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GEOLOGY, ENERGY AND MINERAL RESOURCES ASSESSMENT OF THE WYMOLA AREA, ARIZONA

BY

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GEOLOGY, ENERGY AND MINERAL RESOURCES ASSESSMENT
OF THE WYMOLA AREA, ARIZONA

by

Susan K. Cruver, Antoni Wodzicki and Jan Krason

SUMMARY

The Wymola "Geological, Energy and Minerals (GEM) Resources Area" (GRA) lies within Pinal and Pima Counties, Arizona, and contains the following Wilderness Study Areas (WSAs):

Picacho Mountains (020-194), and
Ragged Top (020-197).

Basement rocks consist of Precambrian (1.7 to 1.68 b.y.B.P.) meta-sedimentary schists intruded locally by granites 1.7 to 1.6 and 1.5 to 1.4 b.y.B.P. The basement is unconformably overlain by younger Precambrian sediments and basalts and intruded by diabases 1.1 b.y.B.P. Precambrian rocks are unconformably overlain by Paleozoic shallow marine clastics and carbonates. During the mid-Mesozoic a magmatic arc extended across southern Arizona and a thick sequence of Jurassic (?) to Cretaceous continental red beds were deposited in the GRA. Andesites were erupted and quartz monzonite and associated porphyries were intruded during the Laramide (70-50 m.y.B.P.) and porphyry copper mineralization of the Silver Bell Mine in the southern part of the GRA formed at this time. The mid-Tertiary orogeny lasted from 35 to 14 m.y.B.P. and involved the following: Deposition of a thick sequence of fluvial and lacustrine sediments in northwest-striking downwarps, outpouring of voluminous calc-alkaline volcanics dominated by ash-flow deposits possibly related to cauldrons, emplacement of metamorphic core complexes, and listric normal faulting which offset mid-Tertiary volcanic and sedimentary rocks. Basin and range faulting became dominant 14-4 m.y.B.P. and was accompanied by bimodal volcanism. Since 4 m.y.B.P. the main geological processes have been erosion and deposition of alluvium.

Geologic environments potentially favorable for the occurrence of mineral or energy resources in the GRA include: Older Precambrian metasedimentary schist, older Precambrian granites, younger Precambrian sediments and diabases, Paleozoic and Mesozoic sediments, Laramide intrusives, mid-Tertiary metamorphic core complexes, mid-Tertiary volcanics and basin-fill sediments, Late Tertiary basin-fill sediments, recent alluvium and active geothermal areas.

Hydrothermal copper, with lesser lead and zinc, deposits are associated with Precambrian schists, granites and diabases. To the north of the area, uranium deposits are found in younger Precambrian sediments associated with diabase intrusions but no occurrences are known in the GRA. Oil and gas may

have formed in Paleozoic sediments, but none has yet been discovered. Laramide intrusives and Paleozoic roof pendants in the southern part of the GRA are host rocks for the important porphyry copper deposits of the Silver Bell Mine and hydrothermal mineralization present in older rocks may also be related to Laramide intrusives. Many copper-bearing quartz veins occur in the Picacho Mountains metamorphic core complex. Silver, lead, copper, gold and manganese mineralize mid-Tertiary volcanics. Mid- to late Tertiary basin-fill sediments contain abundant uranium source rocks and permeable horizons and locally may contain reductants. Evaporites and zeolites occur in late Tertiary basin-fill sediments. Placer gold deposits may occur in recent alluvium. Temperatures reaching 100°C have been measured in wells in deep basins in the GRA.

The Picacho Peak WSA is underlain by a mid-Tertiary metamorphic core complex and copper mineralization is associated with the rocks. The WSA is moderately favorable for the accumulation of metallic minerals and has low favorability for uranium.

The Ragged Top WSA is underlain by Precambrian granites, sediments and diabbases, Cretaceous andesites, mid-Tertiary volcanics, intrusives and sediments and Quaternary alluvium. One copper prospect in the WSA has produced and copper, gold, barite, and lead occurrences, some past producers, are located within close proximity to the WSA. The rich porphyry copper deposits of the Silver Bell Mine are located less than three miles south of the WSA. The WSA has low to moderate favorability for metallic mineralization, and low favorability for uranium and non-metallic resources.

1. Field checking mineral occurrences and prospects in the WSAs to determine if mineralization may be extensive.
2. Field checks for hydrothermal alteration; presence of chloritic breccias, dislocation surfaces and upper plate rocks in the Picacho Mountains metamorphic core complex; and occurrence of pegmatites in Precambrian granites.
3. Geochemical sampling and analysis of chloritic breccias, schists and rocks of dislocation surfaces to determine uranium and metallic mineral potential.

INTRODUCTION

Purpose and Methodology

The need and desirability of the "Geological, Energy and Minerals (GEM) Resources Assessment" of the "Wilderness Study Areas" (WSA) has been recognized and a series of such studies was recently undertaken by the Bureau of Land Management (BLM). The execution of the objective work is being performed by various contractors.

The selected Wilderness Study Areas, widely scattered within the "Sonoran Desert and Mexican Highlands" and grouped into "Region 5", have been studied and assessed by Geoexplorers International, Inc. The present report pertains to two WSAs in south-central Arizona which have been grouped together into the Wymola Geological, Energy and Mineral Resources Area (GRA).

The purpose of the present study is to assess the potential for locateable, leaseable and saleable resources within the GRA, and specifically within each of the WSAs. This assessment has been carried out through literature study of the geology, structure and economic geology of the GRA, and a consideration of the regional paleogeographic, plate tectonic and metallogenic setting of the GRA within the southern Cordillera. Thus, the assessment is based not only on data from the GRA itself, but also on metallogenic concepts within the regional paleogeographic and plate tectonic framework.

Geological, Energy and Mineral (GEM) Resources Area (GRA)

In this report, "resources" are defined as mineral and/or fossil fuel concentrations amenable to economic development under current or reasonably

anticipated conditions. Resources include reserves and other mineral or fossil fuel concentrations that may eventually become reserves but are currently either economically or technically not recoverable. Resources are also defined as deposits inferred to exist, but not yet discovered.

Considering the BLM's requirements, the GRA boundaries have been determined in accordance with the following criteria:

1. The size of the GRA is approximately 211,064 acres (853.8 km²), which if shown on the map to the scale of 1:250,000 (also required by BLM) does not exceed a sheet of paper 8.5 by 11 inches,
2. GRA boundary does not cut across a Wilderness Study Area, and
3. The geologic environment and mineral occurrences are also taken into primary consideration.

The criteria for establishment of the Wilderness Study Areas are not the subject of this report. Also, their boundaries, code numbers and names have been established by the Bureau of Land Management prior to this study.

The name "Wymola GRA," as described below, has been suggested and used by the authors of this report as no name has yet been established by the Bureau of Land Management.

Location and Access

The Wymola Geological Resources Area is located in Pinal and Pima Counties in south-central Arizona. It lies within the Phoenix Resource Area of the BLM-administered Phoenix District. It occupies the western part of the Tucson 1:250,000 quadrangle, approximately between latitude 32° 20'N and 32° 50'N and longitude 111° 10'W and 111° 40'W. The two WSAs within the Wymola GRA are listed in Table 1 and their locations are shown in Figure 1.

Table 1. WILDERNESS STUDY AREAS IN THE WYMOLA GRA

WSA NO.	WSA Name	Acres	km ²
020-194	Picacho Mountains	6,400	25.7
020-197	Ragged Top	4,460	17.9
Total		10,860	43.6

FIG. 1. PHYSIOGRAPHIC MAP OF SOUTH-CENTRAL ARIZONA SHOWING LOCATION OF SONORA, WYMOLA AND KITT PEAK AREAS. Depth to bedrock contours, interval = 1600 ft., from Oppenheimer and Sumner (1980).

Important access into the GRA is provided by the following: the Southern Pacific Railroad and Interstate Highway 10, which run northwest-southeast across the GRA, and Arizona Highway 87, which runs from the northern edge of the GRA south to I-10. Access to the valleys in the GRA is along numerous light-duty and unimproved roads, but access for vehicular traffic to the mountainous areas, with the exception of Silver Bell Mountains, is very limited. Eloy, in the northwestern part of the GRA, is the largest town in the area; several smaller towns are scattered throughout the lowlands of the GRA.

PHYSIOGRAPHY

The Wymola GRA lies within the Sonoran Desert section of the Basin and Range Province (Fenneman, 1931). The area has two topographic grains: a north-south to northeast-trending topographic grain which reflects Miocene Basin and Range faulting and, in the Picacho Mountains, lineation of a mid-Tertiary metamorphic core complex; and a northwest-trending topographic grain in the Silver Bell and West Silver Bell Mountains of the southwest part of the GRA which reflects the trend of pre-Laramide structures. Basin and Range fault scarps have been eroded back to form extensive pediments and the range fronts are embayed (Tucker, 1980). This is because much of southern Arizona has been almost free of tectonic activity for the past several million years.

The GRA can be divided into two distinct physiographic terrains (fig. 1): mountainous-to-hilly and lowland terrains.

The mountainous-to-hilly terrain is comprised of the Silver Bell Mountains, Ragged Top and surrounding area, Cerro Prieto, Picacho Peak, Picacho Mountains and several hills and buttes scattered throughout the area.

Lowlands include the Santa Cruz Flats, Avra Valley and McClellan Wash and the broad, gently sloping alluvial plain coming off the Tortolita

Mountains, Suizo Mountains and Durham Hills (located east of the GRA). All are probably fault-bound basins which have been widened through the formation of pediments. In the western part of the area, the Picacho Basin which underlies the Santa Cruz Valley is filled with more than 9600 feet of sediments as is the Avra Valley in the southeastern part of the GRA (fig. 1; Oppenheimer and Sumner, 1980). The basin between the Picacho Mountains and the ranges east of the GRA is shallower, filled with between 6400 and 8000 feet of sediments.

GEOLOGY

Southern Arizona is an area of highly complex geology. Rocks range in age from Precambrian to Recent, and the region has been affected by Precambrian, mid-Mesozoic, Laramide and Mid-Tertiary orogenies and by Basin and range faulting. Important advances in the understanding of this complex terrain have been made since the publication of the Geologic Map of Arizona (Wilson et al., 1969) and have been summarized by Reynolds (1980). These advances have largely been the result of a greatly increased number of radiometric data (Shafiqullah et al., 1980); regional analysis of deformation (Rehrig and Heidrick, 1967; Davis, 1981); recognition of metamorphic core complexes (Davis and Coney, 1979; Coney, 1980; Davis et al., 1980; Rehrig and Reynolds, 1980); recognition of the relationship between subduction magmatism and metallogenesis in the southern Cordillera (Coney and Reynolds, 1977; Davis et al., 1981); and an increased level of mapping of Cenozoic basins as a result of intense uranium exploration during the late 1970s (Eberly and Stanley, 1978; Scarborough and Wilt, 1979).

The lithology and stratigraphy, structural geology and tectonics, paleontology and geologic history of the Wymola GRA are discussed in this section in order to facilitate the assessment of mineral potential within the GRA and,

specifically, within the enclosed WSAs. The regional geologic setting and detailed geology of the Wymola GRA are shown in Figures 2 and 3 respectively.

Lithostratigraphy - Rock Units

In southern Arizona, older Precambrian crystalline basement is overlain by younger Precambrian and Paleozoic shallow marine sediments; Mesozoic and Laramide intrusives, volcanics and continental clastic sediments; mid-Tertiary volcanics and clastic continental sediments; and late Tertiary volcanics and valley-fill sediments. Intensive activity and metamorphism took place during the Precambrian, mid-Mesozoic, Laramide and mid-Tertiary. Metamorphic core complexes were probably emplaced during the latter event.

Older Precambrian Rocks

Older Precambrian rocks in Arizona crop out most extensively in the northwest-trending Central Mountain region, to the north of the Wymola GRA. Here they have been divided into three distinct northeast-trending belts (Titley, 1982; see Figure 2C) which, according to Anderson (1976), accreted onto the North American craton from the southeast.

The most northwesterly of these belts consists of gneisses which are in part metavolcanic facies (Stensrud and More, 1980) and were deposited about 1.8 b.y.B.P. (Titley, 1982). The central belt consists of the Yavapai Series which was deposited 1.82 - 1.775 b.y.B.P. (Anderson and Silver, 1976). It is a greenstone belt which is approximately 40,000 feet thick and is dominated by volcanic and volcanoclastic rocks of basaltic to rhyolitic composition (Anderson and Silver, 1976; Titley, 1982) and has been metamorphosed to the greenschist facies. Massive sulfide copper-zinc deposits are associated with submarine rhyolitic volcanism, especially in the Prescott-Jerome area (Donnelly and Hahn, 1981). The southeastern belt consists of the Pinal

Figure 2: Paleotectonic and paleogeographic maps of Arizona showing location of the Wymola GRA.

- A. Location of Precambrian terrains and the Holbrook, Bright Angle-Mesa Butte and Colorado lineaments, after Warner (1978) and Titley (1982).
- B. Location of mid-Mesozoic magmatic arc, the Mojave-Sonora megashear and mid- to late Mesozoic red beds, after Dickinson (1981). The red beds postdate the magmatic arc and probably extend farther to the southwest than shown.
- C. Location and age trends of major porphyry copper deposits. Note that these are aligned parallel to northwest-trending Paleozoic-Mesozoic discontinuities (Lowell, 1974; numbers 1-6 correspond to discontinuities named in Heidrick and Titley, 1982), along northwest-trending Laramide magmatic arcs (v pattern), and along northeasterly Precambrian trends (Heidrick and Titley, 1982). Curved black lines show location of arc at different times, as given.
- D. Location of Precambrian alkali and alkali-calcic intrusions and mid-Tertiary metamorphic core complexes, mid-Tertiary alkali-calcic volcanics and sedimentary domains (Scarborough and Wilt, 1979).

Figure 2A.

Figure 2B.

Figure 2C.

FIG.3 GEOLOGIC, ENERGY AND MINERAL RESOURCES MAP OF THE WYMOLA AREA, ARIZONA

Scale
1 : 250,000
LEGEND: see enclosed

Figure 4. **LEGEND**
FOR

GEOLOGIC, ENERGY AND MINERAL RESOURCES MAPS

Scale of all maps is 1:250,000 or as otherwise indicated.

LITHOSTRATIGRAPHY

After Wilson et al. (1969) with modifications from Johnson (1981),
Shafiqullah (1980), Eberly and Stanley (1978), Shafiqullah et al. (1976)
and Yeend (1976).

QUATERNARY	Qs	ALLUVIUM - Sand, gravel, silt; stream deposits, fans and pediment cappings.
LATE TERTIARY TO QUATERNARY	QTs	SEDIMENTS - Fanglomerate, sandstone and siltstone. May include minor basalt.
MID-TERTIARY	Tb	BASALT - Flows and flow breccias of basalt and basaltic andesite composition.
	Ti	DIKES, SILLS, PLUGS AND SMALL STOCKS - Includes North Star stock (granite and monzonite) and intrusive of unknown nature at Ragged Top.
	Tmc	METAMORPHIC CORE COMPLEXES - Muscovite-biotite gneiss, mylonitic gneiss, mostly metasedimentary schists, hornblende-biotite granodiorite, intermediate to felsic dikes.
	Tvi	INTERMEDIATE VOLCANICS - Andesite, trachyandesite, trachyte, ultrapotassic trachytes, latites, quartz latites. Flows, ash flow tuffs, tuff breccias.
	Tr	RHYOLITE - Flows, pyroclastics and breccias, mostly rhyolitic in composition; also includes conglomerate and other Tertiary sediments.
	Ts	SEDIMENTS - Fluvial arkosic sandstone, fanglomerate, lacustrine clay and limestone.
LATE CRETACEOUS TO TERTIARY	TKg	LARAMIDE QUARTZ MONZONITE - Stocks and dikes.
	TKi	LARAMIDE INTRUSIVES AND ASSOCIATED ROCKS - Alaskite, dacite porphyry, andesite porphyry, syenodiorite dikes.
CRETACEOUS	Ka	CRETACEOUS ANDESITE - Flows, breccias and lahars.
	Ks	CRETACEOUS SEDIMENTS - Buff to maroon arkose, siltstone and pebble conglomerate.

PALEOZOIC

**YOUNGER
PRECAMBRIAN**

**OLDER
PRECAMBRIAN**

SPECIAL SYMBOLS OF STRUCTURAL FEATURES

After U.S. Geological Survey

Contact — Dashed where approximately located; short dashed where inferred; dotted where concealed

Contact — Showing dip; well exposed at triangle

Fault — Dashed where approximately located; short dashed where inferred; dotted where concealed

Fault, showing dip — Ball and bar on downthrown side

Normal fault — Hachured on downthrown side

Fault — Showing relative horizontal movement

Thrust fault — Sawteeth on upper plate

Anticline — Showing direction of plunge; dashed where approximately located; dotted where concealed

Asymmetric anticline — Short arrow indicates steeper limb

Overturned anticline — Showing direction of dip of limbs

Syncline — Showing direction of plunge; dashed where approximately located; dotted where concealed

Asymmetric syncline — Short arrow indicates steeper limb

Overturned syncline — Showing direction of dip of limbs

Monocline — Showing direction of plunge of axis

Minor anticline — Showing plunge of axis

Minor syncline — Showing plunge of axis

Strike and dip of beds — Ball indicates top of beds known from sedimentary structures

Inclined Horizontal
Vertical Overturned

Strike and dip of foliation

Inclined Vertical Horizontal

Strike and dip of cleavage

Inclined Vertical Horizontal

Bearing and plunge of lineation

Inclined Vertical Horizontal

Strike and dip of joints

Inclined Vertical Horizontal

Note: planar symbols (strike and dip of beds, foliation or schistosity, and cleavage) may be combined with linear symbols to record data observed at same locality by superimposed symbols at point of observation. Coexisting planar symbols are shown intersecting at point of observation.

