Thrusting and normal faulting definitely occurred at two and possibly more intervals of time. The premineral faulting was probably relatively steep dipping and it was here in these zones of weakness that the mineralization took place.

Post-mineral faulting is evidenced underground by ore bodies being cut off and displaced by both thrusts and northeasterly shears. The faulting above the San Xavier thrust was complimentary to it and of relatively small magnitude. In the east Palo Verde area these steep dipping shears served also as channelways for the late andesite dikes to follow. Minor bedding plane slips, small thrust faults and local rolls along the bedding are indicative of previous compressional stresses in the area. The abundant steep dipping quartz and sulfide veinlets in the quartz monzonite porphyry also indicate pre-mineral fracturing. Drill core information prohibits the interpretation of any definite fracture pattern in the area, but future underground developments will do doubt disclose one or more patterns.

ALTERATION

Alteration of the rock types in the Palo Verde Area has been very intense with very little remaining that did not undergo the hydrothermal processes of recrystallization and metasomatism. Alteration is more pronounced in the vicinity of the intrusive porphyry sill but extends well beyond the boundaries of the Palo Verde area. The zones of alteration in respect to their spatial relationship to the porphyry are (1) Kaolinization, (2) Silicification, pyritization, and (3) Recrystallization of the limestones.

In the quartz monzonite porphyry hydrothermal alteration has kaolinized over 75% of the feldspars and biotite mica. Quartz and small quantities of sericite also resulted from this alteration. The crystal structure of the quartz phenocrysts has been mostly obliterated by resorbtion of the silica. The twinning planes and crystal faces of the feldspars are also obscured by the alteration processes. Sericite and chlorite are present in the porphyry in small scattered amounts of a minor importance. In the sedimentary rocks particularly the graywacke and arkose adjacent to the porphyry secondary feldsparshave been formed. Epidotization of the arkoses and graywacke has taken place over a wide spread area and whenever encountered in quantities the pyrite content increases.

In the tactite-garnet zone at the Palo Verde the alteration products are garnet, clay garnet, hematite, chlorite, and pyroxenes such as diopside and wollastonite. The clay-garnet is undoubtedly the product of some brecciation and hydrothermal alteration of the garnet and epidote rocks. It consists of small rounded and sub-angular fragments of garnet and epidote in an argillaceous matrix with chalcopyrite and bornite appearing as small blebs throughout. The unaltered garnet rock is reddish brown to dark green in color, dense and extremely hard. The chalcopyrite and bornite favor this rock particularly in the lower limits where it approaches the calcium silicate zone where the predominant silicate minerals are diopside, wollastonite and tremolite.

In the calc-silicate zone dark brown to black sphalerite predominates with bornite and chalcopyrite intermixed to some extent. Wherever chalcopyrite is found with the sphalerite it is usually as small blebs speckled throughout. The sphalerite usually serves as a line of demarcation between ore and waste. Small amounts of it are found in the marbleized limestone isolated from the ore bodies by waste. The limestone grades from the calc-silicate zone into barren marble and bleached limestone then into grey-white unaltered limestone where few unrecognizable fossils are present. Graphite is rare but does occur in the limestone in association with a fault zone.

Minor bleaching and alteration of the host rocks is found where the late andesite dikes have intruded. These andesite dikes are unmineralized definitely being post mineralization, but whether they are pre or post thrusting is problematical and do not serve in any useful geologic manner.

ORE DEPOSITS

The known ore deposits in the Palo Verde Mine area are classified as pyrometasomatic in type, occurring in the limestones and contact silicate zones are replacements and in the porphyry, arkose and related clastic rocks as disseminations. The mineralizing solutions appear to have entered the rocks from the south and west in proximity to the porphyry. This assumption is based primarily on the zonal arrangement of the mineral assemblage. The higher grade ore bodies formed in the tactite, below the quartzite, in gentle rolls plunging downward to the north and northwest on dips ranging from 24 degrees to 42 degrees.

