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Albuquerque, New Mexico 37107

A FIELD GUIDE TO THE NORTHWESTERN GRANITE WASH MOUNTAINS, WEST-CENTRAL ARIZONA

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November 6, 1983

STATE OF ARIZONA
BUREAU OF GEOLOGY
AND MINERAL TECHNOLOGY
OPEN-FILE REPORT

83-23

Interpretations and conclusions in this report are those of the consultant and do not necessarily coincide with those of the staff of the Bureau of Geology and Mineral Technology.

1983 AGS Fall Field Trip Route

Led by

Bob Scarborough, Steven Reynolds, and Jon Spencer

Arizona Bureau of Geology and Mineral Technology

Organized by

Stanley B. Keith and Jan C. Wilt

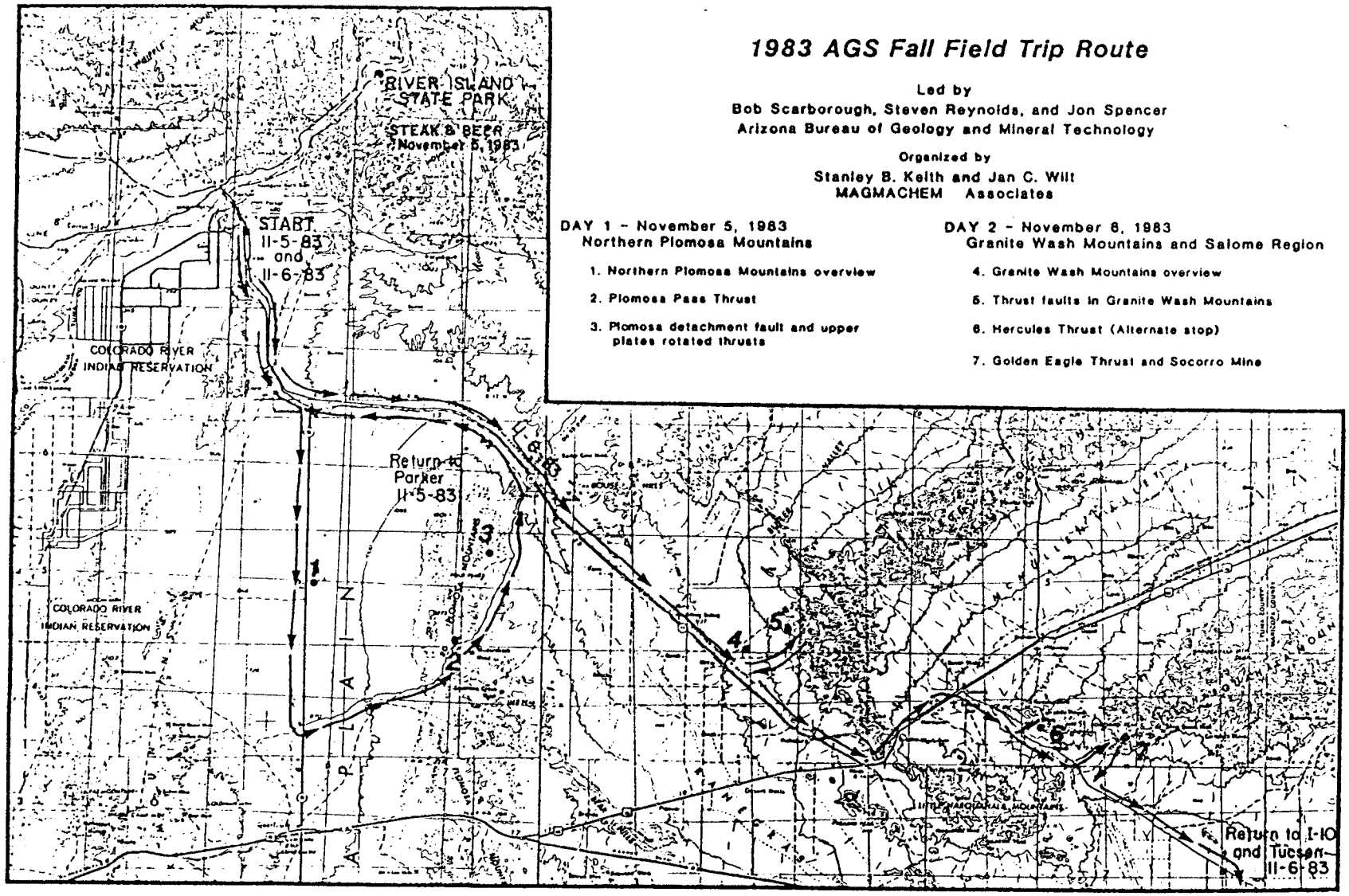
MAGMACHEM Associates

DAY 1 - November 5, 1983
Northern Plomosa Mountains

1. Northern Plomosa Mountains overview
2. Plomosa Pass Thrust
3. Plomosa detachment fault and upper plates rotated thrusts

DAY 2 - November 6, 1983
Granite Wash Mountains and Salome Region

4. Granite Wash Mountains overview
5. Thrust faults in Granite Wash Mountains
6. Hercules Thrust (Alternate stop)
7. Golden Eagle Thrust and Socorro Mine



INTRODUCTION

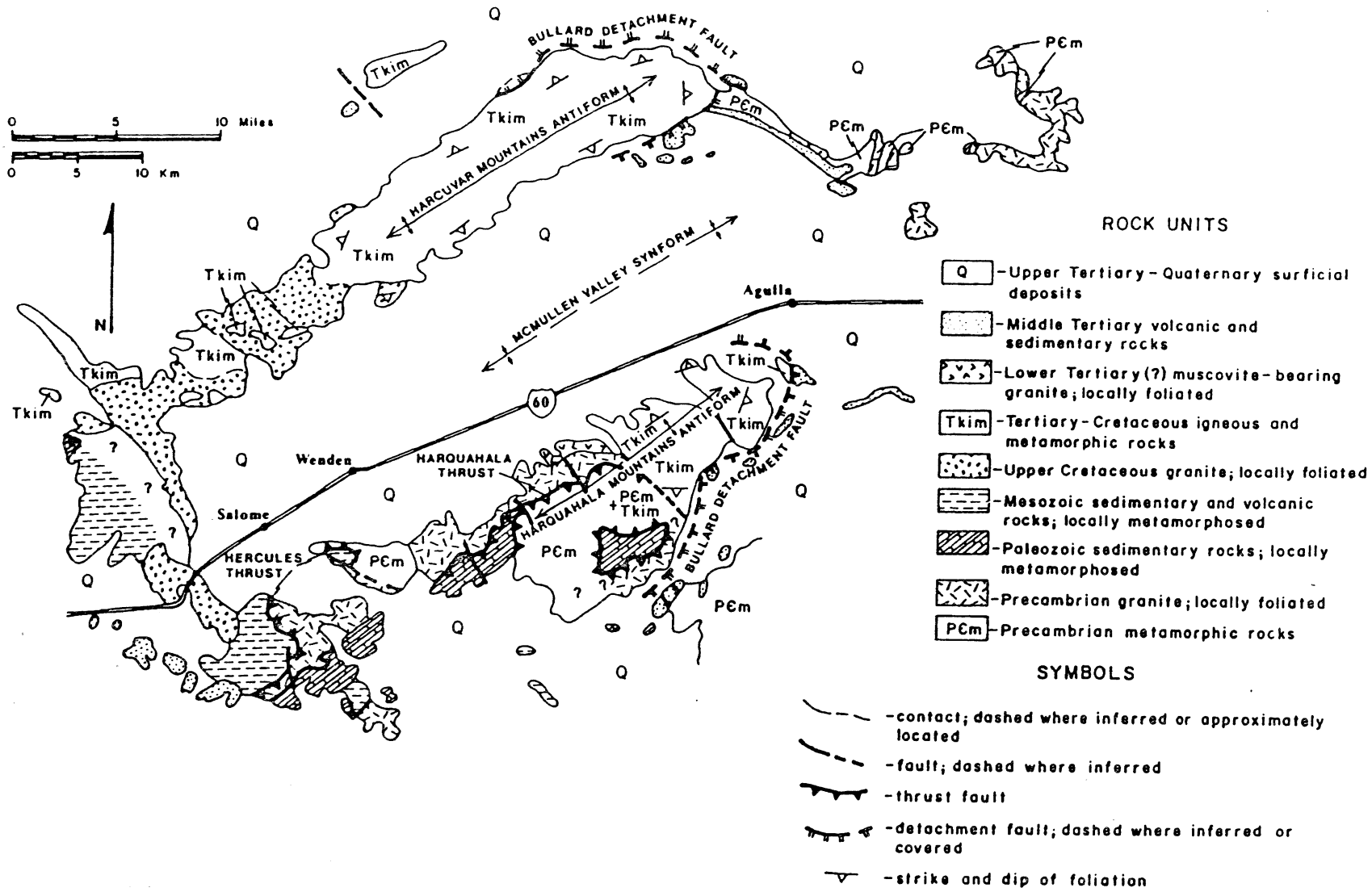
The Granite Wash Mountains are one of the most structurally complicated mountain ranges in Arizona. The northern part of the range is composed of an imbricate stack of structurally interleaved Mesozoic sedimentary and volcanic rocks, Paleozoic strata, and Precambrian crystalline rocks. As part of the 1983 AGS Fall field trip, we will briefly examine the lithologies, structures, and mineralization in the northern part of the range. The geology and mineral deposits of the Granite Wash Mountains are currently being studied as part of an Arizona Bureau of Geology and Mineral Technology geological mapping project in the Phoenix 1x2 degree sheet. Geologic research in the range is not yet finished, so all conclusions and opinions discussed in this field trip guide must be considered **PRELIMINARY.**

With the exception of a thesis by Ciancanelli(1965), previous geologic research in the area is limited to reconnaissance studies (Wilson, 1960; Marshak, 1979; Rehrig and Reynolds, 1980; Reynolds, 1980, 1982) and somewhat cursory examinations of gold mines of the area (see references in Keith, 1978).

REGIONAL GEOLOGIC SETTING

The Granite Wash Mountains are located in west-central Arizona, a geologically complex and poorly understood part of the southern Basin and Range Province. The region is situated northeast of the Mesozoic batholith belt and southwest of the relatively stable Colorado Plateau, and has geologic characteristics intermediate between those of the two flanking areas. Precambrian crystalline rocks are widely exposed in this medial belt, whereas they have been largely obliterated by plutonism in the batholith belt and are covered by flat-lying Paleozoic and Mesozoic strata in the Colorado Plateau. Consistent with this medial position, west-central Arizona was the site of scattered Mesozoic-Cenozoic plutonism and metamorphism. The region also experienced multiple episodes of post-Paleozoic thrusting and deformation. The Paleozoic stratigraphy of the region is thin and cratonic, and Precambrian crystalline rocks are clearly involved in thrusting.

West-central Arizona can be subdivided into three lithologically distinct tectonic terranes whose boundaries are zones of intense deformation (Harding and others,1983). The northernmost terrane, consisting of Precambrian crystalline rocks with an overlying cover of cratonic Paleozoic strata and Mesozoic volcanic and sedimentary rocks, represents the southwestern limit of unequivocal North American craton. In at least two mountain ranges, this terrane has been thrust southward over Mesozoic volcanic and sedimentary rocks of the McCoy terrane. On its southern margin, the McCoy terrane has been overthrust by the composite San Gabriel-Joshua Tree terrane along the north- to northeast-vergent Mule Mountains Thrust and related structures


BULLARD DETACHMENT FAULT
HARCUVAR MOUNTAINS ANTIFORM
MCMULLEN VALLEY SYNFORM
HARQUAHALA MOUNTAINS ANTIFORM
HARQUAHALA THRUST
HERCULES THRUST
Wenden
Salome
Aguila
60
N
0 5 10 Miles
0 5 10 Km
Q
Tkim
P€m
ROCK UNITS
Q -Upper Tertiary-Quaternary surficial deposits
-Middle Tertiary volcanic and sedimentary rocks
-Lower Tertiary(?) muscovite-bearing granite; locally foliated
Tkim -Tertiary-Cretaceous igneous and metamorphic rocks
-Upper Cretaceous granite; locally foliated
-Mesozoic sedimentary and volcanic rocks; locally metamorphosed
-Paleozoic sedimentary rocks; locally metamorphosed
-Precambrian granite; locally foliated
P€m -Precambrian metamorphic rocks
SYMBOLS
-contact; dashed where inferred or approximately located
-fault; dashed where inferred
-thrust fault
-detachment fault; dashed where inferred or covered
-strike and dip of foliation

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(Tosdal,1982; Harding, 1982). The San Gabriel-Joshua Tree terrane is largely composed of Precambrian crystalline rocks of uncertain affinity to North America (Powell, 1981).

The Granite Wash Mountains lie near or on the tectonic boundary between cratonic North America and the McCoy terrane. Regionally, this boundary is marked by a gently to moderately dipping thrust fault that separates two fundamentally distinct lithologic assemblages. The pre-Cenozoic stratigraphic sequence of the North American block includes: 1) a basement of Precambrian metamorphic and granitic rocks; 2) a 1-1.5 km-thick sequence of cratonic Paleozoic strata; 3) up to 2 km of intermediate to felsic volcanics of probable Jurassic age; and 4) a clastic unit of Jurassic or Cretaceous age that is nowhere more than 3 km thick. In contrast, the McCoy terrane is composed entirely of Mesozoic rocks, consisting of a thick lower unit of volcanic rocks whose base is not exposed, and an upper clastic sequence that is locally in excess of 7 km thick. The upper clastic sequences of the McCoy and North American terranes, although in similar stratigraphic positions, are stratigraphically and petrographically distinct (Harding, 1982). The name McCoy Mountains Formation is applied to the thick clastic sequences in the McCoy terrane, whereas the thinner sequences of the North American block are referred to as Apache Wash Formation (Harding, 1982). Both terranes and their mutual tectonic boundary have been locally intruded by late Mesozoic granitoids and depositionally overlapped by mid-Cenozoic volcanic and sedimentary rocks.

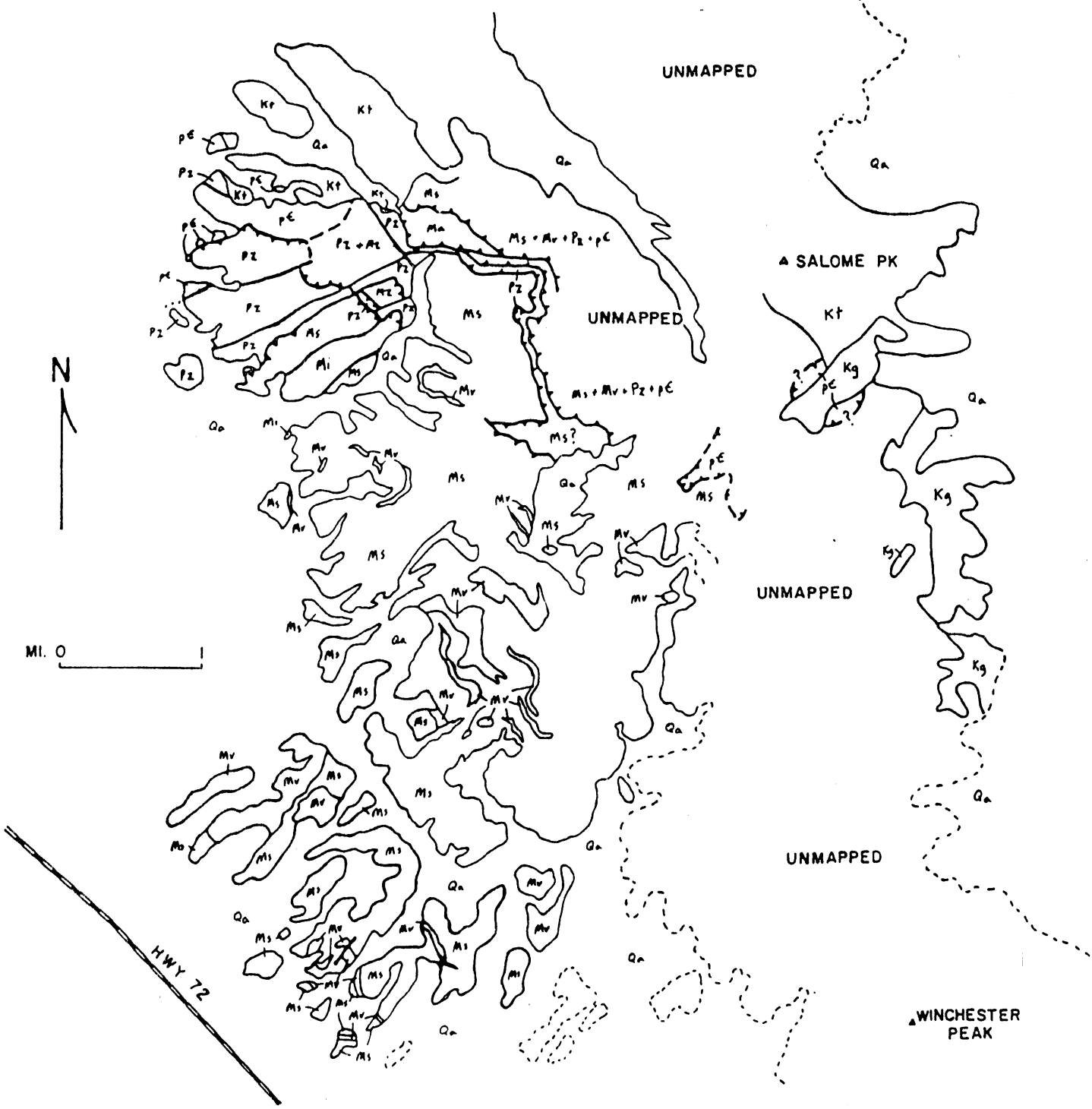
GEOLOGY OF THE GRANITE WASH MOUNTAINS

The Granite Wash Mountains are primarily composed of Mesozoic sedimentary, volcanic, and granitic rocks (Figures 1 and 2). The most widely exposed lithologic unit is an interlayered sequence of immature clastic rocks and intermediate to felsic volcanic rocks. The clastic lithologies include quartzofeldspathic and lithic sandstone, siltstone, and conglomerate. The volcanic rocks include andesitic flows and subvolcanic intrusions, quartz porphyry (ash-flow tuffs(?)), and bedded tuffs. The clastic and volcanic rocks are more highly metamorphosed in the eastern, structurally highest parts of the range. At present, it is unknown whether these Mesozoic rocks are correlative with 1) the McCoy Mountains Formation of the McCoy terrane, 2) the Apache Wash Formation of the North American block, or 3) some other Mesozoic unit.

The Mesozoic rocks described above are in tectonic contact with Paleozoic metasedimentary rocks and Precambrian(?) crystalline rocks. The Paleozoic metasedimentary rocks are correlative with lithologically similar middle and upper Paleozoic formations of the region, including (from bottom to top) Devonian Martin Formation, Mississippian Redwall Limestone, Pennsylvanian-Permian Supai(?) Formation, Permian Coconino Sandstone, and Permian Kaibab Formation. We emphasize that these correlations are based soley on lithology and stratigraphic succession, not on any paleontologic data. Precambrian crystalline rocks of the area include 1) high-grade,

SIMPLIFIED GEOLOGIC MAP OF THE GRANITE WASH MTNS.

MAPPED BY S. REYNOLDS, J. SPENCER, AND S. RICHARD



CORRELATION OF MAP UNITS

Qa				QUATERNARY	CENOZOIC
Kg				CRETACEOUS	MESOZOIC
Kt					
Ms	Mv	Mi	Ma		
Pz					PALEOZOIC
p€					PRECAMBRIAN

DESCRIPTION OF MAP UNITS

Qa Quaternary alluvium

Kg Granite Wash Granodiorite - Medium-grained, equigranular, hornblende-biotite granodiorite with dioritic border phase. Dated at 65 and 69 m.y. (K-Ar biotite, Damon, 1968; Eberly and Stanley, 1978).

Kt Tank Pass Granite - Medium- to fine-grained, leucocratic, biotite granite. Dated at ≈ 85 m.y. (3-point Rb-Sr isochron, S.J. Reynolds, unpublished data).

Ms Mesozoic metasedimentary rocks - Primarily poorly- to very poorly-sorted litho-feldspathic sandstone and locally interbedded phyllite and conglomerate.

Mv Mesozoic volcanic and hypabyssal rocks - Primarily massive flows 1-30 m thick of dark aphanitic metavolcanic rocks and associated fine-grained hornblende diorite(?) hypabyssal intrusives.

Mi Mesozoic igneous rocks - Porphyritic, hypabyssal(?) intrusive with abundant .3 to 3 cm K-spar phenocrysts in dark, microcrystalline groundmass.

Ma Mesozoic alaskite - Fine-grained, leucocratic, altered, granitic intrusives.

Pz Paleozoic metasedimentary rocks - Recognized formations include Martin, Redwall, Coconino, Supai, Kaibab, and evaporites at the top of the Kaibab.

p€ Precambrian granite-gneiss - Includes medium- and fine-grained, equigranular and porphyritic, biotitic granitic and gneissic rocks.

compositionally layered, quartzofeldspathic gneiss; 2) locally porphyritic, medium- to coarse-grained granitic gneiss; and 3) equigranular, medium-grained, foliated granitoid rocks. We have not, as yet, recognized any depositional contacts between Precambrian, Paleozoic, and Mesozoic rocks.

