CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
416 W. Congress St., Suite 100
Tucson, Arizona 85701
520-770-3500
http://www.azgs.az.gov
inquiries@azgs.az.gov

The following file is part of the

James Doyle Sell Mining Collection

ASARCO

Southwestern Exploration Division

May 18, 1979

FILE MEMO

AJO MINE - Cu
Arizona

In 1972 Ajo reserves were reported as 130 million tons of .68% Cu, or a life of about 12 years at 30,000 tpd.

However, during the recent AIME open pit meeting at Ray, Arizona, it was learned that deep drilling encountered ore beneath a barren rhyolite (flow?) and the ultimate pit is now projected to a depth of 1,800', extending the mine life to the year 2020.

Several years ago, J.Kinnison recognized geologic features at Ajo as being similar to those at Mission and hypothesized the existence of a low angle fault with the upper plate having moved north as at Mission. Subsequently, Quintana put down several deep holes on the south, but failed to find the "roots" of the Ajo deposit.

The discovery of ore continuing to considerable depth at Ajo does not prove that the roots of the deposit remain in place, but does suggest that this is most likely the case.

J. H. Courtright
J. H. Courtright

JHC:jlh

c.c. T.C.Osborne
W.L.Kurtz/F.T.Graybeal

J. H. C.

DEC 12 1967

MEMORANDUM FOR MR. J. H. COURTRIGHT/CONFIDENTIAL

November 28, 1967

Going South, Ajo

I met with David Lowell yesterday, November 27, to discuss above subject. We spent approximately two hours in conversation, and I reviewed some of the core and rotary cuttings at his office. At this time I can say only that Quintana's drilling, coupled with drill holes from other company's south of Ajo--which Lowell has compiled and which I was unaware of--establishes without doubt the presence of a "basement fault."

Mr. Lowell did not seem to be able to defend his proposal concerning the direction of movement. This is partly due, to the fact that he personally has spent only three days in field examination, and seems to lack approval of the work done by Mr. Logry who was assigned the project. The one thing that stands out is that the depth to the basement fault is irregular and deep.

I have a tentative appointment to meet again on Friday next, December 1, and between now and that time I will be able to review more properly what has been done in the past and therefore ask more pertinent questions.

The reason Quintana entered the area for exploration goes back to my old Ajo report of about 1960. This statement was made in confidence, and I ask that it be left at that.

John E Kinnison

No Copies Made

J. H. C.
FEB 27 1967

AMERICAN SMELTING AND REFINING COMPANY
EXPLORATION DEPARTMENT
120 BROADWAY, NEW YORK, N.Y. 10005

ASARCO

KENYON RICHARD
CHIEF GEOLOGIST

MR. WES
READ AND RETURN
PREPARE ANSWERS HANDLE
FILE ✓ INITIALS

Air Mail
PERSONAL AND CONFIDENTIAL

February 23, 1967

Mr. J. H. Courtright
American Smelting & Refining Company
P.O. Box 5795
Tucson, Arizona

See Ar - 16.1.0
W.E.S.
MAR 21 1967

Ajo

Dear Sir:

On February 13, I talked with Herb Stewart and John Hope and loaned them our copy of Kinnison's 1961 report.

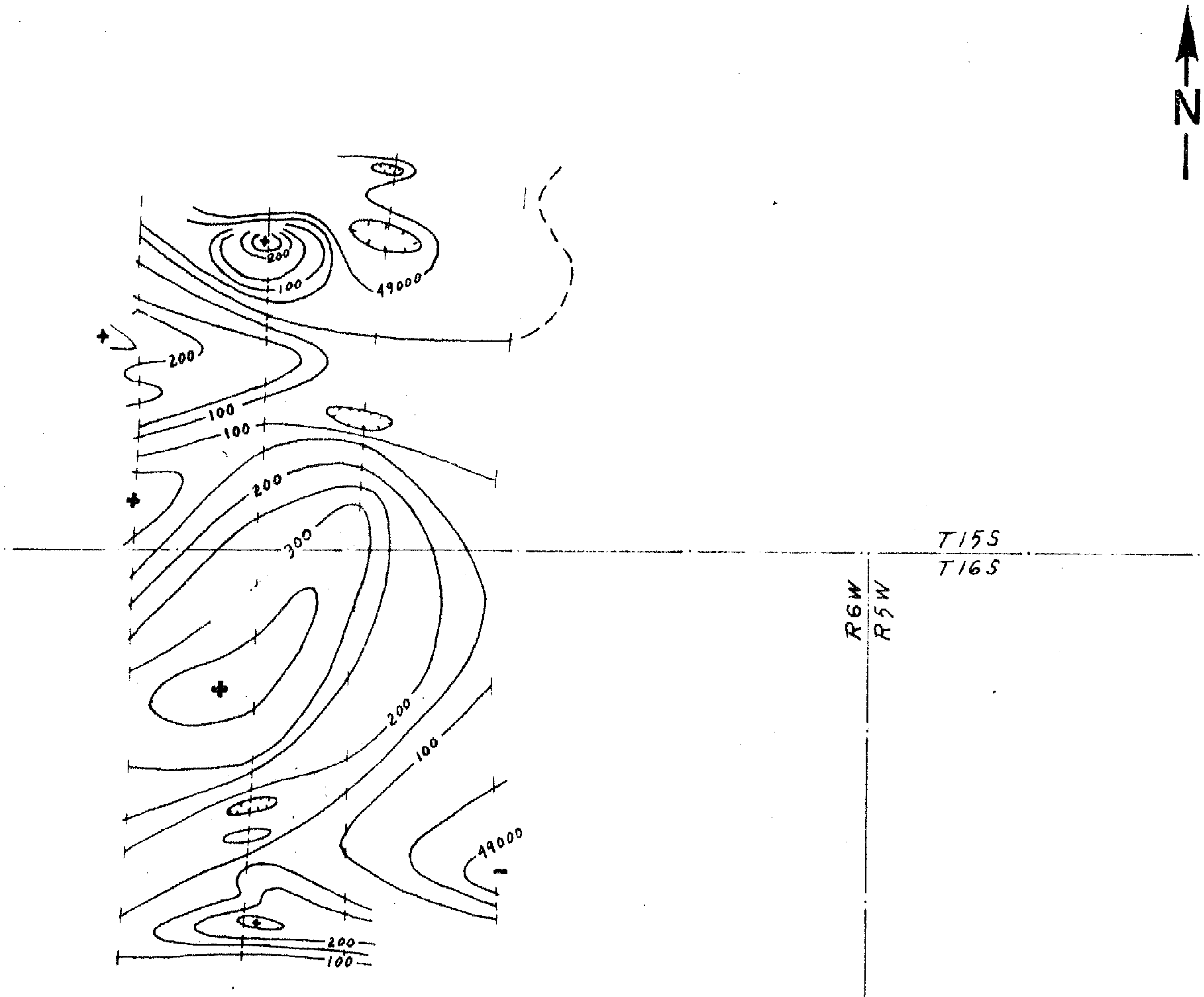
They seemed to be intrigued with the general idea and showed me some drill results (1 hole just south of their property and probably in the old Blue Stone Property was drilled to 2000'). They apparently have some deep holes in the pit area itself but I did not see these results. They stated that the logs did not indicate a flat post-mineral fault. However, they volunteered that due to large foreign blocks in "chaos" formations, they have experienced considerable difficulty in logging core and understanding stratigraphic positions.

The kicker is Quintana has optioned or staked practically all of the ground between the south end of the Ajo claims and the north boundary of the Organ Pipe Momument. This property acquisition by Quintana was a surprise to me. They said that they had anticipated that I was coming to them with a three-way proposition involving Quintana. This kind of a proposition would not, at the moment, seem of interest to me. Therefore, there is probably nothing that we or they can do until (1) Quintana drops the ground or (2) we learn something of their (Quintana) intentions.

Very truly yours,

Kenyon Richard

Kenyon Richard



AEROMAGNETIC
OVERLAY FOR ANOMALY 'D'

VALLEY OF THE AJO, ARIZ.

Scale 1 : 62,500
F.L. Spacing = 3/4 mi North, South
F.L. Elev = 2200 Ft, M.S.L.

B.C.M. & J.M.P. 2-20-67

For J.H.C.
Files

J.H.C.
SEP 13 1966

W.E.S.
OCT 12 1966

J.E.K.
SEP 12 1966

WES, ~~RKK~~, ~~SVF~~, ~~BAW~~
Sept 15

R.K.K.
SEP 15 1966

SEP 1[illegible]

S.V.F.
SEP 27 1966

REFERENCES ON PEDIMENTS

FROM

PHYSIOGRAPHY OF THE AJO REGION, ARIZONA

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Aq 16.1.0

J.H.C.

JAN 05 1966

JAN 1 1967

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

J.E.K.

MR. ~~J.E.K.~~, BAKW, WES

January 3, 1967

W.E.S.
FEB 14 1967

READ AND RETURN ....
PREPARE ANSWERS ..... HANDLE .....
FILE ✓ INITIALS ....

TO: J. H. COURTRIGHT

FROM: J. R. WOJCIK

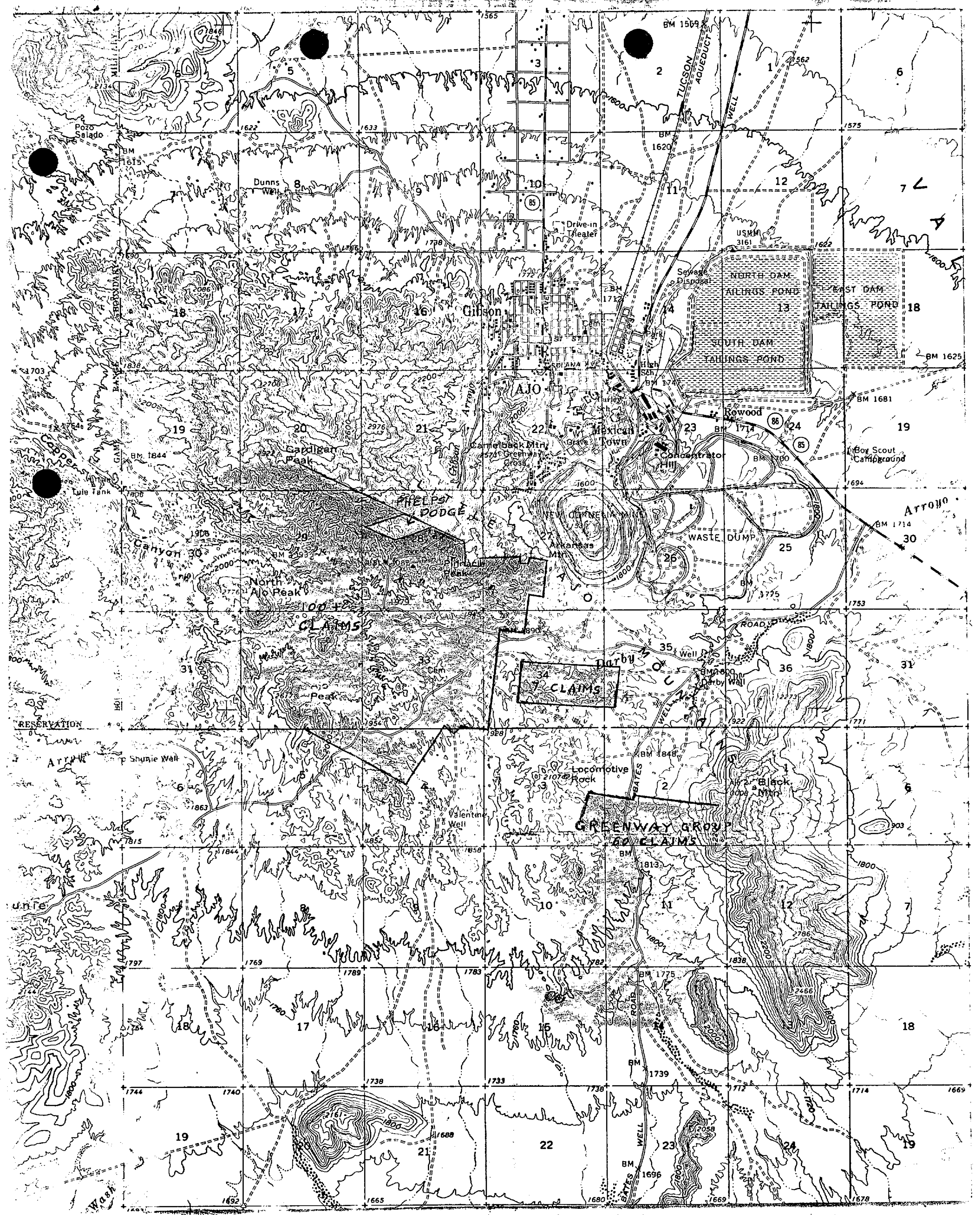
GENERAL EXPLORATION, 12/13-14/66
SHARP PROPERTY, AJO DISTRICT

During the helicopter work in the vicinity of Ajo, a James Sharp asked if we were interested in a series of claims he holds located west of the New Cornelia Pit. While he does hold a few claims east of the Gibson Fault, the larger block is west of the fault, and it is the larger block in which he was trying to interest us. I contacted J. E. Kinnison for his opinion of the ground before I visited it, and after walking over numerous hills of unaltered Cardigan gneiss and Cornelia quartz monzonite, I agree that we are not interested. Reportedly, Great American Industries, Inc. (Pepsi-Cola) of New York has offered $25,000 for a 120 day drilling option on 59 claims closest to pit, but were turned down (J. W. Sharp, personal communication). Property had been recommended to GAI by Arthur E. Little Company's geologist, Bill Watson. Occidental Petroleum has also expressed interest in this group of claims.

Sharp also holds two groups of claims south of the pit. One group contains the two USBM drill holes that were sunk in 1949 and failed to get through the fanglomerate. J. R. Simplot Co. of Idaho and their geologist, Ted Hanks, are running I. P. survey over the Greenway group of claims. Barry Watson visited this group of claims with Mr. Sharp and feels there is no new information available that would make the property attractive to ASARCO at this time.

J R Wojcik
J. R. WOJCIK

JRW/kw
Attachment



Approximate Location of J.W Sharp
Groups of Claims
12-15-66 JRW, BNW

December 21, 1966

Mr. James Sharp, President
Western Equipment Sales Corp.
P. O. Box 6515
Phoenix, Arizona

Dear Mr. Sharp:

I want to thank you again for extending to Mr. Joe Wojcik and myself the privilege of inspecting your properties in the Ajo area. We have consulted Mr. John Kinnison, our geologist most experienced in the Ajo region, and have decided to take no action on the area at the present time.

The information on your properties will go into our files for future reference. Your open and friendly manner toward us was appreciated, and we hope that you will feel free to bring to the attention of ASARCO any future properties that you might acquire and feel to be of particular interest.

Merry Christmas and the best of the New Year to you and your family!

Yours very truly,

Barry N. Watson
ASARCO Geologist

BNW/kw

J. H. C.
DEC 21 1966

Air Mail

December 19, 1966

Mr. J. D. Whitnell, Manager
Industrial Power Sales
Arizona Public Service Company
P.O. Box 2591
Phoenix, Arizona 85002

Dear Sir:

Reference is made to your letter of December 16 to Mr. Pollock. This has been referred to me for reply.

We carry on various kinds of exploration techniques for ore bodies all over the southwest. We have done a little work some distance south of Ajo. Although all results have not been analyzed, this work has not produced anything of interest. Therefore, there is no occasion to begin conversations about electric transmission systems. You can be assured that we will be in touch with you if we are fortunate enough to find an ore body in the southwest.

Yours very truly,

Kenyon Richard

Blcc: TASnedden
JHCourtright / both with attachment

ARIZONA PUBLIC SERVICE COMPANY
P. O. BOX 2591 • PHOENIX, ARIZONA 85002

RECEIVED
DEC 19 1966
K. RICHARD

December 16, 1966

RECEIVED
DEC 19 1966
C. P. POLLOCK

American Smelting and Refining Company
120 Broadway
New York, New York 10005

Attention: Mr. C. P. Pollock, Vice President, Exploration

Gentlemen:

We understand that your company has been conducting extensive exploratory work in the area south of Ajo in Pima County, Arizona. Since this is in our electric service area, we are, of course, interested in any development that you may be planning.

We have only one line into the area which is 21,000 volts and our capacity is somewhat limited.

I call this to your attention because at this time, it takes about a year and a half to secure such items as insulators and transformers to build electric transmission systems. Therefore, we must plan our construction ahead in order to give customers service when they desire it.

If there is any information that you feel you could release to us at this time, we would be very happy to keep it confident and use it to our mutual advantage. I will be glad to meet with any representative of yours at any time or place at your convenience to discuss the matter further.

Sincerely,

J. D. Whitnell, Manager
Industrial Power Sales

JDW/ah

Please Copy for KR 5/4/65

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

April 28, 1965

J. H. C.

READ AND RETURN ___ APR 28 1965
PREPARE ANSWERS ___ HANDLE ___
FILE ___ INITIALS ___

W.E.S.
APR 29 1965

TO: J. H. COURTRIGHT

FROM: J. E. KINNISON

PORPHYRY COPPER EXPLORATION
AJO DISTRICT, ARIZONA

When Mr. Robert Gale recently visited the Ajo pit, he was guided by Donald Dixon, the resident geologist.

Dixon stated that John Cooper of the U.S.G.S. had recently been in the district and that they discussed similarities between the Locomotive fanglomerate and Cooper's Helmet fanglomerate in the Pima district. The San Xavier thrust was also discussed (Basement fault, Asarco files). Dixon then mentioned such things as..."low angle fault offsets in the Ajo pit"..."possible exploration for ore effected by great displacement"..."drilling (exploration?) to the south of the pit, collared in fanglomerate." In short, then, Cooper may have caused the P.D. people to think about possible post-ore faults of large magnitude. To what extent this type of a program will be followed out, of course, there is no way of knowing. If we ever plan to suggest a joint exploration program, along the lines of my proposals for exploration of a few years back, the local people at Ajo might now be more receptive than in the past (for reference, refer to my memo to you of a year ago, 4/7/64, on this subject).

John E. Kinnison
JOHN E. KINNISON

JEK/jak

Copy for K Richard

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

May 7, 1964

J. H. C.

MAY 11 1964

MEMORANDUM FOR MR. J. H. COURTRIGHT:

Ajo, Exploration

At the A.I.M.E. trip to Ajo April 25, 1964 we learned that:

A. Some drill holes beneath the pit reach to about the 300-foot elev., or roughly 800 feet below the bottom of the pit. These holes leave porphyry and stop in rhyolite with only pyrite.

B. The staff geologist is attempting to put together a geologic history of the ore body, both for operational purposes and for expansion of reserves by future drilling.

Mr. Dixon, the resident geologist, largely accepts Gilluly's work on the district. Because my reconnaissance map and report on low-angle fault displacement was of a preliminary nature, it may be criticized in some details; I have a hunch that the people at Ajo would be skeptical if asked to review it in terms of a joint venture.

John E. Kinnison
JOHN E. KINNISON

JEK/jk

J. H. C.
SEP 1 5 1961

AMERICAN SMELTING AND REFINING COMPANY
MINING DEPARTMENT
120 BROADWAY, NEW YORK 5, N.Y.

K. R.
SEP 15 1961

C. P. POLLOCK
EXPLORATION MANAGER

CONFIDENTIAL

MR. ______ READ AND RETURN ______ PREPARE ANSWERS ______ HANDLE ______ FILE ______ INITIALS ______

AIRMAIL

September 14, 1961

Mr. K. E. Richard, Chief Geologist
Southwestern Mining Dept.
Tucson, Ariz.

Possible Roots Porphyry Copper Deposit -
Ajo District, Ariz.

Dear Mr. Richard:

I have now had an opportunity to discuss with Mr. Tittmann Mr. Kinnison's report dated August 25th suggesting a possible root of the New Cornelia orebody in the footwall of a flat basement fault beneath alluvium five to ten miles southeast of Ajo. As I understand Mr. Kinnison's theory, the Ajo situation would be similar to the basement fault in the Pima district in which you have speculated on the possibility of finding roots of the Mission orebody in the Twin Buttes area.

Mr. Tittmann agrees that we could not undertake an exploration project in the Ajo area at this time in view of our relations with Phelps Dodge in southern Peru. Furthermore, a project in that vicinity would not be feasible for any company other than P. D. due to the unavailability of water and other facilities in and around Ajo.

While Mr. Tittmann is reluctant to suggest a joint project to Phelps Dodge at this time, he will keep the matter in mind. In case there is an opportunity at some future time, he will casually mention the possbility to Phelps Dodge officials.

Mr. Kinnison should be complimented on his alertness in recognizing this possibility from studying the Govt. report.

I note you have left the original of Mr. Kinnison's report with me. I shall retain it as our file copy.

