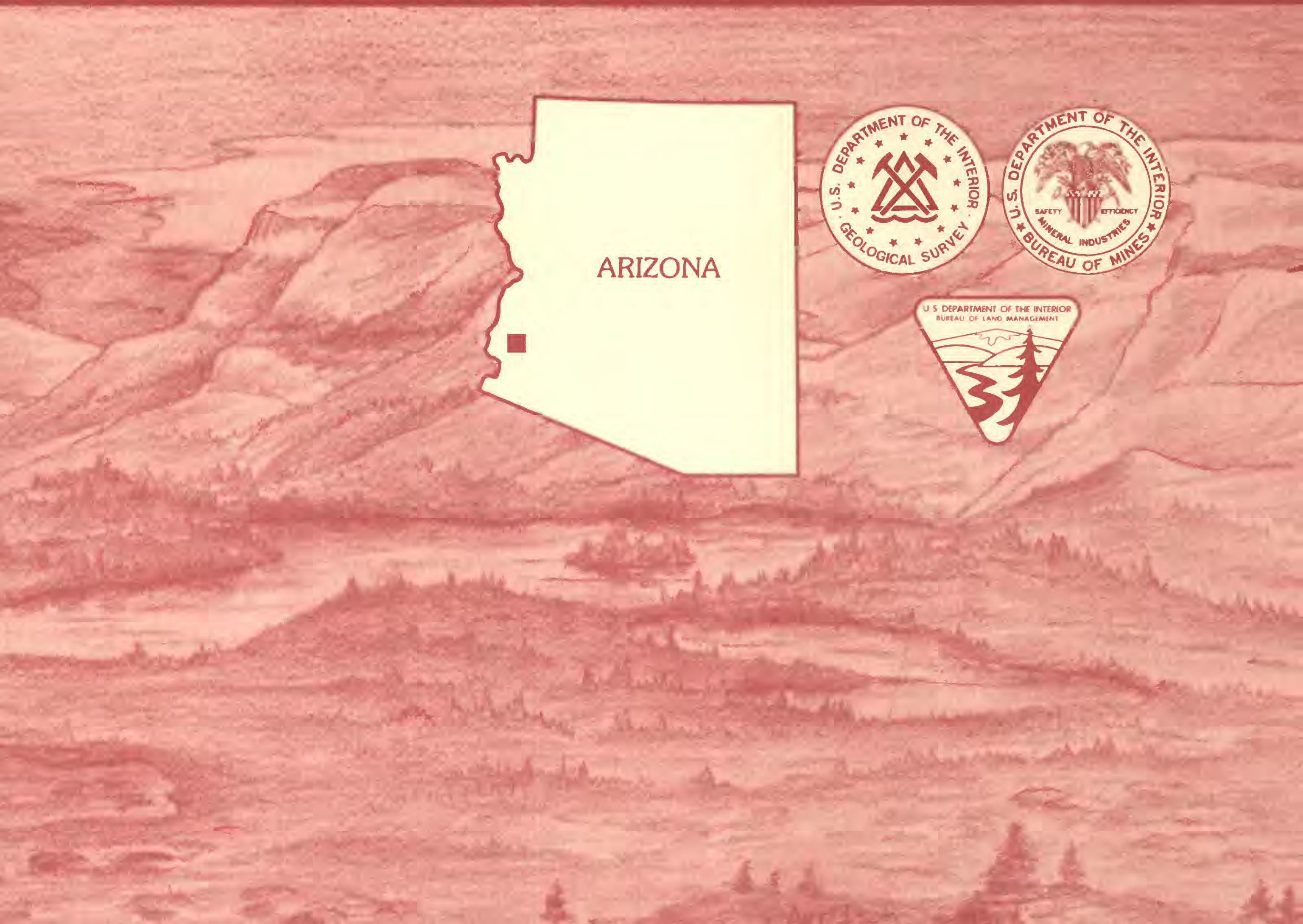
Mineral Resources of the Kofa Unit 4 North Wilderness Study Area, Yuma County, Arizona

U. S. GEOLOGICAL SURVEY BULLETIN 1702–K



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Chapter K

Mineral Resources of the Kofa Unit 4 North Wilderness Study Area, Yuma County, Arizona

By DAVID R. SHERROD, DAVID B. SMITH, and
M. DEAN KLEINKOPF
U.S. Geological Survey

DIANN D. GESE
U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1702

MINERAL RESOURCES OF WILDERNESS STUDY AREAS:
SOUTHWESTERN AND SOUTH-CENTRAL ARIZONA

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys of certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and submitted to the President and the Congress. This report presents the results of a mineral survey of the Kofa Unit 4 North Wilderness Study Area (AZ–050–033), Yuma County, Arizona.