At the Palo Verde Mine we have two types of ore bodies, the first and most extensive being the lower grade disseminated type, and the second type of ore body is of considerable higher grade being located in the tactite zone. Although directly related to the mineralization, the quartz monzonite porphyry contains no appreciable amounts of copper sulphides. The bulk of the sulfide mineralization in the porphyry is iron pyrite, with chalcopyrite averaging less than ore grade. Molybdenite mineralization is confined almost entirely to the porphyry and quartzite suggesting favorability for the more acid rocks.

A definite relationship exists between the intrusives and the ore bodies in the intruded host rocks. Varying with distance from the quartz monzonite contact the degree of metamorphism and intensity of mineralization decreases. Paragenetically the minerals appear to be related in the following manner.

Silicate minerals developed early in the alteration process with sulfide minerals being deposited last and replacing silicate minerals in part. Apparently some recrystallization of the silicate minerals has taken place during the time of sulfide deposition.

Two or more stages of mineralization are associated with the porphyry intrusion and are pre "San Xavier" thrusting in age. The first stage introduced the bulk of the ore minerals whereas the second or later stages formed the small veinlets of quartz, pyrite and molybdenite.

Mineralization has been intense in the more favorable tactite zone where the higher grade of ore is associated with the iron rich reddish-brown garnet rock. The paragenetic sequence and spatial relationship outward from the intrusive quartz monzonite porphyry consists of pyrite, molybdenite, chalcopyrite, bornite , argentiferous tetrahedrite and sphalerite. Magnetite is conspicuous by its absence in this immediate area, but is abundant however on the south flank of the quartz monzonite porphyry sill in the Daisy Mine. A small (6 inch) vein of argentiferous tetrahedrite and quartz cutting the porphyry was discovered in the shaft at the 350 foot level but most of the tetrahedrite is found in the lower tactite zone intermingled with the bornite and sphalerite.

OXIDATION AND ENRICHMENT

The zone of oxidation and secondary enrichment in the Palo Verde area averages 30 feet in thickness with a maximum thickness of 70 feet. The deepest supergene sulfides bottomed at 382 feet below the ground surface. The lack of an appreciable blanket of enriched chalcocite indicates that leaching and migration of copper from the oxide zone was absent. Small amounts of copper oxides were encountered in the caliche capping immediately above the orebody indicating a slight upward migration of the copper.

The principal minerals resulting from the oxidation and enrichment are chrysocolla, chalcocite and various iron oxides. Malachite and azurite have been noted only on rare occasions in this zone. In the lower portion of the oxidized zone black copper oxides are not too infrequently found immediately above the chalcocite coated pyrites of iron and copper. A relatively sharp line of demarcation is formed by the chalcocite with the underlying hypogene sulfides.

Oxidation has obliterated the original texture and characteristics of the rock types found in the upper portions of the oxide zone. The lack of oxides at depth in any of the intensely fractured rocks indicates that the supply of oxygen was cut off at a very definite and uniform limit. This is suggestive of the permanent ground water level at the time prior to the formation of the caliche conglomerate capping.

CONCLUSION

Pending underground development and confirmation of the geologic picture as represented here by drill cores, it appears that the following conclusions and predictions can be made:

1. Chemical favorability rather than structure was the controlling factor in the localization of the ore bodies.
2. The higher grade ore bodies can be located by the use of wall

rock alteration and the zonal arrangement of the ore minerals.