The structure of the Granite Wash Moutains is very complex. The Mesozoic rocks are multiply deformed and weakly to strongly metamorphosed. The dominant structural fabrics are a steep, northwest-striking fracture cleavage and a well-developed subhorizontal cleavage or schistosity that contains a northeast-trending lineation. Refolded folds are locally common. Lithologic units in the Mesozoic section are commonly lenticular and erratic in distribution, possibly due to isoclinal folding. In addition, the Paleozoic section is locally attenuated and interfolded on a fine scale within the Mesozoic units. Many Paleozoic-Mesozoic contacts are faults and ductile shear zones, probably with significant amounts of tectonic transport. Other contacts may represent attenuated limbs of large-scale isoclinal folds and nappes. Isolated fault slivers and tectonic "fish" of Precambrian(?) crystalline rocks occur along some Paleozoic-Mesozoic contacts. In addition, preliminary mapping suggests the presence of a major thrust that places Precambrian crystalline rocks over all Mesozoic and Paleozoic rocks in the range.

The youngest pre-Cenozoic rocks in the range are two Upper Cretaceous plutons, the Tank Pass Granite and Granite Wash Granodiorite (Rehrig and Reynolds, 1980). Both plutons appear to intrude discordantly across all structures in the range, including the suggested major thrust. The ages of the Tank Pass Granite and Granite Wash Granodiorite are both constrained to 85-70 m.y.B.P. by published and unpublished K-Ar and Rb-Sr dates (Reynolds, 1982).

Cenozoic rocks in the range are limited to 1) numerous, northwest-trending dikes; 2) gently dipping, intermediate to mafic flows and pyroclastic deposits exposed on the western flank of the range; and 3) various generations of gravels.

Mineralization in the range consists mostly of (Keith, 1978):

1) Scheelite in quartz veins and pockets in metamorphosed Paleozoic and Mesozoic rocks adjacent to the Tank Pass Granite and Granite Wash Granodiorite; and

2) gold- and copper-bearing veins (locally accompanied by lead and silver) in Mesozoic, Paleozoic, and Precambrian rocks, commonly near intermediate to felsic dikes.

FIELD TRIP STOPS

The main emphasis of the Granite Wash segment of the field trip is to

present a broad overview of the rock units, structure, and mineralization of the range. We will examine the lithology and structure of the Mesozoic sedimentary and volcanic rocks in both weakly and moderately metamorphosed conditions. Depending on the difficulty of access (due to the great flood of 83), we will also examine the tectonic interleaving of Paleozoic and Precambrian rocks within the Mesozoic section. If roads permit, we will do the latter at the Yuma Mine, a site of copper-silver-gold mineralization. The mineralization, including copper oxides and carbonates, is localized in strongly deformed Paleozoic carbonates that occur as tectonic lenses completely enclosed by Mesozoic metasedimentary rocks. Crystalline rocks, such as augen gneiss, locally occur along the Paleozoic-Mesozoic contact.

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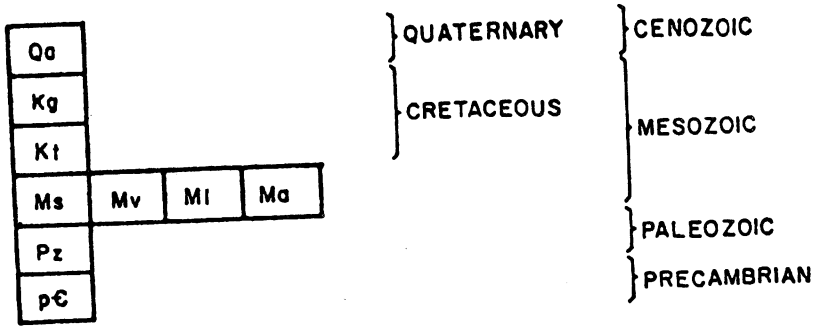
CORRELATION OF MAP UNITS



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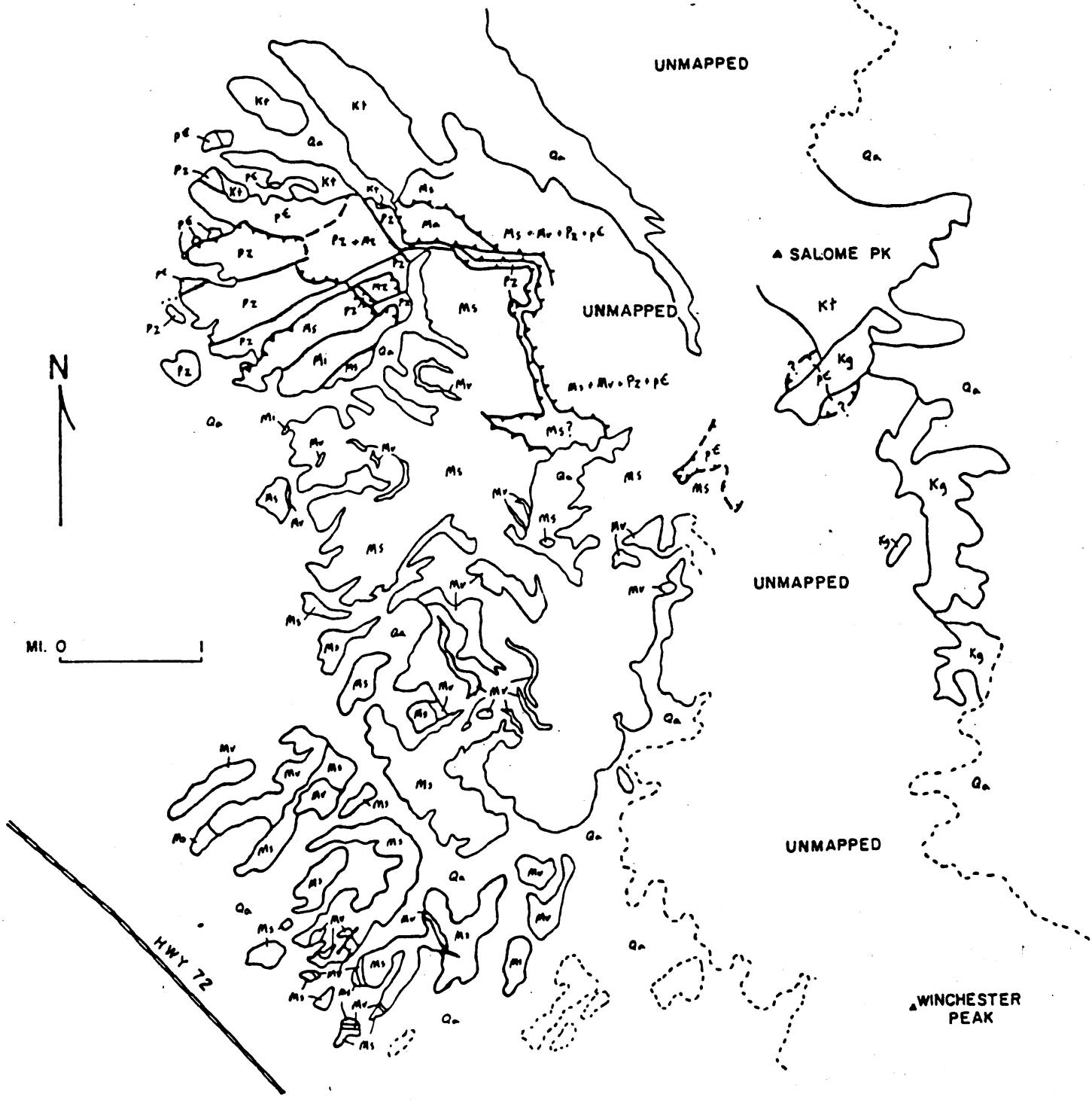


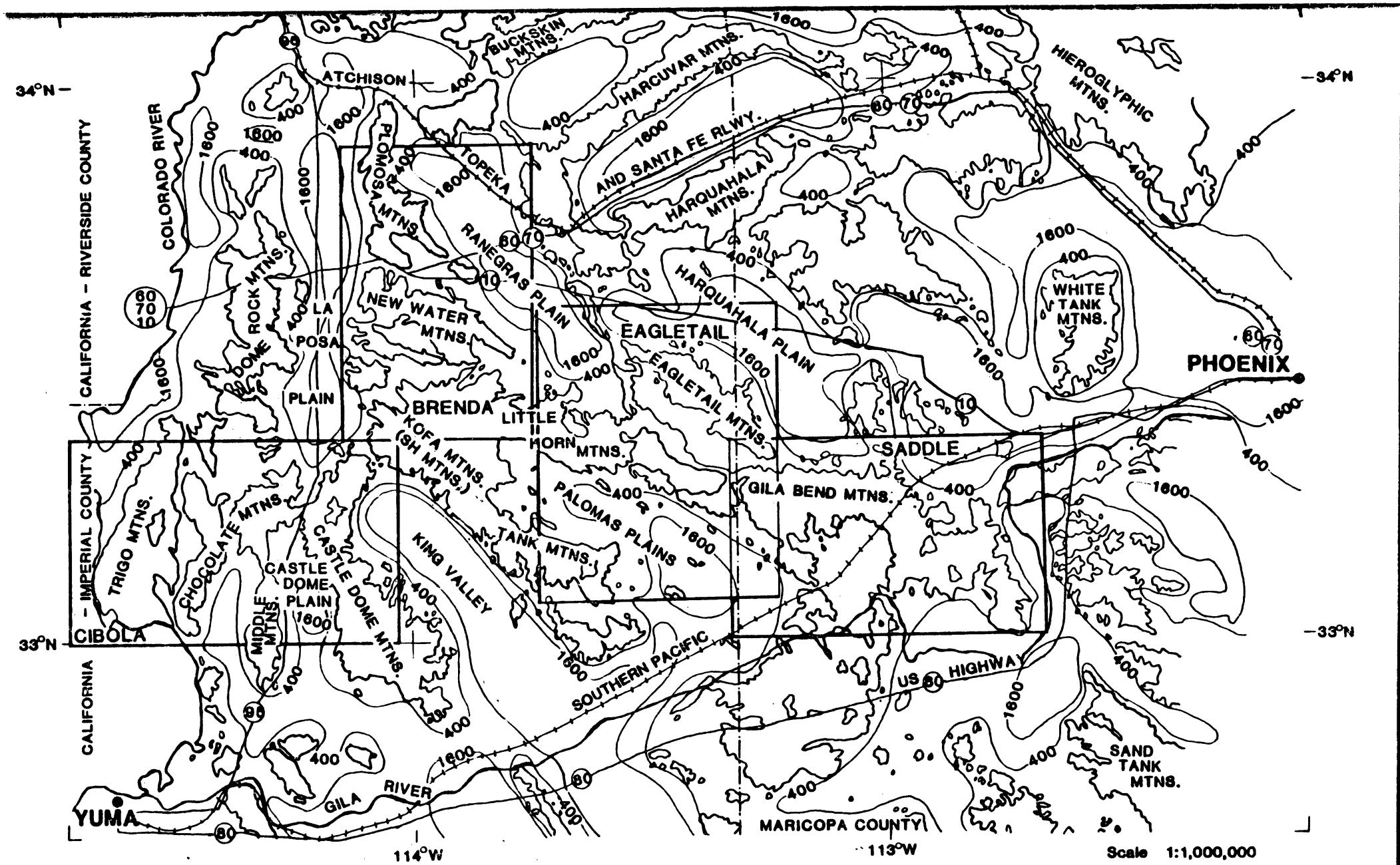
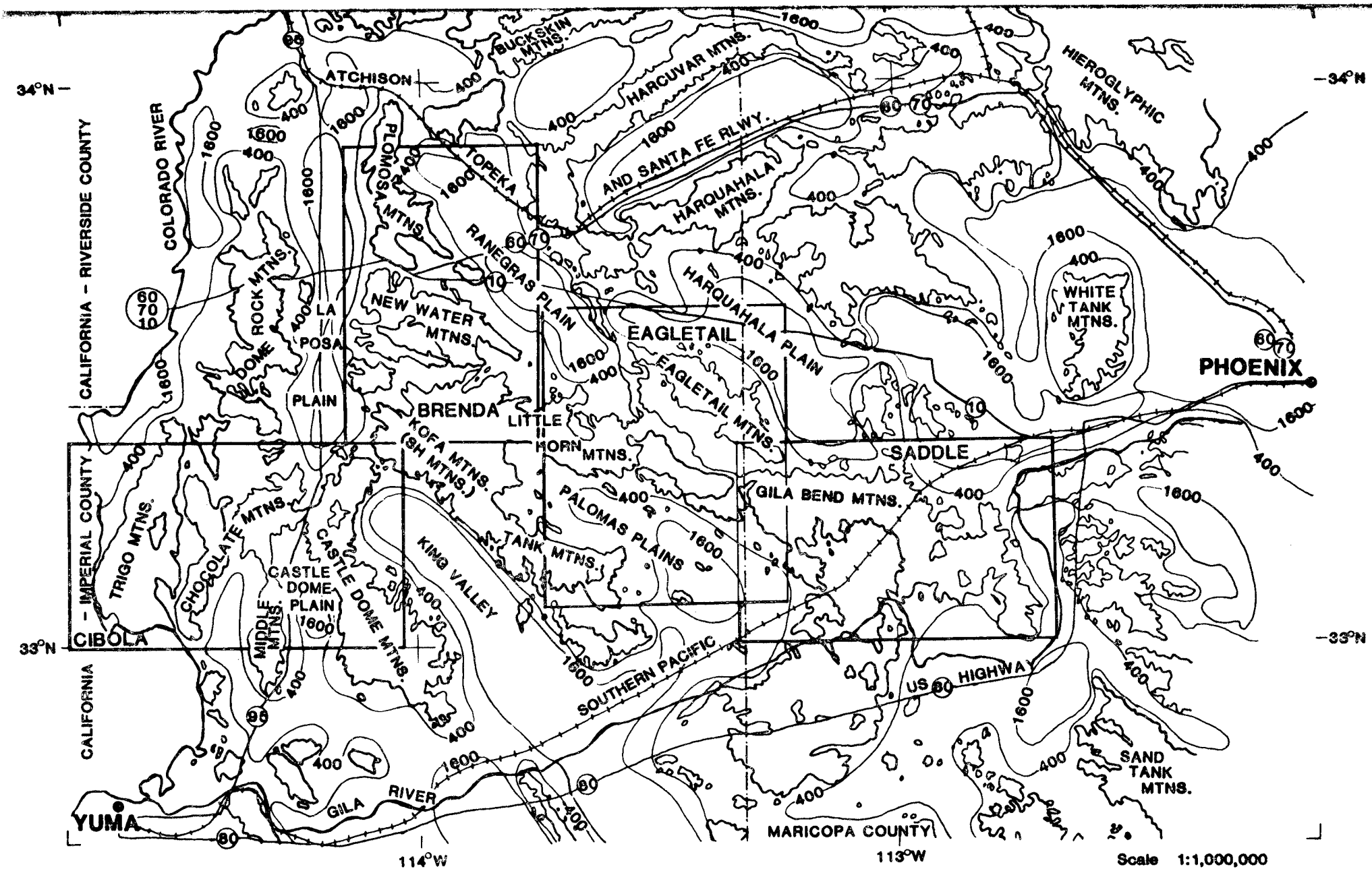


Figure 1. LOCATION OF THE CIBOLA, BRENDA, EAGLE TAIL AND SADDLE SUB-AREAS OF THE KOFA GRA. Surface physiography and depth to basement contours in feet, after Oppenheimer and Sumner (1981).

La Paz Cty - Rept. by Geoexplorers for BLM in AZ Bur Mines Lib



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Sediments of the lowest mid-Tertiary unit of Eberly and Stanley (1978) and Scarborough and Wilt (1979) include algal limestones. Sediments which are interbedded with volcanics of the middle unit include lacustrine deposits with local organic-rich facies as well as algal limestones. Mudstones of the upper unit are reported to contain fresh water ostracods in other parts of Arizona. Late Tertiary sediments, comprised of poorly consolidated fanglomerate plus sandstone and siltstone of fluvial lacustrine origin, are not known to contain fossils. Mid- and late Tertiary rocks which may contain some of the above-mentioned sediments and fossils crop out in all the WSAs except the Needles Eastern Extension (050-005B) WSA. The Pliocene Bouse Formation, a marine unit with foraminifers, mollusks, ostracods, charophytes, and barnacles, crops out near the Gibraltar Mounain (050-012) WSA.

Late Tertiary and Quaternary fanglomerates and alluvium are not known to contain fossils. These sediments occur in all the WSAs except the Needles Eastern Addition (050-005B) WSA.

ENERGY AND MINERAL RESOURCES

Known Mineral Deposits, Mines or Prospects with Recorded Production

1. **Planet Mine**
   Location: 34°10'00"N, 113°51'40"W
   Center sec. 31, T10N, R15W
   Commodities: Pb, Cu, Fe
   Production: Produced about 3 tons of lead, 1936-1940.
   References: USGS, CRIB Mineral Resources File 12, Record 2648, p. 6749; Arizona Bureau of Mines Bulletin 180.

3. **Cienga**
   Location: 34°15'20"N, 114°07'30"W
   NW 1/4 sec. 34, T11N, R18W
   location derived from Arizona Bureau of Mines Bulletin 180
   Commodity: Au
   Ore Materials: Gold present in base-metal sulfide minerals.
   Deposit description and geology:
   Base-metal sulfides replace limestone.
   Production: More than 10,000 oz. Au produced.
   References: USGS, CRIB Mineral Resources File 12, Record 2660, p. 6761; Arizona Bureau of Mines Bulletin 180.

8. **Dutchman Mine**
Other Names: Flying Dutchman
Location: 33°57'17"N, 114°04'32"W
Sec. 7 and 18, T7N, R17W
Commodities: Au (major product); Cu, Ag (minor products); Fe (occurrence).
Ore Materials: Gold, hematite, Cu-stain.
Deposit description:
Small vein. Workings: shaft.
Geology: Mineralization is along a steeply dipping fault zone in Cretaceous shales that have been intruded by granite porphyry.
Production: 1050 tons up to 1941, 0.802 oz Au/T, 1% Cu, 0.1 oz Ag/T
Reference: USGS CRIB Mineral Resources File 12, Record 2778, p. 7084-7086; Keith, 1978.

9. **Old Maid Mine**
Location: E center sec. 13, T7N, R18W
Commodities: Au, Ag, Cu, Fe
Ore Materials: Gold, hematite, oxidized copper minerals.
Deposit Description:
Vein with maximum thickness of 3 feet, trends N and dips 60°W. Workings: underground.
Geology: Mineralization is in a complexly faulted vein in Cretaceous shales which have been intruded by granite porphyry.
Production: 150 tons in the early 1900's-1938, 2.6 oz Au/T, 0.6 oz Ag/T and 0.1% Cu.
References: USGS CRIB Mineral Resources File 12, Record 2779, p. 7087-7089; Keith, 1978.

11. **Mammoth Prospect**
Synonym name: Corona Copper Company
Location: 34°03'38"N, 113°46'13"W
Sec. 1, 12 and 13, T8N, R15W
Commodities: Cu (major product); Au, Ag (minor products); Fe, Ba, F (occurrences).
Ore materials: Cu-silicate, Fe-oxide, barite, fluorite.
Deposit description:
Yes, 1890's and early 1900's, 16% Cu, 0.8 oz Au/T, 1.3 oz Ag/T.
References: USGS CRIB Mineral Resources File 12, record 2788, p. 7113-7115; Keith, 1978.

12. **Copper Glance Mine**
Synonym names: Corona Copper Company, Mammoth Group
Location: 34°03'10"N, 113°45'28"W
Sec. 12, T8N, R15W
Commodities: Cu (major product); Au, Ag (minor products); Ba, Fe (occurrences).
Ore Materials: Chalcopyrite, Cu-silicate, hematite, magnetite, gold, silver, barite.
Deposit description:
Stringers of 4 inch maximum width, trend N52°W

and dipping 60°NE. Workings: inclined shaft.

Geology: Stringers occupy a shear zone in gneiss and schist of the metamorphic core complex which has been intruded by Tertiary pegmatite/aplite dikes.

Production: Yes, small amount.

References: USGS CRIB Mineral Resources File 12, record 2789, p. 7116-7118.

13. **Chicago Prospect**

Other Names: Corona Copper Co., Mammoth Group

Location: 34°03'13"N, 113°47'03"W
Sec. 12 and 13, T8N, R15W

Commodities: Cu (major product); Ag, Au (minor products); Ba, Fe (occurrences).

Ore materials: Chrysocolla, gold, silver, barite, iron.

Deposit description:
Small vein (max. width 4 inches) trends N35W and dips 80°NE. Ore is present as irregular masses and vug fillings. Workings: underground.

Geology: Mineralization is along a fault plane in gneiss of the metamorphic core complex which has been cut by pegmatite and aplite dikes. The rock is brecciated, with thin film of barite coating fragments.

Production: Yes, small amount

References: USGS CRIB Mineral Resources File 12, Record 2790, p. 7119-7121.

14. **Moro Mine Group**

Synonym name: Big Horn

Location: 34°09'02"N, 113°49'00"W
W 1/2 sec. 3, T9N, R15W

Commodities: Cu (major producer); Au, Ag (minor products); Fe (occurrence)

Ore materials: Cu-carbonate, Cu-silicate, leaf gold, specularite, Cu glance, Fe-oxide.

Deposit description:
Small, irregularly shaped deposit. Workings: underground.

Geology: Deposit occurs in conglomerate overlying gneiss.

Production: 2300 tons averaging 3% Cu, minor Au and Ag.

References: USGS CRIB Mineral Resources File 12, record 2798, p. 7141-7143; Keith, 1978.

