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Arizona Geological Survey
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James Doyle Sell Mining Collection

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[redacted]2-65

JHC File → Uekal Mtn.

Rob Radabaugh

70 mil term .63 — .4 cutoff — 50' benches

90 " " .56 — .3 "

3:1 — w/o

recov. 83% — 90% of sulphides +

34% Newmont

34% New J. (asking 1.5 million)

32% Papago Expl.

File Vekol Copper Deposit

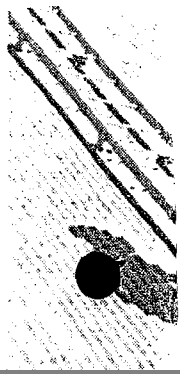
J. H. C.

MAR 15 1974

CASA GRANDE DISPATCH

JUDGED ARIZONA'S BEST
NON-DAILY NEWSPAPER

CASA GRANDE, ARIZONA 85222 | WEDNESDAY, JANUARY 30, 1974 | 10¢ Per Copy | VOL. LX | NO. 13



AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

J. H. C.

FEB 9 1971

February 9, 1971

TO: Mr. A. J. Kroha

FROM: W. E. Saegart

File

Re: Vekol Deposit
Superior Oil and Newmont
Joint Venture

Mr. Ben Dickerson, Southwest Manager of Superior Oil's Minerals Division, gave me the following confidential information today. Based on recent drilling by Newmont, reserves of their joint venture Vekol project have been up-dated to + 100 million tons grading 0.55% Cu, 0.015% Mo, and 14¢ combined gold and silver. Newmont's latest plans call for an initial production rate capacity of 20,000 tons per day. The copper occurs as chalcopyrite and minor bornite. There is also a modest tonnage of oxide copper. Metallurgical tests indicate a concentrate grade of 27% Cu.

The existing lease with the Papago Tribe expires in 1974. Mr. Dickerson indicated that Newmont intends to make an announcement in April of this year concerning the development of the property for production. According to Dickerson, "There is a 95% probability that Newmont will announce their intent to place the property into production."

Mr. Dickerson further pointed out that their agreement with Newmont provides Superior Oil the alternative of taking their 50% share of concentrates in kind. Since annual production will total roughly 36,000 tons of copper per year, Superior Oil will have control of the disposal of concentrates containing some 18,000 tons of copper per year. He very pointedly indicated that Superior Oil is interested in pursuing an outlet for treatment of their concentrates other than Magma's San Manuel smelter. Their concern is with the possibility that stringent pollution controls may eventually require termination of the use of the Sam Manuel smelter. In no event will Superior Oil accept a long term contractual commitment to ship their share of the concentrates to San Manuel.

Superior Oil would be very interested in talking to ASARCO in connection with our consideration of flash (stackless) smelting.

W E Saegart

W. E. Saegart

WES:mw
cc: J. J. Collins
J. H. Courtright

J.H.C. J.H.C.

FEB 27 1968 JAN 15 1968

Ga 16A.10.18
+ JHC file

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

January 10, 1968

To: J. H. Courtright

From: J. D. Sell and J. R. Wojcik

Drill Hole Pattern
New Jersey-Newmont Drilling
Reward Prospect, Vekol Mts.
Pinal County, Arizona

With the securing of additional information the drill hole pattern is finalized from the subject area report dated November 6, 1967. As shown on Attachment A some 241 drill holes, either rotary, diamond drill or a combination were drilled during the project. Three of the holes were rotaried only thru the alluvial cover without further drilling and seven were drilled to the northeast outside the main area.

The tentative outline of one proposed pit is shown on the attachment and shows the corelation between the close spaced drilling and the pit outline.

James D. Sell

James D. Sell

J. R. Wojcik

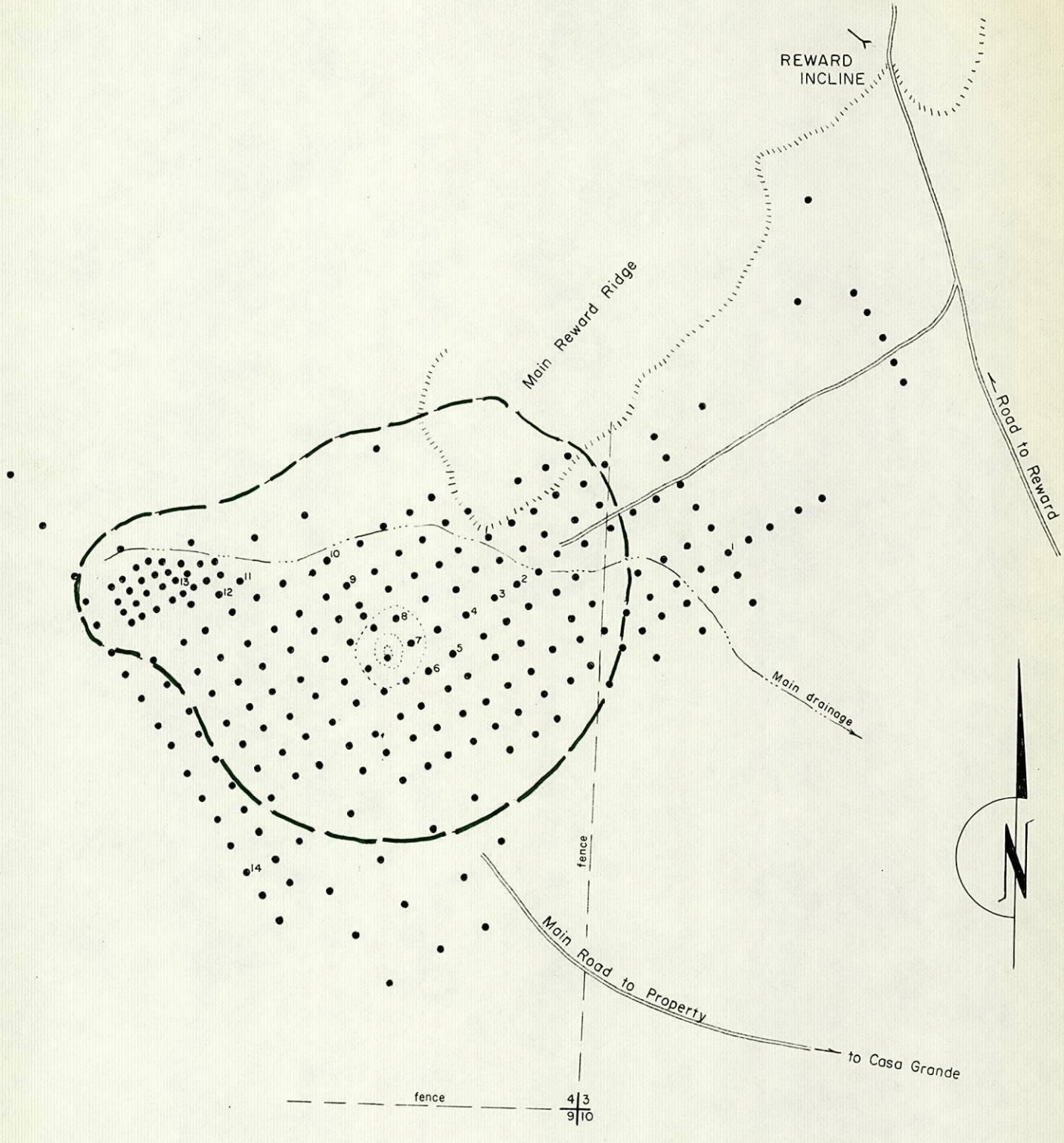
JDS:kc

Attachment

ATTACHMENT A

Cooper Aerial Surveys

Photo: FL 1-2, 10-20-67



Approx. Scale
1" = 1000'

•7 Drill Hole with Core Specimen Number

"Outcrop Hill"

Outline of Proposed Pit

"Vekol Project"
JHC's Office only

December 14, 1967

Mr. R. E. Radabaugh, Mgr. Western Exploration
The New Jersey Zinc Company
Pima Plaza Building
2030 East Broadway
Tucson, Arizona 85719

Dear Bob:

Enclosed is a signed copy of the Letter of Agreement which accompanied the Vekol Project data loaned to this office.

Mr. Wojcik has prepared the attached list noting items included that were not listed and vice versa.

Yours very truly,

J. H. Courtright
Chief Geologist

JHC:lmi
encls.

THE NEW JERSEY ZINC COMPANY
(ESTABLISHED 1848)
160 FRONT STREET
NEW YORK, NEW YORK 10038

NJZ

December 5, 1967

PLEASE ADDRESS REPLY TO
Pima Plaza Building
2030 East Broadway
Tucson, Arizona 85719

Mr. J. H. Courtright
Chief Geologist
American Smelting and Refining Company
1150 North 7th Avenue
Tucson, Arizona

Re: Vekol Project
Vekol Mining District
Pinal County, Arizona

Dear Harold:

In accordance with arrangements made between Mr. C. P. Pollock of ASARCO and Mr. S. S. Goodwin of our Company, we are loaning you for your use in the evaluation of Vekol Project the data available from our Tucson, Arizona office. These data consist of a plan map, a set of longitudinal and cross sections, and drill hole logs prepared by The New Jersey Zinc Company and the strip drill logs and assay reports by Newmont Exploration Company, Ltd. A complete list of these data is attached hereto.

The data are being loaned to you with the understanding that they will not be copied or reproduced and that the information is confidential and is to be used only by those within your company who need to have access to it in connection with your evaluation. It is further understood that all the data will be returned to us as soon as it has served its purpose.

Please indicate your acceptance and the receipt of the listed data by signing and returning to us the inclosed copy of this letter.

Very truly yours,

R. E. Radabaugh

R. E. Radabaugh
Manager of Western Exploration

RER:kk

Agreed to and received by:

_____

J. H. Courtright, Chief Geologist
American Smelting and Refining Company

Date:_____

cc: Mr. J. H. Courtright

NEW JERSEY ZINC COMPANY DATA

Plan Map - Vekol Project Scale 300' = 1 inch

Cross Sections Scale 100' = 1 inch

16 W	2 E
14 W	4 E
13 W	6 E
12 W	8 E
10 W	10 E
9 W	12 E
8 W	14 E
6 W	16 E
4 W	18 E
2 W	20 E
0-0	22 E
	24 E
	42 E

Longitudinal Sections Scale 100' = 1 inch

6 S	10 N
4 S	12 N
2 S	14 N
0-0	15 N
2 N	16 N
4 N	17 N
6 N	18 N
8 N	

Drill Logs

V-1, V-6 A, V-9, V-10, V-15, V-16 and V-17

R-6 to R-235 inc.

R-238 to R-241 inc.