3. The bottom of the ore bodies can be expected once the sphalerite zone is reached.

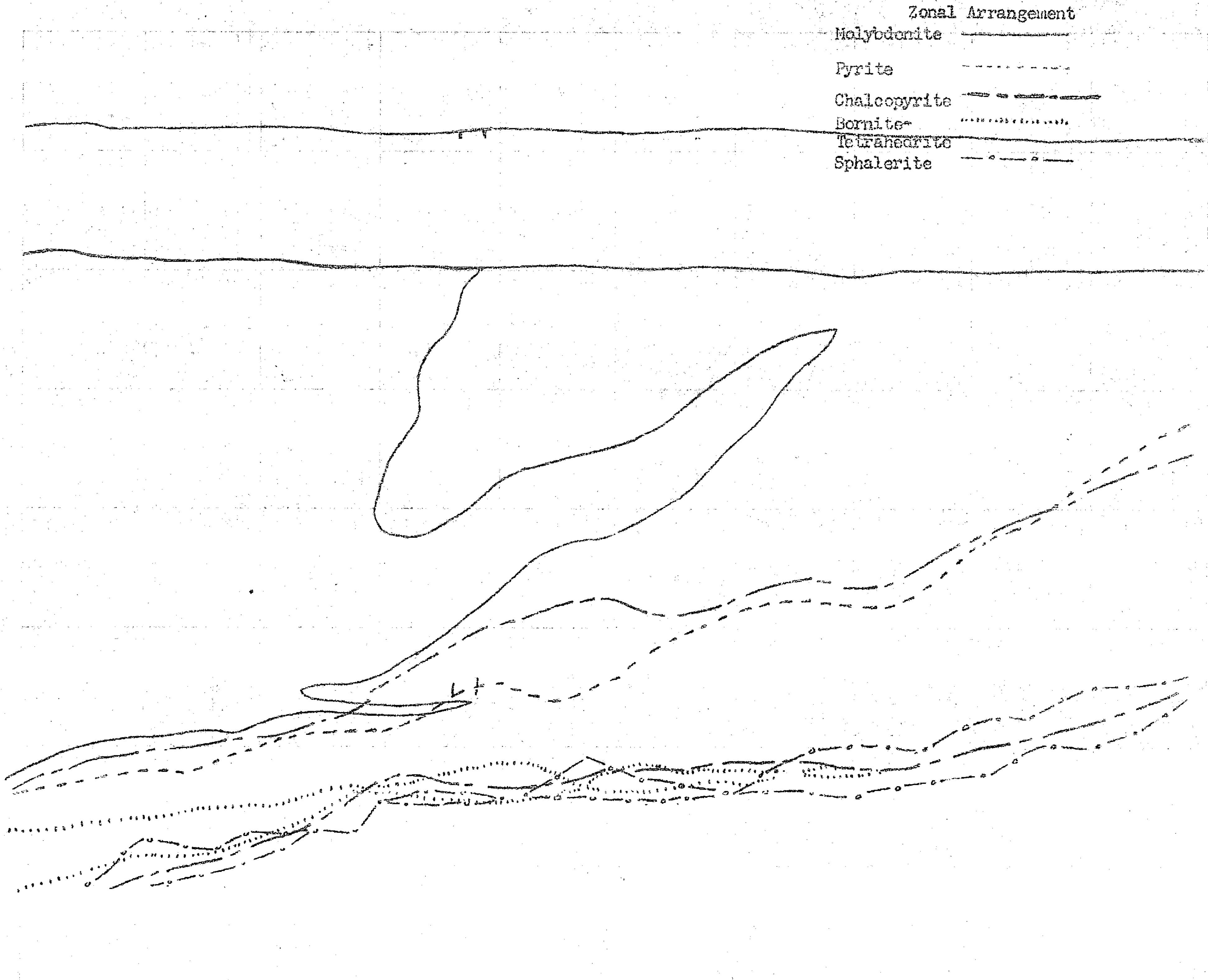
4. Additional high grade ore bodies will be found in the tactite zone beneath the porphyry sill.