15. **Pride Mine**

Other name: Arizona Pride

Location: 34°09'14"N, 114°02'15"W
NW 1/4 sec. 4, T9N, R17W

Commodities: Au (major product); Ag, Cu (minor products); Fe (occurrence).

Ore Materials: Cu-silicate, azurite, malachite, chalcopyrite, hematite.

Deposit description:
Small replacement bodies. Workings: shaft and several adits.

Geology: Deposit is in thin marble beds at or near

Deposit Description:
Small, irregular, tabular shaped vein/replacement, S30°W-trending. Workings: underground, adit tunnel and an inclined shaft.
Geology: Mineralization in Precambrian quartz-mica and amphibolitic schists associated with Tertiary tuff and olivine basalt.
Production: 800 tons.
References: USGS CRIB Mineral Resources File 12, Record 2815, p. 7185-7187; Keith, 1978.

26. **Sue Manganese Mine**
Other name: Sue Mine
Location: 34°11'36"N, 114°12'42"W
Sec. 23, T10N, R19W
Commodities: Mn, Cu, Au, Ag
Ore materials: Chrysocolla, malachite and manganese
Deposit description:
Small N25°W-trending, 80°SW dipping, irregularly shaped vein/shear zone. Workings: underground.
Geology: Mineralization in brecciated zone cutting silicified and metamorphosed Paleozoic limestone and metamorphosed Precambrian rocks.
Production: 400 tons at 3.5% Cu, 0.2 oz Au/T, 0.1 oz Ag/T.
References: USGS CRIB Mineral Resources File 12, Record 2816, p. 7188-7190; Keith, 1978.

27. **Billy Mack Mine**
Other name: Ruby
Location: 34°11'19"N, 11w4°11'27"W
Sec. 24, T10N, R19W
Commodities: Cu, Au (major products); Ag (minor product).
Ore Materials: Malachite, chrysocolla, gold and specularite.
Deposit Description:
Small, NE trending, 45°NW dipping irregular bunches discontinuous pockets. Iregular replacement of hematite and limonite containing small pockets and masses of malachite and chrysocolla, threads and disseminations of gold in quartz.
Geology: Mineralization controlled by fracture intersections in metamorphosed Paleozoic limestone along a steeply dipping thrust fault of Precambrian metamorphics over the sediments.
Production: Some 3000 tons between 1909-1919 and 1943-1960.
References: USGS CRIB Mineral Resources File 12, Record 2817, p. 7191-7193; Keith, 1978.

28. **Lion Hill Mine**
Other names: Glory Group, Rico
Location: 34°10'58"W, 114°11'18"W,
Sec. 25, T10N, R19W.
Commodities: Au (major product); Cu, Ag (minor products).
Ore materials: Gold, silver, chrysocolla, malachite, limonite and specularite.

Geology: Mineralization in fault zone. Wall rock brecciated Paleozoic limestone and shale, with gouge, quartz, calcite and feldspar above Precambrian metamorphics.
Production: Worked sporadically from 1863 to 1937, 60,000 tons at 10% Cu, minor Au, Ag.
References: USGS CRIB Mineral Resources File 12, Record 2835, p. 7242-7244; Keith, 1978.

33. **Midway Mining Disrict**
Location: T9N, R16W (south-central Buckskin Mountains).
Commodities: Cu, Au, Ag, Fe, marble, Ba, F.
Ore Materials: Oxidized copper minerals, sulfides, hematite, barite, fluorite.
Deposit description:
Spotty oxidized, copper mineralization with minor sulfides, usually associated with hematite or with quartz, barite, and fluorite along fracture or fault zones.
Geology: Mineralization in Precambrian schist and Mesozoic sediments or as limestone replacements.
Production: Small prospects and mines worked intermittently since the early 1900's. Total production would be some 212 tons of ore containing about 4-5 tons of copper, 45 ounces of gold, and 35 ounces of silver. No commercial production of marble has been reported.
Reference: Keith, 1978.
Note: District boundary line is approximate.

34. **Cienega Mining District**
Location: T9N, R17W, T11N, R19W (west end of Buckskin Mountains).
Commodities: Cu, Au, Ag, Pb, Hg, W, Ba.
Ore materials: Copper silicates, carbonates, oxides, sulfides, gold.
Deposit description:
Small, pockety replacement bodies, usually closely associated with faults, fractures and shear zones. Some high grade pockets, and reportedly, cupriferous pyrite and copper sulfides at depth.
Geology: Mineralization associated with faults, fractures and shear zones in thrust faulted blocks of partly metamorphosed Paleozoic and Mesozoic limestones, shales, and quartzites, lying unconformably on Precambrian metamorphics, or in Precambrian metamorphics thrusted over Paleozoic and Mesozoic sediments.
Production: Numerous scattered tunnels, shafts and surface workings, were mined sporadically from the late 1800's to 1969. Total estimated and recorded production would be 19,000 tons of ore containing about 917 tons of copper, 11,707 ounces of gold, 3,364 ounces of silver and a few hundred pounds of lead.
Reference: Keith, 1978.

Note: District boundary line is approximate.

35. **Black Metal Copper Mine**
Location: 34°15'22"N, 114°08'53"W, Sec. 33, T11N, R18W.
Commodities: Au, Cu.
Ore materials: Not reported.
Deposit description: Small fissures. Workings: underground.
Production: Yes, small amount.
Reference: USGS, 1972, CRIB Mineral Resources File 12, record 2836, p. 7245-7246.

36. **Mesa Manganese Prospect**
Location: 34°16'54"N, 113°50'44"W, Sec. 20, 21, T11N, R15W.
Commodity: Mn
Ore materials: Psilomelane and pyrolusite.
Deposit description: Small, N32°W-trending, 90° dipping, podlike masses, seams and veinlets in a shear zone and bedded. Workings: Surface and underground.
Geology: Mineralization in Paleocene limestones, and in Tertiary sandstones and volcanics associated with Quaternary basalts.
Production: Yes, small amount.
References: USGS, 1979, CRIB Mineral Resources file 12, Record 2394, p. 2393-2395.

37. **Castaneda Group**
Location: 34°22'27"N, 113°52'47"W, Sec. 4, T12N, R16W.
Commodity: Mn
Ore materials: Psilomelane and manganite
Deposit description: Small, N40°W-trending, 15°NE dipping deposit, located in bedded and fracture zone.
Geology: Mineralization in Pliocene Artillery Sandstone.
Production: Yes, small amount.
References: USGS, 1979, CRIB Mineral Resources File 12, Record 908, p. 2419-2421.

38. **Pilot Rock Mine**
Location: 34°24'35"N, 114°16'30" W, Sec. 6, T12N, R19W.
Commodity: Mn
Ore Materials: Psilomelane and pyrolusite.
Deposit Description: Small, N-trending, east dipping enechelon fractures in veins and fracture zones. Workings: surface and underground.
Geology: Mineralization in Tertiary basalt and sandstones associated with Precambrian granites.
Production: Yes, small amount.
References: USGS, 1979 CRIB Mineral Resources file 12, record

Ore materials: Copper silicate and carbonate, hematite.
Deposit description:
Spotty copper silicate and carbonate with hematite in irregular replacement bodies in limestone.
Geology: In folded and faulted Paleozoic limestone along thrust fault zone bringing metamorphosed Precambrian rocks over Paleozoic sediments.
Production: 175 tons in 1940-1941 and 1949-1950.
References: Stipp, Haiger, Alto and Sutherland, 1967; Keith, 1978.

100. **Cienga District Placers**
Location: T10N, R18W
Deposit description:
Placer.
Production: Some production in 1910.
Reference: Johnson, 1972.

102. **Eagle Nest Mine**
Location: W central sec. 16, T10N, R18W.
Commodity: Cu, Au, Ag.
Ore material: Chrysocolla, malachite, azurite, gold, hematite.
Deposit description:
Spotty and irregular lenses and pods of chrysocolla, malachite, and azurite, and hematite with gold values in Paleozoic limestone.
Geology: Ore bodies closely associated with thrust fault zone and sheared, faulted, fractured and brecciated Paleozoic sediments and thrust faulted overlying metamorphosed Precambrian rocks.
Production: 4000 tons.
References: Stipp et al., 1967; Keith, 1978.

105. **Arizona McGinnis Mine**
Other name: Copper Queen
Location: Cen. sec. 9, NW 1/4 sec. 16, NE 1/4 sec. 17, T10N, R18W.
Commodities: Cu, Au, Ag.
Ore Materials: Cuprite, malachite, chrysocolla, gold.
Deposit description:
Spotty cuprite, malachite and chrysocolla in stringers and replacement. Ore occurs in irregular and shallow shoots with some rich gold pockets. Workings: Shaft, tunnel and open cuts.
Geology: Mineralization in metamorphosed Paleozoic limestone along and below thrust faulted Precambrian quartz schist.
Production: Sporadic workings, 170 tons of ore averaging 9% Cu, 0.6 oz. Au/T, 0.1 oz. Ag/T.
References: Keith, 1978.

109. **New Standard Mine**
Location: SW 1/4 sec. 9, T9N, R17W.
Commodities: Cu, Fe, Ag, Au.
Ore Material: Copper carbonate, chalcopyrite, bornite, hematite.

Ore Materials: Barite, fluorite, copper staining.
Deposit description:
Fissure veins, voids and replacement. Workings: Open cut and shaft operations.
Geology: Barite with variable fluorite and copper staining, mixed with wall rock in fissure veins, voids, and replacement in strongly fractured Tertiary agglomerate and tuff.
Production: Late 1940's 2500 tons of 75% $BaSO_4$ and 14% CaF_2.
References: Stipp et al., 1967, Keith, 1978.

141. **Bentonite Mine**
Location: Sec. 25, T7N, R17W.
Commodities: Bentonitic clay.
Ore material: Bentonitic clay.
Deposit description:
Bentonitic clay in alluvium. Workings: shallow surface.
Geology: Bentonitic clay in alluvium, probable old lake bed, probable swelling type and derived from alteration of tuffaceous sediments.
Production: Few hundred tons in 1940's.
References: Stipp et al., 1967; Keith, 1978.

145. **Green Streak Mine**
Location: NE 1/4 sec. 28, T9N, R16W.
Commodities: Cu, Au, Ag.
Ore Material: Oxidized copper mineralization.
Deposit description:
Spotty copper mineralization in a quartz vein.
Geology: Mineralization in quartz vein cutting metamorphic core complex (gneiss and schist).
Production: 200 tons of ore in 1953-1954 averaging 1.3% Cu, 0.2 oz Au/T and 0.1 oz Ag/T.
Reference: Keith, 1978.

146. **Bullion Mine Group**
Other name: Scotchman
Location: SE 1/4 sec. 12, T7N, R18W.
Commoditieso: Cu, Au, Ba, Fe, Mn.
Ore Materials: Oxidized copper, chalcocite, barite, hematite, manganese oxide.
Deposit description:
Spotty lenses and streaks of leached and oxidized copper mineralization, local chalcocite enrichment. Barite, quartz, calcite, hematite and manganese oxides in gangue.
Geology: Mineralization in fissure veins in metamorphosed Mesozoic schist and limestone cut by diorite porphyry dikes.
Production: 1915-1918 50 tons of ore averaging 11% Cu and 0.09 oz. Au/T.
Reference: Keith, 1978.

151. **Angelus Mine**
Location: SE 1/4 sec. 1, T10N, R17W.
Commodities: Au, Ag, Fe.
Ore material: Gold, iron oxide.
Deposit description:
Finely divided particles of gold in irregular streaks and small, discontinuous pockets of brecciated to pulverized sugary quartz with abundant iron oxide and sericite in a brecciated zone.
Geology: Mineralized breccia zone in siliceous Paleozoic schistose quartzite.
Production: 100 tons averaging 1 oz Au/T and 0.2 oz. Ag/T.
Reference: Keith, 1978.

152. **Argus and Maryland Mine Group**
Location: N central sec. 6, T10N, R16W.
Commodities: Cu, Fe, Au, Ag.
Ore material: Cupiferous hematite.
Deposit description:
Irregular lenses of cupiferous hematite in Paleozoic carbonate rocks.
Geology: Mineralized carbonate rocks along or above the brecciated and schistose contact with underlying Precambrian metamorphics.
Production: 250 tons of ore averaging 3% Cu, 0.4 oz. Au/T, 0.2 oz. Ag/T.
Reference: Keith, 1978.

153. **Lucky Mine Group**
Location: S central sec. 12, N central sec. 13, T10N, R17W.
Commodities: Mn, Fe.
Ore Materials: Manganese and iron oxides.
Deposit Description:
Manganese oxides mixed with iron oxides in irregular replacement lenses in Paleozoic limestone and in fractures, seams, veinlets, and irregular bunches.
Geology: Mineralized limestone beds underlain by sandstone and Precambrian metamorphics.
Production: 275 tons of ore produced.
Reference: Keith, 1978.

154. **Revenue Mine Group**
Location: Central sec. 31, T10N, R15W.
Commodities: Cu, Fe, Ag, Au.
Ore material: Oxidized copper mineralization and hematite.
Deposit description:
Oxidized copper mineralization in lensing hematite replacement bodies in folded and faulted Paleozoic limestone.
Geology: Mineralized faulted Paleozoic limestone along a fault contact with underlying Precambrian metamorphic rocks. Granite nearby.
Production: 200 tons averaging 2% Cu and minor gold.

Oxide and sulfide copper mineralization in irregular, lensing and often massive iron oxide replacement bodies in bedded, faulted, folded and tilted Paleozoic limestone, marble, and dolomite and in Precambrian schist, usually close to faulted and brecciated contact of carbonate beds with Precambrian gneiss and schist. Manganese oxides associated with iron oxides occur in irregular bodies along shear zones in Paleozoic quartzite and limestone and along Paleozoic limestone beds. Free gold occurs in fractures in Paleozoic or Precambrian quartzite.

Production: Several large scale open pit and shaft operations and many smaller mines and prospects worked from the 1860's to recent times. Total estimated and recorded mine production of base and precious metals is some 1.4 million tons of ore containing 23 thousand tons of copper, 1008 ounces of gold, 35 thousand ounces of silver, 400 tons of manganese ore and concentrates have been shipped.

Reference: Keith, 1978.

Note: District boundary line is approximate.

Known Prospects, Mineralized Areas, And Geothermal Resources with No Recorded Production

2. Buckskin Mountain-Mineral Hill

Location: 34°14'20"N, 113°59'30"W, NW 1/4 sec. 1, T10N, R17W. Location was modified from the CRIB location by use of the geologic descriptions in Arizona Bureau of Mines Bulletin 180.

Commodities: Fe, Sb, Cu.

Ore Materials: Hematite, copper minerals.

Deposit description and geology: Specularite and associated copper minerals replace beds of metamorphosed Paleozoic limestone.

Production: Unknown.

References: USGS CRIB Mineral Resources File 12, Record 2657, p. 6758; Arizona Bureau of Mines Bulletin 180.

5. Good Bet Prospect

Other name: Smokey.

Location: 33°56'11"N, 113°55'29"W, Sec. 21, T7N, R16W.

Commodity: Fe.

Ore Material: Hematite.

Deposit Description: Small replacement deposit.

Geology: Ore is in fractured Mesozoic granite and replaces limestone.

Production: None.

Reference: USGS, CRIB Mineral Resources File 12, Record 2775, p. 7076-7077.

10. **Bouse Gold-Copper Prospect**
Location: 33°56'04"N, 114°04'43"W,
Sec. 19, T7N, R17W, and sec. 24, T7N, R18W.
Commodities: Au, Cu, Fe.
Ore materials: Hematite.
Deposit description:
300 feet long, 30 to 40 feet thick, irregularly shaped replacement deposit. Workings: inclined shaft.
Geology: Hematite replaces Precambrian(?) limestone which has been intruded by Precambrian(?)biotite granite.
Production: Unknown.
Reference: USGS CRIB Mineral Resources File 12, Record 2780, p. 7090-7091.

16. **Mineral No. 1 Prospect**
Location: 34°08'45"N, 114°04'42"W,
Sec. 6, T9N, R17W.
Commodity: Au.
Ore material: Gold.
Deposit description:
Small S50°E-trending, NE dipping, irregularly shaped vein. Workings consist of shallow shaft and surface cut.
Geology: Mineralization in Precambrian gneiss and schist associated with Tertiary aplite, pegmatite and basic dikes. Gangue is quartz.
Production: None.
Reference: USGS CRIB Mineral Resources File 12, Record 2800, p. 7147-7149.

17. **Mail Pouch Prospect**
Other name: Little Golden
Location: 34°08'08"N, 114°03'15",
Sec. 9, T9N, R17W.
Commodity: Au.
Ore material: Gold.
Deposit description:
Small S20°E-trending, 40°N dip, irregularly shaped vein, workings consist of a short shaft and open cuts.
Geology: Mineralization in metamorphic core complex (gneiss-schist), associated with Tertiary aplite, pegmatite and basic dikes.
Production: None:
References: USGS CRIB Mineral Resources File 12, Record 2801, p. 7150-7151.

22. **Mohave Chief and Norma Prospect**
Location: 34°13'48"N, 114°00'37"W,
Sec. 10, 11, T10N, R17W.
Commodity: Cu.
Ore materials: Chrysocolla and brochantite.
Deposit description:

Small N20°W-trending, irregular shaped replacement, surface and underground workings consist of several open cuts and an adit.

Geology: Mineralization in Paleozoic limestone, shale and quartz chlorite schist.

Production: None.

References: USGS CRIB Mineral Resources File 12, Record 2812, p. 7177-7178.

32. **Dome City Prospect**

Location: 34°09'39"N, 114°04'44"W, Sec. 31, T10N, R17W, and sec. 36, T10N, R18W.

Commodities: Au (major product); Fe (minor product).

Ore material: Specularite.

Deposit description: Small, irregular shaped vein, surface and underground workings which consist of shallow shafts and open cuts.

Geology: Mineralization in Precambrian gneiss and schist associated with Tertiary aplite, pegmatite and basic dike.

Production: None.

References: USGS CRIB Mineral Resources File 12, Record 2822, p. 7206-7208.

43. **Unnamed Fluorspar Occurrence**

Location: Sec. 21, T10N, R17W.

Commodity: F

Production: Unknown.

Reference: McCrory and O'Haire, 1965.

44. **Unnamed Sand, Gravel and Crushed Rock Occurrence**

Location: Sec. 36, T10N, R19W.

Commodities: Sand, gravel and crushed rock.

Production: Unknown

Reference: McCrory and O'Haire, 1965.

45. **Unnamed Sand, Gravel and Crushed Rock Occurrence**

Location: Sec. 26, T10N, R19W.1

Commodities: Sand, gravel and crushed rock.

Production: Unknown.

Reference: McCrory and O'Haire, 1965.

46. **Unnamed Sand, Gravel and Crushed Rock Occurrence**

Location: Sec. 1, T9N, R19W.

Commodities: Sand, gravel and crushed rock.

Production: Unknown.

References: McCrory and O'Haire, 1965.

47. **Unnamed Barite Occurrence**

Location: Sec. 17, T7N, R17W.

Commodity: Ba.

Production: Unknown.

References: McCrory and O'Haire, 1965.