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Mineral Resources of the Kofa Unit 4 North Wilderness Study Area, Yuma County, Arizona

By David R. Sherrod, David B. Smith, *and* M. Dean Kleinkopf
U.S. Geological Survey

Diann D. Gese
U.S. Bureau of Mines

SUMMARY

Abstract

The Kofa Unit 4 North Wilderness Study Area (AZ-050-033) is located in Yuma County, southwestern Arizona. At the request of the U.S. Bureau of Land Management, 1,380 acres of the Kofa Unit 4 North Wilderness Study Area were evaluated for mineral resources (known) and mineral resource potential (undiscovered). Throughout this report, reference to the "Kofa Unit 4 North Wilderness Study Area" or to the "study area" refers only to that part of the wilderness study area for which mineral surveys were requested by the U.S. Bureau of Land Management.

Inferred subeconomic resources of zeolite are scattered throughout the west half of the study area. Large amounts of sand and gravel in the study area have no unique qualities that make them more valuable than vast quantities in the surrounding areas. The entire study area has low mineral resource potential for gold, silver, lead, and zinc, presumably associated with minor alteration along faults. Resource potential for zeolite ranges from high to unknown and is spotty in distribution because of localized zeolitization in altered tuff. Low resource potential for geothermal energy exists northwest of the range-bounding faults of the study area. The study area has no resource potential for oil or gas.

Character and Setting

The Kofa Unit 4 North Wilderness Study Area is in the northwestern part of the Castle Dome Mountains of Yuma County, about 60 mi northeast of Yuma, Ariz. The Castle Dome Mountains are a rocky desert mountain range having relief as great as 2,000 ft. In the study area the relief is a little less than 700 ft. The mountains are underlain by Tertiary volcanic rocks that underwent a major episode of extensional deformation about 22 to 20 million years ago (see geologic time chart in "Appendixes"). Sedimentary basins that bound the range were created during this time and subsequently filled by coalescing alluvial fans.

Identified Resources

The study area has inferred subeconomic resources of approximately 733,000 short tons (st) of 60- to 98-percent combined zeolites (mordenite and clinoptilolite). Tests for this study show that these zeolites may have commercial value as water purifiers. Zeolites have been mined approximately 1,500 ft west of the study area boundary. Sand and gravel in the study area have no unique qualities that make them more valuable than those that are closer to markets in surrounding areas.

Mineral and Energy Resource Potential

Low resource potential for gold, silver, lead, and zinc is assigned to the entire Kofa Unit 4 North Wilderness Study Area. A high resource potential for zeolite is assigned to three small areas adjacent to demonstrated zeolite occurrences, and an unknown resource potential for zeolite is assigned to other areas underlain by silicic lava flows or intrusions, which may include locally zeolitized, thin, inter-

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bedded lenses of tuffaceous rocks. There is low resource potential for geothermal energy on the valley side of range-bounding faults in the study area. The area has no potential for oil or gas.

INTRODUCTION

This mineral survey was requested by the U.S. Bureau of Land Management and represents a cooperative effort by the U.S. Geological Survey and the U.S. Bureau of Mines. An introduction to the wilderness review process, mineral survey methods, and agency responsibilities is provided by Beikman and others (1983). The U.S. Bureau of Mines evaluates identified resources at individual mines and mineralized areas by collecting data on current and past mining activities and through field examination of mines, prospects, claims, and mineralized areas. Identified resources are classified according to a system that is a modification of that described by McKelvey (1972) and the U.S. Bureau of Mines and U.S. Geological Survey (1980). Studies by the U.S. Geological Survey are designed to provide a scientific basis for assessing the potential for undiscovered mineral resources by determining geologic units and structures, possible environments of mineral deposition, presence of geochemical and geophysical anomalies, and applicable ore-deposit models. Mineral assessment methodology and terminology as they apply to these surveys were discussed by Goudarzi (1984). See "Appendixes" for the definition of levels of mineral resource potential and certainty of assessment and for the resource/reserve classification.

Location, Physiography, and Access

The Kofa Unit 4 North Wilderness Study Area (AZ–050–033). is located about 30 mi south of Quartzsite and 60 mi northeast of Yuma, Ariz. (fig. 1), in the Basin and Range physiographic province of southwestern Arizona. The climate is arid, characteristic of the Sonoran Desert region of the southwestern United States and northern Mexico.

The study area lies along the steep, northwestern escarpment of the Castle Dome Mountains. Elevations range from about 1,500 ft on alluvial fans of the flanking La Posa Plain to nearly 2,200 ft at the top of the escarpment. Access is by secondary roads from U.S. Highway 95, which lies about 0.5 mi west of the study area.