Yours very truly,

C. P. Pollock

C. P. POLLOCK

cc: EMcLTittmann
DJPope
TASnedden A/M (conf.)

Aa-16.1.0

MINING DEPT.
SEP 15 1961
TUCSON

T. A. S.
SEP 18 1961

CONFIDENTIAL

AIRMAIL

September 14, 1961

Mr. K. E. Richard, Chief Geologist
Southwestern Mining Dept.
Tucson, Ariz.

Possible Roots Porphyry Copper Deposit -
Ajo District, Ariz.

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Yours very truly,

C. P. POLLOCK

cc: EMcLTittmann
DJPope
TASnedden A/M (conf.)

Ao-15.1.9

AMERICAN SMELTING AND REFINING COMPANY
Tucson   Arizona

August 25, 1961

<u>Personal-Confidential</u>
Mr. Kenyon Richard, Chief Geologist
Southwestern Exploration Department
American Smelting and Refining Company
Tucson, Arizona

AJO DISTRICT, ARIZONA
<u>Porphyry Copper Exploration</u>

Dear Sir:

Herewith is my report on exploration possibilities in the vicinity of Ajo. For your convenience I am also sending a copy of my memorandum of 2/16/61, and your copy of Gilluly's Ajo paper.

Very truly yours,

JOHN E. KINNISON

JEK/z
cc: KERichard (original sent to New York, 3cc retained in Tucson)
JEKinnison

bcc: WESaegart
JHCourtright
AGBlucher

GEOLOGIC REPORT

Faulted Segment of the Ajo Ore Zone

The New Cornelia mine at Ajo has produced about 240 million tons of open pit copper ore; planned expansion may produce an equal amount in years to come. Production is 30,000 tons/day grading about 0.8% Cu.

The theory here presented is that after the Ajo ore deposit was formed, a low-dipping fault sliced through the ore body and displaced the upper half several miles from its original position. The Ajo ore zone, which lies in the hanging wall plate of this fault, constitutes the upper portion; the lower portion or "root", which remained stationary in the foot wall, now lies buried by younger formations. My belief is that the "root" lies some 5 or 10 miles southeast of Ajo near Black Mountain. Support for this opinion, and suggestions for exploration are given on the following pages.

LIST OF ATTACHMENTS

A. Geology of New Cornelia Mine. 1" = 2000'.

B. Pima District, diagrammatic sketch of Basement fault.

In Pocket

C. Reconnaissance Geology, Ajo District. 1" = 4 miles.

D. Geology of Ajo District. 1" = 1 mile.

INTRODUCTION

James Gilluly of the U.S.G.S. mapped Ajo in the 1930's (Prof. Paper 209, 1946). I suggested a re-interpretation of some of the structural features shown on Gilluly's map (Memo 2/16/61, J.E.K. to K.R.), and subsequently made a brief reconnaissance of the district. **The immediate purpose has been for general information rather than for a specific** exploration program.

CONCLUSIONS

From an examination of geologic features on the ground, I have somewhat revised Gilluly's map (see Att. B). It is almost a certainty that a huge post-ore fault dips at a low angle beneath the Ajo ore body. This fault, which I term the "Ajo Basement fault", surely cuts off the altered and mineralized Ajo ore zone, although whether it actually cuts off commercial grade ore, I cannot say for lack of knowledge of the ore values in depth much below the present pit.

In brief, it can be said that the "root" of this displaced altered zone, within which lies a major porphyry copper ore body, remains yet to be discovered. The exact position of this covered "root" is not now precisely defined, nor is it likely to be without the aid of geophysics.

I tentatively suggest that the "root" lies somewhere in the vicinity of Black Mountain, some 5 or perhaps 10 miles southeast of Ajo. Within this vaguely defined area it is impossible, on geologic grounds, to predict the depth to pre-mineral bedrock. The fact that some of the valleys near Ajo appear to be erosional rather than deep fault-block depressions leaves open the possibility that some bedrock in the valley areas might be within reach of I. P. surveys.

If it is decided to make an active effort in search of the Ajo "root" the following program will be required. Some additional geologic reconnaissance and special studies should be done as a preliminary, but I do not imply anything very extensive. A rather large target area would be selected for reconnaissance I. P. surveys. I imagine that as an aid in interpreting any anomalies which might be found, seismic surveys to determine bedrock depth would be valuable. Gravimetric and magnetic information might also be of use to the geophysical program.

Finally, I must note that Phelps Dodge Corporation may have drill hole information in the Ajo pit vicinity which could contribute materially to geologic interpretations. I might also note that geophysical surveys of the type suggested cannot be conducted in secret in this area.

GEOLOGIC SUMMARY

The general geology of the district is well described by Gilluly, so only a short background is here presented.

The legend on Att. B shows the geologic column. Paleozoic rocks are present locally at Growler pass south of Ajo (Att. C), and their former presence is shown by boulders of carboniferous limestone in the

Locomotive fanglomerate. The Concentrator volcanics are likely to be equivalents of the Tertiary Silver Bell-Cat Mountain group. On Att. C I have correlated the andesitic conglomerates at Growler pass with the Concentrator series.

In the open pit the intrusive is a monzonite porphyry which seems to me distinctly different from the Cornelia quartz monzonite, with which Gilluly had correlated it. I have shown this as a separate porphyry mass, although the limits are not accurately known.

The Locomotive fanglomerate, south of Ajo, is a thick sequence consisting alternately of well-bedded conglomerates, and massive thick mudflow members made of huge boulders and brecciated blocks. The Ajo volcanics made of dark gray andesite breccia intertongue with and, higher in the section, ultimately overlie the fanglomerate. The total thickness of this group of rocks may be 10,000 feet. The Age of the Locomotive fanglomerate is clearly post-ore, and possibly middle Tertiary. Fragments of altered porphyry occur near the base, but are virtually absent throughout the rest of the unit, demonstrating that the ore body was covered early in Locomotive time.

Rocks younger than the Ajo volcanics are mostly volcanic flows, and have been tilted only to a minor degree, whereas the Ajo volcanics dip steeply.

The valley between the Little Ajo mountains and the Growler mountains is formed principally by erosion (see Att C), for the basalts which cap the Growler mountains extend without apparent fault displacement onto the west and south slopes of the Little Ajo range. The Valley of the Ajo between the Batamote and Little Ajo ranges seems to be formed by erosion of a shallow syncline. The depth of alluvial material is great in places, as shown by Childs well near Ajo (Att. D).

MINERALIZATION

The New Cornelia mine is the only ore body in the district. Here a monzonite plug has intruded the Concentrator volcanics, and in an area about a mile wide all rocks have been pervasively altered and impregnated with chalcopyrite and pyrite.

In viewing the Ajo ore body as it now appears, it must be remembered that the plan view more closely approximates the original cross section of the ore body, for it has been tilted south about 60°. The geologic plan and cross section shown in Att. A gives the salient features. Two things are somewhat unique: (1) The limit of alteration (on the west where I could see it) is also the approximate limit of the ore body. (2) The total percent of sulphides is relatively low--about 2 or 3 percent.

South of Ajo some drilling has been directed at oxidized copper showings. These appear at widely scattered localities beginning not far south of the pit, and forming a zone about a mile wide these prospects continue to appear some four miles to the south. The minerals are all supergene, and coat fractures in the Locomotive fanglomerate and Ajo volcanics.

Since the values die out in depth they must be attributed to ground water and streams flowing south from the pit area at some time in the past, and depositing exotic copper minerals. These showings definitely are not derived from copper carried in as boulders in the Locomotive fanglomerate.

I have examined all areas I could find where pre-mineral rocks crop out in the Ajo district. There are no porphyry copper type altered zones exposed. A short distance southeast of Salt wall (south of Childs mt.) a small area of weakly copper stained rock is present, but pervasive alteration and evidence of disseminated sulphides occurs only as small pods. This is not considered to be a lead.

Across the valley southeast of Ajo, at Copper mountain, a monzonite plug arises as an isolated outcrop surrounded by alluvium (Att. C). The monzonite is weakly altered locally, and is cut by narrow quartz-chalcopyrite stringers. Several old drill holes show that the average copper content is nil. This prospect is not a direct lead, although it does exhibit some features of porphyry copper aspect.

Near Growler pass a few narrow veins have been explored for silver.

AJO BASEMENT FAULT

Basis for the hypothesis. -- The Locomotive fanglomerate and Ajo volcanics dip steeply south. Near the open pit the strike of the beds suggest that the fanglomerate wedges out against the erosional surface at its base.

As shown on Att. D, note that the entire section of fanglomerate and Ajo volcanics are faulted out by the Chico Shuni fault. Gilluly believed this to be a hinge fault with great displacement on the south. He commented that north of North Ajo peak the contact between Cardigan gneiss and Cornelia quartz monzonite shows no displacement along the strike projection of the fault, but "the throw (farther south) must be at least 3500 feet, and it is probably still more."

On another page, Gilluly cites an example of the irregular surface on which the Locomotive fanglomerate lies:

> "...on the extreme western spur of North Ajo Peak... the north face is composed of fanglomerate... conformably overlain by the Ajo volcanics (see attached sketch). The formation is now tilted so that it has a dip of about 45°...; nevertheless, the Cardigan gneiss underlies the spur at about the same altitude on both sides, showing that the original hill slope against which the sedimentary formations were deposited had a northward slope on the order of 40°."

This is, indeed, a most unusual slope, as is the hinge action on the Chico Shunl fault rather startling. Here I will begin the low-angle fault hypothesis.

Discussion of the fault. -- On the spur off North Ajo Peak the geometrical relationships are quite as Gilluly described them. The contact between gneiss and Locomotive/Ajo volcanics may be traced around the rim of the spur, and the bedding in the fanglomerate dips from 60° to locally almost 50°. Some of the most western outcrops are detached erosional remnants, and this contact may be traced circularly around knobs of the fanglomerate. It seems to me unreasonable to suppose that this is a depositional contact. Furthermore, the gneiss becomes somewhat sheared and laced withchlorite as the contact is approached, and in a gully on the north side the contact is exposed and appears to be a zone of gouge and breccia. I interpret this critical exposure to represent a very low dipping fault -- the Ajo Basement fault -- along which the Locomotive/Ajo group is brought into contact with a footwall plate of Cardigan gneiss.

Utilizing this explanation, the Chico Shuni fault may be simply interpreted. The outcrop on the little spur is a Klippe. The Chico Shuni fault may have only a few hundred feet of displacement to drop the low-dipping fault out of sight on the east; all but a small remnant of the hangingwall plate was eroded from the west side while 2 miles of tilted strata were preserved on the east, down-dropped side. The Ruby fault in the Pima district effects precisely this outcrop pattern, by dropping the "Basement fault" about 200 feet on the east (refer to Pima district map), causing 3 miles of tilted San Xavier formation to be preserved on the east side and leaving a few erosional Klippen on the west. In both these examples the high angle fault -- the one easily recognized on the surface -- is caused to have an apparently great vertical displacement and hinge-fault action, whereas the great movement actually took place along a low-angle fault. Please note cross section A-A, Att. D.

Another outcrop which may be a Klippe lies a mile south of Salt well. Here Locomotive fanglomerate appears to underlie Ajo volcanics. The exposure is too poor to offer comment on attitude of beds or contacts. (Gilluly had mapped Sneed andesite here and farther south. Att. D shows rock correlations which I prefer.)

The extension of the Ajo Basement fault east toward the pit is generally covered with alluvium at the base of the mountain slope, and no clean exposures exist. The line as shown on Att. D appears to have a dip of 20 to 30 degrees, which is steeper than I have postulated. This may be due to local folding, or perhaps the fault mapped is really a younger one which cuts the basement fault.

In Gibson arroyo, just west of Cardigan camp, a fault zone 10 feet thick, exposed by several prospect pits, strikes north and dips 10° east. It is flooded with transported limonite. I have shown this as a small remnant of the basement fault remaining west of the Gibson fault. A churn drill hole in Gibson arroyo (Att. D) penetrated this limonite-filled fault zone on the east, downdropped side of the Gibson fault. A second churn drill hole farther north appears, based on examination of the sludge pile, to have drilled through granitic rock, and then into red alluvial material or gouge. This hole may have penetrated a wedge of Locomotive fanglomerate carried along the Ajo Basement fault. The Gibson fault may have less movement than Gilluly estimated, because the great difference in rock type on either side is due mainly to the fact that the Ajo side exposes only the hangingwall plate of the basement fault.

THE AJO "ROOT"

The recognition that the basement fault exists, and that it appears to be of great magnitude, does little to aid the resolution of the point of origin of the "root" of the Ajo altered zone.

The reconnaissance map (Att. C) illustrates the abundance of post-ore cover outside the Little Ajo mountains.

In the quadrant to the southwest of Ajo, bedrock exposures and alluvial material derived from that general area (Daniels conglomerate) show no indication of porphyry copper alteration types. The Ajo deposit did not originate there. Elsewhere in the district there are no clues sufficiently positive to be of assistance.

In an effort to analyze the geologic history by a comparative method, I have found a most striking similarity between the Ajo Basement fault, and the Basement fault in the Pima district (Cooper's San Xavier thrust).

Reference should be made to Att. D, cross section B-B. The basement fault must come to the bedrock sub-outcrop near the southern boundary of Att. D, because pre-fanglomerate rocks are there exposed. The Bluestone drill holes near the Ajo pit failed to penetrate the fault at their bottom, about 2000 feet deep. The dip is established, then, as being dominantly to the north.

The Little Ajo mountain fault dips north where exposed. The fanglomerate north of this fault lies nearly horizontal, although steep dips are found near the fault. Actually, stratification is almost absent in the fanglomerate outcrops north of Ajo. A single mudflow breccia seems to be the only unit exposed, and must therefore lie generally flat, else other members of the formation would be apparent.

Now compare the cross section B-B (Att. D) with the sketch of the Pima basement fault on Att. B. The geometry of the Pima fault is well known, and using this as a guide, I have interpretatively drawn in the Ajo Basement fault in a way which emphasizes the striking similarity of these two great structures. Note in both cases that a great thickness of Tertiary layered rocks dips about 40-60° in one direction, and the fault dips 10° in the opposite way. Then the layered sequence is brought down on a major fault and lies horizontally (at Ajo, the Little Ajo mountain fault). The movement in the Pima area is known to be about 6 miles in a down-dip direction.

I have expressly refrained from using the term "thrust fault" in connection with the Ajo Basement fault. The Pima Basement fault shown on Att. B is known to have moved the hangingwall plate down-dip, in part at least, as if it were a free-sliding detached mass, propelled by gravity. Thick sections of fanglomerate appear at many places in southern Arizona, and are frequently found to be tilted and involved in low-angle faulting of this type. Little is known at this time concerning the formation of these excessively thick alluvial basins, or of the mountain building processes which then act to tilt and slide them about. If they have similar origins, then a comparative analysis such as I have presented may be valid.

Under the first heading, "Conclusions", I have already summarized the result of this comparison in terms of exploration. My conclusions must obviously be regarded with caution.

In the vicinity southeast of Black mountain, an area of high level dissected alluvium is made of diverse pre-basalt rock types, suggesting derivation from an underlying source of Locomotive fanglomerate. This suggests that a shallow depth of Quaternary alluvium exists in that area.

Two features of the Ajo altered zone combine to make detection by I. P. surveys difficult if the "root" is deeply buried. (1) The low percentage of total sulphides; (2) The lack of a wide halo of marginal alteration. These features, of course, may not be typical of the entire altered zone, for at Ajo only a limited portion may be seen.

JOHN E. KINNISON

JEK/z

J. H. C.

MAR 9 1961

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona
February 16, 1961

MEMORANDUM FOR KENYON RICHARD

PORPHYRY COPPER EXPLORATION
AJO DISTRICT

Introduction

The Ajo district and the New Cornelia mine may lie on a great post-ore fault dipping at a low angle easterly.

I have not been personally on the ground at Ajo; the foregoing possibility is suggested by an analysis of James Gilluly's work reported in USGS Professional Paper 209 (1946).

For reasons set forth below this postulated fault is similar to the "Basement Fault" at Mission. Although there may or may not be economic justification for Company involvement in such a problem, it is at least of scientific interest in view of our studies of the Mission-Twin Buttes fault problem, and Ajo should be investigated briefly in this light.

Basis for the Hypothesis

The pre-ore rocks at Ajo, broadly speaking, consist of a pre-Cambrian basement overlain by the Concentrator volcanics and intruded by the Cornelia quartz monzonite. The Chico shuni quartz monzonite was emplaced prior to Concentrator extrusion. These rocks are mineralized, and overlain by the post-ore Locomotive fanglomerate, Ajo volcanics, and younger basaltic rocks.

The attached map copied from Gilluly shows the Locomotive fanglomerate to dip south, overlain conformably (partly intertongued) by the Ajo volcanics. Near the Ajo Pit and for some distance west, the strike of the beds in the Locomotive suggest that it wedges out against the erosional surface at its base.

However, note that the entire section of Locomotive and Ajo volcanics are faulted out by the Chico Shuni fault. This fault must have a huge displacement in order to cut out thousands of feet of rock -- yet it must die abruptly, north of the Locomotive fanglomerate, because the contact between the Cornelia quartz monzonite and Cardigan gneiss shows no displacement along the fault's projection. Gilluly noted this, and commented that north of the Locomotive fanglomerate basal contact on Cardigan gneiss, the Chico Shuni fault "must die out within a few hundred feet in this (north) direction", but "the throw (in its southern extent) must be at least 3500 feet, and it is probably still more."

Gilluly cites an example of the irregular surface on which the Locomotive fanglomerate lies:

> "...on the extreme western spur of North Ajo Peak... the north face is composed of fanglomerate... conformably overlain by the Ajo volcanics (see attached sketch). The formation is now tilted so that it has a dip of about 40°....; nevertheless, the Cardigan gneiss underlies the spur at about the same altitude on both sides, showing that the original hill slope against which the sedimentary formations were deposited had a northward slope on the order of 40°."

This is, indeed, a most unusual slope, as is the hinge action on the Chico Shuni fault rather startling. The contact on this little spur described above was not discussed as though it were actually exposed, and here I will begin the low-angle fault hypothesis.

If this contact is a low-angle fault, the outcrop on the little spur is a Klippe. Then the Chico Shuni fault might have had but a few hundred feet of displacement to drop the low-dipping fault out of sight on the east; all but a small remnant of the hangingwall plate was eroded from the west side while 2 miles of tilted strata were preserved on the east, down-dropped side. The Ruby fault in the Pima district effects precisely this outcrop pattern, by dropping the "Basement fault" about 200 feet on the east (refer to Pima district map), causing 3 miles of tilted San Xavier formation to be preserved on the east side and leaving a few erosional Klippen on the west. In both these examples the high angle fault -- the one easily recognized on the surface -- is caused to have an apparently great vertical displacement and hinge-fault action, whereas the great movement actually took place along a low-angle fault.

