DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

MINERAL RESOURCES OF THE CHEMEHUEVI/NEEDLES WILDERNESS STUDY AREA, SAN BERNARDINO COUNTY, CALIFORNIA

By

Barbara E. John[1], William F. Hanna[2], Jerry R. Hassemer[3], James A. Pitkin[2], and Micheal E. Lane[4]

U.S. Geological Survey Open-File Report 87-586

Prepared by the U.S. Geological Survey and the U.S. Bureau of Mines

for the U.S. Bureau of Land Management

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

[1]Department of Earth Science, University of Cambridge, Cambridge, CB2-3EQ, England
[2]U.S. Geological Survey, Branch of Geophysics, MS-964, Box 25046, Federal Center, Denver, Colo., 80225
[3]U.S. Geological Survey, Branch of Geochemistry, MS-973, Box 25046, Federal Center, Denver, Colo., 80225
[4]U.S. Bureau of Mines, Intermountain Field Operations Center, Box 25086, Bldg. 20, Federal Center, Denver, Colo., 80225

1988

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 on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of the Chemehuevi/Needles Wilderness Study Area (AZ-050-004), San Bernardino County, California.

CONTENTS

FIGURES AND TABLES

MINERAL RESOURCES OF THE CHEMEHUEVI/NEEDLES WILDERNESS STUDY AREA, SAN BERNARDINO COUNTY, CALIFORNIA

SUMMARY

Abstract

The Chemehuevi/Needles Wilderness Study Area (AZ-050-004), which includes 960 acres west of the Colorado River in eastern San Bernardino County, California, was evaluated for identified mineral resources (known) and mineral resource potential (undiscovered). The U.S. Bureau of Mines and the U.S. Geological Survey examined the area and collected stream-sediment, rock, and soil samples during the summer and fall of 1985. There are no mines, prospects or identified resources in the area. The Chemehuevi/Needles Wilderness Study Area has low mineral resource potential for copper, lead, zinc, manganese, gold, silver, sand and gravel, building stone and aggregate, uranium and thorium, oil and gas, and geothermal resources.

Character and setting

The Chemehuevi/Needles Wilderness Study Area is in extreme eastern San Bernardino County, California, about 18 mi southeast of Needles, Calif., and about 12 mi northwest of Lake Havasu City, Ariz. (fig. 1). Barren, steep, and rocky topography characterizes the region, although the study area encloses numerous small sandy washes. The study area is underlain by Proterozoic and Cretaceous crystalline basement rocks (see Appendixes for geologic time chart). These rocks are grouped into a Proterozoic suite of layered gneiss and igneous-appearing metamorphic rock, and younger deformed Cretaceous plutonic rocks. Miocene and Oligocene(?) volcanic and sedimentary rocks, and Proterozoic gneisses lie above a major low-angle normal fault cutting this crystalline basement. Quaternary sedimentary deposits make up the modern washes and lie on old erosional surfaces throughout the study area. Alteration and mineralization are confined to Proterozoic rocks and areas near the breccia zones associated with the low-angle normal and detachment faults and numerous other high-angle faults (fig. 2).

Identified resource and mineral potential

The Chemehuevi/Needles Wilderness Study Area contains no identified mineral resources. Near the study area, sparsely distributed areas of small hydrothermal veins (principally copper-barite-silver veins carrying minor lead, gold, and zinc) typify weak epithermal systems. These veins are associated with Tertiary fault breccias and quartz veins in Proterozoic gneiss. Information from geochemical analysis of stream-sediment samples does not show anomalous concentrations of any element that indicates mineralization occurred within the area, and existing geophysical surveys show magnetic anomalies typical of magnetically reversed volcanic flows and provide no information about the possibility of potential resources at depth. Only small insignificant traces of copper and manganese were observed along shears and fault surfaces. Therefore the mineral resource potential for base and precious metals (copper, lead, zinc, manganese, gold and silver) is low (fig. 2). Radioactive mineral resources (uranium and thorium) display concentrations that are slightly above background levels for the Proterozoic