NEWMONT EXPLORATION, LTD. DATA

Drill and Assay Strip Log

V-1 to V-13 inc.
V-15 to V-17 inc.
R-2
R-6 to R-64 inc.
R-66 to R-69 inc.
R-71 to R-78 inc
R-75, R-76, R-78, R-79
R-81 to R-84 inc.
R-89, R-90
R-92, R-102 inc.
R-104, R-105, R-107, R-109, R-110, R-112, R-116, R-120, R-122
R-124 to R-127 inc.
R-130, R-131, R-134, R-135
R-137 N to R-139 inc.
R-175, R-189, R-192, R-200, R-207, R-212, R-214

Drill Hole Log

R-74, R-128, R-133, R-136, R-148 N, R-159, R-165, R-167,
R-190, R-191, and R-239

Drill Hole Data

RV-6 B, R-64, R-70 N, R-74, R-77 N, R-80 N, R-103 N,
R-106 N, R-108, R-111
R-113 to R-115 inc.
R-117 to R-119 inc.
R-121, R-123, R-128, R-129, R-132, R-133, R-136
R-140 to R-162 N inc.
R-164 to R-174 inc.
R-176 to R-188 inc.
R-190, R-191
R-193 to R-199 inc.
R-201 to R-206 inc.
R-208 to R-211 inc.
R-213 to R-235 (R-214 missing)
R-239 to R-241

All data are accounted for except as noted below:

Under heading "Longitudinal Sections", one section number 8N is included although missing from NJZ's list.

Under heading "Drill Hole Data"
Hole number R-64 is not included although listed.
Hole number R-163 is included, but not listed.

JRW
12/14/67

MR. WES

READ AND RETURN

PREPARE ANSWERS ____ HANDLE ____ J. H. C.

FILE ✓ INITIALS

DEC 11 1967

W.E.S.
DEC 20 1967

December 7, 1967

Mr. S.S. Goodwin,
Vice-President,
The New Jersey Zinc Company
160 Front Street
New York, New York 10038

Dear Mr. Goodwin:

This is to acknowledge and thank you for your letter of December 6th confirming substance of our telephone conversation November 30 concerning the Vekol property, Papago Indian Reservation, Arizona.

In accordance with our understanding, I have instructed Mr. Courtright to review the data as suggested and we are now awaiting his evaluation thereof.

I will communicate with you again as soon as we arrive at some decision regarding this matter.

Sincerely yours,

C. P. Pollock

CC:JHCourtright w/attach.

THE NEW JERSEY ZINC COMPANY
(ESTABLISHED 1848)

OFFICE OF THE
VICE PRESIDENT

160 FRONT STREET

NEW YORK, NEW YORK 10038

NJZ

December 6, 1967

Mr. C. P. Pollock, Vice President
American Smelting & Refining Company
120 Broadway
New York, New York 10005

Dear Mr. Pollock:

This will confirm the substance of our telephone conversation on November 30 concerning the Vekol property located on the Papago Indian Reservation near Casa Grande, Arizona. As you know, Newmont and New Jersey Zinc have jointly explored the Vekol property looking for a porphyry copper-type of ore body.

Drilling on the property has disclosed about 80 million tons of .57% copper and .015% molybdenum using a cut-off grade of .3% copper with a stripping ratio of about 2½ to 1. No provision has been made for recovery of copper from oxidized ores or from leaching of waste containing less than .3% copper.

An evaluation of the deposit has indicated that it would be somewhat marginal based on current markets and current estimated costs and work has been suspended. We believe the deposit is a valuable resource to a company that wishes to perpetuate its position in the copper industry or a company that desires to get into the industry. However, it has been the decision of our Company not to pursue the matter at this time and hence this is what prompted my question to you as to whether American Smelting & Refining would be interested in acquiring our interest in the property.

New Jersey Zinc's interest in the Vekol venture is 34.684675%, which is the same as Newmont's interest. Papago Exploration, an independent group, have an active interest of 22.3295% and the carried interest of 8.30115%.

Mr. C. P. Pollock

We have advanced about three-fourths of a million dollars to the venture and we are asking 1½ million for our interest; i.e., a factor of about two to one for the risk we have taken. Under the agreement we have with Newmont they have the right to meet any offer that we receive for the purchase of our interest.

You indicated that AS&R would like to look at the basic data to determine the extent of your interest. To this end we have asked R. E. Radabaugh of our Tucson office to contact J. H. Courtright of your Tucson office and arrange a date for Mr. Courtright to look at the Vekol ore reserves and other pertinent data. We shall look forward to hearing from you as to your further interest after this meeting has taken place.

Sincerely yours,

S. S. Goodwin
Vice President

SSG:ei

J. H. C.

J. E. K.

NOV 20 1967

JAN 15 1968

Ga 16A. 10. 18

W.E.S.

DEC 6 1967

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

November 6, 1967

WES

READ AND RETURN

PREPARE ANSWERS HANDLE

FILE ✓ INITIALS

To: J. H. Courtright

From: J. D. Sell and J. R. Wojcik

New Jersey - Newmont Drilling
Reward Prospect, Vekol Mountains
Pinal County, Arizona

The subject area was visited on November 2, 1967, to check their drilling pattern and collection of core chip samples. For expedience the photos taken after termination of drilling were used for plotting the information. The photos were also checked by stereoscopic examination and the unvisited drill sites were marked on the overlay.

Of the 321 drill hole sites shown on the overlay (Attachment A), the following breakdown is suggested:

105	- Sludge piles seen/or examined.
71	- Site visited but was not drilled.
135	- Sites not visited <u>but</u> probably drilled.
10	- Sites not visited <u>and</u> probably not drilled.
321	Total sites by stereoscopic examination.

The approximate scale is 1"= 1000' giving a drill spacing of 200 feet for the most part. However, when paced on the ground the spacing appeared to be closer to 175 feet.

Although much of the central portion was not visited there is little doubt that all the sites were drilled. On the fringes it was noticed that in some instances they doubled the drill spacing and also that they apparently rotaried some holes but did not core them. By personal communication from the drilling contractor's foreman, most of the holes in the latter part of the program were completed with a down-the-hole hammerdrill primarily for assay information and secondarily for correlation.

As shown by the attached sack of core chips, the area has a very high pyrite content, some of it as veinlets, with a high percentage as extremely fine particles within the diabase. Chalcopyrite is next in abundance in the observed chip specimens and only one specimen (5 mo) was found that contained molybdenum.

The four photos taken by Cooper Aerial Surveys are in the files along with the mylar overlay of photo FL 1-2.

James D. Sell
J. D. Sell

J R Wojcik
J. R. Wojcik

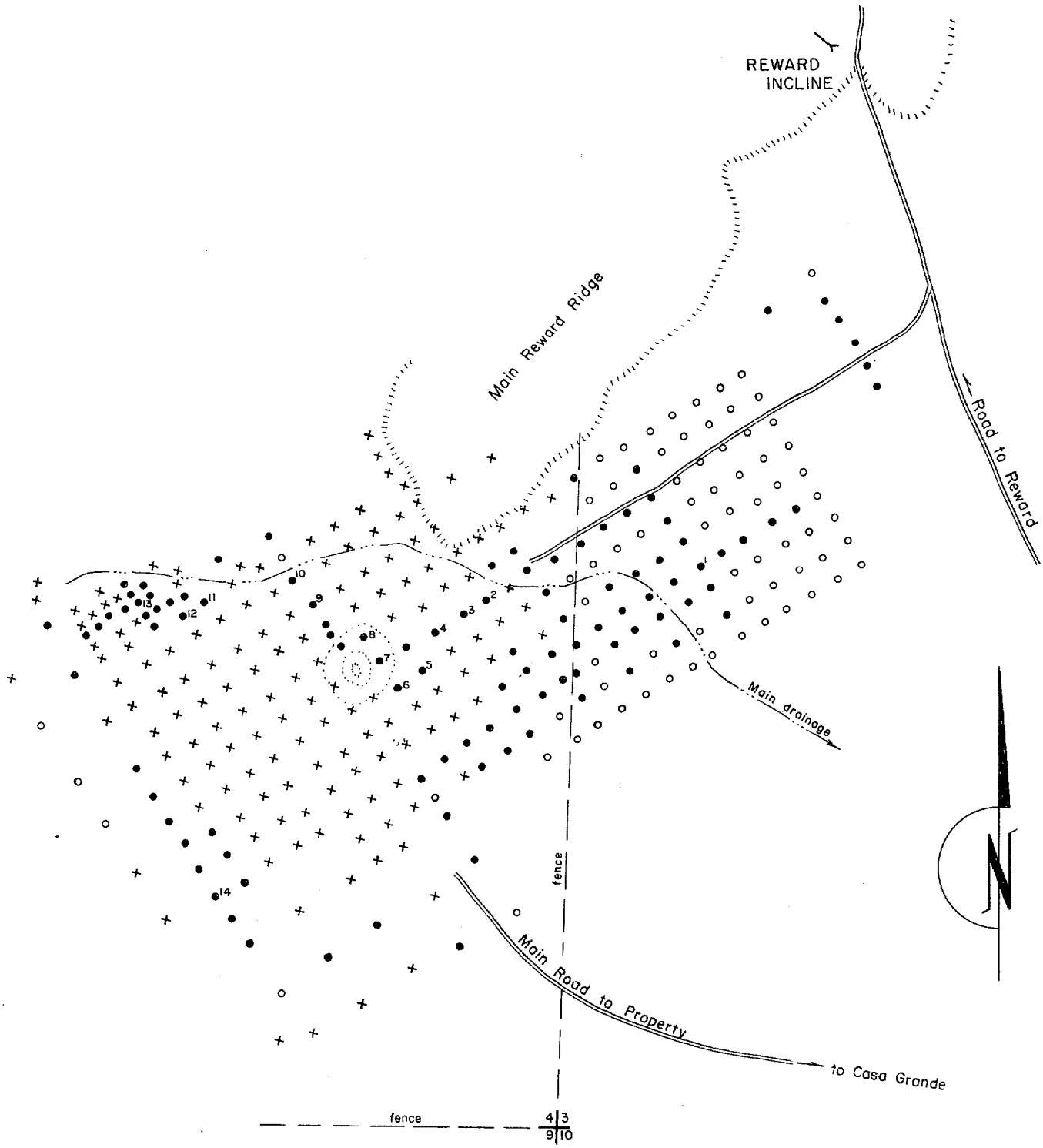
JDS:kc
Attachment

Aerial Photos filed in Library (see ✓ ✓).

ATTACHMENT A

Cooper Aerial Surveys

Photo: FL 1-2, 10-20-67



- Drilled Hole
- Hole NOT Drilled
- x Drill Site Not Visited
- "Outcrop Hill"
- Drill Hole with Core Specimen Number

Approx. Scale
1" = 1000'

1996

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

Aa-16A.3.0

File: Aa 16A.22.22
~~Aa 3.20.20A~~

"Reward Mine (Vekol Mts.)"
"Papago Ind. Res."