Present Investigation

In 1988, the U.S. Bureau of Mines conducted a survey of the study area that focused chiefly on the examination of known mines, prospects, and mineralized areas inside and within about 1 mi of the study area boundary (Gese, 1989). Field studies by the U.S. Geological Survey for this assessment were conducted mainly in 1984 and 1985 and included geologic mapping and geochemical studies. Rock and stream-sediment samples were collected to supply background geochemical information and to identify areas containing anomalous concentrations of economic or indicator elements (Adrian and others, 1986; Bagby and others, 1987).

APPRAISAL OF IDENTIFIED RESOURCES

By Diann D. Gese
U.S. Bureau of Mines

Setting

The study area is about 13 mi north-northwest of the Castle Dome mining district and about 16 mi west of the Kofa district (fig. 1). Both districts, however, are centered on vein deposits restricted to metamorphosed Mesozoic sedimentary rocks (Keith, 1978). Such rocks are buried in the Kofa Unit 4 North Wilderness Study Area by at least 3,000 ft of Tertiary volcanic strata (Grubensky and others, in press). Sand and gravel fill the few washes in the study area.

The zeolites mordenite and clinoptilolite are the only minerals of economic interest known to occur in the study area. The zeolites occur in devitrified greenish silicic tuff that crops out along the west boundary. The tuff forms thin lenses within a more widespread unit of thick silicic lava flows or shallow intrusions.

Mining and Leasing Activity

Zeolites have been mined by open-pit methods and stockpiled along the western boundary of the study area by the Yuma Zeolite Corporation of Phoenix, Ariz., as recently as February 1986. The mine was inactive and appeared abandoned as of April 1988. A group of lode claims staked for zeolites extends into the study area from the west in secs. 20 and 29, T. 2 S., R. 19 W. There has been no mining of precious metals or other industrial minerals from the study area, and there are no oil or gas leases or lease applications in the study area.

Methods of Investigation

U.S. Bureau of Mines personnel collected 11 rock samples during 2 days of field work and analyzed them for zeolite mineral content. Samples containing more than 60 percent combined zeolites were further tested to determine suitability for industrial uses. Complete analytical results for all samples are available for public inspection at the U.S. Bureau on Mines, Intermountain Field Operations Center, Building 20, Denver Federal Center, Denver, CO 80225. Conventional methods were used to estimate area and thickness of the three zeolite deposits found in the study area (Gese, 1989). Tonnages were calculated by dividing the deposit volumes by a tonnage factor of 15.

Results

Three zeolite deposits in the study area contain inferred subeconomic resources totaling approximately 733,000 tons of 60- to 98-percent combined zeolites. Clinoptilolite and mordenite are the major constituents; quartz or secondary silica are minor. Laboratory tests provided to the U.S. Bureau of Mines indicate that the zeolites' ammonium-ion exchange capacity, important in treating radioactive and water wastes, is low, ranging from 0.54 to 0.96 milliequivalents per gram (meq/g), whereas most commercial zeolites have exchange capacities of 1 to 2 meq/g. Some of the zeolite samples are capable of purifying water containing 200 to 1,000 parts per million lead (Pb^{2+}) to drinking water standards of less than 50 parts per billion lead. Additional testing might determine other uses for these zeolites.

All three deposits are suitable for open-pit mining because they are exposed at the surface and are as thick as 25 ft. Potential distribution centers are located within 60 mi, at either Yuma, Ariz., or Blythe, Calif.