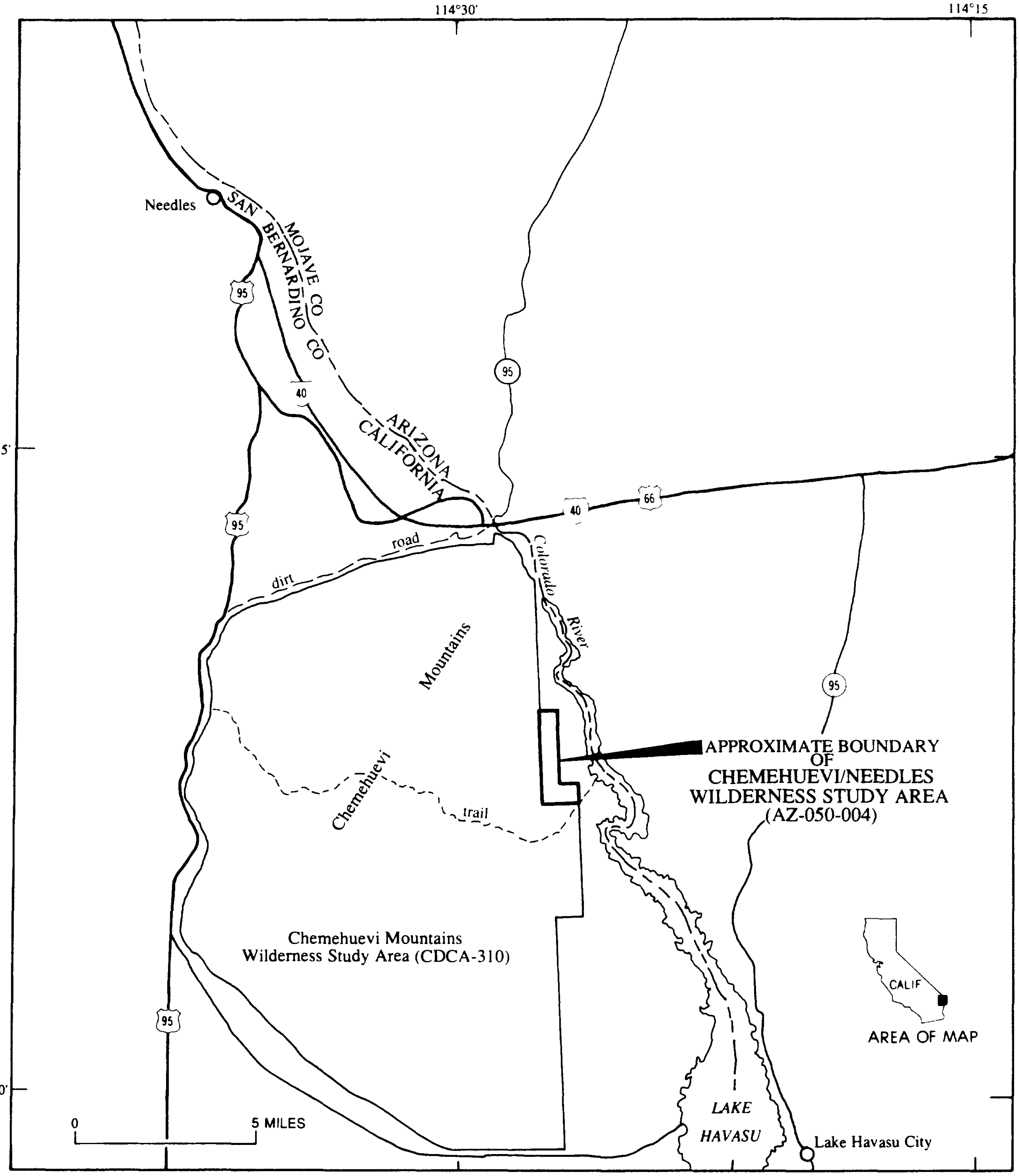

Figure 1. Index map showing the location of the Chemehuevi/Needles Wilderness Study Area, San Bernardino County, California.