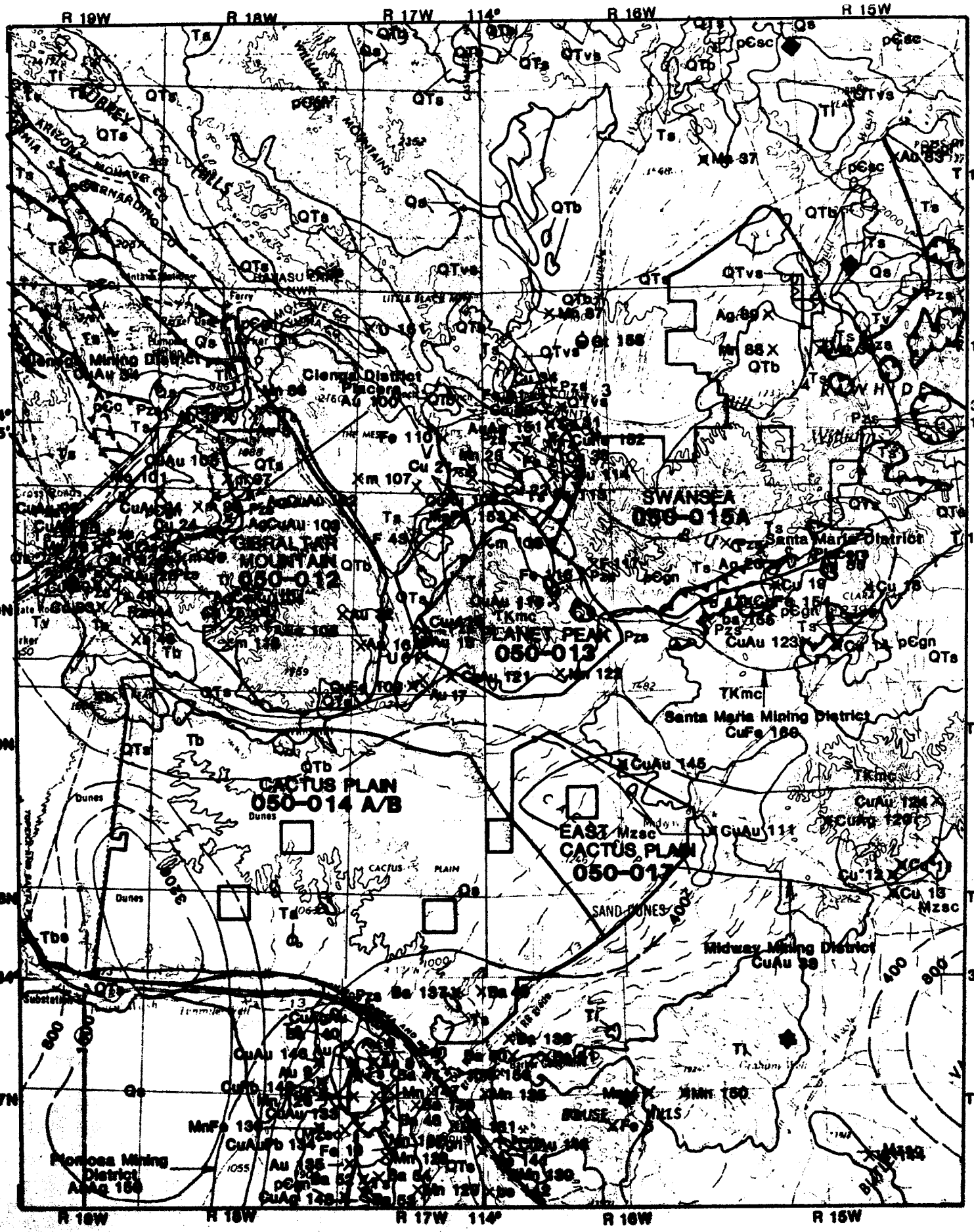

FIG.4 GEOLOGIC, ENERGY AND MINERAL RESOURCES MAP OF THE BUCKSKIN SUB-AREA, ARIZONA

Scale
1 : 250,000

USGS OF 81-503

THE VARIABILITY OF "MESOZOIC SEDIMENTARY ROCKS" IN NORTHERN YUMA COUNTY, WESTERN ARIZONA

Marshak, Stephen, Lamont-Doherty Geological Observatory and Department of Geological Sciences of Columbia University, Palisades, NY 10964

Extensive areas of western Arizona are mapped as "Mesozoic Sedimentary Rocks" on the Geologic Map of Arizona (Wilson, Moore, and Cooper, 1969) (Figure 1). A reconnaissance of exposures of this unit in northern Yuma County revealed that outcrop appearance is highly variable as a consequence of major variations in lithologic composition and degree of metamorphism (Marshak, 1979). To emphasize this variability, lithologic summaries of selected exposures are presented below. The rock names given are field names.

Dome Rock Mountains: Most of the southern half of this range was mapped by Wilson and others (1969) as "Mesozoic Sedimentary Rocks". An approximately 5000 m thick section of mildly metamorphosed sedimentary rocks is exposed in this area (Marshak, 1980). The lower portion of this section is composed predominantly of calcareous quartz sandstone, quartzite, maroon phyllite, and conglomerate (with quartzite and limestone clasts). Higher in the section, the predominant lithologies are greywacke, grey phyllite, and polycomponent conglomerate (which includes granitic clasts). The sedimentary section structurally overlies volcanic and volcanoclastic terranes, generally dips homoclinally southeast, and is cut by north-dipping cleavage. The sedimentary section of the Dome Rock Mountains is very similar to one described by Harding (1980) and Robison (1980) in the nearby Livingston Hills.

The Geologic Map of Arizona shows a small area of "Mesozoic Sedimentary Rocks" at the northern end of the range. This exposure is composed of metamorphic rocks including biotite schist, augen gneiss, quartzite, and marble.

Little Harquahala Mountains: The area mapped as "Mesozoic Sedimentary Rocks" in this range includes two distinctive sequences. The first is composed of interbedded maroon quartzite, maroon silty shale, and limestone. The second is composed of maroon quartzite conglomerate (with cobble to small boulder sized quartzite clasts), green-grey polycomponent conglomerate (with quartzite, limestone, conglomerate, and arkose clasts), feldspathic quartz sandstone, and mudstone. Ripple marks, cross-beds, mudcracks, and raindrop impressions occur widely in the second sequence.

Granite Wash Mountains: The metamorphic grade of lithologies mapped as "Mesozoic Sedimentary Rocks" increases from southwest to northeast (up-section) in this range. For purpose of discussion, the exposed sequence is divided into four units (A-D). Unit A, the base of the sequence, is composed of unmetamorphosed locally conglomeratic greywacke and silty shale. Load casts, graded beds, and rip up clast conglomerate locally occur in this unit. Unit B is composed of interlayered biotite-quartz-feldspar schist, phyllite, siliceous limestone, and amphibole-chlorite-quartz-plagioclase schist. Unit C is composed of quartz-sericite schist and fault-bounded outcrops of amphibole-chlorite-quartz-plagioclase schist. Unit D is composed of coarse-grained augen gneiss, and fine-

grained biotite gneiss that has well developed compositional banding. A 1 m thick layer of marble crops out near the top of the unit. Unit D is intruded by small diorite plugs.

Plomosa Mountains: The area mapped as "Mesozoic Sedimentary Rocks" in this range is composed predominantly of biotite gneiss. Mineralogical and textural characteristics vary from layer to layer. Interlayered with the gneiss are layers of quartzite and phyllite. Also within the area mapped as "Mesozoic Sedimentary Rocks" is a fault bounded block of intensely deformed marble and quartzite (lithologies which resemble rocks mapped as Paleozoic strata in nearby areas) and an extensive terrane of granite with roof pendants of biotite gneiss.

This work was conducted while the author was a student at the University of Arizona. Financial and logistical support provided by the Arizona Bureau of Geology is gratefully acknowledged.

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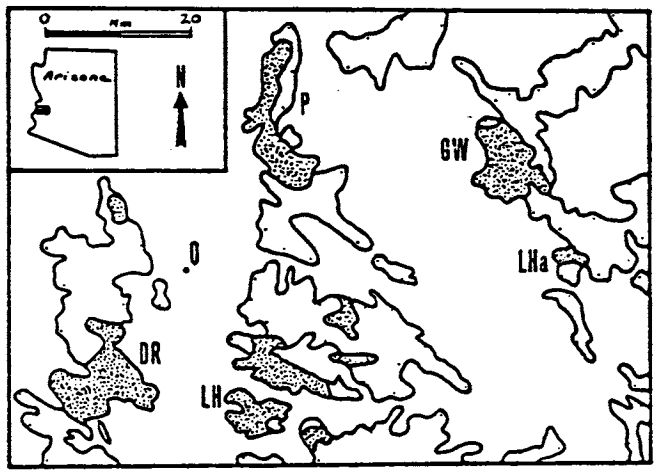

FIGURE 1: Location Map. Shaded areas are "Mesozoic Sedimentary Rocks" after Wilson and others (1969). DR = Dome Rock Mts., GW = Granite Wash Mts., LH = Livingston Hills, P = Plomosa Mts., LHa = Little Harquahala Mts., O = Town of Quartzsite.

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REPORT OF ANALYSIS

JOB NO. UGH 008
July 17, 1982

DEKALB MINING INCORPORATED
Attn.: Mr. Gary A. Parkinson
2659-G Pan American Freeway, NE
Albuquerque, New Mexico 87107

YUMA Co, AZ

Analysis of 46 Rock Chip Samples

ITEM	SAMPLE NO.	Au ppm	Ag ppm	W ppm
1	X 1351	<.02	<.2	2.
2	1352	<.02	<.2	3.
3	1353	<.02	<.2	<2.
4	1354	<.02	<.2	5.
5	1355	<.02	<.2	10.
6	1356	<.02	<.2	3.
7	1357	<.02	<.2	3.
8	1358	<.02	<.2	3.
9	1359	<.02	<.2	2.
10	1360	<.02	<.2	100.
11	1361	<.02	<.2	13.
12	1362	<.02	<.2	8.
13	1363	<.02	<.2	9.
14	1364	<.02	<.2	2.
15	1365	<.02	<.2	4.
16	1366	<.02	<.2	16.
17	1367	<.02	<.2	<2.
18	1368	<.02	<.2	<2.
19	1369	<.02	<.2	<2.
20	1370	<.02	<.2	2.
21	1371	<.02	.8	3.
22	1372	.07	9.6	150.
23	1373	<.02	<.2	42.
24	1374	<.02	.2	<2.
25	1375	<.02	<.2	<2.

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Arizona Registered Assayer No. 9425

James A. Martin
Arizona Registered Assayer No. 11122

SKYLINE LABS, INC.

P.O. Box 50106 • 1700 West Grant Road
Tucson, Arizona 85703
(602) 622-4836

JOB NO. UGH 008
July 17, 1982
PAGE 2

ITEM	SAMPLE NO.	Au ppm	Ag ppm	W ppm
26	1376	<.02	.6	<2.
27	1377	.03	2.0	3.
28	1378	<.02	.2	5.
29	1379	<.02	<.2	3.
30	1380	~~12.00~~ .12 ppm	<.2	9.
31	1381	<.02	<.2	3.
32	1382	.20	.4	22.
33	1383	.38	.4	1800.
34	1384	.05	.2	185.
35	1385	5.20	.2	42.
36	1386	<.02	.2	4.
37	1387	<.02	<.2	<2.
38	1388	<.02	<.2	<2.
39	1389	<.02	.2	<2.
40	1390	<.02	.4	<2.
41	1391	<.02	<.2	<2.
42	1392	<.02	.2	<2.
43	1393	<.02	<.2	<2.
44	1394	<.02	.2	2.
45	1395	<.02	<.2	<2.
46	1396	<.02	<.2	<2.

REGISTERED ASSAYER
CERTIFICATE NO.
9425
WILLIAM L.
LEHMBECK
ARIZONA, U.S.A.

William L. Lehmbeck
Manager

SKYLINE LABS, INC.
P.O. Box 50106 • 1700 West Grant Road
Tucson, Arizona 85703
(602) 622-4836

REPORT OF ANALYSIS

CORRECTED REPORT
JOB NO. UGH 008
July 27, 1982

DEKALB MINING INCORPORATED
Attn.: Mr. Gary A. Parkinson
2659-G Pan American Freeway, NE
Albuquerque, New Mexico 87107

Analysis of 46 Rock Chip Samples

ITEM	SAMPLE NO.	Au ppm	Ag ppm	W ppm
1	1351	<.02	<.2	2.
2	1352	<.02	<.2	3.
3	1353	<.02	<.2	<2.
4	1354	<.02	<.2	5.
5	1355	<.02	<.2	10.
6	1356	<.02	<.2	3.
7	1357	<.02	<.2	3.
8	1358	<.02	<.2	3.
9	1359	<.02	<.2	2.
10	1360	<.02	<.2	100.
11	1361	<.02	<.2	13.
12	1362	<.02	<.2	8.
13	1363	<.02	<.2	9.
14	1364	<.02	<.2	2.
15	1365	<.02	<.2	4.
16	1366	<.02	<.2	16.
17	1367	<.02	<.2	<2.
18	1368	<.02	<.2	<2.
19	1369	<.02	<.2	<2.
20	1370	<.02	<.2	2.
21	1371	<.02	.8	3.
22	1372	.07	9.6	150.
23	1373	<.02	<.2	42.
24	1374	<.02	.2	<2.
25	1375	<.02	<.2	<2.

Charles E. Thompson
Arizona Registered Assayer No. 9427

William L. Lehmbeck
Arizona Registered Assayer No. 9425

James A. Martin
Arizona Registered Assayer No. 11122

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36	1386	<.02	.2	4.
37	1387	<.02	<.2	<2.
38	1388	<.02	<.2	<2.
39	1389	<.02	.2	<2.
40	1390	<.02	.4	<2.
41	1391	<.02	<.2	<2.
42	1392	<.02	.2	<2.
43	1393	<.02	<.2	<2.
44	1394	<.02	.2	2.
45	1395	<.02	<.2	<2.
46	1396	<.02	<.2	<2.

*NOTE: Corrected value.

REGISTERED ASSAYER CERTIFICATE NO. 9425 WILLIAM L. LEHMBECK DATE SIGNED 7/27/82 Arizona U.S.A.

William L. Lehmbeck
Manager

[From the records of the U.S. Weather Bureau]

Year	Precipitation (inches)		Temperature (°F)					
	Aguila	Salome	Aguila			Salome		
			Mean	Maximum	Minimum	Mean	Maximum	Minimum
1939	11.02	10.57	64.8	115	18	68.0	116	22
1940	9.83	7.03	67.7	113	20	69.7	117	24
1941	18.72	16.75	63.9	114	24	65.6	112	26
1942	5.35	4.94	65.3	114	23	67.0	115	24
1943		6.99						
1944		10.53				66.2	113	24
1945		6.62				67.0	114	23
1946		7.58				67.6	113	23
1947		2.99				68.0	114	21
1948	6.53	4.72	65.2	112	18	66.9	115	17
1949	7.91	5.00	64.5	112	18	66.9	114	18
1950		5.29				68.8	118	15
1951	10.44	10.51	65.2	110	20	67.0	114	22
1952	11.73	9.11				66.7	110	24
1953	3.95	3.99	65.5	112	17	67.3	111	16
1954	4.46	5.71	67.4	112	16	69.0	113	20
1955	8.67	7.12	64.2	113	19	66.5	114	22
1956	2.45	1.28	65.3	113	12	67.2	115	15
1957	10.65		65.8	115	22			
Mean	9.45	7.97	65.5	112.7	18.9	67.6	114.3	20.[illegible]

August is the month of greatest precipitation and May and June are the months of least precipitation. Summer rains generally are torrential downpours that cause flash floods. A major part of the runoff occurs at this time. Winter rains commonly are gentle, and much of the precipitation infiltrates the soil.

The minimum annual precipitation in the area, 1.28 inches, was recorded at the Salome station in 1956 and the maximum annual precipitation, 18.72 inches, was recorded at the Aguila station in 1941.

The mean annual temperature is about 65.5°F at Aguila and 67.6°F at Salome. The highest temperature recorded in the valley was 118°F on August 1, 1950, at the Salome station, and the lowest temperature was 12°F on February 3, 1956, at the Aguila station.

HISTORY OF GROUND-WATER DEVELOPMENT

Development of the ground-water supplies in McMullen Valley was begun in 1875. Water was obtained from a dug well, which was used as a watering place on a stage coach route (Ross, 1923, p. 169). In 1907 the Arizona and California Railroad (now a part of the Atchison, Topeka and Santa Fe Railway) was completed from Wickenburg to Parker, and wells were drilled along the right-of-way at Aguila and Salome.

[illegible] the Bonanza Mine in the Little Harquahala Mountains obtained water from a well in Harrisburg Valley and pumped it through a 30,000-foot pipeline to the mine workings. Bancroft (1911, p. 22) reported the existence of "an extensive flow of water" a few feet below the surface along Centennial Wash in Harrisburg Valley. A proposal to build a dam that would force ground water to rise and thus provide a cheap source of water for irrigation was abandoned, probably because of the prohibitive cost of excavating the alluvial material to bedrock.

Wenden obtained its water supply from a well drilled at the schoolhouse in 1916. By 1918 at least 24 stock and domestic wells had been dug or drilled in McMullen Valley (Ross, 1923).

Ground water for irrigation was first used in Harrisburg Valley. Ross (1923, p. 169) stated that in 1917 Mr. Read of the Harquahala Livestock Co. was irrigating with water from 4 wells in the vicinity of the old town of Harrisburg and that an irrigation well about 4 miles to the northwest was capable of producing 400 gpm (gallons per minute). Records indicate that at least five irrigation wells had been drilled between 1917 and 1951 in the Salome-Harrisburg Valley area. The first deep irrigation well in the Aguila area was drilled in 1954. The successful completion of this well, reported to yield more than 2,000 gpm, gave impetus to the development of irrigation. By 1959, 27 more wells had been drilled in that part of McMullen Valley. In the Wenden and Salome-Harrisburg Valley areas, 23 irrigation wells were drilled between 1954 and 1959. Well-drilling activity was greatest during 1957 and 1958.

In 1957 an industrial well was drilled in Wenden to supply water for the Dasco Mine Mill. Another was drilled in the Aguila area in 1958 to supply water for a lettuce-packing plant.

GEOLOGY

The distribution of the various rock units in the McMullen Valley is shown on plate 1. The rocks include granite, gneiss, schist, and quartzite of Precambrian age; metamorphosed limestone, quartzite, and dolomite of Paleozoic age; granite and quartz monzonite of Mesozoic(?) age; sedimentary and igneous rocks of Tertiary(?) age; and lava flows and valley-fill deposits of Quaternary age.

ROCK UNITS AND THEIR WATER-BEARING CHARACTERISTICS

PRECAMBRIAN IGNEOUS AND METAMORPHIC ROCKS

The oldest rocks exposed in the mountains bordering McMullen Valley are regarded as Precambrian in age. These rocks constitute more than 80 percent of the outcrops in the mountains. Although they include granite, gneiss, schist, basic intrustives, and quartzite, they

have been mapped as a single unit. Dikes, mostly of aplite and pegmatite, are common throughout this unit. Some of the dikes may be younger than Precambrian.

The predominant rock in the Harcuvar Mountains is gneiss. The textural forms, however, range from gneiss to normal granite.

Precambrian rocks of the Harquahala Mountains are principally gneisses, although some coarse-grained granite crops out in the southwestern part of the mountains. Wilson and others (1957) considered the granitic and associated crystalline rocks in the east-central part of the range to be Laramide in age, but in this report these rocks have been included as part of the Precambrian complex. In the southwestern part of the Harquahala Mountains, about 4 miles south-southwest of Wenden, fine-grained calcareous, quartz-mica schist and a thin bed of quartzite overlie quartz-diorite gneiss. The same rock sequence crops out about 3 miles south of Salome on the southwest side of Harrisburg Valley. Bancroft (1911, p. 109) considered these rocks to be of Precambrian age.

Metamorphosed sedimentary rocks exposed in the Granite Wash Mountains also have been included in the Precambrian complex. These rocks consist principally of mica schist, quartzite, and some recrystallized limestone. Darton (1925, p. 221–223) stated that some of the limestone in this area is Paleozoic in age.

Many of the isolated mountains and hills north and east of Forepaugh are composed primarily of coarse-grained gray biotite granite of Precambrian age. Dikes of pegmatite and aplite, some several hundred feet long, occur in the granite.

Intense folding and other crustal movements resulted in planes of schistosity, joints, shear zones, and other openings in the crystalline rocks of the mountains. The quantity of water that moves through the openings is undoubtedly small, however. According to the driller's log, well (B–6–11)13bb was drilled through 379 feet of granite before it penetrated a 4-foot bed of water-bearing "sand." Probably the so-called sand is either breccia or gouge. Water production from this well was insufficient for a stock-water supply.

Bancroft (1911, p. 118) reported that the water level in a mine near Cunningham Pass was about 320 feet below the collar of the shaft and that water occurred in gneiss and schist.

Few data are available to evaluate the permeability and porosity of the Precambrian rocks in McMullen Valley. Nevertheless, in most places these rocks probably are not sufficiently permeable to yield large amounts of water.

PALEOZOIC SEDIMENTARY ROCKS

Sedimentary rocks of Paleozoic age crop out in the Harquahala Mountains about 8 miles south-southeast of Wenden. The mapped

outcrop within the drainage area is less than 1 square mile in areal extent and consists principally of quartzite, limestone, and some dolomite. The sedimentary rocks are part of a much larger outcrop of Paleozoic rocks on the south side of the Harquahala and Little Harquahala Mountains.

These rocks were first assigned to the Paleozoic era by Darton (1925, p. 221), who found fossils of Carboniferous age. Metzger (1957, p. 18) reported that E. D. Wilson of the Arizona Bureau of Mines found fossils of Cambrian and Permian age at Martin Peak in T. 4 N., R. 13 W. According to McKee (1951), the Paleozoic rocks are 2,235 feet thick. Thrust faulting has disturbed the original attitude of the rocks. The strike is generally northeast, and reversals of dip appear to be common.

Rocks of probable Paleozoic age are exposed at Eagle Eye Peak and in the Granite Wash Mountains but were not mapped because of their small areal extent. The outcrop at Eagle Eye Peak consists of dark-gray cherty limestone. The stratigraphic relationship is obscured by overlying volcanic material, but the lithologic character of the limestone indicates that it is probably of Paleozoic age. In the Granite Wash Mountains, limestone that Darton (1925, p. 223) believed to be of Paleozoic age is closely associated with quartzite and schist.

Most of the Paleozoic sedimentary rocks are many hundreds of feet above the valley floor and therefore lie above the water table and are not water bearing. Some of the Paleozoic rocks at the southeast end of Harrisburg Valley, however, form the upper part of a subsurface dam. The impervious part of the dam is formed by Precambrian rock.

The hydrologic properties of the Paleozoic strata in the area of the subsurface dam are important, not so much because of their relation to well-water supplies but because these properties affect the rate of ground-water movement from McMullen Valley to the Harquahala Plains where the water table intersects these strata. The strata have been shattered and apparently displaced by faulting. Brecciated fault zones, fractures, and cavities are exposed in the limestone outcrop. Prior to the development of irrigation wells in this area, well (B–5–12)32acc, about 1.4 miles northwest of the narrows, had a depth to water of 18 feet in May 1921. It seems probable that during this time the water table intersected the Paleozoic strata overlying the Precambrian gneiss and that ground water moved through the openings in the limestone into the Harquahala Plains.