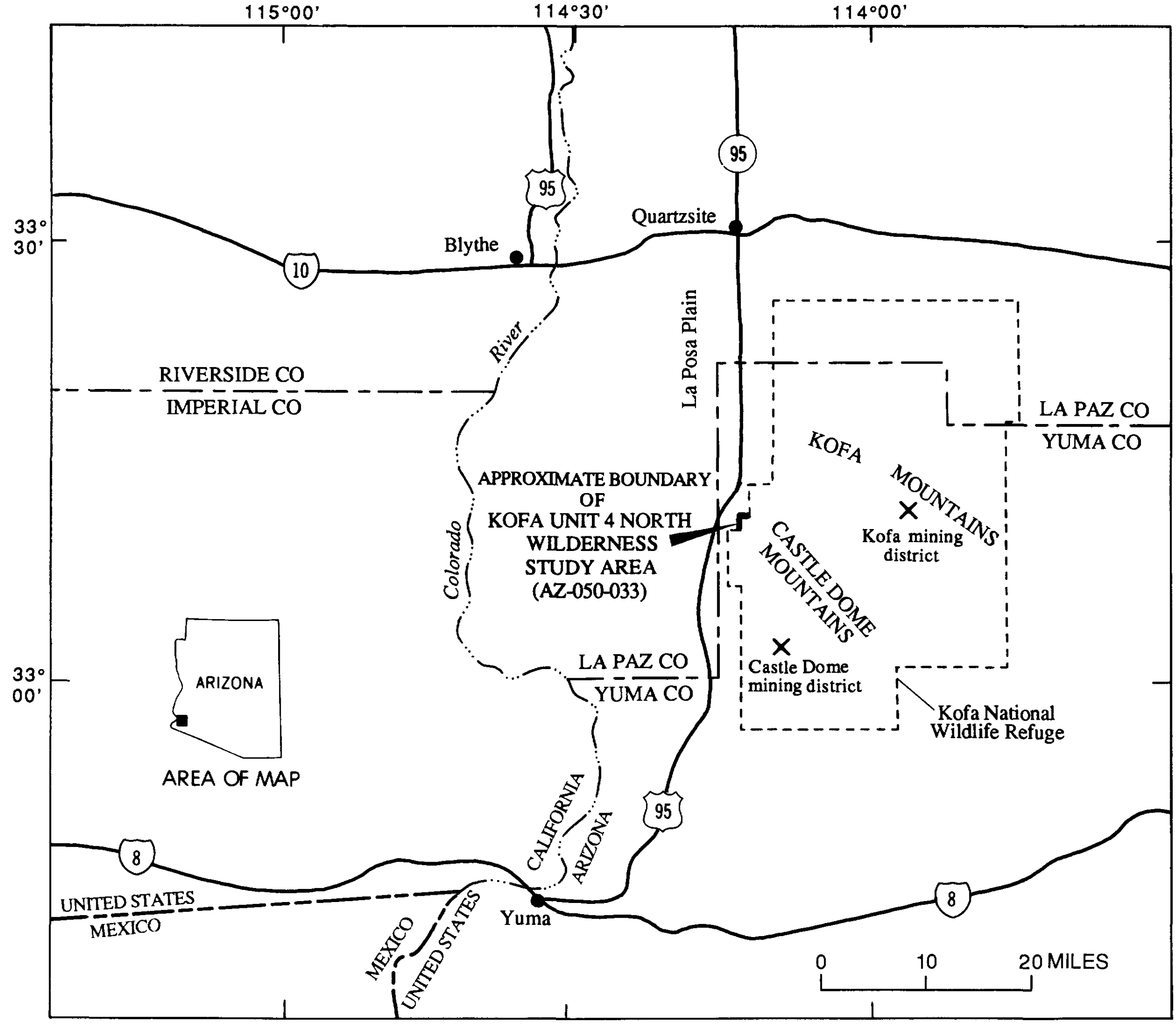


Figure 1. Index map showing location of Kofa Unit 4 North Wilderness Study Area, Yuma County, Arizona.

ASSESSMENT OF MINERAL AND ENERGY RESOURCE POTENTIAL

By David R. Sherrod, David B. Smith, *and*
M. Dean Kleinkopf
U.S. Geological Survey

Geology

The Kofa Unit 4 North Wilderness Study Area, in the northern Castle Dome Mountains, is underlain by Oligocene and lower Miocene volcanic and volcaniclastic rocks (Grubensky and others, in press). These rocks consist mainly of silicic lava flows, shallow intrusions, and interbedded ash-flow tuff that were erupted from caldera sources in the Kofa and Castle Dome Mountains about 24 to 22 million years ago (Ma) (Shafiqullah and others, 1980; Gutmann, 1981; Grubensky and others, 1986).

Normal faulting and sedimentation occurred simultaneously, beginning sometime after about 22 Ma (Sherrod and others, 1987). The region was extended 10 to 40 percent, as indicated by strata in fault blocks that are tilted as much as 60°. Thick sequences of sand and gravel (in unit QTs, fig. 2) accumulated as large alluvial fans that filled grabens and buried the pediment slopes of mountain ranges throughout the area.

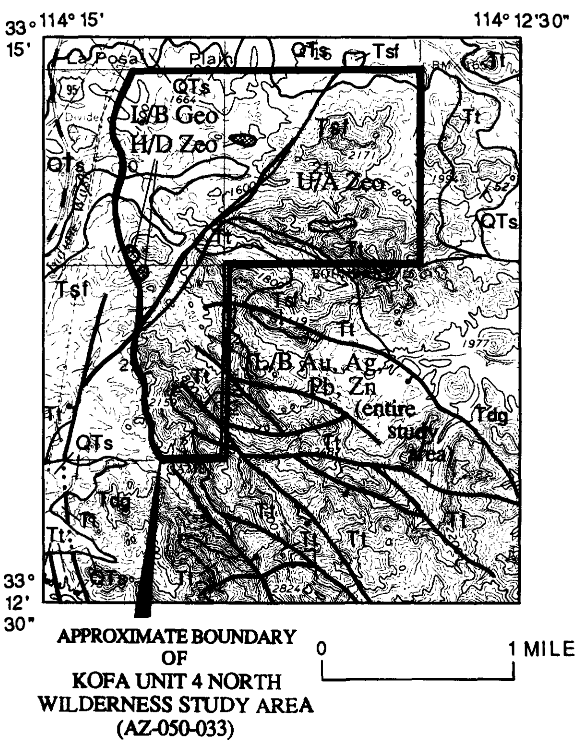
Except for zeolites, mineralization is unreported from the study area, and the Tertiary volcanic rocks elsewhere in the general area have only a few small zones of alteration and iron oxide staining. In contrast, mines in the Kofa and Castle Dome mining districts have produced precious and base metals from vein deposits in metamorphosed Mesozoic sedimentary rocks. Within the study area, however, these rocks are buried beneath at least 3,000 feet of Tertiary volcanic rocks.