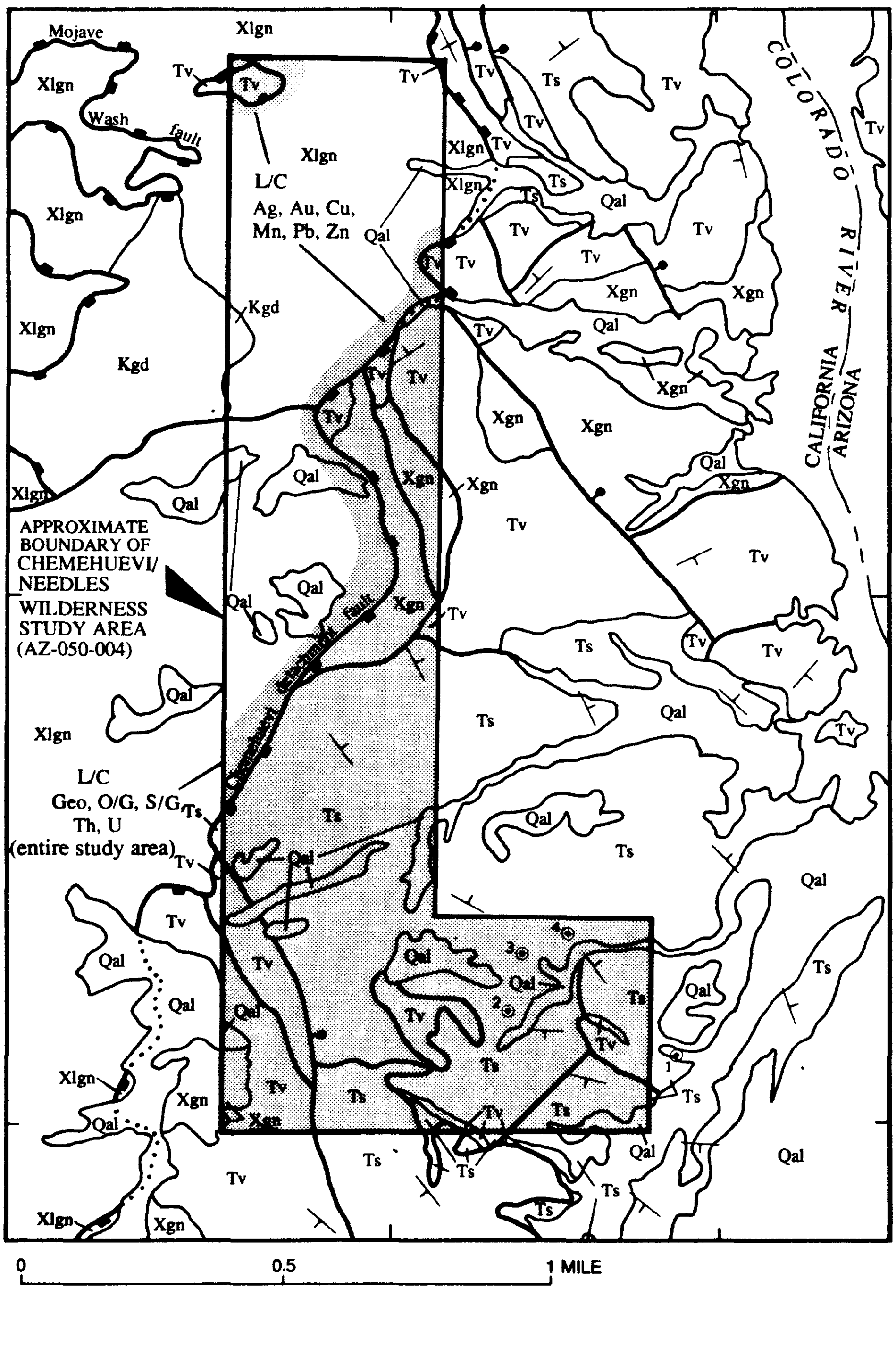

Figure 2. Map showing geology, sample locations, and mineral resource potential of the Chemehuevi/Needles Wilderness Study Area, San Bernardino County, California.