MESOZOIC(?) INTRUSIVE ROCKS

Granitic intrusive rocks are exposed in the western part of the Harcuvar Mountains and in the Granite Wash Pass area in the

695–898 O—64——3

Granite Wash mountains. These rocks form the main part of the mountain mass within the drainage divide from west of Salome Peak to Low Mountain and on both sides of Granite Wash Pass. The granite in the Harcuvar Mountains is an extension of the laccolith mapped by Metzger (1951, pl. 1) in the Ranegras Plain area. The granite and quartz monzonite at Granite Wash Pass may be part of the same general intrusion that formed the laccolith (Metzger, 1951, p. 8).

The granite at Salome Peak is concordant with the Precambrian metamorphic complex. It is light tan where weathered and light gray on fresh fractures. The granite is medium to coarse grained and is composed principally of quartz and milky untwinned feldspar. It contains some biotite and white feldspar with albite twinning. Weathering along joints produces large rounded boulders.

The contact between the Mesozoic(?) granitic intrusive rocks and the Precambrian metamorphic rocks is exposed in a wash at the base of Salome Peak. It is sharp and irregular but generally is controlled by the bedding planes of the Precambrian host rock (fig. 4).

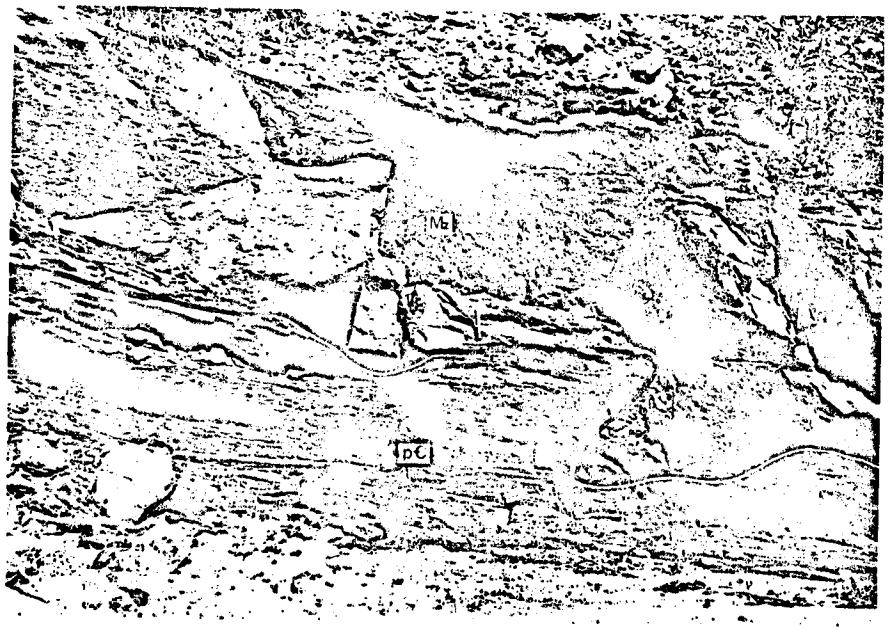

FIGURE 4.—Contact between granite of Mesozoic(?) age (Mz) and metamorphic rocks of Precambrian age (pC) at Salome Peak. View looking east.

West of Harcuvar Peak the granite is in contact with the Precambrian metamorphic rocks which dip into the base of the peak. Here, the foothills are composed of granitic gneiss with innumerable stringers of granite, probably offshoots of the main granitic intrusion, which run in diverse directions.

Dikes, which are alined roughly northwestward parallel to the trend of the Granite Wash Mountains, are associated with the granitic rocks of the Harcuvar and Granite Wash Mountains. Although they vary in composition, their texture is generally fine. Aplite is the most common type in all the areas of granitic intrusions, but—according to Bancroft (1911, p. 30)—some of the dikes in the vicinity of Harcuvar and Salome Peaks are composed of vogesite. The formation of the dikes probably was contemporaneous with the major intrusions. As the upper part of the granitic mass cooled, the lower part continued to push forward rupturing the upper part and permitting the dike material to intrude.

Bancroft (1911, p. 29) and Ross (1923, p. 29) considered the granitic intrusive rocks in the Harcuvar and Granite Wash Mountains to be of probable Mesozoic age. Because no evidence to the contrary has been presented, these rocks are considered by the writer to be of probable Mesozoic age.

The water-bearing properties of the Mesozoic(?) intrusive rocks are generally similar to those of the older granitic rocks in the area. Although small quantities of water probably can be obtained from the fractures, no large supplies can be developed from this relatively impermeable material.

TERTIARY(?) ROCKS

The rocks of probable Tertiary age constitute about 15 percent of the bedrock outcrop in McMullen Valley. The outcrops are limited to the eastern part of the valley, where they form discontinuous ridges and buttes. Sedimentary and volcanic rocks constitute the bulk of the exposures, but intrusive rocks of small areal extent also crop out.

SEDIMENTARY ROCKS

The lithologic dissimilarity of the Tertiary(?) sedimentary rocks in the more widely separated exposures precludes any correlation. The rocks are closely associated with volcanic rocks and owe their topographic prominence to the more resistant lava flows. The sediments have been faulted, tilted, and eroded so that the outcrops are discontinuous, are small in area, and do not occur as consecutive traceable sequences. For these reasons, they have been mapped as a single rock unit. The rocks are discussed according to their stratigraphic relation to volcanic flows and to the occurrence or lack of volcanic fragments in the strata. The units are as follows: (1) Basal arkose, (2) indurated fanglomerate, (3) thin-bedded limestone and sandstone, and (4) conglomeratic sandstone.

BASAL ARKOSE

A basal arkose of probable Tertiary age crops out along a southeastward-trending ridge in the northeastern part of the Harcuvar

Mountains, where it overlies the Precambrian crystalline rocks. The thickness varies, although it probably does not exceed 60 feet. The sorting is poor, and the bedding is indistinct. At the southeast end of the ridge in secs. 17, 19, and 20, T. 8 N., R. 8 W., the arkose contains lenses of conglomerate composed of boulders of granite and gneiss as much as 2 feet in diameter. It is overlain by volcanic flows that form the more resistant part of the ridge.

The arkose is composed of material derived from the granitic rocks upon which it lies and probably represents a fanlike deposit that accumulated along a border of considerable relief. The abundance of boulder beds and the size and character of the boulders in the southeastern part of the ridge indicate derivation from weathered boulder-clad surfaces that probably sloped southeastward. The absence of volcanic detritus from these sediments is significant, because other sedimentary rocks of Tertiary(?) age contain fragments of volcanic material.

Although its age is uncertain, the arkose is tentatively considered to be early Tertiary in age because of its similarity in lithologic character and physical setting to the deposit described by Lasky and Webber (1949, p. 18) as part of the Artillery Formation. The Artillery Formation is exposed in the Artillery and Rawhide Mountains about 35 miles northwest of Aguila and tentatively has been assigned an early Tertiary age by Lasky and Webber (1949, p. 21).

INDURATED FANGLOMERATE

An indurated fanglomerate of Tertiary(?) age crops out at Bullard Peak and consists of purple fragments of several types, principally andesites. The fragments range in size from less than 1 inch to angular blocks several feet in diameter. The fanglomerate is in contact with the Precambrian complex and is overlain by volcanic rocks. The deposit appears to be a clastic assemblage of brecciated volcanic rock (fig. 5), and the angularity of the fragments suggests local origin. The lack of stratification obscures the attitude of the deposit, and its thickness is unknown. The age of the fanglomerate is uncertain, but Bancroft (1911, p. 120) considered the material that constitutes Bullard Peak to be of probable Tertiary age. The fanglomerate is similar in some respects to the breccias in the Artillery Mountains area, which Lasky and Webber (1949, p. 47) considered to be of Tertiary(?) age.

THIN-BEDDED LIMESTONE AND SANDSTONE

Thin-bedded gray and pink limestone and gray coarse- to fine-grained sandstone are exposed at the north end of Eagle Eye Peak. These rocks are faulted, and step faulting has caused displacements

FIGURE 5.—Fanglomerate of Tertiary(?) age at the base of Bullard Peak.

ranging from a few inches to tens of feet. These sedimentary rocks have been intruded by breccia pipes and dikes.

CONGLOMERATIC SANDSTONE

Northeast of Eagle Eye Peak is a small butte composed of sandstone containing interbeds of conglomerate. The strata strike N. 60° E. and dip 26° NW. The sandstone consists of fine to very coarse sand of angular to subrounded quartz and volcanic detritus. The conglomerate consists of angular to rounded granules, pebbles, and boulders of volcanic and granitic rock and a fine to very coarse grained sandy matrix. The outcrop is dark reddish brown, and the rock fragments of the conglomerate are coated with desert varnish.

Southeast of Eagle Eye Peak in sec. 8, T. 6 N., R. 8 W., a conglomerate overlies volcanic rocks. The conglomerate consists of rounded to subrounded pebbles, cobbles, and boulders of granite, gneiss, and volcanic material as much as 1½ feet in diameter. The matrix is composed of a very coarse to fine-grained sand consisting of subangular to subrounded quartz and feldspar and minor amounts of accessory material (fig. 6). The contact of the conglomerate with the volcanic rocks strikes N. 53° W. and dips 56° SW.

Conglomerate crops out also along the drainage divide about 16 miles east of Aguila. It consists of well-cemented volcanic, granitic, and quartz fragments in a matrix of coarse-grained sand, and the bedding, generally indistinct, is flat where recognizable. The unit is underlain by aphanitic volcanic flows and overlain by vesicular basalt that is probably of Quaternary age. The stratigraphic relation of the conglomerate to the overlying basalt and the underlying aphanitic rocks plus the degree of consolidation of the conglomerate suggest a Tertiary age.

Southeast of Bullard Peak in secs. 12 and 13, T. 8 N., R. 10 W., and secs. 8 and 18, T. 8 N., R. 9 W., an isolated butte projects above the alluvium. It is composed of reddish-brown sandstone which contains granitic pebbles and cobbles as much as 12 inches in diameter, and fragments of vesicular basalt. The strata strike N. 35° W. and dip 30° SW. A fault has displaced the south end of the butte so that an underlying aphanitic fractured volcanic rock is exposed. Jones and Ransome (1920, p. 137) and Bancroft (1911, p. 32) considered this sandstone to be of probable Tertiary age. The relation of the outcrop to the other Tertiary(?) sedimentary rocks described is unknown. This outcrop, however, is underlain by volcanic material, and the fact that it contains fragments of vesicular basalt indicates that it probably is younger than the basal arkose that crops out along the ridge east of this point.

The lithologic character of the Tertiary(?) sedimentary rocks indicates that they are capable of transmitting water, although the

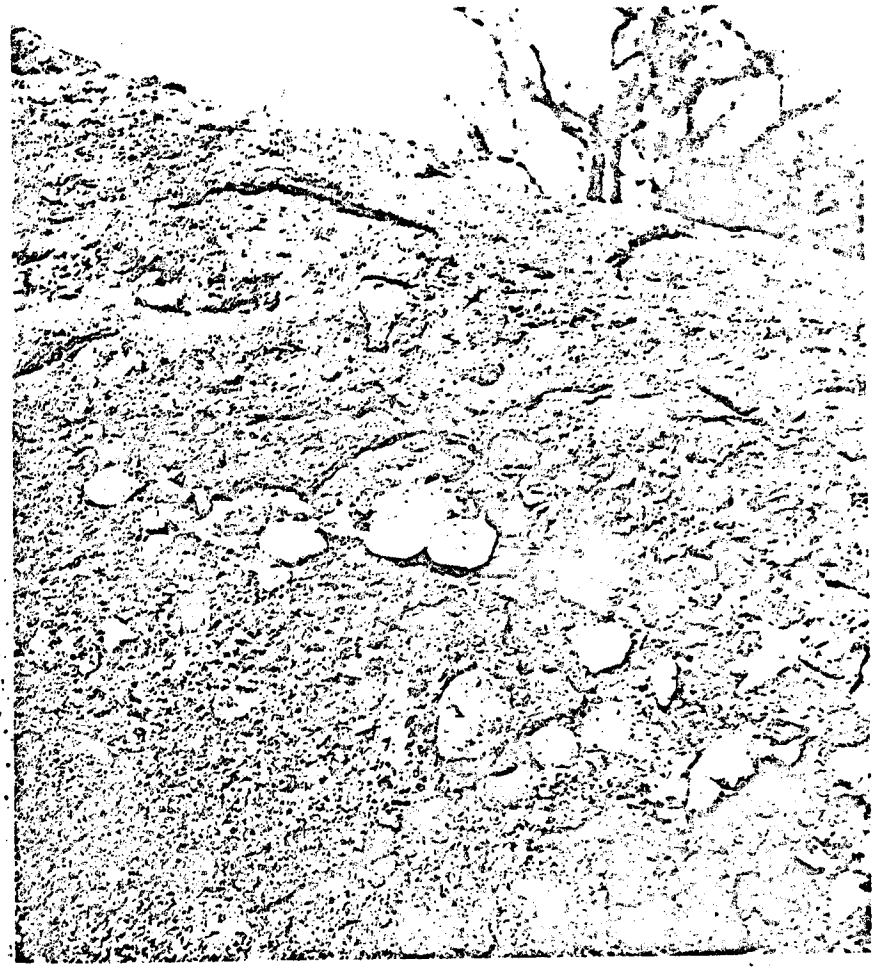

FIGURE 6.—Conglomerate of Tertiary(?) age southeast of Eagle Eye Peak. View looking east.

quantities probably are small owing to the degree of their consolidation and cementation. The potential for recharge from precipitation probably is small, because the outcrops are of small areal extent and are topographically high—a condition that causes rapid runoff.

EXTRUSIVE ROCKS

Extrusive rocks composed of felsite, andesite, and tuff crop out in the eastern part of the valley (pl. 1). Because most of the exposures are associated with the Tertiary(?) sedimentary rocks, these extrusive rocks are tentatively considered to be of Tertiary age.

The best exposure is northeast of Aguila on a prominent ridge that extends southeastward from the Harcuvar Mountains. There, steeply

dipping multicolored felsites overlie the basal arkose of Tertiary(?) age. The angle of the west slope of the ridge conforms generally to the dip of the flows which ranges from 15° to 60° SW. The exposed volcanic sequence is estimated to be about 400 feet thick; the individual flows range in thickness from 2 to a little more than 50 feet.

Although most of the felsites lack any megascopically identifiable crystals, some are porphyries which contain rectangular phenocrysts of white feldspar and a few quartz grains in a fine-grained groundmass. The topmost flow, which is light pink on fresh fractures, contains secondary prismatic quartz in small spherical hollows throughout the flow. The other outcrops generally are similar in appearance, although some flows in sec. 32, T. 7 N., R. 7 W., have structures of perlitic form and nodules and stringers of chalcedony.

The lava flows exposed at Bullard and Eagle Eye Peaks are dark colored and similar in composition. Both resemble basalt, but Bancroft (1911, p. 20) identified the rock at Bullard Peak as an augite andesite. The andesite at Bullard Peak overlies a tuff about 100 feet thick, and these volcanic rocks are underlain by the indurated fanglomerate of Tertiary(?) age (fig. 5).

On the west side of Eagle Eye Peak the volcanic rocks overlie Precambrian rocks. The contact is irregular and dips eastward. At the north end of the peak the volcanic rocks are in fault contact with Tertiary(?) sedimentary rocks.

Although direct evidence as to the age is lacking, the extrusive rocks are considered to be of Tertiary age because of their similarity to other rocks of southern Arizona that have been assigned to that age. This supposition by many geologists is based principally on field relations of these lava flows to rocks of known age.

In general the Tertiary(?) volcanic rocks are relatively impermeable except along faults or fracture zones and are of little value in the storage or transmission of large quantities of ground water. Two wells, (B-6-9)2abd and (B-7-7)17add, that tap these rocks near Eagle Eye Peak and east of Forepaugh yield only sufficient water for domestic use.

INTRUSIVE ROCKS

Intrusive breccia pipes and dikes are limited to a narrow zone at the north end of Eagle Eye Peak. These intrusives, consisting of fragments of sedimentary and volcanic rocks trend northwestward and appear to be concordant to the general structure. Although direct evidence as to the age of these intrusives is lacking, they are younger than the Tertiary(?) sedimentary rocks they invade and probably are related genetically to the volcanic activity that produced the andesite constituting most of Eagle Eye Peak.

QUATERNARY ROCKS

Quaternary rocks in McMullen Valley include basalt and valley-fill deposits. The basalt crops out only in the upper part of the valley. The valley fill, which is the most important rock unit with respect to ground water, is the surface deposit in more than 75 percent of the area. As used herein, the term "valley-fill deposits" is applied to all the unconsolidated and semiconsolidated sedimentary rocks that occupy the structural trough, even though some of the rocks at depth probably are of Tertiary age. Because the thickness of the exposed valley fill is nowhere more than a few tens of feet, the lithologic character and the thickness of the valley-fill deposits in McMullen Valley are known only from well logs, drill cuttings, and electric logs.

The valley-fill deposits have been divided into four subunits (pl. 2), which, in ascending order, are as follows: (1) Conglomerate, consisting of cemented coarse sand and gravel, that may have been deposited contemporaneously with the semiconsolidated strata of Tertiary(?) age; (2) alluvial-fan deposits, composed chiefly of material laid down by torrential streams; (3) lake-bed deposits, composed of clay, silt, and fine sand deposited, in part, contemporaneously with alluvial-fan deposits; and (4) alluvium, consisting of gravel, sand, and silt deposited in the central part of the valley and along the present stream channels.

VOLCANIC ROCKS

Volcanic rocks of Quaternary age are present only in the eastern part of the valley. They consist of basalt and are dark gray to purplish gray and massive. The flows are largely dense but are generally vesicular in the upper part. Erosion has removed large quantities of this material from the area, leaving small and discontinuous remnants. These outcrops form the black buttes north, south, and east of Forepaugh. The contact relations of the basalt with the underlying material are generally obscured by a mantle of slope debris; however, in sec. 17, T. 7 N., R. 6 W., a thin vesicular flow overlies sedimentary rocks of Tertiary(?) age. Southwest of this outcrop, basalt, too small in areal extent to map, lies directly upon Precambrian crystalline rocks. The butte 2 miles south of Forepaugh is composed of a sequence of basalt flows and contains an 8-foot interbed of poorly consolidated conglomeratic sand. The sequence overlies unconformably the pink to red felsites of Tertiary(?) age. About 2½ miles north-northeast of Forepaugh, 2 small hills that project above the alluvium are composed of basalt, but the base of the flow is not exposed. The dip of the flow is less than 10°.

The unconformable relation of the basalt to the underlying Tertiary (?) volcanic rocks 2 miles south of Forepaugh and the gentle

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dip of the basalt flows in contrast to the steep dip of the older volcanics, lend credence to the designation of Quaternary age, although the basalt is probably not younger than early Pliestocene age.

The basalt is not an aquifer. It is of small areal extent and apparently is absent in the subsurface; so it does not affect the occurrence of ground water.

VALLEY-FILL DEPOSITS

Most of the valley fill in McMullen Valley is the result of stream transportation and sorting of rock material from the mountains and subsequent deposition of this material on the adjacent land surfaces, a process that is commonly operative in the arid to semiarid regions of southwestern Arizona.

The mechanics of the process are controlled by several factors, such as the stream gradient and shape of the stream channel, volume of runoff, character of the sediments transported, and position of the local base level. In the mountain areas the streams are confined to narrow channels of steep gradient. After torrential storms, the streams have high velocities and carry heavy loads of detrital material. As the streams emerge into the valley, their channels decrease in slope and widen, thus reducing the velocity of the streamflow. In the central part of the valley, the confluence of the mountain streams with the axial drainage forms an environment characterized by shallow shifting stream channels. Layers of debris accumulate on the surfaces of the slopes, as the valley-floor levels (local base levels) rise by aggradation. Hence, the deposition of material produces the detrital slopes and aggraded valleys which are characteristic of intermontane basins.

Under ideal conditions, the material from the mountain slopes would be arranged in zones parallel to the mountains and normal to the courses of the streams. The coarse material would be deposited near the flanks of the mountains, and the fine detritus would accumulate further downslope toward the central part of the valley. However, the variable factors of precipitation, local base-level fluctuations, and shifting stream channels modify the zonal arrangement. If a local base level lies within the valley and runoff due to precipitation exceeds the rate of dissipation, a body of water accumulates to form a lake. Fine-grained sediments are deposited within the lake concurrently with the deposition of the heterogeneous material around the periphery of the lake.

The total thickness of the valley fill in the deeper parts of the McMullen Valley's structural trough is unknown, but it may be several thousand feet. In the areas where the valley fill is relatively thin, boreholes have penetrated bedrock along which may be the buried periphery of the trough. In the drilling of a well upstream from the narrows in Harrisburg Valley, granite was penetrated at a depth of

52 feet. At the narrows, the fact that bedrock projects from the sediments on both sides of the stream channel indicates that a thin mantle of material covers a structural dam separating McMullen Valley from the Harquahala Plains.

In the western part of McMullen Valley, well (B-5-13)19bcd penetrated 282 feet of valley fill before reaching granitic bedrock. In the eastern part of the valley, wells (B-7-7)17add and (B-7-8)1dac reached volcanic rock at depths of 161 and 297 feet, respectively. However, well (B-7-8)15baa, which is only 2½ miles southwest of well (B-7-8)1dac, is bottomed in valley-fill deposits at a depth of 1,812 feet. This well is the deepest in the valley.

CONGLOMERATE

In the Aguila area drill cuttings indicate that conglomerate is present at a depth of about 850 to more than 1,600 feet. Greater cementation distinguishes the conglomerate from the overlying sediments. Because no well has been drilled completely through the conglomerate its thickness is not known, although 460 feet of this material was penetrated in well (B-7-9)17dcd.