SPECIAL SYMBOLS

FOR ENERGY AND MINERAL RESOURCES

KNOWN DEPOSITS AND OCCURRENCES

-O Oil field	-C Coal deposit	-Mineral orebody - as specified with symbol
-G Gas field	-C Coal occurrence	-Mineral deposit - as specified with symbol
-Os Oil shale		-Mineral occurrence - as specified with symbol
		-Mineral district (Fig.= inserted map)

EXPLORATION AND/OR MINING ACTIVITY

MINERALS AND COAL

Mineral deposit, mine or prospect with recorded prod.	Vertical shaft	Active gravel or clay (cl) pit
Prospect or mine with no recorded production	Inclined shaft	Inactive gravel or clay (cl) pit
Accessible adit, or tunnel	Active open pit, or quarry	Exploration hole with data available
Inaccessible adit, or tunnel	Inactive open pit, or quarry	Exploration hole without data
		Mining district (Fig.= inserted map)

PETROLEUM

Oil well	Show of gas	CO ₂ - or He-hellum- rich well
Oil and gas well	Show of oil	Dry well - abandoned
Gas well	Show of oil and gas
	Shut-in well	

GROUND WATER

Water well of special importance	Brine	Thermal water
Water well of high yield	Mineral water	Radioactive water
Flowing water well		Thermal point

ENERGY RESOURCES

O Oil	C Coal	U Uranium
G Gas	Cb Lignite (brown coal)	Th Thorium
Os Oil shale	Cp Peat	Gt Geothermal
Ot Tar sands		

MINERAL RESOURCES

METALS

Al Aluminum	Cu Copper	Mo Molybdenum	Tl Thallium
Sb Antimony	Ga Gallium	Ni Nickel	Sn Tin
As Arsenic	Ge Germanium	Nb Niobium or Columbium	Ti Titanium
Be Beryllium	Au Gold	Pt Platinum group	W Tungsten
Bi Bismuth	Fe Iron	RE Rare earth	V Vanadium
Cd Cadmium	Pb Lead	Re Rhenium	Zn Zinc
Cr Chromium	Li Lithium	Sc Scandium	Zr Zirconium and Hf Hafnium
Cs Cesium	Mn Manganese	Ag Silver	
Co Cobalt	Hg Mercury	Te Tellurium	

NONMETALS - INDUSTRIAL MINERALS

ab Abrasives	di Diatomite	fs Feldspar	mg Magnesian refractories
al Alum	Nonmarine and marine evaporites and brines	F Fluorite (fluorspar)	mi Mica
as Asbestos	pt Potash	gs Gem stones	ph Phosphate
Ba Barite	na Salt - mainly halite	ge Graphite	pi Pigment and fillers
be Bentonite	gy Gypsum and anhydrite	He Helium	qz Quartz crystals
ca Calcite	nc Sodium carbonate or sulfate	ki Kaolin	sl Silica sand
cl Clay	bn Boron minerals	ky Kyanite and related minerals	S Sulfur
Construction materials:	ni Nitrates	ls Limestone	tc Taic
cs Crushed stone	Sr Strontium	im Lithium minerals	ze Zeolites
la Lightweight aggregates, includ.:	Br Bromine		hm Humate
pm Pumice and volcanic cinders	cc Calcium chloride		
pe Perlite	mg Magnesium compounds		
ec Expanded clay, shale, slate			
vm Vermiculite			
sg Sand and gravel			
cr Cement raw materials			
bs Building stones			
li Lime			

SPECIAL GEOLOGICAL FEATURES

POINT OF SPECIAL GEOLOGIC INTEREST

m Mineral occurrence	s Structural, bedding, foliation, etc.,	u Radioactive spring
f Fossil locality	b Brecciation, shear zone, etc.,	g Thermal spring
v Volcanic phenomenon	y High yield spring	a Extensive rock alteration
t Stratigraphic sequence	p Spring with mineral water	r Lithologic type locality

FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE FOR MINERAL RESOURCES

FAVORABILITY:

- 1A - Undefined
- 1 - Not favorable - combine with either B, C, or D
- 2 - Low
- 3 - Moderate
- 4 - High
- } combine with either A, B, C, or D

LEVEL OF CONFIDENCE:

- A - Insufficient data
- B - Indirect evidence
- C - Direct evidence
- D - Abundant direct and indirect evidence

Schists which were deposited 1.7 - 1.68 b.y.B.P. (Silver, 1978) and consist of quartz-muscovite or quartz-muscovite-chlorite schist, arkose and quartzite (Titley, 1982).

The older Precambrian rocks were metamorphosed and intruded by granites during the Arizonan revolution 1.76 - 1.63 b.y.B.P. (Damon, 1968) and were intruded by granites during the Mazatzal revolution 1.5 - 1.4 b.y.B.P. (Damon, 1968; Silver et al., 1977).

According to Shafiqullah et al. (1980), the metamorphic rocks in the Sonoran Desert section of the Basin and Range Province are generally dark amphibolite gneisses and augen gneisses, in contrast to the lower grade greenschists to the northeast. The southwestern extension of the boundary between the Yavapai Series and the Pinal Schists and the approximately coincident Holbrook Line (see Figure 2A) of the magnetic anomalies projects to the west of the GRA.

The granitic rocks, according to Wilson et al. (1969), may range in composition between granite and quartz diorite.

Older Precambrian schists, gneiss and granite crop out in the Wymola GRA. Pinal Schist crops out in the northwest corner of the GRA and in the northern Picacho Mountains, where it is locally gneissic and is a roof pendant of the Oracle Granite (Johnson, 1981). The Oracle Granite in that area is 1.420 to 1.450 b.y. old and is locally foliated (Johnson, 1981). Precambrian granitic rocks also crop out in the West Silver Bell Mountains and at Ragged Top in the southwest part of the GRA and at Toltec Buttes in the northwest.

Younger Precambrian

Younger Precambrian sediments of the Apache Group and a diabase sill dated as $1,100 \pm 15$ m.y. old (Titley, 1982) crop out in the Ragged Top WSA

in the south central part of the GRA, and another diabase intrusion is located a few miles to the west of WSA.

The Apache Group consists, in ascending order, of the Pioneer Formation, the Dripping Spring Quartzite and its basal Barnes Conglomerate Member, and the Mescal Limestone which locally includes basalt flows. Contact between formations of the Apache Group are unconformable and total thickness of the Apache Group is between 1250 and 1600 feet in areas to the northeast where complete sections have been measured (Shride, 1967; Titley, 1982). The Pioneer Formation consists of basal quartzite and quartz pebble conglomerate overlain by arkose, grayish red tuffaceous siltstone and silty mudstone. Measured sections are from 150 to 500 feet thick. The Barnes Conglomerate, an arkosic quartz pebble conglomerate, is the basal member of the Dripping Spring Quartzite. Thick- to thin-bedded arkose and feldspathic quartzite, often cross-bedded, overlies the Barnes Conglomerate Member. Thinly laminated or cross-laminated, commonly pyritic siltstone with abundant mud cracks and stylolites comprises the upper member of the 550 to 7000 foot Dripping Spring Quartzite. Cherty limestone, locally metamorphosed to calc-silicate marble, overlain by algal dolomite and limestone, make up the Mescal Limestone, which is 190 to 400 feet thick. Porphyritic amygdaloidal basalt overlies the Mescal (Shride, 1967). In the Ragged Top WSA, both the basalt flow and the Mescal Limestone may have been removed by erosion (Titley, 1982; Shride, 1967).

Intrusion of diabase sills and dikes followed local folding of the younger Precambrian sediments (Titley, 1982). Sills are up to 1200 feet thick. Precambrian diabases host ore mineralization in the porphyry copper deposit at Ray, Arizona (Titley, 1982) and may have been the source of uranium for deposits in the Dripping Spring Quartzite (Granger and Raup, 1969).

Paleozoic

Paleozoic sedimentary rocks occur in scattered outcroppings in the southernmost part of the GRA and may underlie Cretaceous volcanics in the Ragged Top WSA. Where present, total thickness of the Paleozoic section is 4000 to 5000 feet and includes the Bolsa Quartzite, Abrigo Formation, Martin Formation, Escabrosa Limestone and possibly the Scherrer Formation and other Paleozoic units in the Silver Bell Mountains. These units are shelf sediments deposited on a stable platform east of the Wasatch Line (fig. 2B), separating them from the Cordilleran geosyncline.

The Cambrian Bolsa Quartzite is 400 to 700 feet thick and consists dominantly of light gray to brownish gray cross-bedded arkose with lesser quartzite and minor shale. The unit rests unconformably on older Precambrian rocks and sediments of the younger Precambrian Apache Group (Titley, 1982; Heindl and McClymonds, 1964).

Conformably overlying the Bolsa Quartzite is the upper Cambrian Abrigo Formation. 1250 feet thick, the unit consists of approximately equal proportions of thin-bedded, fetid limestone and greenish and gray siltstone (Titley, 1982; Graybeal, 1982).

The Devonian Martin Formation unconformably overlies the older Paleozoic sediments. 300 to 400 feet thick, the Martin Formation is composed of limestone, dolomite, silty carbonate, shale and thin beds of sandstone (Titley, 1982). The shallow marine unit contains brachiopods, gastropods, fishes and ostracods.

Conformably overlying the Martin Formation are 600 to 750 feet of the lower Mississippian Escabrosa Group, consisting of a lower, thin-bedded limestone and an upper massive limestone (Titley, 1982; Bryant, 1968). Corals and brachiopods are reported from Escabrosa outcrops near Tucson (Arizona

Geological Society, 1952), with crinoids, corals, bryozoans and brachiopods occurring in outcrops in the Vekol Mountains west of the area (Bryant, 1968).

The Paleozoic is poorly known in the southern part of the Wymola GRA due to the effects of contact metamorphism on the dominantly carbonate section. Titley (1982) reports 600 feet of Upper Pennsylvanian Horquilla Formation unconformably overlying the Escabrosa sediments in the Silver Bell area. The lower half of the formation is dominantly thick-bedded carbonate with lesser clastics. The upper half is more thinly bedded with siltstones and shales nearly equaling the amount of carbonates (Titley, 1982).

Conformably overlying and in gradational contact with the Horquilla Formation is the Upper Pennsylvanian to Lower Permian Earp Formation. Averaging 1000 feet thick in southeastern Arizona, the Earp Formation is composed of thin-bedded, pink, ferruginous silty limestone and dolomite with lesser siltstone (Titley, 1982). Paleozoic isopachs of southeastern Arizona indicate that the Paleozoic section in the Wymola area is thinner than average, so the Earp Formation, if present in the GRA, may be much thinner than the thousand-foot average thickness in southeastern Arizona.

Two hundred feet of Lower Permian Colina Formation sediments overly the Earp Formation in the Silver Bell Mountains (Titley, 1982). The contact is apparently conformable. The Colina Formation consists of thick-bedded limestones with very minor dolomite (Titley, 1982).

The Lower Permian Epitaph Formation may overly the Colina Formation in the Wymola GRA. If present, less than 750 feet of dolomite, limestone and cherty, thin-bedded gypsum comprise the Epitaph in the Silver Bell Mountains and surrounding areas (Titley, 1982).

Richard and Courtright (1966) report that sediments previously identified as Cambrian Bolsa Quartzite in the Silver Bell Mountains also resemble

sediments of the middle Permian Sherrer Formation. The Sherrer Formation consists of lower and upper siltstone and sandstone beds sandwiching 300 feet of silty, carbonate-rich sandstone. Total thickness of the Sherrer Formation is up to 500 feet (Titley, 1982).

The middle Permian Rainvalley and Concha Formations complete the Paleozoic section of southeastern Arizona. The lower Concha Formation consists of thick-bedded limestone and the Rainvalley Formation is composed of thin- to thick-bedded limestone. Both units average 500 feet of thickness in southern Arizona but it is not known if either unit crops out in the Wymola GRA.

Although there is much disagreement as to which Paleozoic units exist in the Silver Bell Mountains and surrounding areas, the fact remains that Paleozoic sediments are very important in the area. Intrusion by Laramide igneous rocks, which caused the contact metamorphism making the units difficult to distinguish, resulted in the Paleozoic sediments of the Silver Bell Mountains becoming important hosts of ore in the Silver Bell porphyry copper deposits (Richard and Courtright, 1966; Graybeal, 1982; Titley, 1982).

Mesozoic

No Triassic or Jurassic rocks are definitely recognized in the Wymola GRA, but Cretaceous sediments and volcanics crop out in the southern part of the area. Titley (1982) identifies Triassic and Jurassic sedimentary and volcanic rocks as occurring just southwest of the Silver Bell porphyry copper deposit; no other workers report any rocks of Triassic and Jurassic age in the area, although a Laramide alaskite intrusive is misidentified as a pre-Laramide Mesozoic granitic body on the Arizona state geologic map (Wilson et al., 1969). Alternatively, older Mesozoic units may underlie the Cretaceous sediments in the area and have gone unreported. Titley's (1982) description of the pre-Cretaceous rocks matches other workers' (Richard and Courtright,

1966) descriptions of Cretaceous sediments, as given below. Titley (1982) also recognized the occurrence of Cretaceous foreland sediments in the Silver Bell Mountains, but does not describe the rocks. Graybeal (1982) describes Mesozoic clastic rocks of the Silver Bell Mountains as well-bedded and well sorted arkose with minor siltstone and pebble conglomerate; color of the clastics varies from buff to maroon. The Mesozoic clastics are intruded by the previously-mentioned alaskite body (Graybeal, 1982) which other workers regard as the earliest Laramide intrusive of the Silver Bell Mountains (Richard and Courtright, 1966). Graybeal's (1982) description of the Mesozoic clastic rocks is similar to Richard's and Courtright's (1966) description of Cretaceous sediments as arkosic sandstone, red shale and conglomerate, of greater than 5000 feet in total thickness. Other workers (Cooper, 1971; Wilson, et al. 1969, Bryant, 1952) correlate the Mesozoic sediments of the Silver Bell Mountains with sediments of known Cretaceous age in the Tucson and Sierrita Mountains. Underlying Cretaceous sediments in both ranges are sediments believed to have been deposited earlier in the Mesozoic (Cooper, 1971; Bryant, 1952).

Laramide Orogenic Period

The Laramide was a period of volcanism, intrusion and intense tectonic activity in southern Arizona. It is of particular importance because a large number of porphyry copper deposits were formed at this time, especially in southeastern Arizona (Damon and Mauger, 1966; Shafiqullah et al., 1980; Titley, 1981; Heidrick and Titley, 1982; see fig. 2C). The magmatic and tectonic activity was related to a southeastward sweep of the magmatic arc as the dip of the Benioff zone decreased (Coney and Reynolds, 1977; Clark et al., 1982).

The latest pre-Laramide rocks (Wilson et al., 1969) or earliest Laramide age rocks in the Wymola GRA are andesite flows, breccias and associated lahar deposits (Titley, 1982; Ka unit on fig. 3). Thickness of this volcanic unit, which crops out in the southwestern part of the area, is not reported in the literature.

The oldest Laramide intrusive is an elongate, northwest-trending alaskite stock emplaced along the southwest side of a major pre-Laramide structure (discontinuity 3 of fig. 2C; Richard and Courtright, 1966). The medium- to coarse-grained alaskite contains 54% weakly perthitic orthoclase, 25% quartz, 18% oligoclase, and 2% biotite, with traces of other minerals (Graybeal, 1982).

Emplacement of the alaskite stock was followed by intrusion of a large sill-like body of dacite porphyry. The dacite porphyry contains enough potassium feldspar to qualify as a quartz latite, but the name dacite porphyry has been retained by recent workers in order to avoid confusion. This intrusive body contains several large roof pendants of folded and faulted Paleozoic sediments. Andesite porphyries crop out in the same part of the Silver Bell Mountains and either post-date the dacite porphyry or represent another phase of the same magma (Graybeal, 1982; Richard and Courtright, 1966). Intrusion of dark colored, strongly porphyritic syenodiorite dikes (Graybeal, 1982) may be related to the dacite and andesite porphyries or may post-date those igneous events.

The latest Laramide event in the Silver Bell Mountains was the intrusion of stocks and contemporaneous dikes of quartz monzonite. The stocks were emplaced parallel to pre-Laramide and Laramide structures but associated dikes cross-cut all earlier structures. The quartz monzonite consists of 44% andesine, 28% orthoclase, 20% quartz, 5% biotite, 1% hornblende and accessory

magnetite, zircon, sphere and apatite. Orthoclase porphyries and biotite-rich rocks of the Silver Bell Mountains in the area may represent a younger intrusive phase. The quartz monzonite stocks are extremely important economically as porphyry copper mineralization was associated with that Laramide igneous event.