EXPLANATION

Area with low metallic mineral resource potential, certainty level C (L/C)

Area with low nonmetallic and energy resource potential, certainty level C (L/C)

See appendix for definition of levels of resource potential (L) and certainty of assessment (C)

Commodities

Ag	Silver
Au	Gold
Cu	Copper
Geo	Geothermal
Mn	Manganese
Pb	Lead
O/G	Oil and gas
S/G	Sand and gravel, building stone, and aggregate
Th	Thorium
U	Uranium
Zn	Zinc

Correlation of Map Units

Qal	QUATERNARY
Ts Tv	TERTIARY
Kgd	CRETACEOUS
Xgn Xlgn	PROTEROZOIC X

Geologic Map Units

Qal	Alluvial deposits (Holocene and Pleistocene)
Ts	Sedimentary deposits (Miocene)
Tv	Volcanic deposits (Miocene and Oligocene)
Kgd	Deformed granodiorite (Cretaceous)
Xgn	Gneiss (Proterozoic X)
Xlgn	Layered gneiss and migmatite (Proterozoic X)

Contact

Fault--Dashed where approximately located; dotted where concealed; ball and bar on downthrown side

Detachment fault--Dotted where concealed; box on hanging wall (upper plate)

General strike and dip of bedding

Vertical bedding

3 Geochemical sample-collection site

Figure 2. Continued.

basement terrane that typifies the study area; mineral resource potential for radioactive minerals is low. The likelihood of occurrence of oil and gas resources is considered remote as evidenced by a lack of geologically or geophysically favorable host rocks and structures. Therefore the mineral resource potential for oil and gas is low. Potential for geothermal resources, sand and gravel, building stone, and aggregate is low. Sand and gravel occurrences in the area are small, access to them is poor, and therefore are not classified as a resource.

INTRODUCTION

This mineral survey was requested by the U.S. Bureau of Land Management and is a joint 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 were provided by Beikman and others (1983). The U.S. Bureau of Mines evaluates identified resources at individual mines and known 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 the system described by the U.S. Bureau of Mines and U.S. Geological Survey (1980). Studies by the U.S. Geological Survey are designed to provide a reasonable 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 appendix for the definition of levels of mineral resource potential, certainty of assessment, and classification of identified resources.

Location and physiography

The Chemehuevi/Needles Wilderness Study Area (AZ-050-004) covers 960 acres of U.S. Bureau of Land Management land adjacent to the Chemehuevi Mountains Wilderness Study Area (CDCA-310), in easternmost San Bernardino County, Calif. The area lies about 18 mi southeast of Needles, Calif., and about 12 mi northwest of Lake Havasu City, Ariz. (fig. 1). The area is in California, but is administered from the U.S. Bureau of Land Management office in Yuma, Arizona. The L-shaped study area is roughly parallel to and lies about 1 mi west of the Colorado River. The only vehicle access to the wilderness study area is by way of an unimproved dirt road that leads southeastward from Lobecks Pass on U.S. Highway 95, about 9 mi west, and ends near the southern boundary of the area (fig. 1). Access from the east is limited to entry from the Colorado River.

The desert terrain is characterized by sandy washes, rocky knobs, and sparse vegetation. The highest elevation is about 1,000 ft in the northwest corner of the study area; the lowest elevation is 560 ft in the washes on the east edge of the wilderness study area. No prominent geographic features exist within the study area.

Procedures and sources of data

The Chemehuevi/Needles Wilderness Study Area is contiguous with the Chemehuevi Mountains Wilderness Study Area (fig. 1) studied by Miller and others (1983) of the U.S. Geological Survey, and Kreidler (1983) of the U.S. Bureau of Mines. Geologic mapping by Miller and others (1983) includes the Chemehuevi/Needles Wilderness Study Area. The U.S. Geological Survey mapped in the area from 1982 to 1986 at a scale of 1:24,000, as part of a broader study of the structural evolution of the Chemehuevi Mountains (John, 1986; 1987).

For this study the U.S. Bureau of Mines searched the literature for evidence of past or present mining activity within and near the study area. No references to mineralization were found. U.S. Bureau of Land Management records were examined and no mining claims or oil and gas leases were found in the study area. Field work done by the U.S. Bureau of Mines consisted of helicopter reconnaissance of the area. No mines or prospects were found and no samples were taken.

Acknowledgments

The U.S. Bureau of Land Management office in Needles, Calif., provided information about the wilderness study area.

