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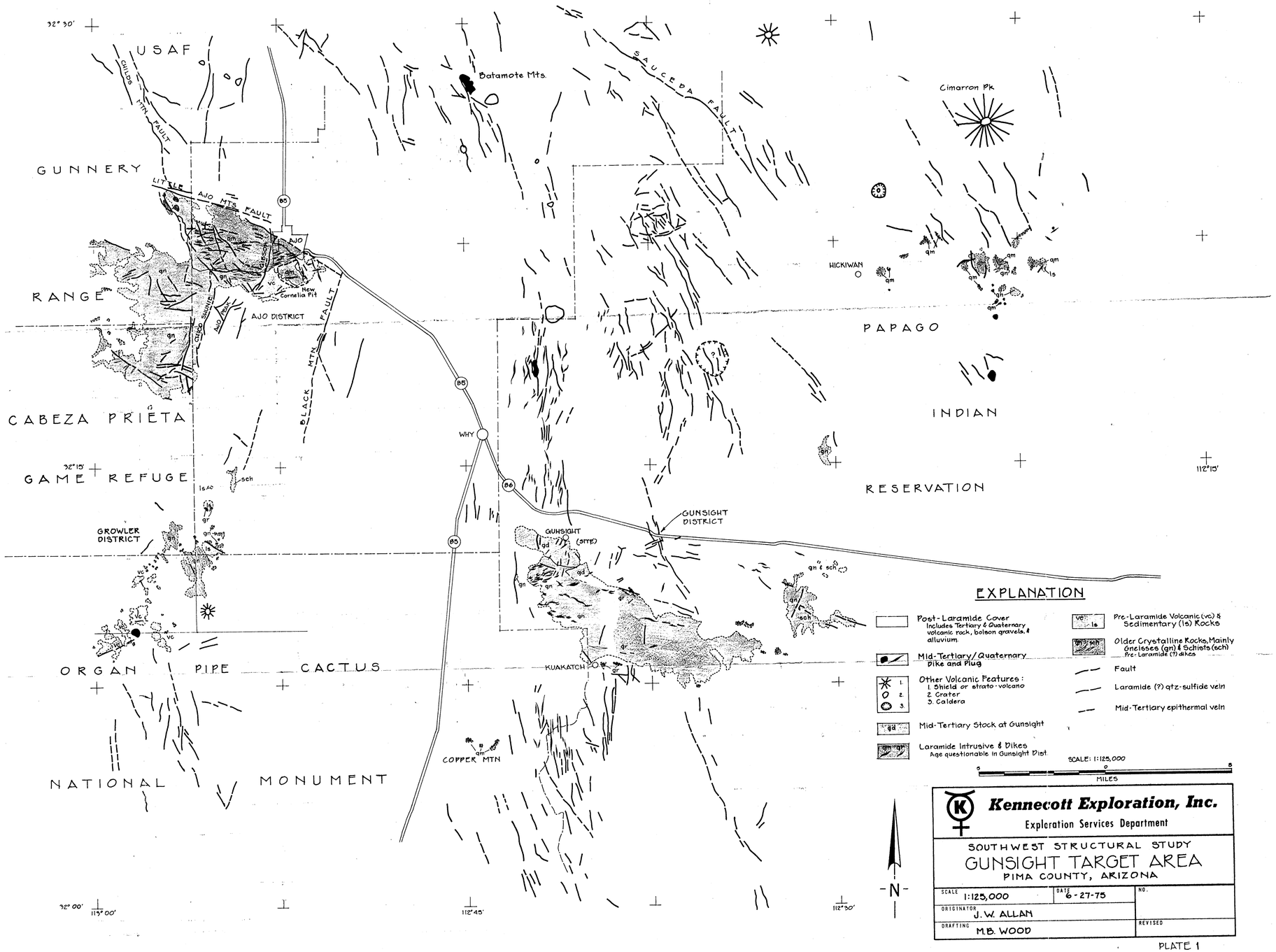
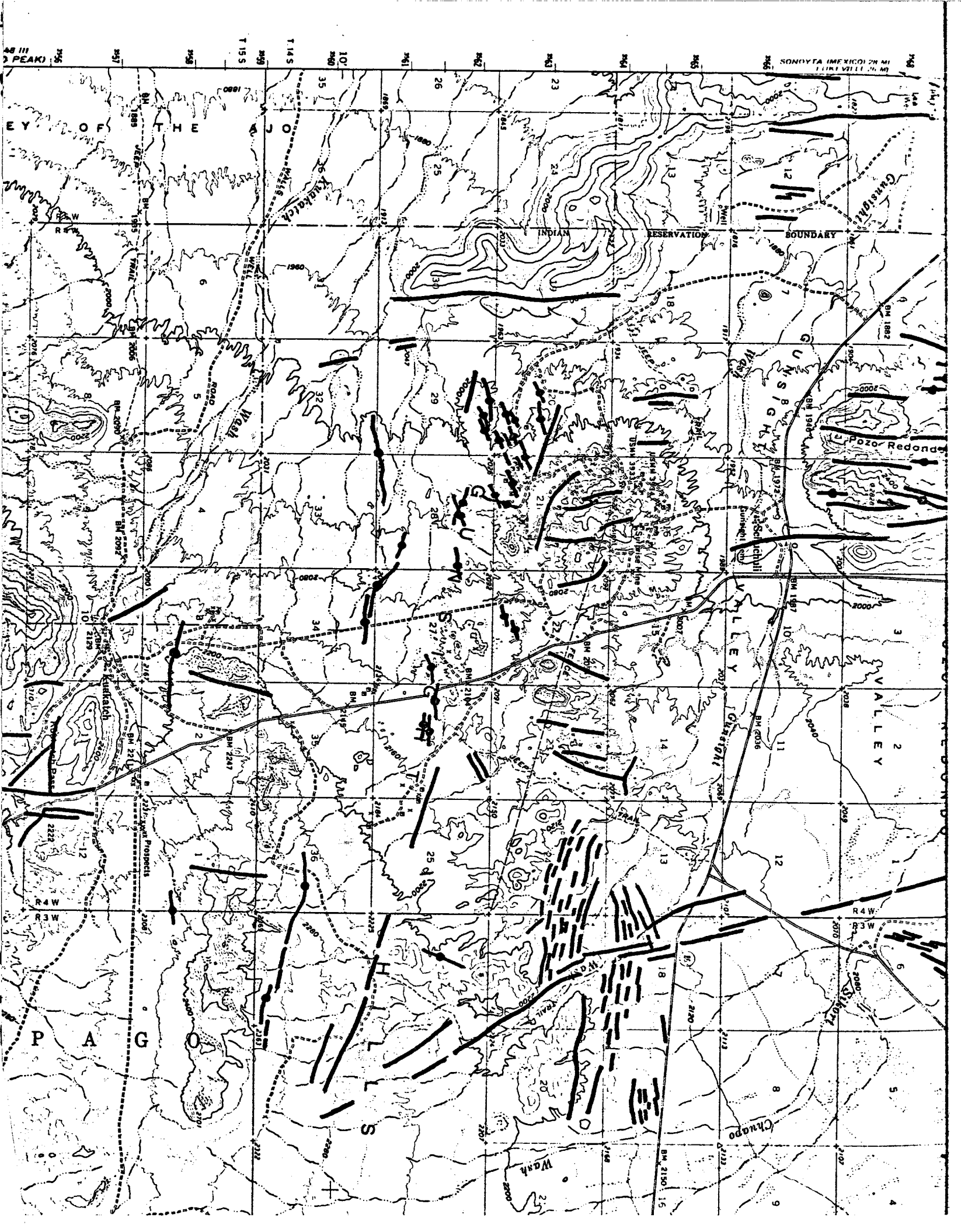

32° 30'
USAF
CHILDS MTN. FAULT
GUNNERY
LITTLE AJO MTS. FAULT
AJO
New Cornelia Pit
RANGE
AJO DISTRICT
CHILDS SYNCLINE
AJO ANT.
BLACK MTN. FAULT
CABEZA PRIETA
32° 15'
GAME REFUGE
GROWLER DISTRICT
ORGAN PIPE CACTUS
NATIONAL MONUMENT
32° 00'
113° 00'
Batamote Mts.
SAUCEDA FAULT
WHY
GUNSIGHT (SITE)
GUNSIGHT DISTRICT
KUAKATCH
COPPER MTN
112° 45'
112° 30'
Cimarron Pk
HICKIWAN
PAPAGO
INDIAN
RESERVATION
112° 15'
EXPLANATION
Post-Laramide Cover
Includes Tertiary & Quaternary volcanic rock, bolson gravels, & alluvium.
Mid-Tertiary/Quaternary Dike and Plug
Other Volcanic Features:
1. Shield or strato-volcano
2. Crater
3. Caldera
Mid-Tertiary Stock at Gunsight
Laramide Intrusive & Dikes
Age questionable in Gunsight Dist
Pre-Laramide Volcanic (vc) & Sedimentary (ls) Rocks
Older Crystalline Rocks, Mainly Gneisses (gn) & Schists (sch)
Pre-Laramide (?) dikes
Fault
Laramide (?) qtz-sulfide vein
Mid-Tertiary epithermal vein
SCALE: 1:125,000
MILES
N
Kennecott Exploration, Inc.
Exploration Services Department
SOUTHWEST STRUCTURAL STUDY
GUNSIGHT TARGET AREA
PIMA COUNTY, ARIZONA
SCALE 1:125,000
DATE 6-27-75
NO.
ORIGINATOR J.W. ALLAN
DRAFTING M.B. WOOD
REVISED

PLATE 1



SONOYTA (MEXICO) 28 MI
FLOREVILLE 26 MI
EY OF THE AJO
INDIAN RESERVATION BOUNDARY
Kuakatch
Wash
Gunsight
GUNSIGHT VALLEY
Pozo Redondo
Schuchuli
Gunsight
Kuakatch
Prospects
Chuapo
Wash
P A G O
R 4 W
R 3 W
T 15 S
T 14 S

USGS OF 81-503

LATE CRETACEOUS TO LATE TERTIARY BASE- AND PRECIOUS-METAL MINERALIZATION, SOUTH-CENTRAL, ARIZONA

R. M. Tosdal, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025

Three distinct base- and precious-metal episodes of mineralization occur in the Papago Indian Reservation and Ajo area, south-central Arizona. The overall range of these episodes is Late Cretaceous to late Tertiary. Copper±molybdenum porphyry systems of the typical Late Cretaceous to early Tertiary age span, an inferred porphyry molybdenum(?) system of early Miocene age, and early to middle Tertiary epithermal fissure-vein systems comprise these episodes. Delineation of these episodes has also involved work by T. G. Theodore, J. A. Briskey, and R. A. LeVeque, U.S. Geological Survey.

