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AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

January 19, 1968

J. H. C.
FEB 15 1968

TO: J. H. Courtright

FROM: R. B. Cummings

Resume of Tour of Mission Mine

On November 29 and 30 I was given a tour of A.S.A.R.C.O.'s Mission unit and the San Xavier North deposit by Dennis Hall the resident geologist.

Mission Geology. Pre-mineral rocks include:

1. Paleozoic sediments - the original rocks include limestone, impure limestone and dolomite, quartzite and argillite.

2. Early Tertiary argillite and conglomerate.

3. Tertiary quartz monzonite ~~and~~ porphyry - occurs as a sill - like intrusion.

Post-mineral andesite dikes cut the rocks in the pit and the deposit is covered by approximately 200 feet of alluvium and from 0-25 feet of conglomerate.

Many structural features are present which have controlled ore deposition. The unconformity between the Paleozoic sediments and the Tertiary argillite has been a localizing factor for sulfides. Even the usually unmineralized Paleozoic quartzite will contain ore when it is on this contact. High angle faults and thrust faults have, in some cases, localized bodies of high grade copper. Throughout the ore zone a set of thin northeast fissures contains abundant sulfides. A northerly trending breccia dike crosses the east end of the pit and contains mineralization of a probable latter stage than the bulk of the mineralization. Pre-ore folding which strikes northwest and post-ore faults striking northeast have further complicated the picture. A large displacement post-ore thrust has probably carried the Mission deposit to its present position from the south. The Twin Buttes deposit may possibly be the "roots" of the Mission ore body.

The complex alteration at Mission can be conveniently divided into two categories. One type involves the feldspathic rocks (quartz monzonite, argillite, and quartzite). Alteration products in these rocks include quartz, sericite, orthoclase, biotite, and clays.

Quartz monzonite	Texture is completely obliterated; quartz-sericite in veins and along seams; most of the rock has been flooded and replaced by orthoclase and quartz; some fine-grained biotite; alteration resembles Esperanza more than Silver Bell.
Argillite	Very fine-grained aggregate; probably recrystallized quartz, sericite, feldspar.
Quartzite	Mostly quartz; recrystallized

The limey rocks have been recrystallized and replaced by lime silicates. For mapping and identification purposes, three main types ore recognized.

Tactite	Massive brownish garnet with some epidote; the garnet is known to be of the andradite group.
Hornfels	White to greenish; fine grained aggregate of diopside with some calcite; contact between tactite and hornfels may be sharp or gradational; migration of Mg suspected.
Marble	Probably recrystallized pure limestone; weakest alteration.

The limits of alteration are gradational and known mainly through drilling. The zone is crudely oriented to the north-northwest.

To the north and south it goes under post-mineral volcanics. The zone is two to three miles wide and is characterized throughout by a high sulfide content. The Mission ore body occurs where the chalcopyrite content is high enough to warrant mining.

Hypogene metallization occurs in the form of pyrite, chalcopyrite, and molybdenite. These minerals, are present in discrete grains, fractures, and veins.

Ore grade mineralization occurs in all rock types to at least a small degree. Following is a list of the percentage each rock type makes of the total volume of the ore:

Hornfels and Tactite	60%
Argillite and Quartzite(minor) . .	35%
Quartz Monzonite	5%

Oxidation and enrichment is almost nonexistant. A very thin layer of supergene chalcocite is sometimes present. Depth of oxidation varies from 0-50 feet.

When the initial figures on the ore body were calculated the grade was .9% copper. In recent years the average grade of the ore mined has been about .7% copper. The molybdenum grade is approximately .02% MoS_2 in the tactite and hornfels and .035% MoS_2 in the quartz monzonite porphyry.

To the present time about 50 million tons of ore has been mined. The calculated reserves are 116 million tons.

Operations Ore and waste are trucked by 85 ton K.W. Darts and some 65 ton Haulpaks. Forty foot benches are used in rock and 50 foot benches are used in alluvium. The final pit slope is 1:1. The stripping ratio is 1.5:1 in bedrock with a final stripping ratio of 3:1. The operating cutoff is .4% copper, but this can be reduced to approximately .3 in some of the soft hornfels. Pit mapping is done on seperate milar sheets for each bench. Mapping control utilizes blast holes which have been surveyed and flagged. Exploration drilling is done on 300' foot centers with some inter-spaced drilling.

The mill capacity is 25,000 tons per day. This is between five and six million tons per years. The mill recovery is 93% for copper. Leaching is not used, as the acid consumption would be quite high.

San Xavier North Deposit The San Xavier North deposit is about two and one half miles northwest of the Mission Mine. At the time of our visit, stripping had exposed a small area of the leached capping on the northwest side of the pit while the rest of the pit was in alluvium. The geology is known mainly through drill holes.

There are two post-ore rocks in the mine area. The Amole arkose is of Cretaceous age. It is intruded by a Laramide quartz monzonite porphyry. The intrusive occurs in the form of a plug with some sills cutting the arkose. The deposit is covered by up to 150 feet of alluvium. Post-ore volcanics outcrop within one mile of the deposit.

The deposit is on the same north-northwest trend which includes Mission. In the deposit it is thought that northeast and east-west trends may be important in ore control. This is assumed from ore trends picked up in drilling.

