STATUS OF MINERAL RESOURCE INFORMATION FOR THE GILA BEND, PAPAGO, AND SAN XAVIER INDIAN RESERVATIONS, ARIZONA

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SUMMARY AND CONCLUSIONS

The Gila Bend, Papago, and San Xavier Indian reservations are in the western part of the southern Arizona porphyry copper province, one of the most productive copper mining areas in the United States. In addition to copper, the reservations also contain a potential for many other metallic and nonmetallic mineral resources. The economic geology of the reservation is incompletely known, however, and additional study is needed. Geologic and geophysical surveys, accompanied by regional geochemical sampling and detailed sampling of the known mineral occurrences, are recommended.

INTRODUCTION

This report was prepared for the U. S. Bureau of Indian Affairs by the U. S. Geological Survey and the U. S. Bureau of Mines under an agreement to compile and summarize available information on the geology, mineral and energy resources, and potential for economic development of certain Indian lands.

The Gila Bend, Papago, and San Xavier Indian Reservations are in Pima, Maricopa, and Pinal Counties in southern Arizona (Figure 1) within an area bounded by long.113º and 110º 45' W., and by lat. 33º 15' N. and the U. S.- Mexican border. The Gila Bend Reservation encompasses 16 square miles, the San Xavier Reservation 110 square miles, and the Papago Reservation approximately 4,300 square miles.

The reservations are in and near one of the most productive copper mining areas in the United States (Figure 1). Deposits within the reservations' boundaries being mined at this time are the San Xavier copper mine and the Lakeshore copper mine. A third deposit, the Vekol, is currently in development and other major copper mines are situated just outside the reservation boundaries. The Ajo deposit is on the western edge of the Papago Reservation and the Silver Bell deposits are on the northeastern edge. The Pima district copper mines lie immediately south of the San Xavier Reservation.

There is little detailed published knowledge of the geology of the reservations, despite their proximity to major copper deposits. Past geologic mapping has been mostly either of the reconnaissance type, as part of ground-water studies on the reservations, or in conjunction with the state mapping program in the 1950's. A few university theses have described small areas within the reservations but there has been no correlation between these areas. Thus, it is difficult to estimate the mineral potential of the reservation until more geologic information has been obtained.

Present Investigation and Acknowledgment

This report summarizes all available published and unpublished information concerning the geology, and development and production of mineral resources on the reservations. The geologic descriptions of rock units and related ore deposits on the Gila Bend, San Xavier, and Papago Reservations have been compiled from a variety of sources. We acknowledge the help of Mr. Addison

F. Smith, Director, Department of Mines and Natural Resources, the Papago Tribe of Arizona, who provided us with much unpublished information.

Previous Mineral Investigations

The most comprehensive studies of the reservation are those published by L. A. Heindl who studied the geology and groundwater conditions of the reservations, and those by Stanton B. Keith, who studied the geology and mineral deposits of large areas of the reservation in Pima County (see references). The Arizona Bureau of Mines and Arizona Department of Mineral Resources have conducted studies and maintain extensive files on mineral occurrences and production. In particular, Arizona Bureau of Mines Bulletin 189 (Keith, 1974) is a thorough catalog of mining activity in the Pima County part of the reservation.

Prior to 1955, the Papago Reservation was subject to the same U. S. mineral location laws as all Federal lands. In 1955, the reservation was closed to further mineral location by the claim method. The U. S. Bureau of Land Management then began an appraisal of all the unpatented claims on the reservation. Although patented claims remained valid, perhaps as many as 1,500 unpatented claims were invalidated. Early invalidations were made on the basis that evidence of mineral occurrence was absent or that abandonment constituted a relinquishment of rights to located claims. Later invalidations have been based on a failure to pay the fees ($.05 per acre) required to hold valid, unpatented claims on the reservation. Records of mineral and claim evaluations by the Bureau of Land Management are held by the Bureau of Indian Affairs (Phoenix office) and the Papago Tribal office (Tucson).

In 1961, Stebbins Mineral Survey, Inc., (formerly Hunting Geophysical Services) was granted the exclusive right for 3 years to explore the reservation for minerals other than hydrocarbons. Certain areas, such as patented claims and the Garcia Strip (generally in T. 14 S., R. 10-11 E.) were excluded from the lease. Results of this study are property of the Papago Tribe. Stebbins made aerial photographs of outcrops on the reservation in color and in black and white as stereo pairs. On the basis of geological study, using the aerial photographs, areas deemed of no interest were not investigated further. Areas of interest were subjected to further geologic mapping, geochemical sampling, and airborne and ground geophysics. One diamond drill hole was completed to 168 feet. About 1,500 geochemical samples were collected and 3,100 analyses made. Geophysical exploration included 65 miles of induced polarization lines, 37 miles of ground and 1,700 miles of aeromagnetic lines, and 2 miles of seismic profiles.

Areas in which the detailed exploration was concentrated are:

Area	Type of study conducted
Gunsight mine center sec. 16, T. 14 S., R. 4 W.	Geochemical survey.
Green mine NE¼ sec. 31, T. 16 S., R. 5 E.	Geochemical survey, traverse and grid.
Ko Vaya Hills secs. 5, 6, 7, T. 16 S., R. 4 E.	Geochemical and one line of induced polarization.
U. S. Geological Survey Comobabi 1:62,500 quadrangle	Extensive induced polarization and geochemical survey of area in this quadrangle, the location of which is unidentifiable in the Stebbins report.
South Slate Mountains, North Santa Rosa Mountains W½, T. 11 S., R. 5 E.	Magnetic and 16,000 feet of induced polarization. Centered on depressions between these two ranges.
Vekol Hills SW¼, T. 9 S., R. 2 E.	Extensive induced polarization traverses east and northeast of Vekol mine.
Vekol Hills NW¼, T. 10 S., R, 3 E.	Extensive induced polarization south-southwest of the Reward mine, but not extending to the Republic mine area.
Brownell Mountains SE¼, T. 13 S., R, 2 E. SW¼, T. 13 S., R. 3 E. NW¼, T. 14 S., R. 2 E.	Extensive induced polarization & geochemical traverses from Brownell mine (sec. 35, T. 13 S., R. 2 E.) to west and south of Brownell Peak (sec. 15, T. 14 S., R. 2 E).

In 1968, J. J. Strutzell, Jr., mining engineer, compiled extensive data on mineral occurrences, geology, production, and development of many of the important mines and prospects on the reservation. This unpublished study was sponsored by the Bureau of Indian Affairs. Amuedo and Ivey, consulting geologists, were retained in 1971 by the Bureau of Indian Affairs to conduct an air photo and aeromagnetic assessment of the reservation. The air photo study included assessment of Gemini IV color photos, Apollo 6 color and infrared color photos, Apollo 9 black and white photos, high altitude 9" x 9" and 70-mm color and infrared color photos, and the Stebbins low altitude photo sets. Among the products of the air photo study was a 1:62,500 photogeologic map of the Silver Reef-Slate-Copperosity-Vekol Hills area of the reservation (generally T8-10S, Rl-6E), probably the largest scale map of that part of the reservation available. Also in the report are several 1:62,500 photogeologic interpretations (using various of the aforementioned photo sets) of the Cimarron

Mountains-Copperosity Hills area, and smaller scale photogeologic interpretations of the entire Papago Reservation and surrounding areas.

An aeromagnetic study, conducted by Scintrex Mineral Surveys, Inc., involved correlating data from the Residual Aeromagnetic Map of Arizona (Univ. of Arizona) and U. S. Geological Survey Maps GP-426 and GP-548. The study employed the stereo contour map technique. Results of this study included an aeromagnetic contour and lineament map of the reservation. The report also presents conclusions concerning possible structural and intrusive patterns and the application of these to mineral prospecting on the reservation.

Setting

The Gila Bend, Papago, and San Xavier Indian Reservations are within the Basin and Range physiographic province which is characterized by elongate north trending block-faulted mountain ranges separated by broad valleys. The valley floors range from approximately 1,200 to 2,500 feet above sea level. Most of the mountain peaks within the region are less than 4,000 feet high. The highest altitude within the reservation is Baboquivari Peak at 7,730 feet on the eastern border of the Papago Reservation (Figure 2).

The major drainage for the Gila Bend Reservation is the Gila River which is dry or nearly dry except during floods. The Santa Cruz River, which drains the San Xavier Reservation, is likewise generally dry, as are the numerous small drainage channels throughout the three reservations.

The Painted Rock Dam, an earth fill flood-control dam, has been constructed on the Gila River in T. 4 N., R. 7 E., approximately 12 miles north-northwest of the Gila Bend Indian Reservation. The area behind this dam, including two-thirds of the reservation is subject to inundation to an elevation of 661 feet. If the reservoir were filled to this level, all cultivated lands, buildings, and mines behind the dam and below the spillway level of 661 feet would be flooded. For this reason, no class-one buildings are permitted on Federal lands within the area of potential inundation, and lessees of Federal land within this area have no cause of action against the U. S. Government for flood damage.

Inundation to the 661-foot level is unlikely because only once since the dam was built has any water been held back, and that was to the 586-foot level.

The Gila Bend Reservation is accessible from U. S. highways 8 and 80. The San Xavier Reservation, adjacent to the city of Tucson, is easily accessible from U. S. highways 86, 19, and state highway 93-89. The Papago Reservation is accessible from U. S. highways 85, 86, 286 and by unnumbered roads which intersect U. S. highways 8 and 10.

Temperatures and precipitation from localities near the reservation are listed in Table 1, and area and population data are listed in Table 2.

TABLE 1

Climatological Data Near Reservation

Station	Average Temperatures High (July)	Average Temperatures Low (January)	Average Temperatures Annual	Average Precipitation High (August)	Average Precipitation Low	Average Precipitation Annual
Casa Grande	91.1	50.0	69.9	1.28	0.12 (May)	8.02
Gila Bend	93.2	52.3	72.2	1.09	0.03 (June)	5.62
Ajo	90.6	52.5	71.5	2.34	0.04 (May)	9.06
Tucson Airport	86.3	49.8	67.7	2.88	0.13 (May)	11.00

TABLE 2

Area and Population Data For the Reservations

Reservation	Area (mi^2)	Population	Population density (persons/mi^2)	Percent employed	Per capita income
Papago	4,313	4,544	1.05	41	$553
San Xavier	111	558	5.02	34	546
Gila Bend	16	103	6.30	20	482

Principal economic activities on and near the Papago Reservation consist of livestock grazing and mining; some tourism-related employment also exists. Principal income sources on the Gila Bend Reservation includes farming on irrigated lands, grazing, and tourism. Industries on the San Xavier Reservation include farming on irrigated land, grazing, mining, and employment related to the U. S. interstate highway, which passes through the reservation.

GEOLOGY

Rock Units

Rock units exposed on the Gila Bend, Papago, and San Xavier Indian Reservations range in age from Precambrian (greater than 1.2 billion years old) to Holocene (less than a few thousand years old). Fifteen different map units are shown on the generalized geologic map (Figure 3). The most important units in terms of potential for mineral deposits, are those that are adjacent to and older than the granitic rocks of Laramide age. These units contain most of the base and precious metal deposits known on the reservations. The younger units, the Tertiary volcanic and sedimentary rock units, contain most of the manganese deposits known on the reservations.

Older Precambrian Metamorphic Rocks

The older Precambrian metamorphic rocks are dominantly gneiss and schist, and include the gray, strongly foliated, siliceous Pinal schist. The schist and gneiss are locally intruded by numerous mafic, felsic, and pegmatite dikes and younger plutonic rocks.

Pinal schist forms the core of the Slate Mountains, where it is a brownish-gray quartz-sericite schist composed of fine- to coarse-grained metasedimentary rocks. Sedimentary structures are locally discernible. Quartz stringers are common.

The Precambrian gneiss and schist in the Gila Bend Mountains have been tentatively correlated with Precambrian Cardigan gneiss in the Ajo area. The gneiss and schist are predominantly brownish gray, conspicuously banded or foliated, and locally closely jointed. Gneiss is generally more resistant to erosion than the schist and forms more conspicuous outcrops.

Precambrian Intrusive Rocks

Precambrian intrusive rock units include granite, quartz monzonite, granodiorite, quartz diorite, and diorite which are in part gneissic and porphyritic. Also included are diabase sills which in the Slate Mountains are grayish green and deeply weathered. The Precambrian granitic intrusives probably are of two ages, one group of about 1670 m.y. (million years) old and a younger generally porphyritic group of about 1450 m.y. old. In favorable localities, granites of both ages have been host rocks for ore deposits, and the diabase is even more favorable as a host rock.

Younger Precambrian Sedimentary Rocks

Younger Precambrian rocks within the three reservations belong to three formations of the Apache Group: (1) Mescal Limestone, (2) Dripping Spring Quartzite, and (3) Pioneer Formation (also referred to as Pioneer Shale). The Apache Group rocks are the principal host for the Vekol copper deposit.

Mescal Limestone.--The Mescal Limestone is an important host rock in the Vekol porphyry copper deposit. Because it is composed of chemically reactive carbonate, the Mescal is highly susceptible to mineralization if it is invaded by metal-bearing hydrothermal solutions.

The Mescal Limestone ranges in thickness from 235 feet in the Slate Mountains to nearly 350 feet in the Vekol Mountains. The predominant rock type is dark-gray, silty, finely crystalline to aphanitic, platy to blocky weathering dolomite. The dolomite, which is locally interbedded with light-gray mud stones and cherts, grades into the underlying limestone and forms ledges and cliffs in outcrops.

The limestones of the unit are grayish, finely crystalline to aphanitic, blocky weathering, and cliff forming. Stringers, nodules, and thin beds of chert as well as local pebble conglomerates are found interbedded with the limestone. Dark-gray, partly siliceous, platy to blocky weathering mudstone occurs locally within the formation. The lowermost unit within the Mescal Limestone is yellow-green to yellow-brown, platy to blocky weathering siltstone. Interbedded with the mudstones are thin-bedded limestones, silty dolomite, and chert.

Dripping Spring Quartzite.--The total thickness of the Dripping Spring Quartzite ranges from 825 feet in the Vekol Mountains to approximately 1,000 feet in the Slate Mountains. The formation is divided into three members: Upper, Middle, and the Barnes Conglomerate Member.

The Upper member is composed of quartzite, mudstone, siltstone, and sandstone. The quartzite is light- to dark-gray or reddish-, greenish-, or brownish-gray, silty to coarse-grained, arkosic, partly crossbedded, platy to blocky weathering, partly calcareous, and forms moderately steep cliffs and steplike slopes in outcrops. The mudstones are red to dark reddish brown or light greenish gray to dark yellowish green. The mudstone weathers fissile to platy or blocky, and forms slopes. The siltstones of the Upper member are greenish gray, dark yellowish, brown or reddish brown; weather platy to blocky; and form steplike slopes. The sandstone is dark red, very fine grained, muddy, blocky weathering, and slope forming in outcrop.

The Middle member consists wholly of quartzites. These are light gray to red, very fine to medium grained, arkosic, partly calcareous, locally crossbedded, and blocky weathering. Ripple marks and raindrop impressions are found at the tops of beds. In outcrop, these quartzite beds form cliffs or dip slopes.

The Barnes Conglomerate Member is a cliff-forming conglomeratic quartzite, light gray to pink, arkosic, partly crossbedded, and blocky weathering. On the Papago Reservation, this conglomerate is thin and discontinuous.

The Dripping Spring is not a favorable host rock for mineral deposits. The quartzites are chemically inert and the shales virtually impermeable. Where the Dripping Spring is mineralized, the higher grade ores occur in contiguous lithologies such as diabase or carbonate rocks.

Pioneer Formation.--The Pioneer Formation lies unconformably on Pinal schist and consists of massive to fissile mudstone and blocky weathering quartzite. The mudstones are reddish purple and purple to dark reddish brown. Interbedded with the mudstones are greenish-gray to brownish-gray siltstones. The quartzite is gray, brownish gray, or greenish gray, very fine to medium grained, arkosic, partly crossbedded, blocky weathering, and forms steplike slopes.

As a host rock for ore deposits, the Pioneer has the same limitations as the Dripping Spring--the quartzites are inert and the shales do not support open fractures suitable for the passage of mineralizing solutions.

Cambrian Sedimentary Rocks

The Cambrian sedimentary rocks include the Middle Cambrian Bolsa Quartzite and the Upper and Middle Cambrian Abrigo Formation. In the Slate and Vekol Mountains, the Bolsa Quartzite lies disconformably on rocks of the Apache Group and in the Waterman Mountains it lies unconformably on older Precambrian schist and granite.