October 11, 1967

Mr. C. P. Pollock, Vice President
ASARCO - New York Office

Newmont Mining Corporation
Vekol Mountains Prospect

Dear Sir:

In reply to your telephone request I am enclosing copies of News releases on Newmont's Vekol Mountains prospect. Also enclosed is a report and map by J. E. Kinnison in case it cannot be located in the New York files.

Drilling on the prospect was terminated about two months ago. There is currently no activity of any kind on the property. As observed from the air, around 200 holes on 100 to 200' spacing have been drilled in an area of about three-quarters of a square mile. It is rumored that the copper mineralization (in the Mescal limestone and in diabase sills) is spotty and discontinuous. This condition is suggested by the close spacing of the drill pattern. The local consensus is that the deposit is marginal and that plans for production have been deferred.

As reported by Mr. Kinnison, the first hole cut 90' of 1% copper in the Mescal limestone (garnetized). According to the Papago News release, a 15,000 TPD operation would produce 50 million pounds of copper per year. This indicates about 10 pounds recovered per ton, or a head grade of around .57% copper. Figures quoted in another News release, which I do not have now at hand, indicated 9 lbs. copper per ton.

It is to be noted that in a subsequent release, Newmont labeled as "erroneous" any implication that they are proceeding or have agreed to proceed with a mining project.

The negotiated royalty to the Papagos amounts to 5% on ores having a net smelter return of $4/ton or under, with an increase of 1% for each $0.25/ton net value increase up to $5 N.S.R., and 10% royalty on $5 to $7 N.S.R.

Incidentally, New Jersey Zinc and Newmont each have a 30% interest, the remaining 22% being held by the Papago Exploration Company, a Minneapolis group.

Yours very truly,

JHC:lmi

J. H. Courtright

Pay Dirt 4-21-67

VEKOL HILLS LEASE SIGNED BY NEWMONT AND THE PAPAGOS

Leases on approximately 2,800 acres of Papago Indian Reservation land have been negotiated between the Papago Indian Tribal Council and Newmont Exploration, Ltd., of New York. The property is in the Vekol Hills, 27 miles southwest of Casa Grande, Arizona, and 50 miles northwest of Sells, the tribal capital.

According to the announcement by Tribal Chairman Robert Mackett, who signed for the Papago Indians, the eight-year leases call for an initial bonus payment of $50,000 and an advance royalties payment of $50,000 for the first year. Similar yearly advance royalty payments, he said, are to be made until production begins. Mackett described the contract as "a turning point in the tribe's history," giving the Papagos a chance to develop "from the poorest tribe in the nation to an economically self-sufficient people." He confidently predicted that Newmont would have the "mine" in full production within three to four years, handling 15,000 tons of copper ore per day.

On the other hand, Newmont Exploration, Ltd., labeled as "erroneous" any statement or implication that Newmont is proceeding or has agreed to proceed with any mining project or operation at the Papago property. The company stated: "Results of work done to date on the property indicate an appreciable tonnage of marginal grade copper ore minable by open-pit methods. Further work and evaluation will be necessary to determine whether or not this property should be brought into production."

The current negotiations modified an earlier lease acquired by Newmont in 1965, and cover the remaining eight years of the original standard 10-year lease. Most of Newmont's exploration to date has been by drill hole testing and sampling and this work is to continue.

$45 Million Deal Biggest Ever For Tribe

Papagos Lease Site For Copper Mine

Indians To Gain 'Self-Sufficiency'

By TOM TURNER

"The Arizona Daily Star"
April 7, 1967

The Papago Indians yesterday signed a lease contract for construction of a $45 million open-pit copper mine and mill on Pinal County reservation land.

Leasee is Newmont Exploration Ltd. of New York. Newmont owns 80.6 per cent of Arizona's Magma Copper Corp. stock. Magma currently operates mines, mills and smelters in San Manuel and Superior that produced a total of 226.5 million pounds of copper last year.

Newmont said yesterday that the new mine on 2,800 acres of Papago land in the Vekol Hills near Casa Grande will be producing upward of 50.5 million pounds per year when paying operations begin in 1970.

At the current market price, Vekol Hills production would bring in excess of $18 million a year in new money to Arizona, and the Papagos would receive $1 million annually in production royalties.

Until then, the mining firm has advanced $50,000 to the Papagos as a lease bonus and $50,000 in advance royalties for the first year. Newmont will pay the Indians $50,000 each year until production begins.

It is the biggest contract ever signed by the Papagos.

"The Papagos now have the chance to develop from the poorest tribe in the nation to an economically self-sufficient people," said Robert Mackett, tribal chairman. "The mine will produce new jobs for the Papagos, and there's nothing more important than finding employment for our people."

Newmont said yesterday that work to clear overburden (topsoil) from the minesite will begin this weeek. Employment at the new mine will increase to a peak of approximately 300 when production begins.

The new mine will be a part of southern Arizona's Copper Circle — an area extending 125 miles in all directions from Tucson — that already produces roughly half the nation's copper.

Newmont officials estimate that some 15,000 tons of ore will be removed and processed daily when the new mine enters production — about half that of Anaconda's new $65 million development south of Tucson.

Vekol production will top that of current operations at Silverbell, Pima and Duval mines in Pima County. It is probable that Magma smelters at Superior and San Manuel will process the new ore.

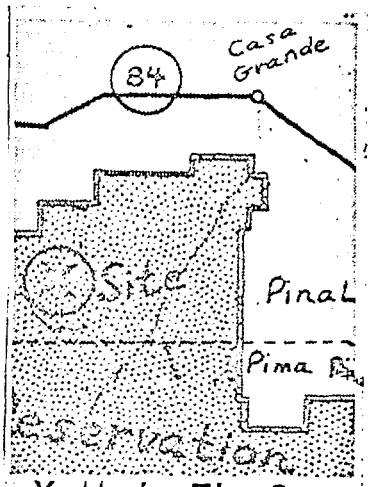
Vekol holds a low grade of ore, about equal in quality to that which will be produced by Anaconda by 1969. The Vekol ore bed is a shallow one, so that the pit will be bigger in area but not quite as deep as Anaconda's.

The lease is a modification of a lease taken out by Newmont in 1964. The original lease covered 1,535 acres. The new lease — good for the remaining eight years of the original, standard 10-year lease — covers some of the same land, plus some new land for future exploration. Newmont said that test drilling will continue. The firm spent more than $500,000 in exploration at Vekol last year.

As long as a mine is in production on the land, the lease will be automatically renewable indefinitely. Under terms of the lease, Newmont must spend $118,000 in the first year, $236,000 the second year and $575,000 each year thereafter to develop the mine.

The mine site is approximately 27 miles southwest of Casa Grande and 50 miles northwest of Sells, the tribal capital. Newmont is reported planning more than $1 million in new road and rail spur construction in the area.

The contract was signed in Phoenix by Mackett and Robert Fulton, Newmont vice president. Also at the contract signing were Edward Berger, Tucson attorney and tribal counsel, and Vernon Smith, tribal mining consultant.



X Marks The Spot

"X" marks area near Vekol Mountain on Papago Indian Reservation which is being leased for a $45 million copper mine. Shaded area is reservation, which extends up into Pinal County.

NEWMONT PRESIDENT SAYS

Star-Citizen 11-21-67

Papago Mining Not Justified Now

The Newmont Mining Corp. says the 75 million tons of copper ore it has discovered on the Papago Indian Reservation cannot be mined under present economic conditions.

In a speech to the New York Society of Security Analyists, Newmont President P. Malozemoff revealed the tonnage estimate and said the grade ore averages 0.6 per cent.

But while mining is not justified now, Newmont still looks on the Papago property as one of three "potential open pit mines" it has.

Newmont paid the Papago Tribe a $50,000 bonus on signing an 8-year lease on the property in April.

At that time, tribal leaders said they anticipated $1 million in annual royalties from the lease along with a 15,000 ton-a-day operation requiring 250 employes, to be mostly Indians.

The property covers 2,800 acres in the Vekol Hill area, 27 miles southwest of Casa Grande, and 60 airline miles northwest of Tucson.

John Artichoker, tribal superintendent, said: "We have had very little contact with Newmont since the lease was signed.

"Things have been quiet. We don't know what this means. But I suppose one would have to assume the development of this ore body would have to be related to the price of copper."

Another potentional Newmont mine is near Copper Creek. In this case, Newmont, with its affiliate, Magma Copper Co., has found ore-grade copper-molybdenum mineralization 2,000 feet deep.

Malozemoff said that, because of the depth of this ore body, very large tonnage would be required to produce a mine, and that drilling is going on now to determine the dimensions of the deposit.

Also in the case of Magma, Malozemoff confirmed that the company has nearly 9 million tons of better than 5 per cent copper ore at its Superior Mine and is considering a $20 million modernization and expansion program there.

A third potential open pit described by Malozemoff is a 40 million-ton ore body averaging 0.7 per cent grade that Newmont has drilled near Princeton, British Columbia.

The company plans further drilling costing about $1.8 million, and will decide late in 1968 whether to undertake production of the Canadian property.

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

C. P. POLLOCK
VICE PRESIDENT

J.H.C.
OCT 30 1967
W.E.S.
NOV 9 1967

October 27, 1967

AIR MAIL

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

MR. WES
READ AND RETURN
PREPARE ANSWERS HANDLE
FILE INITIALS

Newmont Mining Corporation - Vekol Mountains Prospect

Dear Mr. Courtright:

This is to acknowledge receipt of and thank you for your letter of October 11, 1967, pertaining to Newmont Mining Corporation's Vekol Mountains Prospect. We would be interested in obtaining additional information whenever it is available but it will not be necessary for you to request any details directly from Newmont.

Very truly yours,

C. P. Pollock

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

June 2, 1966

Mr. K. E. Richard, Chief Geologist
American Smelting and Refining Company
120 Broadway
New York, N. Y. 10005

Dear Sir:

Enclosed is Mr. Kinnison's memorandum on the Newmont copper prospect in the Casa Grande District and a map showing the position of this prospect and the Lake Shore in the pattern of porphyry copper belts.

Reportedly, the first hole cut 100' of .9% Cu in Mescal limestone underlying Troy quartzite. There is a small outcrop of quartzite but no outcrops of mineralized Mescal in the vicinity. Recently, Mr. Kurtz did some reconnaissance in the area and reported that the quartzite contains traces of copper mineralization.

Apparently a magnetic anomaly was the principal exploration guide. Anomalous induced potential response was reportedly obtained over barren ground as well as over the area of concealed mineralization.