APPRAISAL OF IDENTIFIED RESOURCES

By Michael E. Lane, U.S. Bureau of Mines

No mining claims or oil and gas leases were located within the Chemehuevi/Needles Wilderness Study Area in 1985, and no evidence of previous mining activity was found. No organized mining districts are in or near the wilderness study area. The nearest mine, the Blue Boy mine, is about 7 mi northwest in the Chemehuevi Mountains Wilderness Study Area and was described by Kreidler (1983). Sand and gravel occurrences in the study area are small; they have no unique properties and access to them is poor. There are no identified resources in the study area.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By Barbara E. John, William F. Hanna, Jerry R. Hassemer, and James A. Pitkin, U.S. Geological Survey

Geology

Geologic Setting

The Chemehuevi/Needles Wilderness Study Area lies in the eastern Mojave Desert Province, of the southern Basin and Range Province. The majority of the wilderness study area is underlain by Proterozoic gneiss and migmatite, Cretaceous granitic rocks, and volcanic and sedimentary rocks of Miocene and Oligocene(?) age (fig. 2). In addition, relatively small areas of Quaternary sedimentary deposits make up the modern washes and lie on old erosional surfaces throughout the study area (see Miller and others, 1983, for review).

Structure

The most conspicuous structural feature in the study area is the Tertiary low-angle normal or detachment fault (the Chemehuevi detachment fault) that traverses the area approximately north to northeast (fig. 2). The fault separates allochthonous Proterozoic crystalline rocks and overlying Tertiary volcanic and sedimentary rocks that crop out along the Colorado River from autochthonous Proterozoic layered gneisses and migmatites and deformed Cretaceous granitic rocks to the west (fig. 2). Horizontal separation on the Chemehuevi detachment fault is a minimum of 8 km northeast, and displacement is probably on the order of 20 to 40 km (John, 1986). Structurally below the Chemehuevi detachment lies another low-angle fault, the Mojave Wash fault, which has approximately 2 km of northeastward separation of the hanging wall. Conspicuous northwest- and northeast-striking faults cut the Mojave Wash fault and crystalline rocks below it, as well as the rocks above the Chemhuevi detachment fault in the study area. Gouge zones and (or) breccias of variable thickness, associated with the two low-angle normal and related high-angle faults, apparently acted as conduits for sparse hydrothermal circulation.

Environments for mineral formation

Several geologic settings commonly favorable elsewhere for the occurrence of significant mineral deposits also occur in the Chemehuevi/Needles Wilderness Study Area. Nonetheless, no deposits of precious or base metals (copper, lead, zinc, manganese, gold, and silver) and energy minerals (uranium and thorium) were found at the surface. Sites favorable for mineralization might be expected in the following geologic environments (reviewed by Miller and others, 1983): (1) the layered gneiss and the deformed plutonic suite, both of which contain quartz veins and pegmatitic segregations; (2) altered Tertiary volcanic and sedimentary rocks; and (3) zones of faulting and intense fracturing, where the wallrocks may have been altered by hydrothermal fluids.

1. The Proterozoic gneiss and the deformed plutonic rocks show no evidence of significant mineralization. In these rocks, zones of alteration, pegmatite and quartz veins are rare. Geochemical analyses of rock and sediment samples taken from areas underlain by these rocks show no anomalous concentrations of metals.
2. Alteration and mineralization of Tertiary volcanic and sedimentary rocks is common in areas surrounding the study area. Rocks of this type in the study area are locally intensely fractured and host argillic alteration.
3. Copper and manganese mineralization occurred along sheared zones and faults cutting all types of crystalline rocks, both above and below the Chemehuevi and Mojave Wash detachment faults. Copper stain, rare copper

hydroxide minerals, and pyrolusite are typical of this localized mineralization. Intense limonitic alteration is common in the Proterozoic crystalline rocks above the Chemehuevi detachment fault. This fault is commonly defined by brecciated copper- and manganese-bearing oxides cementing the main fault surface. Similar copper and manganese associations are developed rarely along northeast- and northwest-striking faults in the study area.

Geochemistry

The geochemical survey of the Chemehuevi/Needles Wilderness Study Area was carried out using both original data and data from several previous studies: (1) data from the National Uranium Resource Evaluation (NURE) program (Cook, 1981), and (2) data from the earlier U.S. Geological Survey study of the adjoining Chemehuevi Mountains Wilderness Study Area (Hopkins and others, 1984). All samples were collected outside the Chemhuevi/Needles Wilderness Study Area, but provide regional information for the NURE study, especially for uranium and thorium. The Chemhuevi Mountains study covered all of the Chemehuevi/Needles Wilderness Study Area, but all of the sampled stream drainages extend well beyond the boundaries of the Chemehuevi/Needles Wilderness Study Area. Hopkins and others (1984) also describes analytical procedures for the U.S. Geological Survey samples.