The arkose is altered to a quartz-clay-sericite rock. Fine-grained anhedral quartz grains are surrounded by a very fine-grained matrix of clay with varying (usually small to nil) amounts of sericite. Quartz monzonite porphyry shows argillic and quartz-sericite alteration with some secondary orthoclase. The clay mineral content decreases with depth indicating that the argillic alteration may be secondary. The alteration zone is probably of the same general width as at Mission. To the northwest, the post-mineral volcanic cover becomes very deep.

Hypogene mineralization occurs as pyrite, chalcopyrite, and some bornite in the form of discrete grains and veins. The pyrite content (chalcopyrite also?) decreases to the west (?) of the deposit. The quartz monzonite porphyry is not well mineralized and does not make ore.

Supergene mineralization occurs in the form of chalcocite coating and replacing pyrite and chalcopyrite. The secondary blanket varies in thickness from 40 feet on the east side of the deposit to almost 200 feet on the west side. The enriched zone accounts for about 10 million tons of ore.

The east side of the deposit contains an irregular zone of copper silicates, oxides, and carbonates. J. E. Kinnison has suggested that post-enrichment faulting might have elevated the east end of the chalcocite zone into the oxidation zone and a partial destruction of the chalcocite zone would have resulted.

The average grade of the intrusive is .2% copper. The average grade in the arkose is .6% copper with a .4% cutoff or .5% copper with a .3% cutoff. This does not include 10 million tons of leach material at .7% copper and a .2% cutoff. There are 5 million tons of supergene ore in which the chalcopyrite is wholly replaced. This averages 1.0% copper. There is also 5 million tons of partially replaced supergene ore which averages .7% copper. The primary ore runs .48% copper at the .4% cutoff or .44% copper at the .3% cutoff. The ore also averages .002% molybenum with trace amounts of lead and zinc.

The overall size of the ore body is approximately 1,500 feet with a depth of 800-900 feet. The total reserves are 30 million tons at .6% copper and a .4% cutoff or 69 million tons of .5% copper at a .3% cutoff.

The leached capping is exposed in the west end of the pit and on two small hills to the west and southwest of the present pit. All of the leached capping exposed is in the arkose except for a thin dike in the small hill to the west of the pit. The leached rock contains abundant fine-grained limonite filled cavities. They vary in color from a deep dark red to a maroon to a dark maroon. The limonite filling the cavities often have a pulverant, fluffy appearance. These limonite cavities occur as discrete grains and in seams and fractures and represent limonite after chalcocite. They make approximately 2% of the rock.

The "lead" to this deposit was the presence of limonite after chalcocite on the two small hills near the deposit. This fact along with the presence of alteration in both hills (weak in one, and moderate to strong in the other) was enough to warrant a drilling program in the area.

Operations At the time of our visit, the pit was being stripped by "cats" and scrappers. The final stripping ratio will be 3:1 for a .4% cutoff or 1.7:1 for a .3% cutoff. The exploration drilling was done on a triangular grid with lines 250 feet apart (289 feet centers). The core recovery was greater than 90%. The mill recovery is plus 90%. A leach test was run and the recovery was 80%.

Robert B. Cummings

Robert B. Cummings

RBC:ir

Mr Courtright

How does this look?

Any additions or corrections?

RBC

OUTLINE FOR A TOUR OF AN

OPERATING PORPHYRY COPPER

A. GEOLOGY

I. Rock Types
- a) intrusives - types, etc.
- b) pre-ore rocks - types, etc.
- c) post-ore rocks - types
  1. how close was cover?
  2. evidence of basins in post-ore rocks

II. Structure
- a) major structural trends
- b) local structural trends
  1. had control on ore
  2. didn't have control on ore
- c) breccia pipes

III. Alteration
- a) types - mineralogical, etc.
- b) areal relation to primary mineralization
- c) limits of alteration

IV. Mineralization
- a) metallization
  1. hypogene - for all types of host
     what minerals
     total sulfide content weight or volume
     pyrite: chalcopyrite
     occurrence - discrete grains, veins, etc.
  2. supergene - for all hosts
     what minerals
     thickness of blanket
     occurrence
  3. oxidation
     what minerals
     areal relation of primary mineralization and alteration
     depth of oxidation
- b) grade - for all hosts
  1. Copper - average, primary, supergene, non-sulfide
  2. Moly
  3. Precious Metals
- c) size of deposit   areal dimentions
  1. total tonnage
     mined
     reserve
  2. possible extensions

V. Leached Capping
- a) general appearance - as indicative of former sulfides
- b) evidence of age
- c) number and duration of oxidation/enrichment cycles

VI. Miscellaneous Guides or Expression
- a) geochemical
- b) old districts incl. placers
- c) topographical - basins? why?
- d) geophysical
- e) regional structural trends

VI. History of Discovery incl. capping studies
old districts

B. OPERATIONS

I. Mining
- a) transportation trucks, belt
- b) slope control
- c) pit ~~control~~ Slope
  - final
  - operating
- d) waste: ore
  - in ore
  - final - incl. gravel
- e) cutoff
  - operating
  - design
- f) mapping
- g) exploration drilling spacing: core recovery, etc.

II. Mill Data
- a) Capacity
- b) Recovery

III. Leaching--grade, capacity, % recovery, fluid loss

RBC

File: Mission

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

January 12, 1968

MEMORANDUM TO: Mr. J. H. Courtright
FROM: C. E. Zimmerman

SUBJECT: General Comments in Geological Observations at Mission Mine, Silver Bell Mine, and Esperanza and Sierrita (Duval Mining Co.)

MISSION MINE
Brief Comments:

A visit to the mine area located south of Tucson was conducted by Mr. R. Limon. Details pertaining to operating procedures such as pit mapping and grade control were shown in addition to a complete tour of the Mine.