Metamorphic Core Complexes

More than a dozen metamorphic core complexes have been identified and described recently in southwestern Arizona. They occur along a northwest-trending zone that extends from southeastern to west-central Arizona and are part of a more extensive zone that runs from Sonora to Arizona, through eastern Nevada, Idaho, eastern Washington and southeastern British Columbia (Coney, 1980). Their general features have been summarized recently by Davis and Coney (1979) and Reynolds (1980) as follows. Metamorphic core complexes are characterized by metamorphic and mylonitic rocks whose gently dipping foliation defines broad domes which generally are elongated in an ENE to NE direction. The core of the domes consist of amphibolite facies gneisses and granites that have undergone ductile deformation. Up section a mylonitic fabric with an ENE-to-NE lineation is overprinted on both igneous and metamorphic rocks. This grades upward into a greenschist facies breccia over a short distance and records a sharp thermal and strain gradient. The breccia is overlain by a normal decollement zone, or dislocation surface, above which allochthonous, deformed, but unmetamorphosed upper plate rocks are present. These range in age from Precambrian to Miocene and have undergone listric normal faulting as recently as mid-Miocene. The core complexes typically record 30 - 20 m.y.B.P. K-Ar cooling ages. It is generally agreed that the complexes formed in an extensional environment (back-arc spreading?) during and after the fast regression of the magmatic arc 40 - 20 m.y.B.P. (Coney

and Reynolds, 1977) at a time of high heat flow. Davis and Coney (1979) regard the complexes as megaboudins formed from the crystalline basement. Rehrig and Reynolds (1980) agree that the complexes formed by an extensional process but consider that the metamorphic core complex itself developed between, rather than within, separating blocks.

The Picacho Mountains, including the Picacho Mountains WSA, are considered to be a metamorphic core complex by Johnson (1981), Rehrig and Reynolds (1980) and Banks (1980). Yeend (1976) mapped the range on a reconnaissance level. Information presented below is summarized from those sources.

Much of the southern part of the Picacho Mountains is underlain by fairly coarse-grained, locally mylonitic, muscovite-biotite gneiss of apparent meta-igneous origin. Shallow-dipping foliation trends northeast. Greenstone and hornblende augen gneiss occur sporadically within the gneiss. Potassium-argon dating of biotite from the gneiss gave a cooling age of 23.6 ± 0.5 m.y. To the north, where the Picacho Mountains sharply narrow, the gneiss is intruded by medium-to coarse-grained, equigranular, hornblende monzogranite (Johnson, 1981) or hornblende-biotite granodiorite (Yeend, 1976). The sphene-bearing intrusive is rarely foliated and yielded a biotite K-Ar age of 24.4 ± 0.5 m.y. This granodiorite is similar in age and rock type to intrusives which occur in the Durham Hills, Santa Catalina-Rincon Mountains and Tortolita Mountains metamorphic core complexes located southeast of the Picacho Mountains (see fig. 2D).

Overlying the mylonitic gneiss in local areas is schist, dominantly quartz-muscovite schist with lesser chloritic schist, quartzite schist, quartzite, rare siliceous slate, amphibolite schist and quartzite; some are clearly metasedimentary in origin.

The gneiss, granodiorite and schist of the metamorphic core are cut by pegmatite and aplite dikes, felsic dikes, small stocks and dikes of syenite and monzogranite, and andesite dikes.

Upper plate rocks occur in contact with core rocks only in one small outcropping approximately one-quarter mile southeast of the southeastern corner of the Picacho Mountains WSA. The upper plate rocks are purplish red trachyandesites which are considered correlative with 20.72 ± 0.50 to 22.60 ± 0.48 m.y. old volcanics of Picacho Peak and a smaller hill south of the Picacho Mountains (Shafiquallah et al., 1976). Exxon State (74) No. 1, a wildcat well drilled in Sec. 2, T8S, R8E, about 4 miles west of the northwest corner of the Picacho Mountains WSA in the Picacho basin, bottomed out in quartz diorite gneiss which yielded a K-AR date from biotite of 25 ± 1.4 m.y. and a Rb-Sr age of (whole rock) of 1,275 and 1,540 m.y. This gneiss may be a down-faulted portion of the Picacho Mountains metamorphic core indicating that the protolith of the core is Precambrian, possibly the Oracle Granite or equivalent.

In the northern Picacho Mountains the contact between the mid-Tertiary metamorphic core rocks and Precambrian rocks is a fault, the nature of which is undetermined (Yeend, 1976; Johnson, 1981).

A small intrusive body, the North Star stock in the northern Picacho Mountains, was emplaced during the mid-Tertiary orogeny. The stock consists of a coarse-grained, equigranular granite which has been recrystallized and silicified, and a fine- to medium-grained, typically porphyritic monzonite (Johnson, 1981). Biotite from the monzonite yielded a K-AR age of 24.35 ± 0.73 m.y.B.P. (Shafiquallah et al., 1980).

Desert Peak, in the east-central part of the Wymola GRA, consists of mildly foliated quartz diorite which has been intruded along foliation planes by pegmatite and fine-grained quartz monzonite dikes (Banks, 1980). Banks (1980) suggests that Desert Peak is also part of a metamorphic core complex.

Mid-Tertiary

Mid-Tertiary rocks are here defined to include all sedimentary and igneous rocks deposited after the Laramide orogeny and the post-Laramide period of peneplanation, and before Basin and Range-type faulting became dominant. These pre-Basin and Range rocks have been divided into three units by Eberly and Stanley (1978) and Scarborough and Wilt (1979, and stratigraphy of the units is summarized in fig. 5.

The lowest unit consists of indurated, red to brown arkosic fluvial sandstone, fanglomerates of gneissic and granitic provenance up to 300 feet thick, and minor lacustrine sediments with some algal limestone. Andesitic to rhyolitic volcanics increase in abundance towards the upper part of this unit.

The middle unit is characterized by voluminous intermediate to felsic volcanism that is associated with the mid-Tertiary orogeny. The volcanics consist of flows, ash flow tuffs, tuff breccias and ash of latitic, quartz latitic, rhyolitic, and trachytic composition and flows and flow breccias of basaltic, basaltic andesite, and andesitic composition (Reynolds, 1980). Small intrusions of the above compositions are also present. The volcanic rocks are interbedded with red sand and gravel fluvial deposits, massive fanglomerates, and lacustrine deposits with local organic-rich facies, algal limestones, and water-laid tuffs. It is within such beds that the well-known uranium deposit of the Anderson Mine is located (Sherborne et al., 1979).

The upper unit consists of grayish brown, poorly consolidated sandstones, fanglomerates, mudstones, and water-laid tuffs. The rocks contain abundant volcanic debris. They are overlain and intercalated with basaltic volcanic mudstones in lacustrine deposits and contain fresh water ostracods.

PHOENIX-TUCSON AREA

FIG.5 COMPOSITE STRATIGRAPHIC COLUMN OF SOUTHWESTERN ARIZONA.
Unconformity (a) represents erosional surface that was disrupted by beginning of late Miocene block faulting. From Eberly and Stanley (1978).

The mid-Tertiary rocks rest unconformably on Precambrian, Paleozoic, Mesozoic, and Laramide rocks. They were deposited in northwest-striking basins which were tilted northeastward and southwestward as shown in fig. 2D (Scarborough and Wilt, 1979).

The mid-Tertiary volcanic rocks lie mainly in the middle unit, but they do extend into the lower and upper units. The volcanism was extremely voluminous, and in southern Arizona about a million cubic kilometers were emptied (Shafiquallah et al., 1980). These may have been largely emptied from cauldrons such as have been identified in the Datil volcanics in southwestern New Mexico by Elston (1978) and Elston and Bornhorst (1979). However, no such cauldrons have been identified in southwestern Arizona to date. The volcanism lasted from 35 m.y.B.P. to about 12 m.y.B.P., with the interval between 24 and 12 m.y.B.P. being the transition from the mid-Tertiary orogeny to Basin and Range faulting, which did not take place simultaneously throughout southern Arizona (Shafiquallah et al., 1980). In southeastern Arizona the intensity of volcanism peaked about 26 m.y.B.P. as the volcanic arc swept westward during the steepening of the Benioff zone in the late Oligocene and early Miocene (Coney and Reynolds, 1977). At first the volcanism was calc-alkaline, but as the main magmatic arc passed westward the volcanism became highly potassic with eruption of potassic trachyandesites and ultra-potassic trachytes (Shafiquallah et al., 1980). Towards the close of the mid-Tertiary orogeny, volcanism became almost entirely basaltic.

In the Wymola GRA, mid-Tertiary volcanics and sediments crop out in Picacho Peak and the surrounding area, in the eastern part of the area and throughout the southwestern part of the area. Rock types include flows, tuffs, breccias, agglomerates, conglomerates and sands. Composition of the volcanics is varied, including basalt, andesite, latite, trachyte,

and trachyandesite. Andesite, quartz latite and latite dikes cut the Laramide age rocks of the Silver Bell Mountains. Flows are aphanitic to porphyritic; a few are vesicular, with quartz and epidote filling vugs.

Conglomerates are commonly purple or red and contain clasts of pink granite, phyllite, volcanics and gneiss (not similar to the gneiss of Picacho Mountains. Tuffaceous beds are reported to occur in sedimentary sections of the Picacho Peak. The Wymola Conglomerate of Picacho Peak may be correlative with Pantano and Rillito conglomerates of the Tucson area. Conglomerates of the Silver Bell Mountains contain mineralized material derived from the leached cap of the Silver Bell porphyry copper deposit (Graybeal, 1982; Dohms et al., 1980; Shafiqullah et al., 1976; Richard and Courtright, 1966).

Approximately 1100 feet (336 m) of mid-Tertiary sediments and volcanics were encountered during drilling of Exxon's State (74) No. 1 wildcat well in the Picacho Basin.

Late Tertiary

Late Tertiary deposits occur in all the tectonic basins formed during the Basin and Range disturbance. The depth of these basins have been estimated by Oppenheimer and Sumner (1980) through gravity modeling and drillhole data and is shown in figure 1. The Picacho Basin, in the west-central and northwest of the Wymola GRA, and the Avra Valley, in the southeast, both are greater than 9600 feet deep. The basin in the northeast part of the area is between 6400 and 8000 feet deep.

The deposits consist mainly of poorly consolidated, tan colored fan-glomerate, sandstone, and siltstone of fluvial and lacustrine origin, and minor basalt (Scarborough and Wilt, 1979; Eberly and Stanley, 1978). These deposits rest unconformably on mid-Tertiary or older rocks. Exxon's stratigraphic tests from the Exxon State (74) No. 1 well drilled in the Picacho

Basin reveal that red-brown clay, about 6000 feet of gypsum with lesser halite and green bentonites, and varicolored claystone occur (Eberly and Stanley, 1978; Peirce, 1981, 1976).

The initiation of Basin and Range faulting and deposition of basin-fill sediments took place 13 - 12 m.y.B.P. according to Eberly and Stanley (1978). Shafiqullah et al. (1980), however, present evidence to show that the transition from the mid-Tertiary orogeny to the Basin and Range disturbance took place over the time interval between 19 and 12 m.y.B.P., and that the basaltic volcanism decreased in intensity from 9 to 4 m.y.B.P. The interval during which Basin and Range tectonism, volcanic activity and sedimentation was dominant in southwestern Arizona was probably 14 - 4 m.y.B.P. (Shafiqullah et al., 1980), though some basaltic volcanism is as young as 1 m.y.B.P.

Latest Tertiary and Quaternary

During the last four million years volcanic and tectonic activity has slowed down in southwestern Arizona. The dominant geological processes have been erosion of ranges and formation of extensive pediments, deposition of fanglomerates and deposition of alluvium.

Structural Geology

The GRA lies within the North American craton and east of the Wasatch Line and has been affected by tectonism during Proterozoic, mid-Mesozoic, Laramide and mid-Tertiary orogenies and most recently by the Basin and Range disturbance. The area is, therefore, structurally very complex. It is only recently, and largely as a result of detailed structural studies and extensive radiometric dating, that the structure and tectonics of the area has begun to be understood. Particularly important recent studies include strain analysis of various deformations by Davis (1981) and a summary of recent radiometric dates by Shafiqullah et al., (1980).

During the Arizonan revolution, 1.76 to 1.63 b.y.B.P. (Damon, 1968), the Precambrian rocks were folded about ENE-striking axes and underwent N-S to NNW faulting (Davis, 1981). The Colorado Lineament (see fig. 2), a major strike slip system according to Warner, was initiated about this time and its southwestern extension passes to the northwest of the GRA.

No pronounced tectonic or igneous activity took place during the Paleozoic, but southwestern Arizona was strongly affected by a mid-Mesozoic magmatic arc and a later period of metamorphism and folding. The magmatic arc extended across southwestern Arizona (see fig. 2C) during mid-Jurassic and produced voluminous volcanism and granitic plutonism. The area underwent folding and metamorphism after deposition of molasse-like sediments and prior to the Laramide orogeny. Northwest-trending strike slip faulting was initiated (Davis, 1981) and movement along the Mojave-Sonora left-lateral mega-shear (see fig. 2B) probably took place at this time (Silver and Anderson, 1974). Northwest-trending linear discontinuities in depositional patterns (see fig. 2) were produced in southeastern Arizona (Titley, 1976).

The Laramide was a period of intense tectonism and localized magmatic activity which were associated with the southeastward migration of the magmatic arc (Coney and Reynolds, 1977; Lowell, 1974). The Laramide basement-cored uplifts and thrust faults which strike NNW to NW (Nielsen, 1979; Davis 1981); the WNW left-lateral strike slip faulting of the Texas zone of Schmitt (1966); and the ENE-striking tensional features (Rehrig and Heidrick, 1976) are all probably related to ENE plate motion and compression. Laramide plutons associated with porphyry copper mineralization have a pronounced NNW to NW trend and a secondary ENE trend (Heidrick and Titley, 1982; see fig. 2C). The former is parallel to the Laramide magmatic arc and basement-cored uplifts, and the latter is parallel to Precambrian fold axes and Laramide

tensional features. One of the NE trends and one of the linear discontinuities pass through the southern part of the Wymola GRA (see fig. 2C).

The mid-Tertiary orogeny lasted approximately from 34 to 14 m.y.B.P. (Shafiqullah et al., 1980) and involved eruption of large volumes of volcanic rocks, emplacement of metamorphic core complexes and listric normal faulting. These geologic events accompanied the steepening of the Benioff zone and the resultant westward migration of magmatic arc at this time (Coney and Reynolds, 1977).

The volcanism produced enormous volumes of ignimbrite eruptions and was dominantly calc-alkaline but became potassic in the later stages. In southwestern New Mexico similar volcanics originated from numerous cauldrons (Elston and Bornhorst, 1979). Cauldrons may be present in southern Arizona, although none have been located to date.

Metamorphic core complexes are characterized by mylonitic augen gneiss and an overlying brittle fracture zone separated by a dislocation surface from an allochthonous upper plate which is unmetamorphosed (Davis and Coney, 1979; Coney, 1980; Rehrig and Reynolds, 1980). The mylonitic foliation defines gently dipping, NE-to-ENE-striking dunes which often have physiographic expression. The mylonitic rocks have pronounced NE-to-ENE lineation which is developed parallel to the direction of extension in the lower plate. Most workers agree that the metamorphic core complexes indeed formed as a response to extension in a NE-SW to ENE-WSW direction. Davis (1980) considers the complexes as mega-boudins, whereas Rehrig and Reynolds (1980) consider that the complexes developed in areas of high heat flow between separating blocks. The relationship of the core complexes to the coeval volcanism is not known. The Buckeye Hills in the northwest corner of the Estrella sub-area has local mylonitic foliation which is possibly associated with a metamorphic core complex.

Listric normal faulting is common in the upper plates of metamorphic core complexes. The faults merge downward into the dislocation surface. The spoon-shaped, gravity-like faults generally strike northwest and typically involve Oligocene and mid-Miocene rocks (Davis, 1981). An example is Picacho Peak; the NE tilting volcanics are believed to be listric-faulted upper plate rocks of the Picacho Mountains metamorphic core complex (Rehrig and Reynolds, 1980; Banks, 1980).

About 14 m.y.B.P. a transition occurred between listric faulting and Basin and Range normal faulting. Basin and Range faults strike NW to N-S (see fig. 1) and are high angle faults (Davis, 1981). The present-day ranges and basins resulted from this tectonic episode which was terminated in much of southwestern Arizona about 4 m.y.B.P.

Paleontology

Fossils are important for three major reasons, as follows:

- a) guide fossils which in the sedimentary sequence are most useful for stratigraphic correlation,
- b) outstanding fossil specimens or fossils which are extraordinarily well preserved can be beneficial to science and/or tourism, and
- c) fossils can be excellent indicators of the paleogeographic and paleoecological environments; as a result, even moderately to poorly preserved "uninteresting" fossils can be geologically important.

Plant fossils must also be considered important as organic material can trigger the precipitation of uranium and/or other metals.

The following is a brief summary of the sedimentary formations of the Wymola GRA and WSAs listing types of fossils present. To the authors' knowledge, there are no fossil localities of outstanding importance, either scientifically or as curiosities.