Additional data were obtained on four samples collected within Chemehuevi/Needles study area during a brief visit during the Fall of 1985. These latter samples were collected to test very small stream drainages in the Chemehuevi/Needles Wilderness Study Area. Sample-collection sites are shown on figure 2 and the data are shown in table 1. The four samples were all analyzed by semiquantitative emission spectrography (table 1). Atomic-absorption methods were used to reanalyze some elements to provide lower detection limits. Sieved-sediment samples, in addition to the NURE samples, were analyzed for uranium and thorium by neutron-activation analysis.

With one exception, the geochemical survey shows little indication of mineralization. This exception is a sandstone-hosted, manganese oxide replacement zone, represented by rock sample 3 (table 1). Although the sample is anomalous in several metals, gold and silver were not detected. This occurrence appears to be significant only for its manganese content (iron was determined to be only 2 percent).

Geophysics

Gravity anomaly data

Bouger gravity anomaly data of Gage and Simpson (1983) and Chapman and Rietman (1976) near the study area define a shallow gradient extending across the area with values decreasing eastward and southeastward. This gradient forms the common flank of a broad low associated with low-density sediments in the Lake Havasu region to the southeast. The gravity anomaly data provide no information about the possibility of subsurface mineral occurrences.

Magnetic anomaly data

Aeromagnetic anomalies over the study area are defined by 8 east-west flightlines, spaced one-half mile apart, with a mean terrain clearance of 1,000 ft, referenced to an updated International Geomagnetic Reference Field 1975, six of the lines falling within the boundaries of the study area. Anomalies are generally broad and are low in amplitude, indicating that the gneissic rock terrane and areas of Tertiary sediment are relatively nonmagnetic. The only short-wavelength anomaly worthy of mention occurs at the southwest corner of the study area where a magnetic low correlates with volcanic flows and intrusions; at the southeast corner of the area where a high and a broader low to the northeast are associated at least partially with basaltic dikes and flows; and immediately east of the east-central part of the area where a conspicuous low reflects the occurrence of faulted volcanic flows.

The most significant conclusion that may be drawn from the data is that the total magnetization of volcanic flows and intrusions has on the average a direction that is opposite to that of the Earth's present magnetic field. Thus, these rocks must possess significant amounts of reversed remanent magnetization, a property of potential use for stratigraphic and structural correlation in this region. The anomaly map offers no specific information about the possibility of subsurface mineral occurrences.

Aerial gamma-ray spectrometric data

Aerial gamma-ray spectrometry is a geophysical technique that measures the near-surface (0-50 cm depth) distribution of the natural radioelements potassium, uranium, and thorium. Because this distribution is controlled by geologic processes, aerial gamma-ray measurements can be used in geologic mapping and mineral exploration, and in understanding geologic processes.

Spectrometry data were obtained by the National Uranium Resource Evaluation (NURE) program during the period 1974-1981. NURE data acquisition was keyed to 1^{o} by 2^{o} topographic quadrangles and flightline spacing was usually at 3- and 6-mi intervals. This wide spacing meant that the data are suitable for the production of contour maps and other maps only at scales of 1:500,000 and smaller (Duval, 1983).

Spectrometric data and radioelement maps of the Needles 1^{o} by 2^{o} sheet (U.S. Department of Energy, 1979) indicate that the Chemehuevi/Needles Wilderness Study Area is characterized by concentrations of 1.5 to 2.0 percent potassium, 5 to 6 parts per million uranium, and 8 to 10 parts per million thorium. No anomalous concentrations were observed for the study area (anomalous defined as changes in concentration of at least 50 percent compared to adjacent areas, or concentrations of unusual level for the lithologic types known to occur in the wilderness study area).

Mineral and Energy Resource Potential

Base and precious metals

Broad areas of crystalline rocks in the study area have low potential for base metals (copper, lead, zinc, and manganese) and precious metals (gold and silver). Mineralization is probably caused by low-to moderate-temperature hydrothermal system spatially related to detachment faults, and less commonly high-angle faults. Conceptually, such a mineralizing system, where present, might generate low-grade copper, lead, zinc, manganese, gold, and silver deposits. Overall, evidence of mineralization is sparse. Low-grade gold, silver, and copper mineralized zones exposed 7 mi away in the Blue Boy mine (Miller and others, 1983; Kreidler, 1983) appear to have been caused by secondary enrichment; even lower grades should be expected at depth. The potential for copper, lead, zinc, manganese, gold, and silver resources in most of the study area is low with a C certainty.