Summary of the Deposit:

Close to the vicinity of the deposit the principal rocks are sediments and small bodies of intrusive igneous porphyries. Alteration is pervasive and extends a great deal beyond the limits of principal copper concentration approximately 3 by 2 miles. Alteration of the feldspathic sediments and igneous rock produced sericite, clay, and alteration of limestone formed garnet and diopside.

The principal host rock as a group, the lime silicate rocks, tactite and hornfels, appears to be the most favorable for ore emplacement. The argillite is less amenable to ore emplacement. Ore controls are to be inferred, however I do not fully agree with Kinnison's remark, ". . . clearly did not depend on open channels of circulating hydrothermal solutions", that is, for the major volume of copper concentration suggesting that unconformable contact between the Papago formation and the underlying silicated sediments served as a localizing factor, however an alternative could be offered: Thrust pre-ore faulting which could have introduced significant amounts of mineralizing fluids judging by the fact that fair mineralization occurs in the otherwise unfavorable marble. By the general configuration of the sill-like appearance of quartz monzonite porphyry intruding the unconformable contact between Paleozoic rocks and the Papago formation, it appears plausible that this sill would merge into a plug. However, lateral migration could have readily been a channel through a thrust fault forming an interconnected conduit to the intrusive. Ionic diffusion would probably be essentially correct as the means to produce the dispersion of gases in the process of introduction of iron to form iron-lime silicates along with sulphur, copper and minor metals but only after percolation upward through a freer passage or conduit. A major drawback to this line of thought is (1) the relatively freshness of the granite, and (2) no mineralization found in this fault underlying this thrust, believed to be Basement Thrust.

Conclusions:

The major factor impressed upon the writer was the different aspects of leached capping although there is occasional "live" limonite in the capping, mostly it is honeycomb after pyrite. The ratio of size to alteration seems to be limited to variables and a fixed set could be a very practical way to prospect for other ore bodies. The age of faulting transversing the mine area could be further looked upon as the means to shed new light on this type of orebody.

SILVER BELL MINE
Brief Summary:

A tour of the pit and general pit mapping and operating procedures were shown and conducted by the resident geologists, N. Nuttycomb and R. Edmiston. A brief look at the capping over the orebody, El Tiro pit, suggests a much broader and stronger pervasive alteration. Live limonite box work was found widely dispersed through the zone of alteration, and by comparison to Mission, basically better defined.

Summary of the Deposit:

There are two operating pits: Oxide Pit and the El Tiro Pit. The main structural pattern seems to be N5°E to N50°E fractures within the outline of hydrothermal alteration. Between these two pits there is a small unaltered zone. Minor garnetized limestone is evident at the northern side of the Oxide Pit whereas north and generally northeasterly trend there is much sediments at El Tiro Pit. The zone of alteration strikes northwest whereas a fractured pattern strikes northeast, suggesting a probable tensional attitude between the major structures.

The principal primary sulphide minerals are pyrite and chalcopyrite and occur mainly as thin veinlets to several inches. They are usually accompanied by quartz in sulphide encased by a seam of sericite with fairly uniform distribution. The intrusive rocks are monzonite, andesite porphyry, dacite porphyry and Alaskite and post-mineral dikes andesite and rhyolite, pre-mineral dike diorite, monzonite and hornblende andesite.

Excluding the post-mineral andesite dikes, all igneous rocks in the northwest trending are hydrothermally altered. Kerr analyses show that the known ore bodies are in the more strongly altered area. There are partial similarities to Mission, such as the mineralized tactites have been formed by the same processes that altered and mineralized the intrusive rocks. Consequently, it is hydrothermal metasomatism rather than contact metamorphism caused by the dacite porphyry and the monzonite. Chloritization and propylitic alteration is evident in all the pre-ore sequence. (Deuteric in origin ?)

The deposits consist of approximately tabular accumulations of chalcocite from 100 to 200' thick. The major part of the capping over the ore bodies contains less than 0.1% Cu as cuprite intermixed with the limonite-jarosite product of oxidation. Sudden changes in tenor of the ore occur probably by post chalcocite faults which would tend to blanket or produce reconcentration, and also because of variation in local rock permeability.

Conclusions:

There seems to be no conclusive evidence as to whether possibilities for alteration rules could be laid down in advance as a guideline as far as volume and grade estimation are concerned after visiting the abovementioned pits. However, it provides a useful precedent, that detailed reconnaissance should be done in the area in question.

From a comparison point of view between Mission and Silver Bell from the standpoint of porphyry copper, it seems that Silver Bell is closer to that ideal; the porphyry intrusives are the major ore carrier, whereas at Mission the silicated sediments are the host rocks. However, there is no detraction to classify Mission as a porphyry copper.

Alteration is quite pervasive and widespread at Silver Bell, certainly more impressive than at Mission. Probably scarcity of outcrop would be largely responsible for this apparent difference if we consider the magnitude of Mission compared to Silver Bell.

<u>ESPERANZA AND SIERRITA (Duval Corporation)</u>
<u>Brief Comments:</u>

A tour of the Esperanza pit and a general outline of the proposed new pit for the Sierrita orebody was conducted by resident geologist, Mr. Bruce Wilhelm. Indications that the company is not ready to disclose the operating cutoff at which the Sierrita open pit is to be geared is evident, most probably 0.3% Cu plus molybdenum values.