Yours very truly,

J. H. COURTRIGHT

JHC/kw
Enclosure
cc: WESaegart
JEKinnison

J. H. C.

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

APR 2 2 1966

April 22, 1966

TO: J. H. COURTRIGHT

FROM: J. E. KINNISON

NEWMONT PROSPECT
VEKOL MOUNTAINS
CASA GRANDE DISTRICT
PINAL COUNTY, ARIZONA

This will supplement our recent conversations re the subject property. I was at the Arizona Bureau of Mines Office in Tucson 4/19/66, and obtained the following information from Bob O'Hare. He had in his possession a sketch which someone had drawn for him, freehand, on a piece of writing paper. The attachment (sketch) is one which I made from memory after leaving his office. The reliability of the data and its source is unknown to me.

The attached sketch is based largely on the one which O'Hare had, with a few additions based on reconnaissance in this general vicinity by myself some years ago, and by Jim Sell more recently. The Reward Mine, as we all here know, is a bedded replacement in paleozoic limestone--probably pennsylvanian--consisting largely of sphalerite with some chalcopyrite in a garnet host. The general environment is suggested of a porphyry copper-type but there are no direct leads toward the covered areas near the Reward Mine and the tactite zones are rather narrow.

According to O'Hare there is an outcrop of troy quartzite only 25 feet wide, which occurs in alluvium south of the hills in which the Reward is located. The quartzite there contains a few stringers of copper silicate.

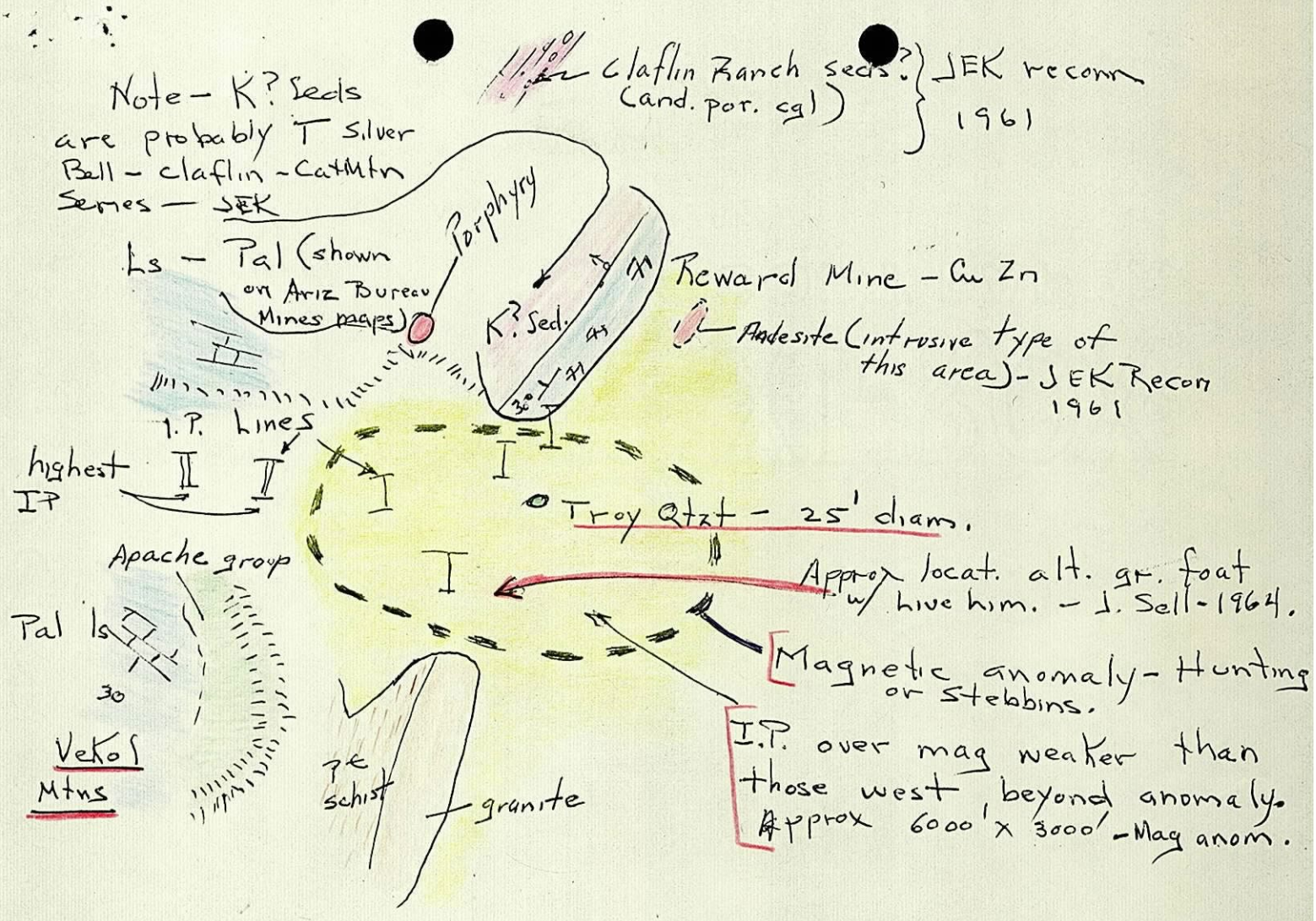
Hunting--who had the three year exclusive option on the Papago country--outlined a magnetic anomaly which affectively encompasses the ore zone. I. P. lines were anomalous over this region, but they also were even more anomalous in the alluvial covered area west of the magnetic anomaly. The drilling sites which Mr. Collins and I saw from the air are grouped principally within the magnetic anomaly as it was shown on O'Hare's sketch. I am told that the first hole was collared on or nearby the outcrop of troy quartzite, and that beneath this the mescal limestone carried about .9% copper as chalcopyrite. This intercept was 100 feet long. Subsequent drilling has established that the mescal is the best host rock.

The sediments at the Vekol area dip 25 or 30 degrees, and so if the mescal were the only mineralized bed, there would be little tonnage potential. We may expect that the paleozoic overlies the troy and is likewise mineralized. Porphyry is exposed a little to the north of the mineralized zone and is fresh--whether or not there is any porphry within the mineralized zone itself was not stated.

This information is intended only to fill the gap between this time and next week when we may have a map and additional information available.

JOHN E. KINNISON

JEK/pjc
Attachment
cc: WLKurtz



Note: No 1 drill hole on Troy outcrop – shows weak stringers of Cu silicate. Drillhole penetrated 100 ft, .9% Cu, in Mescal ls betaw the Troy qtzt. Drilling confirms Mescal best host.

Source: Sketch map drawn on peice of writing paper, Bob O'Hare's files, Ariz. Bureau of Mines. (Copy from memory) JEK

I.P. lines diagramatic.

Sketch of
NEWMONT PROSPECT
VeKol Mtns, Pinal Co, Ariz.

Not to Scale, but Approx. 2" = 1 mile
J. E. K.

APR 19 1966
J. E. K.

EXPLANATION

- Gravels
- Volcanics
- } Post Mineral Rocks
- Pre Mineral Rocks

- Productive Porphyry Copper Deposit
- Marginal Deposits (Undeveloped)
- Deposits Currently Under Exploration
- Sub-Marginal Deposits
- Prospects — Untested

CALIFORNIA

SONORA

CHIHUAHUA

CHLORIDE
Mineral Park
KINGMAN
YUMA
FLAGSTAFF
Bagdad
PRESCOTT
United Verde
JEROME
Iron King
Copper Basin
JEROME ZONE
HOLBROOK
PHOENIX
Sleeping Beauty
Castle Dome
Miami
MIAMI ZONE
Rock House
SUPERIOR
GLOBE
Madera
RAY-POSTEN ZONE
Christmas
Chilito
Pioneer
Ray
Kelvin
Blackwater
Sacaton
Santa Cruz
Posten Butte
J. Sell — Copperosity Linement
Lost Horse
Reward Mine
Newmont
Lake Shore
Greenback
Ajo
Silver Bell
Copper Creek
San Manuel
SAFFORD
Morenci
San Juan
Lone Star
CLIFTON
Steeple Rock
Hitscher
Santa Rita
Tyrone
ALAMOGORDO
MAGDALENA
PLATEAU BOUNDARY
MOGOLLON
DEMING
Organ Dist
TUCSON
Saginaw Hill
Mission-Pima
Twin Buttes
Mc Gee
Esperanza
Helvetia
Johnson Camp
Tombstone
Turquoise
Bisbee
DOUGLAS
Tyndall
Red Mt
Sunnyside
Four Metals
RUBY
NOGALES
Border Pipe
Newmonts Vekol Mountain prospect
SILVER BELL ZONE
SAN PEDRO ZONE
Cananea
Nacozari
Cerrillos

Note: Temporary Revision
April 1966
J.E. Kinnison

After Plate 2, Arizona Bureau of Mines Bulletin No. 145, compiled by J. H. Courtright.

GEOLOGIC MAP
of
ARIZONA AND NEW MEXICO
Showing Porphyry Copper Deposits

SCALE 1 INCH = 40 MILES

August, 1950

Revised February, 1963

Map No. 924

JHC for your file

Leonard Mine
J. H. C.
AUG 3 1966

THE GEOLOGY AND ORE DEPOSITS OF THE VEKOL MOUNTAINS

PINAL COUNTY, ARIZONA

Stanford University Ph.D. thesis submitted by Robert Halstead Carpenter, July, 1947.

GENERAL GEOLOGY

Summary

The rocks in the Vekol Mountains range in age from pre-Cambrian to Quaternary, and comprise one of the most complete columner sections in the Basin Range province of Arizona.

The oldest rock is the fine-grained, greenish-gray schist, which has been correlated with the pre-Cambrian Pinal schist of southern Arizona. It is intruded by a granite which is believed to be of Tertiary age.

The Apache group, estimated to be more than 1,500 feet thick, includes the Pioneer shale, the Burnes conglomerate, the Dripping Spring quartzite and the Mescal limestone. A basalt flow, which is usually included in the Apache group, overlies the Mescal limestone. This group rests unconformably on the schist basement.

The overlying Troy quartzite, of doubtful age, was deposited on the eroded surface of the Apache basalt and Mescal limestone. This formation, the Apache group, and the basement rocks, have been intruded by diabase tentatively regarded as Middle or Lower Cambrian age.

The upper fifty-foot cross-bedded member of the Troy quartzite, the Santa Catalina formation, and the thin Southern Belle quartzite lie above the lower Troy. All contain Cambrian brachiopods. These are succeeded by the Upper Cambrian Abrigo formation. Resting on the Cambrian rocks is an Upper Devonian section composed of three units tentatively designated by the writer as the Picacho de Calera formation, the Martin limestone, and the Lower Ouray formation. The Lower Mississippian Escabrosa limestone follows, and is separated from the Lower Pennsylvanian Naco limestone by a distinct shale marker bed. The Paleozoic section, measured at Promontory Ridge and at the Vekol mine, is approximately 1,681 feet thick. (See Plates 4 and 8.) The entire section of Paleozoic and Apache rocks is essentially conformable in dip and strike, but is separated by at least five disconformities.