The Arizona copper province includes the most important concentrations of large porphyry copper±molybdenum deposits in North America. In the Papago-Ajo area, several porphyry copper±molybdenum deposits are currently being mined, Ajo, Lakeshore, and Silver Bell; whereas other prospects are well known (e.g. Vekol Mountains). Host rock lithologic units have affinities for geologic terranes of central Arizona and are part of the northern Papago terrane of Haxel and others (1980). Late Cretaceous to early Tertiary hornblende-biotite quartz monzonite to granodiorite, and porphyry are associated genetically with the deposits. Sulfide mineralization is present in stockworks, supergene enrichment zones, and in carbonate host rocks. Classic porphyry copper alteration assemblages, potassic, phyllic, argillic, and propylitic, are distributed about the porphyry centers.

An inferred molybdenum(?) porphyry system in the Cimarron Mountains is tectonically and metallogenetically distinct from the Late Cretaceous to early Tertiary copper±molybdenum porphyry deposits. This porphyry system is centered about a Miocene dacite porphyry that occurs in the structural center of a possible caldera complex (Briskey and others, 1978; Dockter and Keith, 1978). An 11-km-across ring fracture/fault system outlines the complex. In the complex, widespread hydrothermal alteration has been recognized in the Precambrian Pinal Schist and quartz monzonite to tonalite (Dockter and Keith, 1978; Haxel and others, 1980), and the Miocene dacite porphyry. The rocks are extensively propylitized and pyritically altered around a core of potassic alteration centered on the dacite porphyry. Hydrothermal fluorite occurs in veins. Phyllic alteration and silicification is superposed on the potassic assemblages. Secondary copper minerals and vein galena have been observed, but no molybdenite has been identified as yet. The caldera complex also is defined by volcanic rocks that are younger than the porphyry system.

Early to middle Tertiary epithermal fissure-vein deposits are areally extensive in the southern Papago-Ajo area, spatially and temporally separate from and genetically unrelated to the known porphyry systems

Fissure-vein deposit districts are present in the Baboquivari Mountains, Comobabi Mountains, Quijotoa-Brownell Mountains, Gunsight Hills, and several ranges in Organ Pipe Cactus National Monument. Some of the fissure-vein deposits previously have been considered to be related to porphyry systems (Keith, 1978); but the characteristics and timing of the fissure-veins indicate that they are best considered to be part of a regional Eocene metallogenic episode. (Tosdal and Briskey, 1981). Moreover, they are apparently a northward lobe of the middle Tertiary epithermal fissure-vein province of the Sierra Madre Occidental of Mexico.

Host rocks for the Eocene fissure-veins are early Tertiary and older (>55 m.y.), differ among districts, and are part of the southern Papago terrain of Haxel and others (1980). No known contemporaneous plutonic or volcanic rocks exist to which the Eocene fissure-veins can be related. An exception exists in a single district of the Baboquivari Mountains (Allison Camp) where fissure-veins cut Miocene hypabyssal dikes.

Texturally, the fissure-veins are characterized by polyphase cavity filling of gangue and ore in breccias and shear zones. Vein textures can be divided into three main types: banded, shear, and crackle breccias. Commonly these have cockscomb, cockade, drusy, and hydrothermal exfoliation textures. Within districts, the veins closely follow the existing regional fault and fracture patterns.

Hypogene ore minerals present in the fissure-veins include one or more of the following: galena, chalcopyrite, chalcocite, bornite, free gold, and less commonly stromeyerite, argentite, sphalerite, molybdenite, tetrahedrite, and scheelite (Williams, 1963, Keith, 1974). Hypogene ore minerals consistently fill open spaces and are late in the vein paragenesis. Supergene oxidation has produced variable amounts of carbonate, silicate, oxide, and sulfate minerals (e.g. Williams, 1963).

Gangue minerals are: milky quartz, sulfides, fluorite, barite, tourmaline, calcite, specular hematite, magnetite, manganese oxide minerals, and epidote. In some districts, barite, fluorite, and manganese oxide minerals have been mined in addition to the base and precious metals (Keith, 1974). Sericitic (white mica+quartz±pyrite), less commonly argillic (kaolinite+quartz), and rarely adularia or phlogopitic biotite alteration occur immediately adjacent to the veins. Propylitic assemblages (chlorite+ epidote±calcite) are distal alteration phenomena to the veins. Moderate to intense silicification and weak to moderate albitization occur immediately adjacent to the veins and diminishes in intensity outward. Fluid inclusions are a two-phase type and probably characterized by moderate salinities.

These Eocene fissure-veins are spatially related to but slightly younger than terranes affected by a pronounced Late Cretaceous and early Tertiary regional orogenic event (Tosdal and Briskey, 1981; Haxel and others, 1980; Haxel, 1981). Ore fluids probably evolved during the waning

ages of this regional thermal episode. Upward ore fluid migration, drothermal circulation, and fissure-vein deposition in dilation fractures d faults occurred during the onset of the extensive Eocene uplift and companying erosion throughout the Papago-Ajo area.

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Target Areas.

E. AREA E -- by John Kirkwood Plates 35-40

Introduction

Area E lies in the south-central part of the Reservation, Pima County, including the Quijotoa Mountains, Sierra Blanca Mountains, and the Brownell Mountains.

Specific areas included in this chapter are; (1) Brownell Pediment, (2) Brownell Northwest Pediment, (3) Brownell West Pediment, (4) Sierra Blanca Pediment, (5) Quijotoa Southwest Pediment, (6) Quijotoa Volcanic Area, (7) Quijotoa Southeast Pediment, (8) Gu Achi Pediment, (9) Gu Achi West Pediment, (10) Tourmaline Breccia Area.

Summary and Recommendations

Pre-ore rocks exposed include; (1) Paleozoic limestones, (2) Cretaceous andesites and rhyolites, (3) Laramide schists and gneiss, (4) Laramide granite and quartz monzonite, (5) Tertiary-Cretaceous sediments and volcanics, (6) Tertiary (Laramide) andesite and quartz monzonite intrusives.

Post-ore cover is composed of Tertiary andesite, basalt, and rhyolite, Tertiary sediments, and Quaternary sediments.

A zone of strong-to-moderate propylitic alteration, characterized by quartz-epidote veins in Laramide granite, occurs on the east side of the Quijotoa Mountains (Quijotoa Southeast Pediment).

Fairly extensive copper oxides in Tertiary-Cretaceous volcanics and a buried pediment indicated by gravity data occur on the east-central side of the Brownell Mountains (Brownell Pediment). Limited limonite and alteration occur at the Brownell Mine.

Limonite and a few anomalous geochemical values occur at the post-ore, pre-ore volcanic contact at the southern end of the Quijotoa Mountains (Quijotoa Volcanic Area).

Two areas exhibiting strong fracturing, silicification, limonite, and sulfide casts occur at the bedrock-gravel contact on the west side of the Quijotoa Mountains (Quijotoa Southwest and Sierra Blanca Pediments). Both areas are about one mile long and one-half mile wide. A few anomalous geochemical copper samples occur in the Sierra Blanca Pediment altered area.

Tourmaline and some clay sericite alteration occur in the Tourmaline Breccia area; no anomalous geochemical copper values occur, but a few anomalous molybdenum values are present. An I.P. anomaly (Hunting) is present here, but drilling and grade prediction based on limonite and geochemical copper indicate no significant mineralization.

Strong limonite, silicification, fracturing and some pyrite occur in a leached capping about one-half mile in diameter located at the Childs Prospect in the Brownell Mountains (Brownell West Pediment). Host rock for mineralization

is Cretaceous rhyolite which is intruded by a Tertiary quartz monzonite stock.

Observed faulting in the Quijotoa Mountains and Brownell Mountains has a northwest trend. Gravity data indicates a major Basin and Range type fault along the eastern edge of the Brownell Mountains.

Six I.P. surveys were conducted in the previous mentioned areas of interest. None had anomalous sulfide responses.

In light of the fact that no I.P. responses were obtained, one can conclude that the propylitic alteration on the east side of the Quijotoa Mountains, while extending under cover, is not a halo effect of a buried copper deposit.

Similarly the weak limonite, silicification, and geochemical copper anomaly in the Quijotoa volcanic area does not represent the halo effects of a copper deposit under post-ore volcanics.

The leached and altered zone on the southwestern edge of the Quijotoa Mountains contains no anomalous geochemical copper values, and if it extends under cover it apparently does not extend far, as resistivity data indicates a rock type change (probably post-ore volcanics at not too great a distance out under the gravel cover). Indicated also, by resistivity data, is a 200 foot to 300 foot gravel cover.

The other leached and altered zone, four miles to the north (Sierra Blanca Pediment) exhibits the same characteristics. While resistivity data does not indicate the proximity of buried Tertiary volcanics to the gravel-bedrock contact, the outcrop pattern of the Tertiary volcanics indicates that they are to be found within about two miles to the west of the contact.

The only area which warrants a recommendation for further work is the leached capping area at the Childs Prospect in the Brownell Mountains. Despite the fact that no I.P. responses was obtained over the outcrop or over the covered zone, and that the one drill hole in the outcrop showed low copper values, it is still possible that a deeply buried copper deposit may exist to the north or northwest of the area. Drill hole data indicates deep oxidation; resistivity data indicates the presence of a possible fault zone near the bedrock-gravel contact. The capping is bounded on the east, south, and west sides by barren rock, and extends under the gravels to the north. Rotary drilling in the gravels to the north might be considered to determine if the capping does extend to any significant distance under cover, and, if it does, to what extent.

Geology

Rocks exposed in the area consist of:

(1) Fine-grained to medium-grained grey-to-tan Paleozoic limestones which crop out on the west side of the Sierra Blanca Mountains and the extreme northern end of the Brownell Mountains (see Gu Achi Area).