The Esperanza and West Esperanza are associated with a broad contact zone that consists of cretaceous volcanic sedimentary rocks and tertiary igneous intrusives. Rock types range from medium grained diroite to quartz monzonite intruded mainly as stocks and sills.

One of the more favorable host rocks, quartz latite porphyry and quartz monzonite porphyry amenable to carry ore, mainly represented as chalcocite, chalcopyrite, pyrite and molybdenite, was found in disseminated and as seams and minor slips in fine fractures associated with quartz veinlets. Alteration zone in the quartz monzonite porphyry ore range to brownish color and have minor grains of sericite with quartz and occasional pyrite. Orthoclase and plagoclase phenocryst has been obliterated by kaolinization and sericitization. Limonite, jarosite and fair hematite are present over the Esperanza. However, very scattered outcrops were seen in the Sierrita area, in fact the hydrothermal alteration appears lacking within a few feet of the orebody. Minor development of silica sericite and potash feldspars were observed on the east side of the pit where a minor outcrop obviously in quartz monzonite was observed.

According to D. W. Lynch's report, "The Economic Geology of the Esperanza Mine and Vicinity," the faults seem to have exerted an important control on grade and emplacement of the hypogene and supergene ores. These faults carry massive and breccia quartz with chalcopyrite, chalcocite, pyrite, galena and molybdenite. This criteria could also hold for the Sierrita deposit. With an estimated 100 million tons of overburden to be stripped and with the marginal grade available, the tonnage output per day will have to be impressive (50,000 T/day).

<u>General Conclusions:</u>

The basic differences in hydrothermal alteration are as follows:

(a) Composition of the solutions;
(b) Composition and structure of the wall rock;
(c) Temperature and pressure of the solution.

Consequently, the alteration mode and composition scale would definitely change from one district to the other. However, in the case between Mission, Silver Bell and Esperanza, the bulk of alteration for the first two is essentially sericite quartz; also, chloritization and propylitic alteration is evident throughout the area. At Esperanza, silicification appears predominant over sericite and except for recrystallization quartz is not affected by any type of alteration.

The volume of unaltered rocks relatively is greater at Esperanza than at Silver Bell and just about equal to Mission, suggesting (1) exothermic effect by the intrusives had less markedly influence than capping (?); (2) fracturing is less evident at Esperanza than at Mission and Silver Bell; (3) wall rock chemical reaction and shear fracturing ability seems to be indicated at Esperanza where, i.e., biotite granodiorite is a poor host rock for copper mineralization; (4) a more complex history of intrusion and extrusion at Esperanza than at the other two properties; and (5) faulting seems to have exerted and controlled movements and migration of hypogene metallization, and also the main channel for down percolating solution at the Esperanza.

CEZ:lmi

Charles E. Zimmerman

J.H.C.
OCT 4 1963

October 3, 1963

Mr. Vincent D. Perry, Vice President and
Chief Geologist
The Anaconda Co.
25 Broadway
New York, N. Y.

Dear Vin:

Enclosed is copy of a paper on the Mission Deposit by John Kinnison of our Tucson exploration staff.

This paper presumably will appear eventually in the volume on Porphyry Copper Deposits now being put together by the Geology Department at the University of Arizona.

In view of our discussion at lunch a few days ago during which you mentioned having some difficulty sorting out the rocks in your current drilling program in the Pima and Twin Buttes' Districts, I thought this advance copy of Kinnison's paper might be of use to you.

Yours very truly,

KENYON RICHARD

att.

blcc: ✓HJCourtright) A/M -
JEKinnison) Tucson

Kinnison Paper

John C Balla

J HC

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J. H. C.
FEB 8 1972

PROBABLE ORIGIN OF MISSION COPPER DEPOSIT

John E. Kinnison
Geologist

American Smelting & Refining Company
Southwestern Exploration Department
Tucson, Arizona

This paper is to be presented at the Annual Meeting of the American Institute of Mining, Metallurgical, and Petroleum Engineers Inc., Dallas, Texas, February 24 to 28, 1963.

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63I33

EVIDENCE INDICATING THE HYDROTHERMAL ORIGIN OF A "CONTACT METASOMATIC" MINERAL SUITE, MISSION COPPER DEPOSIT, ARIZONA

John E. Kinnison
Geologist
American Smelting and Refining Company
Southwestern Exploration Department

INTRODUCTION

The Mission mine, located in southern Arizona near Tucson, is a recently developed open pit which produces 15,000 tons per day of copper ore. The mine lies on a wide and gently sloping bajada sweeping northeasterly from the Sierrita mountains. It derives its name from the nearby Mission San Xavier del Bac, built circa 1700.

The ore body is everywhere covered by about 200 feet of alluvium, as are the adjacent Pima and Palo Verde mines. The geology of the Mission deposit is known principally through the study of diamond drill holes spaced 150 to 300 feet apart. The open pit is in an infant stage and has not yet revealed much of the deposit, although information obtained there by the operating staff, and from a few thousand feet of exploratory underground workings, has added significantly to the general fund of knowledge.

Permission to publish was granted by the American Smelting and Refining Company. I am indebted to Kenyon Richard and J. H. Courtright for criticism of this paper and for their direction during the several years in which I studied the Mission deposit. Acknowledgment is given to consultant in petrography, Robert L. DuBois of the University of Arizona.