Some of the volcanic rocks were glassy because they cooled so rapidly upon eruption. Glass is inherently unstable, however, and through time the Tertiary glass has been converted to minerals, including zeolites and clays. Devitrification of glass, most extensive in silicic tuff (part of unit Tsf) adjacent to silicic lava or intrusions in the study area, has resulted in the zeolite deposits on the west edge of the Castle Dome Mountains in the study area.

Geochemical Studies

Methods of Investigation

Stream-sediment samples were collected from four sites in dry stream beds in the Kofa Unit 4 North Wilderness Study Area in 1985 as part of a more extensive U.S. Geological Survey mineral resource assessment study of the Kofa National Wildlife Refuge and its proposed additions (Adrian and others, 1986; Bagby and others, 1987). Minus-80-mesh stream sediments and heavy-mineral concentrates derived from stream sediments were selected as the primary sample media in that study because they represent a com-



EXPLANATION

Area having high mineral resource potential (H)

Area having low (L) or unknown (U) mineral resource potential

Levels of certainty of assessment

- A — Data are not adequate to determine level of potential
- B — Data only suggest level of potential
- D — Data clearly define level of potential

Commodities

Au	Gold	Pb	Lead
Ag	Silver	Zn	Zinc
Geo	Geothermal	Zeo	Zeolite

Geologic map units

- QTs — Sedimentary deposits and rocks (Quaternary and Tertiary)
- Tsf — Silicic lava flows and shallow intrusions (Miocene)—Locally includes thin lenses of tuff that have been converted to zeolite minerals
- Tt — Tuff and welded tuff (Miocene and Oligocene)
- Tdg — Dacite of Gravel Wash (Miocene and Oligocene)

Contact—Approximately located

Fault—Dotted where concealed. Bar and ball on downthrown side

52 — Strike and dip of bedding or foliation in welded tuff

Figure 2. Mineral resource potential and generalized geology of Kofa Unit 4 North Wilderness Study Area, Yuma County, Arizona. Geology generalized from Grubensky and others (in press). Topographic contour interval 40 ft.

posite of rock and soil exposed in the drainage basin upstream from the sample site. Chemical analysis of the sediment samples helps to identify basins containing unusually high concentrations of elements that may be related to mineral occurrences. Heavy-mineral concentrates are a useful sample medium in arid environments or in areas of rugged topography, where mechanical erosion predominates over chemical erosion (Overstreet and Marsh, 1981; Bugrov and Shalaby, 1975; Zeegers and others, 1985). Analytical data, sampling methods, sample preparation procedures, analytical techniques, and sampling sites are presented in Adrian and others (1986).

The nonmagnetic fraction of one heavy-mineral-concentrate sample was analyzed for 31 elements[1] by semiquantitative emission spectroscopy. A nonmagnetic fraction concentrates ore and ore-related minerals such as pyrite, galena, cassiterite, sphalerite, chalcopyrite, stibnite, free gold, barite, and scheelite and thus permits determination of some elements that are not easily detected in bulk stream-sediment samples.

This method is imprecise for the low concentrations of some elements commonly used as pathfinders for precious metal mineralization. Therefore, the minus-80-mesh stream-sediment samples were analyzed by atomic-absorption methods, which have lower determination limits as follows (shown in parentheses for each element): antimony (2 parts per million, ppm), arsenic (10 ppm), gold (2 to 8 parts per billion, ppb, depending on amount of sample available), mercury (0.02 ppm), silver (0.05 ppm) thallium (0.1 ppm), and zinc (5 ppm). It is impractical to analyze heavy-mineral concentrates by atomic absorption because the preparation of the concentrate results in too little sample material for reliable results by that method.