(2) Aphanitic-to-porphyritic purple-grey Cretaceous andesites crop out mainly in the southern portion of the Quijotoa Mountains, and in the southeast end of the Sierra Blanca Mountains.

(3) Aphanitic to medium-grained gray-white Cretaceous rhyolite crops out extensively in the northwest end of the Quijotoa Mountains and the southwest part of the Brownell Mountains and to a lesser extent, in the southern part of the Quijotoa Mountains. In some places, the rhyolite exhibits relict flow banding.

(4) Medium-grained to coarse-grained equigranular grey to pink Laramide granite makes up the core of the Quijotoa Mountains and the southeast portion of the Brownell Mountains.

(5) Small outcrops of Laramide quartz monzonite occur in the Tourmaline Breccia zone and a few small outcrops of probable Laramide diorite occur between the Quijotoa and Sierra Blanca Mountains.

(6) White to gray gneissic granite comprise the southern core and the northern end of the Sierra Blanca Mountains. Foliation trends N25W. The gneiss is considered to be derived from pre-Laramide granites or quartz monzonites and possibly rhyolites in the northern end of the Sierra Blanca Mountains. Grade of metamorphism increases from southeast to northwest.

(7) Grey sericite schist and greenish-black biotite schist crops out to a minor extent along the southwestern flank of the Sierra Blanca Mountains, and to a major extent in the north end of the Sierra Blanca Mountains. The schist appears to be derived, in part, from pre-Laramide sediments (some metaconglomerate occurs near the northeastern end of the Sierra Blanca Mountains). Schistosity strikes from north-south to N50E. Some Laramide schist, also apparently derived from older sediments, crops out in the hills a couple of miles northwest of the village of Santa Rosa (Gu Achi). Schistosity strikes from N40W to N80W and dips from south to southwest.

(8) Grey-brown to greenish-brown arkose and arkosic santstones, conglomerate, reddish-brown shale, and some limestone, crop out in the Gu Achi and Gu Achi West Pediment areas, the north end of the Brownell Mountains and on the western edge of the Brownell Mountains. These sediments, particularly the arkose and arkosic sandstones are well indurated, and are considered to be Cretaceous or Tertiary-Cretaceous in age. The sandy sediments are predominant and contain interbedded shales and conglomerates. Minor amounts of limestones occur in the vicinity of the Brownell Mountains, and at the village of Noipa Kam (Brownell Northwest Pediment).

(9) Tertiary-Cretaceous rocks consisting mainly of rhyolites are exposed in the north and eastern portions of the Brownell Mountains, and in the southern end of the Quijotoa Mountains.

(10) A quartz monzonite porphyry intrusive body, probably Tertiary in age (Laramide?) crops out at the northwest end of the Brownell Mountains, and small andesitic intrusives, also of probable Tertiary age, are found in the Brownell Mine area and along the eastern edge of the Sierra Blanca Mountains.

(11) Post-ore cover consists of: (a) Tertiary basalts, andesites, and rhyolites west of the Quijotoa Mountains and at the southern end of the Quijotoa Mountains in the vicinity of Ben Nevis Mountain and South Mountains; (b) Tertiary conglomerate and sandstones occurring west and northwest of the

Brownell Mountains; and (c) Loosely consolidated Quaternary sands, silts, and gravels surrounding all the bedrock areas.

A northwest trending fault was observed at the contact of the Tertiary-Cretaceous sediments and the Cretaceous rhyolites in the southwest portion of Brownell Mountains. Northwest trending faults also occur at the contact of the Tertiary-Cretaceous and Cretaceous volcanics and the Tertiary volcanics in the vicinity of Ben Nevis Mountain at the south end of the Quijotoa Mountains. The Paleozoic limestones exposed at the western edge of the Sierra Blanca Mountains appear to have been thrust over the Cretaceous(?) volcanics.

I.P. data suggest that gravel cover in the Quijotoa Southwest Area is nowhere more than 200 feet to 300 feet deep. Resistivity changes, however, indicate a change in rock type under cover, with the contact striking approximately N45W, in general accordance with the structural trend of the area. This change may represent the contact of pre-ore and post-ore buried volcanics.

In the immediate area of the Tertiary quartz monzonite intrusive and the Cretaceous rhyolite in the Brownell West mineralized area, resistivity data suggest either a narrow gravel-filled valley or a major gouge zone. It would seem more likely that the resistivity effects indicate a fault here, as a northeast striking fault was observed in the outcrop in the vicinity of one of the I.P. lines.

Gravity data suggest a major Basin and Range type fault along the eastern edge of the Brownell Mountains.

Northeast trending faults may also occur at or near the contact of the Paleozoic limestones and the Tertiary-Cretaceous sediments in the Gu Achi areas.

Mineralization, Alteration and Limonite

The most significant areas are as follows:

(1) Quijotoa Southeast Pediment--Some propylitic alteration was observed along most of the mountain front in Laramide granite; however, a two mile wide zone of moderate-to-strong propylitic alteration is evidenced by the intensity of chlorite and epidote in the rock. Conspicuous quartz-epidote mineralization in veins, joints, and fractures was observed, with epidote, chlorite, and minor specularite and calcite. This zone trends N45W to N70W and extends under gravel cover. Some copper oxides occur in a fault zone separating rhyolite and granite.

(2) Quijotoa Volcanic Area--Hematite, goethite, and silicification are present in the Tertiary-Cretaceous rhyolite. This small altered zone contains a few anomalous geochemical copper values at the contact with Tertiary volcanic rocks and appears to extend under thin cover. Copper oxides in quartz vein material is observed in the dumps at the Weldon Mine on the west side of Ben Nevis Mountain.

(3) Quijotoa Southwest Pediment--A leached and altered zone about one mile long and one-half mile wide occurs in the Cretaceous rhyolite adjacent

to gravel cover and the Laramide granite which intrudes the rhyolite. The rhyolite is strongly fractured, with the major trends being north and northwest. Silicification is the principal form of alteration with minor amounts of sericite, chlorite,and specularite also present. Goethite, jarosite, and minor hematite is present in moderate amounts primarily as fracture coatings. Moderate to minor amounts of sulfide casts occur as dissemination in the rock, while some boxwork was observed in conjunction with a few shears. Only one anomalous geochemical copper value occur in this area; no copper oxides were observed.

(4) Sierra Blanca Pediment--A leached and altered zone, also about one mile long and one-half mile wide, occurs in the Cretaceous rhyolite adjacent to the gravel cover. This area exhibits the same characteristics as the one described in Quijotoa Southwest area, and lies four miles north of that area.

(5) Tourmaline Breccia Area--An altered zone about one mile square occurs in the Cretaceous rhyolite. Tourmaline and magnetite are concentrated in an area about 1000 feet in diameter in the north part of the zone, while clay, sericite, and quartz alteration occur in the southern part of the zone. Goethite and jarosite occur in moderate amounts, while hematite is weak and appears mainly due to oxidation of magnetite. No anomalous geochemical copper values occur, but some anomalous molybdenum values are present. An I.P. survey by Hunting Geophysical Corporation (see Plate 35) obtained a sulfide response. A hole was drilled by Newmont, but apparently encountered no significant copper mineralization. Grade predictions based on limonite and geochemical copper values do not indicate significant copper values at depth.

(6) Brownell Pediment--Abundant copper oxides with minor amounts of epidote, quartz, and goethite are present in Tertiary-Cretaceous volcanics, primarily rhyolites, which crop out adjacent to the gravel cover at the northeast edge of the Brownell Mountains. Gravity data indicates a buried pediment extending about three-fourths of a mile eastward from the bedrock-gravel contact. About a mile northwest of the eastern bedrock-cover contact is the Brownell Mine which has produced some copper and silver. The mine is located at the contact of Tertiary-Cretaceous volcanics and a Tertiary andesite plug. A narrow ring of argillic alteration surrounds the intrusive. Geothite and jarosite also occurs. An I.P. survey by Hunting Geophysical Corporation disclosed a weak anomaly around the intrusive, however, the small size of the altered zone (it is surrounded by unaltered rock) and the poor grade predictions based on geochemistry and limonite indicate that no significant widespread copper mineralization is present.

(7) Brownell West Pediment--The Childs Prospect is located at the west-central edge of the Brownell Mountains. Here a Tertiary quartz monzonite stock approximately one mile long and three-fourths mile wide intrudes the Cretaceous volcanics. At the contact, and extending about one-half mile to the east into the volcanics is a zone of leached capping about one-fourth to one-half mile wide which is bordered to the north by gravel cover. The zone is characterized by strong silicification, and intense fracturing. Strong jarosite and hematite with lesser amounts of goethite are present in the center of the zone, while the goethite content increases and the jarosite and hematite decrease towards the periphery of the zone. The limonite occurs as fracture coatings, flooding, and disseminations. Massive specularite and copper oxide is exposed in a prospect pit on a fault which strikes N60E and

dip 40 degrees southeast, and disseminated specularite is present in the west-central part of the zone. A circular tourmaline breccia pipe about 400 feet in diameter occurs near the southeast end of the leached capping zone. Eight out of sixteen samples taken in the zone exhibit anomalous copper values ranging from 52 ppm to 2,740 ppm (see Plate 37). The higher values tend to occur in the vicinity of the fault where copper oxides and massive specularite is present. Based on limonite mineralogy, total sulfide content ranges from 1.0 percent to 3.5 percent. Primary grade predictions run from 0.006 percent copper to 0.5 percent copper, with most running somewhere around 0.01 percent copper. A 460 foot churn drill hole was drilled by Miami Copper Company in 1957. The drill hole log indicates that the hole bottomed in the oxide zone with limonite decreasing somewhat at about 190 feet. Specularite and, to a lesser extent, pyrite are present. Copper values throughout the hole range from trace to 0.02 percent.

Both Miami Copper Company and Hunting Geophysical Corporation conducted I.P. surveys over bedrock. No sulfide response was obtained. Bear Creek Mining Company ran I.P. lines over both bedrock and the gravel cover to the north. No sulfide response was obtained.

(8) Miscellaneous--A few local occurrences of copper oxide mineralization occur in a fault zone at the Black Prince Mine on the east side of Sierra Blanca Mountains, at three prospects in the Gu Achi Pediment area in Tertiary-Cretaceous conglomerates as part of the matrix and as pebble coatings, indicating that these deposits may be exotic in nature.