Older metamorphic rocks of the Wymola GRA include the metasedimentary Pinal Schist which was deposited 1.7 to 1.68 b.y.B.P. The Apache Group, of late Precambrian age, includes siltstone and quartzite of the Pioneer Formation; the Dripping Springs Quartzite, which contains siltstone and mudstone beds as well as quartzite; and the Mescal Limestone, a dolomite with siltstone and mudstone beds. To the knowledge of the authors, none of the Precambrian rocks of the Wymola GRA contain any fossils.

Paleozoic fossil-bearing formations crop out in the Wymola area. Trilobites occur in the mid-Cambrian Abrigo Formation (Heindl and McClymonds, 1964). The Devonian Martin Formation contains coalified plant remains, brachiopods, gastropods, fish and ostracods (Teichert, 1965). Crinoids, coral, bryozoans and brachiopods occur in the late Devonian to Mississippian Escabrosa Limestone (Bryant, 1968). No information is available on the paleontology of other Paleozoic formations that may crop out in the area.

Cooper (1971) and Bryant (1952) report fossils of Cretaceous age in rocks correlative with sediments which crop out in the Silver Bell Mountains, but no fossils are reported.

The lowest mid-Tertiary unit of Scarborough and Wilt (1979) and Eberly and Stanley (1978) contains algal limestone in other areas. The middle mid-Tertiary units of the same groups of authors consist of volcanic rock interbedded with fluvial deposits, fanglomerates and fluvial sands and gravels, fanglomerates and lacustrine deposits including organic-rich beds and algal limestones. No reports of plant or animal fossil occurrences in

the late Tertiary and Quaternary basin-fill sediments are known to the authors.

The Picacho Mountains WSA (020-194) is underlain by rocks of a metamorphic core complex and a small area of thin Quaternary alluvium which caps a pediment. No fossil occurrences have been reported from the area; it seems unlikely that any exist.

The Ragged Top WSA (020-197) contains outcrops of mostly igneous rocks, but Precambrian Apache Group sediments and Tertiary sediments do crop out. Fossils have not been reported from the Apache Group, but Tertiary sediments in some localities contain algal limestones.

Geologic History

The geologic history of the area is long and complex, and only a brief synopsis is presented here. Excellent summaries of the main geological events that affected the southern Cordillera of North America are given by Burchfiel (1979) and Dickinson (1981). More detailed accounts pertaining particularly to southern Arizona are given by Titley (1982) and Shafiqullah et al., (1980). The geologic history can be summarized as follows:

1. 1.8 to 1.6 b.y.B.P. volcanic and clastic rocks were accreted onto the North American Craton from the southeast (Anderson, 1976; Anderson and Silver, 1976; Silver, 1978; Titley, 1982). The boundary between the dominantly volcanic and volcanoclastic Yavapai Series and the clastic nonvolcanic Pinal Schists coincides with the Holbrook Linear which passes to the northwest of the GRA (see fig. 2A). The rocks were folded about northeasterly axes, metamorphosed and intruded by granites 1.7 to 1.6 b.y.B.P. (Damon, 1968), and then intruded by anorogenic granites 1.5 to 1.4 b.y.B.P. (Damon, 1968; Silver et al., 1977).

2. Some time after this, but before 1.2 - 1.1 b.y.B.P., the area was uplifted and eroded. The eastern part of the GRA was then submerged beneath epicontinental seas and shallow marine clastic sediments and minor carbonates of the Apache Group were deposited (Heindl and McClymonds, 1964).
3. The Apache Group was intruded by diabase sills and dikes 1.2 to 1.1 b.y.P.B. (Damon, 1968). Locally, the Apache Group is overlain by basaltic rocks of similar age to the intrusives.
4. The area was uplifted and bevelled, and during the Cambrian the GRA was again submerged beneath epicontinental seas. At this time, shallow marine clastic sandstone, mudstone and minor limestone were deposited (Heindl and McClymonds, 1964).
5. No deposition took place during the Ordovician and Silurian, and the Cambrian is disconformably overlain by a thick Devonian to Early Mississippian transgressive sequence of fluvial sandstone, shallow marine clastic rock and dolomitic carbonate rock (Teichert, 1965; Bryant, 1968).
6. Late Paleozoic sediments may or may not occur in the area; possibly they were removed by erosion during the mid-Mesozoic orogeny. Molasse-like Mesozoic sediments were deposited in local basins in the eastern part of the GRA (Heindl, 1965). The upper part of this sequence contains volcanic material, possibly derived from the magmatic arc that extended over the southern part of the GRA during the mid-Jurassic (see fig. 2B).
7. The Laramide was a period of intense tectonic activity characterized by NNW-to-NW-striking basement-cored uplifts

and thrust faults (Neilsen, 1979; Davis, 1981); WNW-striking, left-lateral faults of the Texas zone (Schmitt, 1966); ENE-striking tensional features (Rehrig and Heidrick, 1976); and intrusion of small epizonal plutons along NW and ENE trends (Heidrick and Titley, 1982). The magmatic activity proceeded from northwest to southeast as the dip of the Benioff zone flattened in the time interval from 70 to 50 m.y.B.P. (Coney and Reynolds, 1977). Several Laramide intrusives crop out in the southern part of the GRA.

8. The Laramide was followed by a period of tectonic quiet and erosion.
9. The mid-Tertiary orogeny lasted from about 35 to 14 m.y.B.P. During this time, a great thickness of fluvial and lacustrine sediments interbedded with voluminous felsic to intermediate volcanics were deposited in northwest-striking basins (Eberly and Stanley, 1978; Scarborough and Wilt, 1979). The volcanism was mainly calc-alkaline (Shafiqullah et al., 1980) and was dominated by ignimbrite eruptions, possibly related to cauldrons. Coeval with the volcanism was the emplacement of metamorphic core complexes which occur along a northwest-trending zone (Coney, 1980) going through the GRA and including the Picacho Mountains in the northern part of the GRA. Associated with the core complexes and also present elsewhere in south Arizona are listric normal faults (Davis, 1981) which offset mid-Tertiary volcanic and sedimentary rocks. Volcanism and tectonism migrated westward during the mid-Tertiary as the dip of the Benioff zone steepened (Coney and Reynolds, 1977).

10. After the westward passage of the magmatic arc, listric normal faulting gave way to steep, normal Basin and Range faulting which became dominant after 14 m.y.B.P. (Shafiqullah et al., 1980). At this time basalt became the predominant volcanic rock, the present ranges were uplifted, and the basins were filled with fluvial, lacustrine and marine sediments.
11. Since 4 m.y.B.P. volcanism and tectonism have been minor (Shafiqullah et al., 1980), and the dominant geologic processes have been erosion of ranges resulting in the formation of extensive pediments and deposition of fans in the basins and alluvium along major rivers.

ENERGY AND MINERAL RESOURCES

The following are descriptions of known mineral deposits, prospects, occurrences, mineralized areas and thermal wells and other energy resources (fig. 3) of the Wymola GRA. Information was derived from the following sources: U.S. Geological Survey (1982, entries dated 1981, 1980, 1979, 1977, 1976, 1973, 1972; CRIB), Witcher et al., (1982), Johnson (1981), Eberly and Stanley (1978), Yeend (1976), Arizona Bureau of Mines (1969), Stipp et al. (1967), Richard and Courtright (1966) and McCrory and O'Haire (1965). Also consulted, but found not to contain applicable information, were Union Carbide Corporation (1982 - NURE HSSR data), Scarborough and Wilt (1979), Texas Instruments, Incorporated (1978; 1975 - NURE) and Johnson (1972).

The following descriptions represent a summary of the information about individual mines and occurrences that is available to the authors. Figure 3 illustrates locations of the listed mines, mineral occurrences and energy resources.

Known Mineral Deposits, Mines or Prospects with Recorded Production

11. Magdnigal Mine
Synonym Name:
Location: 32°25'32"N, 111°37'35"W
Sec. 34, T11S, R7E
Commodities: Cu, Au (major), Pb, Mo, Mn (minor)
Ore Materials: Chrysocolla, chalcopyrite, chalcocite, pyrite
(main), wulfenite, manganese oxide, malachite
(?) (minor).
Deposit Description: Disseminated deposit in shear zone, small
deposit with surface and underground workings.
Geology: Mineralization in Cretaceous sediments and
andesitic volcanics.
Production: Yes, small amount.
References: USGS, 1979, CRIB Mineral Resources File 12,
Record 1006, p. 2638-2640, Stipp et. al., 1967.
15. Unnamed Prospect VHNE-029N
Location: 32°23'9"N, 111°30'39"W
Sec. 14, T11S, R8E
Commodities: Au (major), Cu (occurrence)
Deposit Description: Small vein deposit, striking N 75°E.
Underground workings.
Geology: In Tertiary red beds.
Production: Yes, small amount.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1010, p. 2647-2648.
19. Grand Mogul
Location: 32°27'57"N, 111°32'32"W
NW1/4 NW1/4 Sec. 21, T11S, R8E
Commodities: Pb (major), Ag, Cu, Au (minor)
Deposit Description: Metasomatic lenses and pods. Surface workings.
Geology: Mineralization in Paleozoic limestone.
Production: Yes, small amount.
References: USGS, 1981, CRIB Mineral Resources File 12,
Record 1014, p. 2655-2656.
20. New Hope Mine
Location: 32°18'16"N, 111°09'34"W
NW 1/4 Sec. 21, T11S, R8E
Commodities: Cu (major), Ag (minor)
Deposit Description: Metasomatic lenses and pods. Surface workings.
Geology: Mineralization in Paleozoic limestone.
Production: Yes, small amount.
References: USGS, 1981, CRIB Mineral Resources File 12,
Record 1015, p. 2657-2658.
23. Unnamed Prospect VHNE-051N
Location: 32°27'38"N, 111°32'13"W
Sec. 21, T11S, R8E
Commodities: Pb, W, V, Cu (trace)
Ore Materials: Wulfenite, Vanadinite.

Deposit Description: Small, trending N85°W, dipping 55°S vein with unknown workings.
Geology: Agglomerate and welded tuff of Tertiary (?) Mount Lord volcanics.
Production: Yes, small amount.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1018, p. 2663-2664.

25. Rigueza Claims

Location: 32°27'4"N, 111°30'7"W
Sec. 23, T11S, R8E
Commodities: Cu, Pb, Zn
Ore Materials: Sphalerite, galena, chalcopyrite.
Deposit Description: Small disseminated-fissures type deposit, Workings--prospects, short adits.
Geology: Mineralization in granodiorite porphyry, Cretaceous--Tertiary.
Production: Yes, two carloads.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1020, p. 2667-2668.

30. North Silverbell Mine

Location: 32°26'27"N, 111°31'57"W
Sec. 28, T11S, R8E
Commodities: Cu (major); Mo (occurrence)
Ore Materials: Chalcocite, chalcopyrite, oxide copper minerals.
Deposit Description: Small, irregular oval elongate NW shape in a disseminated-fracture type deposit, surface and underground workings.
Geology: Mineralization in Cretaceous quartz latite porphyry.
Production: Yes, small amount.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1025, p. 2677-2678.

33. Silver Lead Mine Group

Location: 32°26'16"N, 111°32'18"W
Sec. 28, T11S, R8E
Commodities: Pb, Zn, Cu, Ag
Ore Materials: Base metal sulphides.
Deposit Description: Small, largely oxidized, spotty in a pyrometamorphic type deposit, underground workings.
Geology: Mineralization in Paleozoic limestone associated with Cretaceous-Tertiary granitic intrusive; limestone block along a fault contact with Laramide intrusive.
Production: Yes, 130 tons.
References: USGS, 1979, CRIB Mineral Resources File 12, Record 1028, p. 2683-2685.

37. Atlas Mine

Location: 32°25'47"N, 111°32'48"W
Sec. 32, T11S, R8E
Commodities: Zn, Cu (major); Ag, Au, Pb (minor)

- Ore Materials: Chalcopyrite, bornite, sphalerite.
Deposit Description: Medium trending ENE, dipping 63°SE, many ore shoots are present and are stopped; mantos, pods and lenses in pyrometasomatic replacement, underground workings.
Geology: Mineralization in Paleozoic quartzite and limestone associated with Laramide alaskite, dac-dacite porphyry and monzonite porphyry.
Production: Yes, medium amount--147,500 tons.
References: USGS, 1981, CRIB Mineral Resources File 12, Record 1032, p. 2692-2694.
53. Ramero Ranch
Location: 32°19'39"N, 111°30'19"W
Sec. 2, T12S, R8E
Commodities: Cu, Au (major); Ba (occurrence)
Ore Materials: Malachite, barite, azurite, native gold, chalcopyrite, bornite.
Deposit Description: Small, shear zone, underground workings.
Geology: Mineralization in Tertiary sediments.
Production: Yes, small amount.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1064, p. 2768-2769.
55. Mammoth Mine/Old Boot, Imperial, Union
Location: 32°24'52"N, 111°31'45"W
Sec. 4, T12S, R8E
Commodities: Cu, Ag (major); Pb, Zn, Au (minor); Mo (potential); F, Ba (occurrence)
Ore Materials: Chalcopyrite, Pb and Zn carbonates and sulphides.
Deposit Description: Small; fissure veins, irregular disseminations in a pyrometasomatic type deposit; underground workings.
Geology: Mineralization in Paleozoic limestone associated with Cretaceous-Tertiary dacite porphyry monzonite.
Production: At least 45,000,000 lbs. Cu produced.
References: USGS, 1979, CRIB Mineral Resources File 12, Record 1066, p. 2772-2774; Arizona Bureau of Mines Bull. 180, 1969; Richard and Courtright, 1966.
56. Silver Bell Copper/Silver Bell Mill
Location: 32°25'13"N, 111°32'25"W
Sec. 4, 11, T12S, R8E
Commodities: Cu (major); Pb, Zn, Mo, Au, Ag (minor); Bi, Cd (occurrence)
Ore Materials: Chalcopyrite associated with pyrite, chalcocite.
Deposit Description: Large porphyry copper, disseminated secondary chalcocite with minor chalcopyrite, also contact replacement-type ore deposits in Cretaceous sediments, flat tabular ore bodies; surface workings.

- Geology: Mineralization in Laramide alaskite, dacite porphyry and monzonite.
Production: Yes, large amount.
References: USGS, 1977, CRIB Mineral Resources File 12, Record 1067, p. 2775-2776; Arizona Bureau of Mines Bull. 180, 1969, Richard and Courtright, 1966.
68. Indiana-Arizona
Location: 32°21'21"N, 111°28'42"W
Sec. 25, T12S, R8E
Commodities: Cu, Pb, Zn, Ag, Au
Ore Materials: Sulfide and carbonates.
Deposit Description: Small, trending E-NE, large lenses of high grade chalcopyrite ore in a vein/shear zone, underground workings.
Geology: Mineralization in Paleozoic limestone.
Production: Yes, small amount.
References: USGS, 1981, CRIB Mineral Resources File 12, Record 1079, p. 2799-2800, Stipp et. al., 1967.
71. Silver Hill Mine Group
Location: 32°20'52"N, 111°28'19"W
Sec. 31, T12S, R9E
Commodities: Cu, Ag, Pb (major); Au (minor)
Ore Materials: Copper and lead carbonates and sulphides.
Deposit Description: Small, lensing in a replacement/veins/shear zone, underground workings.
Geology: Mineralization in Paleozoic limestone and quartzite associated with Cretaceous-Tertiary granitic intrusives.
Production: Yes, small amount.
References: USGS, 1981, CRIB Mineral Resources File 12, Record 1082, p. 2805-2807, Stipp et. al., 1967.
72. Twin Hill Prospect
Location: 32°21'4"N, 111°11'58"W
Sec. 34, T12S, R11E
Commodities: Pb, Zn, Ag, Cu
Ore Materials: Lead-zinc carbonate, copper silicate.
Deposit Description: Small, trending N44°W; lenses, veinlets, vugs in a replacement; surface workings.
Geology: Mineralization in Paleozoic limestone and in Precambrian Pinal schist.
Production: Yes, small amount - 40 tons.
References: USGS, 1979, CRIB Mineral Resources File 12, Record 1083, p. 2808-2810.
73. Sunset Group
Location: 32°25'40"N, 111°37'55"W
Sec. 34, T11S, R7E
Commodities: Mn (major); Cu (occurrence)
Ore Materials: Psilomelane with minor softer oxides of manganese, Cu oxides.