Radioactive-mineral resources

One uranium geochemical anomaly occurs in the southeast corner of the Chemehuevi Mountains Wilderness Study Area (CDCA-310) adjacent to the west. Thorium shows slightly elevated concentrations in the Chemehuevi Mountains Wilderness Study Area as well and thorite is common in panned concentrates (Miller and others, 1983). Because no anomalous concentrations of radioactive elements were determined by either the geochemical or aerial gamma-ray spectrometric studies within the Chemehuevi/Needles Wilderness Study Area, the potential for uranium and thorium resources in this study area is low with a C certainty.

Oil and gas resources

No known geologic structures in the Chemehuevi/Needles Wilderness Study Area are considered favorable for oil and gas. The Chemehuevi Mountains lie along the extrapolated trend of the western overthrust belt, which elsewhere in the Cordillera contains oil and gas in the Paleozoic and Mesozoic strata. The possibility that similar overthrusts in the study area exist and conceal oil- and gas-bearing rocks is considered remote on the basis of geologic and geophysical data. Even if such rocks were present, they most probably would be highly metamorphosed and barren of oil and gas. Therefore, the potential for oil and gas in the Chemehuevi/Needles Wilderness Study Area is low with a C certainty.

Geothermal resources

The eastern Mojave Desert region is characterized by heat-flow values typical of the Basin and Range physiographic province, which are higher than average crustal heat-flow values. Possible young thermal-spring deposits occur 8 mi south of the study area, in the southeastern part of the Chemehuevi Mountains Wilderness Study Area (CDCA-310) (Miller and others, 1983). These deposits are the only evidence for thermal activity in or near the study area. Therefore, the potential for geothermal resources within the Chemehuevi/Needles Wilderness Study Area is low with a C certainty.

Industrial minerals

Occurrences of common borrow sand and gravel are present in the study area. Development of these materials is unlikely in the foreseeable future, however, because they are small, access to them is poor, similar materials of equal or better quality are abundant closer to local markets, and because the probable cost of mining exceeds the present market value of the materials. The Chemehuevi/Needles Wilderness Study Area has a low resource potential for additional undiscovered sand and gravel, building stone, and aggregate resources with a C certainty level.

REFERENCES CITED

Beikman, H.M., Hinkle, M.E., Frieders, Twila, Marcus, S.M., and Edward, J.R., 1983, Mineral surveys by the Geological Survey and the Bureau of Mines of Bureau of Land Management Wilderness Study Areas: U.S. Geological Survey Circular 901, 28 p.

Chapman, R.H., and Rietman, J.D., 1976, Bouger gravity anomaly map of California, Needles sheet: California Division of Mines and Geology, scale 1:250,000.

Cook, J.R., 1981, Needles 1^{o} by 2^{o} NTMS area, California and Arizona. Data report (abbreviated), National Uranium Resource Evaluation Program, hydrogeochemistry and stream sediment reconnaissance: U.S. Department of Energy Open-File Report GJBX-232.

Duval, J.S., 1983, Composite color images of aerial gamma-ray spectrometric data: Geophysics, v. 48, no. 6, p. 722-735.

Gage, T.B., and Simpson, R.W., 1983, Principal facts for 904 gravity stations on or near the Chemehuevi Mountains and Crossman Peak Wilderness Study Area, San Bernardino County, California, and Mojave County, Arizona: U.S. Geological Survey Open-File Report 83-806, 33 p.

Goudarzi, G.H., 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84-787, 51 p.

Hopkins, R.T., Fox, J.P., Antweiler, J.C., and Campbell, W.L., 1984, Analytical results and sample locality map of stream-sediment, heavy-mineral-concentrate, rock, and water samples from the Chemehuevi Mountains Wilderness Study Area (CDCA-310), San Bernardino County, California: U.S. Geological Survey Open-File Report 84-261, 29 p., 1 plate, scale 1:48,000.