Red beds, quartzites and boulder conglomerates exceeding 400 feet in thickness were deposited on eroded Naco limestone. They probably are Cretaceous continental deposits.

The red beds and quartzites appear to grade upward into loosely cemented conglomerates and sandstones. The latter are interbedded with andesitic lavas near the top.* Dacite porphyry, sills, dikes, and flows of intermediate composition

* Hadley, J. B. Copper deposites of the Reward Area, Pinal County, Arizona. Preliminary Report, Strategic Minerals Div., U.S.G.S., 1942.

and rhyolite porphyry are referred to the Tertiary. Tuff, conglomerate, agglomerate and basalt are believed to be Quaternary. Terrace gravels and recent alluvium are distributed throughout the area on pediments and alluvial slopes.

Sedimentary Rocks --- Algonkian Apache Group

The rocks of the Apache group were described and designated as Cambrian by Ransome* in his work in the Ray and Miami area of central Arizona. He

* Ransome, F. L. The Copper Deposits of Ray and Miami, Arizona. U.S.G.S. P.P. 115, 1912. pg. 39.

included the Scanlan conglomerate, the Pioneer shale, the Barnes conglomerate, the Dripping Spring quartzite and the Troy quartzite within this group. Darton* and others, however, consider the Apache group as equivalent to the

* Darton, N. H. Resume of Arizona Geology. Bull. 119 Arizona Bureau of Mines, 1925. pg. 36.

Grand Canyon series. Furthermore, Darton* found evidence, pointed out under

* Idem pg. 36.

the heading "Troy quartzite", page 21 which separates the Troy from the Apache group. For that reason, the Troy quartzite is not considered a part of the Apache group in this report.

In the Vekol Mountains, the rocks of the Apache group are well-exposed in the south-central part of the main range and, to a limited extent, along the southern fringe of the range and the northeastern edge of the east ridges. (See Plate 3.) All are well represented except the Scanlan conglomerate. They form a section estimated at more than 1,500 feet in thickness, and rest unconformably on the schist basement.

Scanlan conglomerate (?)

A few scattered patches of conglomerate consisting of white quartz pebbles in a sandy matrix containing numerous schist fragments were noted along the contact between the schist and the Pioneer shale at the southeast end of Bitter Wells Basin. These patches are but a few inches thick, and they can be traced laterally not more than ten to fifteen feet. They grade upward into maroon, sandy shale containing occasional quartz pebbles.

Pioneer shale

This formation consists largely of maroon, somewhat sandy shale and impure sandstone and quartzite. The lower part is predominantly arenaceous with numerous impure quartzite beds and occasional sandy shales and shaly sandstones; the bedding is moderately thick, ranging from six inches to three feet. In the central and upper part of the formation impure, sandy shales predominate. Toward the top of the formation, the beds contain abundant round or elongated spots of white or tan color. According to Ransome*, these

* Ransome, F. L. The Copper Deposits of Ray and Miami, Arizona. U.S.G.S. P.P. 115, 1912. pg. 40.

are caused by the local reduction and removal of ferruginous pigment. This characteristic marking of the Pioneer shale identifies it from similar beds in the Dripping Spring quartzite. The estimated thickness of this formation is 400 feet.

Barnes conglomerate

This formation is made up of well-rounded, ellipsoidal quartzite pebbles ranging up to 6 inches in diameter embedded in a coarse, arkosic matrix which contains occasional fragments of red jaspar. The pebbles generally lie with their flat sides roughly parallel to the trend of bedding. The sorting is poor and, locally, the formation consists of coarse, arkosic sandstone with only a few pebbles.

The maximum thickness of the formation is 18 feet at the southern end of Bitter Wells Basin. Southward, it thins rapidly, and, along the southern flank of the main range, no Barnes conglomerate is present. It appears to overlie the Pioneer shale conformably.

Dripping Spring quartzite

This formation consists of three members: the lower massive quartzite, the central, thin-bedded impure shale, and the upper banded quartzite. It lies conformably above the Barnes conglomerate and Pioneer shale and conformably below the Mescal limestone.

The lower member consists of hard, medium to fine-grained, reddish, arkosic quartzite. The bedding is indistinct, although occasional shaly partings are evident. Toward the top, the beds become thin and are intercalated with shaly sandstone and sandy shales. The thickness of this unit is estimated at 225 feet.

The central member is made up largely of gray to tan, thinly-bedded, arenaceous shale, which often is well-banded and frequently somewhat platy. The individual beds range from $\frac{1}{8}$ of an inch to 2 inches thick. They grade upward into thinly-bedded, medium to fine-grained, brown quartzite. It is difficult to estimate the thickness of this unit because of faulting and poor exposure, but it is believed to be over 400 feet thick.

The upper member ranges from pinkish-gray, massive, fine-grained, arkosic quartzite near the base, to medium-grained, banded, gray to tan quartzite beds near the top. The latter are from four to ten feet thick, with shaly partings between. At the top, the beds become thin, flaggy and rusty brown and are interbedded with strongly ribbed, impure limestone at the base of the Mescal limestone. The transition zone is generally ten to twenty feet wide. The thickness of the upper unit is 140 feet at the southern end of Bitter Wells Basin.

The Dripping Spring quartzite was deposited in shallow water, for worm casts and ripple marks were noted. It is composed mainly of fine material. Pebbles were found only in a few narrow bands just above the Barnes conglomerate. The thin-bedded shale member in the middle of the formation helps to distinguish it from the Troy quartzite described below.

Mescal limestone

In the Vekol Mountains, this formation consists of tan, buff or gray, often dolomitic limestone. It usually has a ribbed appearance characteristic of exposures in other areas. (See Print 3.) The ribbing is caused by cherty or siliceous layers $\frac{1}{2}$ inch thick interbedded with thin-banded limestone. In some exposures, the more resistant cherty layers are so numerous that the weathered surface has a rough, gnarled appearance. In others, the ribbing is weak or absent.

As illustrated on Plate 4., the Mescal limestone has a thickness of 466 feet, including two diabase sills, which total 175 feet. This thickness probably represents the maximum in the area for in this traverse, the Mescal limestone has a normal contact with the underlying Dripping Spring quartzite. Over 75 feet of Apache basalt lies above. Along the southern end of the Range, the Mescal limestone is only a few feet thick, and the Apache basalt is missing. Apparently, early Cambrian erosion stripped the basalt and much of the Mescal limestone from that area.

The true thickness of the Mescal limestone is probably represented by the actual limestone thickness shown on Plate 4., for there seems to have been very little assimilation of the limestone by the diabase. Wedging appears to have been the main intrusive process exhibited by the diabase.

A remarkable pattern has developed in the Mescal limestone just south of Promontory Ridge. Dr. A. C. Waters* and the writer concur that this arcuate

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* Personal communication

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pattern has been developed by fracturing, solution and subsequent compaction. The following steps are proposed:-

1. Fracturing normal to the bedding.
2. Solution of the limestone along the fractures.
3. Subsequent compaction with arching of the unaffected intermediate areas into the arcuate pattern.
4. Recrystallization along the fractures.

This phenomenon can be traced laterally to normal, banded limestone in adjacent unfractured areas. In some cases, particularly in horizons of strong ribbing, it has developed with such intensity as to form a rock similar in appearance to an intraformational conglomerate. (See Print 6.)

Paleozoic Rocks

The Paleozoic section in the Vekol Mountains, as measured on Promontory Ridge and at the Vekol mine, is approximately 1,681 feet thick. It includes quartzites and shale of Middle Cambrian age, and limestone of Upper Cambrian, Upper Devonian, Lower Mississippian and Lower Pennsylvanian age. The Ordovician, Silurian, and much of the Devonian are not represented.

These rocks are essentially conformable in dip and strike with the underlying rocks of the Apache group. There is an angular unconformity between the Lower Pennsylvanian Naco limestone and the overlying Cretaceous? red beds.

Troy quartzite

Distribution

In the Vekol Mountains, the Troy quartzite is well-exposed in the cliffs along the southwestern edge of Bitter Wells Basin, and, to a limited extent, along the southern fringe of the main range and at the northern end of the east ridges. (See Plate 3.)

Lithology

The formation consists of two distinct members, the lower massive, cliff-forming member and the upper cross-bedded unit. They are separated by a bench-forming shaly marker. The section at the east end of Promontory Ridge, shown on Plate 4., is as follows:

	a.	Strongly cross-bedded, rusty, medium-grained calcareous quartzite in 1 to 5-foot beds with occasional sandy, yellow-brown limestone near the top.	(Top) 39 feet
Upper Member	b.	Thin-bedded shaly zone with abundant brachiopods.	10 feet
		----------Unconformity?----------	
	c.	Well-banded 1-foot quartzite beds interbedded with calcareous quartzite.	30 feet
Lower Member	d.	Massive, vitreous, cliff-forming quartzite with occasional indistinct shale partings.	71 feet
	e.	6-inch to 2-foot beds of quartzite and siliceous, buff sandstone.	52 feet
	f.	Banded, buff sandstone with ¼ inch to 3-inch banding.	48 feet
		Total	252 feet

The upper, brown, highly cross-bedded quartzite (a.) consists mainly of calcareous sandstone. The latter often contain small, poorly preserved brachiopods. The individual beds range from one to five feet in thickness, and consist of medium-grained, rusty sandstone. They form cliffs. (See Print 9.) Toward the top are occasional yellow-brown limestone beds interbedded with cross-bedded quartzites. It is difficult to place the contact of this upper Troy unit and the overlying Santa Catalina formation, for the quartzite beds become less numerous, and finally, and succeeded by impure, brown limestone and micaceous sandstone and shale. The contact is arbitrarily placed at the top of the highest prominent quartzite bed.

The bench-forming shale zone (b.) consists of quartzite and sandstone beds ½ inch to 1 inch in thickness, thin-bedded paper shales, and knotty sandstone nodules embedded in a shaly matrix. In places, patches of grit were noted along the base. Small, poorly preserved brachiopods were found in this shale marker horizon.

Age and Correlation

In his early work in the Globe area*, Ransome considered the Troy quartzite

* Ransome, F. L. The Geology of the Globe Copper District, Arizona. U.S.G.S. P.P. 12, 1903. pg. 28.

a part of the Dripping Spring quartzite. Later, in the Ray quadrangle*, he

* Ransome, F. L. The Copper Deposits of Ray and Miami, Arizona. U. S. G. S. P. P. 115, 1912. pg. 44.

designated the Troy as a distinct formation. He considered the Troy as the youngest formation of the Apache group, and believed this group of rocks included the Ordovician and Silurian and was gradational into the Upper Devonian Martin limestone. For that reason, he placed both the Troy and the Apache group in the Cambrian.