Drill cuttings from deep rotary-drilled wells indicate that the conglomerate consists of a fine to very coarse sand and gravel that is well cemented with calcareous material. Whether argillaceous cement is present was not determined. The sand in the conglomerate is composed principally of angular to subrounded quartz grains. The gravel consists of angular to rounded fragments of volcanic, granitic, and quartzose material as much as 11 mm in diameter. Possibly the larger angular fragments were derived from boulders crushed by the drilling bit.

A qualitative analysis of an electric log of well (B-7-9)16add indicates that the conglomerate varies considerably in relative resistivity and, therefore, in permeability also. The variations are probably due to differential cementation.

The drill cuttings indicate that the conglomerate is sufficiently permeable to be a potential source of water supply. Although pumping tests were made of wells that bottom in the conglomerate, the data from the tests do not indicate the hydrologic properties of the conglomerate, because the wells also tap all the overlying water-bearing material.

ALLUVIAL-FAN DEPOSITS

The alluvial-fan deposits are composed of heterogeneous material laid down by torrential streams issuing from the mountains. In McMullen Valley the coalescing fans form an apron slope which projects from the base of the mountains toward the valley floor. These fan deposits also underlie most of the valley floor; in the Aguila area they overlie the conglomerate, and in Harrisburg Valley they overlie

granitic gneiss. Although the buried fan deposits appear to be a continuation of the material on the valley slopes, those at depth in the central part of the valley are much finer grained than those on the slopes.

The alluvial-fan deposits range in thickness from a thin mantle on the slopes of the mountains to several hundred feet in the valley. In the Aguila area, the unit is about 800 feet thick in wells drilled in secs. 10, 11, and 12, T. 7 N., R. 9 W. In well (B-7-9)17ded it is slightly more than 650 feet thick. An electric log of well (B-7-9)4bbb, 1,650 feet deep, indicated that the unit had not been completely penetrated.

In the Wenden area the total thickness of the alluvial-fan deposits is undetermined, because no wells have been drilled to bedrock. In well (B-6-12)22add the unit is at least 282 feet thick and in well (B-6-12)15bbb at least 232 feet.

The alluvial-fan deposits consist of gravel, sand, silt, and clay. These deposits occur generally as a heterogeneous mixture but locally as sorted gravel and sand containing little fine-grained material. Their accumulation may be illustrated by considering slope building in detail. During a torrential flood, boulders may be carried far out into the valley and deposited on top of fine sediments laid down by a previous smaller flood: in the lower stages after the crest of the flood and in succeeding small floods, sand and clay may, in turn, be deposited over and throughout the coarse material. Furthermore, the deposits of a stream draining a relatively large area may overlap and be interbedded with deposits of a neighboring stream draining a small area. Nevertheless, some stream channels may retain their positions for long periods of time, and in the process of carrying sediments the streams can deposit a train of well-sorted sand and gravel.

The alluvial-fan deposits constitute the principal water-bearing unit in McMullen Valley. Most of the irrigation wells obtain part or all their yield from them. Drill cuttings from wells indicate that the more permeable beds of sand and gravel are lenticular and not extensive. Obviously, the hydrologic properties of these deposits are not uniform.

Large-diameter irrigation wells tapping the heterogeneous lenticular deposits produce 150 to about 3,500 gpm. The wide range in production is due not only to the wide range in hydrologic properties of the material penetrated but also to the different depths and construction of the wells.

LAKE-BED DEPOSITS

Fine-grained materials in the lower part of the valley were probably deposited in a body of standing water. In contrast to the alluvial-fan deposits, these sediments are almost homogeneous. Apparently the material has undergone a more thorough and selective grading than it would have received under ordinary conditions of stream deposition.

The occurrence of gypsum and other salts, although not conclusive, suggests that the lake may have been ephemeral or nearly so, the salts precipitating when the lake was on the verge of drying up. Chemical analyses of water obtained from these sediments show a higher content of dissolved solids than the analyses of water from the underlying alluvial-fan deposits. The lithologic characteristics and thickness of the sediments have been determined from well data, because these deposits are not exposed.

The lake-bed deposits are thickest northeast of Wenden, where well (B-6-12)15bbb penetrated about 1,100 feet of reddish-orange to pale-red clay and silt containing grains of sand and some gypsum and salt (table 2). The driller's log of well (B-6-12)22add, 3½ miles northeast of Wenden, indicates that the lake-bed deposits are 584 feet thick (table 3), and well (B-6-12)29cdc, about half a mile northeast of Wenden, penetrated 400 feet of this material before entering the alluvial-fan deposits. A log of well (B-5-13)2caa, 3 miles southwest of Wenden, indicates a thickness of 150 feet of "bentonite" or silty clay. As illustrated in plate 2, the lake-bed deposits thin to the northeast and also to the southwest from the center of T. 6 N., R. 12 W., and probably thicken northward.

The lake-bed deposits underlie at least 30 square miles and possibly an even larger area. The dearth of subsurface data for the central part of the valley precludes delineation of the boundary of the clay body.

TABLE 2.—*Lithologic log of well (B-6-12)15bbb 4 miles north-northeast of Wenden*

[Colors determined by comparison with the color chips on the rock color chart distributed by the National Research Council (Goodard and others, 1948)]

Depth (feet)	*Description*
	Alluvium
0-90	Sand, silt, and gravel, moderate-orange-pink (5*YR* 8/2), poorly sorted. The sand consists of very fine to very coarse grained quartz. Gravel consists of fragments of granite as much as 6 mm in diameter. Weak calcareous cement.
90-100	Sand and silt, grayish-orange (10*YR* 7/2), poorly sorted. The sand consists of very fine to very coarse grained quartz. Weak calcareous cement.
	Lake-bed deposits
100-110	Silt, clay, and sand, moderate-reddish-orange (10*R* 6/6), poorly sorted. The sand consists of very fine to fine-grained clear and milky quartz. Calcareous and argillaceous cement.
110-160	Same as 100-110; fine-grained sand less abundant.
160-180	Silt, clay, and sand, pale-reddish-orange (10*Y* 5/4), poorly sorted. The sand is fine grained and contains a few coarse particles. Calcareous and argillaceous cement.
180-190	Sand, silt, and clay, moderate-orange-pink (10*Y* 7/4), poorly sorted. The sand grains are angular and consist of very fine to medium-grained clear and milky quartz. Calcareous cement.
190-350	Silt and clay, moderate-orange-pink (10*R* 7/4). Calcareous and argillaceous cement.

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TABLE 3.—*Geologic interpretation of drillers' log of wells in McMullen Valley*—Continued

Well location and rock description	Thickness (feet)	Depth (feet)	Altitude (feet)
(B-6-12)22add—Continued			
Alluvial-fan deposits:			
Decomposed granite	10	670	1,258
Sand, water-bearing (hole filled up 400 feet within 2 minutes)	5	675	1,253
Gravel, water-bearing	10	685	1,243
Clay and gravel	8	693	1,235
Clay and gravel streaks	8	701	1,227
Decomposed granite	24	725	1,203
Gravel	15	740	1,188
Cemented gravel	5	745	1,183
Gravel, water-bearing	90	835	1,093
Decomposed granite	25	860	1,068
Gravel, water-bearing	10	870	1,058
Hard shell	5	875	1,053
Gravel, water-bearing	25	900	1,028
Hard shell	5	905	1,023
Gravel, water-bearing	5	910	1,018
Hard shell	20	930	998
Sand, water-bearing	10	940	988
Hard shell	3	943	985
Total		943	

Geologic literature on the western part of the United States is replete with data concerning lake-bed deposits in the intermontane basins of the Basin and Range province. Hundreds of ancient lakes have left deposits as evidence of their existence. Many of these lakes may have collected in basins, persisting only so long as the valley had not been filled with sediments up to the level of an outlet. Little is known of the climate that caused the lakes to form and then disappear, but it is a reasonable assumption that the climate was more humid than at present. Blackwelder (1948, p. 11) stated:

> For reasons which are unkown, there occurred in the Pliestocene epoch at least four and perhaps five ages * * * of much colder climate which induced the formation of glaciers on all the higher mountains of the great basin and particularly upon the marginal ranges to the east and west. * * * During the coldest ages, when the temperature was probably * * * below the long term average, the evaporation was much slower, and hence the region must have been decidely less arid.

Thick bodies of clay are present along the Gila River in Arlington Valley, Salt River Valley, and other areas in southwestern Arizona. Ross (1923, p. 91), in his treatment of the Gila River, stated:

> The formation of any such mass of clay as appears to be present in the valley of the Gila River must have occurred under conditions very different from those of the present day. Clay silts are deposited in quiet places in the present stream, but that hundreds of feet of clay, mixed with only minor amounts of sand, could be laid down by a turbulent and variable river like the Gila is not conceivable. It would appear that the clay must have been deposited in some quiet body of water such as a lake. The record of the presence of the clay is not continuous throughout the river valley, and the clay may not be a continuous and uninterrupted body. It may have been formed in a series of lakes, perhaps corresponding to the series of structural valleys that unite to form the long, sinuous valley of the Gila.

The fine-grained sediments in McMullen Valley may be contemporaneous with the clay described by Ross.

The lake-bed deposits in McMullen Valley are not considered to be a potential source of water supply for irrigation, because the fine-grained material has a very low permeability. Thus ground-water movement toward a well is retarded. Although some stock and domestic wells obtain water from these deposits, the quantities are small and the water has a higher concentration of dissolved solids than water from the other units.

ALLUVIUM

The upper part of the valley-fill deposits in McMullen Valley consists of alluvium deposited by Centennial Wash and its tributaries in late Pliestocene and in Recent time. The alluvium is composed largely of unconsolidated silt, sand, and gravel: in places, cementation by calcium carbonate has produced layers of caliche. In the central part of the valley the alluvium overlies lake-bed deposits, but elsewhere in the valley it overlies alluvial-fan deposits. The contact of the alluvium with underlying materials is generally apparent from drill cuttings, electric logs, and drillers' logs. The exposed contact of the alluvium with the alluvial-fan deposits mantling the lower slopes of the mountains is not so obvious, however.

The exposed alluvium along the channel of Centennial Wash is about 10 feet thick. Where penetrated by wells, the alluvium ranges in thickness from slightly less than 50 feet to about 470 feet. (See pl. 2.) The thickest section, as determined from an electric log, is 470 feet in well (B-7-9)16add. A driller's log of well (B-7-9)15cdd indicates that the alluvium is about 415 feet thick. The log of well (B-7-8)32ddd southwest of Aguila indicates a thickness of 190 feet. Well (B-7-8)1dac near Forepaugh penetrated 297 feet of alluvium, and well (B-7-7)17add, 3 miles southeast of Forepaugh, penetrated 161 feet of alluvium.

According to logs of wells, the thickness of the alluvium averages about 100 feet in the Wenden-Salome areas and is less than 50 feet

near the southeast end of Harrisburg Valley. In both areas the alluvium thins to a featheredge along the margins of the valley floor.

The alluvium is not an important aquifer in the areas of Wenden, Salome, and Harrisburg Valley, because the water table lies near or below the base of the unit. In the Aguila area many of the domestic and stock wells obtain water only from the alluvium, but irrigation wells obtain water from both the alluvium and the alluvial-fan deposits.

STRUCTURE

McMullen Valley owes its origin to faulting rather than to erosion; thus, it is a structural valley similar to many others of the Basin and Range province. The alinement of the mountain ranges and valley area is the result of movement along major faults, the mountain block having been lifted and tilted in relation to the intervening valley.

Displacement along a major fault on the west side of the Granite Wash Mountains has elevated the mountains with respect to the Ranegras Plain. The northeastward alinement of McMullen Valley suggests that large-scale cross faulting is responsible for the trend of the Harquahala and Harcuvar Mountains. Ross (1923, p. 176) suggested that the northwest side of the Harquahala range facing McMullen Valley is a fault scarp. The steep southeastward dip of the Paleozoic sedimentary rocks in the Harquahala Mountains (Metzger, 1957, pl. 1) suggests that the range may be a tilted fault block. Similar conditions may be postulated for the Granite Wash Mountains, because highly metamorphosed sedimentary rocks in those mountains dip to the northeast. In contrast, steeply dipping volcanic and sedimentary rocks at the northeast end of the Harcuvar Mountains are tilted to the southwest. Harrisburg Valley, which separates the Harquahala from the Little Harquahala Mountains, trends northwestward. This small wedge-shaped valley appears to be a depressed block that is tilted northwestward. At the narrowest point of the wedge, bedrock was penetrated at less than 50 feet, whereas well (B-5-13)26acc was drilled to a depth of 570 feet without penetrating bedrock.

The bedrock that underlies the sedimentary deposits of the valley undoubtedly has an irregular surface of high relief which is more closely related to the structural history than to the erosional history of the area. The outlying granitic mountains, which in the eastern part of the area are almost buried by alluvium, and the sequence of steeply dipping volcanic and sedimentary rocks are an indication of the complexity of the structure. The attitude of the volcanic rocks in the eastern part of the valley indicates that the bedrock lies at a relatively shallow depth. This probability is verified by subsurface evidence obtained from drillers' logs of well (B-7-7)17add and (B-7-8)1dac. Well (B-7-7)17add penetrated "andesite rock" at a depth of 161 feet, and well (B-7-8)1dac penetrated volcanic breccia at a depth of 297 feet and red granite at a depth of 482 feet. It is significant that well (B-7-8)15baa, which is only 2½ miles southwest of well (B-7-8)1dac and 1,812 feet deep, did not reach bedrock.

The age of the structural trough occupied by McMullen Valley cannot be determined precisely. Displacement of Tertiary(?) sedimentary and volcanic rocks by faulting indicates that much of the major structural movement in the area probably occurred during Tertiary time. The youngest rocks known to have been deformed are the basalt flows of Quaternary age. These rocks, however, appear to be only slightly deformed, whereas the rocks of Tertiary(?) age have been considerably deformed. In all probability the elevation of the ranges proceeded step by step during an extended period, the displacement occurring along pre-existing planes of structural weakness. Displacement may still be in progress.

The configuration of the bedrock is one of the principal factors controlling ground-water movement. The relatively impervious mountain areas on the north, south, and west sides of McMullen Valley prevent subsurface inflow to and outflow from the area; although the bedrock surface at the southeast end of Harrisburg Valley is higher than the bedrock surface in the central part of the valley, it is the lowest part on the "rim" of the bedrock basin and so is the overflow lip for ground water.

GROUND WATER

OCCURRENCE

The principal ground-water reservoir in McMullen Valley consists of the valley-fill deposits that occupy the structural trough between the mountain ranges.

The porosity of the material within the ground-water reservoir determines the amount of water that can be stored. Porosity is the percentage of the total volume of the material that is occupied by interstices or pore space and is dependent upon the shape, arrangement, degree of sorting, and cementation of the component particles. Thus, an unconsolidated material consisting of well-rounded and well-sorted loosely arrayed particles has a high porosity. Unsorted material has a low porosity, because fine-grained material reduces the size of the voids between the larger particles.

The valley fill is saturated up to a surface termed the "water table," and the water occurs chiefly under nonartesian conditions. The buried

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northwest (southeast-directed subduction) if the chemical trends reflect the approximate geometry of a paleosubduction zone. This zone is on the opposite side of the arc from the position generally assumed, indicating that the Jurassic plutonic rocks were not generated in response to classical Andean-type convergent plate margins. The magmatic arc probably formed in an intraocean enviroment and subsequently was rafted northward and accreted to this part of the northern Pacific rim during the late Mesozoic. Middle and Upper Jurassic clastic sediments underlying Cook Inlet to the southeast, and derived from the magmatic arc, are classified as backarc deposits rather than an arc-trench gap sequence.

GEOCHRONOLOGY AND TECTONIC EVOLUTION OF THE PRIEST RIVER CRYSTALLINE/METAMORPHIC COMPLEX OF NORTHEASTERN WASHINGTON AND NORTHERN IDAHO

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The Priest River complex straddling the Idaho-Washington border shares many similarities with the Kettle and Okanogan metamorphic core complexes farther west. Continued regional work indicates that an intricate sequence of plutonic, metamorphic and deformational events ranging in age from Precambrian to early Tertiary has affected the Priest River terrain. Decifering the absolute chronology of this history is made difficult because of a widespread Eocene thermal event which correlates with mylonization and cataclasis along the Newport detachment fault. Recent study revealing progressively more brittle mylonitic textures, slickensiding, and incipient chloritic breccia (near Rathdrum) along the complex's eastern margin with the Purcell Trench and Coeur d'Alene Lake suggest the presence of a detachment fault analogous to the Newport structure.

Lineation in gently east-dipping mylonitic rocks along the east edge of the Priest River complex trends N70-80°E. This deformational fabric apparently has been superimposed upon an earlier (Cretaceous?) metamorphic fabric with N50-60°E lineation. Isotopic and structural evidence suggests that both low-angle foliations have resulted from the transposition of high-angle, NE-trending, metamorphic fabrics in pre-Belt gneisses. This ancestral structural grain remains adjacent to the Newport fault on the west and southwest.

Results of new Rb-Sr and U-Pb dating on gneissic and intrusive rocks critical to unraveling the sequence of metamorphic, intrusive and mylonitic events will be discussed.

NAMING FOSSIL SOILS IN PALEOENVIRONMENTAL RECONSTRUCTIONS

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Fossil soils (paleosols) have been extensively used for stratigraphic correlation, and have usually been called "soils," and (perhaps more appropriately) "geosols" or "pedoderms." In each of these cases the named object was a traceable ancient land surface, with its catenae of different kinds of soils varying laterally according to regional differences in climate, organisms, parent material, topography and time of formation.

A different system of naming is required for the paleoenvironmental interpretation of different kinds of fossil soils, either laterally within an ancient land surface or on successive ancient land surfaces within a stratigraphic section. I propose extending the standard soil mapping units of the U.S. Department of Agriculture to the naming of fossil soils. These units are named after localities, for example the Avalon Series paleosols. Specific paleosols are named from the texture of their A horizon, *e.g.* the Avalon silt loam paleosol, or named from other features. These names are non-interpretative mapping units independent of genetic classifications of modern soils.

Named and described fossil soils are then open to interpretation. The effects of diagenesis after burial of the soil must be carefully considered. The remaining non-diagenetic features of fossil soils may provide evidence for past climate, topographic position, depth to water table and its chemistry, vegetation, fauna and rates of sedimentation, subsidence and uplift.

Such a system of naming has proved useful for the paleoenvironmental interpretation of Triassic paleosols from near Sydney, Australia, and of Late Eocene and Oligocene paleosols from Badlands National Park, South Dakota. These paleosols will be discussed as examples.

SUPERIMPOSED MESOZOIC AND CENOZOIC TECTONICS, WEST-CENTRAL ARIZONA

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Mountain ranges around Salome, Arizona contain evidence for a complex superposition of Mesozoic and Cenozoic tectonism. The main tectonic events are listed below in apparent chronologic order from oldest to youngest: 1) Deposition of middle Mesozoic volcanic and volcaniclastic rocks; 2) Deposition of thick sequences of Mesozoic clastic rocks; 3) Formation of major northeast-trending, southeast-vergent folds that overturn much of the Paleozoic and Mesozoic section in the Little Harquahala and western Harquahala Mountains; 4) Possible emplacement of thrust sheets in the Granite Wash Mountains; 5) Late Cretaceous plutonism, locally accompanied by high-grade metamorphism and northeast-vergent ductile deformation in the Harcuvar and Harquahala Mountains; 6) Major north-vergent thrusting that emplaced Precambrian crystalline basement over Paleozoic and Mesozoic rocks in the Little Harquahala and Harquahala Mountains; 7) Intrusion of Eocene (?) muscovite granites discordantly across fabrics related to events 5 and 6, accompanied by cooling of metamorphic and plutonic rocks in the western Harcuvar and Granite Wash Mountains; 8) Intense mylonitization that produced a gently dipping foliation and conspicuous, east-northeast trending lineation; 9) Intrusion of post-mylonitization microdiorite dikes at 25 m.y.B.P.; 10) East-northeast-directed detachment faulting (from ? to 15 m.y.B.P.) accompanied by antithetic rotation of upper-plate rocks, by uplift and cooling of lower-plate mylonitic rocks, and possibly by formation of large east-northeast-trending anticlines and synclines that define the present physiography of the region; and 11) Formation of Basin and Range(?) high-angle faults.

LATE CRETACEOUS-EARLY TERTIARY PERALUMINOUS GRANITOIDS OF ARIZONA - CALIFORNIA AND THEIR RELATED MINERAL DEPOSITS

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Peraluminous granitoids of Late Cretaceous to early Tertiary age in Arizona and southeastern California 1) contain primary muscovite and garnet; 2) have well-developed pegmatitic, alaskitic, and aplitic phases; 3) are highly silicic with SiO_2 >65%; and 4) postdate typical Laramide, metaluminous plutons. They are markedly depleted in the lithophile elements K, Rb, U, Th, and Li when compared to peraluminous, muscovite-bearing granitoids of Eurasia that commonly contain significant U, Sn, W, Mo, Be, Li, and F mineralization. Most peraluminous granitoids of Arizona and California are not associated with significant mineral deposits. Commercial W mineralization occurs in the wall rocks adjacent to several plutons, and Mo, Be, and Li minerals occur locally, but are not presently commercial. The Arizona-California granitoids, like their world-wide counterparts, have relatively high Sr^{87}/Sr^{86} initial ratios (>.710), indicating that they contain a significant crustal component. The regional variations in lithophile content of the granitoids may reflect differences in composition of the underlying crust. If so, deep crustal materials beneath Arizona and southeastern California were greatly depleted in most lithophile elements before the peraluminous granitoids were produced. As we have suggested previously, the Arizona-California lower crust may have been depleted by an episode of anatexis that produced the voluminous 1.45 b.y.-old granites. Alternatively, the chemical differences between the Arizona-California and Eurasian granitoids may be partly a reflection of their different tectonic settings. Specifically, the Arizona-California granitoids were produced during an episode of low-angle subduction, whereas the Eurasian granitoids resulted from continental collision.