John, B.E., 1986, Structural and intrusive history of the Chemehuevi Mountains area, southeastern California and western Arizona: Calif., U.C. Santa Barbara, unpublished Ph.D. dissertation, 295 p., 1 sheet, scale 1:24,000.

_______ 1987, Structural reconstruction of the Chemehuevi Mountains plutonic suite: geometry of a mid-crustal intermediate to silicic magma chamber [abs.]: Geological Society of America Abstracts with Programs, v. 19, n. 7, p. 717.

Kreidler, T.J., 1983, Mineral investigation of the Chemehuevi Mountains Wilderness Study Area, San Bernardino County, California: U.S. Bureau of Mines Open-File Report MLA 42-83, 9 p.

Lane, M.E., 1985, Mineral investigation of the Chemehuevi/Needles Wilderness Study Area (AZ-050-004), San Bernardino County, California: U.S. Bureau of Mines Mineral Land Assessment Open-File Report MLA 50-85, 6 p.

Miller, D.M., John, B.E., Antweiler, J.C., Simpson, R.W., Hoover, D.B., Rainer, G.L., and Kreidler, T.J., 1983, Mineral resource potential map of the Chemehuevi Mountains Wilderness Study Area (CDCA-310), San Bernardino County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1584-A, scale 1:48,000.

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, 5 p.

U.S. Department of Energy, 1979, Aerial radiometric and magnetic survey, Needles national topographic map, California and Arizona: U.S. Department of Energy Grand Junction, Colorado, GJBX-114 (79), 2 vol.

U.S. Geological Survey, 1981, Aeromagnetic map of the Needles 1° by 2° quadrangle, California and Arizona: U.S. Geological Survey Open-File Report 81-85, scale 1:250,000.

Table 1. Selected analyses for rock samples collected in and near the Chemehuevi/Needles Wilderness Study Area

[All values in parts per million; N, not detected; AA, analysis by atomic absorption; S, analysis by semi-quantitative spectrography; SS, sieved sediment; PC, panned concentrate; r, rock; s, soil; numbers in ( ), detection limit; numbers in [ ], sieve wash size. See figure 2 for localities]

Sample No. (fig. 2)	Ag-S	As-AA	Au-AA	Ba-S	Bi-AA	Cu-S	Hg-AA	Mn-S	Mo-S	Pb-S	Sb-AA	Sn-S	Th-S	U-S	W-S	Zn-S
1 [-35]	--	--	--	--	--	7	--	--	N(5)	15	--	--	--	--	--	37
[-100]	--	--	--	--	--	20	--	--	N(5)	15	--	--	20	4.6	--	60
2 PC	N(1)	--	N(0.05)	--	--	30	--	--	N(10)	20	--	N(20)	--	--	N(100)	N(500)
3 r	--	410	--	>(5,000)	13	100	--	>(5,000)	70	150	12	--	--	--	--	180
4 s	N(0.05)	N(10)	--	--	--	15	0.02	--	N(5)	--	--	--	--	--	--	N(200)

APPENDIXES

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

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 few or no indications of having been mineralized.

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 of resource accumulation, and (or) where an application of mineral-deposit models indicates favorable ground for the specified type(s) of deposits.

HIGH mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurence, where interpretations of data indicate a high degree of likelihood for resource accumulation, where data supports 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.

UNKNOWN mineral resource potential is assigned to areas where information is inadequate to assign low, moderate, or high levels of resource potential.

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

Levels of Certainty

LEVEL OF RESOURCE POTENTIAL →

A	B	C	D
U/A UNKNOWN POTENTIAL	H/B HIGH POTENTIAL	H/C HIGH POTENTIAL	H/D HIGH 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 →

A. Available information is not adequate for determination of the level of mineral resource potential.

B. Available information 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.

Abstracted with minor modifications from:

Taylor, R. B., and Steven, T. A., 1983, Definition of mineral resource potential: Economic Geology, v. 78, no. 6, p. 1268–1270.

Taylor, R. B., Stoneman, R. J., and Marsh, S. P., 1984, An assessment of the mineral resource potential of the San Isabel National Forest, south-central Colorado: U.S. Geological Survey Bulletin 1638, p. 40–42.

Goudarzi, G. H., compiler, 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84–0787, p. 7, 8.

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 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 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	~570[1]
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.