Bolsa Quartzite.--Bolsa Quartzite is light gray to brownish gray, or light red to partly purple, fine grained, crossbedded, locally arkosic and blocky weathering. Within this formation are also sandstones which are light brown, reddish brown to pink, fine to coarse grained, partly crossbedded, locally silty, and soft to blocky weathering. Some of the sandstone beds grade laterally into quartzite. Rocks previously called Troy Quartzite within the reservations are probably mostly Bolsa Quartzite, with perhaps locally some Troy at the base.

In the Slate Mountains, the Bolsa consists of pinkish, coarse- to fine-grained, moderately well sorted, medium to very thin-bedded, locally crossbedded sandstone with scattered lenses of grit and quartzite pebbles. The upper beds of sandstone and quartzite contain fragments of generally poorly preserved fossil brachiopods and worm borings. The aggregate thickness of the Bolsa Quartzite in the Slate Mountains is more than 450 feet. Because it is chemically inert, it is not a favorable host for metal deposits.

Abrigo Formation.--The Abrigo Formation on the Papago Reservation consists of sandstone, quartzite, and mudstone. The sandstone is light brown to pale red, very fine grained, partly dolomitic, and blocky weathering. It is interbedded with platy, light-brown to grayish-red silty dolomite which is locally fossiliferous.

Devonian and Carboniferous Sedimentary Rocks

Sedimentary rocks of post-Cambrian and pre-Triassic age are included in this unit. These include limestone, dolomite, sandstone, quartzite, siltstone, shale, conglomerate, gypsum, and marl.

Martin Formation.--The oldest unit included is the Devonian Martin Formation, which is a thick-bedded, blue-gray, cherty, fossiliferous limestone and dolomite interbedded with mudstone and thin-bedded friable siltstone. In southern Arizona the Martin Formation is a favorable host rock for replacement deposits of lead and zinc.

Escabrosa Limestone.--The Mississippian Escabrosa Limestone lies above the Martin Formation and is a cliff-forming, light- to dark-gray, thick-bedded to massive, coarse-grained, non-magnesian limestone. It is fossiliferous, locally chert banded, and contains sand lenses. The Escabrosa Limestone is the primary host rock for base metal replacement deposits in the Vekol Mountains.

Naco Limestone.--Pennsylvanian and Permian Naco Limestone lies conformably above the Escabrosa and is a pinkish-gray fine-grained medium-bedded cherty limestone.

Mesozoic Rock Units

The four lithologic units of known or presumed Mesozoic age on the reservation are volcanic and sedimentary rocks, with most of the sedimentary rocks having been derived from volcanics. These rocks have been cut by faults, and intruded and altered by dikes, sills, and stocks. They are locally metamorphosed to gneisses and schists. These units vary and may be missing locally. The sequences best studied are in the Vekol Mountains, Comobabi Mountains, and Baboquivari Mountains. Throughout the reservation the Mesozoic units serve as host rock to small base and precious metal deposits. The sedimentary rocks are the major host for the San Xavier copper deposit, and the volcanic rocks are probably one of the major hosts for the disseminated sulfide body at the Lakeshore copper mine.

Mesozoic Metamorphic Rocks.--This unit is mainly gneiss derived from Mesozoic and possibly Tertiary intrusive rocks, as well as schists and phyllites derived from Mesozoic sedimentary rocks. Metamorphism possibly occurred during the Late Cretaceous-Early Tertiary period when Laramide plutons were intruded throughout southern Arizona. In the Santa Catalina Range, similar metamorphism is of known Tertiary age. The gneissic rocks are apparently poor host rocks for major ore deposits; the plutons from which they were derived seemingly did not generate major ore-bearing fluids.

The metamorphic rocks, derived from sedimentary and volcanic rocks, are most widely exposed in the Baboquivari Mountains where they are the host rocks for tungsten deposits; they also occur in the South Comobabi Mountains, Coyote and Quinlan Mountains, and Cimmarron and Sierra Blanca Mountains. Lithologies in the Baboquivari Mountains include silicified sedimentary and volcanic material, subordinate phyllite, quartzite, and rare sericitic schist. Lithologies in the Comobabi Mountains, and Coyote and Quinlan Mountains are predominantly hornfels and quartzite.

Mesozoic Sedimentary Rocks.--Numerous named rock units with different sedimentary lithologies are included in the map units. Many units, in particular the Amole Arkose and Comobabi Group are considered to be Cretaceous in age; others, however, originally considered Cretaceous, such as the Recreation Redbeds, are now thought to be as old as Triassic or Jurassic. Lithologies throughout the reservations are diverse and include both coarse-grained and fine-grained clastic deposits, as well as some limestones. Volcanic rocks of rhyolitic and andesitic composition are frequently interbedded in the sedimentary sequences. The host rock for the San Xavier oxide copper mine is arkosic conglomerate of presumed Cretaceous age.

Mesozoic Volcanic Rocks.--This unit is comprised of various rhyolitic to andesitic flows, dikes, and sills, pyroclastics, and associated breccias and conglomerates. The unit may locally include sedimentary rocks, primarily shale, sandstone, and conglomerate. In the South Comobabi Mountains, the sequence of volcanic and sedimentary rocks reaches a thickness of 20,000 to 35,000 feet. Included in the Mesozoic volcanic rock units are numerous named formations. With several exceptions, the equivalency of the various formations in geographically separated areas has not been established because of limited fieldwork and lack of radiometric dates. The rocks within this unit have locally been folded, faulted, intruded, and metamorphosed.

Mesozoic volcanics in the North and South Comobabi Mountains are dense, reddish, porphyritic andesite to latitic flows and greenish-black amygdaloidal andesite flows. These andesites, which attain a composite thickness of some 5,000 feet, are economically significant because they are host rocks for gold, silver, and copper deposits.

Mesozoic Granitic Rocks.--The granitic rocks and associated intrusives in this unit are of varying compositions and textures. Granite, quartz monzonite, granodiorite, quartz diorite, and some porphyry equivalents of these rocks occur as dikes, sills, and plugs. The textures range from very fine to coarse gained, and locally, to pegmatitic. Color ranges from very light gray and pinkish to dark brown and olive gray. The following have also been identified and are included in this unit: alaskite, aplite, tonalite, diorite, syenodiorite, and hornblendite. Most of the intrusive rocks are of Mesozoic age, but older than Laramide; they occur in the western part of the Papago Reservation, an area where geologic knowledge is sparse.

Nearly all porphyry copper deposits of southern Arizona are associated with intrusive rocks younger than the Mesozoic intrusives; however, one major deposit (Bisbee) is related to a Mesozoic granite and therefore Mesozoic intrusives must be considered as potential indicators of ore.

Rock Units of Laramide Age

Intrusive Rocks of Laramide Age.--This unit contains granitic rocks of various compositions which were intruded within the Laramide interval of 50-75 million years ago. Granite, quartz monzonite, granodiorite, quartz diorites, and their porphyritic equivalents as well as aplites are included in this unit. The Laramide Ruby Star Granodiorite, which is exposed in the southwestern portion of the San Xavier Reservation, has yielded radiometric dates of 58.7, 59.0, and 61.6 m.y. A Laramide granite in the southwestern Slate Mountains has yielded a radiometric date of 66 m.y. This unit is not shown on existing maps and it is possible that the rocks considered Precambrian granites are at least in part Laramide in that area.

Other granitic rocks of assumed Laramide age occur in several of the ranges within the reservation. Some units previously thought to be Laramide are either older than 75 m.y. or younger than 50 m.y., and hence not Laramide. In particular, it should be pointed out that granitic rocks at Kitt Peak in the Baboquivari Mountains have yielded a date of 27 m.y., although they have been mapped as Laramide in age; it is not known if this date is from the main granitic mass or from a small Tertiary intrusive body within the large pluton.

The majority of porphyry copper deposits in southern Arizona are genetically related to granitic rocks ranging in age from 50 to 75 m.y. This includes the Vekol, Lakeshore, and San Xavier deposits within the reservation boundaries, as well as those at Ajo, Silver Bell and the Pima districts. Thus the areas near Laramide age intrusive rocks are favorable for discovery of copper deposits.

Volcanic Rocks of Laramide Age.--Volcanic rocks of this unit are lithologically similar to the rocks described as Mesozoic volcanic rocks.

Indeed, if geochronologic studies were made of the supposedly older unit, parts of those sequences probably would be shown to be Laramide in age. Distinctive lithologies in the sequence of Laramide age are thick welded tuff units (dated at 74 and 71 m.y.) which occur in the Roskruge Mountains and are correlated with similar tuff units in the Silver Bell Mountains and the Tucson Mountains, just outside the reservation. The tuffs in the Sil Nakya Hills at the north end of the Comobabi Range are correlated with the Roskruge tuffs.

Tertiary Rock Units

Tertiary Intrusive Rocks.--Tertiary rhyolitic to basaltic dikes, sills, and plugs are included in this unit.

Tertiary Volcanic Rocks of Intermediate Composition.--These rocks include flows, tuffs, breccias, and agglomerates of silicic to intermediate composition which interfinger in places with Tertiary sedimentary rocks. The most extensive outcrops of these volcanics occur in the Ajo Range, Pozo Redondo Mountains, Sauceda Mountains, Sand Tank Mountains, although intermediate volcanics are found, at least in isolated outcrops, in nearly every mountain range within the Papago and San Xavier Reservations.

The Tertiary volcanic rocks are hosts for manganese deposits as well as for vein and replacement deposits of base and precious metals. The porphyry copper deposits, however, are older than the Tertiary volcanics and may be covered by them. The search for underlying mineralized rock requires careful examination of the Tertiary volcanics for favorable structures and leakage of indicator minerals as a result of remobilization of primary ores.

Tertiary Basalts.--Tertiary basalts include basaltic flows, agglomerate, tuffs, and cinders.

Tertiary basalts may cover potentially economic mineral deposits and should be searched for indications of such mineralization.

Tertiary and Quaternary Alluvium

Poorly consolidated sedimentary deposits which fill the intermountain basins and cover the lower slopes of mountains ranges are collectively referred to as alluvium.

These deposits consist primarily of gravel, sand, and silt. They occur in flood plains, terraces, fans, and pediment cappings. Within this unit are also lake deposits, dune sand, landslide debris, clay, gypsum, marl, limestone, and intercalated basalt flows and felsic tuff beds. Alluvium covers more than one-half the combined areas of the Gila Bend, Papago, and San Xavier Indian Reservations and fills the intermountain basins as well as the bottoms of valleys on mountain flanks. Erosional remnants of alluvium locally occur at higher elevations.

Alluvium generally lies unconformably on all the other formations, although in some areas, older alluvium is capped by Tertiary and Quaternary volcanics. The alluvium can be divided into three major parts: (1) older alluvium and lake deposits, (2) pediment gravels, and (3) younger alluvium.

Older alluvium underlies the intermountain valleys and consists of stream sediments, fanglomerates, and lake beds which in some areas have been faulted and slightly folded. Gravel, sand, silt, and clay are the predominant constituents of the older alluvium which ranges in thickness from less than 50 feet to well in excess of 1,000 feet. Locally, it is interbedded with andesitic flows, tuff, and breccia. Older alluvium may conceal ore deposits of all ages.

The pediment gravels form a thin unconformable capping over the erosional surfaces cut on bedrock and on older alluvium. They are generally of the same composition as recent stream gravels and are generally less than 25 feet thick but can reach thicknesses of 100 feet or more. The pediment gravels are of particular economic importance because they may cover potential mineral deposits with a relatively thin overburden which can be removed at comparatively little cost to allow mining. The distinction between the thinner pediment gravels and the alluviated valleys which have much thicker prisms of sediment is not known in all cases.

The younger alluvium consists of recent and near-recent stream deposits in basins, fans, terraces, flood plains, and channel deposits. It is composed of gravel, sand, silt, and clay, and is generally less consolidated than the older alluvium. Included in the younger alluvium are the adobe flats which are broad, nearly flat, central, or lower parts of desert basins formed by the deposition of silt and sandy clay from sheet floods. Younger alluvium may contain saline deposits in the playa areas. The younger alluvium may also conceal older mineral deposits.

Structure

The major structural features within the area of the reservations include frontal or boundary faults which separate the basin and range blocks; various normal, strike-slip, reverse, and thrust faults which are often alined in zones; and various kinds and degrees of folds.

The fault blocks which form the ranges are alined in a general northwest direction and are cut by numerous cross faults. The down faulted blocks between the ranges are largely covered by volcanics and alluvium.

The Texas lineament is a broad and ill-defined zone of faults and other tectonic features which extends west-northwest from southern Texas to the vicinity of Los Angeles, oblique to the general Cordilleran trend. Many of the structural features within the area of this study are local expressions of this broad structural lineament.

These geologic structures need to be studied if we are to understand the mode of formation of their contained mineral deposits. Several small areas within the reservation have been mapped and local structures have been investigated. However, structural details within the entire area are not well understood.

Ore Controls and Ore Indicators

Important ore controls include faults, fissures, joints, bedding slips, contacts, and shattered rock. Where these interact with favorable host rocks and a source for ore-bearing fluids, such as the Laramide intrusives, chances for mineralization are good. Other variables, such as rock alteration, barriers to fluid movement, and ground water, also are important in localizing mineral deposits. Certain generalizations about the more obvious ore controls can be made; however, detailed knowledge of local structure and ore controls is absolutely necessary before any accurate assessment can be made about the size and value of a given mineralized area.

Lithologic composition of host rocks is an important ore control. As a general rule, the more chemically reactive a rock, the more favorable it is as a host. On this basis, limestone, dolomite, diabase, and marls are favored, whereas the quartzites are least favored. Granitic and volcanic rocks are of intermediate favorability.

Hydrothermally altered rock is an excellent indicator of ores. The effects of hydrothermal alteration generally extend far beyond the limits of ore both for porphyry copper deposits and base and precious metal deposits. Some types of hydrothermal alteration are inconspicuous and require careful, detailed examination to recognize. The recognition of one or two indicator minerals, such as biotite, or pyrite, may be sufficient to mark an area as highly favorable for a concealed ore deposit.

Physiography may contain clues to mineralized rocks. Silicified rocks are highly resistant to erosion, and for some types of deposits, silicification is a favorable indicator. In topographic contrast, disseminated sulfides in highly fractured rocks produce subdued topography or basins covered with a deep soil; such areas offer excellent exploration targets. Interpretation by skilled geologists are required to recognize topographic indicators to mineralized ground.

In a reconnaissance, rock color can be an indicator. The oxidation of sulfides induces particular colors of rusty brown and yellow, which can be recognized by trained observers. In some places, such alteration can be recognized on color aerial photographs.

Baboquivari Mountains

The crest of the Baboquivari Mountains forms the southeastern boundary of the Papago Reservation. The west flank of the mountains has been withdrawn from mineral entry by the Papago Tribe since 1955. Prior to that time, numerous small occurrences of base and precious metals, molybdenum, tungsten, and manganese occurrences were sporadically worked, but the area had few major producers.

Mineralization within the range was apparently controlled by a northwest-striking system of faults and wide shear zones that is especially well developed in the north and central portion. A general zoning pattern to the mineralization is apparent. Gold, silver, copper, and molybdenum are concentrated in numerous lensing quartz and quartz-calcite veins in close association with fault zones and swarms of dikes and sills in the central part of the range. Tungsten mineralization occurs mostly to the north and south and is concentrated in widely spaced shears and fractures. Manganese minerals occur throughout most of the range, primarily as a gangue mineral but also as fracture filling in Tertiary rocks. The majority of metalliferous deposits are in faults cutting Mesozoic metamorphic host rocks associated with supposedly Laramide-age swarms of dikes and sills. The most productive deposit, the Allison mine (Figure 5, Table 3) is in a fault zone cutting Tertiary conglomeratic host rocks and associated andesite dikes, and is post-Laramide in age.

Comobabi Mountains

Small deposits of copper, lead, silver, and gold have been mined intermittently in the South Comobabi Mountains and the Ko Vaya Hills. Most of the ore deposits are found in andesite near one or more of these intrusives: alaskite, microbreccia, quartz latite, and felsite. Planar structures, such as faults and contacts, clearly controlled the localization of veins, but controls for the ore shoots within the veins are not as obvious. Wallrock alteration is often intense, and there is sparsely disseminated pyrite and base-metal mineralization near major fault zones.