Summary of Results

Within the study area, a sample from one site contains 0.05 ppm gold in minus-80-mesh sediments; the heavy-mineral concentrate from the same site contains 1,000 ppm lead and detectable arsenic (that is, arsenic was detected but below the limit of determination, 500 ppm). Geochemically, the Kofa Unit 4 North Wilderness Study Area lies within the "northern Castle Dome anomaly" as defined and discussed by Bagby and others (1987). That anomaly covers approximately the northern quarter of the Castle Dome Mountains and encompasses scattered anomalous concentrations of gold, thallium, and zinc in minus-80-mesh stream sediments and scattered anomalous concentrations of tin, arsenic, silver, zinc, lead, antimony, and bismuth in nonmagnetic heavy-mineral concentrates.

Geophysical Studies

The geophysical data discussed here are from reconnaissance gravity and magnetic surveys of the region. The Bouguer gravity anomaly map (fig. 3) was compiled from U.S. Geological Survey digital gravity files. Control for the map consists of randomly spaced stations that average about 2 mi apart, but no control points are located within the study area. The study area lies near the south flank of a broad and deep gravity minimum. The lowest gravity value is negative 92 milligals near the center of the La Posa Plain. This low has been attributed to a subsided block, possibly resulting from caldera-forming volcanism in Miocene time (Bagby and others, 1987; Gutmann, 1981). Gravity modeling by C.L.V. Aiken (cited in Gutmann, 1981) suggests that the area is underlain at about 5 mi depth by a silicic batholith.

The aeromagnetic anomaly map (fig. 4) is from a residual total intensity map of the Salton Sea 1:250,000-scale sheet prepared for the National Uranium Resource Evaluation program (LKB Resources, Inc., 1980). That survey was flown along north-south flightlines having 3-mi

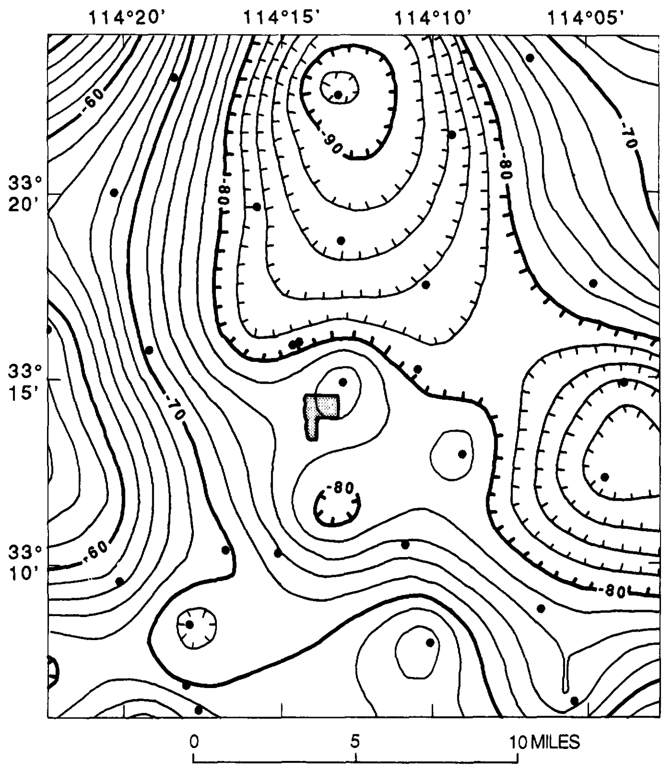


Figure 3. Bouguer gravity anomaly map of region including Kofa Unit 4 North Wilderness Study Area (shaded block), Yuma County, Arizona. Contour interval 2 milligals; hachures indicate area of closed low; dots represent gravity stations. Compiled by Viki L. Bankey.

[1]Arsenic, antimony, barium, beryllium, bismuth, boron, cadmium, calcium, cobalt, chromium, copper, gold, iron, lanthanum, lead, magnesium, manganese, molybdenum, niobium, nickel, silver, scandium, strontium, thorium, tin, titanium, tungsten, vanadium, yttrium, zinc, and zirconium.