Specularite-copper oxide mineralization is reported at the Mond Tel Claims in the west-central part of the Brownell Mountains. Host rocks are an acid volcanic intrusive complex. Miami Copper Company drilled two churn drill holes on the claims. One hole, 130 feet deep, encountered limonite, minor specularite, and traces of pyrite. Copper values ranged from 0.02 percent to 0.06 percent. The other hole, 218 feet deep, encountered similar amounts of limonite, specularite and pyrite, but gave only trace values of copper.

Geochemistry

For distribution of geochemical copper, molybdenum, zinc and manganese values, and location of anomalous values for these metals (see Plates 37, 38, 39 and 40).

As would be expected, anomalous geochemical copper, and sometimes anomalous geochemical molybdenum values occur where copper oxides are present. The only significant anomalous geochemical copper zone in the entire area occurred at the Childs Prospect where the leached capping is present (Brownell West Pediment). The leached capping in the Quijotoa Southwest Pediment has only one moderately anomalous copper value. The leached capping in the Sierra Blanca Pediment has two moderately anomalous copper values. Some scattered anomalous geochemical molybdenum values occur in the northern portion of the area and also in conjunction with the Childs Prospect, the Tourmaline Breccia Area, and the Sierra Blanca Leached capping. Likewise, a few scattered geochemical zinc and manganese values occur in the whole area.

Geophysics

Bear Creek Mining Company conducted I.P. surveys in the following areas (Plate 35).

(1) Brownell Pediment

(2) Brownell West Pediment

(3) Sierra Blanca Pediment

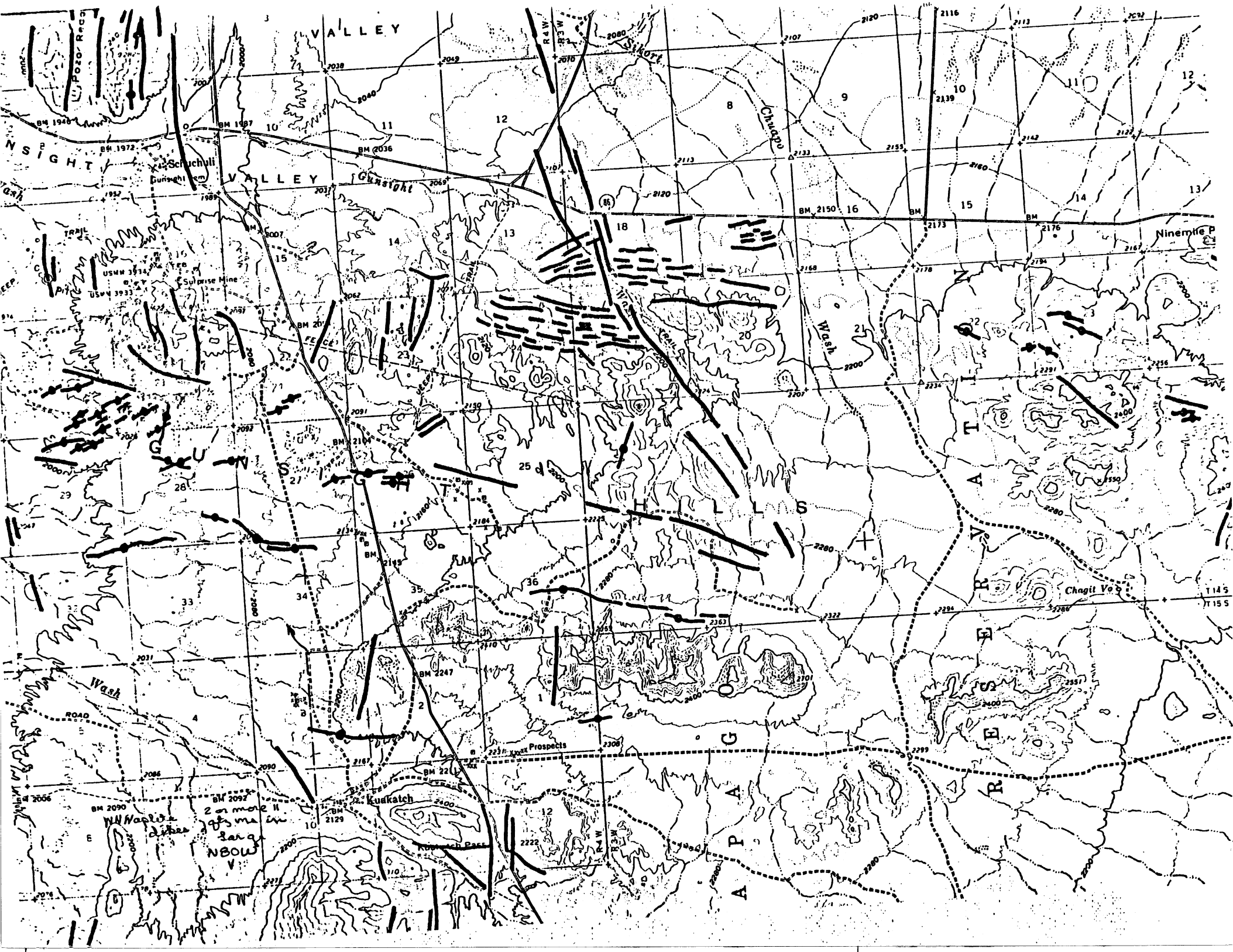
(4) Quijotoa Southwest Pediment

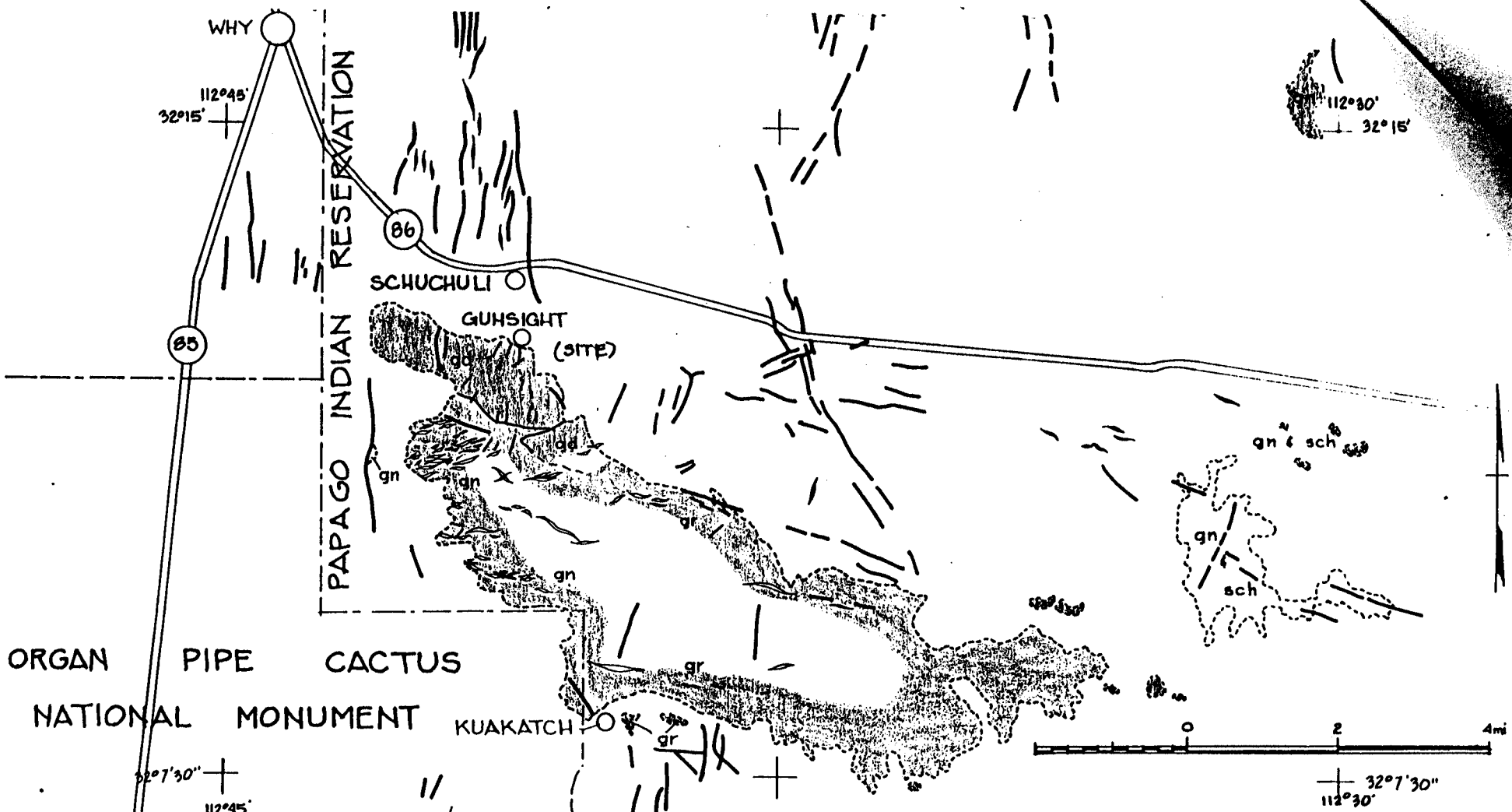
(5) Quijotoa Volcanic Area

(6) Quijotoa Southeast Pediment

No I.P. sulfide response was detected in any of these areas. Resistivity data did indicate (a) A narrow pediment in the Brownell area: (b) Three hundred to 400 feet of cover and a rock type change in the Quijotoa Southwest area; (c) A wide pediment in the Quijotoa Southeast area; (d) The presence of a narrow gravel filled valley, or a large gouge zone just north of the leached capping in the Brownell West area.

Bear Creek Mining Company gravity surveys indicated the following: (a) A narrow pediment and a major Basin and Range faulting on the east side of the Brownell Mountains; (b) A pediment about a mile wide east of the Quijotoa Mountains; (c) Deep areas, with probable faulting in the Window Valley area northeast of the Sierra Blanca Mountains.