- Deposit Description: Small, trending northwest, dipping 60°SW, ore body parallels bedding in limestone and terminates on northwest side of N40°E trending fault; lens in a replacement/vein, surface and underground workings.
- Geology: Mineralization in limestone associated with Cretaceous or Tertiary porphyry dike.
- Production: Yes, small amount.
- References: USGS, 1972, CRIB Mineral Resources File 12, Record 1308, p. 3454-3456.
74. El Tiro Open Pit Mine/ Red Rock Group, Silver Bell Mine
- Location: 32°24'58"N, 111°32'13"W
Sec. 4, T12S, R8E
- Commodities: Cu (major); Mo, Ag, Pb, Au (minor)
- Ore Materials: Pyrite, chalcopyrite (primary); chalcocite (secondary); cuprite or limonite in leached capping.
- Deposit Description: Large; tabular in porphyry copper, ore in thin quartz-sulfide veinlets but aggregate thickness of many make a disseminate type.
- Geology: Mineralization in Laramide monzonite and Paleozoic sediments associated with Cretaceous-Tertiary alaskite, dacite porphyry.
- Production: Yes, large amount.
- References: USGS, 1973, CRIB Mineral Resources File 12, Record 1324, p. 3493-3495; Arizona Bureau of Mines Bull. 180, 1969, Richard and Courtright, 1966.
75. Oxide Open Pit Mine/Young American, Silver Bell Mine
- Location: 32°23'49"N, 111°30'7"W
Sec. 11, T12S, R8E
- Commodities: Cu, Mo, Au
- Ore Materials: Pyrite, chalcopyrite (primary); chalcocite (secondary); cuprite or limonite in leached capping.
- Deposit Description: Large, tabular in porphyry copper; ore in thin quartz-sulfide veinlets but aggregate thickness of many make a disseminated type.
- Geology: Mineralization in Laramide monzonite associated with Cretaceous-Tertiary alaskite, dacite porphyry..
- Production: Yes, large amount.
- References: USGS, 1973, CRIB Mineral Resources File 12, Record 1325, p. 3496-3498, Stipp et. al., 1967, Richard and Courtright, 1966.
81. Arizona Portland Cement
- Location: Sec. 34, T12S, R11E
- Commodity: Limestone for cement
- Ore Material: Limestone.
- Geology: Escabrosa and Naco Group limestone.
- Production: Yes.
- References: Stipp et. al., 1967; Arizona Bureau of Mines Bull. 180, 1969.

154. Better Pay
Location: Sec. 22, T9S, R9E
Location very approximate
Commodity: Pb
Production: 27 tons of ore shipped in 1940.
References: Arizona Bureau of Mines Bull. 180, 1969.

Known Prospects, Mineralized Areas, and Geothermal
Resources With No Recorded Production

1. Unnamed Prospect
Location: 32°31'9"N, 111°40'46"W
Sec. 30, T10S, R7E
Commodity: Cu
Ore Materials: Malachite, chrysocolla, chalcocite (?),
limonite.
Deposit Description: Vein, with sericitic alteration, small body
10-20 feet in width, striking N75°W.
Geology: Quartz vein cutting Precambrian granite.
Production: Unknown.
References: USGS, 1979, CRIB Mineral Resources File 12,
Record 1666, p. 4316-4317.
2. North Star Mine
Location: 32°49'31"N, 111°20'32"W
Sec. 7, 8, T7S, R10E
Commodity: Cu
Ore Materials: Chrysocolla, malachite, chalcocite,
chalcopyrite.
Deposit Description: Small, striking N40° to N60°W, dipping
30-40°SW.
Geology: Granite, dikes, sills of monzonite, dacite,
and andesite porphyry.
Production: Unknown.
References: USGS, 1972, CRIB Mineral Resources File 12,
Record 1746, p. 4483-4484, Johnson, 1981.
3. Sundown
Location: Sec. 3, T10S, R11E
Commodities: Cu, Ba
Ore Materials: Tenorite, Azurite, malachite, chalcopyrite,
chrysocolla, barite.
Deposit Description: Vein.
Geology: Quartz barite veins in Tertiary sediments.
Production: Unknown.
References: USGS, 1976, updated 1981, CRIB Mineral
Resources File 12, Record 1855, p. 4737-4738.
4. Gold Bell
Location: 32°43'7"N, 111°22'19"W
NW1/4 NW1/4 sec. 24, T8S, R9E
Commodities: Unknown, may be copper.
Production: Unknown.
References: USGS, 1973, CRIB Mineral Resources File 12,
Record 1912, p. 4850, Johnson (1981).

5. Unnamed Prospect VHNE-028N
Location: 32°22'39"N, 111°30'19"W
SW1/4, sec. 14, T12S, R8E
Commodities: Unknown.
Deposit Description: Disseminated, fractures, propylitic alteration.
Geology: Mineralization in Cretaceous (?) red beds.
Production: No.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 974, p. 2567-2568.
6. Sunset Claims
Location: 32°25'43"N, 111°38'W
Sec. 33, T11S, R7E
Commodities: Cu, Mn
Ore Materials: Copper carbonates, chrysocolla, manganese oxides.
Deposit Description: Dike intruded along fault.
Geology: In Tertiary-Cretaceous granodiorite porphyry.
Production: Unknown.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 982, p. 2583-2584.
7. Unnamed Prospect VHNW-014N
Location: 32°27'38"N, 111°38'12"W
Sec. 22, T11S, R7E
Commodity: Cu
Ore Materials: Chrysocolla, chalcocite, malachite.
Deposit Description: Disseminated, fractures, small deposit.
Geology: Mineralization in welded tuff.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1002, p. 2630-2631.
8. Unnamed Prospect VHNE-124N
Location: 32°26'34"N, 111°36'00"W
Sec. 25, T11S, R7E
Commodity: Cu
Ore Materials: Chrysocolla, chalcopyrite.
Deposit Description: Disseminated, fracture/vein small deposit.
Geology: Mineralization in Cretaceous volcanics.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1003, p. 2632-2633.
9. Unnamed Prospect VHNE-125N
Location: 32°26'38"N, 111°35'56"W
Sec. 25, T11S, R7E
Commodity: Cu
Ore Materials: Chrysocolla, chalcocite.
Deposit Description: Small, disseminated deposit.
Geology: Mineralization in Cretaceous welded tuff.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1004, p. 2634-2635.

10. Unnamed Prospect VHNE-127N
Location: 32°26'53"N, 111°35'55"W
Sec. 25, T11S, R7E
Commodity: Cu
Ore Materials: Chrysocolla, azurite.
Deposit Description: Small disseminated deposit with underground workings.
Geology: Mineralization in Cretaceous volcanics.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1005, p. 2636-2637.
12. Unnamed Prospect VHNE-007R
Location: 32°25'40"N, 111°37'55"W
SE1/4 sec. 33, T11S, R7E
Commodity: Cu
Ore Materials: Chrysocolla, chalcopryrite, pyrite.
Deposit Description: Small disseminated deposit.
Geology: Mineralization in Paleozoic limestone.
Production: Unknown.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1007, p. 2641-2642.
12. Unnamed Prospect VHNW-008R
Location: 32°25'52"N, 111°38'23"W
Sec. 34, T11S, R7E
Commodity: Cu
Ore Materials: Chrysocolla, tenorite, chalcopryrite.
Deposit Description: Small disseminated deposit.
Geology: Mineralization in Permian limestone.
Production: Unknown.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1008, p. 2643-2644.
14. Unnamed Prospect VHNE-043N
Location: 32°28'52"N, 111°30'17"W
Sec. 11, T11S, R8E
Commodity: Mn
Ore Materials: Coronadite (?) or hollandite.
Deposit Description: Small vein deposit, 1 foot in width, striking N50°E.
Geology: Mineralization in Tertiary basalt.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1009, p. 2645-2646.
16. Unnamed Prospect VHNE-044N
Location: 32°28'2"N, 111°30'34"W
Sec. 15, T11S, R8E
Commodity: Cu
Deposit Description: Small deposit, associated with alteration along dike.
Geology: Associated with diabase intruding Precambrian granite.
Production: None.

- References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1011, p. 2649-2650, Stipp et. al., 1967.
17. Unnamed Prospect VHNE-068N
Location: 32°28'25"N, 111°32'26"W
Sec. 16, T11S, R8E
Commodities: Pb, Cu, Zn (occurrence)
Ore Materials: Galena, malachite, chrysocolla, sphalerite.
Deposit Description: Small deposit in shear zone.
Geology: Mineralization in Precambrian granite.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1012, p. 2651-2652.
18. Unnamed Prospect VHNE-072N
Location: 32°27'22"N, 111°33'10"W
Sec. 20, T11S, R8E
Commodity: Cu
Ore Materials: Chalcocite.
Deposit Description: Small deposit, boxwork chalcocite.
Geology: Mineralization in Cretaceous sediments.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1013, p. 2653-2654.
21. Unnamed Prospect VHNE-036N
Location: 32°27'5"N, 111°32'2"W
Sec. 21, T11S, R8E
Commodities: Cu, Pb, Zn.
Ore Materials: Chalcopyrite, sphalerite, galena.
Deposit Description: Disseminated fractures. Underground workings.
Geology: Mineralization in Cretaceous volcanics.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1016, p. 2659-2660.
22. Unnamed Prospect VHNE-062N
Location: 32°27'20"N, 111°31'50"W
Sec. 21, T11S, R8E
Commodities: Pb, Cu, Zn, Ag
Ore Materials: Galena, cerussite, malachite-sphalerite
boxwork.
Deposit Description: Small, trending N67°E, dipping 70°S,
fracture disseminated type deposit, under-
ground workings.
Geology: 3 minor adits on minor fault with quartz-
sericite-pyrite-galena-sphalerite, copper
showings in dump as malachite.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1017, p. 2661-2662.

24. Unnamed Prospect VHNE-050N
Location: 32°27'50"N, 111°30'44"W
Sec. 22, T11S, R8E
Commodity: Cu
Ore Materials: Chrysocolla, malachite-chalcopryrite and chalcocite boxwork.
Deposit Description: Small, disseminated-fracture type deposit.
Geology: Mineralization in Precambrian (?) diabase associated with Cretaceous-Tertiary quartz monzonite porphyry; whole area has "live" limonite colors; some of the alteration in diabase may be potassic.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1019, p. 2665-2666.
26. Unnamed Prospect VHNE-139N
Location: 32°26'52"N, 111°30'47"W
Sec. 27, T11S, R8E
Commodity: Cu
Ore Materials: Malachite.
Deposit Description: Small, tabular shaped in a fracture-disseminated type deposit, surface workings.
Geology: Mineralization in granodiorite porphyry associated with Cretaceous-Tertiary fine-grained dike.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1021, p. 2669-2670.
27. Unnamed Prospect VHNE-137N
Location: 32°26'22"N, 111°30'55"W
Sec. 27, T11S, R8E
Commodity: Cu
Ore Materials: Malachite (sulfide boxwork).
Deposit Description: Small, disseminated-fracture type deposit, unknown developments.
Geology: Mineralization in Laramide quartz latite porphyry.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1022, p. 2671-2672.
28. Unnamed Prospect VHNE-138N
Location: 32°26'52"N, 111°30'40"W
Sec. 27, T11S, R8E
Commodity: Ba
Ore Materials: Barite.
Deposit Description: Small, vein type, underground workings.
Geology: Mineralization in Cretaceous-Tertiary granodiorite porphyry; coarse barite with quartz gangue in dump. Overall propylitic alteration of rhyodacite, spotty light pyrite stains in area.

- Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1023, p. 2673-2674.
29. Scott Claims
Location: 32°36'36"N, 111°31'55"W
Sec. 28, T11S, R8E
Commodities: Cu, Pb, Zn, W, F
Ore Materials: Chrysocolla, wulfenite, galena, sphalerite boxwork, fluorite.
Deposit Description: Small, trending N30°E, dipping 65°W-faulting, disseminated-veinlet type deposit, surface workings - 4-5 prospects and trench.
Geology: Mineralization in Cretaceous-Tertiary granodiorite porphyry; vein fractured quartzose intrusive, veins of fluorite, galena, sphalerite, also quartz (vuggy) + pyrite veinlets, overall alteration is propylitic but sericite occurs = adjacent to quartz-pyrite veins.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1024, p. 2675-2676.
31. Unnamed Prospect VHNE-076N
Location: 32°26'22"N, 111°32'32"W
Sec. 28, T11S, R8E
Commodities: Cu, Mo
Ore Materials: Chalcopyrite, molybdenite.
Deposit Description: Small, disseminated-fracture type deposit, surface workings--drill hole tailings.
Geology: Mineralization in Laramide quartz latite; heavy quartz sericite-pyrite with abundant moly and light amounts of chalcopyrite in drill hole tailings.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1026, p. 2679-2680.
32. Unnamed Prospect VHNE-035N
Location: 32°26'60"N, 111°32'11"W
Sec. 28, T11S, R8E
Commodity: Cu
Ore Materials: Copper stains.
Deposit Description: Small, trending N50°E, dipping steeply, disseminated-fractures type deposit.
Geology: Mineralization in Cretaceous Mount Lord volcanics.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1027, p. 2681-2682.

34. Unnamed Prospect VHNE-023N
Location: 32°26'27"N, 111°35'10"W
Sec. 30, T11S, R8E
Commodity: Unknown
Ore Materials: Unknown.
Deposit Description: Small, trending N60°W, dipping 58°NE, three prospect pits.
Geology: Mineralization in Cretaceous volcanics; moderate to heavy veining with light pyrite mineralization and 1-2 mm sericite envelopes.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1029, p. 2686-2687.
35. Unnamed Prospect VHNE-025N
Location: 32°25'49"N, 111°34'55"W
Sec. 31, T11S, R8E
Commodity: Cu
Ore Materials: Chrysocolla, malachite.
Deposit Description: Small, trending N15°W, dipping steeply E and W, disseminated, surface and underground workings.
Geology: Mineralization in Cretaceous welded tuff (Mount Lord volcanics); series of closely spaced quartz-sulfide veinlets to 5 cm with now all oxidized and leached. Chrysocolla and malachite make it showy.
Production: Undetermined.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1030, p. 2688-2690.
36. Unnamed Prospect VHNE-117N
Location: 32°25'56"N, 111°34'18"W
Sec. 31, T11S, R8E
Commodity: Cu
Ore Materials: Chrysocolla-tenorite (chalcocite boxwork).
Deposit Description: Small, disseminated-fracture type deposit, surface workings.
Geology: Mineralization in Cretaceous volcanics, Tertiary basalt dike.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1031, p. 2690-2671.
38. Unnamed Prospect VHNE-109N
Location: 32°25'22"N, 111°33'13"W
Sec. 32, T11S, R8E
Commodity: Cu
Ore Materials: Chrysocolla (chalcocite boxwork, probably chalcopyrite boxwork.)
Deposit Description: Small, disseminated-fracture type deposit.
Geology: Mineralization in Laramide quartz monzonite.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1033, p. 2695-2696.

39. Unnamed Prospect VHNE-113N
Location: 32°25'39"N, 111°32'57"W
Sec. 32, T11S, R8E
Commodity: Cu
Ore Materials: Chalcocite-chrysocolla.
Deposit Description: Small, disseminated-fracture type, surface and underground workings.
Geology: Mineralization in Laramide quartz monzonite.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1034, p. 2697-2698.
40. Unnamed Prospect VHNE-078N
Location: 32°26'9"N, 111°32'46"W
Sec. 32, T11S, R8E
Commodities: Cu, Mo
Ore Materials: Malachite (chalcopyrite boxwork), molybdenite.
Deposit Description: Small, disseminated-fracture/veins/gossan type, surface and underground workings.
Geology: Mineralization in Cretaceous-Tertiary granodiorite porphyry; very altered intrusive, moderate amount of sulfides with K-feldspar halos on veins, malachite stains observed and good chalcopyrite boxwork accounts for at least 1/2 of sulfide gossan.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1035, p. 2699-2700.
41. Unnamed Prospect VHNE-079N
Location: 32°25'59"N, 111°32'38"W
Sec. 32, T11S, R8E
Commodity: Cu
Ore Material: Chalcopyrite
Deposit Description: Small, disseminated-fracture type, surface workings.
Geology: Mineralization in Laramide quartz latite porphyry.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1036, p. 2701-2702.
42. Unnamed Prospect VHNE-160N
Location: 32°25'24"N, 111°32'32"W
Sec. 33, T11S, R8E
Commodity: Cu
Ore Materials: Malchite.
Deposit Description: Small, disseminated-fracture type, underground workings.
Geology: Mineralization in Laramide quartz latite porphyry.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1037, p. 2703-2704, Stipp et. al., 1967.

43. Unnamed Prospect VHNE-156N
Location: 32°25'50"N, 111°32'2"W
Sec. 33, T11S, R8E
Commodity: Cu
Ore Materials: Chalcocite-copper carbonates.
Deposit Description: Small, disseminated-fracture type,
underground workings.
Geology: Mineralization in Laramide quartz latite
porphyry.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1038, p. 2705-2706.
44. Unnamed Prospect VHNE-155N
Location: 32°25'51"N, 111°31'43"W
Sec. 33, T11S, R8E
Commodity: Cu
Ore Materials: Turquoise, chalcocite.
Deposit Description: Small, disseminated-fracture type,
underground workings.
Geology: Mineralization in Laramide quartz-latite.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1039, p. 2707-2708.
45. Unnamed Prospect VHNE-154N
Location: 32°26'9"N, 111°32'9"W
Sec. 33, T11S, R8E
Commodity: Cu
Ore Materials: Chalcocite, turquoise.
Deposit Description: Small, disseminated-fracture type.
Geology: Mineralization in Laramide quartz latite
porphyry.
Production: Yes, small amount.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1040, p. 2709-2710.
46. Unnamed Prospect VHNE-153N
Location: 32°26'8"N, 111°31'55"W
Sec. 33, T11S, R8E
Commodities: Cu, Mo
Ore Materials: Chalcopyrite, molybdenite and chalcocite.
Deposit Description: Small, disseminated-fracture type, drill hole.
Geology: Mineralization in Laramide quartz latite
porphyry.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1041, p. 2711-2712.
47. Unnamed Prospect VHNE-152N
Location: 32°26'9"N, 111°31'47"W
Sec. 32, T11S, R8E
Commodity: Cu
Ore Materials: Chalcopyrite, chalcocite.