STRUCTURE AND STRATIGRAPHY OF THE LITTLE HARQUAHALA MOUNTAINS, YUMA COUNTY, ARIZONA

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A continuous Paleozoic to Mesozoic depositional sequence is exposed in the southern Little Harquahala Mountains. The Paleozoic section is approximately 1000 m thick and is correlative with the lower Paleozoic Bolsa, Abrigo and Martin Formations of southeast Arizona, and the upper Paleozoic Redwall, Supai, Coconino and Kaibab Formations of the Colorado Plateau. This Paleozoic section is depositionally overlain by a lithologically varied Mesozoic (?) section composed of up to 1000 m of rhyodacitic volcanic and volcaniclastic rocks, capped by a minimum of 1100 m of arkose. Dips within the section increase northward (down-section) from 50°S to vertical and overturned. The large-and small-scale structures indicate the presence of a major SSE-vergent fold. Regional relationships suggest that the fold is cut off at its base by sub-horizontal faults. North-dipping faults cut the Paleozoic rocks and have northerly tectonic transport, locally placing Paleozoic rocks over Precambrian granite. At the southern end of their exposure, Mesozoic rocks overlie a complex assemblage of intrusive and metamorphic rocks along a low-angle fault. No tectonites or lineated rocks are present in the lower plate. East-dipping faults associated with intense brecciation cut all other low-angle faults in the Paleozoic rocks. The youngest faults are north-to northwest-trending, oblique-slip faults which locally involve Tertiary (?) gravel. Clockwise oroclinal bending of the sedimentary rocks accompanied this faulting. Structures in the Little Harquahala Mountains are apparently the result of superimposed Mesozoic to Recent compressional, extensional and wrench tectonics.

A MODEL FOR GAHNITE AND MAGNETITE FORMATION DURING METAMORPHISM OF SULFIDE-RICH ROCKS

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Studies of four Precambrian Pb-Zn-Cu sulfide deposits from central Colorado reveal that each contain the minerals gahnite ($ZnAl_2SiO_4$) and magnetite. These deposits have been regionally metamorphosed to the amphibolite facies with the ore minerals displaying recognizable metamorphic textures. This suggests that the sulfides formed early (premetamorphic) within the host pelitic schists, probably originating as disseminated sulfides within black shales. Many previous investigators have evaluated these deposits as hydrothermal and magmatic in origin.

Regional metamorphism to the amphibolite facies produced reactions,

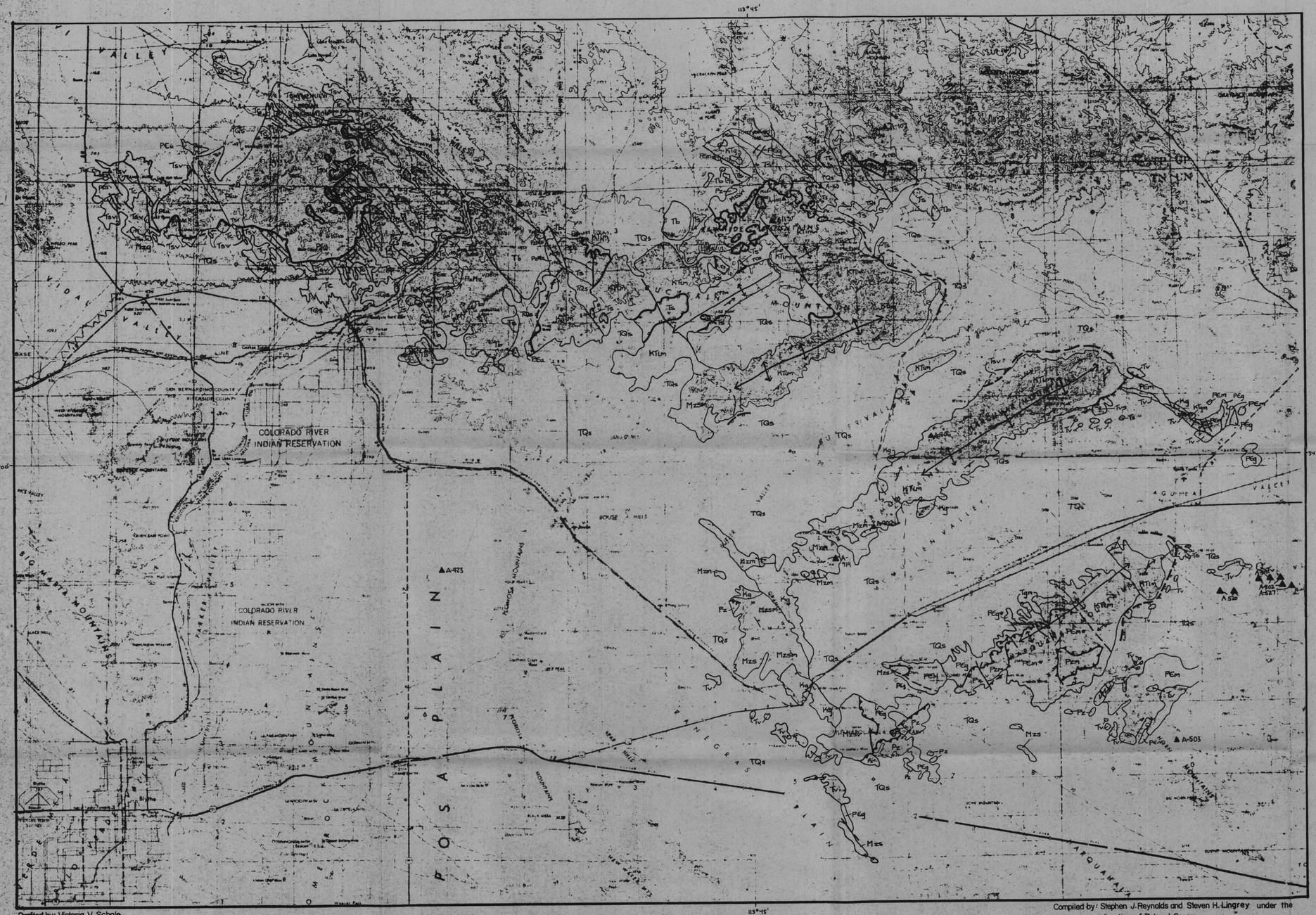
USBM IC 8252

TABLE 16. - Arizona mercury properties

Reported property name	County	Reported location	Production, flasks	Development	Mode of occurrence (mineralization, cinnabar unless otherwise noted)	Reported owners	References in bibliography
MAZATZAL MOUNTAINS DISTRICT							
Blue Bird (Red Bird, Tonto).	Gila....	Sec 12, T 7 N, R 9 E.	Occurrence.	200-foot adit and surface pits.	Quartz veinlets in schist.	C. O. Carlson..	4
Gold Creek group (Northern Light, Bernice No. 1, Big Tunnel).	do....	Sec 3, T 7 N, R 9 E.	do....	Short adits and shallow open cuts.	Quartz stringers in schist.	Robert McGhee..	4
Irl group (Bowman, Robbins, Cornucopia).	Maricopa	Sec 7, T 7 N, R 9 E.	Small.....	1,500 feet of underground workings.	Quartz veins in schist.	Irl Conway.....	4
Mercuria group.....	Gila....	Sec 3, T 7 N, R 9 E.	Occurrence.	Short adit.....	do.....	Dick Robbins...	4
National (Arizona Sunflower, Arizona Quicksilver, Sunnyside).	Maricopa	Sec 12, 13, T 7 N, R 8 E.	1,278	Extensive workings.	Veinlets in altered schist.	Allen, Allen, and Ross.	4, 5, 7
Oneida group (Ward, L & N).	Gila....	Sec 18, T 7 N, R 9 E.	Small.....	1,700 feet of underground workings.	In quartz veins in quartzite.	Tom Bolick.....	4
Ord group.....	do....	Sec 3, T 7 N, R 9 E.	2,901	Extensive underground workings.	Cinnabar, native mercury, and termatite along shear zones in altered phyllites.	Vance Thornburg	2, 4, 7
Pine Mountain group (Turnbull).	Maricopa	Sec 4, T 7 N, R 9 E.	2,341	Small open pit and 28-foot shaft.	As disseminations in brown schist.	George Cline...	4
Rattlesnake group..	Gila....	Sec 10, T 7 N, R 9 E.	Occurrence.	Test pits and trenches.	Veinlets in silicified zones in schist.	Ed and Irl Conway.	4
DOME ROCK MOUNTAINS DISTRICT							
Cinnabar group.....	Yuma....	Sec 4, T 2 N, R 20 W.	Over 150...	640-foot shaft, seven levels, inaccessible.	Filling in fault breccia in schist.	Jack Fisher....	4
Carlson claims.....	do....	Sec 31, T 3 N, R 20 W.	Occurrence.	Unknown.....	Unknown.....	C. O. Carlson..	-
French-American group.	do....	Sec 6, T 3 N, R 20 W.	do....	do.....	In association with tourmaline and quartz.	Unknown.....	4
[illegible] prospect.	Maricopa	Sec [illegible], T [illegible] N, R 3 E.	Occurrence.	Test pits.....	In foliations of schist.	Unknown.....	-
Eureka.....	do....	Sec -, T 3 N,	do....	50-foot shaft, 150	In vein in schist	[illegible]	

PHOENIX MOUNTAINS DISTRICT							
Brown Mercury prospect.	Maricopa	Sec 36, T 3 N, R 3 E.	Occurrence.	Test pits.....	In foliations of schist.	Unknown.....	-
Eureka.....	do....	Sec -, T 3 N, R 3 E.	do....	50-foot shaft, 150 feet of drifts.	In vein in schist.	Louis Larsen...	4
Mercury.....	do....	Sec 27, T 3 N, R 3 E.	do....	Shallow shafts and adits.	In breccia zone in schist.	Unknown.....	4, 6
Sam Hughes or Rico mine.	do....	Sec 34, T 3 N, R 3 E.	Small.....	100-foot shaft, 500 feet of drifts.	With metacinnabarite and native mercury in vein in schist.	Sam Hughes.....	4, 6
Seal Rock.....	do....	Sec -, T 2 N, R 3 E.	Occurrence.	Test pits.....	In altered schist, with kyanite and tourmaline.	Unknown.....	6
COPPER BASIN DISTRICT							
Mercury (Cinnabar King, Cinnabar Queen).	Yavapai.	10 miles southwest of Prescott.	Small.....	Shallow shafts...	Siliceous veins in granite and gabbro.	Unknown.....	4
Zero Hour.....	do....	do.....	Occurrence.	Unknown.....	Unknown.....	do.....	4
MINOR DISTRICTS AND OCCURRENCES							
Cerro Colorado mine (Heitzelman).	Pima....	45 miles southwest of Tucson.	Occurrence.	Silver-lead mine.	In tetrahedrite along with galena and native mercury.	Unknown.....	4
Chinle Formation...	Coconino	Lee's Ferry....	do....	None.....	Ancient placer....	do.....	3
Cowboy mine.....	Gila....	South of Globe.	do....	Unknown.....	Unknown.....	do.....	-
Deadman Wash.....	do....	9 miles north of National group.	do....	do.....	In schist.....	do.....	4
Fey mine.....	Mohave..	In Gold Basin district.	do....	do.....	Unknown.....	do.....	-
J. Guy claims.....	Pima....	45 miles southwest of Tucson.	do....	35-foot shaft....	Quartz veinlets in fault zone in rhyolite.	do.....	4
Mickey Welch claims.	Pinal...	South of Casa Grande.	do....	Unknown.....	Unknown.....	do.....	-
Nations Mercury property (Mountain View Cinnabar).	do....	Sec 31, T 1 N, R 10 E.	do....	do.....	Native mercury in schist.	do.....	-
Roadside mine.....	Pima....	35 miles west of Tucson.	do....	Road cut.....	With pyrite, chalcopyrite, and other sulfides.	do.....	4
Westerdahl claims..	Maricopa	Near Morristown	do....	Unknown.....	Unknown.....	do.....	-

				workings, small glory holes.	dike near granite contact; also in fracture and small breccia veins.	Co.	9, 12, 49
TUSTIN DISTRICT							
Red Hill mine (Tustin).	Orange.....	Sec 14, T 5 S, R 9 W.	Several.......	Short exploratory adits.	With native mercury in barite veins in tertiary sandstone.	F.B. Browning..	12, [illegible]
SAN BERNARDINO COUNTY							
Bimetallic (Desert Mercury).	San Bernardino	Sec 33, T 7 N, R 17 E.	Several.......	Shallow shafts, surface pits.	Ore-bearing breccia zones and fractures along contact of granitic gneiss, and quartz-porphyry.	A.B. Day.......	12, 62
City Creek.........	do......	6 miles from San Bernardino on City Creek.	Occurrence....	Unknown.............	Unknown.............	Unknown........	12, 66
Idria Quicksilver group (Turtle Dove, Mercury).	do......	Sec 24, T 9 N, R 18 E.	do.........	Two 25-foot shafts, trenches.	Ore-bearing chalcedony veins in a hornblende granitic schist.	F.H. Chaussee and others.	12, 62
Jack..............	do......	Sec--, T 16 N, R 15 E.	do.........	Unknown.............	Byproduct of wolframite mine.	Unknown........	12, 66
Myrick.............	do......	Sec--, T 18 N, R 1 E.	do.........	do...............	With chalcedony in volcanic rock.	do..........	12, 66
Red Bird...........	do......	S 28, T 9 N, R 3 W.	do.........	do...............	Unknown.............	C. Davson......	66
Red Canyon.........	do......	Sec--, T 2 N, R 2 E.	do.........	do...............	Sparsely disseminated in gouge along fault between quartzite and siliceous limestone.	R.B. Stephenson	66
Red Chief..........	do......	Secs 17, 18, T 14 N, R 16 E.	do.........	do...............	Unknown.............	W.D. Ford and others.	66
Red Fox............	do......	Sec 28, T 3 N, R 5 W.	do.........	do...............	do...............	W.T. Elliot....	66
Redlead............	do......	Sec--, T 7 N, R 22 E.	do.........	do...............	do...............	S.E. Kennedy...	66
Rhumba.............	do......	14 miles north of Barstow.	do.........	do...............	Disseminated in shear zone in granitic rock.	L.E. Martin....	66



Drafted by: Victoria V. Schale

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EXPLANATION

MAP UNITS:

- TQs — Late Tertiary-Quaternary surficial deposits
- Tb — Late Tertiary basalt with interbedded sediments
- Tc — Late Tertiary clastic rocks
- Ts — Middle Tertiary sedimentary rocks
- Tv — Tertiary volcanic rocks
- Tsv — Tertiary sedimentary and volcanic rocks
- Tgm — Tertiary muscovite-bearing granite
- KTim — Cretaceous-Tertiary igneous and metamorphic rocks
- Kg — Cretaceous granitic rocks
- Mzs — Mesozoic sedimentary rocks (Mzsm where metamorphosed)
- Mzsv — Mesozoic sedimentary and volcanic rocks
- Mzg — Mesozoic granitic rocks
- Pz — Paleozoic sedimentary rocks (Pzm where metamorphosed)
- PCg — Precambrian granitic rocks (PCg* where mylonitic)
- PCm — Precambrian metamorphic rocks (PCm* where mylonitic)
- PCu — Precambrian metamorphic and granitic rocks undifferentiated

SYMBOLS:

- Contact, dashed where approximately located
- Fault, dashed where approximately located
- Low-angle normal fault
- Low-angle thrust fault
- Dislocation surface
- tie leader
- A-507 Uranium occurrences

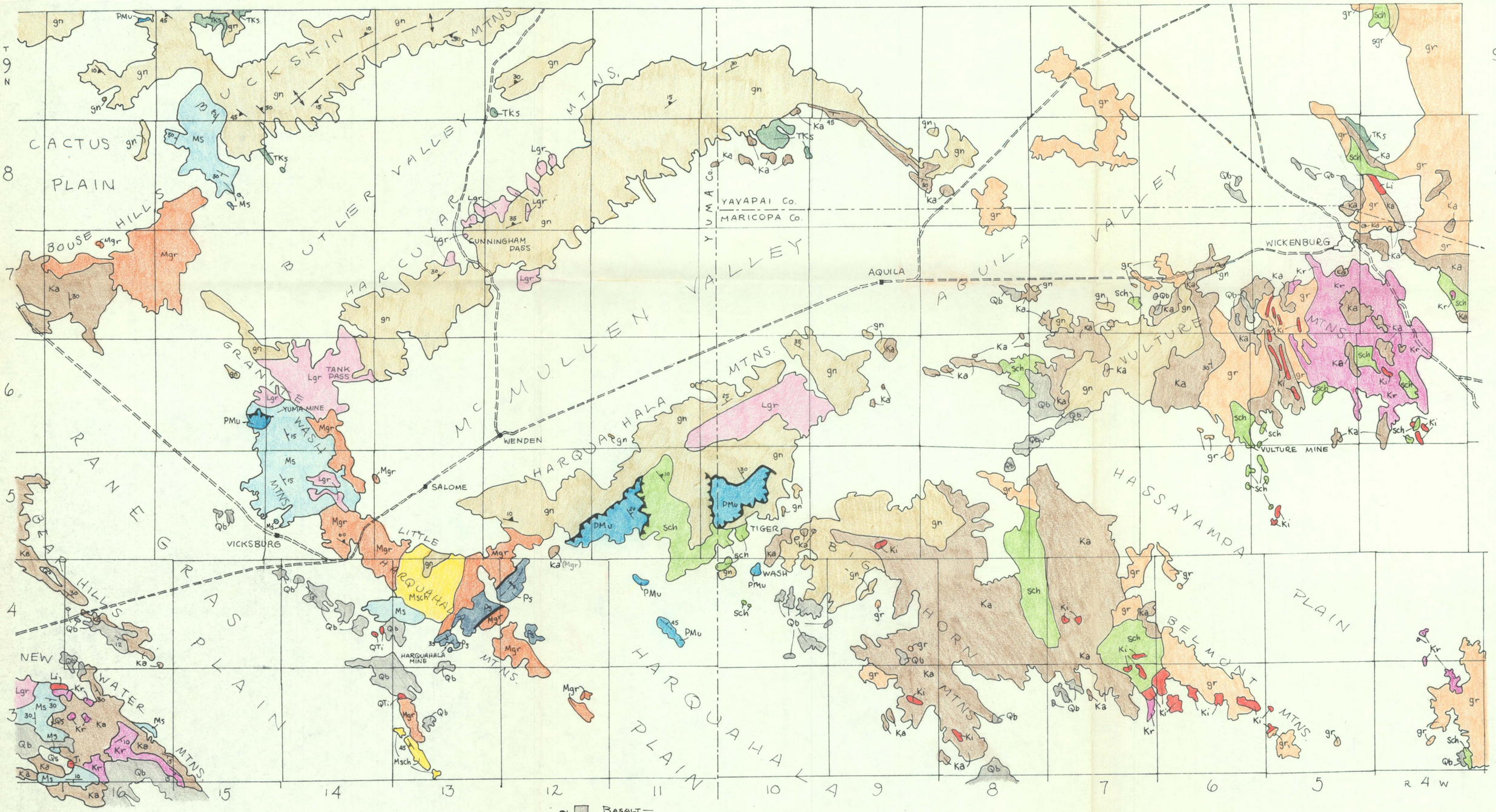
N

SCALE 1:250,000

5 0 5 10 15 20 Kilometers

TECTONIC MAP OF THE WHIPPLE, RAWHIDE-BUCKSKIN, HARCUVAR, AND HARQUAHALA METAMORPHIC CORE COMPLEXES, CALIFORNIA AND ARIZONA

Map D-8



TKs — SANDSTONE, SHALE & CONGLOMERATE, INCLUDES SOME VOLCANIC ROCKS.

PMu — SHALE, QUARTZITE & LIMESTONE.

Ms — SHALE, SANDSTONE, CONGLOMERATE & LIMESTONE. LOCALLY METAMORPHOSED.

Ps — LIMESTONE, SHALE, SANDSTONE, & QUARTZITE.

Msch — SCHIST, INCLUDES LOCAL CALC-SILICATE ZONES.

sgr — GRANITE & SCHIST, UNDIFFERENTIATED

gn — GRANITE GNEISS.

Qb — BASALT — FLOWS, TUFFS & AGGLOMERATE

Kr — RHYOLITE — FLOWS, DIKES, PLUGS & TUFFS.

Ka — ANDESITE — FLOWS, DIKES, PLUGS, TUFFS & AGGLOMERATE.

PRECAMBRIAN

sch — SCHIST, LOCALLY INCLUDES DIORITE, RHYOLITE, & GREENSTONE.

QTi, Li, Ki — DIKES & PLUGS — RHYOLITIC TO BASALTIC IN COMPOSITION

Lgr — GRANITE & RELATED CRYSTALLINE INTRUSIVE ROCK

Mgr — GRANITE & RELATED CRYSTALLINE INTRUSIVE ROCKS.

gr — GRANITE & RELATED CRYSTALLINE INTRUSIVE ROCKS.