The only previous publication pertaining directly to the geology of the Mission deposit appeared in 1959 (Richard and Courtright), and may not be everywhere readily available. Cooper (1960) has published a short paper on the district

SUMMARY

In the close vicinity of the Mission ore deposit, the principal rocks are sediments and small bodies of intrusive igneous porphyries, all of which are pre-ore in age. The bedrock surface is a buried pediment, and only a few small outcrops protrude from the alluvial plain. These small and isolated knobs, which are the tops of bedrock hills, lie within a large area of pervasive alteration and constituted one of the principal exploration leads. The very simplified geologic sketch in Figure 1 shows these features.

Alteration --- the formation of new minerals or textures and the destruction of the original rock character --- is pervasive within the Mission ore deposit, and extends a considerable distance beyond the principal area of copper concentration. The limits of the Mission altered zone, although

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AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona
May 26, 1959

FILE MEMORANDUM

HELMET PEAK GEOLOGY
Age of Sierrita Granite

A coarse-grained granitic rock termed Sierrita granite has been cored in several diamond drill holes on the Mission property (East Pima), and crops out at several localities in the Pima Mining District (Fig. 1). This formation is referred to by John Cooper (U.S.G.S.) as Mineral Hill granite (near Mineral Hill) and as pre-Cambrian granite (the other outcrops).

This rock forms the footwall of the Basement thrust (Mission 100 scale geologic cross sections, November, 1957), and has been cored at depths of 1100-1500' in the Mission area. It crops out below the thrust west of the San Xavier Mine. Granite was also penetrated by drill holes near the Daisy Mine (850') and San Xavier Mine (1200' more or less.) Below the thrust the granite is, of course, everywhere in fault contact with the overlying, mineralized rocks, and so here no evidence is present which would indicate its age.

I believe the Sierrita granite is pre-Cambrian, on the basis of indirect evidence, summarized below.

1. A first problem to be resolved is that of correlating widely separated outcrops of granite. The name Sierrita granite was applied to the coarse-grained granite below the Basement thrust, which is characterized by large blebs, and interlocking prismoid shapes of quartz, together with conspicuous wisps or shreds of muscovite-biotite, most commonly altered to chlorite. The outcrops and drill hole intercepts of granite below the thrust all appear to be of the same unit. At Mineral Hill, the granite differs from this type Sierrita granite only in that it contains in places more abundant chlorite; and also the granite in the Twin Buttes area which crops out near the Minnie and Morgan Mines, although gneissic-structured, is otherwise megascopically similar. On the isolated hill three miles southeast of Helmet Peak, granite underlies a sedimentary contact with bolsa quartzite. Here the granite is so weathered and crumbly that on the surface a really satisfactory specimen may not be found. It appears that the texture of quartz and feldspar is similar to that of the Sierrita granite.

2. All of the areas above the Basement thrust which contain Sierrita granite appear to be overlain, or at least spatially associated with, Cambrian Bolsa quartzite. The contacts are pre-mineral faults. Contacts with post-Cambrian formations also are always faults in those places where I have seen them.

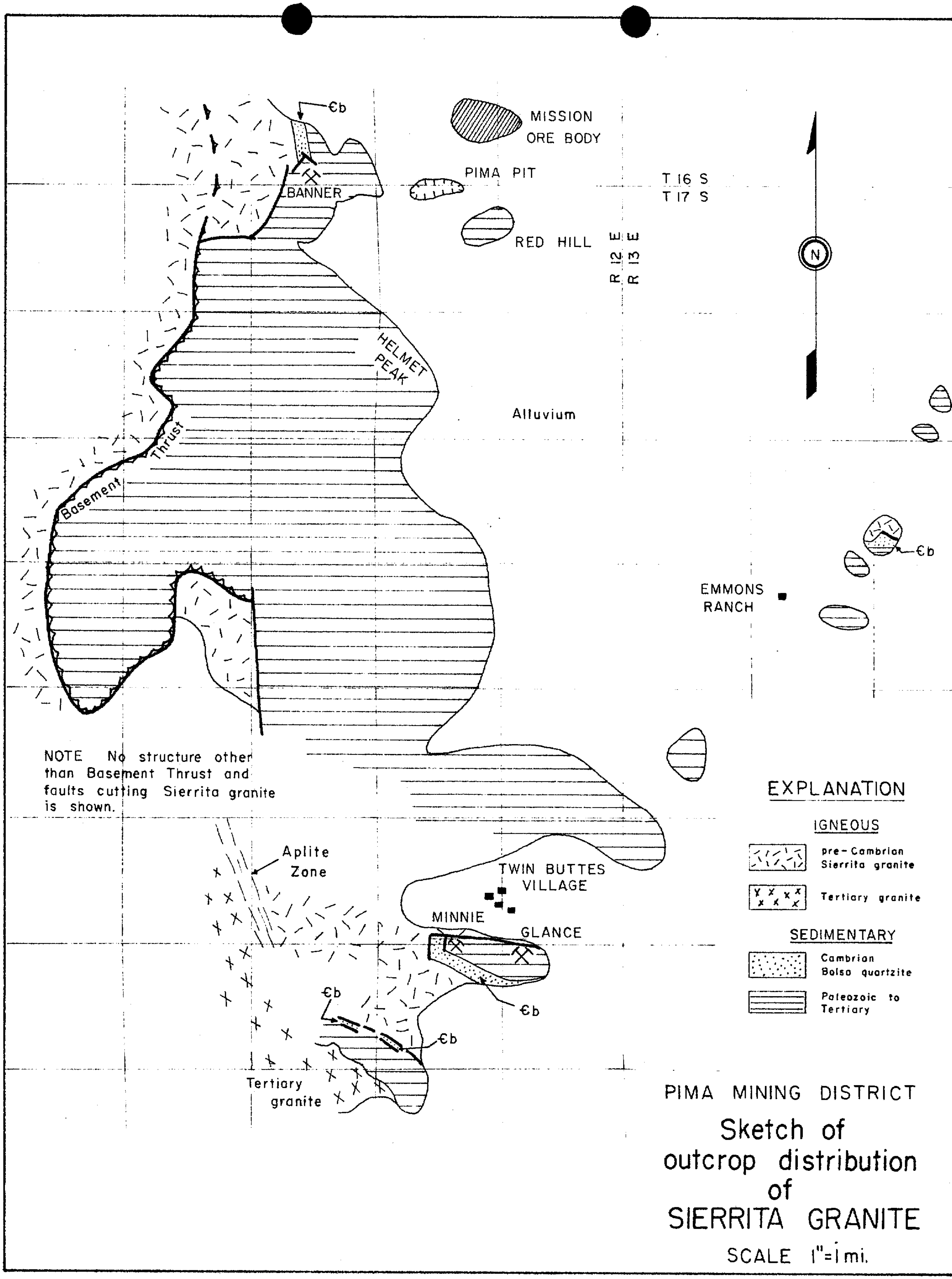
3. Fine-grained chloritized diorite dikes (?) or xenoliths are a common occurrence in the Sierrita granite near Mineral Hill, Twin Buttes, and in the granite southeast of Helmet Peak. These dioritic rocks do not intrude the Paleozoic rocks, and if they are xenoliths rather than dikes, have no possible source in the Paleozoic rocks.