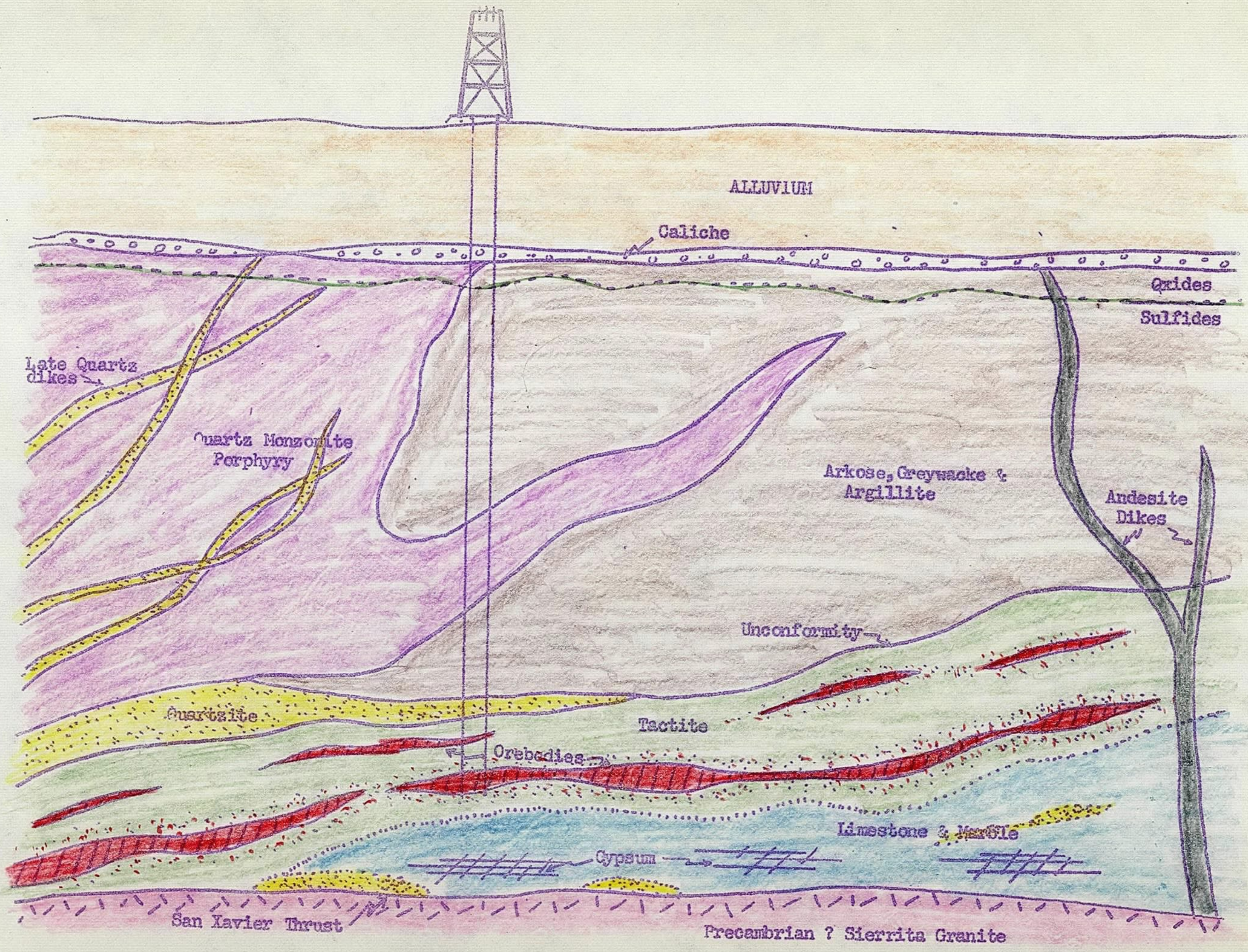
ACKNOWLEDGEMENT

Acknowledgement is due the management of the Banner Mining Company for permission to make this report possible.