Intersecting structures seem to have localized some of these deposits. At the Empress-Duchess mine (Figure 5, Table 3), an east-trending quartz latite porphyry dike intersects a north-trending group of veins. Metallization is concentrated near this intersection but decreases north and south away from the dike. Similar concentrations of ore can be seen in other places in this district where various structures intersect. The ore-bearing veins are inferred to be of Laramide age.

Vekol Mountains

Prior to the discovery of the disseminated copper deposit under alluvium at the eastern edge of the Vekol Mountains, base-metal deposits has been mined in three general areas. In the central and northern parts of the range, silver, lead, and zinc deposits were localized along the upper, weathered surface of the Escabrosa Limestone, beneath nearly impermeable brick-red to greenish-gray shale beds. The deposits which include the Vekol, Great Eastern, and Pomona mines (Figure 5, Table 3) were localized near north-trending normal faults. Copper and zinc deposits, especially at the Copperosity mine (Figure 5, Table 3) and Hinshaw claims along the southern flank of the range, were localized in the Copperosity fault zone and related faults; replacement ore bodies in limestone also occurred near the faults. The group of low hills on the east side of the range contained replacement ore bodies in limestone along small displacement faults, especially at the Reward, Christmas Gift, and Republic mines (Figure 5, Table 3). The Vekol disseminated copper deposit is located just south of these low hills.

The Vekol deposit is buried under as much as 250 feet of alluvium and only a few mineralized outcrops are exposed. The deposit covers a roughly circular area of about 4,000-foot diameter in host rocks which include Apache Group to Cretaceous sedimentary rocks. A porphyry stock of probable Laramide age has intruded the entire section and is genetically associated with the mineralized rocks. Most of the mineral deposit defined is confined to the Apache Group within one fault block bounded by two major parallel faults.

Slate Mountains

In the northern part of the Slate Mountains, lead, zinc, silver, and gold mineralization occurs in northeast-striking veins. The ore is localized where branching premineral faults intersect the major vein structures at small angles. Here silicified and brecciated Escabrosa Limestone has been replaced by ore minerals along steeply dipping northeast-trending faults.

The Lakeshore copper mine (Figure 5, Table 3), one of the largest porphyry copper deposits discovered in southern Arizona, is situated on the southwest pediment of the Slate Mountains. The mine has been worked since the late 1800's, but the large porphyry body was not developed until the past decade. Host rocks for the deposit include Precambrian Pinal schist, Troy(?) quartzite, and, at greater depths, andesites and intrusive porphyritic rocks. A quartz monzonite in the area has been dated at 66 m.y., but its relation to the ore deposit is not known. Altered sedimentary rocks of unknown age occur at depths of 1,000 feet or more. The near-surface copper deposits were associated with northeast-striking faults, and part of the oxide copper deposit was found in highly brecciated, magnetite-bearing quartzite. The disseminated sulfide deposit occurs in the andesites and intrusive porphyry, and a tactite body with high-grade copper sulfide ore occurs in the altered sedimentary rocks.

Potential Resources

Copper

The Papago and San Xavier Indian Reservations lie within the Arizona copper province. Although the source of the copper is speculative, enough is known to relate the deposits to structures, certain age intrusives, and favorable rock types. The large porphyry copper deposits are associated with Laramide age granitic intrusives and such intrusives occur extensively on the reservations. The Bisbee deposit, 75 miles to the southeast of these reservations, is associated with a Mesozoic pluton. Plutons of similar age and composition also occur on the Papago Reservation. They offer a potential of secondary importance to the Laramide intrusives. Figure 4 shows the distribution of plutons on the Gila Bend, San Xavier, and Papago Reservations and their ages, where known.

The Laramide and Mesozoic plutons comprise about 30 percent of the Laramide and older bedrock. If equivalent percentages of these Laramide and Mesozoic plutons occur in those parts of the reservations covered by younger volcanic and sedimentary rocks, the mineral potential attributable to these favorable intrusive rocks is high.

The entire southern Arizona region has been extensively explored over the past 55 years, particularly for porphyry copper deposits. It is doubtful that any completely exposed disseminated copper deposits remain undiscovered, but it is highly probable that partly covered or completely buried blind deposits await discovery.

Other Resources

Detailed information on base-metal occurrences and on economic geology of the reservation is sparse, but the metal potential does appear promising. However, before mineral potential can be evaluated, the reservations will have to be mapped with particular attention to geologic indicators of metals such as structure, alteration, and mineralization, and the existing deposits studied and sampled.

In southern Arizona, replacement and vein lead-zinc deposits occur as deposits peripheral to the porphyry coppers and as distinctly younger deposits associated with volcanics and shallow intrusives. The geologic environment on parts of the Papago Reservation is favorable for such deposits, and the literature suggests that they occur.

Silver-gold quartz veins, commonly found near porphyry copper deposits, occur in the Quijotoa and Comobabi Mountains.

Tuffaceous sediments in the Tertiary volcanic rocks may contain manganese deposits. Economic quantities of lightweight aggregate might also be found in the Tertiary volcanics. Clay deposits might be developed in hydrothermally altered volcanic rocks. Saline deposits may contain economically important lithium, sulphates, and potassium and sodium salts. Listed below are other resources of possible importance on the reservations.

Metals	Nonmetals
antimony	asbestos
beryllium	barite
cobalt	diatomite
lithium	feldspar
mercury	fluorspar
molybdenum	limestone
tellurium	marble
thorium & rare-earth metals	stone (construction)
tungsten	volcanic aggregates
uranium	

MINERAL OCCURRENCES

General

Mining districts or areas for the Gila Bend, Papago and San Xavier Reservation are shown on Figure 5 and location and production from mines and prospects of the Papago Reservation are listed in Table 3. Production from the Papago and San Xavier Reservations is listed in Table 4. No mineral occurrences have been reported from the Gila Bend Reservation.

Total production statistics are difficult to compile because early production often was reported only in dollar values, with no accompanying data on tonnages or metal content of the ore. In some instances, only metal content or tonnage is stated. Therefore, totals presented in the tables should be considered as the best approximation possible because of the variable quality of data used.

San Xavier Reservation

The San Xavier mine of American Smelting and Refining Co. (ASARCO) is within the San Xavier Reservation in sections 23 and 24, T. 16 S., R. 12 E. This mine, in the period 1967-1973, produced 545,900 tons of ore that yielded 8,320,665 pounds of copper. The high silica ore was used for smelter flux as well as for a source of copper.

During 1972, construction of an open pit leaching plant complex was started at the San Xavier property. Mine production in this period was 4,000 tons of ore and 14,000 tons of waste per day (Moore, 1972). Leaching was initiated on San Xavier ores (ASARCO, 1973) early in the history of this property. Through 1973, 837,100 tons of leach ore was mined and 4,955,319 pounds of copper recovered.

The Mission (Pima) disseminated copper ore body extends onto the San Xavier Reservation, generally in the area of sec. 30, T. 16 S., R. 13 E. Initial stripping, conducted from the Mission mine, is preparing the way for extracting the reservation part of the ore body.

Both the Mission and San Xavier mines are typical shovel-truck operations.

Slate Mountains

The old Mammon mine in the Slate Mountains, sited on an occurrence of quartz-gold veins in schist, produced an estimated $35,000 in gold in the 1890's (J. J. Strutzell, unpub. data, 1968).

Copper occurs as replacements in limestone at the Slate Mountain mine. No production is known from this property, which is about 1½ miles southeast of the Lakeshore deposit and is now part of the lease on that property.

Lakeshore Mine

History.--The Lakeshore deposit is the most important mineral occurrence in the Slate Mountains. Prior to the discovery and delineation of the primary sulfide mineralization in 1966, work at the Lakeshore mine had attempted to develop the upper, oxidized, and apparently fringe ore of the deposit. The original deposit was located in the 1880's. In 1914, the main shaft, located on the Arizona patented claim, was sunk to the 225-foot level, and considerable development was done. Ultimate depth of the original workings was 285 feet. Most of the workings were near the Lakeshore fault and some penetrated the fault. Ore in these workings consists principally of chrysocolla veinlets, fracture fillings, and disseminations in altered schists, quartzites, granites, and andesites (Romslo, 1950). Several different operators reportedly produced some 280,000 pounds of copper from the Lakeshore mine through 1929 (Romslo, 1950). In 1949, the U. S. Bureau of Mines studied the mine and drilled one diamond and five churn drill holes, extensively sampled the underground workings, and made metallurgical tests. Between 1955-1962, intermittent and unsuccessful attempts were made to open-pit mine and process the oxide copper ores exposed on the Arizona claim.

In 1966, El Paso Natural Gas Co. acquired the Lakeshore property and started exploration that outlined the deposit now being developed.

Geology.--The principal structural feature of the deposit is the post-ore Lakeshore fault, which strikes NNW and dips 50º - 80º W. A quartz monzonite stock forms the footwall of the fault, and quartz monzonite porphyry in the hanging wall has intruded Cretaceous volcanic and sedimentary rocks and diabases. A second fault zone about 2,000 feet west of the Lakeshore fault has dropped the area west of this fault 600 to 1,000 feet relative to the central block.

The ore, which is probably confined to the hanging wall side of the Lakeshore fault, consists of veinlets and disseminations of pyrite-chalcopyrite in the quartz monzonite porphyry and adjacent rocks. Tactite ore is present in calcareous sediments where high grade chalcopyrite-bearing rocks is associated with magnetite and calc-silicate minerals. The upper part of the ore body, particularly in the central block, is oxidized to depths of 800 - 2,000 feet.

Four types of copper ores are represented in the Lakeshore deposit: primary sulfide ore, oxidized-enriched ore, metasomatic replacement ore in limestone, and remnants of enriched chalcocite.

Reserves.--Reserves estimated as of February 1969 are as follows (Harper and Reynolds, 1969):

Primary sulfides	241 million tons	0.70% copper
Oxide ore	207 do	0.71% do
Tactite sulfide	23.6 do	1.69% do

The extent of the mineralized area west of the second fault zone has not been fully evaluated.

Mining.--Twin declines driven on a 15º slope for a distance of 7,200 feet will develop the Lakeshore ore body. These will place the bottom of development under proven reserves. An underground crusher will be constructed at the bottom of the declines, and conveyors will transport the crushed ore to the surface.

Because the oxide ore body partly overlies the main body of disseminated primary sulfides, it must be mined prior to extraction of the sulfide body. This will be accomplished by sinking a 660-foot vertical shaft away from the oxide ore body and developing a panel cave-mining system for this ore. The tactite and possibly part of the enriched chalcocite ores will be mined by room-and-pillar, load-haul-dump (LHD) methods.

Mining of the tactite and oxide ore bodies will proceed simultaneously, and preliminary production is scheduled at 9,000 and 6,000 tons per day of sulfide and oxide ores respectively. When the oxide ore has been removed, the main sulfide body will be developed and mined by block-caving methods.

Sulfide ore will be concentrated by conventional flotation methods and refined hydrometallurgically to yield electrolytic copper. The oxide ore will be vat-leached and precipitated to produce cement copper.

Vekol Mountains

General

Available figures indicate that $50,000 in gold and $1.1 million in silver have been produced in the Vekol Mountains. The principal silver producer was the Vekol Mine (J. J. Strutzell, Jr., unpub. data, 1968). Copper production has been 760,000 pounds about equally divided between the Copperosity and Reward mines. A few tons of lead ore have been mined, also.

Republic Mine

The Republic mine, in sec. 17, T. 10 S., R. 3 E., contains replacement deposits in limestone closely associated with quartz monzonite porphyry dikes, which are numerous in the area. The strongest mineralization is associated with a large fault which abuts Precambrian schist against Pennsylvanian(?) limestone. The fault zone has been intruded by quartz monzonite porphyry. Minerals consist of carbonate veinlets, together with chrysocolla and malachite and associated limonite, jarosite, and gypsum. There are some ore minerals in the quartz monzonite porphyry, but the greatest amount is in the limestone. There has been little production or development.

Copperosity Mine

In the Copperosity area, sec. 14, T, 10 S., R. 2 E., the dominant structural feature is a large fault which brings Precambrian schist in contact with a series of Paleozoic limestones, shales, and conglomerates. Quartz porphyry outcrops have been noted in the area. Mineral occurrences are replacements in Devonian limestone, which is fractured by a series of parallel faults. Copper carbonates, silicates, and oxides in a limonite, gypsum, and calcite gangue comprise the mineral suite.

A 300-foot shaft and two levels constitute the main development. There are several hundred feet of lateral workings. Mining produced 360,000 pounds of copper in the early part of the century.

Vekol (Reward) Mine

History.--History in this area refers to the Reward mine or group. This included copper occurrences in the Reward incline and zinc occurrences in the Phonatory shaft, which is about ¾ mile southwest of the Reward. Recent literature, discussing principally the disseminated copper orebody about 1 mile southwest of the Reward, terms the area the Vekol property.

The Reward deposit was first discovered in the 1880's. Early activity included sinking of the Reward incline (200 feet in depth) and Phonatory shaft (325 feet in depth). The Reward shaft reportedly encountered 12 percent copper oxide in this period. Activity ceased and was not renewed until 1902 when several companies successively operated the property for a few years. The Reward incline was continued down to the sixth level, and a 225-foot wide was sunk from this level. The George shaft, about 1,000 feet south of the Reward, was sunk to 400 feet in depth. The property became dormant in the early 1910's. It was purchased at tax sale in 1924. In 1942, with the help of a Reconstruction Finance Corp. loan, the

Phonatory shaft was retimbered and 130 feet of lateral was driven on the 283-foot level.

Beginning in late 1942, the U. S. Bureau of Mines conducted diamond drilling, sampling, and a metallurgical study of the "zinc" part of the property (Denton, 1946) and completed fourteen diamond drill holes, aggregating about 6,000 feet. They extensively sampled the Phonatory shaft and level, the Bat tunnel, and various smaller workings. A bulk sample from the Phonatory shaft was collected for metallurgical testing.

In 1965 an industry partnership leased the Vekol (Reward) area and began an extensive drilling program that delineated a large disseminated, porphyry copper deposit adjacent to and south of the Phonatory shaft area. They excavated an exploration shaft 440 feet deep, completed 1,700 feet of lateral workings to bulk sample the orebody for confirmation of ore reserve and grade estimates, and for metallurgical testing. Since on-site evaluation ended in 1971, the Vekol deposit has been the subject of continuing feasibility studies. The decision to develop the Vekol deposit has been delayed by the possible lack of a smelter market for copper concentrates owing to controversies over sulfur-dioxide emission standards, environmental approvals, and presently the falling price of copper.

Geology.--The Reward incline and George shaft are in a block between the Reward and Bat Tunnel faults (secs. 23-24, T. 9 S., R. 3 E.). Ore mined in these workings was of the copper replacement type in Cambrian limestones. Southwest of this block, between the Bat Tunnel and Phonatory faults (secs. 3-4, T. 10 S., R. 3 E.), the Phonatory shaft intersected zinc replacement deposits in favorable horizons in Carboniferous limestones. The U. S. Bureau of Mines diamond drilling program between the Phonatory and Bat Tunnel faults indicated additional zinc replacement orebodies. Ore-bearing rock includes marmatite with minor sphalerite, magnetite, pyrrhotite, pyrite, and chalcopyrite in a lime-silicate gangue. Occurrences are erratic both as to size and grade.

The Vekol disseminated copper deposit is south of the Phonatory shaft in secs. 3-4, T. 10 S., R. 3 E., and is on the northeast edge of a granitic to monzonitic porphyry intrusive. Ore minerals are in Precambrian to Devonian quartzites, limestones, shales, sandstones, diabase sills, and to a minor extent in the Laramide porphyry intrusive. Common minerals are pyrite, chalcopyrite, and molybdenite, and occur as disseminations, fracture fillings in breccias, and in quartz veinlets. The upper 100 to 150 feet of the deposit is oxidized. Principal minerals in the zone are native copper and copper oxides, silicates, and carbonates. A supergene zone contains bornite and chalcocite. Limestones have been altered to skarn. Calcite veining, silicification, and argillization have been noted.

Production and Reserves.--The Reward has produced 400,000 - 450,000 pounds of copper (Denton, 1946). Although the U. S. Bureau of Mines drilling program confirmed considerable zinc mineralization, the Bureau made no reserve estimates. J. J. Strutzell, Jr. (unpublished data, 1968), states that zinc reserves proved by this drilling are 66,000 tons of 10 percent zinc.