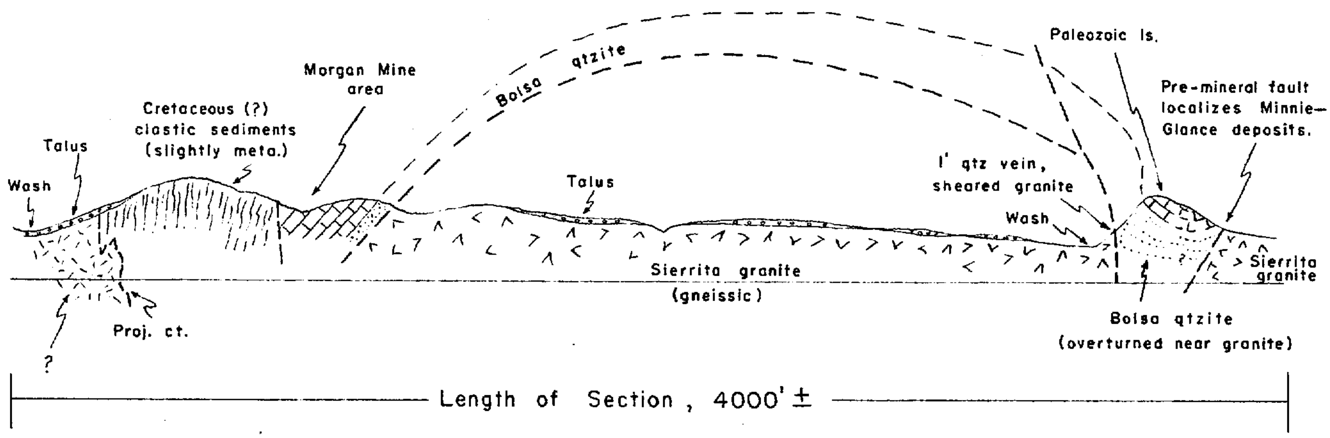
In summary, I point out that the association of Sierrita granite with Bolsa quartzite is suggestive of a pre-Cambrian age, and the fact that the contacts with that formation are faults is to be expected due to slippage along the basement-Bolsa contact. The contact appears to be sedimentary in the little hill southeast of Helmet Peak. Diorite bodies are common to the granite, and by indirect evidence appear to be younger than the Paleozoic rocks.

Other geologists have assumed the granites of the Pima District to be intrusive into the Paleozoic rocks because of the spatial association to contact-type ore deposits. At Twin Buttes, particularly, this relationship is suggested. Figure 2 shows an interpretation of structure in the Twin Buttes area in which the central core of granite is inferred to be pre-Cambrian.

JOHN E. KINNISON

JEK/ds
cc: KERichard
JHCourtright
AGBlucher


Єb
MISSION
ORE BODY
PIMA PIT
BANNER
T 16 S
T 17 S
RED HILL
R 12 E
R 13 E
N
HELMET
PEAK
Alluvium
Basement
Thrust
Єb
EMMONS
RANCH
NOTE No structure other than Basement Thrust and faults cutting Sierrita granite is shown.
Aplite
Zone
TWIN BUTTES
VILLAGE
MINNIE
GLANCE
Єb
Єb
Єb
Tertiary
granite
EXPLANATION
IGNEOUS
pre-Cambrian
Sierrita granite
Tertiary granite
SEDIMENTARY
Cambrian
Bolsa quartzite
Paleozoic to
Tertiary
PIMA MINING DISTRICT
Sketch of
outcrop distribution
of
SIERRITA GRANITE
SCALE 1"=1 mi.



DIAGRAMATIC CROSS SECTION
Looking West

MORGAN-MINNIE MINE AREA

GEOLOGY OF THE MISSION COPPER DEPOSIT, ARIZONA

To be presented as a talk before the December meeting of the Arizona Section, A.I.M.E., 1961, by John E. Kinnison.