- Deposit Description: Small, disseminated-fracture type, surface workings.
- Geology: Mineralization in Laramide quartz latite porphyry.
- Production: None.
- References: USGS, 1976, CRIB Mineral Resources File 12, Record 1042, p. 2713-2714.
48. Unnamed Prospect VHNE-159N
Location: 32°25'35"N, 111°31'53"W
Sec. 33, T11S, R8E
Commodity: Cu
Ore Materials: Chalcocite, turquoise.
Deposit Description: Small, disseminated-fracture type, underground workings.
Geology: Mineralization in Laramide quartz latite.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1043, p. 2715-2716.
49. Unnamed Prospect VHNE-158N
Location: 32°25'38"N, 111°31'49"W
Sec. 33, T11S, R8E
Commodity: Cu (tr.)
Ore Materials: Turquoise.
Deposit Description: Small, disseminated-fracture type, surface and underground workings.
Geology: Mineralization in Laramide quartz latite porphyry.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1043, p. 2717-2718.
50. Unnamed Prospect VHNE-135N
Location: 32°25'52"N, 111°30'56"W
Sec. 34, T11S, R8E
Commodity: Ba, pb
Ore Materials: Barite, galena, angelsite, cerussite.
Deposit Description: Small, trending N15°-20°E, dipping 80°W, tabular form in a vein type deposit, surface and underground workings.
Geology: Mineralization in Tertiary-Cretaceous quartz latite porphyry.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1045, p. 2719-2720.
51. Unnamed Prospect VHNE-151N
Location: 32°25'21"N, 111°30'26"W
Sec. 35, T11S, R8E
Commodity: Cu
Ore Materials: Chalcocite boxwork.
Deposit Description: Small, disseminated-fracture type, underground workings.
Geology: Mineralization in Cretaceous Mount Lord volcanics.

Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1046, p. 2721-2722, Stipp et. al.,
1967.

52. Unnamed Prospect VHNE-041N
Location: 32°19'55"N, 111°30'19"W
Sec. 35, T12S, R8E
Commodity: Cu
Ore Materials: Malachite.
Deposit Description: Small, vein-disseminated type deposit.
Geology: Mineralization in Permian Concha (?) or
Scherrer Fm. (?) (limestone) or other Paleozoic
formation.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1063, p. 2766-2767, Stipp et. al.,
1967.
54. Unnamed Prospect VHNE-042N
Location: 32°19'55"N, 111°30'7"W
Sec. 3, T12S, R8E
Commodity: Cu
Ore Material: Malachite.
Deposit Description: Small, trending N65°W, dipping 55°S,
fissure type deposit.
Geology: Mineralization in Concha (?) fm. (limestone);
abundant malachite along fault zone, associated
quartz veins and oxidized sulfide.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1065, p. 2770-2771, Stipp et. al., 1967.
57. Unnamed Prospect VHNE-083N
Location: 32°24'44"N, 111°33'19"W
Sec. 5, T12S, R8E
Commodity: Cu
Ore Materials: Malachite, chrysocolla, neotocite.
Deposit Description: Small, disseminated-fracture type, surface
and underground workings.
Geology: Mineralization in Cretaceous-Tertiary quartz
monzonite or alaskite; abundant copper oxides
in trenches, moderate pyrite veining and
gossan in footwall block showing some chalcocite
boxwork. Tertiary gravel in hanging
wall shows some exotic copper oxide and this
copper was apparently the target of mining.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1068, p. 2777-2778, Stipp et. al., 1967.

58. Unnamed Prospect VHNE-094N
Location: 32°24'27"N, 111°33'23"W
Sec. 5, T12S, R8E
Commodity: Cu
Ore Materials: Chrysocolla.
Deposit Description: Small, surface workings.
Geology: Mineralization in Cretaceous sediments
(Claflin Ranch Fm. ?)
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1069, p. 2779-2780.
59. Unnamed Prospect VHNE-086N
Location: 32°23'42"N, 111°32'14"W
Sec. 9, T12S, R8E
Commodity: Cu
Ore Materials: Chrysocolla.
Deposit Description: Small, exotic type, underground workings.
Geology: Mineralization in Cretaceous sediments.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1070, p. 2781-2782, Stipp et. al.,
1967.
60. Unnamed Prospect VHNE-83N
Location: 32°23'30"N, 111°31'42"W
Sec. 9, T12S, R8E
Commodity: Cu
Ore Materials: Malachite chalcocite boxwork.
Deposit Description: Small, disseminated-fracture type,
surface workings.
Geology: Mineralization in Cretaceous red beds.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1071, p. 2783-2784.
61. Unnamed Prospect VHNE-085N
Location: 32°23'45"N, 111°32'22"W
Sec. 9, T12S, R8E
Commodity: Cu
Ore Materials: Malachite, chrysocolla.
Deposit Description: Small, disseminated-fracture type,
surface workings.
Geology: Mineralization in Cretaceous sediments.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1072, p. 2785-2786.
62. Unnamed Prospect VHNE-008R
Location: 32°23'32"N, 111°31'37"W
Sec. 9, T12S, R8E
Commodity: Cu
Ore Materials: Copper oxide-chrysocolla, malachite.
Deposit Description: Small, trending N53°W, dipping steeply,
variable; disseminated-fracture type.

Geology: Mineralization in Cretaceous sediments.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1073, p. 2787-2788.

63. Unnamed Prospect VHNE-082N

Location: 32°23'23"N, 111°31'9"W
Sec. 10, T12S, R8E
Commodity: Cu
Ore Materials: Malachite (chalcocite gossan).
Deposit Description: Small, disseminated-fracture type.
Geology: Mineralization in hornfelsed Cretaceous
red beds.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1074, p. 2789-2790.

64. Unnamed Prospect VHNE-080N

Location: 32°22'49"N, 111°31'1"W
Sec. 15, T12S, R8E
Commodity: Cu
Ore Materials: Malachite, chrysocolla.
Deposit Description: Small, disseminated-fracture type.
Geology: Mineralization in Cretaceous red beds.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1075, p. 2791-2792, Stipp et. al.,
1967.

65. Unnamed Prospect VHNE-009R

Location: 32°22'38"N, 111°30'37"W
Sec. 15, T12S, R8E
Commodity: Cu
Ore Materials: Chrysocolla, malachite, boxwork chalcopryrite-
chalcocite-pyrite.
Deposit Description: Small, trending N60°E, dipping steep S.
disseminated-fracture type, underground
workings.
Geology: Mineralization in Cretaceous sediments associ-
ated with Tertiary quartz latite dike.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1076, p. 2793-2794.

66. Unnamed Prospect VHNE-026N

Location: 32°12'37"N, 111°33'55"W
Sec. 19, T12S, R8E
Commodity: Cu
Ore Materials: Trace of copper carbonate.
Deposit Description: Small, variable trending, disseminated type
deposit.
Geology: Mineralization in Cretaceous andesite associ-
ated with quartz-epidote veining.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12,
Record 1077, p. 2795-2796.

67. Unnamed Prospect VHNE-030N
Location: 32°22'46"N, 111°30'35"W
Sec. 22, 23, T12S, R8E
Commodity: Cu
Ore Materials: Chalcocite, covellite, malachite, chrysocolla.
Deposit Description: Small, fissure-vein type.
Geology: Mineralization in Cretaceous sediments associated with quartz gangue.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1078, p. 2797-2798, Stipp et. al., 1967.
69. Unnamed Prospect VHNE-047N
Location: 32°20'48"N, 111°30'10"W
Sec. 26, T12S, R8E
Commodity: Cu
Ore Materials: Chalcocite.
Deposit Description: Small, EW trending vein type.
Geology: Mineralization in Precambrian Oracle Granite.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1080, p. 2801-2802.
70. Unnamed Prospect VHNE-043N
Location: 32°20'3"N, 111°30'6"W
Sec. 35, T12S, R8E
Commodities: Cu, Pb (potential); V, Ba, Ag (occurrence)
Ore Materials: Azurite, galena, cerrusite, anglesite, vanadinite, barite.
Deposit Description: Small, contact metamorphic type, several prospects.
Geology: Mineralization in Permian Sherrer Fm. + Precambrian Oracle Granite.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1081, p. 2803-2804.
76. Unnamed Prospect 145-2
Location: 32°21'7"N, 111°11'60"W
Sec. 34, T12S, R11E
Commodity: Cu
Ore Materials: Cu silicate.
Deposit Description: Small, shear zone type, surface workings.
Geology: Mineralization in Precambrian Pinal Schist and in Paleozoic limestone associated with Cretaceous quartz monzonite; prospect at contact between gray-brown limestone to west and brecciated Pinal Schist; scarce Cu silicate on fractures.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1326, p. 3499-3500.

77. Unnamed Prospect 145-1
Location: 32°21'5"N, 111°11'56"W
Sec. 34, T12S, R11E
Commodity: Cu
Ore Materials: Cu silicate.
Deposit Description: Small, trending N44°W, dipping 87°W, veinlets in a mesothermal/shear zone, surface workings.
Geology: Mineralization in Precambrian Pinal Schist and in Cretaceous quartz monzonite.
Production: None.
References: USGS, 1976, CRIB Mineral Resources File 12, Record 1327, p. 3501-3503.
78. Unnamed Sand and Gravel Occurrence
Location: Sec. 34, T8S, R9E
Commodities: Sand and gravel
Production: Unknown.
Reference: McCrory & O'Haire, 1965.
79. Unnamed Fluorspar Occurrence
Location: Sec. 18, T12S, R8E
Commodity: Fluorospars
Production: Unknown.
References: McCrory & O'Haire, 1965.
80. Unnamed Limestone Occurrence
Location: Sec. 26, T12S, R11E
Commodity: Limestone
Production: Unknown.
References: McCrory & O'Haire, 1965.
82. Unnamed Tungsten Occurrence
Location: Sec. 10, T7S, R11E
Commodity: Tungsten.
Production: Unknown.
References: Stipp, Haigler, Alto and Sutherland, 1967.
83. Unnamed Silver, Copper and Gold Occurrence
Location: Sec. 14, T9S, R9E
Commodities: Ag, Cu, Au
Production: Unknown.
References: Stipp, Haigler, Alto and Sutherland, 1967.
84. Unnamed Silver, Copper and Gold Occurrence
Location: Sec. 28, T9S, R9E
Commodities: Ag, Cu, Au
Production: Unknown.
References: Stipp, Haigler, Alto and Sutherland, 1967.
85. Unnamed Mineral Occurrence
Location: Sec. 31, T9S, R11E
Commodity: Unknown
Production: Unknown.
References: Stipp, Haigler, Alto and Sutherland, 1967.
86. Unnamed Manganese Occurrence
Location: Sec. 33, T11S, R7E
Commodity: Mn

- Production: Unknown.
References: Stipp, Haigler, Alto and Sutherland, 1967.
87. Unnamed Limestone Occurrence
Location: Sec. 26, T12S, R11E
Commodity: Limestone
Production: Unknown.
References: Stipp, Haigler, Alto and Sutherland, 1967.
88. Unnamed Copper Occurrence
Location: Sec. 31, T6S, R10E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981.
89. Unnamed Copper Occurrence
Location: Sec. 32, T6S, R10E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981, Yeend, 1976.
90. Unnamed Copper Occurrence
Location: Sec. 32 T6S, R10E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981.
91. Unnamed Copper Occurrence
Location: Sec. 1, T7S, R9E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981.
92. Unnamed Copper Occurrence
Location: Sec. 6, T7S, R10E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981.
93. Unnamed Copper Occurrence
Location: Sec. 6, T7S, R10E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981.
94. Unnamed Copper Occurrence
Location: Sec. 6, T7S, R10E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981.
95. Unnamed Copper Occurrence
Location: Sec. 6, T7S, R10E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981.

96. Unnamed Copper Occurrence
Location: Sec. 5, T7S, R10E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981.
97. Unnamed Copper Occurrence
Location: Sec. 4, T7S, R10E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981, Yeend, 1976.
98. Unnamed Copper Occurrence
Location: Sec. 3, T7S, R10E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981, Yeend, 1976.
99. Unnamed Copper Occurrence
Location: Sec. 9, T7S, R10E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981.
100. Unnamed Copper Occurrence
Location: Sec. 7, T7S, R10E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981.
101. Unnamed Copper Occurrence
Location: Sec. 7, T7S, R10E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981.
102. Unnamed Copper Occurrence
Location: Sec. 7, T7S, R10E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981.
103. Unnamed Copper Occurrence
Location: Sec. 7, T7S, R10E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981.
104. Unnamed Copper Occurrence
Location: Sec. 7, T7S, R10E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981, Yeend, 1976.

105. Unnamed Copper Mine
Location: Sec. 7, T7S, R10E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981, Yeend, 1976.
106. Unnamed Copper Occurrence
Location: Sec. 18, T7S, R10E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981, Yeend, 1976.
107. Unnamed Copper Occurrence
Location: Sec. 13, T7S, R9E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981.
108. Unnamed Copper Occurrence
Location: Sec. 24, T7S, R9E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981.
109. Unnamed Copper Occurrence
Location: Sec. 33, T7S, R9E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981, Yeend, 1976.
110. Unnamed Copper Occurrence
Location: Sec. 33, T7S, R9E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981.
111. Unnamed Copper Occurrence
Location: Sec. 33, T7S, R9E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981.
112. Unnamed Copper Occurrence
Location: Sec. 34, T7S, R9E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981.
113. Unnamed Copper Occurrence
Location: Sec. 34, T7S, R9E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981.

114. Unnamed Copper Occurrence
Location: Sec. 36, T7S, R9E
Commodity: Cu
Production: Unknown.
Reference: Johnson, 1981.
115. Unnamed Copper Occurrence
Location: Sec. 36, T7S, R9E
Commodity: Cu
Production: Unknown.
References: Johnson, 1981, Yeend, 1976.
116. Unnamed Copper Occurrence
Location: Sec. 36, T7S, R9E
Commodity: Cu
Production: Unknown.
Reference: Johnson, 1981.
117. Unnamed Copper Occurrence
Location: Sec. 36, T7S, R9E
Commodity: Cu
Production: Unknown.
Reference: Johnson, 1981.
118. Unnamed Copper Prospect
Location: Sec. 33, T6S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
119. Unnamed Copper Occurrence
Location: Sec. 33, T6S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
120. Unnamed Copper Prospect
Location: Sec. 4, T7S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
121. Unnamed Copper Prospect
Location: Sec. 4, T7S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
122. Unnamed Copper Prospect
Location: Sec. 4, T7S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976

123. Unnamed Copper Prospect
Location: Sec. 4, T7S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
124. Unnamed Copper Prospect
Location: Sec. 3, T7S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
125. Unnamed Copper Prospect
Location: Sec. 5, T7S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
126. Unnamed Copper Prospect
Location: Sec. 5, T7S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
127. Unnamed Copper Prospect
Location: Sec. 5, 8, T7S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
128. Unnamed Copper Prospect
Location: Sec. 6, T7S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
129. Unnamed Copper Prospect
Location: Sec. 6, T7S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
130. Unnamed Copper Prospect
Location: Sec. 6, T7S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
131. Unnamed Copper Prospect
Location: Sec. 7, T7S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.

132. Unnamed Copper Prospect
Location: Sec. 8, T7S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
133. Unnamed Copper Mine
Location: Sec. 8, T7S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
134. Unnamed Copper Mine
Location: Sec. 8, T7S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
135. Unnamed Copper Mine
Location: Sec. 7, 8, T7S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
136. Unnamed Copper Mine
Location: Sec. 18, T7S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
137. Unnamed Copper Mine
Location: Sec. 19, T7S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
138. Unnamed Copper Mine
Location: Sec. 19, T7S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
139. Unnamed Copper Mine
Location: Sec. 19, T7S, R10E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
140. Unnamed Copper Occurrence
Location: Sec. 3, T8S, R9E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.

141. Unnamed Copper Prospect
Location: Sec. 4, T8S, R9E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
142. Unnamed Copper Prospect
Location: Sec. 4, T8S, R9E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
143. Unnamed Copper Prospect
Location: Sec. 13, T8S, R9E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
144. Unnamed Copper Prospect
Location: Sec. 13, T8S, R9E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
145. Unnamed Copper Occurrence
Location: Sec. 34, 8, T8S, R9E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
146. Unnamed Copper Prospect
Location: Sec. 24, T8S, R9E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
147. Unnamed Copper Prospect
Location: Sec. 24, T8S, R9E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
148. Unnamed Copper Prospect
Location: Sec. 23, T8S, R9E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
149. Unnamed Copper Mine
Location: Sec. 24, T8S, R9E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.

150. Unnamed Copper Occurrence
Location: Sec. 23, T8S, R9E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
151. Unnamed Copper Prospect
Location: Sec. 21, T8S, R9E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
152. Unnamed Gravel Pit
Location: Sec. 20, T8S, R9E
Commodity: sg
Production: Unknown.
Reference: Yeend, 1976.
153. Unnamed Copper Occurrence
Location: Sec. 28, T8S, R9E
Commodity: Cu
Production: Unknown.
Reference: Yeend, 1976.
155. Red Rock
Location: Sec. 24, 8, T7S, R11E
Location very approximate
Commodities: Ti, Fe
Ore Material: Titaniferous magnetite and ilmenite.
Deposit Description: Placer.
Geology: Alluvial deposits with disseminated and stratified magnetite deposits.
Production: Unknown.
Reference: Arizona Bureau Mines, Bull. 180, 1969.
156. Unnamed Analcime Occurrence
Location: Sec. 25, T7S, R8E
Commodity: Analcime (zeolite)
Deposit Description: Discovered in drill hole.
Geology: In silty claystone of late Tertiary age.
Reference: Arizona Bureau of Mines (1969).
157. Thermal Well
Location: NE1/4 NE1/4 NE1/4, Sec. 36, T11S, R8E
Temperature: 32°C.
Well Depth: 235 meters.
Reference: Witcher et. al., 1982.