Stripping for the extraction of ore from the disseminated copper deposit will open part of the Phonatory zinc block. A possibility then would exist for mining and exploration for zinc via load-haul-dump underground methods starting from the pit faces. The technical and economic feasibility of such a project remains to be proven, however.

The Vekol copper deposit has estimated reserves of 103 million tons averaging 0.56 percent copper (Moore, 1971). Molybdenum may be economically recoverable, but no reserve figures are available.

Mining Method.--The Vekol disseminated copper deposit is amenable to mining by conventional shovel-truck operations. Preliminary planning estimates suggest mining 20,000 tons of ore per day. Stripping ratios are estimated at about 2:1.

Silver Reef Mountains

Manganese occurs in both the north and south ends of the Silver Reef Mountains in fracture and shear zones in granites and in volcanic breccias. Principal minerals in the shallow depths prospected are psilomelane and pyrolusite, generally with calcite gangue. Approximately 360 long tons of manganese ore have been produced, mostly via open cuts and hand sorting. In the central Silver Reef Mountains, ore valued at approximately $62,000, principally silver with minor gold, has been shipped. Ore occurs in shear zones and near a rhyolite contact with granite.

The Old Standard Copper mine has had only small gold production from veins. However, estimates in the middle 1960's of reserves made by the U. S. Bureau of Mines and Powdered Metals Corp. indicate between 32,000 and 2 million tons of greater than 2 percent copper on the property. Geologic information on the copper occurrence is sparse.

North Slate Mountains and South Tat Momoli Mountains

The North Slate Mountains and South Tat Momoli Mountains are discussed as a unit because of the similarity of mineralization. Most mineral occurrences are fissured fillings or replacements along strong shear zones in limestone and are normally adjacent to or near diorite-rhyolite porphyry dikes. Quartz and calcite are the principal gangue minerals. Ore deposits are small and erratically distributed.

Silver, with some gold, has been the principal mineral commodity. The Camino (Monarch) mine yielded some lead as cerussite. Silver and gold production is estimated at about $85,000, mostly between 1880 - 1930.

Other mineral occurrences are copper (principally as chrysocolla), vanadium, molybdenum, pyrolusite, tungsten, and gypsum.

Copperosity Hills

In the Papago mine area of the Copperosity Hills, sec. 8 and 17, T. 10 S., R. 2 E., gold and silver minerals are disseminated in a wide band of brecciated, silicified granite. This breccia zone has been prospected over a strike length of about 1 mile.

J. J. Strutzell, Jr. (unpublished data, 1968) reports assay and monetary values for the breccia deposit. The outcrop in the central area (approximately 650 feet long) of the breccia zone contains values of about $14.50 - $15.00 per ton at present-day metal prices (assuming $170 per ounce for gold and $4.00 per ounce for silver). An area extending 1,200 feet west from the central area would bring $9.50 - $10.00 per ton and a similar area running 1,000 feet east $6.86 - $20.67 per ton. Some other more limited areas, for example, one 40 feet wide, would bring between $29 - $36 per ton.

Development has been limited to surface trenching of the outcrop and one 40-foot shaft. No production has been reported for the Papago mine or Copperosity Hills.

Quiatoa District

General

Principal production in the Quiatoa District has come from gold-silver bearing quartz-calcite mineralization in fissure and breccia zones cutting volcanic and sedimentary rocks, along faults and fractures in intrusives, and volcanic-sedimentary contacts.

Copper oxides (chrysocolla, cuprite) occur in strong shear zones and shattered monzonite, rhyolite, and rhyolite porphyry. Strong silicification and kaolinization has been noted in some areas. The copper minerals occur over a wide area in the Brownell Mountains (generally in T. 14 S., R. 2 E.). The U. S. Bureau of Mines estimated in 1942 that a possible 85,000 tons of ore containing 4 ounces silver per ton and 3-4 percent copper could be extracted at the Brownell mine.

Copper minerals are widespread in the Copper V. O. (By Chance), Mondtell, and St. Patrick groups.

Bands of magnetite with minor hematite and ilmenite in epidotized granite constitute a distinct type of mineralization. Outcrops can be traced for about 3 miles. Widths of the magnetite bands range from 15 to 40 feet.

Another mineral occurrence is the Quijotoa Iron prospects (T. 15 S., R. 2 E.). Assays by the U. S. Bureau of Mines in selected areas over widths of 15 - 40 feet averaged 49.3 percent iron and 19.7 percent silica (Harrer, 1964).

Production

The Arizona Bureau of Mines (Keith, 1974) reported that 15,600 tons of ore, yielding 245,000 ounces of silver, 11,600 ounces of gold, 122,000 pounds of copper, and 58,000 pounds of lead, has been produced in the district.

Cababi District

General

The principal mining in the Cababi District in the Comobabi mountains has been in oxidized, erratically distributed, gold-silver pockets in quartz veins along faults and shear zones. The primary zone also contains minor lead, zinc, tungsten, molybdenum, and vanadium. Alteration is often widespread and some metallic disseminations have been noted.

The Padres Hester claims (sec. 1, T. 16 S., R. 3 E.; sec. 6, T. 16 S., R. 4 E.) have been exposed in the past. J. J. Strutzell, Jr., (unpub. data, 1968) states that the mineral occurrence is in quartz monzonite porphyry which has been extensively fractured. Copper minerals, consisting of malachite, azurite, chrysocolla, and chalcocite, are widespread but sparse. The Stebbins mineral survey, Inc. (unpublished data, 1961) reported that the Anaconda Co. drilled a few holes in the 1950's which encountered disseminated copper minerals in rock that assayed less than 0.01 percent copper.

Production

The Arizona Bureau of Mines (Keith, 1974) reports a production of 6,500 tons of ore, which yielded 102,000 ounces of silver, 3,450 ounces of gold, 364,000 pounds of lead, 184,000 pounds of copper, and minor zinc and tungsten. Most of the commercial mineral production thus far appears to have been feasible owing to the enrichment of silver and gold in the oxidized zone.

Baboquivari District

General

Tungsten minerals in the Baboquivari District occur along shear zones and fractures in metamorphosed sediments that have been intruded by igneous dikes. Major faults cut the mineralized areas. Minerals associated with tungsten are epidote, garnet, fluorite, and some copper oxides.

Gold and silver are in lensing quartz and calcite veins in or near fault zones in metamorphosed sedimentary rocks. Accompanying minerals, to date noncommercial, are chalcopyrite, galena, and sphalerite.

Production

Only part of the Baboquivari District is within the Papago Reservation, and the following figures apply only to the reservation. About 1,500 tons of tungsten ore (Dale and others, 1960) have been produced from small mines and prospects. Only incomplete assay data are available on this production. An estimated 28,300 pounds of tungsten concentrate (Dale, 1960) (none of it derived from tonnages cited above), has been produced, mostly from the Big Banana and San Juan mines. Less than 200 tons of copper-silver ore and about 180 long tons of manganese ore have been mined from small properties (Keith, 1974).

The Big Banana mine, sec. 32, T. 17 S., R. 7 E., produced some ore development in 1972 (Moore, 1972) but no consistent production is known from this property or any other within the district.

Coyote District

General

In the Coyote District, copper oxides and carbonates occur as disseminations and fracture fillings in highly altered volcanic rock. Sulfide minerals, tetrahedrite and cinnabar, are in a gangue of calcite and epidote. Manganese oxides occur as replacement minerals and fillings in fracture zones in rhyolite and rhyolite porphyry. An occurrence of tungsten is in fractured quartzite.

Primary minerals at the Roadside mine (sec. 11, T. 16 S., R. 8 E.) consist of pyrite and chalcopyrite in a large faulted zone in andesite. The outcrop area around this deposit contains widespread copper carbonates. The main shaft is 800 feet deep and has extensive lateral workings. A quartz monzonite intrusive is exposed on the 400-foot level of this shaft. At least four diamond drill holes and one churn drill hole have been drilled in the area, but no results are available.

Production

About 150 long tons of manganese ore, yielding 38,000 pounds of manganese has been produced (Farnham and Stewart, 1968). Five hundred tons of copper-silver ore, yielding 38,000 pounds of copper and 5,700 ounces of silver (J. J. Strutzell, Jr., unpub. data, 1968), also was mined.

Cimarron Mountains District

General

The principal production in the Cimarron Mountains District has come from manganese oxides in fault zones and as replacements in limestones, quartz diorite, and andesite porphyry. Silver and gold have been produced from faults and fractures. Values were generally erratic and probably economic only because of oxidation and leaching of base metal sulfides near the surface. Disseminated copper minerals in latite-quartz monzonite porphyry have been reported.

The Greenback Camp mine (sec. 28-32, T. 10 S., R. 2 E.) contains chrysocolla and copper carbonates widely disseminated throughout shattered Precambrian schists and intrusives of latite-quartz monzonite porphyry. Alteration includes sericitization and kaolinization.

Production

The Arizona Bureau of Mines (Keith, 1974) estimates production as 9,500 long tons of manganese ore yielding 2.7 million pounds of manganese. About 120 tons of precious-base metal ore produced 22,000 pounds of copper, 400 ounces silver, and 80 ounces gold.

Gunsight District

General

In the Gunsight District, gold and silver associated with base metals occur in narrow quartz, calcite, and barite veins in a granitic intrusive. Oxidation and leaching of base metals probably enriched the gold-silver ores that were mined.

Production

Estimated production is 16,000 tons of ore, which yielded 100,600 ounces of silver, 400 ounces gold, and 1.56 million pounds of lead (Keith, 1974). A small quantity of scheelite has been shipped.

Waterman District

General

Within the Waterman District, silver-bearing cerussite associated with minor malachite and azurite occurs along contacts of granite porphyry with limestone and quartzite, and in fissures in the intrusive and sedimentary rocks.

Production

About 8,600 tons of ore (Keith, 1974) principally from the Indiana mine (Indiana-Arizona), has been extracted. This ore yielded 1.2 million pounds each of lead and zinc, 344,000 pounds of copper, and 65,000 ounces of silver.

EXPLORATION TARGETS

Several specific properties or areas, which now belong wholly or in part to the Papago Indian Tribe, seem especially worthy of further evaluation. Information concerning these has been excerpted from work by J. J. Strutzell, Jr.,(unpub. data, 1968).

Gold occurs in a 3-foot vein on a contact between granite and rhyolite at the Old Jonah mine (SE¼, sec. 23, T. 8 S., R. 5 E.). The vein has been traced for about 2,000 feet along its outcrop. Values reportedly range from about $30 to $900 per ton at current gold prices ($170 per ounce).

The old Mammon mine group (sec. 23-24, T. 10 S., R. 4 E.) has at least two gold-quartz veins, both averaging 20 inches in width. Assuming a 5-foot mining width, the value of ore potentially minable from these veins is $50 - $60 per ton.

Disseminated gold and silver mineralization occurs in a 40- to 150-foot-wide breccia zone at the Papago mine (sec. 8, T. 10 S., R. 2 E.) The breccia zone has been traced for more than 1 mile. Values over a 48-foot width range from $10 - $15 per ton, with smaller, higher grade areas interspersed.

At the Cara Vaca claims (sec. 9, T. 14 S., R. 1 E.) gold-mineralized rock assayed 0.16 - 0.38 ounces per ton over a width of 3 feet.

The Black Prince claims (T. 14 S., R. 1 E.) contain silver, lead, and copper minerals in limestone. Scattered assays indicate ore with a gross value of $60 - $70 per ton over a reasonable mining width.

The Republic mine (sec. 17, T. 10 S., R. 3 E. -- 3 miles south of the Vekol deposit) and the Brownell, Copper V. O., Mondtel, and St. Patrick mines (Ts. 13, 14 S., R. 2 E. in the Brownell Mountains) contain disseminated copper oxide minerals in a geologic environment quite similar to the Lakeshore and Vekol deposits.

MINERAL LEASING

General

Permits to prospect definite areas of Indian lands are available. (25 CFR 171.27a). The duration of a prospecting program must be stated in the application, and no ores may be removed other than for assaying or testing purposes. Unless negotiated in advance, prospecting permits do not convey preference rights to leases on any discoveries that might be made.

A "walk-on" permit can be obtained for the entire area of the Gila Bend, Papago, and San Xavier Reservations, although the prospector may be asked to avoid certain areas. This permit will allow geophysical, geochemical and geologic mapping, but presumably not drilling, trenching, or exploratory drifting, crosscutting, or shaft sinking. A $10 fee with a $2,000 surety bond is initially posted, and is good for four months. After four months, the fee is $500 per month (A. F. Smith, oral commun., 1975).

Figure 6 diagrams the procedure for obtaining a mineral lease on the reservations. Notice of intent to receive bids on tracts must be posted by the Reservation Superintendent 30 days prior to actual processing of bids, unless the Commissioner of Indian Affairs has granted the Indians the right to shorten this period. A lease application must contain a bonus bid unless the lease is negotiated. A payment of 25 percent of the bonus bid must be filed with the initial application, and within 30 days of a successful bid, the potential leasee must remit the balance. A single lease may not be for more than 2,560 acres. Payments for lease bonds are as follows:

Less than 80 acres	$1,000
Above 80, less than 120 acres	1,500
Above 120, less than 160 acres	2,000
For each additional 40 acres, or fraction thereof	500

Oil and gas leases are subject to an annual rent of $1.25 per acre. Leases on the "hard rock" minerals require an annual development expense of not less than $10 per acre and yearly rentals of not less than $1 per acre.

Royalties on non-negotiated leases are roughly 10 percent of the net smelter returns for the metallic minerals, and not less than $0.10 per ton for coal.

A part of the San Xavier Reservation has been allocated to individual Indian owners. Leasing procedures and leases are generally the same as heretofore described, except the manner in which rental and royalty payments are made.

Present Status

Five "soft" prospecting permits now (1975) are in effect on the reservation. Holders of the permits may engage in such activities as geologic mapping and geochemical and airborne geophysical investigations. The permits encompass the entire reservation; however, permit holders are asked to avoid certain areas, as for example the present mineral and business leases held in the Lakeshore, Vekol, and San Xavier area, and areas in which the individual Papago District councils do not want mineral exploration activity. The soft or prospecting permit does not require that investigative reports be supplied to the Papago District council; thus, results of any exploration activity currently being conducted are unavailable.

With exception of the Lakeshore project and the San Xavier pit, where additional mineral information is being collected in the process of development, no "hard" or specific area exploration leases were in effect in mid-1975 on the reservation.

MINING AND EXTRACTION

The mining of copper is, and seems likely to continue to be, the principal mineral activity on the Papago and San Xavier Reservations.

Most copper mining in Arizona is by shovel-truck method. The disseminated ore is drilled, blasted, and loaded by electrically powered shovels (generally 10- to 15-cubic-yard capacity) Some open pit operations load by shovel into railroad cars for haulage.

Large-scale underground mining operations, as at San Manuel, practice block caving. This technique involves undermining an ore body until it collapses or caves, after which the broken rock can be removed to the surface. Much of the Lakeshore deposit will be mined in this manner.

Underground mining methods for small tonnage may involve many different procedures. According to recent practice, the ore is drilled and blasted, then loaded and hauled by a rubber-tired vehicle to some control point. Although this method has been used mostly in replacement or bedded deposits (ore-bodies with large lateral or horizontal dimensions), it can be and is being used in vein-type mining.

Table 5 lists costs for mine-plant facilities similar to those that could be constructed on the reservations if sufficient new ore tonnages were developed.

TABLE 5
Costs of Operation of Some Copper, Silver and Gold Mine-mill Complexes
(Stated as capital investment/ton per day of design capacity, 1971-1974 prices)
(-, not applicable)

	mined	(tons/day)	Surface	Underground
Arizona:				
Lakeshore	Copper	14,500	-	9,000
Metcalf	do	30,000	6,000	-
Pinto Valley	do	40,000	2,500	-
Sacaton	do	9,000	4,000	-
San Xavier, North	do (Vat leaching)	4,000	3,300	-
Mexico:				
Las Torres	Silver	2,000	-	5,500
Nevada:				
Apco Oil	Gold	250	-	5,200

The source of data in Table 5 is the Engineering and Mining Journal, 1971-1975, Annual survey of plant expansion for the years 1971 through 1975.

Some representative costs of mining are as follows (Wimpfen, 1973):

	Direct cost/ton
Underground	
Shrinkage stoping	$10.60
Cut-and-fill stoping	13.05
Surface (shovel-truck)	0.38
Milling (standard copper flotation)	1.37

Most copper mined in Arizona is recovered by the milling method of flotation. The resulting concentrate is then processed pyrometallurgically to form a blister copper and electrolytically refined to metallic copper.