VALLEY
VALLEY
Schuchuli
Gunsight
Sikort
Chuapo
Wash
Ninemile P
Surprise Mine
GUNSIGHT HILLS
APAGO RESERVATION
Chagit Vo
Prospects
Kuakatch
Kuakatch Pass
Wash
ROAD
T 14 S
T 15 S
R 4 W
R 3 W
BM 1946
BM 1972
BM 1987
BM 2036
BM 2150
BM 2173
BM 2176
BM 2104
BM 2145
BM 2247
BM 2090
BM 2092
BM 2129
BM 2222
USMM 3934
USMM 3933
2 or more ll
NBOW



GENERALIZED GEOLOGIC MAP
GUNSIGHT MINING DISTRICT
PIMA COUNTY ARIZONA

EXPLANATION

- Tertiary/Quaternary volcanic rocks & gravel
- dd — Mid Tertiary (?) intrusion
- Laramide (?) intrusion
- Precambrian (?) rocks
  - gr - granite
  - gn - gneiss
  - sch - schist
- Tertiary dike
- Laramide (?) dike
- Fault
- Veins

FIGURE 3

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REPORT ON THE PAPAGO PROJECT

PAPAGO INDIAN RESERVATION

ARIZONA

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BY

Louis H. Knight

May 1974

Report on the Papago Project

Papago Indian Reservation

Arizona

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SUMMARY

Approximately 1,200 square miles in the central part of the Papago Indian Reservation of Southern Arizona have been examined and geologically mapped in order to determine the potential for skarn-porphyry copper mineralization targets and to define the basic tectonic framework. A limited amount of reconnaissance was done in the adjacent Silver Bell mining district in an attempt to tie in the geology of the two areas.

Stratigraphic units exposed in the studied area range from Older Precambrian Pinal schist through the Younger Precambrian Apache Group, Cambrian through Permian Paleozoic rocks, Triassic-Jurassic volcanics, and sediments, Cretaceous volcanics and sediments, and Middle Tertiary volcanics and sediments. Periods of igneous intrusion are recognized in Older Precambrian, Younger Precambrian, and Late Cretaceous to Early Tertiary time.

The major ages of structural disturbance are during Laramide time and in Middle to Late Tertiary time. The Laramide structure is characterized by broad northwest-trending folds and extensive regional scale left-lateral faults of northwest strike. These features predate the Laramide copper mineralization and can be demonstrated to have relatively minor post-mineral movement. Structural features of Mid-Tertiary and younger age are extensional in nature. They include the Santa Rosa Valley graben, the large displacement Lakeshore gravity fault, and several other normal faults.

Large areas of alteration and mineralization exclusive of the Lakeshore, Newmont, and Silver Bell areas occur in the northern Santa Rosa Mountains, and in the Brownell Mountains.

The Santa Rosa Mountains area consists of about 6 to 8 square miles of

intense propylitic alteration with associated monzonite porphyry dikes and weak copper mineralization. The Brownell Mountains mineralized area consists of about 1 1/2 square miles of Jurassic-Triassic rocks containing disseminated specular hematite and minor copper showings. The former seems to offer a target possibility whereas the latter does not.

Three target areas, one rather speculative, have been recognized, the faulted continuation of the Santa Rosa altered zone, the likely area of extension of the Lakeshore mineralization in the footwall of the Lakeshore fault, and the possibility of faulted pieces of the Newmont property dropped into the Santa Rosa Valley graben.

A reconnaissance I. P. and resistivity survey is recommended to test the faulted continuation of the Santa Rosa alteration. In addition a low level aeromagnetic survey is recommended to better define the locations of two of the possible target areas.

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INTRODUCTION

The Papago Indian Reservation comprises a region in central Pima, southwestern Pinal, and southeastern Maricopa Counties, Arizona, of which approximately 1200 square miles in the central part were chosen for geologic reconnaissance mapping. This work was aimed at the following objectives:

1) to determine the potential for additional skarn-porphyry copper mineralization similar to the Lakeshore and Vekol properties.
2) to establish the basic tectonic framework of the Papago Reservation as an aid to interpretation of southern Arizona regional geology.

Geologic mapping was undertaken by the writer assisted by J. A. Raney on colored aerial photographs at a scale of 1:24,000. A total of six months was spent mapping the area of interest. Although many details had to be ignored because of the time allotted for the study the writer feels confident that the major mineralized areas and structure have been recognized.

In addition to examining the Papago country, a limited amount of reconnaissance mapping and compilation of existing maps was done for the Silver Bell district that adjoins the Reservation on the east. The area considered in this report is outlined in figure 1.

GEOLOGY

Stratigraphy (Plate 1)

Stratigraphic units ranging in age from older Precambrian through Recent age have been mapped during this investigation. In general the

older units are exposed in the northern portion of the mapped area and the younger (pre mid-Tertiary) units are exposed in the south. Most attention has been focused upon the rocks from younger Precambrian through Early Tertiary age.

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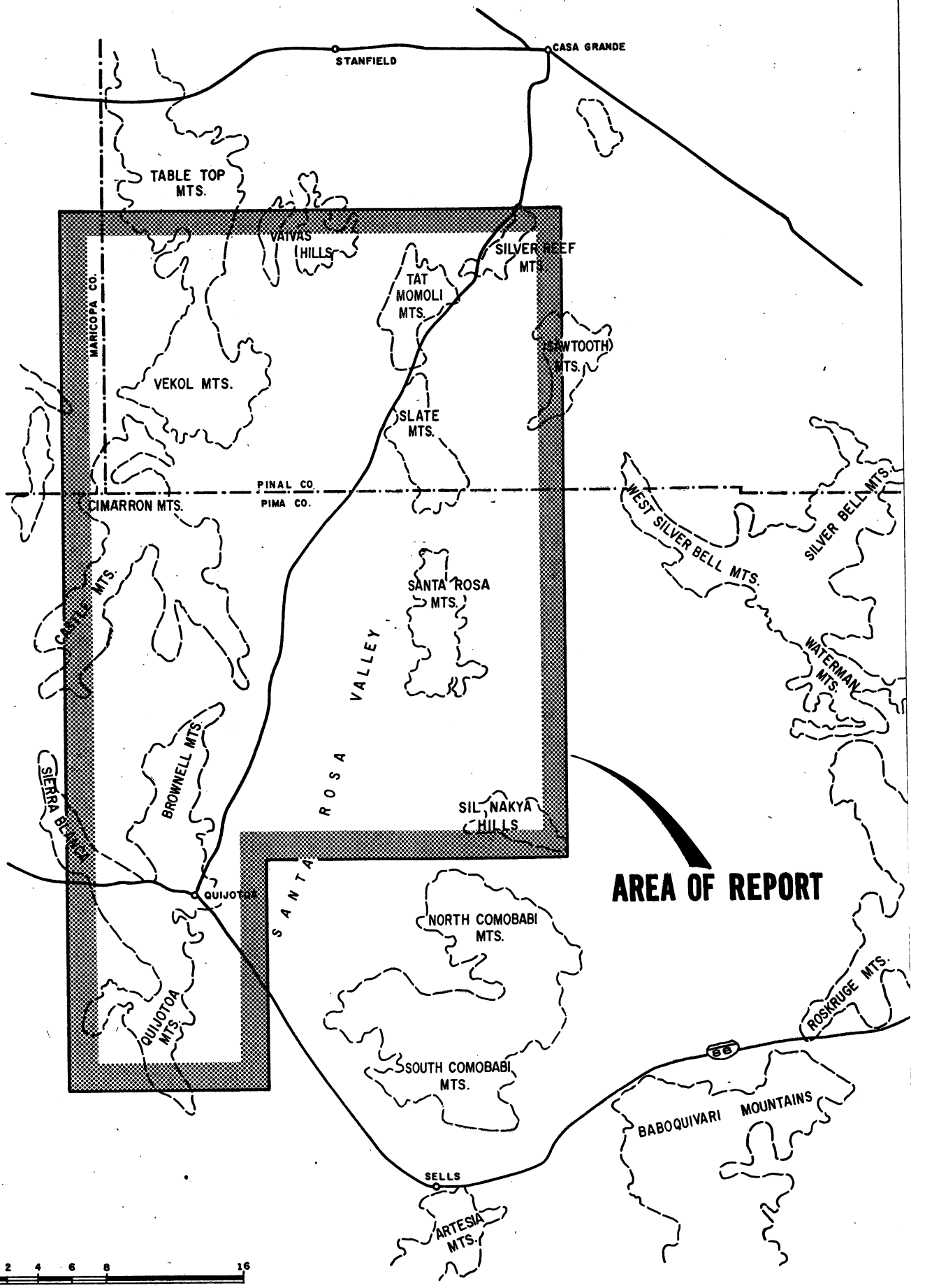
Older Precambrian Rocks

No detailed mapping of stratigraphic units in the older Precambrian rocks has been attempted except to distinguish areas of granitic rocks from those of dominantly quartz-sericite schist and quartz-chlorite schist. On Plate 1 all schistose older Precambrian rocks have been grouped as Pinal schist.

Examination of those areas of Pinal schist traversed during this investigation suggests that the dominant original lithologies were fine clastic sedimentary rocks and interbedded sandstones. In only one area has any definite material of volcanic affinity been observed. This is about one mile east of the Lakeshore mine portal where a few tens of feet of quartz eye porphyry was noted. It is possible however, that much of the quartz-chlorite schist was derived from fairly mafic volcanics or volcanoclastics.

Younger Precambrian Rocks

Younger Precambrian time is represented by rocks of the Apache Group of which all principal formations are represented. The formations are in ascending order; Scanlan conglomerate, Pioneer Shale, Barnes Conglomerate, Dripping Spring Quartzite, and Mescal Limestone. For mapping purposes the Scanlan has been included in the Pioneer Shale and the Barnes has been included in the Dripping Spring Quartzite. Both conglomerates although very persistant laterally are but a few feet thick. No sections were measured during this study, but Carpenter (1947) and Hammer (1961) report the following



INDEX MAP

FIG. 1

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Apache Group thicknesses in the Vekol and Slate ranges respectively:

	Vekol Mts.	Slate Mts.
Mescal Ls.	291	193
Dripping Spr. Qtzte	765	1149
Barnes Conglomerate	18	30
Pioneer Shale	400	374
Scanlan Conglomerate	10-15	-

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The only other areas where Apache Group rocks have been mapped are the Tat Momoli Mts and the Vaiva Hills. In these areas the Mescal Limestone is very thin or entirely absent, and to the south and east of the Slate and Vekol Mts. the entire Apache Group is absent with Cambrian Bolsa Quartzite resting directly on older Precambrian rocks.