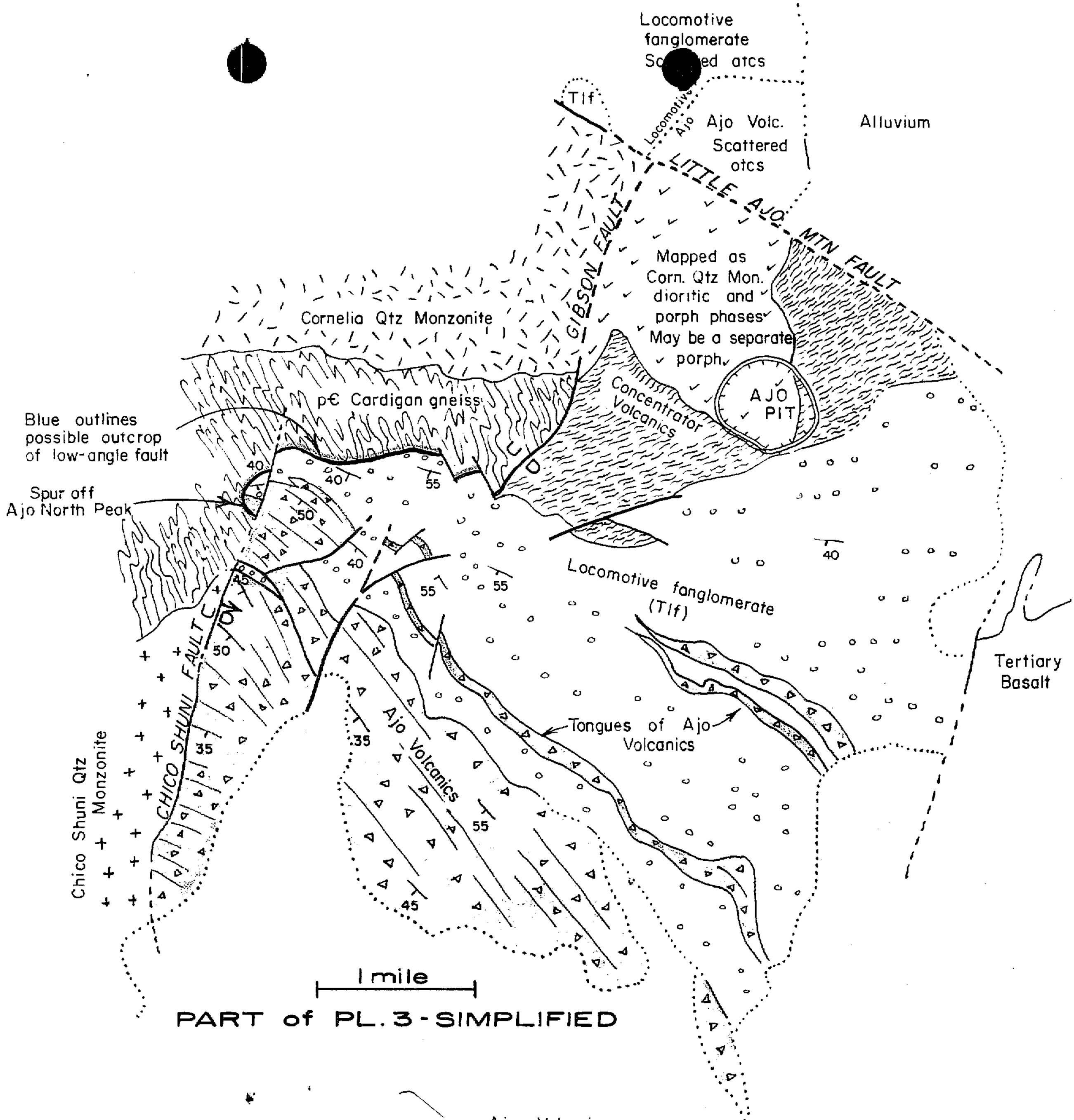
The contact between Locomotive fanglomerate and Cardigan gneiss, where it lies between the Chico Shuni and Gibson faults, is mapped as covered along most of its length, and everywhere occurs at the base of the hill slope. This would be the trace of the low-angle fault, misinterpreted by Gilluly as the extension of the sedimentary contact at the base of the Locomotive as it appears near the Ajo pit.

Gilluly estimated the Gibson fault to have a minimum displacement of 4000 feet. He notes that "it apparently does not disturb" the Locomotive fanglomerate (underline mine). The Gibson fault may now be interpreted to have a small to moderate displacement, enough only to submerge from view the low-angle fault, as does the Chico Shuni fault farther to the west.

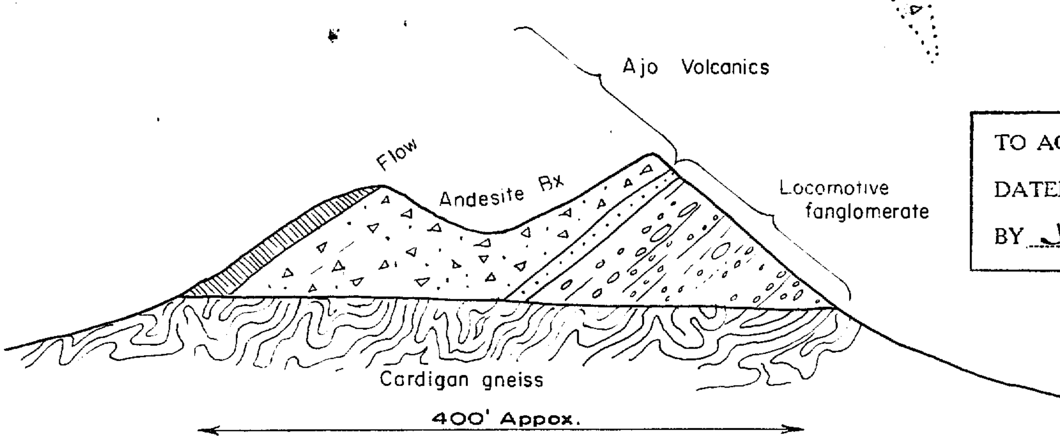
ORIGINAL SIGNED BY
JOHN E. KINNISON

JOHN E. KINNISON

Attachments
JEK/ds
cc: JHCourtright
AGBlucher



PART of PL. 3 - SIMPLIFIED



COPIED from FIG. 5, p. 36
Sketch Section, Spur west of North Ajo Peak

TO ACCOMPANY Meme
DATED Feb. 16, 1961
BY J. E. Kinnison

AJO DISTRICT

Modified from Prof. Paper 209 - James Gilluly, 1946 - J.E.K.

Ajo - Ariz - Mar. 24, 1949
reserves - + 200 M tons
Pit bottom level - 1460

40' benches - 80' wide
ultimate slope 1:1 -
1½ : 1 on SW

3% grade on ore haulage
30 cu yd hyd side dump cars
diesel electric motors -

9½ inch blast holes - 15' spacing
29 T Bucyrus cat mount -

Concentrator - 28000 tons -
Heads .8% Cu - .01 NS
3% sulphides (2% Fe)
.006 Au, .07 Ag. Conc 30% Cu
Recov 90% - 200 gpt fresh water
- Recov 80% water -

Ajo Visit - Mar 24, 1949

Mill heads (28000 tpd)

Tot. Cu	NS	Au	Ag
.8%	.01	.006	.07

Mill Rec. 90%

J.H.G.

(See over)

T-1.1

See also Aa-16.1.0

AMERICAN SMELTING AND REFINING COMPANY
Tucson, Arizona

March 4, 1949

MEMORANDUM TO:

Mr. F. V. Richard

PHELPS DODGE CORPORATION
AJO, ARIZONA
CHURN DRILL EXPLORATION

On February 28th Mr. Playter and myself made a brief inspection of churn drill operations in the New Cornelia Mine, located at Ajo, Arizona. Mr. Lentz, Chief Engineer of the Mining Division, kindly arranged for a tour of the open pit. In the following, a few points worthy of note in connection with porphyry copper exploration are discussed.

Of special interest is the fact that the churn drill is now used for exploratory purposes in a disseminated copper deposit that was originally explored and measured by diamond drilling. No specific reference is at hand, however, it is generally considered that extraction checked fairly well with estimates based on the diamond drilling. This means of sampling was discontinued in 1936. According to local information churn drill exploration was adopted for three reasons:

(1) Churn drill rigs used for blast hole drilling were available for prospect work,

(2) Lower costs per foot than in diamond drilling, and

(3) The churn drill provided a larger and, therefore, a more representative sample, thus more reliable as a basis for reserve estimates.

In contrast, at two other major porphyry copper deposits, Chino and Bingham Canyon, Kennecott Copper Corporation has discontinued churn drilling and adopted diamond drilling for exploratory work.

The Ore - The deposit, a porphyry copper of the primary type, occurs in a rather hard, fresh appearing monzonite. The copper is present as chalcopyrite with minor bornite in very narrow irregular seams for the most part. Ore reserves are said to total around 200 million tons.

Churn Drilling - Present exploration consists of churn drilling to depths of 400 or 500 feet below the pit bottom. The drills, operated by the company, are Bucyrus 29 and 42T's, Caterpillar track mounted. The holes are drilled 9-1/2 inches in diameter, without casing.

Sampling - Samples are taken at 5 foot intervals by means of a dart valve type bailer. A "blast hole" splitter, consisting of a narrow upright orfice located in the center of the launder below the dump box, extracts a 1/16 portion of the sludge which is further reduced to two gallons in volume by a Jones-type splitter. A one pint portion is saved for laboratory examination and for preparation of a sludge board.

Mr. Lentz stated that close supervision over the sampling and assaying was found to be necessary to obtain reliable results. Accuracy in sampling is of considerable importance here in view of the extreme irregularity of the ore. He stated further that he believed the churn drill sample to be more reliable than the diamond drill sample as a basis for ore reserve estimates.

J. H. COURTRIGHT
J. H. Courtright

JHC:cms
cc-D. J. Pope
Silver Bell - 2

T.H.C.

THE STORY OF MINING CONCENTRATING AND SMELTING AT THE NEW CORNELIA BRANCH OF THE PHELPS DODGE CORPORATION AJO, ARIZONA

JANUARY 1, 1964

HISTORY OF AJO

Earliest Mining Attempts

Prior to 1854 Probably no one will ever accurately trace the history of Ajo from its beginnings. When the first Americans arrived in Ajo in 1854, they found abandoned workings, rawhide ore buckets, and crude tools as mute evidence of earlier attempts to mine the small veins of native copper, cuprite and chalcocite occurring in the three small hills that stood where the modern open pit mine is today. It is probable that Mexican miners from some of the silver mines in Sonora had prospected as far north as Ajo in quest of silver ore, worked the veins for a short time and finally abandoned them because of low values in precious metals.

1853 The Gadsden Purchase. This area becomes a part of the United States.

1854 The first Americans to mine in Arizona, known as the Arizona Mining and Trading Company, arrived in Ajo in October, 1854. The names of the men in the party as far as is known were Peter R. Brady, F. Ronstadt, E. E. Dunbar, G. Kibbers, Geo. Williams, Joe Yancy, Dr. Webster, Charles Hayward, McElroy, Porter, Bendel and Cook.

1855 Mining was mostly confined to small bodies of native copper and cuprite ores. The ore mined was hauled by horse and mule teams to San Diego, California, and Yuma, Arizona, and from these ports was transported in sailing ships to Swansea, Wales, for smelting.

1859 The Arizona Mining and Trading Company failed.

1860 to 1890 Intermittent attempts to exploit the deposits followed, but the lack of water and the difficulties of transportation prevented success. Among the prospectors who persisted in these attempts were Tom Childs and Reuben Daniels, who by the late 1890's had acquired many claims in the area.

In the meantime the Civil War was fought and later the Southern Pacific Railroad built a railroad across southern Arizona within forty-four miles of Ajo.

Period of Fraud and Folly

1890 to 1899 A. J. Shotwell, a fake mine promoter and swindler, interested John R. Boddie of St. Louis and others in the Ajo mines and they organized the St. Louis Copper Company.

Shotwell organized the "Rescue Copper Company" to rescue the St. Louis Copper Company.

Shotwell, Boddie, Capt. Huie, W. W. Brown, E. E. Neely and others formed the Cornelia Copper Company. The name "Cornelia," was in honor of Boddie's first wife. The Shotwell Tri-Mountain Copper Company was also organized.

1900 to 1907 A weird invention called the "Rendall Process," which it was claimed "would treat all classes of copper ore with equal facility," was tried out by the Rendall Ore Reduction Company which had optioned some of the Ajo claims. The Rendall Process proved to be a complete failure.

The Rescue Copper Company, the Shotwell Tri-Mountain Copper Company, and the Cornelia Copper Company merged under the ownership of the Cornelia Copper Company.

The mystifying McGahn Vacuum Smelter was built at Ajo at a cost of $34,000. This invention of "Professor" Fred L. McGahn "would melt the ore and pure gold, silver, copper, etc., which would then be drawn off in separate spigots. After the furnace was once started, the oxygen and hydrogen gases which escaped from the ore would be used to fire the furnace and the purchase of any other fuel would be unnecessary." The McGahn Smelter produced nothing but a vacuum in the pockets of those who invested in it.

Shotwell and McGahn disappeared from the Ajo scene.

Boddie and his stockholders invested $20,000 in a hydrofluoric-acid leaching process almost as fantastic as the vacuum smelter. This leaching plant did produce a few pounds of copper at a cost of a dollar a pound.

1907 Panic of 1907. Ajo again became practically deserted.

Period of Scientific Error

1908 to 1910 Success at the Utah Copper Company at Bingham Canyon, Utah, put an entirely new aspect on low-grade copper deposits. The desert was alive with engineers hunting for the new "porphyries." The big copper companies were actually bidding against each other for a chance to develop Boddie's folly. The General Development Company, headed by Mr. J. Park Channing, secured an option on a majority of stock of the reorganized New Cornelia Copper Company. Mr. Seeley W. Mudd, and associates optioned the Rendall Ore Reduction Company's claims on the south edge of the Ajo basin. A group of English capitalists took an option from Tom Childs on some outlying claims in the Ajo basin. The engineers of these three companies were among the greatest in the world. In the course of their prior successes they had acquired theories that guided the development they planned. Strange to say, all three theories were different but they all agreed that the three hills on the New Cornelia property contained a fair amount of copper, but the rock was far too hard to allow for the necessary mineral enrichment. None of the companies drilled in the hills and all three failed to find the ore body.

Period of Successful Development

1911 to 1916 Capt. John C. Greenway, the new manager of the Calumet and Arizona Mining Company directed the company's geologist, Ira B. Joralemon, to find an open pit copper mine. Joralemon, who had passed through Ajo in 1909, decided it might be worth a try to return to Ajo to see what was under the three Ajo hills which the big mining companies had by-passed in their drilling. A few days of study and sampling convinced Joralemon that there might be a great mine at Ajo.

Greenway optioned 70% of the New Cornelia Copper Company's stock from John R. Boddie.

Within two years, 25,000 feet of drilling proved that the Ajo hills were underlain by millions of tons of 1.5 percent ore--Carbonate ores on top and sulphide ores below.

There was still no known method for treating the carbonate ores. Greenway employed Dr. Louis D. Ricketts to help solve the problem. After three years of experimentation, Greenway, Ricketts and dozens of chemists and metallurgists developed a successful miniature one-ton leaching plant at Douglas, Arizona.

A 40-ton pilot leaching plant was built at Ajo and operated successfully.

By drilling a well six miles north of Ajo, sufficient water was found to conduct a large-scale operation.

The Tucson, Cornelia and Gila Bend Railroad from Gila Bend to Ajo was completed in February, 1916.

Period of Operation and Growth

1917 A 5,000-ton leaching plant was built and began operations. First electrolytic copper shipped on May 1, 1917.

1919 Work began on the test mill for the sulphide ores in September.

1922 Construction of a 5,000-ton flotation concentrator was begun in October, 1922, and ore dressing operations started on January 8, 1924.

1926 to 1930 During 1928 and 1929 the daily production was increased to 8,000 tons by the addition of three treatment units.

In 1929 the New Cornelia Copper Company was consolidated with the Calumet and Arizona Mining Company.

The Leaching Plant ceased operations in 1930 after all the carbonate ore had been mined. More than 16 million tons of carbonate ore had been treated.

1931 Calumet and Arizona Mining Company merged with the Phelps Dodge Corporation, and this mine became known as the New Cornelia Branch of the Phelps Dodge Corporation.

1932 World economic conditions forced a shutdown of the operations on April 20, 1932.

1934 Production was resumed on July 2, 1934.

1934 to 1940 Alterations were made in the Concentrator which increased its capacity to 16,000 tons a day.

The Electric shovels replaced the steam shovels in the pit.

1940 to 1950 The Electrification of mine haulage system was completed in 1947. Electric locomotives replaced the steam locomotives.

The Concentrator capacity was increased to 20,000 tons per day.

1950 to 1961 The Concentrator was further increased to over 30,000 tons per day.

The Smelter was completed and first anodes were produced on July 14, 1950.

The Rotary Drills replaced Churn Drills for blast hole drilling in 1955.

* * * * * * * * * * * * *

From 1916 to January 1, 1964, 551 million tons of rock had been mined from the open pit operations of which 263 million tons were ore and 288 million tons were waste material.

Since 1916 over $55,000,000 has been expended on the development of the open pit mine, construction of a mill, smelter, power plant, shops, and purchase of equipment. Housing, a hospital, a store, a theater, recreational facilities, and other elements essential to the modern American community have been provided.

The New Cornelia Branch operations provide direct employment for approximately 1,400 persons, which represents an annual payroll of over $10,500,000.

The New Cornelia Branch of the Phelps Dodge Corporation is now the second largest copper producer in the State of Arizona and the third largest in the United States.

MINING

The New Cornelia ore body is a low grade, disseminated copper deposit, occurring in a hard rock formation classified as quartz monzonite porphyry. The principal ore minerals are chalcopyrite and bornite. The ore body has been developed by open pit methods which require the additional removal of large tonnages of associated rock formations having no economic value. The pit now covers an area of approximately 400 acres and has reached a depth of about 720 feet below the average rim elevation. Mining operations are conducted on levels or benches, which are normally established at vertical intervals of 40 feet in the ore body and 33 feet in the south end stripping. Present production is at a rate of 31,000 tons of ore and 47,000 tons of waste per day.

All material within the scope of the pit operations must be broken by blasting, and the mining cycle begins with the drilling of a series of blast holes. These are located near the edge of a bank and are drilled somewhat deeper than the height of the bank to be blasted.

The New Cornelia ore body is overlain in the south portion of the pit by a tough, blocky fanglomerate which constitutes a drilling problem separate from that of the ore body. In this area, 7-inch diameter holes inclined 20 degrees from the vertical are drilled by heavy percussion "Down-the-Hole" drills in which the hammer type drill follows the bit down the hole. Heavy rotary drill machines are used for drilling 12¼-inch diameter holes in areas other than the fanglomerate.

These primary blast holes are each loaded with from 200 to 1,200 pounds of explosives, the exact amount depending on the type of rock and the dimensions of the holes and bank. All holes in a series are connected together with a detonating fuse and are fired as a unit. A typical rotary drill hole blast will break about 60,000 tons of rock.

After primary blasting, some portions of the broken rock may still be too large to handle in loading operations. The further reduction of such material is accomplished by one of three methods depending on its nature and accessibility; these are (1) blockholing by which small diameter holes are drilled into the boulders or unbroken rock and blasted with small amounts of explosives, (2) "adobe" blasting by which an explosive charge is applied to the surface of a boulder and covered with a layer of mud, and (3) drop-ball by which a 6-ton steel ball is dropped on the boulders by a large mobile crane.

The broken material is loaded into haulage units by electric-powered shovels equipped with dippers ranging from 6 to 9 cubic yards capacity.

Rail haulage units normally consist of a 125-ton locomotive with seven to eight 30-cubic yard, side-dump cars. Each car carries a payload of 65 tons. Locomotives are Diesel-electric units with rated horsepower of 1200, 1750 and 2250.

Truck haulage units consist of 25-ton capacity rear dump trucks, which are used at various times on the upper level stripping areas. A combination truck and train haulage operation is used when developing a new level in the bottom.

The railroad track is built in panels or sections normally 39 feet in length. The track is moved with a crane as mining progresses. Main line tracks connecting the various levels of the pit with the crusher and waste dumps are laid on a maximum grade of 3%. Rail traffic over the main line haulage system is controlled by a dispatcher through the use of two-way radio communications, power track switches and signal lights. Forty-seven miles of standard gauge railroad track are in use and the haul from the bottom level of the pit is 6.45 miles to the waste dumps and 5.34 miles to the crushers.

CRUSHING

The purpose of the crushing plant is to reduce the size of the ore by stages to a minus 5/16ths of an inch product. The mined ore is dumped into a receiving hopper and the ore is transported on an apron feeder to the primary crusher where it is reduced in size to about 8 inches. The ore then is conveyed to the intermediate crusher bins and then is fed by apron feeders and conveyors to grizzlies. The minus one-inch size material passes through the grizzlies to conveyors and is transferred to the screen bin. The material passing over the grizzlies goes through the intermediate crushers where it is reduced in size to a minus 1½-inch product and is then conveyed to the screen bin. The ore then passes over a series of vibrating screens; the minus 5/16-inch product goes through the screens and is conveyed to the mill ore bin; the oversize is routed to the fine crushers and then returned to the screens.

CONCENTRATING

Rubber covered conveyors carry the ore from the crushing plant to the mill bins from which the material is drawn and fed into the ball mills with water. The ball mills are long steel cylinders containing about 30 tons of steel balls. The grinding action takes place as the mills revolve, and the balls within tumble and roll and crush the ore particles between themselves and between the balls and the sides of the mill.

Extra amounts of water are added as the pulp flows from the mill to the classifier which separates the fine and coarse particles of ore. The degree of fineness of the grinding product depends upon the dilution in the classifier. Rotating spirals in the classifier tank return the coarse material to the ball mill for further treatment. The ore which has been ground finely enough overflows the classifier in a more dilute pulp and proceeds to the flotation machines.

Chemicals which were added during the grinding stage and just prior to flotation serve to separate the copper minerals from the unwanted gangue minerals such as quartz, mica and feldspars. Low-pressure air is blown into the flotation cells; the small mineral particles (less than 35-mesh in size) have a natural affinity for the air bubbles and are lifted through the pulp on the rising bubbles which form a froth on the top of the flotation cell; this froth is removed into launders at the sides of the machine. This concentrate contains all of the copper that has been extracted from the raw ore; the worthless material (or tailing) discharges from the bottom of the flotation cell, and, after thickening to recover water for re-use, is pumped to the tailing dams.