A considerable quantity of copper is being recovered by leaching. This procedure is used principally on ores too poor in copper to be concentrated economically by conventional milling methods. An aqueous reagent dissolves copper in the rock, and the copper is precipitated later from the aqueous solution to form cement copper.

TRANSPORTATION

There are no railroads on the Papago Indian Reservation. The closest access to rail haulage is on the eastern edge and south of the San Xavier Reservation where the Tucson-Nogales branch of the Southern Pacific Railroad provides haulage for mines of the Pima District. Casa Grande, 25-30 miles north of the Lakeshore-Vekol areas, is serviced by the Southern Pacific. The Tucson, Cornelia, and Gila Bend Railroad is a truck line servicing Ajo, west of the Papago Reservation.

Arizona Highway 86 transects the Papago Reservation, and is a primary, all-weather road. Another all-weather road, extends from Quijotoa to Casa Grande. There are a few light-duty, all-weather roads on the Papago Reservation. Interstate Highway 19 runs through the eastern quarter of the San Xavier Reservation, and provides excellent access to the San Xavier and Mission mine areas.

MARKETS

Copper prices rose steadily beginning in the mid-1960's and reached a record level of 86.6 cents/lb for domestic production in July-August 1974. A recent lessening in growth rate of the world economy and market saturation by the large supply of available copper (resulting from earlier record price levels) has now caused a downturn in price quotations. Several large domestic producers are trimming production by an average of 10 percent.

One important factor in the economic viability of a potential mining development is the availability of processing facilities to which the products of mining may be sold. Assuming a stabilizing or improving copper price situation, the potential for continued copper mining development on the Papago and San Xavier Reservations is quite favorable. A large part of the United States copper smelting and refining capacity is in Arizona, and includes the following:

Location	Operating Company	Smelter	Refinery
Miami	Inspiration Consolidated Copper Co.	x	x
Hayden	Kennecott Copper Co.	x	x
Hayden	ASARCO	x	
Ajo	Phelps Dodge	x	
Douglas	Phelps Dodge	x	
Morenci	Phelps Dodge	x	
San Manuel	Magma Copper	x	x

RECOMMENDATIONS FOR FURTHER WORK

Because of the incomplete geologic knowledge of the Gila Bend, San Xavier, and Papago Indian Reservations, any reasonably comprehensive study of the potential mineral resources requires: (1) geologic mapping covering the entire reservations, (2) mapping directed toward the distribution of altered and mineralized rocks to show areas of high potential for mineral deposits, and (3) mapping directed toward the distribution of areas with high potential for industrial minerals, salines, and lightweight aggregates. The geologic evaluation should be supplemented by geochemical surveys and by detailed aeromagnetic and gravity surveys.

Data derived from aeromagnetic surveys can be important to mineral evaluation of alluvium-covered areas. Specifically, magnetic data can aid in (1) inferring the geology underlying sedimentary cover, (2) locating and determining the extent of concealed or partly concealed intrusive bodies, (3) defining target areas where alteration has reduced the previous magnetization of rocks, (4) identifying mineralized bodies that contain anomalous concentrations of magnetic minerals, and (5) determining the thickness of sediments overlying volcanic rock or magnetic basement. Possibly in small selected areas other geophysical techniques such as induced polarization (IP), electro-magnetic (EM), and audio-magnetic telluric (AMT) would be used to further delineate potentially mineralized targets.

Data derived from regional gravity surveys are useful in interpreting the thickness and extent of sediments in deep basins and can usually indicate the extent of pediments. Identification of the outer edges of suballuvial benches is extremely important, as these edges are commonly marked by range-front faults. Beyond these faults, the valley fill is generally too thick for recovering metallic minerals. Large saline bodies within alluvial basins can be identified by gravity surveys. Gravity data are also used to infer the topography of basement rock underlying a volcanic cover and are used in some special studies of bedrock geology.

The geologic signposts for metal and nonmetal deposits are apt to be subtle and small. Careful, detailed geologic mapping of rocks, structures, alteration, and metallization by competent economic geologists is the best means of recognition of potential mineral deposits. This work should be augmented by detailed sampling and analyses of all known mineral occurrences.

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APPENDIX

1. Index to geologic maps (Figure 7).

2. Index to aeromagnetic and gravity anomaly maps (Figure 8).

3. Index to U.S. Geological Survey topographic maps (Figure 9).

REFERENCES FOR FIGURE 7

(Numbers refer to outlines on index to geologic maps) (Figure 7).

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TABLE 3.--Location of mineral occurrences and production from mines and prospects on the Papago Reservation (T-ton; LT - long ton; cen. - center)

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District or area mine/claim	Number figure 5	Location Sec	T	R	Production	Remarks and data source
Slate Mountains						
Orizabab mine........	1	NE¼ 26	9 S.	4 E.	$10,000 in Ag, Au (1880-1925)	USBM files.
Jackrabbit mine......	2	NE¼ 31	9 S.	5 E.	$20,000 in Ag (1892-1932)	(Strutzell, 1968)
Desert Queen mine....	3	W cen 31	9 S.	5 E.	$10,000 in Ag, Au (1905-07)	USBM files.
Turning Point........	4	SW¼ 36	9 S.	4 E.	$10,000 in Au, Ag (1898-1932)	Do.
Red Chief............	5	NW¼ 6	10 S.	5 E.	-	Indicated on Arizona county highway maps.
Camino, Monarch Orphan(?)..........	6	1, 11	10 S.	4 E.	2 carloads 10 percent Pb ore.	(Strutzell, 1968)
Boomerang............	7	NE¼ 23	10 S.	4 E.		Indicated on Arizona county highway maps.
Old Mammon...........	8	23, 24	10 S.	4 E.	$35,000 in Au (1892-1897)	(Strutzell, 1968)
Lakeshore mine.......	9	25, 36	10 S.	4 E.	280,000 lbs. Cu (1917-1929)	471.6 million tons of 0.754 percent Cu in reserves. USBM files (Romslo, 1950)
Slate Mountain mine.. (House, Confidence).	10	SW¼ 31	10 S.	5 E.	3 carloads of 5 percent Cu. 38 T (4,180 lbs. Cu).	(Strutzell, 1968).

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TABLE 3.--Location of mineral occurrences and production from mines and prospects on the Papago Reservation (T-ton; LT - long ton; cen. - center) -- Continued

District or area mine/claim	Number figure 5	Location Sec	T	R	Production	Remarks and data source
Vekol Mountains						
Christmas Gift mine....1		NW¼ 34	9 S.	3 E.	$50,000 in Au (1883-1885)	USBM files.
Vekol (Reward) 2		33, 34 3, 4	9 S. 10 S.	3 E. 3 E.	400,000 lbs. Cu.	Est. 66,000 T Zn reserves 109 million T Cu @ 0.54 percent.
Vekol mine............	3	34 4	9 S. 10 S.	2 E. 2 E.	$1,000,000 in Ag	USBM files.
Great Eastern mine....	4	SW¼ 35	9 S.	2 E.	$100,000 in Ag	Do.
Pomona................	5	N cen 2	10 S.	2 E.	Small	W, Pb, Vanadinite showings noted USBM.
Copperosity mine......	6	E cen 14	10 S.	2 E.	360,000 lbs. Cu.	USBM files.
Silver Lake...........	7	E cen 14	10 S.	2 E.	Small	Pb, Zn occurrence USBM files.
Republic mine..........8		17	10 S.	3 E.	Do.	Some evidence of Cu disseminations (Strutzell, 1968)
Copperosity Hills:						
Papago mine...........	1	SW¼ 8	10 S.	2 E.	No record.	Do.
Silver Reef Mountains:						
Black Chief mine.....	1	13	8 S.	5 E.	6 T Mn ore	(Farnham and Stewart, 1968)
Magnesium Queen.....	2	E cen 13	8 S.	5 E.	-	Indicated on Arizona highway maps.
Black Jewel..........	3	SE¼ 13	8 S.	5 E.	100 LT ore (64,960 lbs. Mn).	(Farnham, 1958)
Black Prince No. 1....	4	SE¼ 13	8 S.	5 E.	250 LT Mn ore (145,600 lbs. Mn).	Do.

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TABLE 3.--Location of mineral occurrences and production from mines and prospects on the Papago Reservation (T-ton; LT - long ton; cen. - center) -- Continued

District or area mine/claim	Number figure 5	Location Sec	T	R	Production	Remarks and data source
Silver Reef Mountains--Continued:						
Old Jonah (Gold Nuggett)............	5	W cen 24	8 S.	5 E.	7 railroad cars brought between $225-$1,800/car.	(Strutzell, 1968)
Silver Reef mine.....	6	SE¼ 23	8 S.	5 E.	$60,000 (1905-34) Ag. 16 cars dump, 1948	Do.
Old Standard copper..	7	W½ 24, 25	8 S.	5 E.		Reserves inferred: 32,000 T @ +2 Cu. Powdered Metals Corp. 2.12 MM @ 2.5 percent Cu. (Strutzell, 1968)
Santa Rosa Queen....	8	W cen 36	8 S.	5 E.	None.	Manganese prospect (Farnham and Stewart, 1958)
Quiatoa District:						
Brownell mine......	1	Cen 35	13 S	2 E	1,056 T (60,217 lbs. Cu 4,600 oz. Ag).	Reserves: Possible 85,000 T ore assaying 3-4 percent Cu, 4-9 oz. Ag. USBM files.
Copper, V. O. (By Chance)........	2	NE¼ 12	14 S	2 E	1,900 T. (38,000 lbs. Cu 9,500 oz. Ag) 10,000 T S: flux.	(Keith, 1974) (Strutzell, 1968)

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TABLE 3.--Location of mineral occurrences and production from mines and prospects on the Papago Reservation (T-ton; LT - long ton; cen. - center) -- Continued

District or area mine/claim	Number figure 5	Location				Production	Remarks and data source
			Sec	T	R		
Quiatoa District: Continued							
Mondtel.............	3		15	14 S.	2 E.	No recorded production	(Strutzell, 1968) Several thousand T of probable Cu ore averaging 2-3 percent Cu.
Man's Dream.........	4	SW¼	9	14 S	2 E.	250 T (7,000 lbs. Cu).	(Keith, 1974, p. 140.)
Black Prince........	5	Center	13	14 S	1 E	50 T (450 oz. Ag, 11,000 lbs. Pb, 1,000 lbs. Cu.)	Do.
Cara Vaca...........	6	W cen	29	14 S	2 E	80 T ore (40 oz. Au, 40 oz. Ag.)	Production (Keith, 1974) 3' widths of vein assayed 0.16-0.38 oz. Au. USBM files.
Copper Squaw.......	7	Center	31	14 S.	2 E.	80 T ore (8,000 lbs. Cu, 80 oz. Ag.)	(1147-A) notes uranium present (Keith, 1974, p. 140)
St. Patrick........	8	E cen	33	14 S.	2 E.	730 T ore (29,200 lbs. Cu, 730 oz. Ag)	(Keith, 1974, p. 141)
White Prince........	9		17	15 S.	2 E.	None	Barite, minor fluorspar some widths of 12' have 60 percent $BaSO_4$. (Strutzell, 1968).

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TABLE 3.--Location of mineral occurrences and production from mines and prospects on the Papago Reservation (T-ton; LT - long ton; cen. - center) -- Continued

District or area mine/claim	Number figure 5	Location Sec	T	R	Production	Remarks and data source
Quiatoa District--Continued:						
Helderado Gold and Silver (Silver Queen)........10		10	15 S.	2 E.	None recorded	(Strutzell, 1968)
Ballas mine............11		NE¼ 14	15 S.	2 E.	100 T ore (20,000 oz. Ag, 17,000 lbs. Pb, 2,000 lbs. Cu)	(Keith, 1974, p. 139).
Mocking Bird group.....12		W cen 13	15 S.	2 E.	450 T ore (125 oz. Au, 450 oz. Ag)	(Keith, 1974, p. 140).
Morgan mine group......13		N cen 23	15 S.	2 E.	600 T ore (420 oz. Au, 420 oz. Ag)	(Keith, 1974, p. 141)
Horseshoe Basin Placera (Quijotoa Placers)........14		13	15 S.	2 E.	6,000 oz. Au, 1,000 oz. Ag	(Keith, 1974, p. 140).
Quijotoa Iron..........15			15 S.	2 E.	None	Extensive magnetite, hematite banding in granite (Harrer, 1964).
Peer and Peerless group (Quijotoa mine)......16		SW¼ 35	15 S.	2 E.	50 T ore.	(Keith, 1974, p. 141).
Weldon mine............17		E cen 3	16 S.	2 E.	2,500 T ore (2,500 oz. Au, 2,500 oz Ag)	Do.

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TABLE 3.--Location of mineral occurrences and production from mines and prospects on the Papago Reservation (T-ton; LT - long ton; cen. - center) -- Continued

District or area mine/claim	Number figure 5	Location Sec	T	R	Production	Remarks and data source
Quiatoa District--Continued:						
Ben Lomand mines	18	E cen 11	16 S.	2 E.	300 T ore (3,000 oz. Au, 2,610 oz. Ag)	(Keith, 1974, p. 139)
Cababi District:						
Coyote Hole	1	NW¼ 34	15 S.	4 E.	1,200 lbs. W. concentrate.	USBM files.
Silver Dollar mine	2	Center 34	15 S.	4 E.	Few tons tungsten ore	(Wilson, 1939)
Silver Queen	3	NE¼ 4	16 S.	4 E.	125 T ore (3,500 oz. Ag, 4,000 lbs. Cu, 12 oz. Au)	(Keith, 1974, p. 112)
Old Timer mine	4	SW¼ 3	16 S.	4 E.	Few T high grade Ag	Do.
Picacho mine	5	NW¼ 9	16 S.	4 E.	500 T ore (125,000 oz. Ag, 151 oz. Au)	Do.
Cunquian (Cooncan)	6	NE 18	16 S.	4 E.	600 T. ore <18,000 lbs. Cu, 15,600 lbs. Pb, 300 oz. Ag.	Do., p. 111
Desert Lode mine	7	Center 17	16 S.	4 E.	Few T.	Do.
Padres Hester	8	SW¼ 6	16 S.	4 E.	9 T ore	Low grade disseminated Cu mineralization. USBM files.
Mildren mine	9	E cen 16	16 S.	4 E.	460 T ore (5,520 oz. Ag. 64,400 lbs. Pb, 14,720 lbs. Cu, 92 oz. Au.)	(Keith, p. 112)

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TABLE 3.--Location of mineral occurrences and production from mines and prospects on the Papago Reservation (T-ton; LT - long ton; cen. - center) -- Continued

District or area mine/claim	Number figure 5	Location Sec	T	R	Production	Remarks and data source
Cababi District: Continued:						
Sun Gold mine........	10	S cen 15	16 S.	4 E.	Few T Au, Ag, Pb, Zn, Cu ore.	(Keith, 1974, p. 113).
Little Mary mine....	11	SW¼ 23 NW¼ 26			800 T ore (86,400 lbs. Pb, 12,000 oz. Ag, 64,000 lbs. Cu, 160 oz. Au.)	Do., p. 111
Comobabi-Crusader.... mines	12	N cen 25	16 S.	4 E.	100 T ore (2,400 oz. Ag, 12,000 lb. Cu, 20 oz. Au.)	Do.
Green mine............	13	NE¼ 31	16 S.	5 E.	Few T Ag-Cu ore.	Do.
Emperior and Duchess mines............	14	E cen 29	16 S.	5 E	140 T ore (14,000 lbs. Cu, 1,260 oz. Ag.)	Do.
Midnite mine.........	15	5	17 S.	5 E.	No information	Indicated on Arizona County highway maps.
High card............	16	SW¼ 4	17 S.	5 E.	Few T Au-Ag ore	(Keith, 1974, p. 111)
Corona Group..........	17	27	16 S.	5 E.	1 T ore (1 oz. Au)	(Wilson, 1939)
Badger................	18	SE¼ 34	16 S.	5 E.	Few T high grade Au-Ag ore	(Keith, 1974, p. 110)
Lucido Group..........	19	NE¼ 3	17 S.	5 E.	100 T. ore (40 oz. Au, 40 oz. Ag)	Do., p. 112
Jaeger (Akron) mine...	20	NE¼ 10	16 S.	5 E.	15,000 T ore (7,500 oz. Au, 4,500 oz. Ag.)	(Strutzell, 1968)

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TABLE 3.--Location of mineral occurrences and production from mines and prospects on the Papago Reservation (T-ton; LT - long ton; cen. - center) -- Continued

District or area mine/claim	Number figure 5	Location Sec	T	R	Production	Remarks and data source
Cababi District--Continued:						
Silver Giant mine.....	21	NE¼ 3	17 S.	5 E.	Few T high grade Ag	(Keith, 1974, p. 112)
Columbia Group.......	22	S cen 1	16 S.	5 E.	Few T high grade Cu-Ag ore.	Do., p. 110
Cobreza mine.........	23	13	16 S.	5 E.	Few T high grade Cu-Ag	USBM files.
Baboquivari District:						
Lone Eagle claims....	1	1	17 S.	6 E.	20 T W ore	(Dale and others, 1960).
Clavert Claims......	2	13	17 S.	6 E.	150 pound 50 percent WO_3 concentrate.	Do.
Southside...........	3	13	17 S.	6 E.	150 pound WO_3 concentrate.	Do.
Cable and Cajewski....	4	N½ 24	17 S.	6 E.	None recorded	Do.
Independence group claims.............	5	24	17 S.	6 E.	10 T W ore	Do.
Jezebel mine........	6	S cen 19	17 S.	7 E.	600 T W ore	Do.
Last Chance claim....	7	30	17 S.	7 E.	20 T W ore	Do.
San Juan mine.......	8	NE¼ 30	17 S.	7 E.	4 T W concentrate	Do.
Big Juanita (Brown)...	9	29, 30	17 S.	7 E.	50 pounds WO_3 concentrate.	Do.