158. Area of Low Temperature Geothermal Waters
Location: T6S, R7, 8, and 9E,
T7S, R7, 8, and 9E,
T8S, R7, 8, and 9E,
T9S, R7, and 8E,
T10S, R7, 8, 9, 10, 11E
T11S, R9, 10, 11 and 12E
T12S, R9, 10, 11 and 12E
Geology: Deep Basin
Production: None
References: Information from Witcher et. al., 1982, who
state: "Existing knowledge does not in
general permit the inference that thermal
waters may be found everywhere within the
depicted areas, nor do the boundaries
represent current knowledge of the area's
extent of the geothermal resources."
Note: Wells have reported temperatures of
32°C - 110°C and well depth varies from
235 m to 3101 meters.
159. Exxon State (74) No. 1
Location: NW1/4 NW1/4, Sec. 2, T8S, R8E
Commodity: Oil and gas exploration well
Ore materials: None - dry, abandoned.
Production: None. Total depth = 3,102 m (10,177 ft.)
Reference: Eberly and Stanley, 1978.
160. Berry No. 1 Federal
Location: NE1/4 SE1/4, Sec. 27, T11S, R10E
Commodity: Oil and gas exploration
Ore Materials: None - dry, abandoned.
Production: None. Total depth = 979 m.
Reference: Eberly and Stanley, 1978.

Mining Claims, Leases and Material Sites

Mining claim density (number of claims per square mile) of the two WSAs and their surrounding areas is summarized in table 2 and shown in figure 6. Additionally, an outline of all land currently either fully or partially leased for oil and gas is shown in figure 6 (area enclosed by hachured lines). Much of the federal and fee land is leased for oil and gas for five or ten year terms. All data were obtained from the BLM's records of June, 1982.

Eight unpatented claims are located within the Ragged Top WSA (020-197). Numerous patented claims, some associated with ASARCO's Silver Bell mine, are located within a few miles of the WSA. The entire WSA is leased for oil and gas.

TABLE 2

CLAIM DENSITY RECORDS IN THE WILDERNESS STUDY AREAS (WSA), WYMOLA GRA
ACCORDING TO BLM (JUNE 1982), ARIZONA STATE OFFICE

Township	Range	Section	Claims For Each Section	Claimants	Latest Assmt. Date	Remarks
WSA 020-194 Picacho Mountains						
8S	9E	10	SW 1	Moyer, Ray	none	1ode
		27	SE 1	Blanton, Jimmie	1981	"
WSA 020-197 Ragged Top						
11S	8E	11	SE 2	Asarco, Inc.	"	"
		23	SE 4	Leeman, Harold	none	"
		26	N2 1	"	1981	"
			NW 3	"	"	"

Figure 6 CLAIM DENSITY MAP, WITH OIL AND GAS LEASING STATUS, OF THE WYMOLA AREA, ARIZONA.

Note: hachured lines enclose oil and gas leases; numbers are claims per section.

Two unpatented claims are located within the Picacho Mountains WSA (020-194), and the entire area is leased for oil and gas. No patented claims are located near the WSA. No information is available about commodities present in any claimed land in the Wymola GRA.

Mineral Deposit Types

Geological environments considered potentially favorable for the occurrence of mineral and energy resources include the following:

Older Precambrian igneous and metamorphic rocks,

Younger Precambrian rocks,

Paleozoic and Mesozoic sediments,

Laramide intrusive rocks,

Mid-Tertiary metamorphic core complexes,

Mid-Tertiary volcanic rocks,

Mid-Tertiary sediments,

Late Tertiary basin-fill sediments,

Recent alluvium, and

Active geothermal systems.

Table 3 lists these geological environments in relation to types of mineral deposits that may be expected.

Older Precambrian Igneous and Metamorphic Rocks

Ore deposit types that may have formed during the Precambrian include volcanogenic massive sulfide deposits and hydrothermal deposits associated with Precambrian intrusive activity or metamorphism.

Numerous occurrences of massive sulfide deposits are found in older Precambrian rocks in Arizona. They are invariably associated with submarine rhyolitic volcanism (Donnelly and Hahn, 1981), and are either of

Table 3. GEOLOGICAL ENVIROMENTS OF THE WYMOLA AREA AND ASSOCIATED POTENTIAL MINERAL DEPOSIT TYPES

[illegible]

the copper-rich proximal type or the zinc and lead-rich distal type (Anderson and Guilbert, 1979). They are commonly associated with banded iron formations which are zoned, with sulfide facies near the rhyolitic center and carbonate and oxide facies further away (Anderson and Guilbert, 1979). Metavolcanic rocks occur in the Yavapai Series and in the gneissic terrain to the northwest and both lie to the northwest of the Holbrook line which separates them from the non-volcanogenic Pinal Schist (see fig. 2A). The GRA is located to the southeast of the Holbrook line and is probably largely underlain by meta-sedimentary Pinal Schist and Precambrian granitic intrusives. No massive sulfide occurrences are known in the Wymola GRA.

There are many occurrences of hydrothermal copper mineralization in Precambrian Pinal Schist and Oracle Granite of the northern Picacho Mountains (see fig. 3). At least some of these occurrences are related to the Tertiary North Star Stock (Johnson, 1981) but others may be related to granitic intrusion or a Precambrian metamorphic event. Hydrothermal copper mineralization also occurs in Precambrian granitic rocks of the West Silver Bell Mountains (Cu 1) and in the area just west of the Ragged Top WSA (Cu 16; Pb 17, containing copper and zinc in addition to lead). These occurrences may also be related to Precambrian events or later hydrothermal events. Mineralization in Pinal Schist (Pb 72) of the Twin Peaks, southeastern part of the GRA is continuous into Paleozoic sediments and thus is doubtlessly post-Precambrian.

Younger Precambrian Rocks

Forty-six uranium deposits or occurrences have been identified in carbon- and potassium-rich siltstones of the Dripping Spring Quartzite of the Precambrian Apache Group in Gila County, northeast of the Wymola GRA. The deposits occur in close proximity to younger Precambrian diabase intrusives

and the diabases have been suggested as the source of the uranium concentrated in sediments of the Dripping Spring Quartzite (Granger and Raup, 1969).

No uranium occurrences have been reported for the Wymola GRA, but both Precambrian diabases and Apache Group sediments crop out in the southern part of the GRA and a possibility exists that undiscovered occurrences may be present within the GRA.

Two copper occurrences (16 and 24) are located in Precambrian diabase, one (Cu 16) along the contact where the diabase intrudes older Precambrian granitic rocks. These occurrences may be related to the diabase or may have resulted from a later event.

Paleozoic and Mesozoic Sediments

Paleozoic and Mesozoic sediments are potential host rocks for accumulation of hydrocarbons and possibly red-bed type copper and silver deposits.

In south Arizona, Paleozoic and Mesozoic sediments, especially in the possible extension of the Overthrust Belt, have been considered potentially favorable for the accumulation of hydrocarbons (Keith, 1980; Peirce, 1982). All exploration wells drilled to date however, have been dry (Peirce, 1979; Keith, 1981; Peirce, 1982; see fig. 7). In the Wymola GRA, eight such holes have been drilled in the deep basins of the area (fig. 7).

Paleozoic and Mesozoic sedimentary rocks crop out in the Twin Peaks, Waterman Mountains and Silver Bell Mountains in the southern part of the GRA. Potential source rocks for hydrocarbons are shales and fetid limestones in the Abrigo and Martin Formations. Mesozoic rocks are non-marine, are not known to be rich in organic matter and are unlikely to be good source rocks for hydrocarbons. Locally, they could be effective reservoir rocks.

Both the Paleozoic and Mesozoic sediments have undergone deformation during the Laramide and mid-Tertiary orogenies with Paleozoic sediments

FIG.7 LOCATION OF OIL AND GAS EXPLORATION HOLES IN SOUTHERN ARIZONA, after Jones (1979).

subjected to the mid-Mesozoic orogeny as well, and during Basin and Range faulting. They have been metamorphosed and are structurally highly complex. Thus, they are not considered favorable for the accumulation of hydrocarbons. It should be noted, however, that there has been recent drilling activity in southern Arizona based on a reinterpretation of seismic data which suggests that extensive thrust sheets are present in the area (Keith, 1980; Peirce, 1982). According to this interpretation rocks cropping out at the surface have been thrust over Paleozoic and Mesozoic sediments which are potentially favorable for the accumulation of hydrocarbons. We have no data to support or refute this except to note that one hole drilled near Florence (just north of the GRA) on the basis of such an interpretation bottomed in granite at 18,000 feet (Keith, 1981).

Thick Mesozoic red beds crop out in the Silver Bell Mountains within the Wymola GRA. Such beds are potentially favorable for red bed-type, copper silver deposits such as are present in Permian and Triassic sediments in central and northern New Mexico (LaPoint, 1974a, 1974b). No occurrences of this sort are known in the GRA, but the presence of permeable red-beds suggests that a favorable environment for such deposits could be present.

Laramide Intrusives

The Laramide was a time of emplacement of all but one (Bisbee) of the porphyry copper deposits in Arizona and adjacent New Mexico and Mexico. Of the 35 major porphyry copper deposits in this region, 32 lie to the southeast of the Holbrook line where basement is the Pinal Schist and three lie to the northwest where basement consists of Yavapai Series and gneissic-metavolcanic terrain (see fig. 2C). The intrusives associated with the porphyry copper deposits were emplaced during the westward sweep of the magmatic arc (Damon et al., 1981; Clark et al., 1982), possibly related to the decrease in the

dip of the Benioff zone at this time (Coney and Reynolds, 1977). The porphyry copper deposits appear to be aligned along northwest and east-northeast trends (Heidrick and Titley, 1982; see fig. 2). The northwesterly trend is sub-parallel to Mesozoic linear discontinuities in depositional patterns (Titley, 1976); the trend of Laramide basement-cored uplifts and thrust faults (Nielson, 1979; Davis, 1981); the Texas zone of Schmitt (1966); and the trend of the Laramide magmatic arcs. The ENE trend is sub-parallel to Precambrian fold axes and Laramide tensional features (Rehrig and Heidrick, 1976). The intrusions related to the porphyry copper deposits are small in area (seldom over 3 km²) and may have been emplaced along the NW and ENE structural intersection (Titley, 1981).

ASARCO's important Silver Bell porphyry copper deposit is located a few miles south and southwest of the Ragged Top WSA in the southern part of the Wymola GRA. High-grade replacement deposits in Paleozoic limestones intruded by Laramide igneous rocks were the first source of ore in the Silver Bell Mountains (Richard and Courtright, 1966). Prior to 1930, replacement deposits of Mammoth Mine, Union Mine (both included as Cu 55) and Atlas Mine produced about 100 million pounds of copper (Richard and Courtright, 1966). Production from disseminated deposits in Paleozoic sediments and Laramide porphyries mined in the Oxide (Cu 75) and El Tiro (Cu 74) of the Silver Bell Mine (Cu 56) yielded 75,655,000 tons of ore averaging 0.80% Cu, 0.07 ounces Ag per ton and 0.022% MoS₂ between 1954 and 1977 (Graybeal, 1982). Laramide mineralization is also hosted by Cretaceous andesites and sediments and possibly Precambrian rocks in addition to the Paleozoic sediments and Laramide intrusives. Most of the numerous occurrences and deposits of the southern GRA shown in figure 3 resulted from Laramide mineralization.

Laramide intrusives in the Silver Bell Mountains are elongated parallel to pre-Laramide discontinuities (see fig. 2C) and apparently were emplaced

along a fault contact which separated Paleozoic and Mesozoic sediments (see fig. 3; Richard and Courtright, 1966; Graybeal, 1982). It is possible that other Laramide intrusives and, potentially, porphyry copper deposits exist in the GRA and remain unroofed.

Mid-Tertiary Metamorphic Core Complexes

The potential for mineral deposits associated with metamorphic core complexes is not well known as only during the last ten or so years have the complexes themselves been widely recognized. In an important work, Coney and Reynolds (1980) and several co-workers have attempted to assess uranium favorability of these complexes and in so doing they have also provided useful information on some other elements. Some important findings of this study which also includes the report by Keith and Reynolds (1980) and Reynolds (1980) are as follows:

1. Uranium related to plutonic processes tends to be associated with potassium-rich rocks ($K_2O > 4\%$)
2. Uranium related to metamorphic processes may be transported by fluids released through dehydration reactions. Geochemical studies by Keith and Reynolds (1980) show that mylonitization is not associated with any changes in U or Th concentration. However, the rich uranium deposit of Graeber Lease in the Kettle Metamorphic Core Complex, Washington, occurs in mylonitic gneisses and may be of metamorphic origin (Reynolds, 1980).
3. The dislocation surface and the underlying chloritic breccia represent a permeable horizon along which fluids migrated (Reynolds, 1980). Geochemical studies in the Rawhide Mountains by Keith and Reynolds (1980) show that these rocks are enriched

in U, Th, Cu, Zn, Fe, V, Li and Cr compared to the protolith, contain uranium occurrences, and more widespread hematite, limonite, Cu, and Au mineralization. Coney and Reynolds (1980) consider that investigation of these zones downdip into the nearby basins may be worthwhile.

Overall, metamorphic core complexes are moderately favorable for Cu, Au and Ag deposits. Deposits in the Buckskin Mountains in the Bill Williams GRA of western Arizona formed along fracture zones related to dislocation surfaces and listric normal faulting. Circulation of metal-bearing fluids may have resulted from temperature gradients associated with the emplacement of the metamorphic core complexes and/or with mid-Tertiary volcanism.

In the Wymola GRA, numerous copper occurrences, and possibly the lead, copper, silver and gold deposits and occurrences in upper plate rocks of Picacho Peak (Ag 83 & 84, Pb 154), are associated with the Picacho Mountains metamorphic core complex. Much of the copper in the Picacho Mountains is merely chrysocolla staining (Johnson, 1981). Greater mineralization may exist in upper plate rocks which are buried by late Tertiary and Quaternary sediments on the southern, eastern and western sides of the Picacho Mountains.

One occurrence (85) and possibly another (3) appear to be associated with the metamorphic core complex at Desert Hills in the eastern part of the GRA.

Mid-Tertiary Volcanic Rocks

Mid-Tertiary volcanics in southern Arizona, southwestern New Mexico and Mexico are associated with gold-silver and base metal lode deposits (Damon et al., 1981; Clark et al., 1982). The volcanics were erupted when the magmatic arc swept rather rapidly westward, possibly as a result of the steepening of the Benioff zone (Coney and Reynolds, 1977). In southwestern

New Mexico the deposits are associated with cauldrons from which voluminous ignimbrites and other volcanics were erupted (Elston, 1978). As yet, no such cauldrons have been identified in Arizona, but the voluminous ignimbrites and presence of numerous deposits suggest that such cauldrons could be present.

In the Wymola GRA, mid-Tertiary volcanics crop out in much of the southern two-thirds of the GRA and underly the deep basins (Eberly and Stanley, 1978). Two deposits (Mn 14, and Au 15, a past producer, are definitely related to a Tertiary hydrothermal event, and at least one (Cu 2, the North Star Mine) and possibly many more occurrences in the northern Picacho Mountains are related to a Tertiary intrusive. Some mineralization in the Silver Bell and West Silver Bell Mountains, Waterman Mountains and Picacho Peak may also be a result of Tertiary magmatism.

As mentioned previously in this report, an association between high potassium content in igneous rocks and high uranium content has been established (Keith and Reynolds, 1980; Reynolds, 1980). Ultrapotassic trachytes and trachyandesites (unit Tvi, fig. 3) of Picacho Peak and the south-central part of the GRA, with up to 14% K₂O (Shafiqullah et al., 1976), must be considered as excellent source rocks for uranium deposits. Some sediments are interbedded with the volcanics; if they contain adequate reductants uranium could concentrate. Although no uranium occurrences have been reported, the potassium-rich mid-Tertiary volcanics and sediments have at least low favorability for uranium occurrences.

Mid-Tertiary Sediments

Mid-Tertiary valley-fill sediments are widespread in central and southern Arizona, and since the discovery of the Anderson Mine (Sherborne et al., 1979), have become a prime target for uranium exploration. In order for a uranium deposit to form by the agency of groundwater or connate water,

it is necessary to have an adequate uranium source rock, permeable sediments for water to flow through, and a reductant to precipitate the uranium. In the southern part of the GRA where the mid-Tertiary sediments are located, suitable source rocks may be the mid-Tertiary volcanics, especially the ultrapotassic volcanics, and possibly the Precambrian granites. The mid-Tertiary sediments are interbedded in the volcanics and are suitably permeable. It is not known where the reductants are present, but past or present geothermal waters (Gt 157 and Gt 158) could be sufficiently reducing to cause uranium precipitation. No uranium occurrences are located in mid-Tertiary sediments of the Wymola GRA, but Tertiary sediments in the deep basins of the GRA, especially those near the metamorphic core complexes and ultrapotassic Tertiary volcanics, should be considered as possible sites of uranium concentration.