Subsequent work has shown that the Apache group is not gradational into the Devonian. Stoyanow* has measured over 700 feet of fossiliferous

* Stoyanow, A. A. Correlation of Arizona Paleozoic Formations. Bull., G. S. A. Vol. 42, 1947. pg. 459-530. pg. 474.

Middle and Upper Cambrian beds between the Troy and the Martin limestone. In the Vekol Mountains, about 360 feet of Middle and Upper Cambrian beds separate the Troy from the Upper Devonian. Darton is also opposed to the Cambrian

* Darton, N. H. Resume of Arizona Geology, Bull. 119 Ariz. Bureau of Mines, 1925. pg. 36.

age of the Apache group. He believes it is comparble to the Grand Canyon series of Proterozoic time.

Darton* points out an unconformity between the Mescal limestone and

* Darton, N. H. Resume of Arizona Geology. Bull. 119 Ariz. Bureau of Mines, 1925. pg. 36.

the Troy quartzite with thinning of the Troy toward central Arizona. This unconformity is confirmed by the presence of the vesicular, Apache basalt flows and by channelling of the basalt and Mescal limestone in the Vekol Mountains, in the Superior district* in the Santa Catalina Mountains,** and in other areas.

* Short, N. M. and others. Geology and Ore Deposits of the Superior Mining Area, Arizona. Bull. 151, Ariz. Bureau of Mines, 1943. pg. 34.

** Stoyanow, A. A. Correlation of Arizona Paleozoic Formations. Bull. G.S.A., Vol. 42, pp. 459-540. 1947. pg. 474.

Stoyanow* separates the Troy from the Apache group "not only because

* idem. pg. 474.

it overlaps the Mescal limestone, but because it carries Cambrian fossils and conformably underlies younger Middle Cambrian strata." Fossils were found by M. R. Campbell as early as 1904 in the Troy in Deer Creek Canyon south of the Mescal Mountains in central Arizona.* They were determined by Walcott

* Same reference. pg. 475.

as Lingulella pegonipensis (Walcott) and Dicellomus politus (Hall) and were classified as "probably Middle Cambrian".

Stoyanow* also mentions that in the Mescal Mountains near the top of

* Same reference.

the Troy, there are abundant, but poorly preserved brachiopods.

In the Vekol Mountains the following evidence can be pointed out regarding the age of the Troy quartzite:

1. Although it apparently is conformable in strike and dip with the Mescal limestone, it is separated from that formation by the vesicular Apache basalt flows.

2. There appears to be marked channelling of the Apache basalt and Mescal limestone. The basalt is missing locally along the northern fringe of the range, and the Mescal limestone is not more than 50 feet thick in the same area. The overlying lower Troy is at least 100 feet thick.

3. The top, cross-bedded member of the Troy and the underlying shaly zone not only contain numerous Cambrian brachiopods, but also are conformable with the overlying Santa Catalina beds and appear to grade upward into them.

4. Diabase has intruded all of the units of the Apache group and penetrates the lower Troy to within a few feet of the shale zone which separates the main, massive, cliff-forming Troy from the upper cross-bedded fossiliferous member.

5. Also, this same shaly zone and the upper cross-bedded member overlap a well-exposed diabase erosion surface. A definite basal conglomerate consisting largely of diabase pebbles, cobbles and fragments in a cross-bedded sandy, cherty and calcareous matrix has been deposited on the old surface.

The writer believes the upper Troy may represent middle Cambrian deposition in the Vekol Mountains which continued through Santa Catalina and Southern Belle time.

The age of the lower massive, cliff-forming and sandy horizons is questionable. As outlined above, there appears to be a definite erosional break at the top and bottom of this member of the Troy. No fossils have been found to date it as Middle or Lower Cambrian; nor is there any evidence in the Vekol Mountains to date it as immediately post Apache basalt. On the contrary, the apparent channelling of the Mescal erosion surface in the northern part of the range would tend to date this unit as definitely post Apache basalt.

In the opinion of the writer, further regional work should be carried out to see if the unconformity separating the upper from the lower Troy in the Vekol Mountains can be traced to central Arizona. If so, are the fossils found by Hall, Stoyanow, and others restricted to the upper Troy? Also, does the unconformity pointed out by Darton involve the entire Troy as described

* Darton, N. H. Resume of Arizona Geology. Bull. 119, Arizona Bureau of Mines, 1925. pg. 36.

BY THE WRITER IN THE Vekol Mountains?

Santa Catalina Formation

This formation is well-exposed along the east front of the main range, and, to a limited extent, along its southern fringe and at the base of the east ridges in the northeastern part of the Vekol Mountains.

The section on the east end of Promontory Ridge is typical. (See Plate 4.) It is 265 feet thick. The lower sixty feet consist largely of yellowbrown, impure limestone containing numerous intraformational conglomerate horizons of fine-grained, arenaceous limestone fragments.

The central 175 feet is largely greenish-grey, micaceous shale interbedded with thin, ½ to 1 inch, brown, micaceous sandstone, shaly sandstone, and occasional brown limestone beds containing intraformational conglomeratic structure.

In the top 30 feet, the sandstone beds are thicker, occur more frequently and usually are cross-bedded. Small brachiopods are numerous in this part of the section.

The Santa Catalina formation was first described by Stoyanow* in the

* Stoyanow, A. A. Correlation of Arizona Paleozoic Formations. Bull. G.S.A., Vol. 42, pp. 459-540, 1947. pg. 476.

Santa Catalina Mountains north of Tucson. He designates the Santa Catalina as a separate formation of Middle Cambrian age on paleontologic evidence.

An unusual feldspathic persists through the cubits formation, not [illegible] either in the overlying Abrigo or the underlying Troy quartzite. No diagnostic fossils were found in the Santa Catalina formation in the Vekol Mountains, although numerous small Cambrian brachiopods and a few fragments of trilobites were collected. The correlation is based largely on comparable lithology and stratigraphic position.

Southern Belle quartzite

In the Vekol Mountains, this formation is well-exposed along the east front of the main range and in the east ridges. It consists of well-cross-bedded, medium-grained, brown quartzite with a siliceous to calcareous cement. The beds range from 1 to 8 feet thick. Like the upper member of the Troy, however, it grades laterally into patches of sandstone with strong calcareous cement. These areas often contain numerous small brachiopods similar to those found in the Santa Catalina and upper Troy.

The maximum thickness of approximately 30 feet was measured at the northern end of the main range. To the south, at Promontory Ridge, the thickness is 21 feet, while farther south, in the vicinity of 2865 peak, it is but 5 feet thick and may be missing locally. This change appears to be caused by a lateral gradation of the lower part of the Southern Belle into deposition of Santa Catalina type rather than to an unconformity. The upper member of the Troy is very similar lithologically to the Southern Belle. Both probably represent similar depositional conditions.

This formation is described by Stoyanow in the Santa Catalina Mountains, and is considered by him to be of Middle Cambrian age.

Abrigo formation

Infrequent exposures of these beds are found along the east front, through the central section and along the southern flank of the main range. Scattered outcrops were found in the east ridges. The Abrigo is poorly exposed because of the soft nature of the beds.

At Promontory Point, in the Vekol Mountains, the base of the Abrigo consists of light brown limestone beds a few inches to a foot in thickness. They frequently show pronounced intraformational conglomerate structure. Approximately five feet from the base, the character of the beds changes to thin-bedded limestones and brown sandy shales. The thickness of the beds ranges from a fraction on an inch to 6 inches. This zone is about fifty feet thick. At the top, the 2 to 5 foot tan limestone beds which lie above the thin-bedded Abrigo may be comparable to the Rincon limestone, described by Stoyanow* in southern Arizona. No fossils were found, however, and the writer

*Stoyanow, A. A. Correlation of Arizona Paleozoic Formations. Bull. G.S.A., Vol. 42, pg. 471.

tentatively includes these beds in the Abrigo.

The thickness of the Abrigo formation at Promontory Ridge is [illegible]. (See Plate 4.) In the southern edge of the area, on the south side of [illegible] peak, the Abrigo is well-exposed. It is approximately 240 feet thick and consists almost entirely of rusty-brown, thin-bedded, sandy limestone and calcareous sandstone. Beds comparable to the Rincon are missing here. At the Vekol mine, toward the northern end of the main range, the Abrigo is 95 feet thick. Immediately south of Promontory Ridge in the vicinity of Diabase Traverse #3, the Abrigo is estimated at less than 40 feet. This thinning may be caused by local, pre-Upper Devonian erosion of the Abrigo surface.

This formation was first described by Ransome* at Bisbee, and was named

* Ransome, F. L. The Geology and Ore Deposits at Bisbee, Arizona. U.S.G.S. P. P. 21, 1904.

the Abrigo limestone. As described, it included the section between the Cambrian, Bolsa quartzite and the Devonian, Martin limestone. Because of lithologic changes northward, Stoyanow*, in the Santa Catalina Mountains, has divided

* Stoyanow, A. A. Correlation of Arizona Paleozoic Formations. Bull. G.S.A., Vol. 42, 1947. pg. 480.

this section into the following formations:

Upper Cambrian	Peppersauce sandstone
	Abrigo formation
Middle Cambrian	Southern Belle quartzite
	Santa Catalina formation
	Troy quartzite (Bolsa equivalent?)

In this report, the writer follows Stoyanow's restricted use of the Abrigo because of the lithologic similarity between the Cambrian rocks in the Vekol Mountains and those in the Santa Catalina Mountains.

No identifiable fossils were found in this formation in the Vekol Mountains, but Obolus and Lingulella and trilobite fragments were reported by Hogue*

* Hogue, W. G. The Geology and Ore Deposits of the northern end of the Slate Mountains, Pinal County, Arizona. Masters Thesis, Univ. of Ariz., 1940.

in the Slate Mountains ten miles southeast of the Vekol Mountains. The rocks of the Abrigo formation exposed in these two areas are similar lithologically, and occupy identical stratigraphic positions.

Upper Devonian rocks

At Promontory Ridge, rocks of Upper Devonian age include a 230 foot section of light brown limestone, gray dolomitic limestone and calcareous sandstone. The writer has tentatively divided this section into three units, on the basis of lithologic and paleontologic correlation with nearby areas.

These rocks are well-exposed along the east front of the main range and east ridges.

Picacho de Calera formation?

Seventy feet of cliff-forming, black dolomitic limestone and banded blue and tan limestone overlies the Abrigo formation. Throughout the central part of the range these beds are separated from the Abrigo by a distinctive tan, coarse-grained calcareous sandstone with well-rounded grains. This sandstone is missing in the northern and southern sections. The Picacho de Calera? is separated from the overlying Martin limestone by a coarse-grained, calcareous sandstone with sub-rounded grains. This sandstone bed ranges from 3-18 feet in thickness and is a continuous marker throughout the area.