The concentrate, which now assays about 30% copper, is thickened and routed to the filter plant where most of the remaining water is removed by filtration. A filter consists of a rotating cylinder which is connected to a vacuum system. As the filter rotates through the concentrate in the filter tank, the vacuum sucks the concentrate onto the drum and holds it there while water is being removed; the barely moist filter cake is removed from the filter and falls onto the first of several conveyors which carry it to the smelter.

The efficiency of the concentrating process is illustrated by the relative recoveries of the ore constituents; about 90% of the desired copper is contained in the concentrate, whereas only 1/3 of one percent of the gangue minerals are sent to the smelter.

SMELTING

When filtered concentrates arrive by conveyor at the Smelter building, they are discharged into containers holding about 10 tons each. The containers, or "cans," are carried by overhead crane to the reverberatory furnace which is about 100 feet long, 30 feet wide, and 11 feet high. The concentrate is dropped from the cans into machines called slingers, which charge the material into the furnace through openings in the sidewalls. The main purpose of the furnace is to melt the concentrate. This is done by firing with a large amount of natural gas. Melted concentrate accumulates in the bottom of the furnace making a pool or "bath" about four feet deep. The lighter components of the bath rise to the top making a "slag" which is periodically skimmed off and is a waste product. The heavier (copper-bearing) part of the bath seeks a lower level and is withdrawn into ladles for further treatment. This product is called "matte" and is composed primarily of copper, iron and sulphur. As the slag and matte are withdrawn from the furnace, more concentrate is added; the melting process proceeds continuously.

The next step in the smelting process is converting the liquid matte into metallic copper. Periodically, several ladles of liquid matte are transferred from the reverberatory furnace to one of the converters, which are cylindrical furnaces 30 feet long and 13 feet in diameter; low pressure air is blown through the liquid material. Oxygen in the air unites with sulphur to form sulphur dioxide gas which goes through the flue system to the chimney or stack. The iron in the matte is also oxidized and when silica ore is added to the converter, the iron oxide and silica combine to make a slag which is skimmed off and returned to the reverberatory furnace. This process is repeated until a charge of "blister" copper (about 50 tons) is left in the converter.

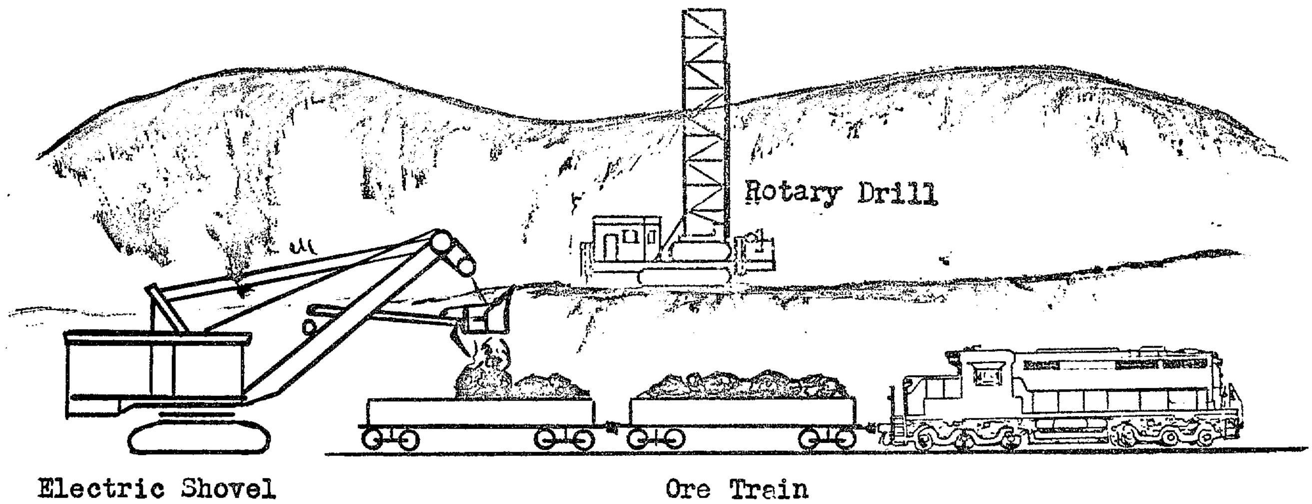
Blister copper, which contains a small amount of sulphur, is transferred from the converter by ladle and crane to a smaller vessel which is called an "oxidizing" furnace. Air is blown through the liquid copper until all the sulphur is removed, leaving in the copper a small excess of oxygen.

The copper is then transferred to the anode furnace where it is accumulated for a twenty-four hour period and then refined by blowing a reducing gas (reformed mixture of natural gas and air) through the molten charge. The carbon in the gas unites with the oxygen in the copper, thereby purifying it. When nearly all the oxygen has been eliminated, the copper is cast into 700-pound bars called anodes which are shipped to El Paso where they are put through the electrolytic process for further refining and for recovery of the small amount of gold and silver that is carried with the copper through the smelter.

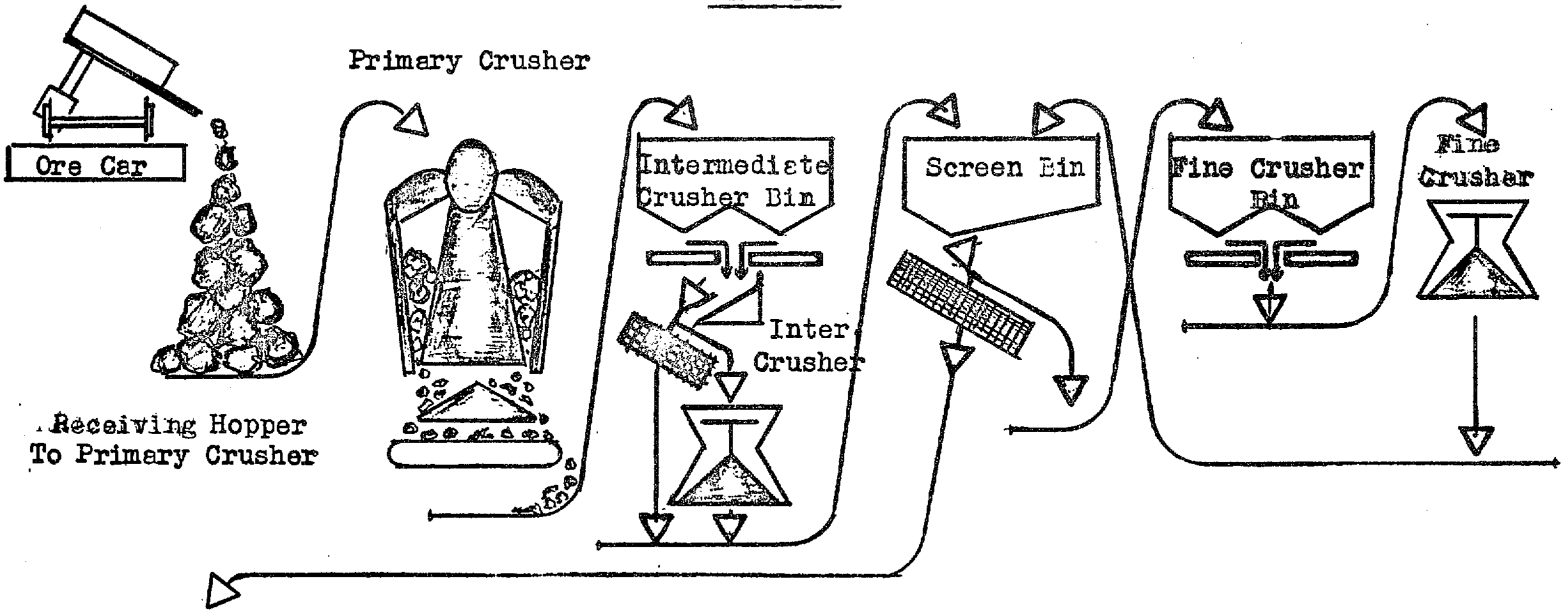
Gases from the reverberatory furnace pass through a pair of boilers, which make supplemental steam for use in the power house. All gases pass through a Cottrell Plant, where valuable dust is recovered before the gases pass to the chimney which is 360 feet high and 15 feet in diameter at the top.

*   *   *   *   *

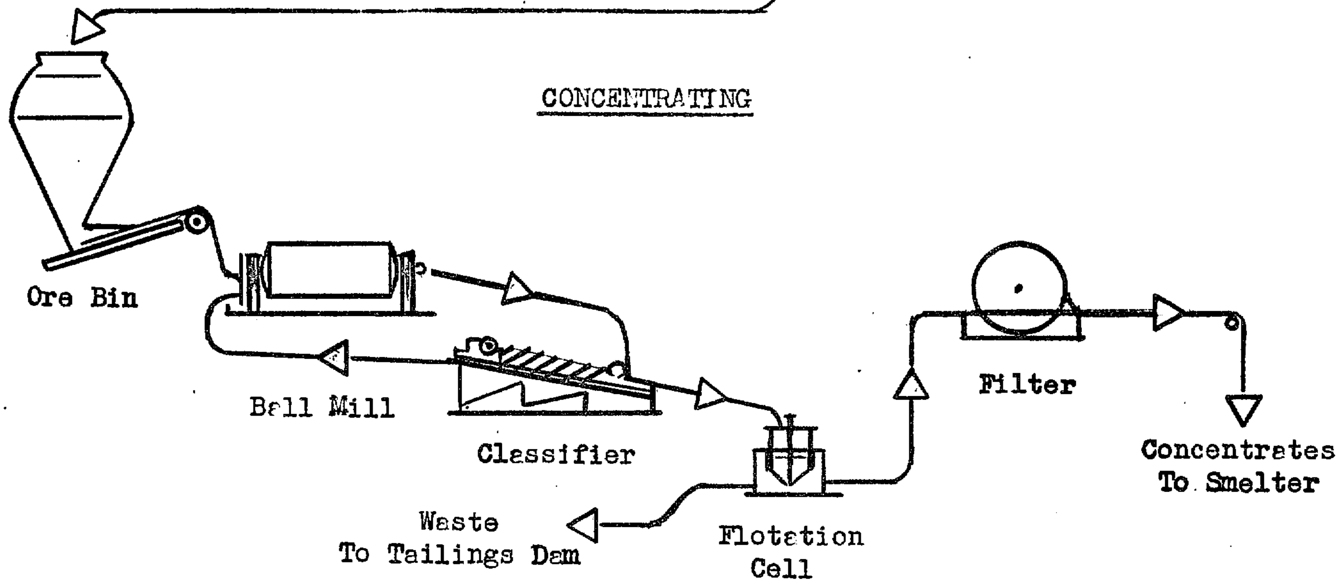
MINING



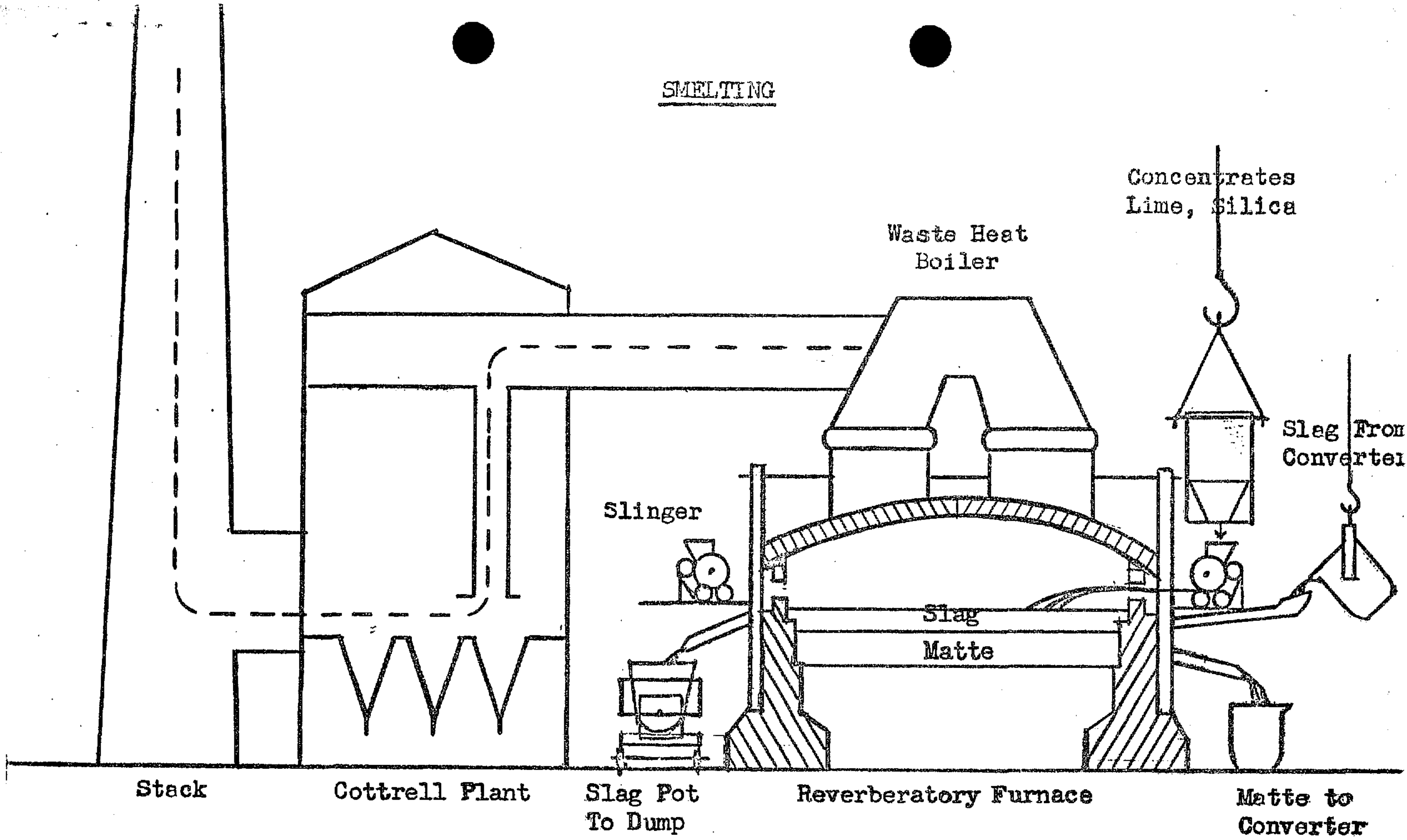
CRUSHING



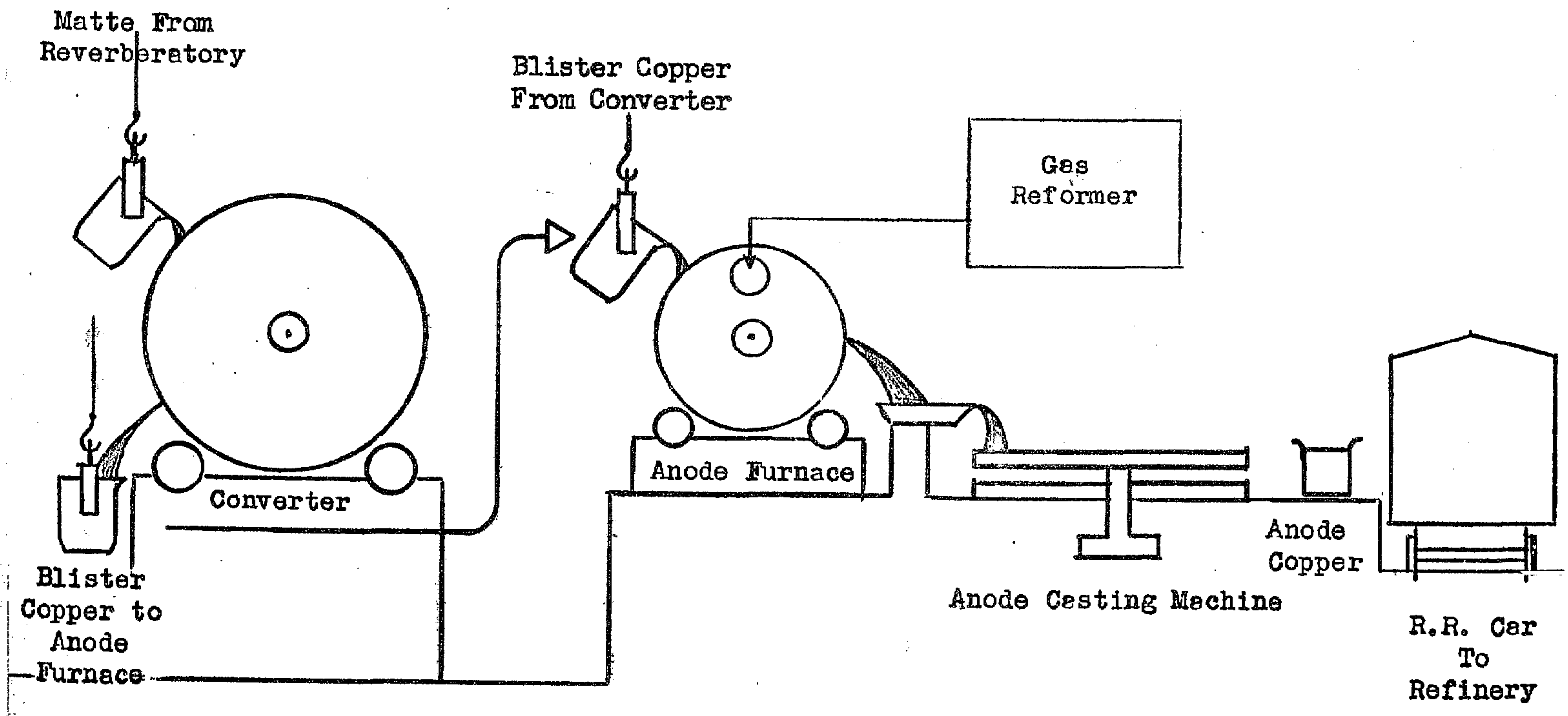
CONCENTRATING



SMELTING



Concentrates
Lime, Silica
Waste Heat
Boiler
Slag From
Converter
Slinger
Slag
Matte
Stack
Cottrell Plant
Slag Pot
To Dump
Reverberatory Furnace
Matte to
Converter



Matte From
Reverberatory
Blister Copper
From Converter
Gas
Reformer
Converter
Anode Furnace
Blister
Copper to
Anode
Furnace
Anode
Copper
Anode Casting Machine
R.R. Car
To
Refinery

J.H.C.

AMERICAN INSTITUTE OF MINING METALLURGICAL AND PETROLEUM ENGINEERS

ARIZONA SECTION - MINING GEOLOGY DIVISION

Spring Meeting
April 25, 1964

Host: *Phelps Dodge Corporation*
New Cornelia Branch
Ajo, Arizona

total sulphides 3% by vol

bn cpy | cpy py
west | east

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ARIZONA SECTION
A.I.M.E.
MINING GEOLOGY DIVISION

SPRING MEETING: APRIL 25, 1964

SCHEDULE FOR THE DAY

9:00-10:00 A. M.

REGISTRATION
(The Recreation Hall in the Town Plaza at Ajo)

Coffee and Doughnuts will be Served by the Ladies of the WAAIME. FOR THE CONVENIENCE OF GUESTS, MEMBERS OF THE AJO SUBSECTION WILL WEAR GREEN NAME TAGS.

10:00-12:00 A. M.

TECHNICAL SESSION
(Recreation Hall)

1. "AJO IN THE FORMATIVE YEARS" By W. J. Thomas
2. "THE GEOLOGY OF THE NEW CORNELIA MINE" By D. W. Dixon
3. "ORE CONTROL AT THE NEW CORNELIA MINE" By T. R. Couzens

12:00-1:30 P. M.

LUNCH
Luncheon Guests will Board the Mine Busses in Front of the Recreation Hall for Transportation to the Luncheon Where Mexican Food will be Served

1:30-4:30 P.M.

TOUR OF THE NEW CORNELIA OPEN PIT MINE
(TRANSPORTATION WILL BE FURNISHED)
(Anyone That Wishes to Visit Other Areas of Interest can Make Arrangements at Registration)

6:00-7:00 P. M.

COCKTAILS
(Recreation Hall)

7:00-9:00 P. M.