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TABLE 3.--Location of mineral occurrences and production from mines and prospects on the Papago Reservation (T-ton; LT - long ton; cen. - center) -- Continued

District or area mine/claim	Number figure 5		Location Sec	T	R	Production	Remarks and data source
Baboquivari District--Continued:							
Sparks mine	10		29, 30	17 S.	7 E.	100 T W ore	(Dale and others, 1960.)
Big Banana mine	11	N. cen	32	17 S.	7 E.	20,000 pounds WO_3 concentrate.	Do.
Black Dragon claims	12		15, 22			184 T Mn ore (17,500 lbs. Mn)	Do.
Allison mine	13	Center	33	18 S.	7 E.	47,000 T ore (10,340 oz. Au, 126,900 oz Ag)	(Keith, 1974, p. 107)
Ventana mine	14		18	19 S.	7 E.	185 T ore (4,800 lbs. Cu, 370 oz. Ag, 130 oz. Au)	Do., p. 110
Yellow Star mine	15		19 6	17 S. 17 S.	7 E. 6 E.	700 T W ore (5,100 lbs. WO_3.)	(Dale, 1960)
Giant Tungsten claims	16		24,25 19, 30	20 S. 20 S.	6 E. 7 E.	50 T W, Mo ore	Do.
Coyote Mountains:							
Rushby Prospect	1		19	16 S.	7 E.	Several T W ore	USBM files.
Black Eagle Manganese	2		14	16 S.	7 E.	No production	Do.
Black Hawk	3	SE¼	13	16 S.	7 E.	46 LT ore (20,608 lbs. Mn)	(Farnham and Stewart, 1958)
Jean E.	4	SW¼	13	16 S.	7 E.	100 LT Mn ore (17,050 lbs. Mn)	Do.

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TABLE 3.--Location of mineral occurrences and production from mines and prospects on the Papago Reservation (T-ton; LT - long ton; cen. - center) -- Continued

District or area mine/claim	Number figure 5	Location Sec	T	R	Production	Remarks and data source
Coyote Mountains: Continued:						
Roadside (St. Francis mine)..........	5	W cen 11	16 S.	8 E.	500 T ore (38,000 lbs. Cu, 5,700 oz. Ag)	(Keith, 1974, p. 117) Presence of mercury noted (Strutzell, 1968)
Black Bear............. (Freilinger).	6	SW¼ 13	16 S.	8 E.	None	Mn prospect.
Cimarron Mountains:						
Greenback Camp mine...	1	28, 29 30, 31, 32	10 S	2 E.	None recorded	Low grade dissemin- ated copper mineral- ization, (Strutzell, 1968).
Isabella mine.........	2	NW¼ 21	11 S.	2 E.	20 T ore (10 oz. Au, 2 oz. Ag)	(Keith, 1974)
Black Diamond group...	3	7	11 S.	3 E.	38 LT Mn ore (13,620 lbs. Mn)	(Farnham and Stewart, 1958).
Montizona group.......	4	SW¼ 19	11 S.	3 E.	15 T ore (1.5 oz. Au, 20,100 lbs. Cu, 120 oz. Ag, 2,100 lbs. Pb)	(Keith, 1974)
Stella Maris #1.......	5	NW¼ 36	11 S.	2 E	5,300 LT ore (5,698,560 lbs. Mn)	(Farnham and Stewart, 1958)
Stella Maris #2	6	36	11 S.	2 E.	539 LT Mn ore	Do.
Manganese King.......	7	NW¼ 36	11 S.	2 E.	583 LT Mn ore (386,552 lbs. Mn)	Do.

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TABLE 3.--Location of mineral occurrences and production from mines and prospects on the Papago Reservation (T-ton; LT - long ton; cen. - center) -- Continued

District or area mine/claim	Number figure 5	Location				Production	Remarks and data source
			Sec	T	R		
Cimarron Mountains:							
Continued: Black Jack.............	8		36	11 S.	2 E.	1,240 LT Mn ore (972,160 lbs. Mn)	(Farnham and Stewart, 1958)
Monte Cristo mine.....	9	NW¼	7	12 S.	3 E.	65 T ore (33 oz. Ag, 1,300 lbs. Cu)	(Keith, 1974, p. 115)
Oro Grande mine.......	10	W cen	7	12 S.	3 E.	Few T Cu, Au, Ag, Ag ore	Do.
Waterman District:							
Carlo and Eclipse mines............	1	NW¼ NW¼	1 2	13 S.	8 E.	600 T ore (24,000 lbs. Cu, 6,600 oz. Ag)	Do., p. 144
Indiana Arizona mine...	2	NE¼	25	12 S.	8 E.	8,000 T ore (1,120,000 lbs. Pb, 1,120,000 lbs. Zn, 320,000 lbs. Cu, 64,000 oz Ag)	Do., p. 144
Gunsight District:							
Cadillac...........	1	E½	18	13 S.	4 W.	239 LT Mn ore (78,700 lbs. Mn)	(Farnham and others, 1961)
Gunsight mine......	2	Center	16	14 S	4 W	15,000 T Pb-Ag (value $600,000 1881-1184) 120 T (52,800 lbs. Pb, 600 oz. Ag.)	(Strutzell, 1968, p. 43) (Keith, 1974, p. 122)
Surprise mine.......	3	SE¼	16	14 S	4 W.	Few tons Au ore	(Keith, 1974, p. 123)

Continued

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TABLE 3.--Location of mineral occurrences and production from mines and prospects on the Papago Reservation (T-ton; LT - long ton; cen. - center) -- Continued

District or area mine/claim	Number figure 5	Location Sec	T	R	Production	Remarks and data source
Gunsight District: Continued--						
Lucky Strike.......	4	NW¼ 35	14 S.	4 W.	15 T Au ore (7 oz. Au)	(Keith, 1974, p. 123)
Sunset Limited (Yellow Aster).....	5	SW¼ 25	14 S.	4 W.	50 T Au ore (50 oz. Au), 1 T scheelite ore.	(Wilson, 1950)
Lilly, Saguaro, Empire............	6	N cen 3	15 S.	4 W.	15 T Au-Ag ore (15 oz. Au and Ag)	(Keith, 1974, p. 122)
Ajo Gunsight........	7	W cen 11	15 S.	4 W.	Few T	Do.
Bullion Bar.........	8	NE¼ 11	15 S.	4 W.	Few T	Do.
Black Bess..........	9	SW¼ 1 SE¼ 2	15 S.	4 W.	80 T Au ore	Do.
Little Chief.........	10	SE¼ 19	14 S.	2 W.	SiO_2 flux	Do., p. 123

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TABLE 4.--Summary of production through 1973, Papago and San Xavier Indian Reservations

(LT = long ton; T = ton)

District or area	Ore	Copper (T)	Gold (ounces or dollars)	Silver (ounces or dollars)	Lead (T)	Manganese (T)	Reserves
San Xavier Reservation	545,900 T	4,165.3					Not available.
Papago Reservation							
Silver Reef Mountains	360 LT Mn ore		$62,000 gold and silver	See gold		105.3	Between 32,000 and +2 million Cu @ 2 percent Cu. 471.6 million @ 0.754 percent Cu. 66,000 Zn, 109 million Cu @ 0.54 percent
Slate Mountains (includes Tat Momoli Mountains)	2,800 T	140	$85,000 gold and silver	See gold			
Vekol Mountains	7,600 T	380	$50,000	$1,100,000			
Cababi District	6,500	92	3,450	102,100	182		85,000 Cu-Ag ore
Quijotoa District	15,600 T	61	11,600	233,000	25		
Cimarron Mountains	120 T Cu-Ag 9,500 LT Mn ore	11	400	80		1,350	
Gunsight District	16,000 T			100,600	780		
Baboquivari District 1/	48,500 T	2.4	10,470	127,270			
Coyote Mountains	710 T Cu-Ag 600 LT Mn ore	71		5,700		18.8	
Totals	655,500 T	4,922.7	26,320 and $141,200	568,750 and $1,100,000	987	1,474.1	

1/ Also 1,500 T of tungsten ore of unknown metal content, and 20,350 pounds of tungsten concentrate.

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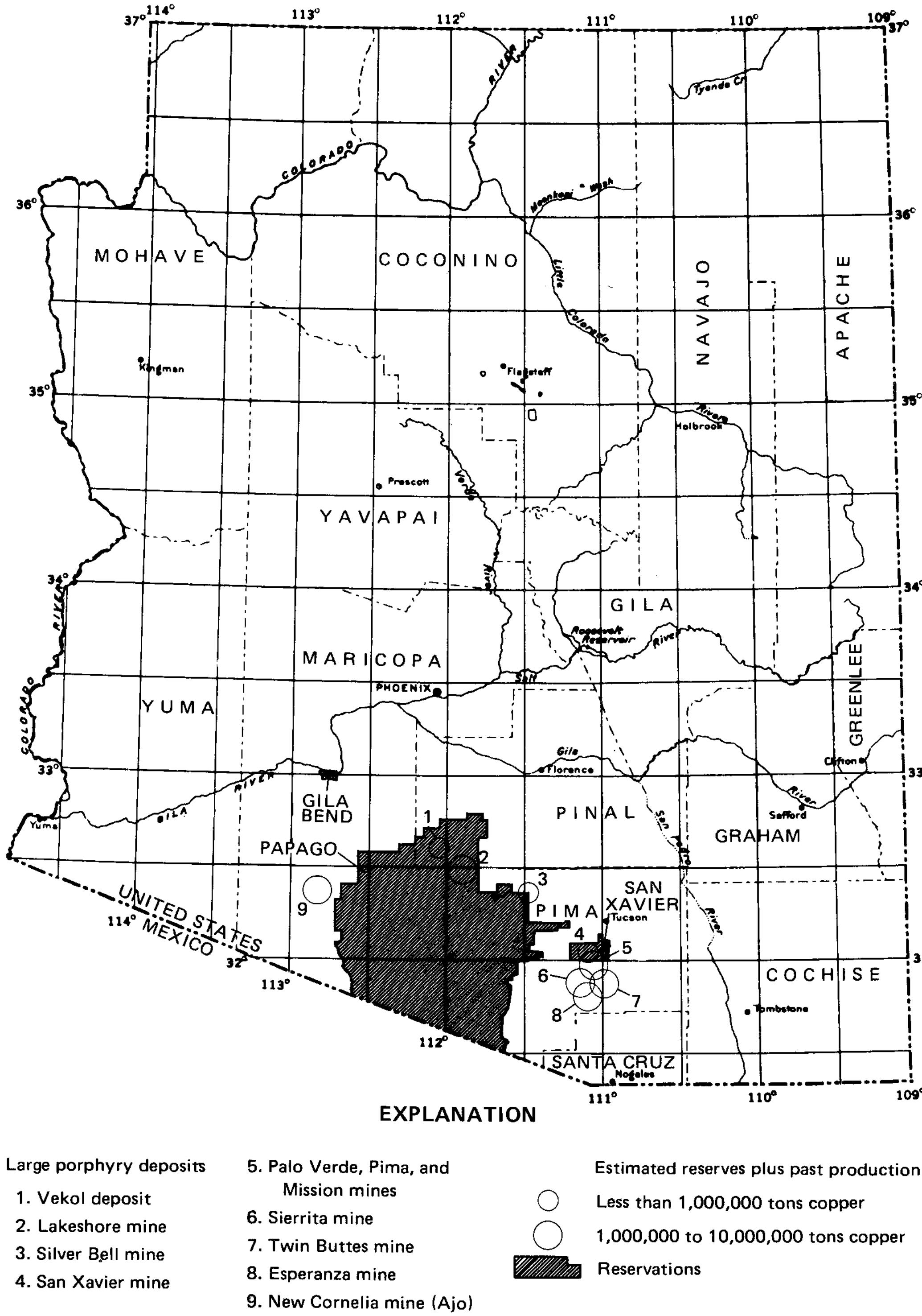

Figure 1. Index map of Arizona showing Gila Bend, Papago, and San Xavier Indian Reservations and large porphyry copper deposits near the reservation.

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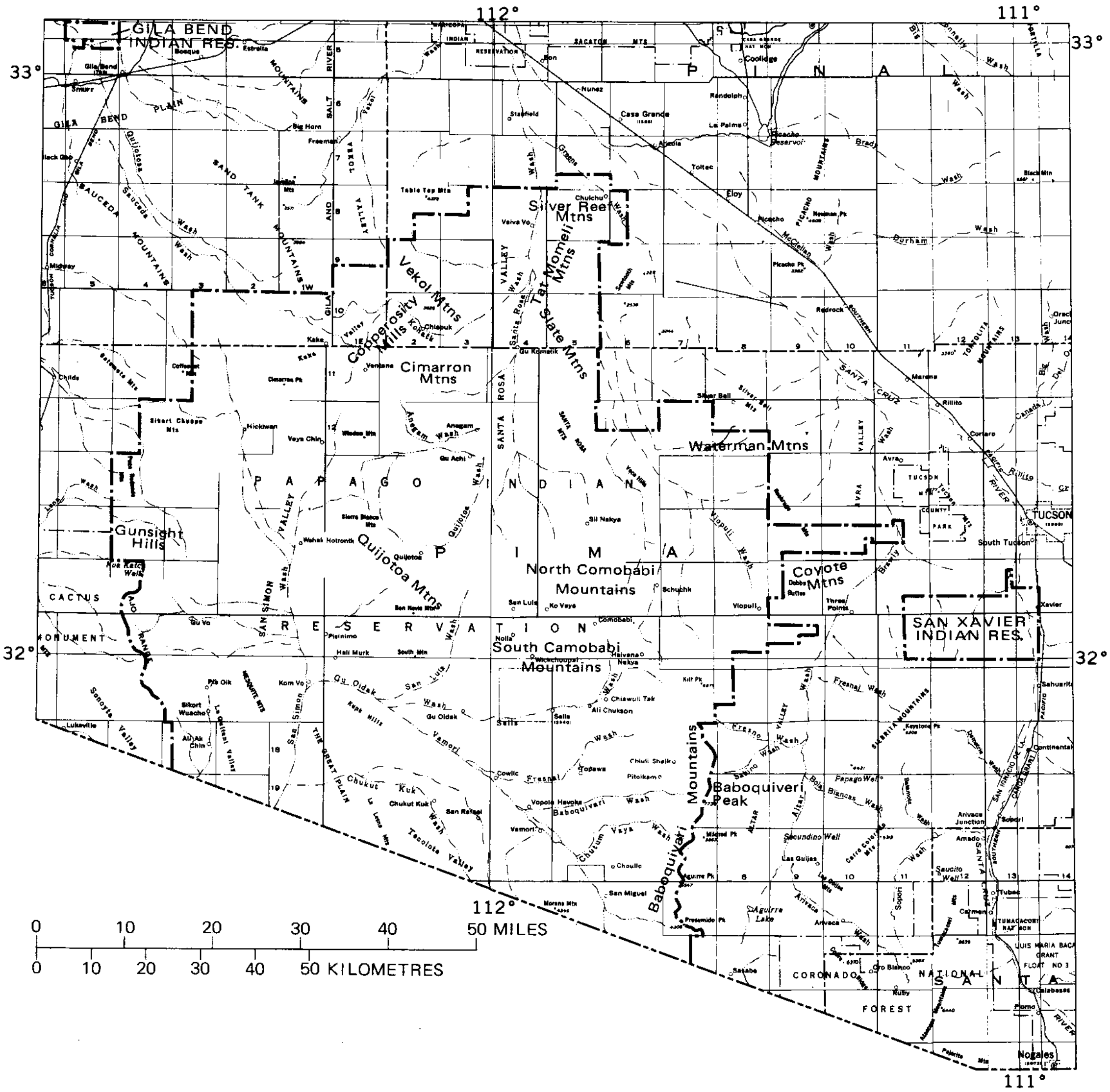

Figure 2. Map showing physiographic features in and near Gila Bend, Papago, and San Xavier Indian Reservation.