Richard and Courtright (1966) report the occurrence of a mid-Tertiary conglomerate or fanglomerate which consists mainly of clasts of the leached cap of one of the Silver Bell Mine ore bodies. To the north of the GRA, in the White Canyon area, Kennecott is exploring the mid-Tertiary Whitetail Conglomerate, which is comprised of clasts of mineralized Pinal Schist that were deposited as talus. It is possible that a similar conglomerate, composed of mineralized clasts and not leached cap, could be found in the southern part of the Wymola GRA.

Late Tertiary Sediments

Late Tertiary sediments are present in all basins formed as a result of Basin and Range faulting, including the basins of the GRA (see fig. 1; Eberly and Stanley, 1978). As in the case of the mid-Tertiary sediments, adequate uranium source rocks and permeable horizons are present. Extensive organic reductants are not known to be present in these sediments but warm geothermal

waters (Gt 157, 158) could be sufficiently reducing to cause uranium precipitation. No uranium occurrences are known to be present within the late Tertiary sediments of the GRA.

Thick anhydrite beds, with lesser halite, were discovered by drilling done in the Picacho Basin of the western part of the GRA (Peirce, 1981 and 1976, Eberly and Stanley, 1978). This deposit is not being exploited but does represent a potential resource.

Analcite (Ze 156), a zeolite mineral, occurs in subsurface tuffaceous lacustrine sediments of the Picacho Basin (Arizona Bureau of Mines, 1969) and was also discovered by oil and gas drilling. The potential for large zeolite deposits, like those currently being exploited in southeastern Arizona, must be considered as low to moderate in deep basins of the GRA.

Recent Alluvium

Alluvium deposited in present-day stream valleys is a possible site for concentration of placer gold. Johnson (1972) reports that stream beds in the Silver Bell Mountains or surrounding area were worked for gold, but the location of the deposit is unknown and there are no records of production.

Geothermal

Extensive but low temperature geothermal resources are known to be present in southern Arizona (Jones, 1979). Factors that are favorable for the existence of substantial geothermal systems are: Presence of a high temperature heat source; presence of aquifers which allow large volumes of water to circulate through the hot rocks; and the presence of cap rocks which prevent the escape to the surface of at least some of the hot fluid.

In southern Arizona the intensity of volcanic activity has been waning during the past 9 m.y. and that may explain why most geothermal areas are

at a low temperature. Aquifers and cap rocks are plentiful and extensive in Tertiary valley-fill sediments. Both the Picacho Basin and the Avra Valley (Gt 158) in the Wymola GRA are considered by Witcher and others (1982) as areas of low temperature geothermal waters. Temperatures and depths of wells range from 32°C (235 m) to 110°C (3101 m - Exxon State (74) No. 1 oil and gas exploration well, listed as 159 on fig. 3 and in the deposit listings).

Mineral Economics

The assessment of the geological, energy and mineral resources favorability should rely upon not only geology, but must also be concerned with economic factors and priorities. Discovery, recovery, cost of production of the resource from sources with varying qualities and/or concentrations are included in those considerations. Special consideration must be given to the strategic and critical minerals and metals. As this project is of limited scope, and because of special difficulties in southwestern Arizona, economic analyses of various commodities can only be discussed briefly.

Some factors especially important to the evaluation of the mineral and energy resources of southern Arizona include the following:

1. The geology of the Wymola GRA is very complex and detailed information on the geology and mineral deposits of the WSAs is, for the large part, limited. This is multiplied by recent and ongoing reinterpretations of the geology of the Basin and Range in Arizona. In order to interpret the geology of the WSAs, and thus be able to project the types of mineral deposits that may be present in those areas, it is necessary to apply information about known areas of apparently similar geology to the interpretation of the geology of the WSAs. These are not optimum

conditions. A wide variety of possibilities must be considered and, therefore, discussions of mineral economics must be considered tentative.

2. Contributing to the problems listed above, and creating some other distinct difficulties, are the ruggedness and roadless nature of the WSAs. Roadlessness, a criterion for WSAs, inhibits exploration and development of mineral resources due to poor access, distance to market, and other factors which increase the expense and difficulty of geological and mineral exploration.
3. A number of commodities, including strategic and critical minerals and metals, are known to occur in the GRA.
4. Considering all the above mentioned problems, it is very possible that sophisticated methods currently used by professional geologic explorationists have not been fully employed in southern Arizona. Many of the mines and occurrences in the GRA were discovered many years ago by prospectors using simple techniques.

Three copper occurrences are located within the Picacho Mountains WSA (020-194). One past producer of copper, lead and zinc is located within the Ragged Top WSA (020-194) and several occurrences of copper, along with gold, manganese and barite are located within two miles of the WSA boundary.

There has been much recent speculation about the potential for oil and gas occurrences in the Basin and Range of southern Arizona. It has been suggested that the Overthrust Belt, related to oil occurrences from Canada to Utah, extends into Arizona as a wide NW-SE trending belt curling around the Colorado Plateau in the Basin and Range area (Peirce, 1982; Anschutz, 1980).

The theory states that around 60 m.y.B.P. older crystalline rocks thrust over younger, possibly oil-rich, strata (Peirce, 1982). The complex structures, including Basin and Range faults, found in southern Arizona coupled with the high temperatures created by igneous activity since that time dim the possibility of preservation of oil and gas. Peirce (1982) states if the Overthrust Belt exists, or ever has existed, in Arizona, geologic complexity obscures it and drilling has not yet resolved the issue. Anschutz (1980) suggests that the Overthrust Belt could become the most important oil and gas province to be discovered in the last 20 to 30 years, but also states that it is one of the most difficult and expensive areas to explore and develop.

Strategic and Critical Minerals and Metals

Within the WSAs of the Wymola GRA are a few occurrences of the strategic and critical minerals and metals copper, lead and zinc.

Zinc has a variety of industrial applications, the most important being zinc-base alloy die castings, galvanizing iron and steel products, and brass production. Much of the lead used in the United States is consumed in the manufacture of storage batteries and as a gasoline additive, although use in gasoline is not as important as it once was. Use in ammunition and solder is also important, increasingly so during wartime. Copper, although considered a strategic and critical metal, occurs in abundance in Arizona.

In summary, it must be noted that the Wymola GRA contains a large number of mineral occurrences and many different commodities. Deposits of strategic and critical commodities, some which have produced, are known to occur in the WSAs and surrounding parts of the GRA. Further exploration could lead to the discovery of potentially important deposits in the GRA and WSAs.

THE GEOLOGY, ENERGY AND MINERAL RESOURCES OF THE WILDERNESS STUDY AREAS

In this section each individual WSA is discussed with respect to its physiography, geology, mineral occurrences, resource potential, and recommendations for further work. For most of the WSAs, detailed and specific information is lacking; in these cases, information pertinent to the particular WSA will be summarized from the preceding sections. The classification of resource potential and level of confidence is according to the scheme provided by the Bureau of Land Management (attachment 9, dated March 24, 1982). The classification is summarized on the maps in Figures 8 through 10 and detailed below.

Classification Scheme

1. The geologic environment and the inferred geologic processes do not indicate favorability for accumulation of mineral resources.
2. The geologic environment and the inferred geologic processes indicate low favorability for accumulation of mineral resources.
3. The geologic environment, the inferred geologic processes, and the reported mineral occurrences indicate moderate favorability for accumulation of mineral resources.
4. The geologic environment, the inferred geologic processes, the reported mineral occurrences, and the known mines or deposits indicate high favorability for accumulation of mineral resources.

Level of Confidence Scheme

- A. The available data are either insufficient and/or cannot be considered as direct evidence to support or refute the possible existence of mineral resources within the respective area.

- B. The available data provide indirect evidence to support or refute the possible existence of mineral resources.
- C. The available data provide direct evidence but are quantitatively minimal to support or refute the possible existence of mineral resources.
- D. The available data provide abundant direct and indirect evidence to support or refute the possible existence of mineral resources.

The Picacho Mountains WSA (020-194)

Physiography

The WSA lies on the southern part of the Picacho Mountains. Slopes in the north- to northeast-trending Picacho Mountains are steep; total relief in the WSA is about 2700 feet.

Geology

The WSA is almost entirely underlain by locally mylonitic muscovite-biotite gneiss and associated schists, augen gneisses and dikes of a mid-Tertiary metamorphic core complex. Parts of the western portion of the WSA are underlain by Quaternary sediments, most likely pediment and fan deposits.

Mineral Deposits

Three copper prospects and occurrences are located within the WSA and numerous other occurrences, prospects and mines (4, the Gold Bell Mine) occur within a couple of miles outside the WSA boundaries. Yeend (1976) gave only a brief description of the copper mineralization, stating that chrysocolla and/or hematite are found in quartz veins one inch to eight feet in width.

Metamorphic core complexes have been recognized in Arizona only recently and little is certain about the relationship between core complexes and mineralization. Recent studies by Keith and Reynolds (1980) and Reynolds (1980), however, found that the dislocation surface and underlying chloritic breccia are enriched in U, Th, Cu, Zn, Fe, V, Li and Cr compared to the protolith, contain uranium occurrences and more widespread hematite, limonite, Cu and Au mineralization.

Land Classification for GEM Resources Potential

Metallic Minerals

The WSA (area 1; fig. 8) is classified as having moderate favorability for the occurrence of metallic minerals at a confidence level of B. The reasons for the above classification are as follows:

- (a) Copper occurrences are known within the WSA, and
- (b) Uranium occurrences and copper and gold mineralization, as well as high concentrations of Fe, Cr, and Zn are reported for other metamorphic core complexes, however:
- (c) Little is reported of the extent of mineralization within the Picacho Mountains, and dislocation surfaces, which have been eroded away in all but one small area in the very southeastern most Picacho Mountains, and chloritic breccias, which remain only in several small areas of the Picacho Mountains, are believed to be the parts of core complexes that are most likely to be mineralized.
- (d) The level of confidence is not high because the relationship between metamorphic core complexes and mineralization is still in the early stages of understanding.

Uranium

The WSA (area 5, fig. 9) is classified as having low favorability for the occurrence of uranium at a confidence level of B. The reasons for this classification are as follows:

- (a) No uranium occurrences have been found in the WSA, however,
- (b) Uranium occurrences and anomalously high concentrations of uranium, thorium and other elements are reported for metamorphic core complexes of the Rawhide Mountains and the rich Graeber lease uranium deposit of Kettle Dome, Washington, may have formed by processes related to formation of the metamorphic core complex.

Other Resources

The WSA is not favorable for the occurrence of other resources at a confidence level of B as there are no indications suggesting their presence.

The Ragged Top WSA (020-197)

Physiography

The WSA lies within an area of low hills overlooking Santa Cruz Plats (the Picacho Basin) and the Avra Valley that is dominated by Ragged Top, a steep-sided butte. Ragged Top is an outcropping of Tertiary intrusive rock and may be a volcanic neck or subvolcanic pluton. Total relief of the WSA is about 1700 feet.

Geology

In the Ragged Top WSA, older Precambrian granitics are overlain by younger Precambrian Apache Group sediments and intruded by Precambrian diabbases. Cretaceous andesites in the southwestern part of the WSA have

been intruded by Laramide igneous rocks, probably dacite porphyry. Mid-Tertiary sediments overlie the Precambrian granitic rocks and Apache Group sediments in the eastern part of the WSA. Mid-Tertiary volcanics of andesitic to trachytic composition crop out at the southeastern and northwestern corners of the area and a Tertiary intrusive, possibly a plug or sub volcanic stock, crops out at Ragged Top. Quaternary sediments overlie the rocks in the northwest and southeast. A northeast-trending fault in the center of the WSA cuts all the Precambrian units, Cretaceous andesite and the Tertiary intrusive.

Mineral Deposits

One deposit with past production, the Franco Riqueza Claims (Cu 25), is located within the WSA. Copper, lead and zinc have been recovered. Several other occurrences and deposits are located within a mile of the western and southwestern boundaries of the GRA, including an unnamed hydrothermal gold prospect (Au 15), located in Cretaceous or Tertiary red beds, which has produced a small amount of ore.

Geologic environments similar to those in the WSA occur elsewhere in the GRA and contain mineral deposits of the following types:

- (a) Hydrothermal veins, most containing copper but also some with lead, zinc, gold, silver, barite, fluorite and manganese, occur in Precambrian granitics and diabases, Cretaceous andesites, Cretaceous and/or Tertiary sediments and mid-Tertiary volcanics. These deposits are located west and southwest of the WSA in the Silver Bell and West Silver Bell Mountains.
- (b) Tertiary sediments found a few miles to the south of the WSA in the Silver Bell Mountains contain abundant clasts of leached cap material from Silver Bell porphyry copper

deposits. Rocks with higher-grade mineralization may have been eroded, also.

Land Classification for GEM Resources Potential

Metallic Minerals

Area 2 (fig. 8), including the eastern two-thirds of the WSA, is classified as having low favorability at a confidence level of B. The reasons for this are as follows:

- (a) No occurrences have been found in the area, but
- (b) Similar geologic environments that contain mineralization exist elsewhere in the GRA, and undiscovered occurrences and deposits may be associated with the Tertiary intrusive at Ragged Top.
- (c) It is possible that Laramide intrusives, associated with porphyry copper deposits, occur beneath the WSA.

West and southwest of area 2 and continuing to the northwesternmost of the three major structures in the Silver Bell Mountains (area 3), is classified as moderately favorable for the occurrence of metallic minerals at a confidence level of C. The reasons are as follows:

- (a) Several deposits, including some past producers, occur in this area.
- (b) Nearby to the south are the porphyry copper deposits of the Silver Bell Mine. Laramide intrusive rocks were responsible for the mineralization and similar Laramide porphyry rocks may occur within the Laramide intrusive bodies in area 3.

The area south of area 3 (area 4) includes the rich deposits of the Silver Bell Mines. Many millions of tons of ore containing copper with lesser molybdenum, gold, lead, zinc, silver and occurrences of barite,

fluorite, bismuth and cadmium, have been produced from rich replacement deposits on Paleozoic limestones and quartzites and from disseminated deposits in Laramide porphyry intrusives. This area (area 4) is classified as highly favorable for the occurrence of metallic minerals at a confidence level of D.

Uranium

Areas in the WSA underlain by Precambrian diabases and Apache Group sediments, highly potassic mid-Tertiary volcanics, mid-Tertiary intrusives and mid-Tertiary sediments (area 6) is classified as having low favorability for the occurrence of uranium at a confidence level of B. The reasons for this classification are as follows:

- (a) No uranium occurrences have been located in the WSA or CRA, however
- (b) Organic-rich siltstones of the Apache Group contain uranium deposits near diabase intrusions in localities in Gila County to the northeast of the Wymola CRA. In addition, highly potassic volcanic rocks most frequently contain anomalously high amounts of uranium. Sediments interbedded with the mid-Tertiary potassic volcanics, Tertiary sediments and the Tertiary intrusive which may be related to the potassic volcanics all could contain uranium.

Non-metallic Minerals

The portion of the WSA underlain by Precambrian granitic rocks (area 7) is classified as having low favorability at a confidence level of A. The reasons are as follows:

FIG.10

FAVORABILITY AND LEVEL OF CONFIDENCE MAP FOR NON-METALLIC RESOURCES OF THE WYMOLA AREA, ARIZONA

- (a) Precambrian granitic rocks in Arizona often contain pegmatites which may include resources of mica, feldspar and other non-metallics. However,
- (b) No occurrences are reported in this area and it is unknown if pegmatites are existent in this Precambrian granitic body.

Other Resources

The WSA is considered unfavorable for the occurrence of other resources. No occurrences of other resources are known and deposits aside from those types discussed in the previous paragraphs are highly unlikely to be found in the Ragged Top WSA.

Recommendations

For area 1 it is recommended that:

- a. The area should be field checked for the presence of hydrothermal alteration.
- b. The three copper occurrences should be field checked to determine the extent of mineralization.
- c. Schist bodies, possibly containing chloritic breccia, should be field checked and given special attention in checks for alteration and mineralization. Additionally, they should be checked to see if dislocation surfaces and upper plate rocks are present atop the schist bodies. When Yeend (1976) mapped the area, metamorphic core complexes were not well recognized in Arizona.

For area 2 it is recommended that:

- a. The area should be field checked for hydrothermal alteration.
- b. Tertiary sediments should be investigated to check for the presence of conglomerates rich in mineralized clasts.

For Area 3 it is recommended that:

- a. Deposits Au 15 and Cu 25 be field checked to evaluate the extent of mineralization.
- b. Alteration minerals should be dated to determine the age of mineralization.

For area 5 and 6 it is recommended that:

- a. Units Tvi and Ti in area 6 and schist bodies in area 5 (see Yeend, 1976) should be sampled and geochemical analysis for U, Th, K, Ca, phosphate, fluoride and carbonate should be performed.

In addition, it is recommended that outcroppings of Tertiary and Precambrian sediments be checked for the occurrence of organic-rich beds.

For area 7, it is recommended that Precambrian granitics be field checked for the occurrence of pegmatites and especially mica and feldspar.

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