DINNER
(Recreation Hall)

THE NEW CORNELIA BRANCH OF THE PHELPS DODGE CORPORATION IS PLEASED TO SERVE AS YOUR HOST FOR THIS ONE-DAY MEETING

ROSTER OF REGISTRANTS

John L. Alexander
Charles Arnold
Sal. A. Anzalone
Zana Earl Arlin
Dirk D. Baars
John Coleman Balla
Arthur G. Barber
John Baber
David B. Beck
David W. Blake
Samuel I. Bowditch
Calvin C. Brown
Donald C. Bulmer
Robert D. Burns
Maurice A. Chaffee
Jackson L. Clark
William D. Collins
Russell M. Corn
James H. Courtright
Bruce H. De Wyk
Robert H. Dickson
Joseph J. Durek
Maurice A. Enright
A. J. Erickson, Jr.
Samuel C. Fall

M. J. Fitzgerald
Joseph E. Fowells
John E. Frost
Joseph L. Gillson
Amorin Gonzales
Orazio Gonzales
Mostyn G. Grant
Frank F. Green and
two guests
Hauck
Troy B. Hinton
John W. Hoyt
Daniel L. E. Huckins
J. Bruce Imswiler
C. Phillip Jenney
David Wesley Johnson
Alex Jones
John a Journeay
H. D. Kennedy
Howard G. King
John E. Kinnison
Joseph L. Kirby
R. K. Kirkpatrick
George Freeman Leaming
James D. Loghry

K. D. Loughridge
J. David Lowel
Dean W. Lynch
James F. Machamer
Wilson McCurry
Francis McDonald
R. A. Metz
Harry E. Metz
Thomas Wilson Mitcham
Hernan Navarro
Albert J. Perry
Nels P. Peterson
John S. Phillips
Paul A. Pickard
R. E. Radabaugh
Marvin W. Ratcliff
Romulo Romani
George S. Ryan
Schnepfe
James D. Sell
W. W. Simmons
Adrian Soto
L. C. Tauber
Joseph V. Tingley
H. T. Urband

W. J. Walker

Wayne K. Wallace

Reed F. Welch

Frank E. Williams

E. A. Winter

F. R. Wojcik

James Youell

ROSTER OF AJO SUB-SECTION
ARIZONA SECTION, AIME

MINE

Alvin D. Bausman
D. J. Crawford
Don Cratty
R. E. Glenn
J. A. Littrell
J. E. O'Neill
Walter L. Price
R. E. Rhoades
J. C. Smith
E. T. Seaberg
W. T. Sparkman
W. T. Sullivan
Alvan J. Arnold

MILL

W. H. Keener
Stanley Jones
D. L. Moore
Warren D. Caton
Robert L. Fulkerson
John H. Wyatt
Carlos Kovacs-Figueroa

SMELTER

F. W. Denny
F. R. Rickard
T. M. Shumaker
B. Higgins
Joseph R. Alsip
D. M. Hickman
A. H. Lyons
John R. Ivey
Donald A. Schultz

ASSAY OFFICE

Frank Matt
W. C. Yentzer
J. M. Shea
Morris Wood
Charles Shelton

ENGINEERING OFFICE

R. E. West
O. F. Fenzi
J. M. Sudler
John H. Kane
Charles J. Gaetjens
D. W. Savory
Donald W. Dixon
R. M. Rice

FIELD ENGINEERS

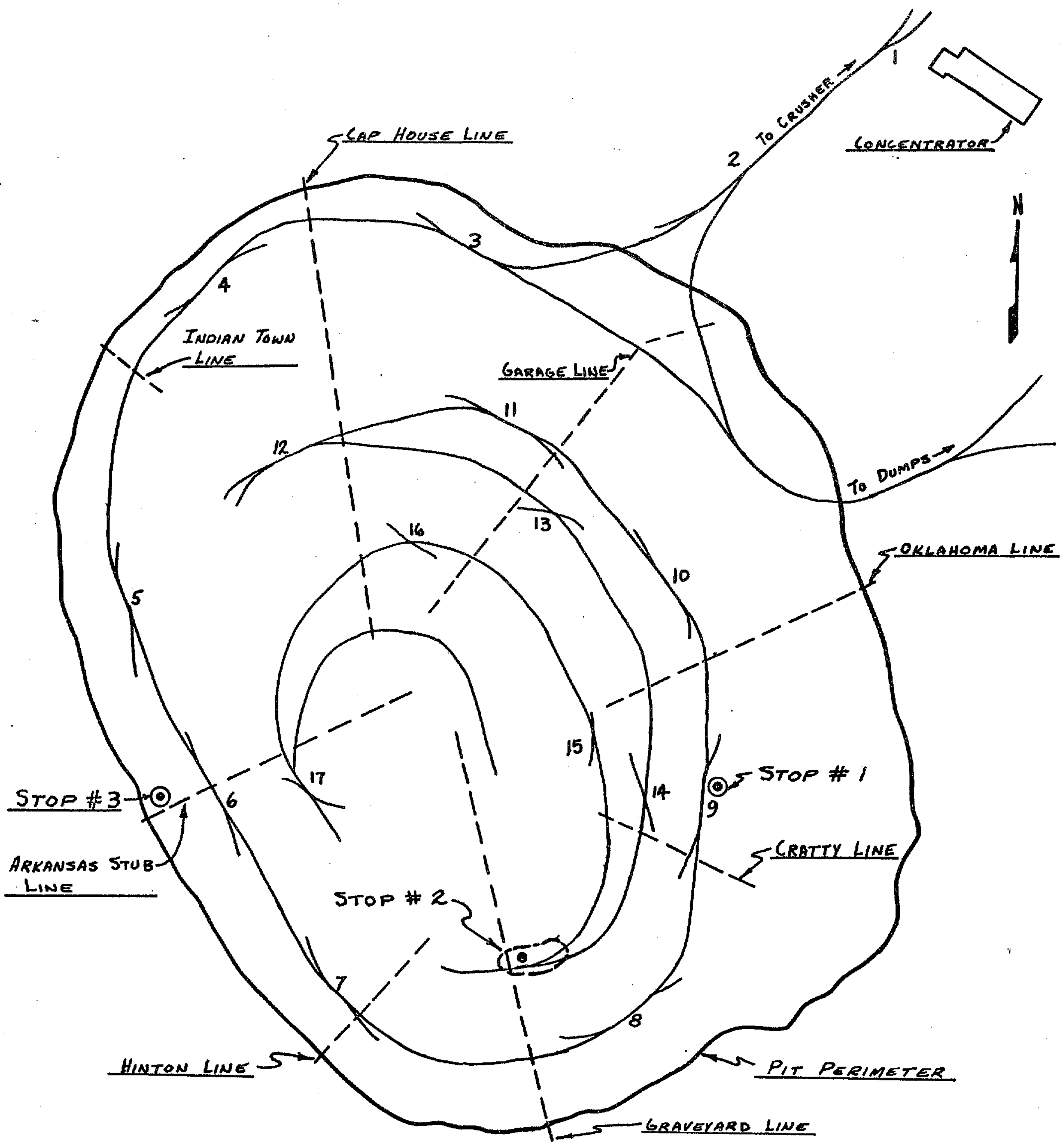
Owen A. Gensman
Thomas R. Couzens
Allen L. Northrup
Leon J. Mayhew

MISCELLANEOUS

Frank Galloway
W. J. Thomas
T. E. Diehl

GENERAL OFFICE

J. A. Briggs
John E. Coppo



Itinerary of Pit Tour
New Cornelia Mine
Ajo, Arizona
April 25, 1964

LOG OF PIT TOUR

1:30 P. M. — START OF TOUR - Visitors will board busses at the Restaurant immediately after the luncheon.

1:30-3:00 P. M. — STOP NO. 1 - NO. 9 CROSSOVER ON THE 1500 LEVEL

From this point we will have a panorama of the west side of the Pit. The Able Fault can be seen in the slide area at the northwest corner of the Pit. In addition, we will see a vertical sequence across the high grade tail of ore in Rhyolite in the bank to the east. On the south is leached Rhyolite, then Rhyolite with secondary Chalcocite, then primary Bornite and finally Rhyolite with Pyrite and Chalcopyrite on the north end.

3:00-4:00 P. M. — STOP NO. 2 - THE GRAVEYARD POWER LINE ON THE 1300 AND THE 1260 LEVELS

At this point the busses will leave the group. The new shot to the south is in oxidized Monzonite and Rhyolite. Native Copper and Oxide Copper minerals are commonly found just west of the Graveyard Power Line. To the east, the Charlie Fault ends in oxidized Monzonite breccia. As we move east, we see a small intrusive pipe in Monzonite. Following the mainline as it goes down, we will see the highly altered east side Monzonite at the foot of the first truck ramp that we reach. Here we will cross the mainline and walk in on the 1260 Level. At the Graveyard Power Line the hard high-grade west side Monzonite is exposed in the bank. Here we will again board the busses.

4:00-4:30 P. M. — STOP NO. 3 - THE ARKANSAS STUB LINE ON THE 1620 LEVEL. PASSENGERS WILL NOT DEBARK AT THIS STOP.

At this point we will have a panorama of the east side of the Pit. The small intrusion that we saw on the 1300 Level can readily be outlined from this point. The steep southward dip of the locomotive fanglomerate is readily visible from here. The sharp change in rock character across the Charlie Fault can be seen in the northeast corner of the Pit.

4:30 P.M. — STOP NO. 4 - RECREATION HALL, TOWN PLAZA - END OF TOUR

AJO
DURING ITS
FORMATIVE YEARS

By

William J. Thomas, Engineer

PHELPS DODGE CORPORATION
NEW CORNELIA BRANCH
AJO, ARIZONA

APRIL, 1964

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AJO DURING ITS FORMATIVE YEARS

Introduction:

This paper is a short summary of the literature concerning the Ajo Mining District which was written during the past by others; geologists, mining engineers and historians. Their names are familiar to most of us and it is from the words of James Gilluly, Ira B. Joralemon, A. B. Parsons, and Thomas E. Farish that this story unfolds. With the aid of a map prepared by the Rendall Reduction Co., in the year 1908, we are able to piece together this early history of Ajo.

Location and Physical Features:

The New Cornelia open pit mine, a property of Phelps Dodge Corporation, is located at Ajo, Arizona, near the western end of Pima County. The City of Tucson is 136 miles to the east on State Highway 86. Southward, 42 miles away, is the Mexican border town of Sonoyta. State Highway 85 meets Highway 80 at Gila Bend, 42 miles north of Ajo.

The region around Ajo is typical of the Sonoran desert section of the Basin and Range province. Average annual rainfall is about 9.0 inches. Maximum summer temperatures range from 110 to 115 degrees Fahrenheit, while minimum winter temperatures range from 39 to 17 degrees.

Early History:

The date of the earliest mining activities in the Ajo Region cannot be set with any accuracy, but they were probably later than 1702. Father Kino, the famed Jesuit priest, made extensive journeys through these regions in the years between 1691 and 1702, but he makes no mention of any mining at Ajo in his very accurate and detailed descriptions of the country. Historical writers say that Spanish prospectors from the Tucson Missions worked the high grade copper veins as early as 1750. Abandoned workings, rawhide ore buckets, and crude tools provided evidence of the earliest attempts to mine small veins of native copper occurring in the Ajo hills.

When the Gadsden Purchase made the Ajo area a part of the United States in 1854, there was a rekindling of interest in exploring the new territory.

From 1854 to 1859, the Arizona Mining and Trading Company made the first attempt, by Americans, to mine the copper deposits. High grade copper ores of native copper and cuprite were hauled by oxen and mule teams to Yuma or San Diego, and from these points it was taken in sailing ships around Cape Horn to Swansea, Wales.

From 1860-1890 numerous attempts were made to exploit the high grade vein deposits but failed due to lack of water and the difficulties of transportation.

Period of Metallurgical Promotions:

Between 1890-1907, after these other efforts had failed, the principals fell victim to a series of metallurgical promotions that proved both bizarre and worthless.

The first of these visionary schemes was a smelting process known as the Rendall Ore Reduction process. It was claimed that this weird invention would treat all classes of copper ore including oxides, carbonates, sulphides, chlorides, silicates, and arsenides with equal facility. It was a shocking process in which a special fluxing gas was to prevent the fusion of both metals and gangue rock. Even so, the volatilized ore was to be plunged into a vat containing water to shock it into breaking up. The ore was then to be crushed in an arrastra. As it turned out, the plant treated all ores with equal difficulty and was a complete failure.

The next visionary scheme on the list was promoted by Professor Fred R. McGahan with his vacuum smelting method for ore treatment. The smelter was a marvelous piece of equipment. The furnace itself was a brick-lined steel cylinder twenty-five feet high and six feet in diameter. Supported on a steel frame were smaller horizontal cylinders, to hold the oxygen and hydrogen gases that entered into the reactions. There was a powerful pump to maintain the vacuum. A bewildering array of pipes, guages and spigots stuck out from all sides of the furnace. McGahan's marvelous discovery was that when the air was pumped out of the furnace and ore fed in with a little fuel oil and just enough oxygen to burn it, he could regulate the temperature so accurately that all the elements in the ore would be melted, one by one. First, the gold would melt and sink to the bottom, where it could be drawn off through the lowest spigot. The next spigot was for silver, and the next for copper, then one for calcium, then sodium and silicon, and finally, up at the top, spigots for oxygen and hydrogen gas. After the furnace was once started, he could burn the hydrogen again with the oxygen, and so get along without any outside fuel at all. Nothing was lost, and all the elements came out absolutely pure.

The Professor achieved a number of things: He condensed a unique amount of pseudo-scientific nonsense in one invention; he exploded a dozen then-prevailing theories in chemistry and physics and he dissipated the funds invested.

A third visionary scheme cost the early stockholders another $20,000 for a hydrofluoric-acid leaching process almost as fantastic as the vacuum smelter. This promoter built a leaching plant that did turn out a few pounds of copper, but at a cost of a dollar a pound!

Period of Scientific Error:

In 1907, pioneers had started production of a large tonnage low-grade copper deposit at Bingham Canyon, Utah. Their theory was that costs could be significantly reduced with the treatment of thousands of tons of ore per day produced by using steam shovels to load railroad cars in an open pit operation. It was predicated that costs would be low enough to profitably mine 2% copper ore. Because of the success of the experiment at Utah Copper Co., the desert was alive with engineers hunting for new porphyry copper ore deposits!

The map presented with this paper is part of one prepared by the Rendall Ore Reduction Company during 1908. This marks the period of scientific error prior to successful development of the Ajo Mining District.

Geologically, the area consisted of barren quartz monzonite on the North. In the middle zone, the rock was a pyrite-rich rhyolite. Copper Mountain consisted of a group of three quartz monzonite hills that out-cropped as an island in the rhyolite. To the South the rock was a poorly-sorted, well-cemented alluvial conglomerate. Along the conglomerate contact the rhyolite carried a wide zone of strong hematite and limonite stain. Many of the hills throughout the area carried segregations of copper oxides (malachite) that varied from 2 to 12% copper.

The bulk of the area was held by three groups of owners. Copper Mountain was covered by the claims owned by the Cornelia Copper Co. The oxide-covered rhyolite hills were in the much larger holdings of the Rendall Ore Reduction Co. The third group of claims covered the small valley that separated the two oxide-rich areas described above. This group was owned by the Childs family.

In the Fall of 1909, the Lewisohn Interests, advised by J. Park Channing, optioned a majority of the New Cornelia Copper Co. Stock. Seeley W. Mudd and Associates optioned the Rendall property and an English Syndicate took an option on the Childs claims. The three groups began development about the same time.

1. English Syndicate and Childs Group: The English group sunk a shaft -- we think, on the Hermosa claim. We do not know what philosophy of ore-search guided the efforts of the English Syndicate that sunk this shaft because the high-grade cuprite and chalcocite veins mined before 1908 came from veins Southeast of the Childs claims. The English found nothing in their area but high pyrite and low copper mineralization.

2. Seeley W. Mudd and Rendall Property: The Mudd group put down four churn drill holes on the Rendall area. Two holes were in favorable locations and two others were in the barren conglomerate to the East. The dip of the high grade cuprite and chalcocite veins on the Rendall property must have guided the Mudd group in locating their holes. This group missed the orebody by not drilling deeper through the rhyolite on their favorable locations and by drilling the unfavorable areas to the East.

3. J. Park Channing and Cornelia Copper Co: The Channing group drilled five diamond drill holes on the fringes of Copper

Mountain. This group located their holes in this way because no one wanted to drill the hard, silicified, monzonite hills. Their reasoning was that the siliceous rocks were too impermeable to permit the secondary enrichment necessary to produce the sought-for chalcocite. Two shallow holes, Numbers 3 and 5, drilled by Channing developed a small amount of low grade, siliceous malachite ore and several deeper holes penetrated to underlying copper sulphides assaying 2-4% copper. However, since Channing's work was in the lower ground surrounding the hard silicified outcrops of Copper Mountain, he also missed the ore deposit. Channing discontinued drilling because the little amount of ore found was not enough to justify continued exploration.

All three groups missed the three hills of Copper Mountain that contained the orebody, and due to the disappointing results of their drilling, they allowed their options to lapse. After this burst of activity the Ajo District returned to idleness.

Period of Successful Development:

In the Fall of 1911, John C. Greenway, General Manager of the Calumet and Arizona Mining Co., on the advice of Ira B. Joralemon, Geologist, optioned the New Cornelia Stock, and started diamond drilling to prove more thoroughly what lay beneath the highly stained outcrops of Copper Mountain. The initial drilling was favorable, so test pitting was started to speed development and to check drill hole results. All but 12 holes were checked by pits normally 40 to 50 feet deep. Drifting was also done in the sulfide zone to prove the continuity of the ore between the drill holes. This work showed that the silicified iron and copper stained hills of Copper Mountain were the outcrop of a great low-grade copper orebody. Calumet and Arizona drilled 84 diamond drill holes on the three green hills of Ajo between December, 1911, and May, 1913. By September, 1913, an aggregate of 40 millions tons of oxide and sulphide ore had been blocked out. The area covered approximately 55 acres and reached a depth of over 600 feet.

After the development of Copper Mountain was begun, an option was taken on the Rendall property that Mudd had dropped. Greenway drilled five churn drill holes 65A through 69A. Two of the holes, 65A and 66A, were located on the same coordinates as Mudd's "A" and "B" holes respectively. Four of the five holes never left the conglomerate and the assay reports on these holes were so discouraging that the option was dropped. This property was then bought by a group organized as the Ajo Consolidated Copper Co. and it lay idle until 1915.

The option on the Childs group, dropped by the English Syndicate, was taken up by the United States Smelting Refining and Mining Co. A few churn drill holes were sunk in this area. The results were unfavorable and this option was also dropped.

In 1913, development work on the Calumet and Arizona property, New Cornelia Copper Co., was discontinued because no known practical metallurgical process was available for treatment of the oxide ore. Research on the problem was started in 1912 and by 1915 a suitable leaching method was developed.

By 1914, Joralemon had worked out the geology of the Ajo District and in August of that year he published the results of his work. At this time he knew of the 2% sulphide orebody with its oxide capping that made up the three hills of Copper Mountain. He also knew that rich chalcocite and cuprite veins cropped out in the rhyolite to the South and suggested that they might yield considerable tonnage. Since, the area had never shown favorable results with drilling, he did not speculate further.

In 1915, the owners of the Rendall property, Ajo Consolidated Copper Co., started diamond drilling on the oxide-covered rhyolite hills to the East of Copper Mountain and on the high-grade vein area to the South of the New Cornelia property. This drilling soon outlined a large tonnage blanket of chalcocite-bornite ore in this section. After drilling 64 holes the Ajo Consolidated Copper Co. outlined the limits of the chalcocite zone in 1917, and in this same year sold the property to the New Cornelia Copper Co. By this time, New Cornelia had also purchased the Childs group to consolidate the ownership of the Ajo District.

Recent History:

From 1915 to 1917, the New Cornelia Copper Co. had consolidated ownership, built a whole mine plant, developed a source of water, and started production in April of 1917. In 1929 the New Cornelia Copper Co. was consolidated with the Calumet and Arizona Copper Co., with which its affiliations had always been close, and the new company was merged with the Phelps Dodge Corporation in 1931. The Ajo mine now operates as the New Cornelia Branch of the Phelps Dodge Corporation.