REFERENCE

(1) John Cooper U.S.G.S. Bulletin No. 1112-C


Zonal Arrangement
Molybdonite
Pyrite
Chalcopyrite
Bornite
Tetrahedrite
Sphalerite


ALLUVIUM
Caliche
Oxides
Sulfides
Late Quartz dikes
Quartz Monzonite Porphyry
Arkose, Greywacke & Argillite
Andesite Dikes
Unconformity
Quartzite
Tactite
Orebodies
Limestone & Marble
Gypsum
San Xavier Thrust
Precambrian ? Sierrita Granite

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September 5, 1975

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SEP 30 1975

Mr. Norman Visnes
General Manager
American Smelting & Refining Company
Mining Department
1150 N. 7th
Tucson, Arizona 85703

Dear Norm,

Enclosed is Jim Kelly's recent report on the drilling of the Palo Verde area. Prints of the drill logs are also included.

If there is any other information required, please call me. Jim Kelly will be back from vacation Monday, September 8th.

Sincerely,

Edwin J. Eisenach
President

EJE:vm
Enc.

cc: Mr. A. J. McDonell
Mr. Jim Kelly

PALO VERDE HOLES

Twin Buttes Coordinates

Hole No.	North	East	Elevation
1357	157,107.9	117,108.8	3227.7
1358	157,438.4	116,799.9	3229.4
1359	157,328.2	116,490.0	3236.9
1361	157,328.0	116,609.2	3237.8
1362	157,328.8	116,735.2	3229.9
1363	157,329.1	116,860.3	3227.5
1364	157,328.2	116,985.9	3225.2
1366	157,217.1	116,931.4	3225.7
1368	157,217.9	116,679.9	3236.9
1369	157,107.96	116,361.31	3241.69

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EW/vm

RECENT DRILLING AND ORE RESERVES
OF THE HIGH GRADE COPPER MINERAL ZONE
AT THE PALO VERDE MINE

ANAMAX MINING COMPANY
Pima County, Arizona

July 1975

INTRODUCTION

The Palo Verde Property of Anamax Mining Company is in the Mineral Hill District seven miles north of the Twin Buttes Mine. It is a rectangular area one-quarter of a mile wide and about three-quarters of a mile long, the mineral rights of which are held by Anamax through mineral leases from the State of Arizona. The property is bounded on the south and east by ASARCO's Mission Mine and on the north by San Xavier Indian Reservation land leased to ASARCO.

The Palo Verde orebody is part of an extensive mineral zone now being mined in the adjacent Mission Pit and nearby Pima Mining Company's pit. ASARCO recently started stripping operations on Indian Reservation ground immediately north of the Palo Verde property and it has notified Anamax that it intends to start stripping and open pit mining into Palo Verde ground under terms of an agreement between the two companies.

A plan map and Sections H, I, J, J-1, K, K-1, L, M, N, O, and P, scale 1 in. = 100 ft., accompany this report. The plan map shows drill hole locations with widths and grades of the high grade zone, the high grade ore reserve block, the ore reserve comparison block, etc. Vertical slices of the high grade ore block with widths and grades in the drill holes are shown on the sections.

GENERAL GEOLOGY

At the Palo Verde property, moderately inclined beds of limestone and quartzite are overlain by a thick section of argillite, arkose and conglomerate intruded by quartz monzonite porphyry, all covered by 200 feet of post-mineral alluvium. All rock units are mineralized with copper, local zinc, minor molybdenum and some silver. Better grade copper mineral is found in garnetized and calc-silicated sections of the limestone beds (skarn zones) and the best grade sulfide copper occurs at or near the base of the skarn horizon in the lowest limestone bed.

Chalcopyrite, bornite, sphalerite and pyrite are scattered throughout the skarn in indiscriminate bunches, blebs and stringers. Copper values are very erratic with assays of core samples ranging from less than one percent to more than ten percent copper. The hanging wall or top of the high grade band is an arbitrary assay cut-off to give a reasonable thickness of the best possible grade. The footwall, for the most part, is marked by a sharp contact with barren crystalline limestone.