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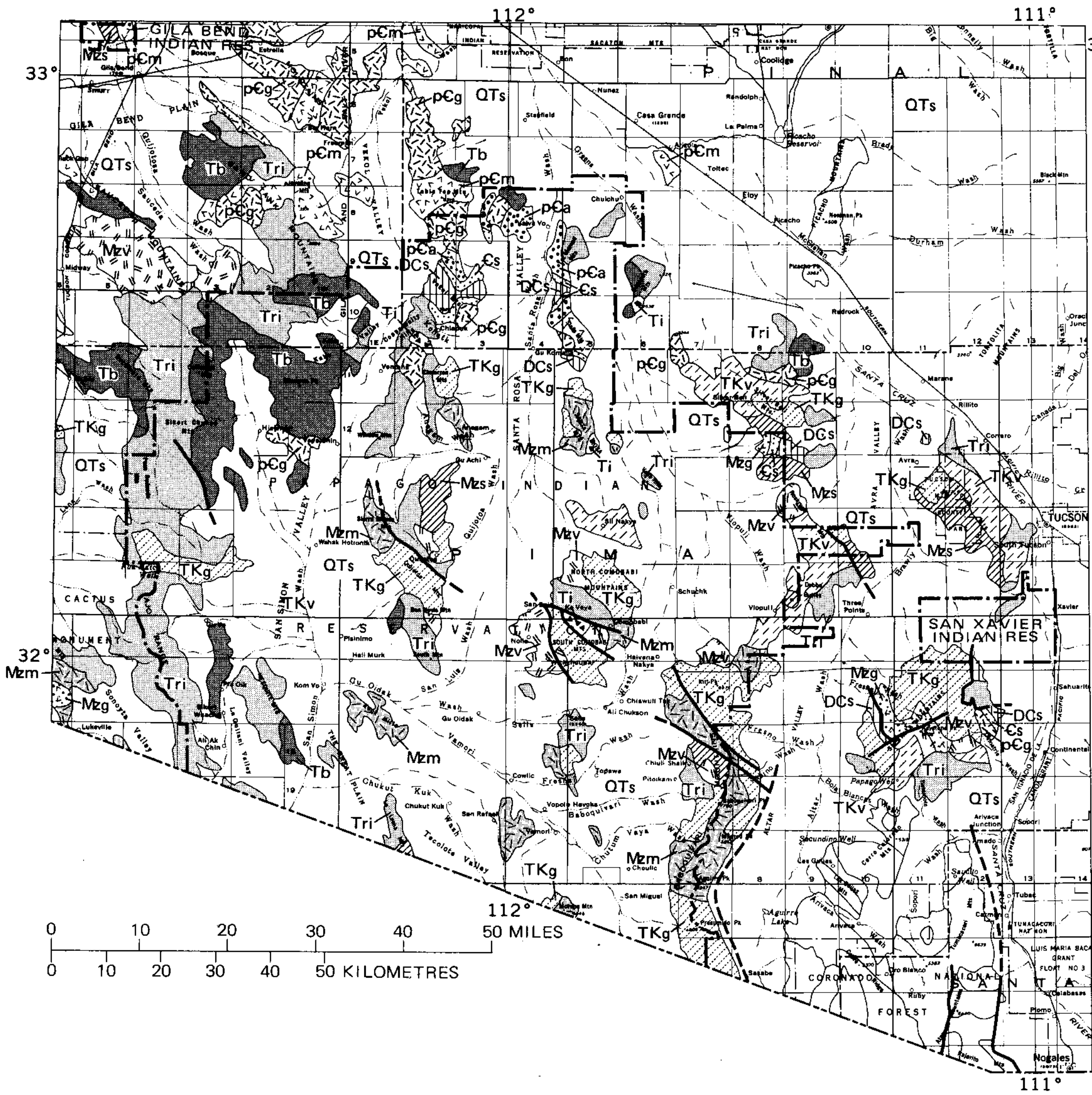

Figure 3. Generalized geologic map of area that includes Gila Bend, Papago, and San Xavier Indian Reservation. (See Figure 3a for explanation).

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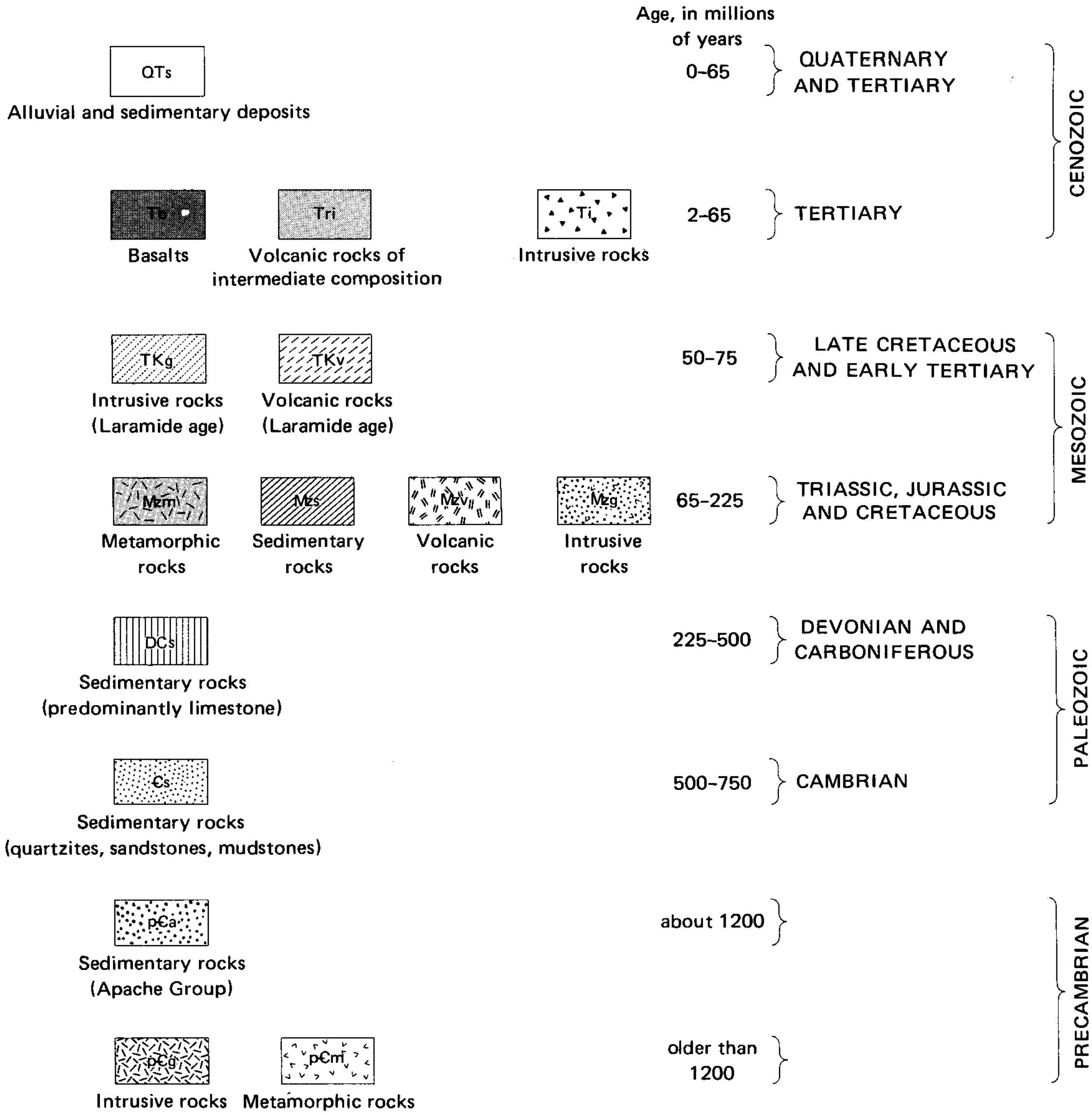

Figure 3a. Explanation for Figure 3.

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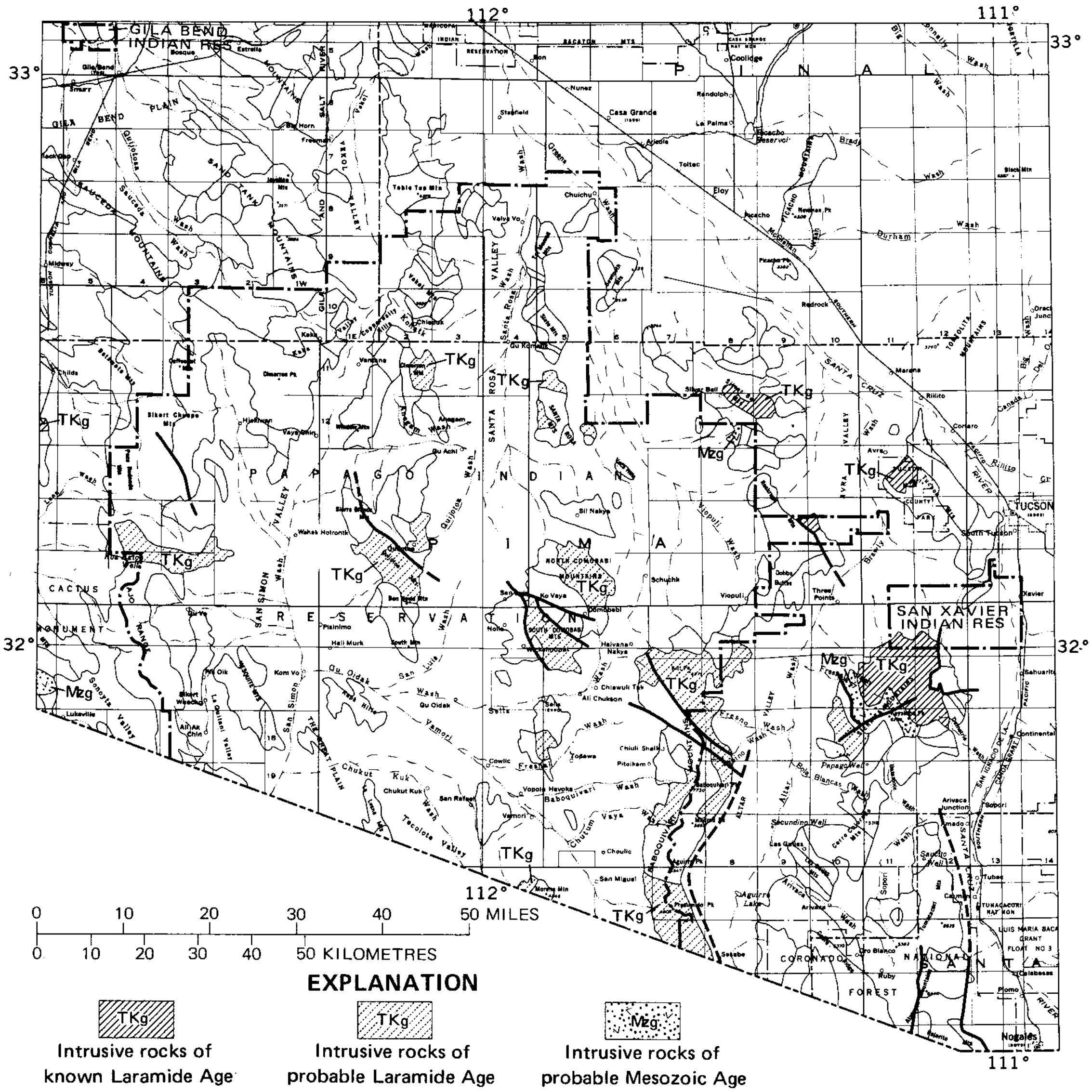

Figure 4. Distribution of Mesozoic and Laramide age plutons on and near Papago and San Xavier Reservations.

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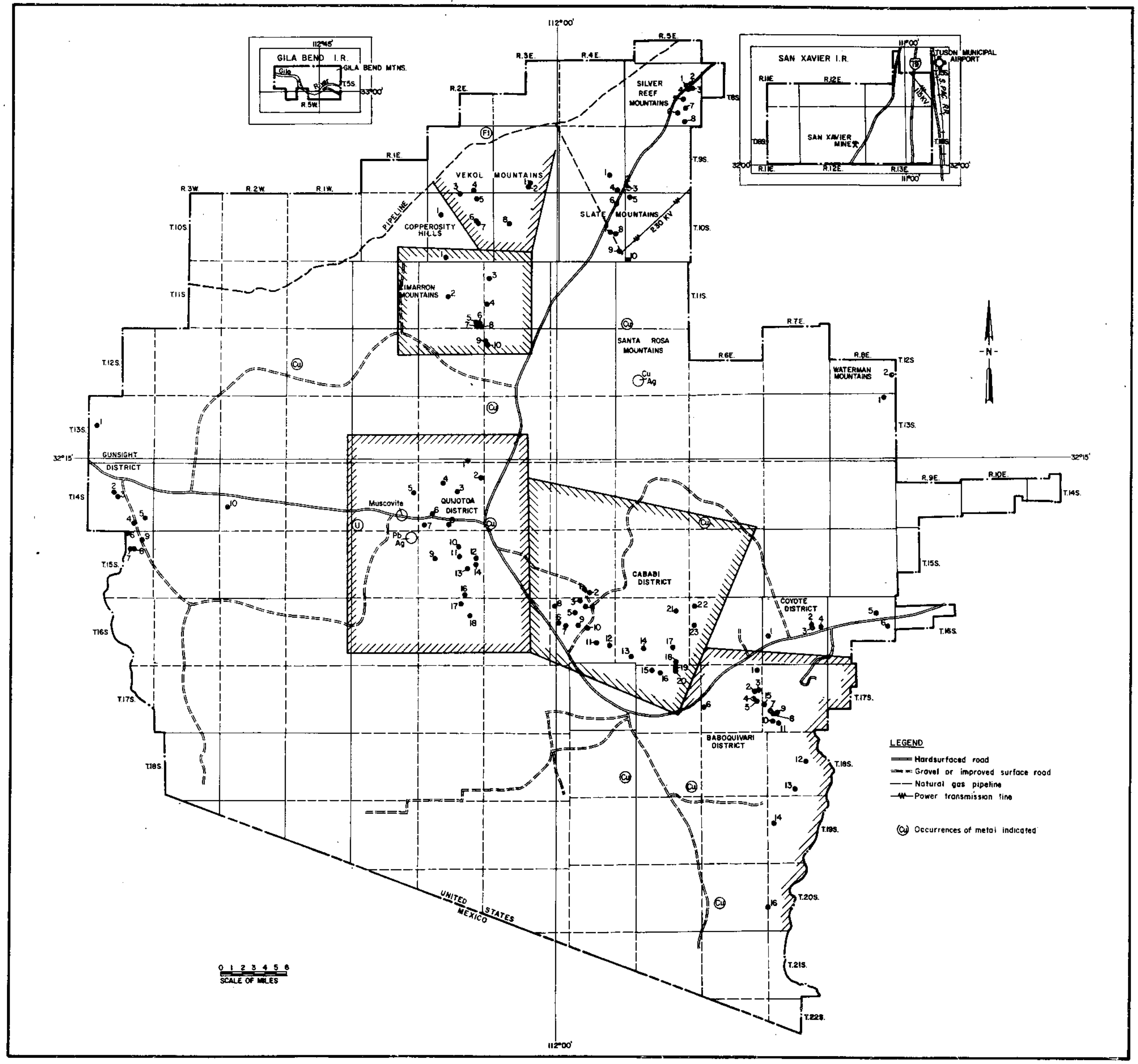

Figure 5. Map of Gila Bend, Papago, and San Xavier Indian Reservations showing mining districts or areas and mineral occurrences. Number refer to listings in Table 3.