Epilogue:

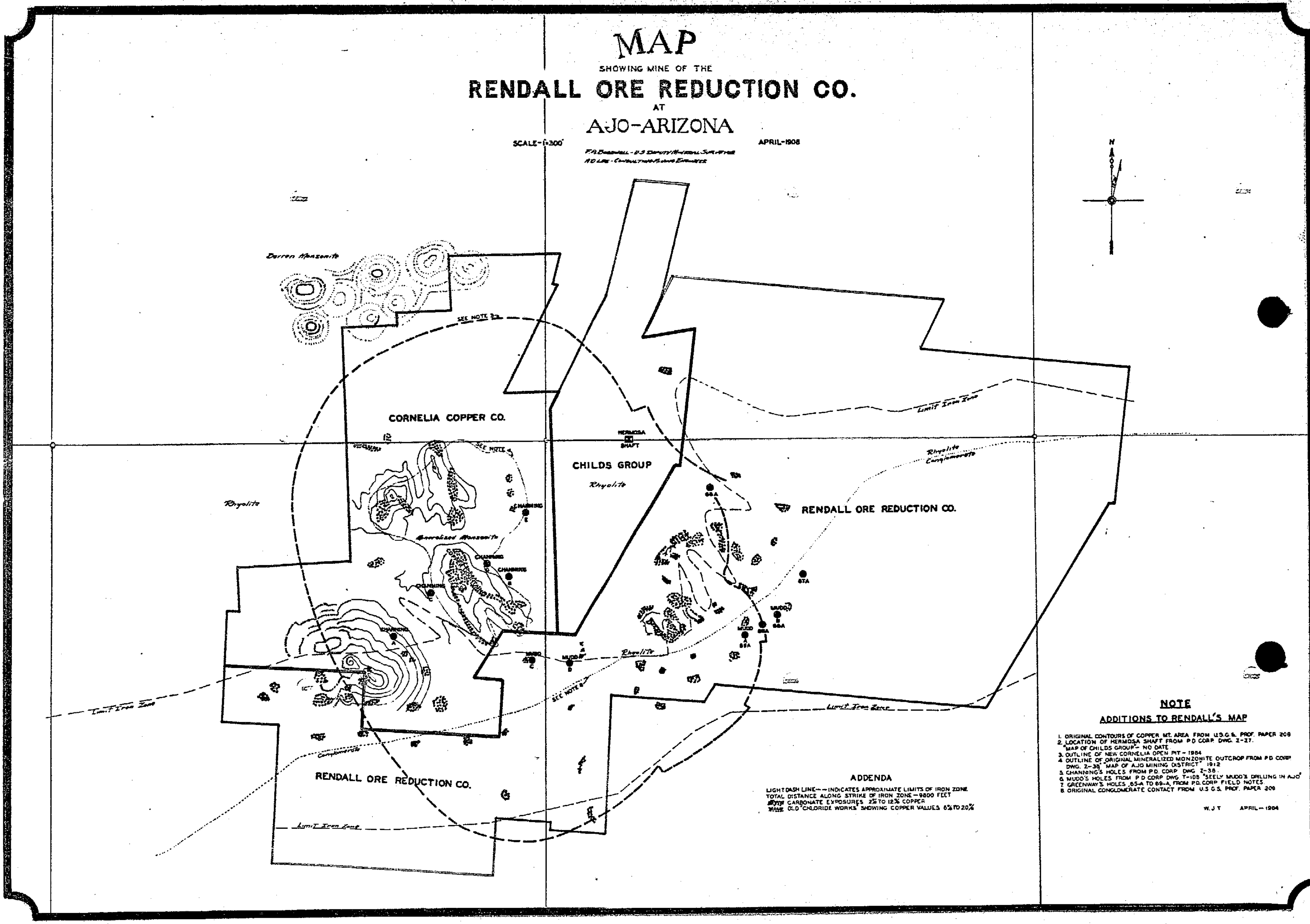
All of the orebodies known today had been found by 1917. The great bulk of the ore remaining today, and the ore that has contributed to the production of the past 47 years, became so through the increases in mining efficiency that has enabled management to progressively lower the cut-off grade during this period of time.

This has been a brief chronicle of the making of a mine.

A disappointing prospect has been followed from the initial discovery to the final outline of a low-grade orebody of many millions of tons.

In ending I might note that the mine produced 17 million tons of oxide copper ore from 1917 to 1930. Sulphide ore production started in 1924 and to January 1, 1964, has yielded 247 million tons of ore. This mining has required the removal of 287 million tons of waste rock.

Initial mill capacity was 5,000 tons per day. The mill is now treating in excess of 31,000 tons per day, and in addition, we mine 55,000 tons of waste rock per 24 hours.


MAP
SHOWING MINE OF THE
RENDALL ORE REDUCTION CO.
AT
AJO-ARIZONA
SCALE-1"=300'
APRIL-1908
N
Barren Monzonite
SEE NOTE 3
CORNELIA COPPER CO.
SEE NOTE 4
HERMOSA SHAFT
CHILDS GROUP
Rhyolite
Mineralized Monzonite
CHANNING
MUDD
SEE NOTE 8
RENDALL ORE REDUCTION CO.
Limit Iron Zone
Rhyolite
Conglomerate
RENDALL ORE REDUCTION CO.
Limit Iron Zone
ADDENDA
LIGHT DASH LINE — — INDICATES APPROXIMATE LIMITS OF IRON ZONE
TOTAL DISTANCE ALONG STRIKE OF IRON ZONE — 9800 FEET
CARBONATE EXPOSURES 2% TO 12% COPPER
OLD "CHLORIDE WORKS" SHOWING COPPER VALUES 6% TO 20%
NOTE
ADDITIONS TO RENDALL'S MAP
1. ORIGINAL CONTOURS OF COPPER MT. AREA FROM U.S.G.S. PROF. PAPER 209
2. LOCATION OF HERMOSA SHAFT FROM P.D. CORP. DWG. Z-27. "MAP OF CHILDS GROUP" — NO DATE
3. OUTLINE OF NEW CORNELIA OPEN PIT — 1964
4. OUTLINE OF ORIGINAL MINERALIZED MONZONITE OUTCROP FROM P.D. CORP. DWG. Z-38, "MAP OF AJO MINING DISTRICT" 1912
5. CHANNING'S HOLES FROM P.D. CORP. DWG. Z-38.
6. MUDD'S HOLES FROM P.D. CORP. DWG. T-108 "SEELY MUDD'S DRILLING IN AJO"
7. GREENWAY'S HOLES, 65-A TO 69-A, FROM P.D. CORP. FIELD NOTES.
8. ORIGINAL CONGLOMERATE CONTACT FROM U.S.G.S. PROF. PAPER 209
W.J.T. APRIL — 1964

GEOLOGY OF THE NEW CORNELIA MINE
AJO, ARIZONA

By

D. W. Dixon, Engineer

PHELPS DODGE CORPORATION
New Cornelia Branch
Ajo, Arizona

April, 1964

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LIST OF ILLUSTRATIONS

I. THE GEOLOGIC PROGRAM AT AJO.

Numerous references to Ajo are found in the geologic literature. However, only four papers are based on any degree of field work in the area. These are Joralemon (1914), Bryan (1925), Ingham and Barr (1932) and Gilluly (1946).

In the years since 1934 when the last published field work was completed, the mine has been deepened by 600 feet and many thousand feet of prospect holes have been drilled.

During these years the geology maps have been revised at regular intervals, and prospect hole samples have been identified and cataloged.

In 1946-1947 the pit area was remapped in detail. Geological cross-sections were then constructed, based upon this new work and the prospect drill information that had been accumulated since 1934.

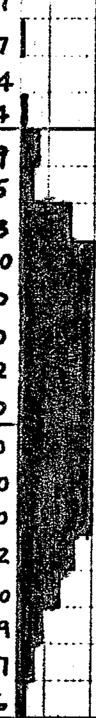
Since 1960 a detailed pit mapping program has been underway. This mapping has been conducted with the ultimate goal of working out the structural history of the immediate pit area. During this period a systematic drilling program was conducted in the pit area. This program utilized diamond drills to recover solid cores. The cores were carefully logged, and particular attention was given to characteristics that would be significant to structural studies. A field log sheet of a hypothetical drill hole that penetrates the chalcocite enrichment zone is shown on page 2. The criteria found to be most useful were <u>rock type</u>, <u>hardness</u>, <u>evidence of oxidation</u> and <u>degree of fracturing</u>.

MINE COORS. X+00, 20+100 D.D.H. Nº HYPOTHETICAL

COLLAR ELEVATION 1888
BOTTOM ELEVATION 780
DEPTH 1108

HOLE DATA										ROCK DATA									ASSAY DATA	DRILLING DATA	
DEPTH FROM	DEPTH TO	DATE	LEVEL FROM	LEVEL TO	HOLE SIZE	CORE SIZE	SP. GR.	CORE WEIGHT	%REC	ROCK TYPE	HARDNESS	COLOR	TEXTURE	STRUCTURE	ALTERATION OXIDATION	SECONDARY MINERALS	ORE MINERALS OPAQUES	FRACTURING	%Cu	REMARKS	CEMENTING, MUD, REAMING ETC.
648	653	9/10	1240	1235		NX WIRELINE	2.56	7220		FAN	HARD	BROWN				HEMATITE	—	NONE	—		
653	658		1235	1230			"	7380		"	"	"				-		"	—		
658	663		1230	1225			"	7320		"	"	"				"		"	—		
663	668		1225	1220			"	7600		"	"	"				"		"	—		
668	673		1220	1215			"	7500		"	"	"				-		"	—		
[illegible]	678		1215	1210			"	7200		"	"	"				"		"	—		
678	683		1210	1205			"	7300		"	"	"				"		"	—		
683	688		1205	1200			2.60	7800		RHY	VERY HARD	RED-BROWN	APHANITIC	RECEMENTED BRECCIA		HEMATITE		NONE	.01		
688	693	9/11	1200	1195			-	7850		"	"	"	"			"		"	.01		100% RETURN WATER
693	698		1195	1190			"	7900		"	"	"	"	"		NATIVE COPPER		" (0.05₅)	.07		
698	703		1190	1185			"	7750		"	"	"	"	"		"		"	.04		
703	708		1185	1180			"	7890		"	"	"	"	"		-		"	.14		CHANGED BIT AT 705'
708	713		1180	1175			2.62	7900		"	"	GRAY	"	"		MINOR Cc		MINOR	.29		
713	718		1175	1170			-	7550		"	MED.	-	"	"		Cc		MODERATE	.45		
718	723		1170	1165			"	7860		"	-	"	"	"		"		"	.73	ZONE OF SECONDARY ENRICHMENT	
723	728		1165	1160		BX WIRELINE	"	4300		"	"	"	-	"		"		ABUNDANT	1.60		
728	733		1160	1155			"	4250		"	"	-	"	"		-		" (1.12)	1.70		
733	738		1155	1150			"	4300		"	"	-	-	-		Cc	Bo	MINOR	1.10		
738	743		1150	1145			2.67	4400		MZ	HARD	GRAY-GREEN	PHANERITIC	MASSIVE		"	"	"	1.62		
[illegible]	748	9/12	1145	1140			-	4300		"	-	"	"	"		"	"	"	1.50		
748	753		1140	1135			-	4250		"	"	"	"	"			"	"	1.70		
753	758		1135	1130			-	4350		"	"	-	"	"			-	"	2.00		
758	763		1130	1125			"	4450		"	"	"	"	"			Bo Cp	"	1.40		
763	768		1125	1120			-	4340		"	-	"	-	"			-	" (0.92)	0.82		
768	773		1120	1115			2.60	4200		RHY	VERY HARD	GRAY	APHANITIC	BRECCIA			Cp Py	VERY ABUNDANT	0.60	FAULT ZONE	
773	778		1115	1110			-	4150		"	-	-	"	-			-	"	0.39		CHANGED BIT AT 775'
778	783		1110	1105			-	4250		"	-	"	-	"			Py Cp	"	0.27		
783	788	9/13	1105	1100			-	4200		"	-	"	-	MASSIVE			"	MINOR	0.16		

GRAPH % Cu



II. GENERAL GEOLOGY

Regional Setting

The Ajo quadrangle lies between meridians 112°45' and 113°00' West and parallels 32°15' and 32°30' North. The New Cornelia Mine, in the Little Ajo Mountains, covers portions of Sections 22, 23, 26 and 27 in Township 12 South, Range 6 West of the Gila and Salt River Meridian. An area map is shown on page 4.

Physiography

There are two types of mountains in the quadrangle. The Little Ajos are maturely dissected Sierra-type mountains with sharp ridges and peaks. Other mountains around Ajo are youthful mesas composed of gently inclined blocks of massive lavas.

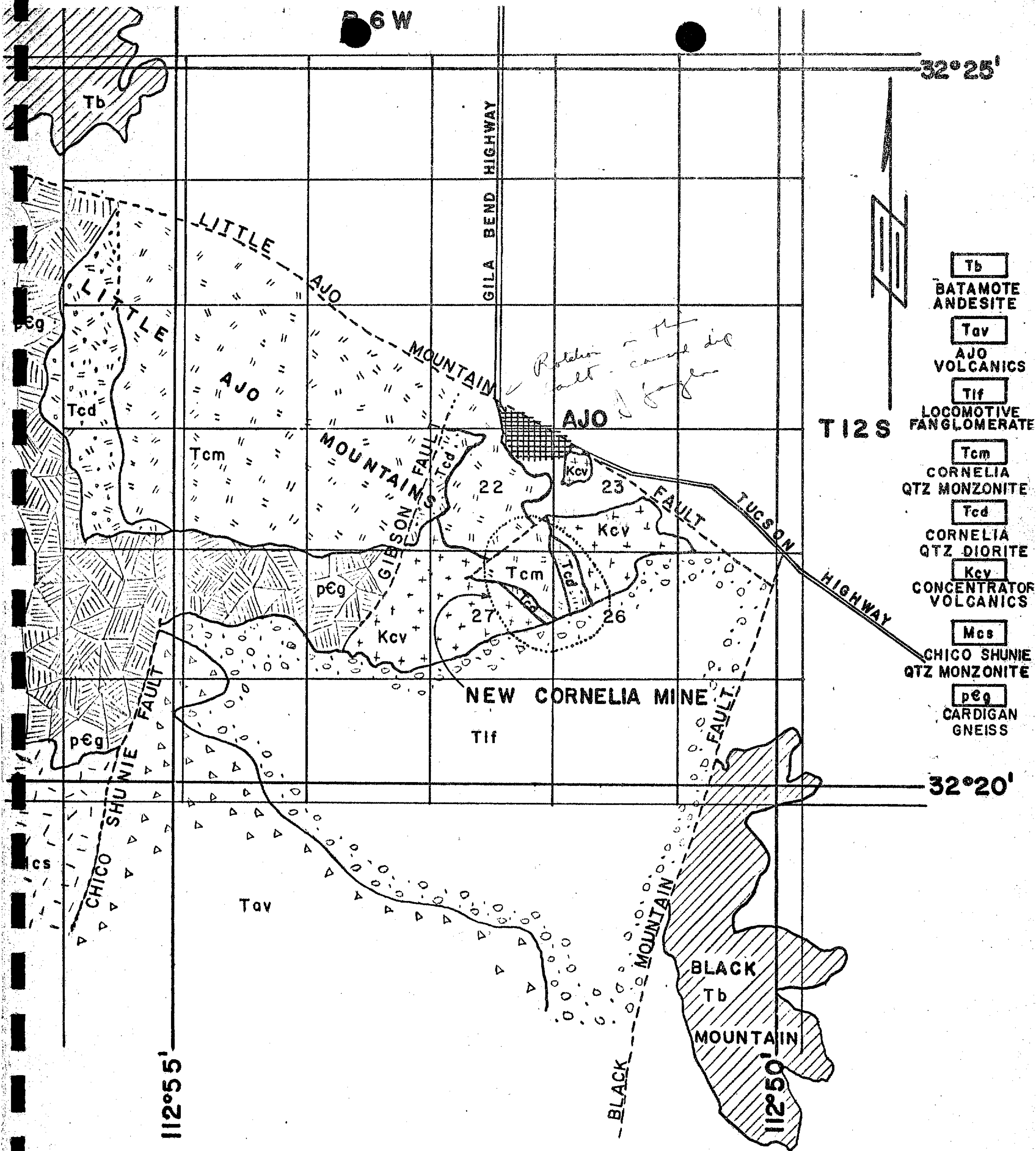
Strong pediments have been developed on the bases of the Little Ajo Mountains. The narrow ranges are separated by broad, detritus-filled alluvial valleys.

Rock Types

The New Cornelia mine is located at the east end of the Little Ajo Mountains, which are composed of rocks which range in age from the Pre-Cambrian gneiss of the Cardigan area to the later Tertiary lavas of Black Mountain. Very detailed descriptions of these rocks may be found in Gilluly (1946).

Structure

The Little Ajo Mountains are made up of a series of tilted fault blocks. The fault block that includes the mine area is bounded by two northeast trending normal faults - the Gibson and the Black Mountain and the northwest trending Little Ajo Mountain fault.



GENERALIZED GEOLOGY OF THE AJO AREA

SCALE 1" = 1 MILE

The oldest of these is the Gibson Arroyo fault, a normal fault that has brought the Concentrator Volcanics down against the Cardigan gneiss. Estimated displacement is about 4,000 feet, and the fault is believed to be post-Cornelia monzonite.

Next in age is the Little Ajo Mountain fault which bounds the mountains on the north, trends about north 60° west, and dips steeply north. It may have as much as 10,000 feet displacement. A rotational movement along this fault tilted the entire mountain range about 50 degrees to the south.

On the east the Little Ajo Mountains are cut off by the Black Mountain fault, a northeast trending fault, that is exposed on the west flank of Black Mountain. This fault, downthrown on the east, is believed to limit the Little Ajo Mountain fault at its eastern extremity.

III. MINE GEOLOGY (Map on Page 15)

A. Rock Types

Concentrator Volcanics

This is the oldest formation exposed in the mine area. It outcrops along both the east and west sides of the pit. The exact stratigraphic relationship of these volcanics is not known. They abut against the older Cardigan gneiss along the Gibson fault and are intruded by the Cornelia monzonite, both of which are unconformably overlain by the Locomotive fanglomerate. The rocks vary in lithology. They consist of flows, flow breccias and tuffs. The massive flows generally crop out in the center and north part of the mine. The flow breccias are found along the south end of the mine directly under the fanglomerate. The rocks range in composition from soft, dark gray andesites to white, hard brittle rhyolites. Throughout the mine area and to the west the formation is predominantly rhyolite with numerous irregular residual patches of andesite. In almost every case, deep drill holes in the mine area bottom in rhyolite or andesite.

Cornelia Quartz Monzonite

This rock occurs as hard, massive, unaltered, gray, equigranular quartz monzonite throughout the Little Ajo Mountains and in the area where it outcrops immediately north and west of the mine. In the pit area it exhibits two very different facies. On the west side of the mine the monzonite is very hard, massive, porphyritic quartz monzonite with strong silicification and minor sericitization of feldspars. On the east side of the mine, the monzonite is a soft to medium-hard porphyritic quartz monzonite with strong sericitization and minor clay alteration.

Cornelia Quartz Diorite

This is the dioritic border facies of the monzonite intrusion. It occurs in the mine area in two distinct types. On the east side of the mine above the 1300 level the formation occurs as a medium-grained, equigranular, dark gray quartz diorite. On the west side of the mine the formation occurs as a border phase of the monzonite on the upper levels. Here it is a finer grained diorite. In recent years, with mining below the 1300 level, another body of diorite has been exposed. This block shows as an island of diorite in the monzonite at the center of the pit. It is generally like the west side diorite but is very fine grained.

Locomotive Fanglomerate

This is an alluvial conglomerate that rests on an erosion surface that cuts all the older rocks in the area. It is a land-laid deposit, and it contains boulders of all the previously described rocks. Many hundred feet in vertical sequence of fanglomerate are exposed in the pit area, and it is very frequently interbedded with the Ajo volcanics.

Ajo Volcanics

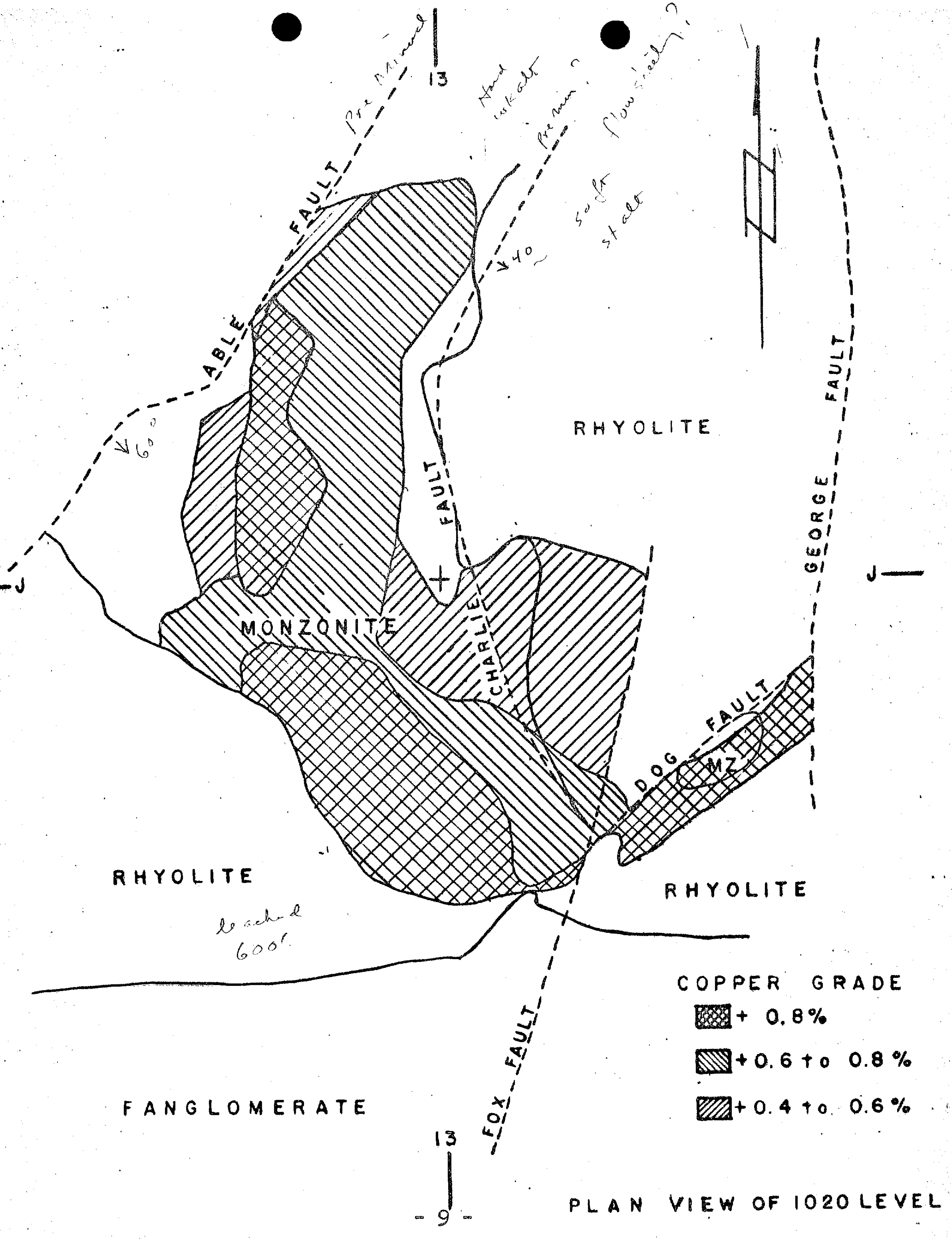
These are a thick series of andesite breccias, flows and tuffs, which are interbedded with and overlie the fanglomerate. They make up a very large part of the rocks that overlie the old Tertiary erosion surface in the mine.