The following section, measured on the cliffs about 500 feet southwest of Promontory Ridge is characteristic of the Picacho de Calera? in the Vekol Mountains:

		(Top)
a.	Tan, medium to coarse-grained, cross-bedded sandstone with calcareous cement.	14 feet
b.	Soft, nodular, reddish-brown, sandy limestone.	4 feet
c.	Dark gray dolomitic limestone with algal bands and faint outlines of brachiopods.	23 feet
d.	Black, sugary dolomite.	2 feet
e.	Alternate blue and tan limestone. Sandy toward base.	22 feet
f.	Tan, calcareous sandstone with well-rounded grains.	2 feet
	Total	67 feet

The above section compares favorably with Stoyanow's description of the Picacho de Calera formation in the Picacho de Calera Hills twenty-five miles northwest of Tucson.* Stoyanow's section is as follows:

* Stoyanow, A. A. Correlation of Arizona Paleozoic Formations, Bull., G.S.A. Vol. 42, 1947. pg. 488.

		(Top)
a.	Brown calcareous sandstone replete with fish teeth, Ptyctodus aff. calceolus (Newberry and Worthen), two species of Cladodus, and one species of Lambodus (?) have been identified.	2 feet
b.	Black dolomite.	25 feet

c. Yellow, crystalline limestone largely made of small calcified algal bodies and interbedded with thin, flaggy, blue limestone; small goniatites are sporadically found; no closer identification has yet been possible. 2 feet

d. Blue limestone in beds, 2 to 4 feet thick composed of large spherical stromatoporoids and algae with abundant, but poorly preserved zaphretoid and favositoid corals. 40 feet

e. Yellow calcareous sandstone with well-rounded sand grains probably of sub-eolian origin. 4 feet

73 feet

No identifiable fossils were found in this part of the Upper Devonian section in the Vekol Mountains. However, because of the similarity of the section in the Vekol Mountains with the Picacho de Calera formation in the Picacho de Calera Hills and comparable stratigraphic position, the writer tentatively designates this part of the Upper Devonian section as Picacho de Calera formation.

Martin limestone

In the Vekol Mountains, the Martin limestone is well-exposed in the east ridges, along the east front and in the central and southern sections of the main range. Its thickness ranges from 85 feet along the southern end of the main range to 125 feet in the central area.

The section exposed on Promontory Ridge is as follows:

a.	Muddy, gray limestone in 1-3 foot beds.	13 feet (Top)
b.	Buff, thin-bedded limestone, 6 inch to 1 foot beds.	17 feet
c.	Buff, massive, cliff-forming limestone.	38 feet
d.	Thin-bedded, buff limestone with ½ inch quartz-lined geodes.	18 feet
e.	Thin-bedded, buff limestone.	20 feet
f.	Soft, shaly limestone, poorly exposed.	12 feet
	Total	118 feet

The upper part of unit 3 is highly fossiliferous. Atrypa reticularis Linne was found in abundance with wide variation. Spirifer hungerfordi Hall was found occasionally, together with other poorly preserved forms which have not been identified. Cladopora prolifica Hall and Whitfield occur sporadically in this same horizon.

The Martin limestone was first described by Ransome* at Bisbee. There,

* Ransome, F. L. The Geology and Ore Deposits of Bisbee, Arizona. U.S.G.S. P.P. 21, 1904. pg. 35-38.

it consists largely of dark gray, hard, compact limestone 340 feet thick. It is underlain by the Abrigo limestone and overlain by the Escabrosa limestone. The Martin limestone is Upper Devonian in age. **

* Ransome, F. L. Same reference as above.
** Stoyanow, A. A. Correlation of Arizona Paleozoic Formations, Bull., G.S.A. Vol. 42, pg. 487. 1927.

Lower Ouray formation?

The soft, bench-forming limestones which lie directly above the Martin limestone in the Vekol Mountains, range from 38 to 57 feet in thickness. On Promontory Ridge, the following section is exposed:

a.	Roughly-banded, light tan to white, cliff-forming, medium-grained quartzite with sandy, calcareous bands.	(Top) 12 feet
b.	6 inch to 3 feet beds of pinkish-gray limestone.	16 feet
c.	½ inch to 6 inch, yellowish- to reddish-tan, soft, highly-jointed, poorly bedded limestone, mudstone, and calcareous shale. Atrypa reticularis (Linne).	23 feet
		51 feet

The upper quartzite member is missing at the northern end of the east ridges and along the southern fringe of the main range. There is a gradual thinning from the central part of the range outward. The remainder of the section ranges from 38 to 45 feet, and is thicker toward the fringes of the mountains.

Stoyanow* describes this formation in Peppersauce Canyon in the Santa

* Stoyanow, A. A. Correlation of Arizona Paleozoic Formations, Bull., G.S.A. vol. 42, pg. 489. 1937.

Catalina Mountains, twenty-five miles north of Tucson. It also is described by Hogue* in the Slate Mountains, ten miles east of the Vekol Mountains.

* Hogue, W. G. The Geology and Ore Deposits of the northern end of the Slate Mountains, Pinal County, Arizona. Masters Thesis, Univ. of Ariz. 1940.

Hogue's section is as follows:

"a. Thin-bedded, pink mudstone, sandstone, limestone and shale with some thicker yellow sandstone and light gray limestone beds. About 25 feet below the top is a 4-foot sandstone bed of coarse-grained, pink and yellow, friable sandstone. (Top) 80 feet

b. Light blue, fossiliferous limestone with Schizoporia striatula, Retzia sp., Schuchertella sp. and several small brachiopods. 4 feet

c. Yellow and pink, thin-bedded sandstone, limestone and shale. 12 feet

Total 96 feet"

The writer has examined the section described above. He believes the rocks lying between the Martin limestone and the Escabrosa limestone in the Vekol Mountains are equivalent to the Lower Ouray formation described by Hogue in the Slate Mountains, even though no characteristic Lower Ouray fossils were found in the Vekol section.

Escabrosa limestone

This resistant limestone forms prominent outcrops along the southern and eastern sides of the main range and along the crests of the east ridges and hills.

It is a thick-bedded, non-magnesian, light to dark gray limestone and is generally granular, although some beds are fine-grained. Crinoid stems are prevalent at certain horizons.

This limestone averages about 400 feet in thickness in the Vekol Mountains. In the center of the main range, at Promontory Ridge, it is 353 feet thick; at the Vekol mine toward the northern end of the main range, it is 410 feet thick; and at 2854 Peak, just south of Copperosity Basin, it is approximately 415 feet thick. Hadley* reports a maximum of 420 feet in the Reward area

* Hadley, J. B. Copper Deposits of the Reward Area, Pinal County, Arizona. Preliminary Report, Stratigic Minerals Division, U.S.G.S., 1942.

on the eastern edge of the mountains.

Generally, the lower 125 feet is massive, gray or bluish-gray limestone; the succeeding 75 feet is banded limestone with alternate dark gray, tan and bluish-gray beds ranging from 6 inches to 5 feet; the upper 200 feet is a massive, gray limestone with occasional cherty horizons.

The top 20 to 100 feet of Escabrosa is altered to a pinkish-tan color. Measurements from a gray marker bed in the central banded zone show that the contact with the overlying Naco limestone is irregular, and probably represents and old erosion surface. Pre-Naco jointing appears to be present, and undoubtedly, weathering and ground water action were effective in the formation of the zone of alteration. The bedding gradually fades upward into this zone. On 2854 peak, clastic dikes occur in the upper five feet of the Escabrosa limestone.

Well-preserved fossils were difficult to find in the Escabrosa. Spirifer centronatus Winchell, the guide fossil of the Escabrosa and a Syringopora coral were the only two definitely identifiable fossils found by the writer. Hedley* reports numerous Pentremites 300 feet from the base of the formation in the Reward area.

* Hedley, J. B. Copper Deposits of the Reward Area, Pinal County, Arizona. Preliminary Report, Strategic Minerals Division, U. S. G. S., 1942.

According to Stoyanow*, the Escabrosa limestone is Lower Mississippian in age. He states "Upper Mississippian deposits are known only in southeastern Arizona".

* Stoyanow, A. A. Correlation of Arizona Paleozoic Formations, Bull., G.S.A. Vol. 42, pg. 505. 1927.

The Escabrosa limestone was first described by Ransome at Bisbee. He describes it as "rather thick-bedded, nearly white to dark gray, granular limestones, which close examination often shows to be made up very largely of crinoid stems". The average thickness at Bisbee is 700 feet.

Naco limestone

In the Vekol Mountains, the Naco limestone consists of light gray limestone beds from 1 to 5 feet thick, separated by shaly partings. The shale partings usually are a few inches thick, but a few are several feet thick. The shale is fine-textured, and reddish-brown in color. On a steep slope, it weathers readily to form a series of step-like benches.

The following section, exposed on the ridge at the Vekol mine, is the most complete in this area:

a.	Alternate ½ foot beds of light gray limestone with a variable degree of silicification and included layers of chert nodules interbedded with 1 inch to 1 foot red shale beds. Abundant fossils occur on the weathered surfaces of many beds. The top is not exposed.	(Top) 100 feet
b.	Coral marker bed containing numerous Campophylum torquium (Owen).	2-8 feet
c.	1 to 4 foot beds of light gray limestone with occasional fossils, separated by red shaly partings. Chert horizons every few feet.	97 feet
d.	Soft, brick red shale with nodules of limestone and occasional thin limestone bands. Generally very poorly exposed.	40 feet
e.	Gray, massive beds 2 to 8 feet thick with infrequent bands of chert nodules or irregular chert lenses.	120 feet
f.	Red shale with zoned chert nodules and grit lenses.	10 feet
	Total	415 feet

The majority of the identifiable fossils were collected from limestone beds of unit a. Among these are:

Spirifer cameratus Morton
Dictyoclostus americanus Dunber and Condra
Spirifer occidentalis Girty
Spirifer rockymontanus Marcou
Spurmularia perplexa McChesney
Composita subtilita (Hall)
Campophylum torquium (Owen)
Rhynchopora sp.
Cleiothyridina sp.

Numerous bryozoans were found locally, as well as plates and spines of sea urchins. Well-preserved Orthoceras sp., and unidentified gastropodes were found in the topmost exposed beds just north of the Vekol ghost town. Crinoid stems ½ inch in diameter are numerous in the upper part of the Naco.

The following forms were collected by Bryan* from the south slope of

* Bryan, Kirk. Erosion and Sedimentation in the Papago Country, Arizona, with a sketch of the Geology. U. S. G. S. Bull. 730b, 1922.

the mountains at the Vekol mine and were determined by G. H. Girty*:

* Darton, N. H. Resume of Arizona Geology, Bull. 119 Arizona Bureau of Mines, pg. 74, 1926.

Cladochonus sp.	Productus semireticulatus
Campophylum torquium	Marginifera splendens
Rhombophora lepidodendroides	Spirifer cameratus
Schizophoria? sp.	Spirifer rockymontanus
Chonetes vernueilianus	Composita subtilita

Girty considered them as Lower Pennsylvanian, corresponding to the lower part of the Naco limestone of the Bisbee district.