The scope of this paper is the geology and genesis of the Mission ore body and its environment, as interpreted from the exploratory program which preceded operation.

Mine is owned and operated by American Smelting and Refining Company. Staffed by 2 resident geologists. Geology is mapped in detail and will ultimately furnish a complete picture of the ore body.

Permission for presentation granted by Asarco. Acknowledge the help given by K. Richard and Harold Courtright; and by consultants R. L. Dubois (petrography) and D. L. Bryant (stratigraphy).

Location - 15 miles south of Tucson.

History

A. Discovery of Pima Mine by United Geoph. in early 1950's.

B. Recognition of the altered nature of Red Hill, and its significance in view of the disseminated Cu in the Pima hanging wall.

C. Recommendation to explore the alluvial covered area to the north and east by diamond drilling wide spaced holes to determine limits of alteration. This commenced during 1954.

D. About 250 drill holes spread 150-300 feet apart measure the ore body.

Operation

Open pit; ultimate limits according to present design to be 5000 x 2500' horizontal dimension. Milling began in September 1961, rated capacity 15,000 tons per day. Capital investment including exploration is approximately $36 million to date.
Approximate annual production: 5,400,000 tons ore
45,000 tons Cu

District Geology

Pre-ore Rocks - brief statement; no descriptions.
Post-ore Rocks - " " " "
Refer John Cooper's excellent U.S.G.S. Bulletin, 1960.

Slide 1 - Index map

Position of Mission and other mines.

A cross-section extending south from Black Mountain (point to map) shows the gross structural features.

Slide 2 - Upper figure

This cross-section shows the great low-angle fault mapped by Cooper. The fault plane has been penetrated by many deep Mission drill holes. Point out rock types.

Discuss age of fault--briefly.

Mention the extensive and well developed pediment extending north from Mission area. Point to principal rock units.

Slide 2 - Lower figure

A very simplified diagram, vertical scale exaggerated, Mission altered zone.

Point to slide, showing extent of pervasive rock alteration; point out lime-silicate zone. Mention intrusives that appear on slide.

Summary of major conclusions - to be amplified at end of talk.

1. The monzonite porphyry within the altered area has no specific spatial relationship to either ore or alteration.

2. Alteration and sulphide impregnation were more or less contemporaneous. Alteration, as used here, includes the silication of large masses of limy host rocks. This is not regarded as being a so-called "contact metasomatic" effect.

3. Diffusion was a process of major importance in the emplacement of sulphides. Major channels of open circulation were widely spaced.

4. The Mission mine is a "porphyry copper" deposit.

Mine Geology

For working purposes, the stratigraphic units within the ore body are given special names.

Slide 3 - Pointing to map, discuss Papago, Pima and Kino formations, and probable age. Mention lithogy of Papago and its correlation to Pima mine hanging wall.

Slide 3 (Cont'd)

Discuss porphyry sills.

Point out ore distribution pattern, and major pre-ore faults. Ore-rock types: argillite comprises 25%, altered limestones of Pima formation comprise 75%. Grade of the ore body is comparable to that of other open pit porphyry copper mines in the southwest. Range of grade is from .05 up to 15% Cu.

Mineralization

Alt. zone surrounding Mission - 2 x 2 miles; includes Pima and Palo Verde mines. All rocks within this area are altered and impregnated with sulphides.

Clastic sediments and igneous - quartz-sericite or quartz-orthoclase alteration.

Limy sediments - garnets, diopside, and other Ca-silicates.

Outside this zone the rocks are unaltered and contain no sulphides.

Discuss composition of hornfels and tactite. Diopside-hedenbergite. Alteration to actinolite. Composition of garnet (andradite).

Mission ore deposit differs from the altered zone only in the relative abundance of Cu and its availability to low cost open pit mining. Sulphide minerals are principally Py and Cpy. Minor bornite. Some shalerite and galena.

Ratio of Py/Cpy in the ore body varies - elaborate briefly. Total sulphide content--between 5-10% generally.

Chalcocite is confined to thin blanket. Oxidation is 10-30' deep. Chalcocite and oxide ore makes but a fraction of ore reserve.

The structure of Pima formation sediments is complex in parts of ore body. Dominant are folds and warped thrust faults.

Slide 4 - Section through east part.

Point out thrust faults, bedding attitudes, general distribution of copper.

(Blind note: This is 1500 W section, which was shown in the dedication film by Western Knapp. Assays are not legible when projected in this manner because of the small size of lettering.)

Structural features controlling sulfide deposition.

A. East vein
B. Unconformity
C. Quartzite beds.
D. Low angle thrusts.
E. Northeast trending fractures are commonly mineralized but show no relation to surrounding disseminated sulphides.

Conclusions:

Discuss the geometry of porphyry intrusion, and relationship, --or rather the lack of it--to the zone of alteration. Note that porphyry is itself mineralized and carries typical "protore" grades of Cu - about 0.2-0.4% Cu.

Note that sulfides are consistently disseminated in altered zone, and that no alteration is without sulphides and vice-versa. The conclusion is that these two features - sulphides and alteration, represent concurrent events.

Discuss the wide spacing between known major channels which localized higher grade concentrations, and the role of diffusion in emplacement of sulphides, and alteration.

Discuss and elaborate on the aspects of alteration and wide dissemination of sulphides, concluding that the Mission deposit is a porphyry copper deposit.