The erratic nature of the copper mineral in the skarn zone is also demonstrated by results from Hole A-521, drilled 10 feet north of Hole D-265 (Section J), and Hole A-522, drilled 12 feet west of Hole D-133 (Section I) as part of the early drilling program. In Hole A-521 the high grade band averages 1.34% Total Cu for a 34-foot width and in Hole D-265, 10 feet away, the same zone averages 2.68% Total Cu for a 50-foot width. The high grade band in Hole A-522 averages 1.92% Total Cu across 37 feet and in nearby Hole D-133 the average grade is 1.28% Total Cu for a 45-foot width.

The inconsistent, spotty and erratic copper sulfide occurrence in the skarn was readily apparent in the Palo Verde Mine where a face of good ore would abruptly give way to a poorly mineralized or barren face. In some, but not all instances, this resulted from fault off-sets.

The base or footwall of the high grade zone is about 500 feet below surface at the south edge of the Palo Verde property and reaches a maximum depth of approximately 1,400 feet at the north boundary. The upper reaches of the zone, at the south side of the property, have been mined through the Palo Verde shaft on and above three levels at 700, 800 and 900 feet across a strike length of 1300 feet. Production totaled 472,585 tons at an average grade of 2.23% Total Cu and 0.69 oz. Ag per ton.

RECENT DRILLING

Initially the Palo Verde ore zone, including the footwall high grade band, was developed by vertical drill holes from the surface on centers of about 250 feet. The early drilling indicated that the shoot of better grade ore extends down-dip to the northwest from the 900 level stopes. To check grade and mineral continuity between old drill holes and give better ore definition in part of this ore shoot, ten drill holes were recently completed near the north side of the property. This is in the deep part of the ore zone where an underground mining operation might start.

The ten new holes are Numbers 1357, 1358, 1359, 1361, 1362, 1363, 1364, 1366, 1368 and 1369 circled in blue on the plan map. Total footage drilled is 12,569 feet with hole depths ranging from 1085 to 1370 feet.

ORE RESERVES

In this ore reserve a factor of 10 cubic feet per ton in place was used for tonnages as dictated by specific gravity determinations of new hole drill cores.

Acid soluble copper and silver assays for all the old drill hole cores, as well as moly assays for some of the old drill hole cores are not available. Acid soluble copper and silver assays assigned to the total ore reserve are proportionate to the total copper and acid soluble copper and silver average grades of the tonnages represented by the new drill holes only. The moly grade assigned to the total tonnage is the average grade of the tonnage represented only by holes with moly assays. This tonnage 84% of the total tonnage.

Tonnage and average grades of the entire high grade block as shown on the plan map and sections are: 6,596,000 tons at 2.32% Total Cu, 0.05% AsCu, 0.011% Mo, 0.92 oz. Ag per ton. This block has a minimum thickness of 10 feet, a maximum thickness of 118 feet and average thickness of 41 feet.

For comparative purposes, ore reserves in the small block directly influenced by the new drill holes have been computed using the initial drill hole data only and also using both initial and new drilling data. The comparison block is outlined in green on the plan map. The results are:

	Tons	% Total Cu	Lb. Contained Copper
Initial Drilling Only	1,384,370	3.263	90,343,986
Initial & New Drilling	1,420,880	3.164	89,913,286
Difference (lb. Cu)			430,700
Percent difference			0.48%

The close check of pounds of contained copper indicates that the reserves in areas of wide-spaced drilling only are reasonably valid.

SUMMARY

The 6,596,000 ton total reserve at 2.32% total Cu, 0.05% AsCu, 0.011% Mo, 0.92 oz. Ag per ton is a geologic or in-place reserve regardless of mining methods or limitations. A close check of contained copper in the two reserve computations for the small block of new drilling substantiates the validity of the total reserve.

For mine planning and actual mining, small to moderate fault displacements and abrupt changes in grade along strike and dip must be anticipated. The exact locations of these off-sets and changes cannot be accurately predicted at this time. Close definition drilling from underground, careful geologic mapping and projections of structures, as well as a flexibility in mining procedures, will be required for a successful underground production of high grade copper ore from the skarn zone.

James L. Kelly

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