B. Nature of the Orebody

The New Cornelia orebody lies in the apex of an offshoot from a quartz monzonite stock to the west. The mineralized part of the apex is about 3/4 of a mile wide and 1 1/4 miles long. The deposit is mined by an open pit that is roughly elliptical in plan. The long axis of the pit trends about north 30 degrees west. The vertical range of mining extends from about 2000 feet elevation to 1140 feet elevation at the present bottom of the pit. The pit encompasses the entire width of the mineralized monzonite apex and cuts deeply into the Concentrator Volcanics rhyolite that served as host for the intrusive monzonite. On both sides of the apex, a fine to medium-grained border facies of quartz diorite fringes the monzonite.

The plus 0.8% copper ore zone follows the long axis of the pit and at the south end turns abruptly to the east. After making this turn, the copper mineralization disappears about 1,000 feet east of the long axis of the pit. To the east of the pit axis, the ore contains less than 0.6% copper. This can be seen on the plan view of the 1020 level on page 9.

Generally, the values are concentrated in the monzonite and to a slightly lesser degree in the quartz diorite. As the monzonite-rhyolite contact is crossed, the disseminated mineralization becomes restricted to microfractures which soon become barren. The apex of the monzonite has a known floor where the rocks revert to rhyolite and andesite. This contact limits the economic mineralization in depth. Only in the plus 0.8% ore zone that hooks to the east does the rhyolite carry significant values. To the north, mineralization ends at a pre-mineral fault and to the south it is cut off by the tip of the apex that was truncated by erosion.



PLAN VIEW OF 1020 LEVEL

C. Structure

The detailed mapping of structure and rock types in the pit, along with study of drill cores, has shown the existence of a series of well defined faults in the pit. These are shown on the Pit Geology Map.

The faults are listed in their estimated chronological order.

Able fault

This is a very strong pre-mineral fault that cuts across the northwest corner of the pit. The fault strikes north 40° east and dips about 60° southeast. Economic mineralization is found in the hanging wall of the fault. Across the fault the mineralization drops to 0.2% copper, then to 0.1% and within a few feet to traces of copper. This is the same fault that Gilluly shows extending westerly from the pit in plate 21 of U.S.G.S. Prof. Paper 209. A zone of strong hydrothermal alteration about 20 feet wide follows the fault surface. This fault limits mineralization to the north and the northwest.

Baker fault

This is a small fault in the southwest corner of the pit which strikes about north 80° east and dips about 25° southeast. It has offset the monzonite-rhyolite contact about 400 feet to the west and is cut off to the east by the Charlie fault.

Charlie fault

This is a major fault that extends from the northeast rim of the pit southwesterly to the bottom of the pit, thence southerly along the pit axis almost to the fanglomerate contact where it is cut off by a northeast trending fault. It has a dip varying from 40° to 65° to the east, and is by far the most significant fault in the pit. The rocks in the footwall of this fault are hard massive monzonite, usually containing chalcopyrite-bornite mineralization and minor amounts of pyrite. These rocks show heavy fracturing in some areas near the fault. At the south end where the fault is cut off, the footwall rock is a monzonite breccia. The rocks in the hanging wall block are a complex mixture of diorite, rhyolite and monzonite. They are much softer than the footwall rocks and invariably show much more intense hydrothermal alteration. The mineralization in these rocks is pyrite and chalcopyrite with rare bornite. The block is cut by innumerable subsidiary faults that roughly parallel the main fault and dip at moderate angles to the east. It is striking to see the large number of similarly oriented parallel faults on the east side of the pit as one proceeds from the bottom to the east rim of the pit. This block shows another unique structural feature, a flow sheeting that occurs indiscriminately in all rock types. It is sometimes so strong as to form groups of chevron folds in the solid intrusive rocks.

At one point in the northeast corner of the pit, the Charlie fault cuts across a monzonite bank. The monzonite in the footwall is hard and massive with no evidence of folding, sheeting, jointing or cleavage planes. Mineralization is chalcopyrite. Ten feet away in the hanging wall of the fault, the same rock type, monzonite, is soft, has strong hydrothermal alteration, is abundantly folded due to sheeting and the mineralization is pyrite with minor chalcopyrite. Much of the apex has been mined out, and the drill logs are not sufficiently detailed to reveal what spatial relation the soft, highly-folded intrusives of the east side originally had to the hard, massive intrusives of the west side.

Dog fault

The tip of the monzonite apex and its accompanying rhyolite capping were leached in middle Tertiary. Oxidation and enrichment extended to about 600 feet. After substantial enrichment, a low angle fault (25°) that roughly paralleled the erosion surface shifted the rhyolite capping and the accompanying chalcocite blanket about 1,200 feet to the southeast. The fault is shown by extensive brecciation encountered in drill holes that penetrate under the chalcocite blanket. The faulting occurred in rhyolite which shows very abundant fracturing. The rhyolite and minor monzonite in the chalcocite zone immediately above is massive and hard and totally without brecciation. This fault accounts for the geometrical configuration of the +0.8% ore zone to the east as shown on the plan view of the 1020 level.

The following features support this theory:

1. The displaced blanket has a width, in so far as drilling information is available, that matches the width of the truncated tip of the monzonite apex.

2. The oxidation products over the chalcocite zone in the rhyolite are similar to those in the monzonite zone except that the latter has a larger concentration of hematite. Primary chalcopyrite is known to be more abundant in the monzonite than in the rhyolite.

3. The depth of leaching in the rhyolite is about 600 feet, but in the monzonite it does not exceed 150 feet. This discrepancy suggests two periods of enrichment since the monzonite is probably more permeable than the rhyolite.

4. The rhyolite in the +0.8% ore zone to the east is massive. If it were assumed that this zone was a recemented breccia and that the mineralization came in prior to recementation, there would be no reason to expect the zone to feather out towards the main orebody as it does. This can be seen on the plan view of the 1020 level. Likewise, the width of the zone would not be expected to match the width of the apex. Finally, mineralization would be concentrated on fracture planes, but this is not the case.

5. The monzonite in this easterly ore zone is exactly like the hard, massive monzonite in the apex to the west.

6. Numerous bodies of diorite are found on the west end of the easterly +0.8% ore zone. This diorite megascopically resembles the hard, black, fine grained diorite that fringes the west side of the monzonite apex.

Easy fault

This is a strong, almost vertical north-south fault that offsets the fanglomerate at the southwest corner of the pit. The vertical displacement on the fault appears to be about 700 feet with the block on the west being faulted down. There has been about 700 feet of movement to the north for the west block as measured in plan.

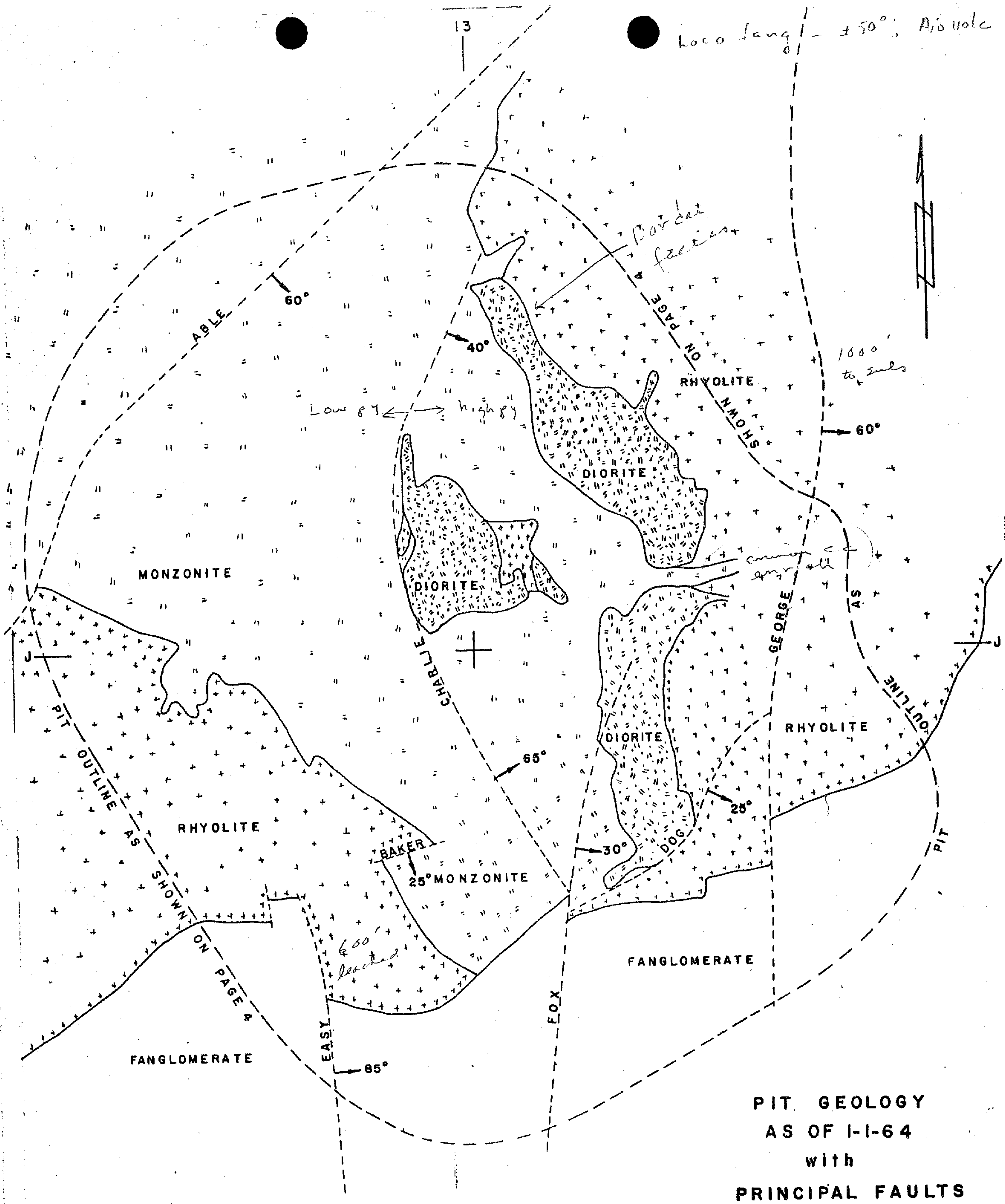
Fox fault

This is one of a group of late faults that strike north to northeast and dip about 30° east. It can be traced from the south rim of the pit down to the Tertiary unconformity where it offsets the fanglomerate-monzonite contact about 100 feet in plan. At this point the fault cuts off any easterly extension of the Charlie fault.

The fault then trends northeasterly at a decreasing dip and is lost in the complexity of the east side rhyolite and diorites.

George fault

This is a very strong fault of northeast trend that is first seen at the southeast corner of the pit. It dips about 60° to the east at this point, cuts across the east fringe of the pit, thence across the west slope of Concentrator Hill and is lost in the alluvium to the north. This fault is known to have as much as 1,000 feet of vertical displacement as rhyolite on the west side of the fault has primary pyrite at the surface and rhyolite on the east side shows almost 1,000 feet of leaching before sulfides are reached. The fanglomerate-rhyolite contact is offset about 600 feet where it intersects this fault. On this basis, it can be estimated that the amount of horizontal displacement on the fault is at least 600 feet.



PIT GEOLOGY
AS OF 1-1-64
with
PRINCIPAL FAULTS

E. Ore Controls

The primary ore control appears to have been the line of fracturing on the long axis of the pit. This is the so-called pegmatite axis and it corresponds with the zone of +0.8% copper mineralization except where the zone is offset to the east. The offset block of ore appears to be a faulted segment of the tip of the apex.

If this is true, then the picture becomes one of a fracture zone through the center of the apex which allowed the spread of mineralization laterally in the highly fractured monzonite and to the very tip of the apex which at the time was covered by a rhyolite capping. Strong bornite mineralization probably penetrated several hundred feet into the rhyolite above the apex.

F. Supergene Enrichment

There were two widely separated periods of oxidation and enrichment at Ajo. The first period of oxidation came in Middle Tertiary when the rhyolite capping was oxidized to a depth of about 600 feet. As would be expected, only a minor amount of chalcocite formed in the rhyolite where primary mineralization was weak. In the small area of rhyolite that overlaid the monzonite apex, the strong bornite mineralization yielded a considerable thickness of chalcocite enrichment which merged gradually in depth with primary bornite mineralization.

After faulting displaced the rhyolite capping, the monzonite which was exposed at the tip of the apex carried strong bornite and chalcopyrite mineralization. Oxidation of this zone yielded an oxide zone with very abundant hematite and minor cuprite which changed in depth to chalcocite and finally to bornite and chalcopyrite. The only copper carbonates or silicates found in this area occur in the oxidized part of the surrounding rhyolite as chrysocolla, shattuckite and malachite.

The second period of enrichment was on the present erosion surface. Here the oxidation yielded malachite and chrysocolla to an average depth of about 50 feet. There was very little migration of copper values during this enrichment which took place over the exposed monzonite that carried strong bornite-chalcopyrite mineralization. In the rhyolite areas a slight amount of downward migration of copper occurred. The copper redeposited as sooty chalcocite. The pyrite was unaffected but with exposure to the atmosphere it is now beginning to break down. In these areas secondary chalcocite is occasionally associated with high concentrations of pyrite. The yellow ferrous sulfates are extremely common.

IV. GEOLOGIC HISTORY

The decipherable history of the Ajo area actually begins with the formation of the Pre-Cambrian basement gneiss that presumably underlies the mine area. Since this is treated in exhaustive detail in Gilluly's paper, it will not be reviewed here.

The oldest rocks in the mine area are the Concentrator Volcanics, which were Cretaceous flows that were deposited on the basement gneiss. After being chloritized, albitized and sericitized the formation was intruded by the Cornelia Quartz monzonite in early Tertiary. The copper orebody is localized in the apex of an offshoot of the large monzonite stock to the west. At the time of intrusion, a border facies of quartz diorite developed around the apex. Soon after consolidation, north-south fractures developed in the apex. These were filled by orthoclase-rich pegmatites. The mineralizing solutions chloritized and sericitized the apical rock and deposited the copper sulfides.

Following the mineralization, the Gibson fault dropped the hanging wall block several thousand feet. The mineralized apex was in this block. After long erosion the rhyolite capping was removed to within about 500 feet of the tip of the mineralized monzonite apex. During this period leaching penetrated about 600 feet into the rhyolite and underlying monzonite. This leaching caused secondary enrichment in the rhyolite capping over the apex with the formation of a chalcocite blanket. Then a low angle fault shifted the rhyolite capping about 1,200 feet to the southeast. This movement exposed a small area of monzonite at the tip of the apex. This area was along the pegmatite axis and carried strong chalcopyrite-bornite mineralization. For a shorter interval of time, a brief period of enrichment followed and allowed leaching to a maximum depth of 150 feet. In some areas monzonite with primary mineralization occurs on the old erosion surface, directly under the fanglomerate. Enrichment was brought to a quick end by the deposition of the rapidly accumulating fanglomerate and the interbedded Ajo Volcanics.

After deposition of the fanglomerate, the northwest trending Little Ajo Mountain fault developed and tilted the entire Little Ajo Mountain block about 50° to the south. There is direct evidence for this in that the unconformity upon which the fanglomerate rests has a consistently high dip to the south along the rhyolite-fanglomerate contact in the mine area.

Once again after prolonged erosion, the mineralized monzonite apex was exposed at the surface. This time the surface exposed was essentially what would have been a vertical section through the center of the apex in the original orientation. With this exposure the atmospheric moisture content was so low that oxidation occurred only in zones of strong mineralization, and there sulfides were oxidized to carbonates with little migration of copper.

V. SUMMARY

In the past few years, the geology of the New Cornelia pit has been reviewed. A fault pattern, based on current mapping and drill hole data, was worked out.

The pit rocks fell into two groups - divided by the Charlie fault. This is a north-south fault that dips steeply to the east and passes through the center of the pit. The rocks on the west side, in the footwall of the fault were hard, massive quartz monzonites with bornite-chalcopyrite mineralization and weak hydrothermal alteration. The rocks in the hanging wall block, on the east side of the pit, were soft quartz monzonites, quartz diorites and rhyolites with abundant flow sheeting and strong hydrothermal alteration. Mineralization is pyrite and chalcopyrite. In spite of the diversity in rock type, the east side of the pit is a structural unit with similar mineralogy and hydrothermal alteration.

A plus 0.8% copper zone occurs in the displaced block at the southeast corner of the pit. This block consists of massive rhyolite with secondary chalcocite deposited with primary bornite.

ORE CONTROL AT
NEW CORNELIA
OPEN PIT
MINE

BY

T. R. Couzens, Engineer

PHELPS DODGE CORPORATION
NEW CORNELIA BRANCH
AJO, ARIZONA

APRIL, 1964

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INTRODUCTION

Ore control is the process of distinguishing between ore and waste, while mining, and insuring that a blend of ore of the desired character and content is sent to the concentrator. There must be a daily detailed examination of the material being mined and the material immediately available in order to determine its destination and to plan further mining. Ore control involves continual sampling of the rock as it is exposed, it involves keeping detailed production records, and it involves presentation to management of information that will enable the producers to maintain a steady flow of ore. Achieving this steady flow requires a team effort; the informational side of the effort is provided by engineers, laboratory technicians, and samplers, and the planning and producing side is provided by the mine management and engineers.

The importance of ore control is obvious from the standpoint of producing a given amount of copper concentrate. At the Phelps Dodge Corporation's New Cornelia Branch at Ajo, a further control requirement lies in the fact that the smelter does not blend concentrates, but relies on the daily concentrator output for feed. Therefore, ore production must be such as to keep the smelter adequately supplied with concentrate. This requires frequent reappraisal of mining plans within the framework of monthly, yearly, and long range estimates. And the ore must be developed in a way that will prevent serious imbalance at the smelter.

THE ORE CONTROL MAP

Ore control begins with a map. An assay map of the mine is maintained at a scale of 1 inch to 100 feet, showing the toe and crest of each bench and the location of prospect holes, blastholes, survey stations, and such culture as railroad tracks and power lines. Each month the toes and crests are surveyed in active mining areas and the map is revised. Along each bank are depicted the drill holes and their assays that are taken to represent the material that could be mined from the bank. Copies of this map, showing the estimate areas for the month, are issued to operating departments. A representative portion of this map is shown in Figure 1.

The ore control work map is kept in the mine engineers' office. New blastholes are plotted on it daily, and as assays are received from the laboratory they are entered in the proper circles on the map. Loading tracks are stationed and marked at 50 foot intervals, the even 100 foot stations are located with transit and stadia rod, and the track is plotted on the map. This track stationing serves as a valuable tool in the field work of ore control; it enables the engineer to locate accurately the digging pits where the shovels are working, it enables him to find points of critical assay information in the field so that regions of ore and waste can be staked out for the production men, and it is very useful in mapping geological data. By the end of the month the ore control map has become a graphical history of the month's mining, a record of drilling and blasting, locations and progress of the shovels, successive positions of work tracks, and accumulated assay and geological information.