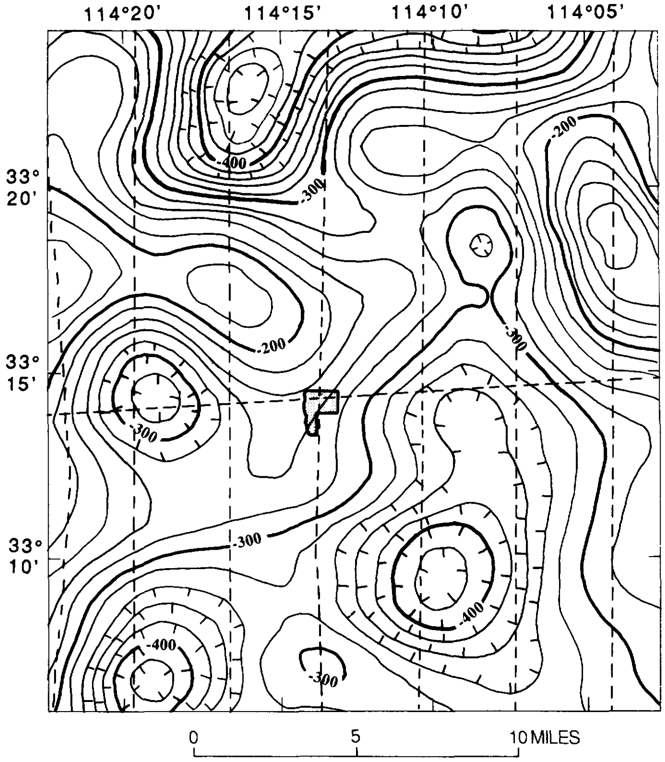


Figure 4. Total intensity aeromagnetic anomaly map of region including Kofa Unit 4 North Wilderness Study Area (shaded block), Yuma County, Arizona. Contour interval 20 nanoteslas; hachures indicate area of closed low. Dashes show flightlines. Data from LKB Resources, Inc. (1980).

line spacing and terrain clearance of 400 ft. The Kofa Unit 4 North Wilderness Study Area lies along a north-south flightline and an east-west tie line. The magnetic anomaly map indicates that the study area is about 4 mi northwest of a large negative anomaly having an amplitude of 80 to 100 nanoteslas. This and several other negative anomalies on the map may be explained by low magnetization in pre-Tertiary rock units that underlie the volcanic rocks of the study area. The low magnetization may also result from alteration.

Mineral and Energy Resources

Gold, Silver, Lead, and Zinc

The entire study area has low resource potential, certainty level B, for the precious and base metals of gold, silver, lead and zinc. This assignment is based on anomalous concentrations in one of the four stream-sediment samples from the study area and on the position of the study area within the northern Castle Dome geochemical anomaly, a broad area characterized by scattered anomalous concentrations of gold, thallium, and zinc in stream-sediment samples and erratic concentrations of tin, arsenic, silver, zinc, lead, antimony, and bismuth in heavy-mineral concentrates (Bagby and others, 1987). The specific location and style of mineralization and alteration responsible for the anomalous concentrations is undefined on the geologic map of the mountains (Grubensky and others, in press), but presumably the metal concentrations result from alteration and minor mineralization along fault zones or are associated with small veins and iron oxide staining. The metals are probably mobilized from buried pre-Tertiary rocks, which are locally mineralized elsewhere in the region.

Zeolites

A high mineral resource potential, certainty level D, for zeolite is assigned to areas adjacent to three small demonstrated zeolite occurrences in silicic tuff. The scattered distribution of these areas probably reflects spotty zeolitization of rocks in the area. An unknown resource potential, certainty level A, for zeolite is assigned to the northern part of the study area, which is underlain by Tertiary silicic lava flows that may include unrecognized small deposits of zeolite.

Geothermal Energy

The Castle Dome Mountains are in the Basin and Range physiographic province, which is characterized by high regional heat flow. Heat-flow values of 101 milliwatts per square meter (mW/m^2) were measured 30 mi north of the study area near Quartzsite, and values of 80 to 88 mWm^2 were measured 60 mi south near Yuma (Muffler, 1979). A well at Stone Cabin, 1.5 mi north of the study area on U.S. Highway 95, intercepted water having a temperature of 44 °C at 1,020 ft depth (Witcher and others, 1982). Several alluvial basins located 20 to 60 mi east of the study area are considered "favorable for the discovery and development of local sources of low-temperature (less than 90 °C) geothermal water" suitable for space heating, agriculture, and perhaps industry (Sammel, 1979). This water is heated by deep circulation along fault zones in areas of high regional heat flow. Conceivably, similar thermal conditions may exist in the La Posa Plain at the north edge of the study area, but the hydrology of the basin is unexplored. No igneous-related geothermal systems—those in which water is heated by young shallow intrusions—occur within 100 mi of the study area (Muffler, 1979).

Aquifers of the La Posa Plain lie chiefly in Tertiary and Quaternary alluvial fill and are outside the study area. Low-temperature thermal fluids, possibly from the La Posa Plain, may be convecting near the major range-bounding fault in the study area. Therefore, a low resource potential, certainty level B, for geothermal energy is assigned to the area northwest of that fault along the west boundary of the study area (fig. 2).

Data about geothermal gradients and lithologic conductivity are insufficient to show that the study area lies within a locally enhanced zone of heat flow. Nevertheless, an encouraging view of geothermal resources was offered by Gutmann (1981), who relied on a broadly defined negative Bouguer gravity anomaly, the depth to the Curie isotherm, and an anomalously shallow (6-mi depth) electrical conductor as favorable indicators that valleys near the northern and central Castle Dome Mountains are more attractive for geothermal development than surrounding areas. However, much of the evidence is sketchy and ill-defined; see Gutmann (1981) for references.