Comparison to other deposits: Of the porphyry copper deposits described in the literature, the Mission alt. zone most closely resembles the Ely porphyry copper belt, because at Ely more sediments lie within the altered zone than at most other porphyry districts. A most excellent description of that district is found in U.S.G.S. Prof. Paper 96, A. C. Spencer, 1917. The differences are of degree only; at Ely there being more ore in porphyry and less in altered sediments than at Mission.

The following quotes present Spencer's views on the history of ore deposition at Ely:

"Two kinds of metamorphism of the rocks of the district are distinguished. Under igneous metamorphism are included all those alterations which attended or followed the invasion of the sedimentary formations by the magmatic material that eventually crystallized as monzonite porphyry. These alterations have affected the invaded limestones and shales and also the igneous rocks themselves. To this metamorphism is to be attributed the formation of the primary metalliferous deposits of the district."

"The principal zone of porphyry intrusion has a length of about 7 miles and a width of half a mile to nearly a mile. Within this zone and for irregular distances along the flanks of the numerous separate intrusions the invaded limestones and shales have been variously changed from their normal condition. Within this zone also the masses of igneous rock themselves have been greatly altered. The action of heated solutions is regarded as the cause of this metamorphism, and the source of these solutions is sought not in the porphyry masses themselves but in the general magmatic reservoir from which the intrusive masses had been derived, and it is shown that the principal metamorphic changes were effected after the bodies of porphyry that are now altered had become crystalline."

"The principal zone of porphyry intrusion extends for 7 miles through the Ely district with a width of one-half mile to nearly a mile. Within this zone and for irregular distances on the flanks of the numerous separate intrusions the sedimentary formations, including limestones and shales, have been variously changed from the normal facies which are exhibited in situations at greater distances from the porphyry masses. Along this zone the masses of intrusive rock themselves have been metamorphosed to a great extent. The distribution of the altered sedimentary rocks is so definitely limited to a zone comprising the medially disposed intrusive masses that no extended argument is required to support the conclusion that the metamorphism is casually related to these ingeous rocks. However, as will be more fully stated further on, the relation is not entirely a direct one as regards the bodies of porphyry which appear at the present surface, for it is held that the alterations were effected by hot solutions expelled from deep-seated masses of igneous material, of which the observed intrusive bodies are off-shoots. In the vicinity of minor intrusions that lie well away from the principal zone there is usually almost no alteration of the wall rocks, and a similar lack of alteration is noted around a considerable area of porphyry north of Lane Valley.

The changes in the limestones comprise (1) loss of color and crystallization to white fine-grained marble; (2) silicification with the formation of jasperoid usually carrying large amounts of pyrite; and (3) the development of silicate minerals, including garnet, tremolite, pyroxene, and scapolite."

"The porphyry masses which are exposed within the area of metamorphism are thought to be of insufficient size to warrant regarding them as the source of the materials which have been introduced into the invaded rocks, or of the heat which was required to effect the observed mineral transformations, or yet as the source of the great volume of transfusing water, which must be predicated as the carrier both of the exotic materials and of the heat or energy required for the alterations that have taken place on so grand a scale. Furthermore, the porphyry masses along the main zone of intrusion have themselves suffered alteration involving great losses and gains of substance, so that the metamorphosing agencies were certainly in large part of an origin extraneous to these masses."

"The deposition of pyrite and chalcopyrite in disseminated grains and crystals throughout great masses of porphyry, jasperoid, limestone, and shale when broadly considered, was merely an incident of the very complete metamorphism of these bodies of rock."

"The escape of these solutions occurred after the now metamorphosed bodies of porphyry had consolidated, but, it is conceived, at a time not long subsequent to this consolidation."

"Throughout the central zone of the Ely district the effects of igneous metamorphism are seen in the intense and thoroughgoing alteration of very large masses of porphyry, limestone, and shale. Though the different rocks have yielded to chemical reorganization and to metasomatic replacement, each in a manner depending primarily on its original composition, yet the resulting products are all heavily charged with pyrite, and in the main this mineral is accompanied by minor amounts of chalcopyrite. In a general way the sulphides are evenly distributed through the altered rocks, but their proportion ranges from perhaps 2 or 3 per cent up to 10 per cent."

The tenor of these quotes indicates Spencer's belief, based on a long and careful study that alteration and sulphides are, in a broad sense, contemperaneous, and that the tactites and other altered sediments which classically would be termed "contact metasomatic," are to be regarded as an integral part of the porphyry copper zone of alteration.

Another comparison may be made with the Linchburg mine, New Mexico -- Spencer Titley, Economic Geology, 1961. Here a zone of lime-silicate minerals, of classical "contact" type, occur along the Linchburg fault, well away from a known igneous mass.

He states, in part: "Neither of the alteration stages can be fixed in time. There is no direct evidence to indicate either continuity of deposition or a time break in the depositional process. Certain arguments, however, suggest that a time-break, if one existed, was of such short duration as to be insignificant."

"The alteration, therefore, is considered as a continuing process in which the ore-bearing fluids, although changing slightly in their chemical properties, were more influenced by the nature of their environment of deposition than by any gross change in composition."

Zoning halos of alteration and sulphides are attributed to continuing growth of each alteration halo, away from feeder-veins, with the inner halos expanding and replacing the halo adjacent. Note similarity to the Sales-Meyer proposals for the formation of sericite-clay "envelopes" at Butte. Titley's careful work indicates another lime-silicate assemblage in which, contrary to common assumptions of early silication followed by fracturing and sulphide replacement, the silication and sulphide formation are contemporaneous.