12" rotary blast holes sample split down to 10 lbs.

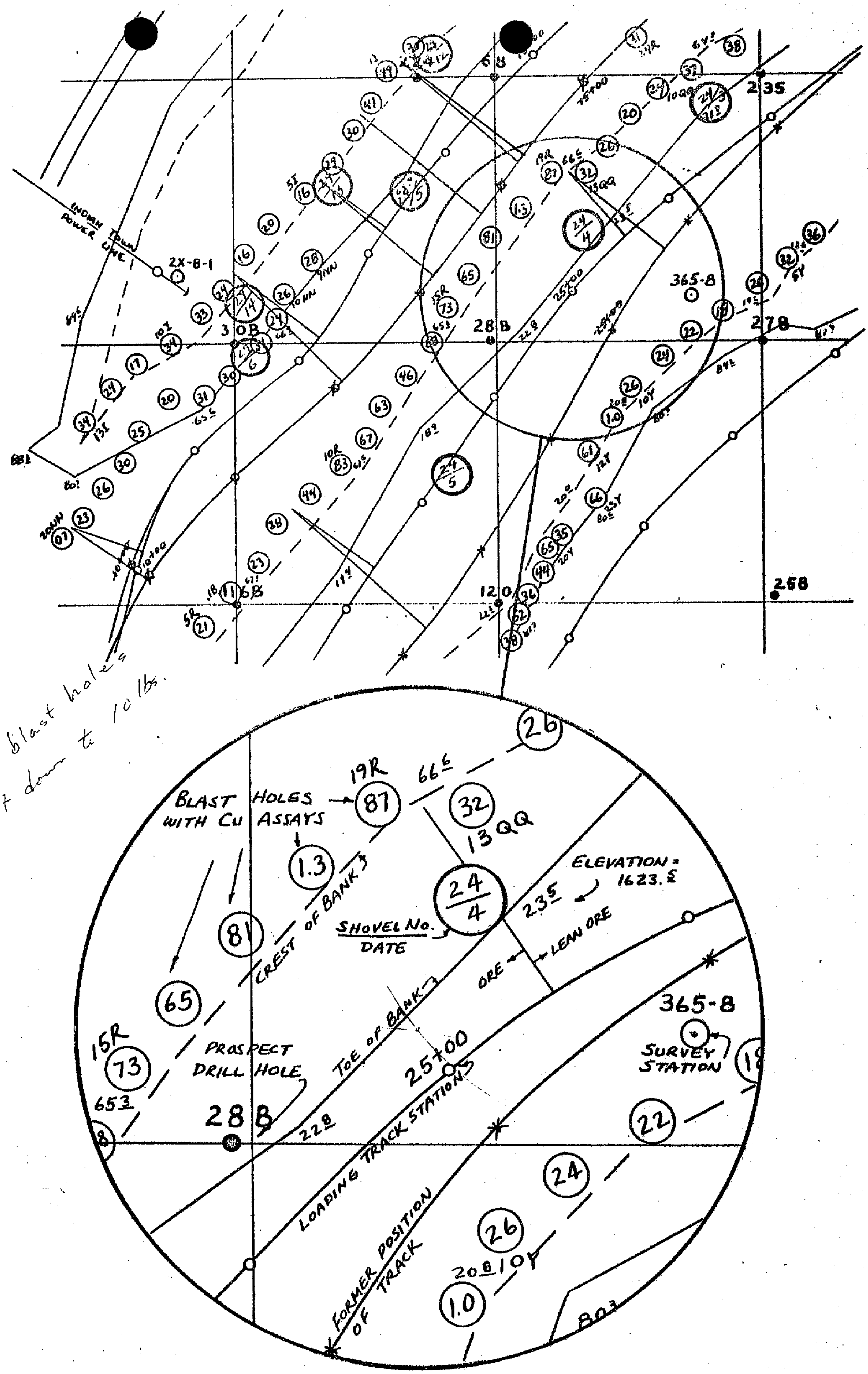


FIGURE 1. A SECTION OF THE ORE CONTROL MAP.

SAMPLING AND DETERMINING ORE AREAS

When the time comes to mine a section of bank, areas of ore and waste are determined by the use of blasthole assays. Most of the holes in the orebody are 12 inch diameter holes made with rotary drills. The drill crew sets a wedge-shaped sample collector against a short length of casing placed at the collar of the hole and this sample collector receives about 1/44 of the cuttings as they are blown out of the hole. They withdraw the collector when the depth to the next level is reached and samplers repeatedly split the cuttings until they have reduced the sample to about ten pounds. An engineering crew assigns matching numbers to the holes and samples, locates the holes and plots them on the map. When the assays are entered in the circles that denote the holes, the decisions can be made as to which portions of the blast are ore and which are waste.

There are two cutoff grades now used at Ajo, one for the majority of rocks and a higher one for the hard, west side rhyolite. Sulfide material with slightly less than the cutoff grade of copper is designated "marginal ore" or "lean ore" and is stockpiled on special dumps for possible future classification as ore. Thus for production purposes there are three kinds of rock: ore, marginal ore, and waste.

In the main part of the orebody, where the rock is characterized by a low grade disseminated primary mineralization, the separation between ore and waste is made on the basis of "two hole segregation". That is, the average of two adjacent assays must equal or surpass the cutoff grade to indicate ore. Each assay is given influence half the distance to the next assay. A line drawn midway between holes and perpendicular to the track shows the track station at the point of change.

At this point the engineer places a metal target near the track to notify the foremen and operating crews that a change is to be made in the destination of the material. Other aids in determining ore are prospect drill logs, which often yield information that supplements blasthole assays, and composite level maps, which show all holes and assays since the level was begun. Both of these tools are more used in estimating than for production.

Special situations, usually on the fringes of the orebody, call for less statistical approaches to the problems of separation. Visible distinction between mineralized and unmineralized rock, barren dikes, and isolated veins are examples of features for which an average of assays may not be the governing criterion for milling or wasting. Such occasions, however, relate to only a tiny fraction of the total material mined; they are dealt with by decisions made after examination of the broken material. Copper oxides, carbonates and silicates, sooty chalcocite, and some native copper are examples of mineralization that may lead to wasting of the rock regardless of the total copper content. Such rock requires closer study than the ordinary sulfide "porphyry" material, by panning drill cuttings, by analyzing for oxide copper, and sometimes by batch flotation tests. Whenever the evidence indicates that recovery will be too low to warrant milling, the rock is sent to the lean ore or waste dumps. A small part of this kind of material is sometimes salvageable as smelter flux, if the silica content is high enough.

PETOGRAPHIC DESCRIPTIONS

Between 1957 and 1960 a series of bulk samples were taken from different parts of the pit for metallurgical testing in the pilot plant. Some of these samples were also the subject of petrographic study. Megascopic description of the rocks was followed by microscopic study of thin sections and polished surfaces. Concentrates from these samples were also studied in polished specimens and the minerals identified in the non-opaque fraction of each concentrate.

The quartz monzonites are holocrystalline porphyritic intrusives with phenocrysts averaging 3 millimeters in size. In the phenocrysts plagioclase is most abundant, followed by quartz, orthoclase, and chlorite.

The quartz diorites are hypidiomorphic granular-textured rocks with numerous quartz veins. The grain size is generally less than 2 millimeters.

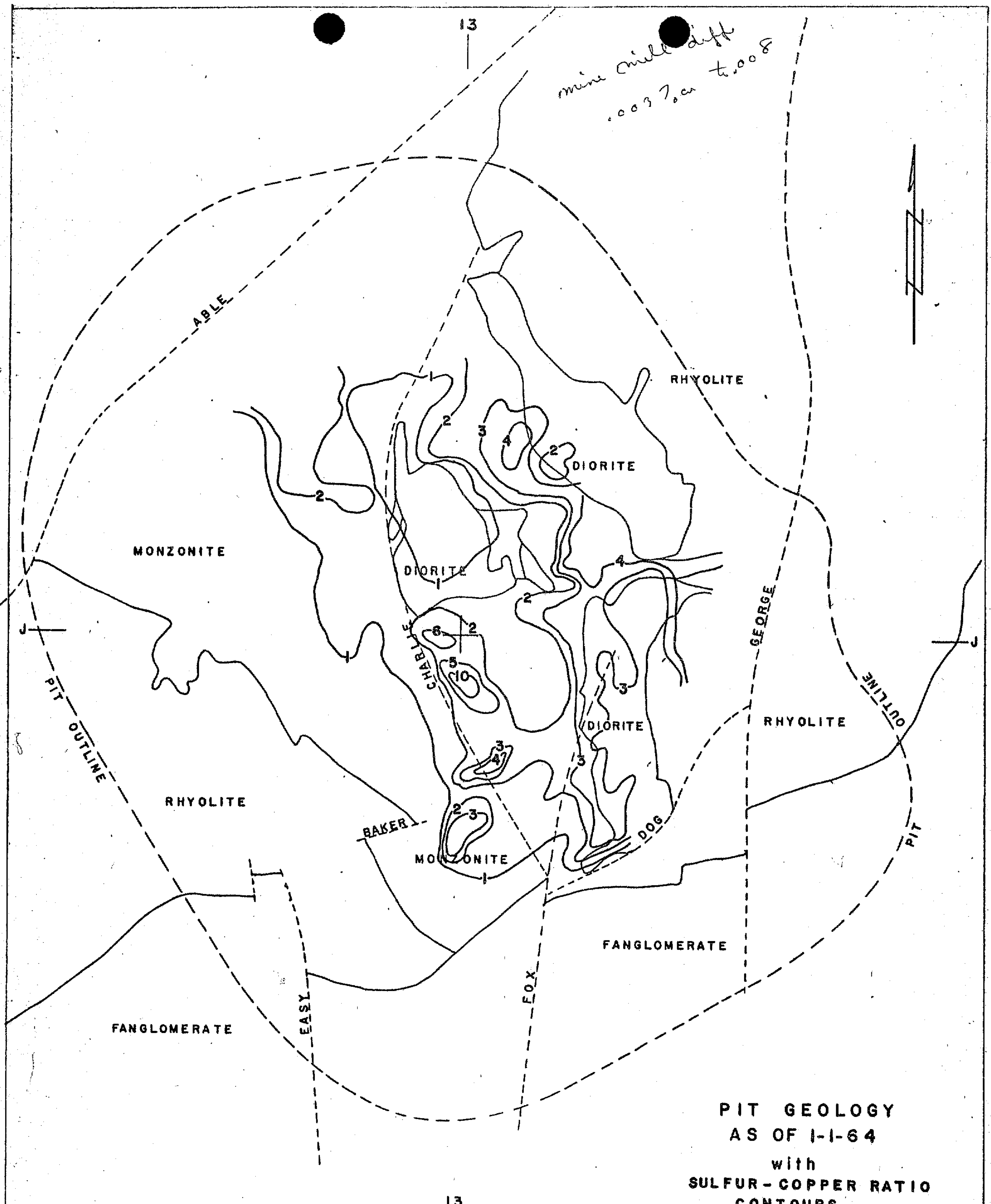
The rhyolites are holocrystalline and porphyritic with quartz and orthoclase phenocrysts under 2 millimeters in a microcrystalline groundmass.

Mineralization in these rocks is disseminated throughout the rock and also distributed along veinlets. The monzonites tend to show predominantly disseminated mineralization associated with the quartz-orthoclase matrix. The diorites, and the rhyolites, feature more prominent distribution of sulfides along veins and small cracks as well as some disseminated distribution.

Principal alteration products are sericite, and clay, chlorite and minor leucoxene and rutile. Calcite and, to a lesser extent, gypsum are present in veinlets and filled cavities.

The mine naturally divides into two major parts corresponding with the structural units of the orebody. All three rock types are represented in both parts. There are the generally hard, massive west side rocks with hydrothermal alteration estimated at about 20% of the volume. Their average bornite:chalcopyrite:pyrite ratio is about 3.2 : 1.0 : 0.7. The other group is composed of soft, altered rock from the east side of the pit, characterized by hydrothermal alteration of about 40% and a bornite:chalcopyrite:pyrite ratio of 0.1 : 1.0 : 1.1. The orthoclase content is about the same in these two groups of rocks, but in the non-opaque part of their concentrates the orthoclase fraction from the east side was about twice that from the west side.

Figure 2 is a map of the pit showing sulfur:copper ratio contours. Thousands of blastholes have been assayed for sulfur in the last several years and it can be seen that these ratios outline the high pyrite zones in the mine. From the pilot plant tests the metallurgists have discovered an empirical relationship between the sulfur:copper ratio of the ore and the expected iron:copper ratio in the final concentrate. This relationship has value in predicting amounts and composition of concentrates to be produced by various ore shipments.



PIT GEOLOGY
AS OF 1-1-64
with
SULFUR-COPPER RATIO
CONTOURS

FIGURE 2

ORE CONTROL ENGINEER'S DUTIES

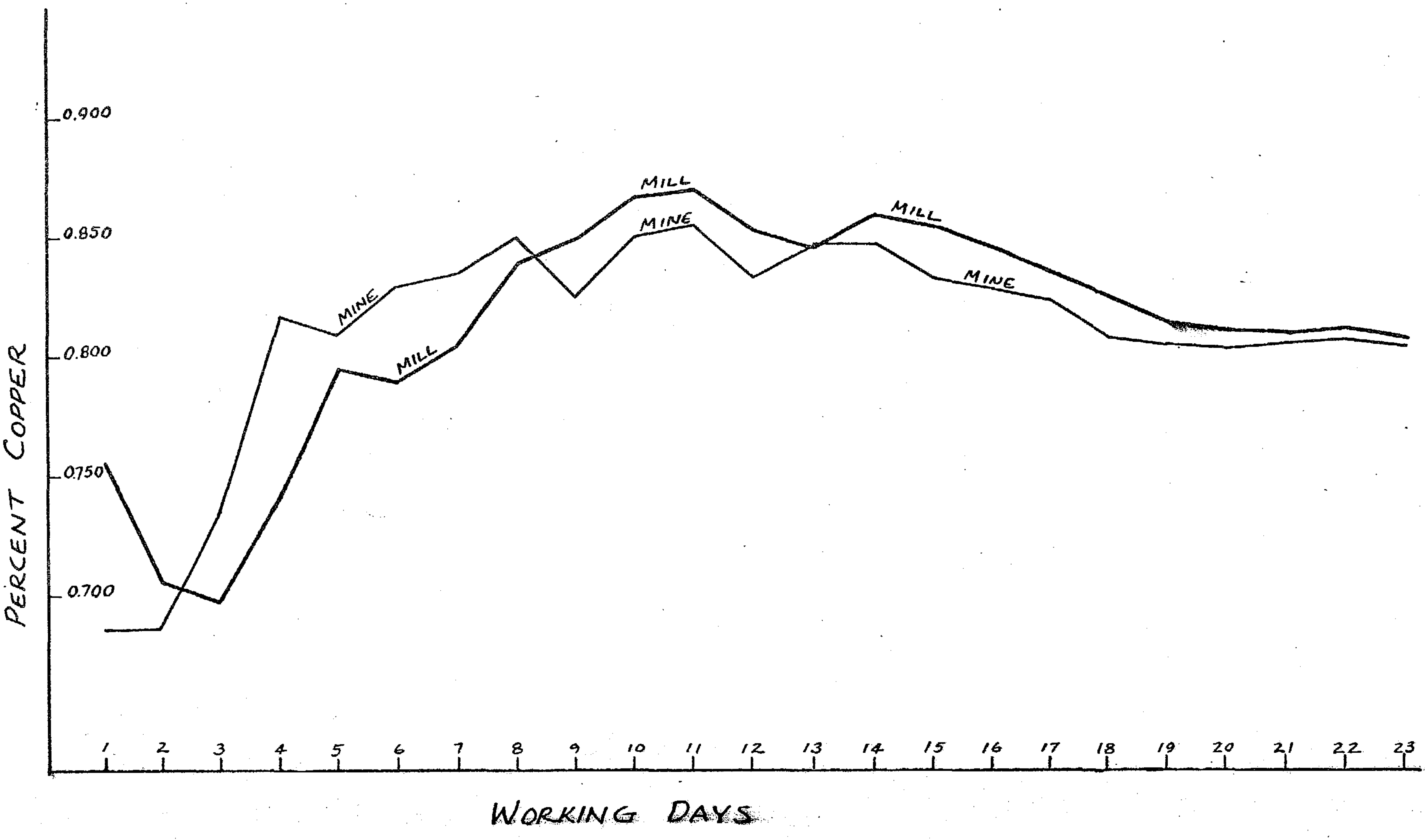
The ore control engineer visits each shovel every morning, examines the rock in the digging pit and ahead of the shovel, and notes the track station of the pit or otherwise locates it as accurately as possible. Returning to the office, he plots the shovel positions on the map, including shovel moves and changes of direction. By averaging assays between shovel positions, with occasional weighting of assays according to tonnage factors for different bank heights or digging conditions, he figures an ore and waste grade for the material mined by the shovel during the preceding day. Using tonnage figures derived from a count of the cars loaded, he calculates the total grade of ore mined and the cumulative grade for the month to date. This calculation serves as a continuous check on mine sampling because the mill feed is thoroughly sampled during processing. Figure 3 is a graph of the cumulative mine and mill grades during an actual month. Some indication of the lag between mine and mill can be seen as well as certain vagaries that are hard to understand, but the overall agreement, particularly late in the month when many days are represented, is typical. This agreement allows confidence in the mine blasthole sample results. In 1963 the largest discrepancy between end of month mine and mill grades was 0.008% copper. The average discrepancy during 1963 was 0.003% copper.

The daily mine report is completed before noon and contains the following information:

Pit map coordinates of the shovel locations at the beginning of day shift,

Grade and tonnage of material mined by each shovel during the preceding day,

FIGURE 3. COMPARISON OF CUMULATIVE MINE AND MILL GRADES DURING MONTH.



Grade and tonnage of material mined by each shovel for the month to date,

Cumulative totals of tonnage and grade for the day and month to date,

Hardness and size description of ore,

Geological description of ore and waste.

This daily report is typed and distributed to company officials concerned.

Tonnage records are kept by levels for each of nine combinations of rock type and mineralization. The three major rock types -- quartz monzonite, quartz diorite, and rhyolite -- are each divided into three classifications according to the sulfide minerals present. These categories provide for a predominantly chalcocite-bornite type, a chalcopyrite-bornite-pyrite type, and a chalcopyrite-pyrite type, of mineralization. The value of this kind of production reporting for ore control work is that it permits correlation of the concentrator's performance with the character of the ore as an aid in making metallurgical predictions.

After the daily report is submitted, the ore control engineer prepares a line-up for the general mine foreman. This line-up is a prediction of the grade and character of material available for the three following shifts and aids in making the shovel working assignments. A similar line-up is prepared for the concentrator metallurgist indicating the sulfur:copper ratio and milling characteristics of the ore to be mined.

The remainder of the ore control engineer's time each day is spent in preparation for the coming days mining. He makes additions to the map to bring it up to date with respect to assays, track moves, and newly exposed geology. He places targets in the mine to show areas of ore, marginal ore, and waste. In all this work he is in frequent touch with shift foremen and other interested production men.

ORE BLENDING

Ore blending is achieved by working shovels in various combinations of ore types. There are fourteen shovels at Ajo, and twenty-two shovel shifts are worked each day. Some of the shovels are confined to stripping operations, others are almost entirely worked in ore, while others are in mixed areas where they mine both ore and waste. Except for minor variations because of surge in the ore bins or crusher down-time, two shovels work in ore on day shift and three on each of the night shifts for a total of eight shovel shifts of ore in each twenty-four hours. Shovels must be worked in relatively high grade areas as well as in lower grade areas in a balanced manner that will contribute to the systematic development of new ore.

In a daily conference with the general mine foreman, the ore control engineer points out the location of the shovels with respect to the assay information. The general mine foreman assigns the shovels to be worked each shift, guided by the ore control engineer's line-up. Of course, these assignments depend on operating requirements such as necessary maintenance of equipment, track construction, and drilling and blasting. Metallurgical and physical properties of the ore are also factors, but blending to maintain the daily and monthly grade is of primary importance.

LONGER RANGE USES OF ORE CONTROL INFORMATION

The informational aspect of ore control work is of value in estimation of future production. For example, the empirical relationship between the sulfur:copper ratio in the ore and the iron:copper ratio of the concentrate is used both in daily predictions and in longer range estimates of concentrate production. Extrapolation of assay information often hinges on geological contacts which are kept up to date on the map by the ore control engineer. Production reporting brings to light special milling problems of different rock types and mineral groups. All of this information that accumulates during daily ore control activities is available to the engineering department for use in intermediate and long range planning and, together with prospect information, furnishes knowledge that contributes to the profitable exploitation of the orebody.