According to Stoyanow*, the forms collected in the Vekol Mountains by

* Personal communication.

the writer also represent the Lower Pennsylvanian phase of the Naco and probably are equivalent to the Wewoka fossils of Oklahoma.

The thickness of the Naco limestone varies greatly throughout the area because of post-Naco erosion. On the east side of Bitter Wells Basin, it is estimated at less than 100 feet thick. On the south side of Copperosity Basin, the measured thickness is 270 feet. At Vekol mine, the exposed thickness is 415 feet. The top is covered by terrace gravels and alluvium.

The contact bed at the base of the Naco limestone is from 5 to 10 feet. thick, and consists of soft, highly-jointed and "squeezed" red shale with rounded area of reddish-brown and gray sandstone, finely crystalline limestone $\frac{1}{8}$ of an inch to 1 foot in diameter, and zoned chert nodules which have white centers and reddish halos 1/16 to $\frac{1}{2}$ inch wide. Grit lenses and bands consisting largely of chert fragments occur irregularly in this zone. There usually is a rough banding in this bed parallel to the contact, and bedding movement has been effective locally. It is a persistent horizon throughout the area.

Toward the south end of the range on 2854 peak, the contact bed is somewhat different in appearance. The following section was noted at the base of the Naco limestone:

1.	Pebbly breccia with angular chert fragment in a somewhat silicified, shaly matrix.	1 foot
2.	Brick red to chocolate colored, splintery shale with a few zoned chert nodules.	5 feet
3.	Tan, medium-grained quartzite.	1 foot
4.	Impure red shale with numerous zoned chert nodules, and with an occasional thin shaly sandstone bed $\frac{1}{2}$ inch to 4 inches thick.	7 feet
	Total	14 feet

A. C. Waters has suggested to the writer that this horizon, in the vicinity of the Vekol mine, resembles the charty soils which are now developing in some parts of Oklahoma and Arkansas. They are said to consist of red and gray soils with interspersed chert fragments and nodules. They are believed to be the result of weathering of limestone in place, and of the deposition of eroded material from adjacent hills of charty limestone.

If the contact bed is an ancient soil, rapid submergence of a gently sloping plain would have been necessary to prevent it from being removed by wave action.

Correlation

The Naco limestone was described by Ransome* at Bisbee from the section

* Ransome, F. L. The Geology and Ore Deposits of Bisbee, Arizona. U.S.G.S. P.P. 21, 1904. pg. 44.

in the Naco Hills near the Mexican border. There, it is characterized by light colored beds, which consist largely of calcium carbonate and range in thickness from a few inches to 10 feet. They are described as being usually thinner than the Escabrosa and are more aphanitic in texture. The thickness at Bisbee is estimated at 3,000 ft.

Mesozoic Rocks

Cretaceous Red Beds

Siliceous red beds and quartzites, resting with a slight angular unconformity on the Naco limestone are found in the southwestern part of the main range in the Copperosity Basin. Plane Table Traverse D shown on Plate 5 illustrates this section.

The measured thickness exceeds 400 feet. Several hundred feet of additional section is believed to be present, but no measurement was attempted because of faulting in the upper beds.

A basal conglomerate usually is present. It consists of sub-rounded to sub-angular pebbles ranging from ¼ inch to 1 inch in diameter in a coarse- to medium-grained, sandy matrix. Silicification in many areas has resulted in a conglomerate consisting largely of chalcedonic pebbles held together in a chert or jasper matrix. The original identity of the constituent pebbles is largely obscured. The thickness of this unit varies from a few inches to more than twenty-five feet. Locally, it fills channels in the Naco erosion surface. (Print 13.)

The major part of the section illustrated on Plate 5. consists largely of brick red to yellow-brown, splintery, siliceous shale and shaly siltstone with occasional 5 to 10 foot beds of massive, medium-grained to pebbly quartzite. A 5 foot bed of coarse, gray, arkosic sandstone is located about 190 feet from the base.

The first boulder conglomerate was found at 278 feet from the base. It is 3 feet thick, and is made up of sub-rounded quartzite and limestone boulders, cobbles and pebbles in a loosely cemented matrix of coarse sand. A second boulder conglomerate was found at the top of the measured part of the section. This boulder horizon is approximately 25 feet thick and is comparable to the one just described. A third, at least 200 feet thick, occurs in the upper, unmeasured part of the section.

These rocks are believed to be continental. The section illustrated on Plate 5. probably represents deposition of fine-grained muds, silts, and thin sandy and pebbly beds on a flood plain. The loosely cemented, rounded, boulder horizons would indicate deposition under conditions in which stronger currents prevailed.

The writer has not done sufficient work in the upper part of this group of rocks to determine its contact with the rocks tentatively designated as Gila conglomerate. It is possible that the topmost vitreous quartzite, which lies directly beneath the 200 feet of bouldery conglomerate in the Copperosity Basin, is the upper contact of this unnamed Cretaceous? formation. Or, it may be that this conglomerate and the 2,000 feet of conglomerate described by Hadley* in the Reward area should be included. Further work will be required

* Hadley, J. B. Copper Deposits of the Reward Area, Final County, Arizona. Preliminary Report, Strategic Minerals Division, U. S. G. S., 1942.

to solve this problem. For purposes of mapping, the writer tentatively places the contact at the top of the highest vitreous quartzite occurring in the Copperosity Basin.

Age and Correlation

The writer has no evidence of the age of these rocks except that they overlie the Naco limestone unconformably, and in turn, are overlain by volcanics believed to be largely Tertiary in age. The Recreation Red Beds, described by Brown* in the Tucson Mountains are somewhat similar and may be contemporaneous.

* Brown, W. H. Tucson Mountains, An Arizona Basin Range Type. Bull. G.S.A. Vol. 50, pp. 697-760, 1939.

No fossils were found in the Vekol section, however. The writer expects to make a further study of this problem.

Tertiary-Quaternary Rocks

Gila Conglomerate?

Exposures of the bouldery conglomerate described above, occur at frequent intervals along the west front of the main range. Just west of the Pomona mine, they appear to lie unconformably above the red beds and quartzites.

At the northern end of the main range, this conglomerate is well-exposed beneath the Quaternary volcanics. It consists of sub-rounded boulders and cobbles averaging between 4 and 5 inches in diameter with occasional boulders as much as 3 feet in diameter. Limestone and quartzite are the main constituents, but a few volcanic and diabase pebbles usually are present. The matrix grades from pebbles to coarse sand. The cementing material is somewhat limy. The trend of this exposure roughly parallels the Vekol ridge, and the beds dip about 45 S.W. This conglomerate appears to rest directly on a Naco limestone erosion surface and on scattered patches of the basal Cretaceous conglomerate. At the pass, where the Bitter Wells road crosses the divide north of the Vekol mine, the Gila conglomerate is well-exposed. (See Plate 2.) It consists of a 40 foot pebble and cobble horizon, which may grade laterally northward into the thick tuff beds on the flank of 2917 peak.

III. STRUCTURAL GEOLOGY

Summary

The foliation and the schistosity of the basement rocks in the Vekol Mountains indicates strong structural activity during pre-Cambrian time. The general structural trend of these rocks, shown on Plate 3., probably influenced the development of later structures.

The base of the Algonkian, Apache group appears to rest on a surface of low relief, indicating a period of long erosion and quiescence. This period of "calm" continued throughout the Apache time and the Paleozoic except for possible disturbances due to the emplacement of the diabase. During the Ordovician, Silurian, and much of the Devonian, this area, like most of southern Arizona was uplifted and was being eroded, or at least not receiving sediments. Late Paleozoic rocks are essentially conformable in strike and dip with the rocks of the Apache group.

During the Permian, Triassic and Jurassic, the area must have undergone a second extended period of erosion, for no rocks of those ages appear to be represented. The basal conglomerate of the non-marine red bed unit of probable Cretaceous age rests with angular unconformity on the Naco limestone, indicating the end of the long period of quescence and probably, the beginning of the extensive Jurassic, Laramide and Tertiary structural disturbances common to the Basin Range province.

The Vekol Mountains represent the eastern flank of a northwest trending synclinal structure. The axis of the syncline is located along the southeastern edge of the main range. An anticlinal fold is indicated by the trend of the beds on the northern end of the Slate Mountains about ten miles southeast of the Vekol Mountains. These structures probably represent the first step in the structural evolution of the mountains in this part of Arizona. The granite intrusives may have accompanied this folding, or followed soon after it developed.

Block faulting along two major systems is the controlling structural feature in the structural development of the Vekol Mountains. Northwest trending, east dipping, normal faults have formed the northwest trending blocks including the main range and the sharp ridges on the northeast. Somewhat later, the east-west and northwest trending Copperosity and Bitter Wells faults divided the mountains into three distinct structural blocks: the northeastern, and the central, and the southern. East-west faults of moderate displacement appear to have been adjustment faults related to both major systems. Steep, north-south faults play a minor role in the structural picture. Faulting on the two major systems is believed to have continued intermittently through the late Tertiary into Quaternary time.

Dacite porphyry forms large sills, sheets and dikes which trend northwest. Also, it intrudes many of the east-west fault zones. An east-west trending rhyolite porphyry plug and dike cuts the Paleozoic and Cretaceous rocks and the dacite porphyry.

The pronounced northeast trend and northwest dip of the Quaternary volcanics along the northwestern edge of the area may be due to recent tilting to the northwest.

Folding

The synclinal fold, of which the Vekol Mountains are a part, trends northwest-southeast, and plunges northwestward. (See Plate 3.) The axis of the syncline is located along the southern edge of the main Vekol range. The synclinal nose, illustrated by the curving trend of the Cretaceous? red beds is clearly visible around the edges of Copperosity Basin. The trend of the beds on the east limb is shown on Plate 3. Their strike along the east ridges in the vicinity of the pipe line road at the northern edge of the area is southeastward. Farther south, in the hills of the Reward area, it is north-south. In the main range, the beds strike southwestward and even east-west along the extreme southern fringe.

Minor folding is suggested along the east front of the main range near its northern end. The beds along the exposed edge of the pediment are approximately horizontal, and, in some instances, dip slightly to the northeast. The beds on the adjacent ridge to the west, dip slightly to the northeast. The beds on the adjacent ridge to the west, dip from 35 to 50 southwesterly. This

folding may represent minor flexures on the synclinal flank or may have developed by faulting.

The marked drag folding on the north side of 3231 peak north of the Hinsdow mine and adjacent to the Copperopolis fault is believed to be the result of drag along a fault rather than to regional folding. Its southeast trend roughly parallels the trend of the spur faults, and it dies out within a few hundred feet. The beds are badly contorted and broken by small faults within the drag-fold. (See Print 25.)