The Apache Group rocks rest with pronounced angular unconformity on the older Precambrian rocks.

Paleozoic Rocks

The Paleozoic formations are the same units as those recognized over much of southeastern Arizona ranging from Cambrian through Permian in age. The formations recognized within the mapped area are as follows:

Permian	Concha Limestone
	Scheerer Formation
	Colina Limestone
Pennsylvanian	Horquilla Limestone
Mississippian	Escabrosa Limestone
Devonian	Martin Formation
Cambrian	Abrigo Formation
	Bolsa Quartzite

The Cambrian Bolsa Quartzite everywhere forms the basal unit of the Paleozoic sequence and rests disconformably upon the Apache Group or unconformably upon the Older Precambrian rocks.

Early Paleozoic units are exposed in the northern ranges, the Vekol, Slate, Cimarron, Viava, and Tat Momoli Mountains whereas only Permian and younger rocks (through Jurassic) are exposed to the south.

Mesozoic Rocks

Triassic-Jurassic Volcanic Rocks...Volcanic rocks of probable Triassic or Jurassic age have been recognized in the southern part of the mapped area in the Santa Rosa, Brownell, and the Quijotoa Mountains. These rocks consist principally of quartz latite porphyry flows and ignimbrites. Similar looking rocks have been observed in the Baboquivari Mountains, the Ali Molina sequence (Fair, 1965); in the western Sierrita Mountains, Jurassic rhyolite (Baker, 1968); and in the Oro Blanco district, the Cobre Ridge tuff (Knight, 1970).

The principal exposures of the Triassic-Jurassic rocks which lie in the Quijotoa Mountains are insufficiently mapped to allow any estimate of the stratigraphic thickness, but probably several thousands of feet are represented.

Jurassic-Triassic sediments...Terrestrial sedimentary rocks of Triassic-Jurassic age are very widespread in the mapped area. These consist of non-fossiliferous redbeds, arkose, lithic wackes, and conglomerate. The fragments in the coarser clastic rocks are made up of Paleozoic rocks and locally the Triassic-Jurassic volcanics.

In the hills north of the Brownell Mountains the upper part stratigraphically of this unit contains large exotic blocks of Paleozoic rocks commonly several hundreds of feet in length.

The age assignment of Jurassic-Triassic to this sequence is based on a Jurassic potassium-argon date on overlying volcanics and that the sediments overlie Permian and presumed Triassic or Jurassic volcanics. Very similar looking rocks have been observed disconformably overlying Jurassic ignimbrites in the Sil Nakya Hills and have been called Cretaceous.

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Jurassic Rocks

Volcanic rocks of Jurassic age are very widespread in the southern part of the mapped area. These consist of several thousands of feet of quartz latite ignimbrites and flows and lesser amounts of andesite. A potassium-argon date on biotite from quartz latite ignimbrite (sample KA-5A) near Quijotoa yields a Late Jurassic age of 156 million years.

Cretaceous Volcanic Rocks

Andesite porphyry flows and breccias lithologically similar to the Silver Bell andesite of the Silver Bell district are exposed in the northeastern Vekol Mountains and are reported to occur in the subsurface at the Lakeshore mine. These rocks conformably overlie the Triassic-Jurassic sediments on the Newmont property and are unconformably overlain by Mid-Tertiary andesites. One sample from a presumed feeder dike for the andesite yields ages of 89.7 and 97.2 million years from hornblende.

Tertiary Rocks

Mid-Tertiary Rocks.....Mid-Tertiary rocks are represented by a sequence of late Oligocene andesite porphyry extrusives and Miocene basalt and fanglomerate.

The Oligocene rocks lie unconformably upon the early Tertiary and older rocks and dip gently west in the area to the west of Santa Rosa Valley and east to the east of Santa Rosa Valley. The andesites are widespread in the ranges on the west side of the Santa Rosa Valley but occur only in the Tat Momoli, Silver Bell and Waterman Mountains on the east. In addition the Sawtooth Mountains just northeast of the mapped area are composed of this unit.

Potassium-argon ages for the andesite sequence are as follows:

Sample	KA-7	27.4 my	biotite	Vekol Mts.
	KA-7	35.1 my	hornblende	Vekol Mts.
	KA-8	26.1 my	biotite	Vekol Mts.
	KA-9	27.5 my	biotite	Cimarron Mts.
	PED-1-63	27.9 my	biotite	Silver Bell Mts.

The andesite thickness is extremely variable up to a maximum of about 2,000 feet.

Conformably overlying the andesite sequence are basaltic flows and interbedded poorly consolidated fanglomerate of probable Miocene age. The age assignment is based upon correlation with a basalt in the subsurface at the Lakeshore mine which lies at the base of fanglomerate and has been dated at 24 million years by Hecla geologists (Erickson, 1973). The basalt and/or fanglomerate occur in all ranges within the mapped area except the Sil Nakya Hills.

Intrusive Rocks

Intrusive rocks of several ages are represented on the Reservation ranging from older Precambrian through mid-Tertiary in age. The age assignment of several areas of intrusive rocks, especially some of those considered as older Precambrian is uncertain. In many areas a rock having a composition and texture similar to the older Precambrian granite has been termed Precambrian solely on this basis. The difficulty here is that a Paleocene alaskite texturally and compositionally very similar to the older Precambrian rocks is known from the Silver Bell district.

Older Precambrian Granite

An extensive area of older Precambrian granitic rocks lies in the area just north and northeast of the Vekol range. Here a medium to coarse grained somewhat porphyritic biotite quartz monzonite clearly intrudes the Pinal schist and is unconformably overlain by Younger Precambrian rocks. Except for the many aplite dikes cutting the quartz monzonite the rock is very uniform throughout. It is characterized by abundant coarse gobby gray quartz blebs averaging about 1/4 inch across.

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Younger Precambrian Diabase

The Apache group rocks generally contain one or more sills of fine-grained diabase. The sills generally range up to a few tens of feet in thickness. They have been observed to cut units no younger than the Mescal Limestone.

Late Cretaceous Rocks

Diorite...Four areas of a fine grained equigranular hornblende-biotite diorite to granodiorite have been mapped. These lie in the northeastern Vekol Mountains, the Cimarron Mountains, the northern Santa Rosa Mountains, and the southeastern Santa Rosa Mountains. The rock intrudes units as young as the Jurassic-Triassic sediments and is cut by hornblende andesite porphyry in the Vekol area and by Early Tertiary (?) porphyritic quartz monzonite in the Cimarron Mountains. In addition it is cut by numerous dikes of monzonite porphyry in the northern Santa Rosa mountains.

Hornblende andesite porphyry...Small dikes and sills of hornblende andesite porphyry are very abundant in the northern Slate Mountains and the northeastern Vekol Mountains. These bodies have been observed cutting rocks as young as the Jurassic-Triassic sediments and commonly intrude along north-northwest striking fault zones. Throughout much of this study these were considered to be of mid-Tertiary age and the feeders for the Oligocene andesite porphyry volcanics. Potassium-argon date on one of the dikes of 89.7 (97.2) million years from hornblende suggested that the initial age assignment was in error. A return visit to the northeastern Vekol area brought out two significant features:

1) that beneath the unaltered mid-Tertiary andesites lies a somewhat altered and mineralized sequence of andesite porphyry flows and breccias.

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2) that on the ridge southwest of the Reward mine a dike of early Tertiary quartz porphyry from the Newmont porphyry center cuts a dike of hornblende andesite porphyry.

Thus it seems likely that the original age assignment was in error and that the hornblende andesite intrusives are pre-mineral and likely Late Cretaceous in age.

Biotite andesite...A few thin sills and dikes of a porphyritic biotite andesite have been mapped generally in close association with hornblende andesite porphyry. It has similar geologic relations but in a few localities seems to cut the hornblende andesite.

Early Tertiary Rocks

Quartz Monzonite and Porphyritic Quartz Monzonite... Batholithic bodies of medium-grained equigranular biotite quartz monzonite and porphyritic quartz monzonite are exposed in the Vekol, Slate, Santa Rosa, Cimarron, Brownell, and the Quijotoa Mountains. In addition a small exposure of this rock lies in the extreme western part of the West Silver Bell Mountains. The following potassium-argon ages have been determined on biotite from these rocks:

Sample KA-1	Vekol Mts.	61.6 my
--	Slate Mts.	67 my

The quartz monzonites everywhere post-date the Jurassic-Triassic sediments and intrude diorite in the Cimarron and Santa Rosa Mountains.

Quartz monzonite porphyry and monzonite porphyry...

Quartz monzonite and monzonite porphyry intrusives have been noted in only four areas during this study, the Silver Bell district, on the Newmont property in the Vekol range, at the Lakeshore mine, and in the northern Santa Rosa Mountains. No description of the porphyries at Silver Bell will be given here as this is already covered in published literature on the district.

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On the surface at the Newmont property (Plates 1 & 6) is an irregularly shaped mass of intrusive quartz eye porphyry which cuts rocks as young as the Jurassic-Triassic sediments. The rock is but weakly altered, but some copper bearing skarn is developed at its contacts with Escabrosa Limestone. An isolated dike of this rock cuts the Late Cretaceous hornblende andesite porphyry. This rock has not been dated but is considered to be genetically related to the 61.6 million year old batholith to the south. The dike is spatially associated with the porphyry and skarn mineralization on the Newmont property.

Except for one isolated dike the quartz monzonite porphyry at the Lakeshore mine is not exposed on the surface. This dike cuts a hill of strongly propylitized Jurassic-Triassic sediments about 2 miles southwest of the Lakeshore pit. It consists of a chloritized hornblende quartz monzonite porphyry having an aphanitic to aplitic groundmass. The rock contains no sulfides. At the Lakeshore mine Helca geologists have dated the porphyry at 67 million years by K-Ar on biotite.

The last area of porphyries noted is in the northern Santa Rosa Mountains where a northeast-striking swarm involving 20 to 30 dikes in widths of a few feet to a few tens of feet cut strongly propylitized diorite. The dikes consist of monzonite porphyry containing a very few 1-2 mm quartz eyes, a fine aplitic mafic & K-spar rich groundmass, and numerous 4 to 5 mm. plagioclase phenocrysts. The mafics, principally biotite, are replaced by chlorite. Epidote is very abundant in the groundmass.