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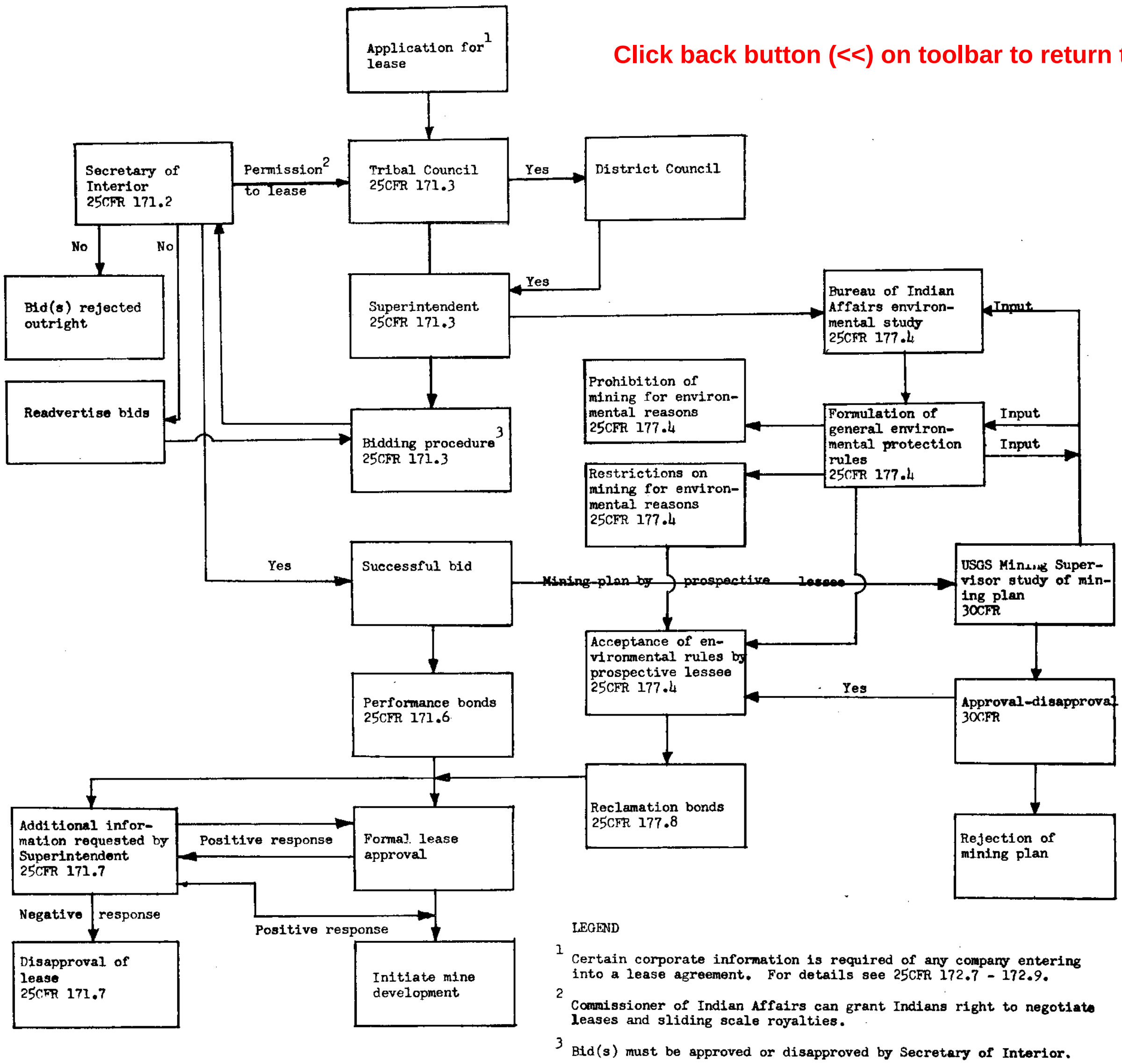

Figure 6. Diagram of procedure for obtaining mineral leases (excluding gas and oil) on the Gila Bend, Papago, and San Xavier Reservations.

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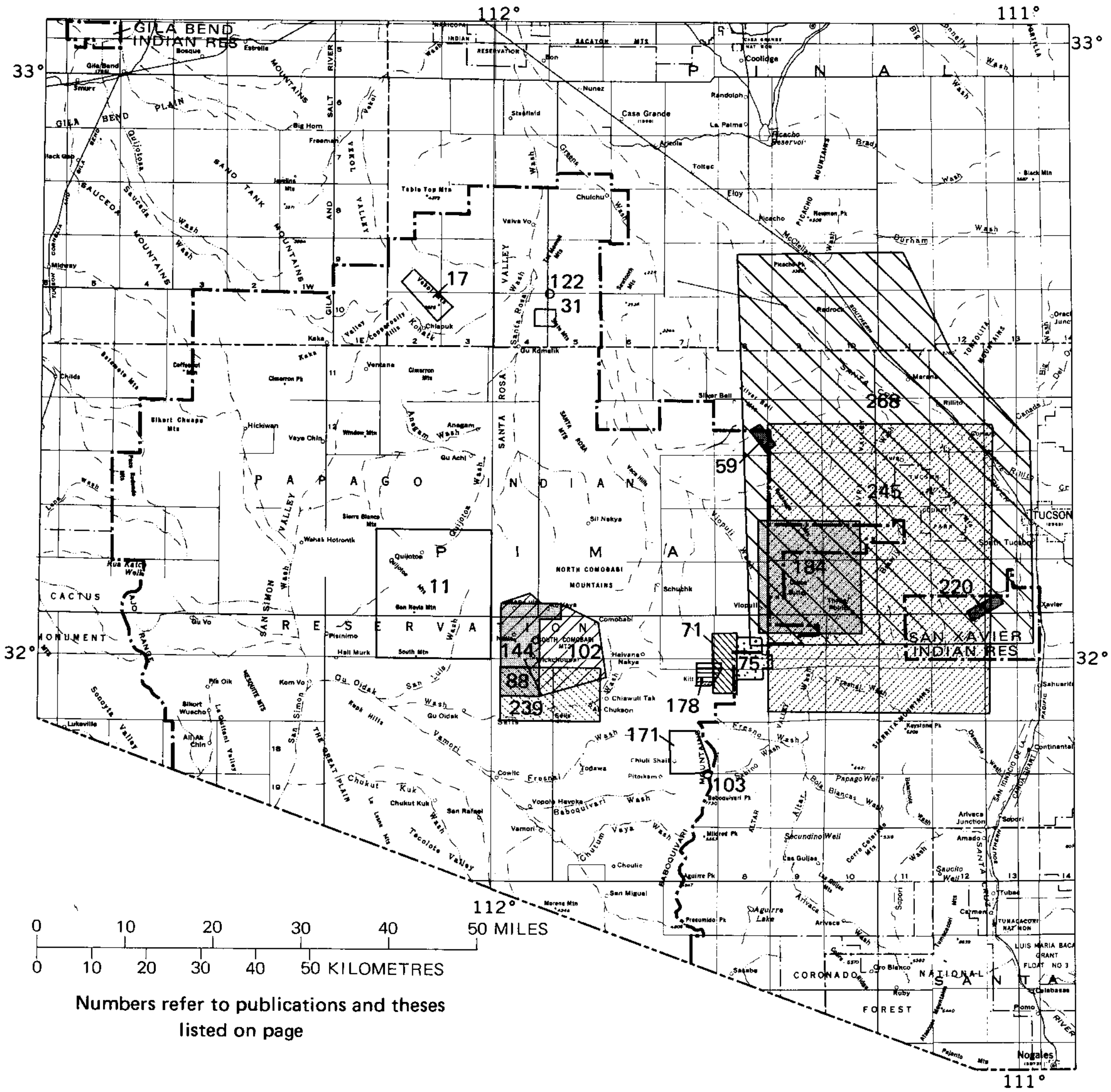

Figure 7. Index to geologic maps for Gila Bend, Papago, and San Xavier Indian Reservations.

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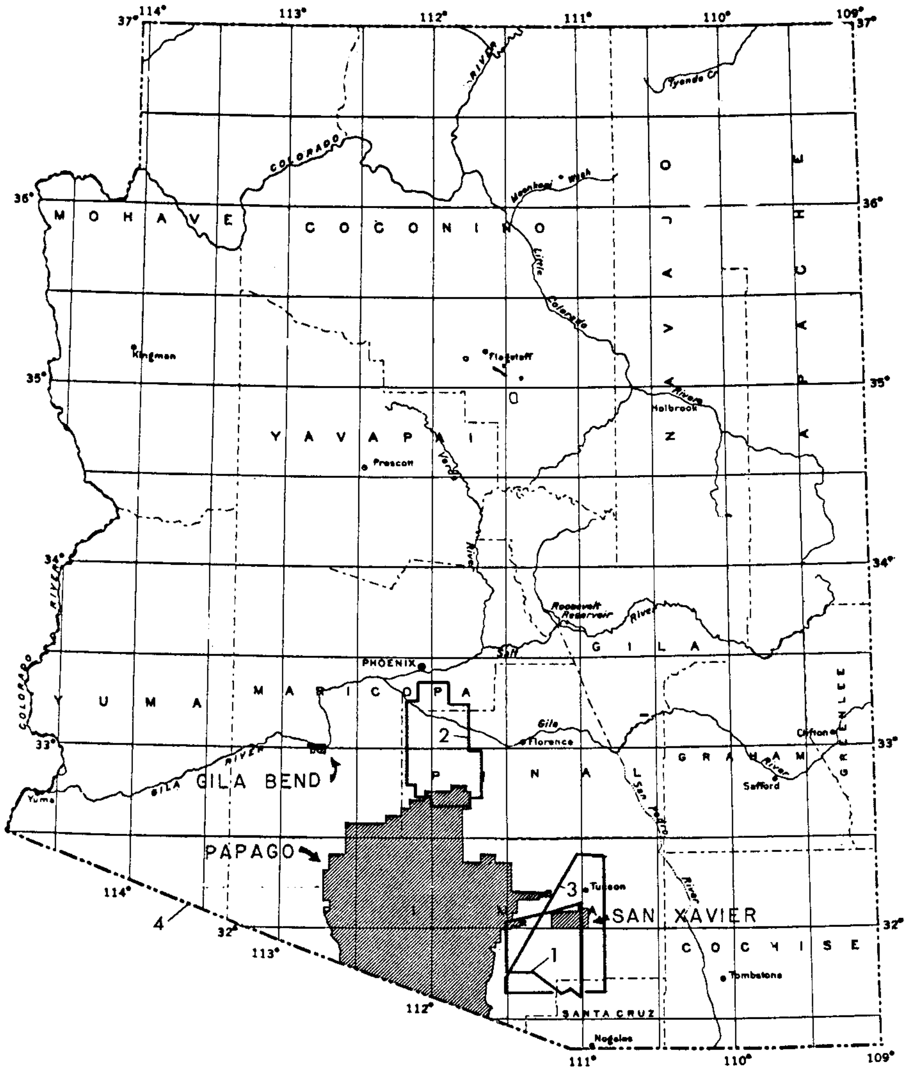

EXPLANATION

Number	References
1	........Andreason, G. E. and Pitkin, J. A., 1963, Aeromagnetic map of the Twin Buttes area, Pima and Santa Cruz Counties, Arizona: U. S. Geol. Survey Geophys. Inv. Map GP-426.
2	........Mitchell, C. M., and Zandle, G. L., 1965, Aeromagnetic map of the Casa Grande area, Maricopa and Pinal Counties, Arizona: U. S. Geol. Survey Geophys. Inv. open-file map, scale 1:62,500.
3	........Plouff, Donald, 1962, Bouguer gravity anomaly map of the Twin Buttes area, Pima and Santa Cruz Counties, Arizona: U. S. Geol. Survey open-file map, scale 1:125,000.
4	........Sauk, W. A., and Sumner, J. S., 1970, Residual aeromagnetic map of Arizona: Arizona Univ., Dept. Geosciences, Tucson, Arizona, scale 1:1,000,000.

Figure 8. Index to aeromagnetic and gravity anomaly maps.

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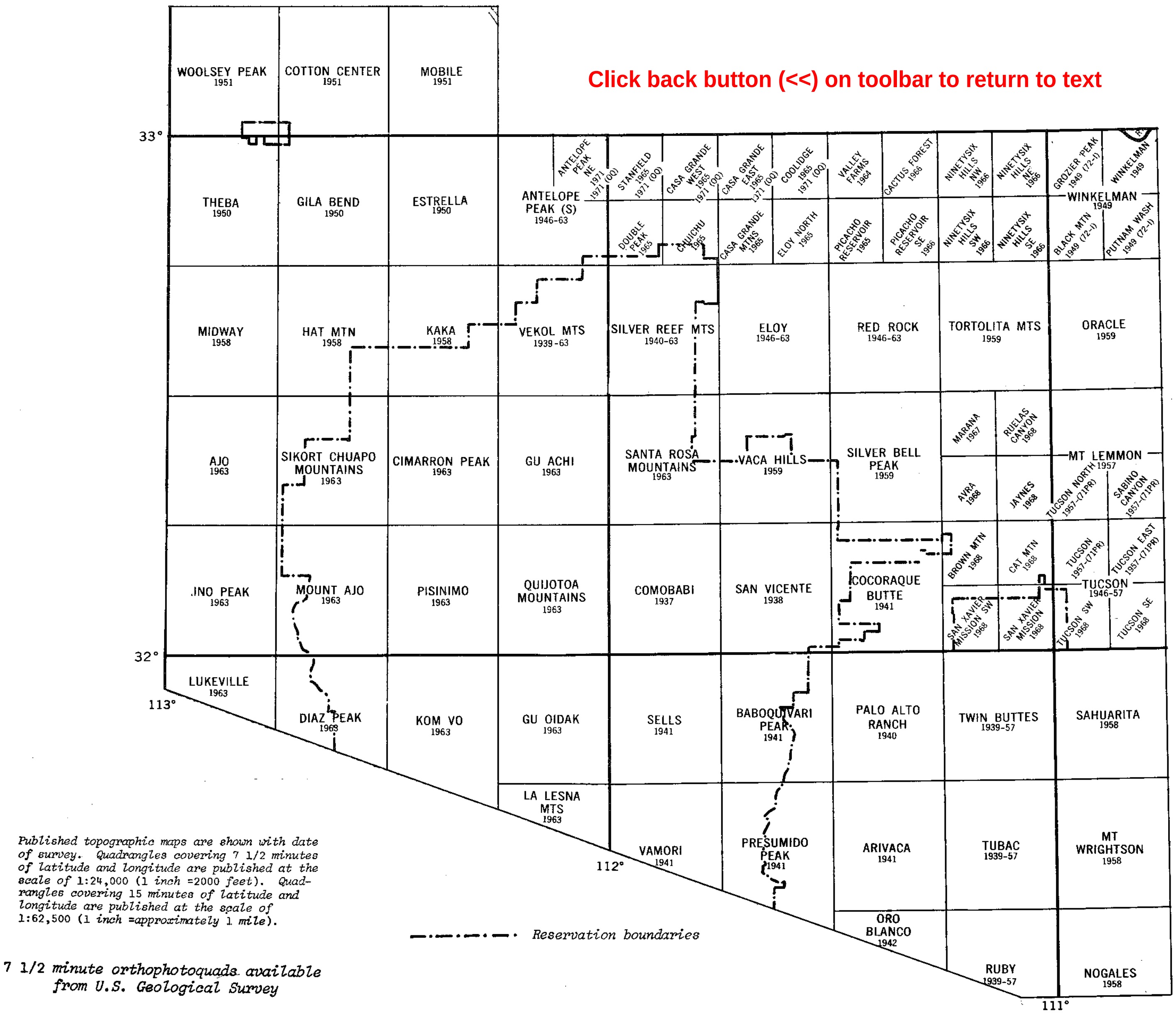

Figure 9. Index to U.S. Geological Survey topographic maps of a portion of Southern Arizona including the Gila Bend, Papago, and San Xavier Indian Reservations.