Other Commodities

Sand and gravel are high-volume, low-unit-value commodities that require a local market for economic development. The occurrences in the Kofa Unit 4 North Wilderness Study Area have no unique properties that make them more valuable than other deposits closer to markets.

The Kofa Unit 4 North Wilderness Study Area has no potential, certainty level D, for oil and gas resources. It is in a part of the Basin and Range physiographic province that was considered by Ryder (1983) to have low or zero potential for oil and gas. No tar or oil seeps, black shales, or other evidence of hydrocarbon source beds are found in the Tertiary volcanic rocks that underlie most of the study area. The Tertiary alluvial fill of La Posa Plain may have limited potential for gas, but these rocks are relatively thin where they abut the Castle Dome Mountains in the study area.

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APPENDIXES

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

LEVELS OF RESOURCE POTENTIAL

H **HIGH** mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a high degree of likelihood for resource accumulation, where data support mineral-deposit models indicating presence of resources, and where evidence indicates that mineral concentration has taken place. Assignment of high resource potential to an area requires some positive knowledge that mineral-forming processes have been active in at least part of the area.

M **MODERATE** mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate reasonable likelihood for resource accumulation, and (or) where an application of mineral-deposit models indicates favorable ground for the specified type(s) of deposits.

L **LOW** mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics define a geologic environment in which the existence of resources is permissive. This broad category embraces areas with dispersed but insignificantly mineralized rock, as well as areas with little or no indication of having been mineralized.

N **NO** mineral resource potential is a category reserved for a specific type of resource in a well-defined area.

U **UNKNOWN** mineral resource potential is assigned to areas where information is inadequate to assign a low, moderate, or high level of resource potential.

LEVELS OF CERTAINTY

A Available information is not adequate for determination of the level of mineral resource potential.
B Available information only suggests the level of mineral resource potential.
C Available information gives a good indication of the level of mineral resource potential.
D Available information clearly defines the level of mineral resource potential.

LEVEL OF RESOURCE POTENTIAL →

A	B	C	D
U/A	H/B HIGH POTENTIAL	H/C HIGH POTENTIAL	H/D HIGH POTENTIAL
UNKNOWN POTENTIAL	M/B MODERATE POTENTIAL	M/C MODERATE POTENTIAL	M/D MODERATE POTENTIAL
	L/B LOW POTENTIAL	L/C LOW POTENTIAL	L/D LOW POTENTIAL
			N/D NO POTENTIAL

LEVEL OF CERTAINTY →

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RESOURCE/RESERVE CLASSIFICATION

	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Probability Range	
	Measured	Indicated		Hypothetical	Speculative
ECONOMIC	Reserves		Inferred Reserves		
MARGINALLY ECONOMIC	Marginal Reserves		Inferred Marginal Reserves		
SUB-ECONOMIC	Demonstrated Subeconomic Resources		Inferred Subeconomic Resources		

Major elements of mineral resource classification, excluding reserve base and inferred reserve base. Modified from McKelvey, V.E., 1972, Mineral resource estimates and public policy: American Scientist, v. 60, p. 32-40; and U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, p. 5.

GEOLOGIC TIME CHART

Terms and boundary ages used by the U.S. Geological Survey in this report

EON	ERA	PERIOD		EPOCH	AGE ESTIMATES OF BOUNDARIES IN MILLION YEARS (Ma)
Phanerozoic	Cenozoic	Quaternary		Holocene	0.010
				Pleistocene	1.7
		Tertiary	Neogene Subperiod	Pliocene	5
				Miocene	24
			Paleogene Subperiod	Oligocene	38
				Eocene	55
				Paleocene	66
	Mesozoic	Cretaceous		Late	96
				Early	138
		Jurassic		Late Middle Early	205
		Triassic		Late Middle Early	~240
	Paleozoic	Permian		Late Early	290
		Carboniferous Periods	Pennsylvanian	Late Middle Early	~330
			Mississippian	Late Early	360
		Devonian		Late Middle Early	410
		Silurian		Late Middle Early	435
		Ordovician		Late Middle Early	500
		Cambrian		Late Middle Early	[1]~570
Proterozoic	Late Proterozoic				900
	Middle Proterozoic				1600
	Early Proterozoic				2500
Archean	Late Archean				3000
	Middle Archean				3400
	Early Archean				
- - - - - - (3800?)- - - - - -					
pre-Archean[2]					4550

[1]Rocks older than 570 Ma also called Precambrian, a time term without specific rank.
[2]Informal time term without specific rank.

Mineral Resources of Wilderness Study Areas: Southwestern and South-Central Arizona

This volume was published as separate chapters A-K

U.S. GEOLOGICAL SURVEY BULLETIN 1702

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

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[Letters designate the separately published chapters]

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