GEOLOGY FROM ARIZONA COUNTY MAP SERIES.

SCALE 1: 250,000

COMPILED & DRAWN 1975 NIC/PKK.

HARCUVAR-HARQUAHALA REGION
YUMA-MARICOPA COUNTIES, ARIZONA
GEOLOGY MAP

FIGURE 1.

ENERGY RESERVES GROUP

PROSPECT THREE MUSKETEERS

COUNTY/STATE YUma, Arizona

SAMPLE NO.	LOCATION T	R	S	FNL	FEL	COLLECTOR	DATE	RESULTS Au (ppm)	Ag (ppm)	As (ppm)	Sb (ppm)	W (ppm)				DESCRIPTION
1434	6N	15W	25	4000	300	WSD		0.014	< 0.5			5860				From old workings, scheelite pods with copper staining, bleached chloritic schists with iron staining and limonite pseudos after pyrite.
1435	"	"	"	3900	300	"		0.007	1.0			1150				Dump of open cut.
1436	"	"	"	3600	600	"		0.014	0.5			50				"Au-adit" on small vein quartz & scheelite in granitic rock. Good Au values reported.
1437	"	"	"	4000	900	"		0.043	3.5			< 10				"Bull quartz" extension of "Au-vein"(?) minor iron and manganese staining.
1245						SS	6-25-81	0.030		7.0	1.2	15800				Sample from prospect pit on center hill top of road samples all FeOx MnO stained schist w/ about 10' exposed in pit. No quartz included. Testing disseminated Au and W potential.
1246						"	"	0.003				1200				From face of N. side of N. hill. Testing disseminated Au & W. Samples FeOx, MnOx stained schist. No quartz.
1247						"	6-26-81	<0.003				720				Sample of dump from 40' shaft into andesite dike? flow? very wide, reported to run .1 oz/ton.
1248						WSD	"	0.050				280.				Specular hematite bearing limestone
1249						"	"	0.070				240				Au hi-grade,Fe stained limestone lenses hematite lenses in open cut.
1250						"	"	<0.003				78				Open cut in specular hematite-epidote hb schist, hematite-rich

Arizona Bureau of Geology and Mineral Technology
FIELDNOTES
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The Copperstone Mine: Arizona's New Gold Producer

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Arizona's annual gold output will almost double in 1988 as a result of production from Cyprus Minerals Company's Copperstone gold deposit in La Paz County, west-central Arizona. During 6 years of expected mine life, the deposit is predicted to yield approximately 510,000 troy ounces of gold worth $230 million, based on a value of $450 per ounce. Unlike many recent gold discoveries in the Southwest, Copperstone is a new discovery in an area not previously identified as a mineral district. In this article, the geology and regional setting of the Copperstone deposit are described. Although the deposit is still not completely understood, enough is known to warrant reassessment of estimates of mineral-resource potential in west-central Arizona.

Regional Geologic Setting

West-central Arizona and adjacent areas of California and southern Nevada contain some of the most spectacularly exposed detachment faults in the world. The term "detachment fault" is commonly applied to large-displacement, gently dipping (inclined) normal faults. In this region, hanging-wall rocks, or rocks overlying the detachment faults, were displaced northeastward relative to footwall rocks, rocks that underlie the faults. The faults originally dipped to the northeast, but are now rotated and warped to form undulating surfaces that are nearly horizontal over large areas.

The north- to northeast-dipping Moon Mountains detachment fault, exposed at the northern tip of the eastern Moon Mountains, separates two large, geologically distinct areas: to the northeast lie numerous detachment faults, such as those in the Buckskin, Rawhide, and northern Plomosa Mountains; to the south, in the Dome Rock, southern Plomosa, and most of the Moon Mountains, detachment faults are absent. The Copperstone gold deposit lies within the hanging wall of the Moon Mountains detachment fault and flanks the area of pervasive faulting.

Miocene (5- to 24-million-year [m.y.]-old) detachment faults in west-central Arizona are associated with numerous copper, iron, and gold deposits, especially in the Buckskin and Rawhide Mountains, that have yielded metals worth many millions of dollars (Figure 1; Table 1; Wilkins and Heidrick, 1982; Spencer and Welty, 1986). Copper-gold deposits associated with detachment faults typically lie along or within a few tens of meters of the faults; a few, however, are hundreds of meters above the faults. Detachment-fault deposits contain fractures and thick, irregular zones that are commonly filled with the minerals specular hematite, chrysocolla, quartz, barite, fluorite, calcite, and manganese oxides. Pyrite and chalcopyrite, which are commonly oxidized, are also present in many deposits.

The northeastern tip of the Moon Mountains is primarily composed of Mesozoic (63- to 240-m.y.-old) granitic rocks that form the footwall of the Moon Mountains detachment fault. Hanging-wall rocks are mostly metamorphosed Jurassic (138- to 205-m.y.-old) volcanic rocks. Older (Paleozoic; 240- to 570-m.y.-old) metamorphosed sedimentary rocks that are brecciated (composed of

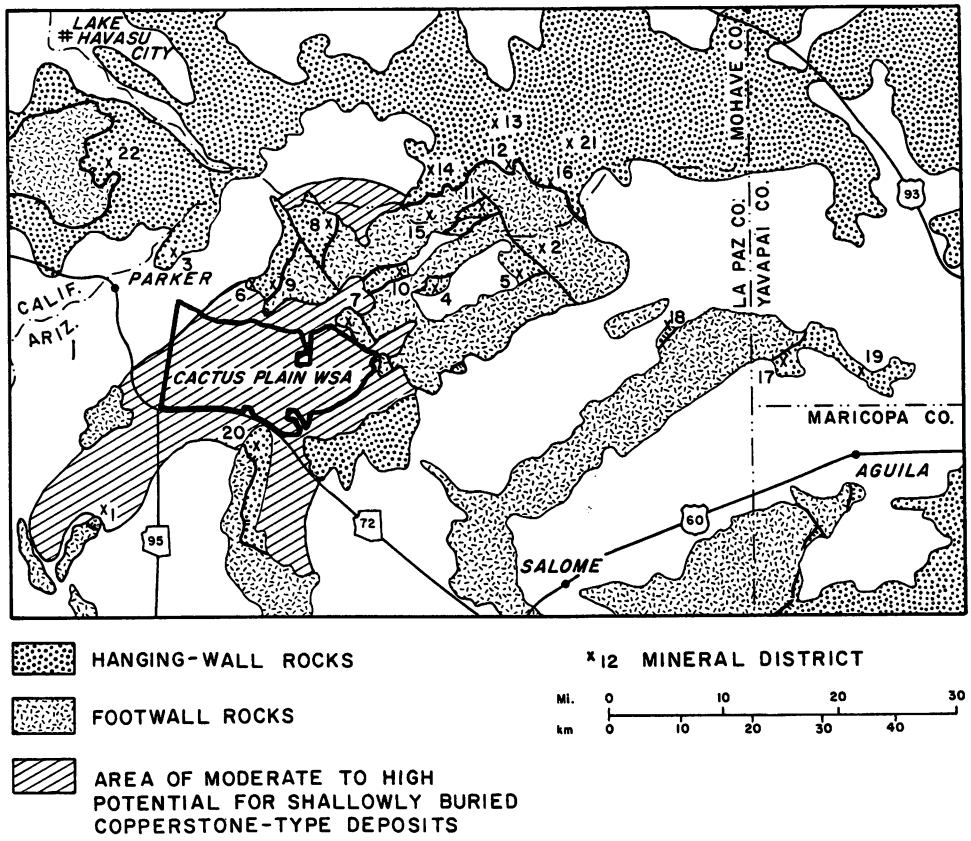

Figure 1. Map of part of west-central Arizona showing mineral districts where mineral deposits are known or suspected to be related to detachment faults. Middle Tertiary and older rocks are divided into hanging wall and footwall rocks, which lie above and below, respectively, regionally northeast-dipping detachment faults. Also shown is the outline of the Cactus Plain and Cactus Plain East Wilderness Study Areas. Numbers refer to mineral districts listed in Table 1.

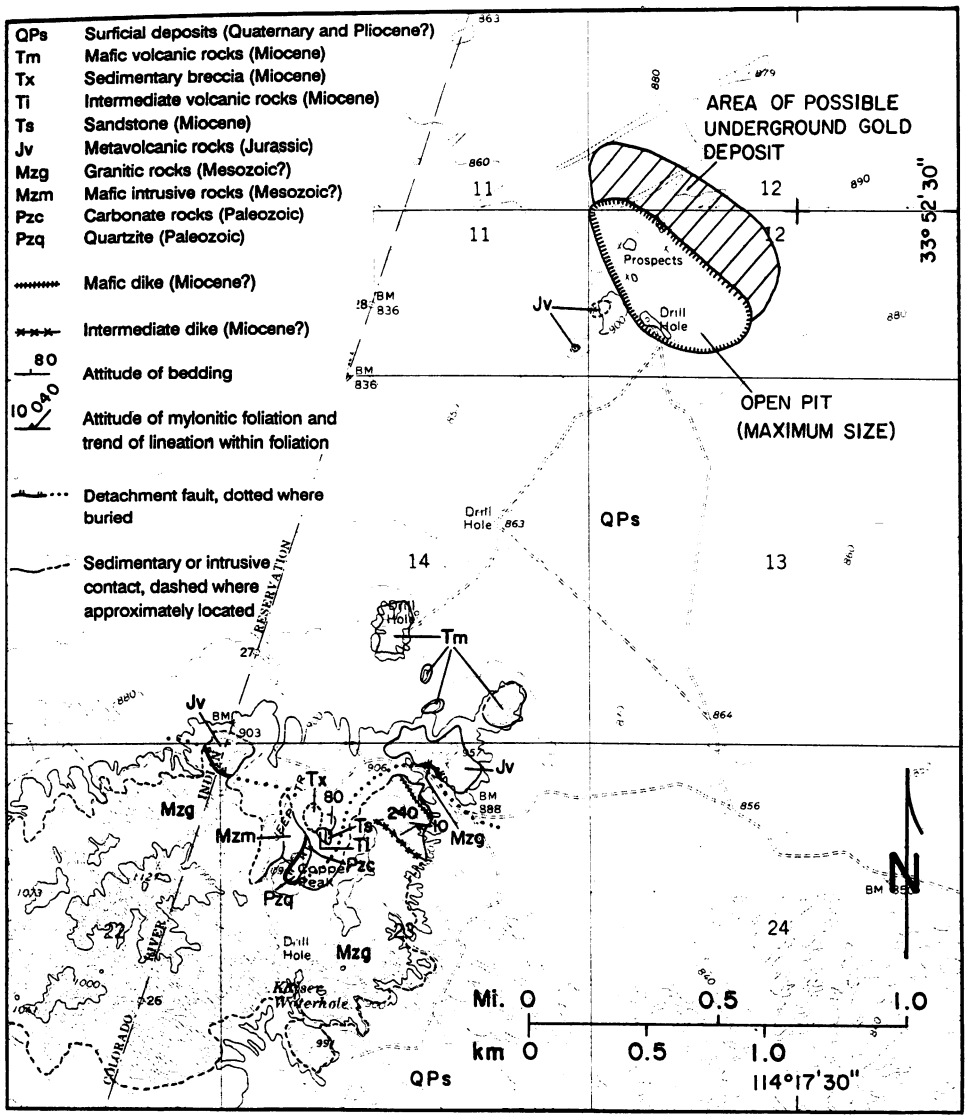

Figure 2. Geologic map of northeastern Moon Mountains showing location of Copperstone mine.

broken rock fragments) underlie Copper Peak; steeply dipping, younger (Miocene) volcanic and sedimentary rocks, including sedimentary breccias derived from the Jurassic volcanic rocks, are also present adjacent to Copper Peak (Figure 2). The copper-iron mineralization that characterizes detachment-fault deposits elsewhere in west-central Arizona is also evident in brecciated rocks along the Moon Mountains detachment fault at Copper Peak and at the edge of the Colorado River Indian Reservation.

Geology

The Copperstone mine is approximately 1½ miles northeast of exposed bedrock in the northeastern Moon Mountains (Figure 2). Bedrock exposures in several very small hills surrounded by alluvium contain evidence of gold mineralization and led to the discovery of the Copperstone deposit. Mineral deposits are present above and along a gently dipping contact that is probably a fault; the contact separates Jurassic metamorphosed volcanic rocks and overlying sedimentary breccias derived from them. The mineralized contact zone dips approximately 30° to the northeast, extends horizontally for 3,000 feet and at least 1,000 feet down dip, and is generally several tens of feet thick. The sedimentary breccia and a volcanic rock that contains vesicles (relict gas bubbles) are almost certainly Miocene in age and are mineralized, indicating that mineralization is Miocene or younger.

Drill-core samples reveal that some brecciation occurred after quartz veins were formed; however, numerous northwest-trending quartz-amethyst veins exposed in the mine pit are not brecciated. Steeply dipping, northwest-striking fractures and narrow shear zones exposed in the mine pit locally cut quartz-amethyst veins and contain subhorizontal slickenside lineations, which are smooth and polished striations that result from friction along a fault plane.

Gold is present where quartz and specular hematite are abundant in the breccia zone and locally within veins in the metamorphosed volcanic rocks. Chrysocolla, barite, earthy red hematite, and malachite are also common in the gold-mineralized zone. Fluorite, adularia, magnetite, calcite, chalcopyrite, pyrite, and manganese oxides are present in smaller quantities. Gold, however, is rarely visible. The presence of quartz, hematite, and chrysocolla is a good indicator of gold mineralization.

Fluid-Inclusion Characteristics

Fluid inclusions are bubbles of liquid and gas that are commonly trapped inside minerals during mineral formation. The composition of fluid inclusions in mineral deposits reflects the composition of the aqueous fluids that formed the deposits. One can determine the salinity of the inclusions by determining the freezing temperature of the fluid within them. The minimum temperature of the fluid at the time it was trapped can be determined by heating the sample until the two phases (liquid and gas) in the inclusion become one. Fluid inclusions in quartz-amethyst from the Copperstone mine contain between 16 and 22 percent sodium-chloride equivalent (by weight) and were trapped at minimum temperatures between 200° and 260° C. These characteristics are similar to those of other mineral deposits along Miocene detachment faults in west-central Arizona, but are substantially different from those of most other types of deposits, such as epithermal-vein gold deposits (Figure 3; Wilkins and others, 1986).

Origin

The following characteristics of the Copperstone deposit suggest that it originated from the same processes that formed mineral deposits along numerous other Miocene detachment faults: (1) fluid-inclusion salinities and temperatures of entrapment; (2) abundant specular hematite with less abundant copper minerals such as chrysocolla, malachite, and chalcopyrite; (3) geographic proximity to a detachment fault; and (4) probable Miocene age. Two characteristics of the Copperstone deposit, however, differ from those of other detachment-fault deposits: abundance of quartz-amethyst veins and abundance of gold. These authors believe that most evidence at the Copperstone deposit supports a relationship between mineralization and detachment faulting.

A working model for the origin of the Copperstone deposit is as follows: hot, saline, aqueous fluids containing dissolved gold, copper, iron, and other elements moved up-dip along the north- to northeast-dipping Moon Mountain detachment fault. These fluids encountered highly porous and permeable sedimentary breccias in the hanging wall of the detachment fault and began ascending through the breccia zone. As a result of cooling or mixing with more oxygen-rich, shallow-level ground water, largely within the sedimentary breccias, gold and

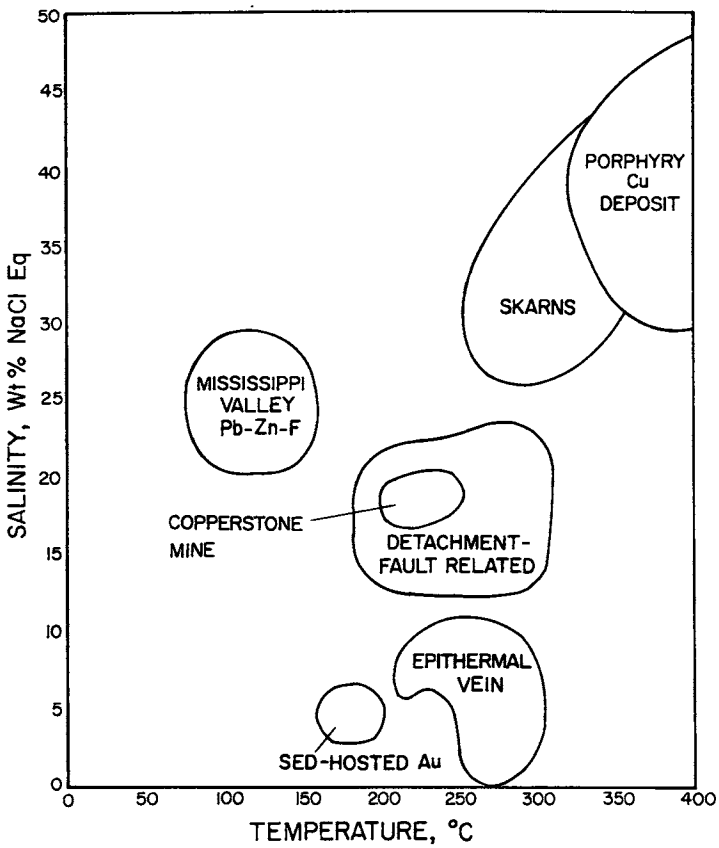

Figure 3. Diagram of salinity and homogenization temperature fields for fluid inclusions from several major mineral deposits, including those associated with detachment faults. Fluid inclusions from the Copperstone deposit clearly fall within the field of other detachment-fault-related deposits. Many geologists suspected that the Copperstone deposit was an epithermal-vein deposit, as are many other gold deposits in the Southwest; fluid-inclusion data, however, strongly suggest otherwise. Modified from Wilkins and others (1986), with additional data from the Copperstone mine.

Table 1. Value of production for commodities from mineral districts in west-central Arizona that are known or suspected to be related to detachment faults. Manganese mineral deposits, although not clearly understood, are suspected to be related to detachment faults. District locations are shown on Figure 1.

District	Commodities*	1986 Value**
1. Copperstone	Au (reserves)	$189,306,900
2. Alamo	Cu, Pb, Ag, Au	72,303
3. Cienega	Cu, Ag, Au	5,571,167
4. Clara	Cu, Ag, Au	3,066,661
5. Lincoln Ranch	Mn	18,960,000
6. Mammon	Cu, Ag, Au	93,913
7. Midway	Cu, Ag, Au	43,743
8. Planet	Cu, Ag, Au	12,771,828
9. Pride	Cu, Ag, Au	37,679
10. Swansea	Cu, Ag, Au	17,471,085
11. Black Burro	Mn	261,490
12. Cleopatra	Cu, Pb, Ag, Au	1,118,459
13. Lead Pill	Cu, Pb, Ag, Au	303,365
14. Mesa	Mn	47,400
15. Owen	Cu, Pb, Zn, Ag	107,561
16. Rawhide	Cu, Pb, Zn, Ag	116,573
17. Bullard	Cu, Ag, Au	1,763,481
18. Burnt Well	(unknown)	(minor)
19. Harris	Mn	79,395
20. Northern Plomosa	Cu, Pb, Ag, Au	2,123,413
21. Artillery	Mn	75,135,320
22. Whipple	Cu, Pb, Zn, Ag, Au	683,550
TOTAL		$329,135,287

* Ag = silver; Au = gold; Cu = copper; Mn = manganese; Pb = lead; Zn = zinc.
** Values do not add to total because of rounding.

other elements precipitated from the fluids to form the Copperstone deposit.

Implications for Land-Use Planning and Management

The presence of the Copperstone gold deposit in a geologic setting that is characteristic of large areas of west-central Arizona indicates that the mineral-resource potential of this area in the State is greater than previously suspected.

The Copperstone deposit was probably not discovered until recently because it was almost entirely concealed by young surficial deposits. Undiscovered mineral deposits similar to Copperstone may also be concealed beneath other surficial deposits, such as those covering nearby Cactus Plain (Figure 1). Application of more sophisticated geophysical techniques may eventually result in discovery of such deposits. Many areas in west-central Arizona, such as the Cactus Plain and Cactus Plain East Wilderness Study Areas, are presently under consideration for Federal wilderness-area status. If designated to be managed as wilderness, these areas would no longer be open to mineral exploration or mining activity.

Mineral deposits associated with detachment faults have only been recognized as a distinct deposit type during the past 10 years. The recent discovery of the Copperstone deposit and recognition of its association with a detachment fault are generating renewed interest in detachment-fault-related deposits and in areas where such deposits might be located. Future improvements in our understanding of Arizona geology and future mineral-deposit discoveries will undoubtedly lead to renewed interest in areas that presently receive little attention from research or exploration geologists.

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GSA Centennial Field Guides

The Geological Society of America (GSA) has published two Centennial Field Guides that include areas in Arizona: the Cordilleran Section and the Rocky Mountain Section (volumes 1 and 2, respectively). The first volume contains field-guide articles and maps to 100 outstanding geologic locations in Alaska, British Columbia, California, Hawaii, Nevada, Oregon, and Washington, as well as Arizona. The second volume contains 100 guides for Alberta, Arizona, Colorado, Idaho, Montana, New Mexico, South Dakota, Utah, and Wyoming. These two volumes are part of the 71-item GSA publishing project, the Decade of North American Geology (DNAG). To obtain copies, send $43.50 for each volume to The Geological Society of America, Publication Sales, P.O. Box 9140, Boulder, CO 80301; tel: (800) 472-1988.