The dikes strike northeast and dip southeast at moderate to steep angles. They tend to follow northeast fissure veins and seem to post-date copper mineralization in the veins.

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Felsite...

Several small intrusive bodies of uncertain age intrude Jurassic-Triassic sediments in the hills north of the Brownell Mountains and in the southeastern Santa Rosa Mountains. This rock consists of a white aphanitic felsite that rarely contains a few small white feldspar phenocrysts. Its relationship to rocks younger than the sediments is unknown.

Structure (Plates 1, 2, & 3)

Three major periods of structural activity have affected the Papago country, in Older Precambrian, Late Cretaceous-Early Tertiary, and in Late Tertiary time. The Old Precambrian deformation is reflected in the intense chevron folding in the Pinal schist which has not affected any younger units. Little information about this deformation was gained in this study except to say that everywhere the Pinal schist has been observed it is severely folded and metamorphosed.

Late Cretaceous-Early Tertiary Structure

Most of the major structural features of the Papago Reservation originated during this time, these include large scale northwest-trending cylindrical folds, northwest-striking lateral faults, and normal faults. These features seem to have developed largely prior to mineralization and emplacement of the quartz monzonite batholiths.

At least some of the Early Tertiary lateral faults have been reactivated in Late Tertiary or Recent time as evidenced by normal offset of mid-Tertiary fanglomerate.

Folds...Cylindrical folds of northwest and north-northwest trend are very abundant throughout the mapped area. Rocks as young as early Tertiary (in the Silver Bell district) are involved, but the folds are best developed in the Jurassic-Triassic and older rocks. They commonly have

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wavelengths of from about one to five miles and amplitudes on the order of a few thousands of feet. Where sufficient control exists to define the plunge it generally seems to be at low to moderate angles to the northwest.

Lateral Faults...One of the more important results of this study is the recognition of large scale left-lateral faulting which has affected much of the mapped area. Other lateral faults of northwest strike have been recognized in southeastern Arizona, but their sense and amount of displacement have been poorly defined. These include such structures as the Mogol fault, the Sawmill Canyon fault, and the Baboquivari fault.

Three major faults within the mapped area can be demonstrated to have left-lateral displacements on the order of miles. These are the Tat Momoli fault in the Slate Mountains with at least 2 miles of movement; the Chaipuk fault in the southern Vekol Mountains with an estimated 6 to 8 miles of displacement; and the Santa Rosa fault near Santa Rosa village with about 7 miles of displacement. Other faults of left-lateral displacement include the Copperosity fault in the Vekol Mountains of somewhat less than 1 mile displacement, the Brownell fault in the Brownell Mountains and the Ben Nevis fault in the Quijotoa Mountains. The displacement of the latter two faults is not known, but assuming a left-lateral movement of 3 to 4 miles on each fits well with the stratigraphy.

The lateral faults are plainly visible on the ERTS satellite imagery and can be traced for many miles southeast of the mapped area. The Santa Rosa and Chaipuk fault zones can be traced through the Comobabi Mountain area into the northern Baboquivari Mountains, where the Baboquivari fault (Fair, 1965) has four miles or more of left-lateral displacement.

The major displacement on the lateral faults post-dates the emplacement

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of the Jurassic quartz latite, but seems to have occurred before intrusion of the Laramide quartz monzonite batholiths and mineralization. This is also in keeping with the relations observed in the Silver Bell district where the northwest striking "district fault" has localized the mineralized Laramide porphyries. The sense of displacement on the "district fault" is not known but probably is left-lateral.

Normal Faults...Normal faults of various strikes and with dips ranging from nearly horizontal to steep have been mapped throughout the area. Some are Late Cretaceous to Early Tertiary in age of principal movement, whereas other may be as young as late Tertiary. A few normal faults are clearly of Middle or Late Tertiary age such as the Lakeshore fault and will be discussed later.

Features believed to be Late Cretaceous-Early Tertiary normal faults include the Window Valley structural zone, moderately dipping north northwest faults in the Vekol Mountains, and Quijotoa areas, and the Bitter Wells fault of the Vekol Mountains.

The Window Valley structural zone is a major east-northeast to east-west striking zone of normal (?) faulting which post-dates the Jurassic quartz latite but predates the left-lateral faulting. This feature is traceable from the low hills north of the Brownell Mountains through the Cimarron Mountains and probably projects into the West Silver Bell Mountains to join the Ragged Mountain fault which offsets Early Tertiary Mount Lord Ignimbrite.

Several north-northeast striking moderately eastward dipping normal faults repeat the Paleozoic and Mesozoic stratigraphy in the northeastern Vekol Mountains. These are pre-mineral faults that are cut by late Cretaceous andesite porphyry dikes and by Early Tertiary quartz porphyry

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at the Newmont property. Normal displacements of from a few hundreds to a about 2,000 feet are indicated. One of these structures, the West fault on the Newmont property has some post-Mid Tertiary movement as well. A low angle normal fault in the southwestern Vekol Mountains dips about 40 degrees northwest and has displaced Pinal schist over Jurassic-Triassic rocks by means of about 2 1/2 miles of normal displacement. This structure is bounded by two lateral faults, the Chaipuk fault and the Copperosity fault.

A low angle fault which is of probable Early Tertiary age lies just south of the Brownell Mountains. Here a fault dipping 30 degrees south offsets the Tertiary (?) quartz monzonite and Jurassic quartz latite. A dip-slip movement of at least 2 miles is needed to place the quartz monzonite into its present position. The fault movement predates the deposition of the Tertiary fanglomerate.

The last area of normal faulting presents a bit of a problem for interpretation. This is the Bitter Wells fault in the Vekol Mountains. The Bitter Wells fault has a strike parallel to the left-lateral Copperosity fault but has a right-lateral sense of apparent offset. The age of the Bitter Wells structure can be said only to predate the Mid-Tertiary andesite and postdate Jurassic-Triassic sediments. Because of the spatial closeness of the quartz porphyry on the Newmont property and the genetically related porphyritic quartz monzonite batholith the Bitter Wells fault must either be a prebatholith right-lateral fault or a post batholith dip-slip fault with the north side downthrown. In view of the vastly different structural levels implied by the now nearly adjacent porphyry and batholith, the lack of a right laterally offset mineralized halo on the south side of the fault, and the lack of right-lateral drag on the fault, the fault is probably a

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post batholith normal fault. Dip-slip movement of about 9,000 feet north side down would be required to produce the present outcrop pattern.

Late Tertiary and Younger Structure

Three major structural zones of Late Tertiary age have been recognized, the Lakeshore and related faults, the Quijotoa fault, and numerous low angle faults in the Vaiva Hills and Tat Momoli Mountains. The former two zones have large displacements in a normal sense, and offset Tertiary fanglomerate. Movement of the Lakeshore fault cannot be determined with any degree of certainty but must be of many thousands of feet in order to bring Jurassic-Triassic sediments now in the hanging wall from a position on the northeast pediment of the Slate Range or from Jurassic-Triassic sediments which are now eroded from the crest of the Slate Range. The entire mineralization pattern at the Lakeshore mine lies in the hanging wall and as slices within strands of the Lakeshore fault. Movement on the Quijotoa fault as determined from the fanglomerate is probably at least 2,000 feet in a normal sense.

The low angle faults dip from 0 to about 30° and have normal displacements of from a few hundred to about 3,000 feet.

Many of the Early Tertiary faults have been reactivated in Late Tertiary time. The Bitter Wells, Copperosity, and Ben Nevis faults display small offsets where they pass through Mid-Tertiary andesite and fanglomerate.

Other minor displacements in Late Tertiary time are evident in the Tontk Valley west of the Sheridan Mountains where the gently west dipping andesite, fanglomerate, and basalt have been repeated by a hypothesized north-northeast striking fault.

Santa Rosa Valley Garben...The Santa Rosa Valley may be a Middle to Late Tertiary graben.

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The depth of alluvial fill for the valley is probably on the order of 5,000 feet based upon the -25 milligal gravity anomaly indicated for this area on the Arizona Bouger Gravity anomaly map (West and Sumner, 1973). Mid-Tertiary andesite and basalt flows dip gently away from the valley on both the east and west margins suggestive of antithetic rotation on the margins of a graben. In addition the large southwestward normal movement on the Late Tertiary Lakeshore fault is compatable with sliding into a trough in the valley.

Unfortunately the gravity control is not sufficiently close to determine the location of range front faults. A possible exposure of a range front fault is a north striking eastside down fault separating Precambrian granite from fanglomerate 3 miles west of the Vaiva Hills.

Discussion of Structure

A point which has not been emphasized above is the importance of northeast and east-northeast tension fractures in the localization of dikes and mineralization. Swarms of monzonite porphyry and quartz monzonite porphyry with spacially associated copper mineralization occur in the northern Santa Rosa Mountains and in the Silver Bell district. The importance of the northeast-striking tension fractures upon the localization of ore at the Lakeshore and Newmont properties is not evident from surface exposures, but many porphyry copper districts of southeastern Arizona exhibit this control (Rehrig and Heidrick, 1972).

The northeast-striking tension fractures, the northwest-trending folds adn the northwest-striking left-lateral faults, are all manifestations of the same stress field operating throughout much of southern Arizona during the Laramide orogeny. That is, southeastern Arizona was subjected to a stress field having a northeast to east-northeast oriented maximum principal

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stress axis. The ultimate origin of this stress field will not be speculated upon here.

The origin of the low angle faults in the Vaiva Hills is somewhat uncertain because their age is poorly known. They cut rocks as young as Mississippian but do not offset the Mid-Tertiary basalts. It is likely that these faults are land slide blocks that have been transported into the trough of the Santa Rosa graben. This would require initiation of the graben before extrusion of the basalts, which is not unreasonable.

Mineralization and Alteration (Plate 5)

Three major skarn-porphyry copper deposits lie within the area examined, the Lakeshore mine, the Newmont Vekol property, and El Tiro mine of the Silver Bell district. All three contain Laramide age plutons having a spatial and probable genetic relationship to mineralization and have developed high grade skarn copper mineralization in the younger Precambrian and/or lower Paleozoic stratigraphy. Best hosts for copper mineralization are the Abrigo Formation, Mescal Limestone, and the diabase sills.

In addition to these three major centers are several other areas of alteration and mineralization. These include areas of intense propylitic alteration and minor copper mineralization in the northern Santa Rosa Mountains, and in the hills north of the Brownell Mountains, the pyritic fringe and copper bearing zone on the Pinal Copper property, a pyritic zone at the north range front of the Brownell Mountains, and an extensive area of specularite and copper mineralization in the Brownell and Quijotoa Mountains.

Detailed descriptions of the Lakeshore mine and the Silver Bell mineralization will not be given here as the writer has seen these deposits only as a tourist.

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For information on these areas the reader should refer to the company files on the Lakeshore mine and the Silver Bell district.

Newmont Property

The Newmont property in the Vekol Range (Plates 1 and 6) lies on the axis of a moderately northwest plunging syncline formed in the Younger Precambrian, Paleozoic, and Mesozoic rocks. The area containing the grid drilling is bounded on the west by a steeply northwest striking eastward dipping normal fault, the West fault, and on the east by a steeply westward dipping normal fault, the East Fault. Both structures have post-mineral movement but mineralization has been noted following the West fault so it must have some pre-mineral movement as well. Early Tertiary quartz porphyry cuts a northwest-striking fault parallel to the West fault so that pre-mineral displacement is demonstrated for this direction of faulting.

The quartz porphyry exposed on the surface one mile west of the Newmont shaft is only slightly altered having fresh feldspar and chloritized mafics. It generally contains only traces of pyrite. In the northeast part of the porphyry exposure some thin contact skarn containing small amounts of copper has developed in the Escabrosa limestone. In the area of the quartz porphyry the sediments are generally unaltered and unmineralized.

Alteration is most plainly evident in the Jurassic-Triassic sediments which contain several percent of epidote as veinlets and disseminations. Most of these sediments exposed in the two areas adjoining the Newmont drilled area contain abundant epidote. Alteration in the Paleozoic rocks is restricted to recrystallization of the limestones and spotty pods of garnet skarn in the Abrigo Formation near the Reward mine.

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The ore grade mineralization is reported (see Reward mine file) to consist of about 100 million tons of +0.5% copper as chalcopyrite of which about 50% is in diabase, 10% in Mescal Limestone, and 40% in the Dripping Springs Quartzite. The Mescal mineralization is reported to contain abundant pyrite and pyrrhotite, some magnetite, very minor garnet, and copper grades to 10%. The Abrigo Formation in the east part of the drilled area is also mineralized but is reported to be lower in grade, maximum of 3% copper.

Low angle post-mineral faults that we had hoped would be present in the northeastern Vekol Mountains are not obvious from the geologic mapping. If such features are present they would have to lie beneath the gravels to the east. Except for the possibility of gravity slide blocks derived from the Newmont area and emplaced into the Santa Rosa Valley graben there is little reason to suspect any repetition of the Newmont mineralization by low angle post mineral faults.

Santa Rosa Mountains

In the northern Santa Rosa Mountains the Cretaceous (?) diorite and Jurassic-Triassic sediments are intensely propylitized. The rocks commonly contain several percent of epidote and the mafics in the diorite have been replaced by chlorite. An area of some 6 to 8 square miles of similarly affected rocks is exposed here. The alteration is similar to that found in the Jurassic-Triassic sediments adjacent to the Lakeshore and Newmont mineralization. In addition the altered area contains a well-developed northeast-striking swarm of altered monzonite porphyry dikes. The dikes follow numerous fractures and copper bearing fissure veins that cut the diorite and seem to postdate the mineralization. A similar zone of northeast-striking monzonite porphyry dikes has been described in the Silver Bell

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district northeast of El Tiro pit (Watson, 1964). In the northern portion of the diorite are exposures of numerous northeast-striking mineralized fissure veins containing quartz, iron oxides, and locally abundant oxide copper.

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Pinal Copper Property (See company file - Pinal Copper Prospect)

An area of intense pyritization and locally strong "A" quartz veining with associated copper mineralization lies on the Pinal Copper Property at the northern flank of the Cimarron Mountains. The property was examined several years ago by the geology department and rejected. The mineralization has been variously described as oxide copper mineralization occurring in a heavily "A" veined diorite porphyry. Visible copper is exposed on the surface only in some shallow cuts in the strongly veined area that covers an area but a few tens of feet square. To the north lies a belt of east-west trending pyritization in the "diorite porphyry" which covers an area of about one-half square mile. To the east of the copper bearing area extends a narrow zone of discontinuous quartz stringering that blossoms into definite quartz veins in the Greenback mine area.

Upon examination of the area by the writer two features of significance became apparent:

1) the "diorite porphyry" is identical in texture and composition to the andesite porphyry mapped in the Mid-Tertiary extrusives in the Vekol Mountains,

2) the "A" type quartz veining as well as the copper mineralization is confined to a relatively narrow nearly east-west zone extending eastward to the Greenback mine. It is the writer's contention that the Pinal Copper property is merely a Mid-Tertiary vein zone developed in the andesite and not related to either Early Tertiary or Jurassic age mineralization which has generated all of the productive Arizona porphyry copper deposits. This conclusion

is supported by the potassium-argon age of 27.5 million years obtained from biotite in the copper bearing quartz veined andesite. I feel we can confidently dismiss the Pinal Copper area from any further consideration.

Area North of Brownell Mountains

Two small areas of about 1/4 square mile each of propylitized Jurassic-Triassic sediments have been mapped in the low hills north of the Brownell Mountains. The southern surrounds a felsite plug. The northern one has no exposed associated intrusive rocks. Neither of the areas seems to be of any economic significance.

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Brownell Mountains

At the northwest edge of the Brownell Mountains lies an area of pyritization in the Jurassic-Triassic (?) volcanics of about 1/4 square mile. In this area the quartz latite to rhyolite volcanics have about 1/2 percent of disseminated pyrite and at least an equal amount of disseminated specularite. Locally where the volcanics have been brecciated they are cemented with nearly massive specularite that contains considerable oxide copper staining. Work on the Mond-Tel group of claims on a similar type of occurrence (see Anaconda Mond-Tel file) several years ago indicates that the copper occurs as primary chalcocite.

The pyritized zone fades to the south, east, and west, but is bounded by a Late Tertiary fault on the north. No dikes or other intrusions of mineralized porphyry have been observed here and except for the pyrite alteration is nil.

An area of extensive specularite mineralization crops out southeast of the above area in the region just south of Brownell Peak. Here an area of over 1 1/2 square miles contains about 1/2 to 1 percent of specularite as fine disseminations and fracture fillings in the Triassic-Jurassic (?)

volcanics. This is the Mond-Tel group of claims referred to above. Locally where the rock is brecciated it is cemented by several percent of specularite containing oxide copper. Again no apparent intrusive is associated with the mineralization.

Numerous other areas of similar mineralization but smaller in area occur throughout the Brownell and part of the Quijotoa Mountains. Examples of prospects on these areas in company files are the White Wing, the St. Patrick, and Knight prospects. In general specularite is very widespread in the Quijotoa area. It is abundant as a cement in the precious metal veins of the Quijotoa district and forms huge "iron dikes" several feet wide along with quartz and epidote in the Quijotoa Mountains.

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Exploration Targets

Three exploration targets are evident from this study the last of which must be regarded as highly speculative. These are indicated on the Mineralization and Alteration overlay (Plate 5).

Target No. 1...This area is related to the altered area exposed at the northern end of the Santa Rosa Mountains.

The altered area in itself does not seem to offer an attractive exploration target, but it may be a part of a more interesting mineralized pattern. The exposed part of the alteration is probably bounded on the northeast at about the edge of outcrop by the southward continuation of the post-mineral Lakeshore fault. To the southwest the alteration and mineralization fades into unaltered diorite, even though the monzonite porphyry diking continues. Any exploration related to testing a portion of this altered zone would have to be centered upon finding the portion of the pattern in the footwall block of the Lakeshore fault some distance to the northeast. Such a block could exist at the southeast end of the Slate Range in a position

beneath the gravels such that the dike swarm would intersect the Paleozoic and Younger Precambrian rocks on the northeast flank of the Slate Range. The possibility that such an area exists is supported by the occurrence of numerous small irregular diorite intrusives cutting the Pinal schist at the east end of the Slate Mountains. Although the data points are sparse, regional gravity data suggests that a pediment could lie in this area.

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Target No. 2...This target represents the possible northeast extension of the Lakeshore mineralization that might remain in the footwall block of the Lakeshore fault. It is in an area which should consist of northeast dipping Younger Precambrian and Paleozoic rocks that would have been downdip in the Slate Mountain anticline at the time of mineralization. It is also on the projection of the northeast fracture and mineralization trend in the Lakeshore orebody (Rehrig & Hendrick, 1972). It is in a position quite far removed from the probable cupola overlying the quartz monzonite batholith so that its not likely that significant mineralization will be found here.

Target No. 3...The recognition of the Late Tertiary Santa Rosa graben and the sliding of the Lakeshore mine block in towards this feature creates a possibility for the Newmont property to have been truncated by a fault similar to the Lakeshore fault. The presence or absence of such a structure would have to be determined geophysically since nothing of this nature is exposed near the property. However, the low-angle gravity faults on the west side of the Vaiva Hills may be indicative of eastward slump into the graben so that this might have occurred to the south at the Newmont property as well. The unfortunate point here is that Newmont has a lease on the covered area for a distance of about 2 miles east of the outcrop so that the depth of cover on available ground may be prohibitive.

Recommendations

A geophysical followup is recommended for target area 1 and to a lesser extent area 2. Area 3 is too poorly defined and speculative to deserve any further work at the present.

I recommend that a low level aeromagnetic survey be undertaken of the region covering the northern Santa Rosa Mountains, the Slate Mountains, and the valley area to the east of these ranges to about Silver Bell with the objective of further refining the locations of targets 1 and 2.

Several reconnaissance I.P. and resistivity lines should be run in the unsurveyed sections 1, 2, 3, 10, and 12, T11S, R5E (Area 1) with the objectives of determining if a mineralized center related to the Santa Rosa altered area is present and to determine the depth of alluvial cover. Such work would require reapplication for a walk-on permit from the Papago Tribe since the permit used for this study has been terminated.

Respectfully submitted,

Louis H. Knight

LHK/jh

7/19/74

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