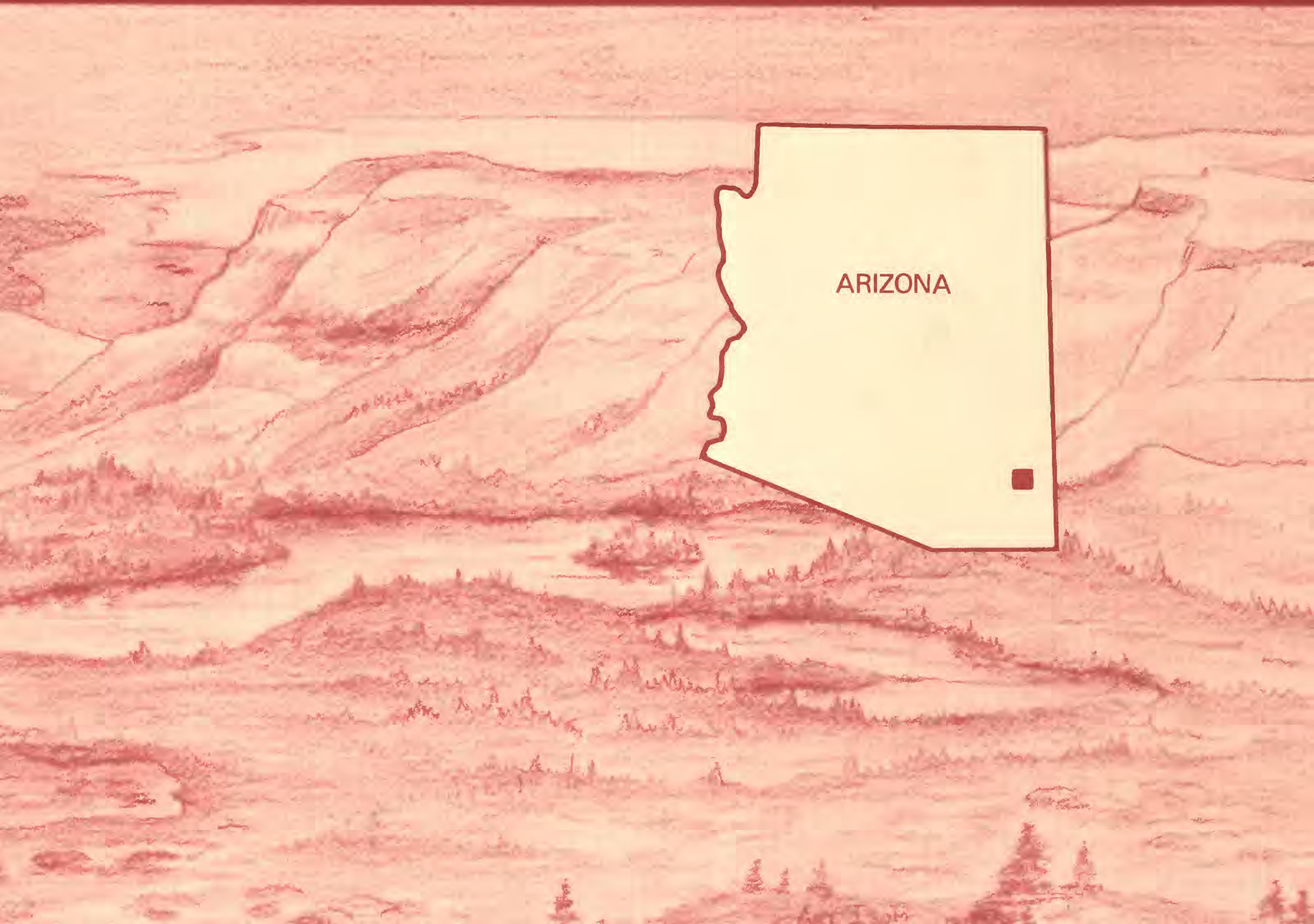
2.00
#8

Mineral Resources of the Dos Cabezas Mountains Wilderness Study Area, Cochise County, Arizona

U.S. GEOLOGICAL SURVEY BULLETIN 1703–D



DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

Definitions of Mineral Resource Potential

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 unlikely. This broad category embraces areas with dispersed but insignificantly mineralized rock as well as areas with few or no indications of having been mineralized.

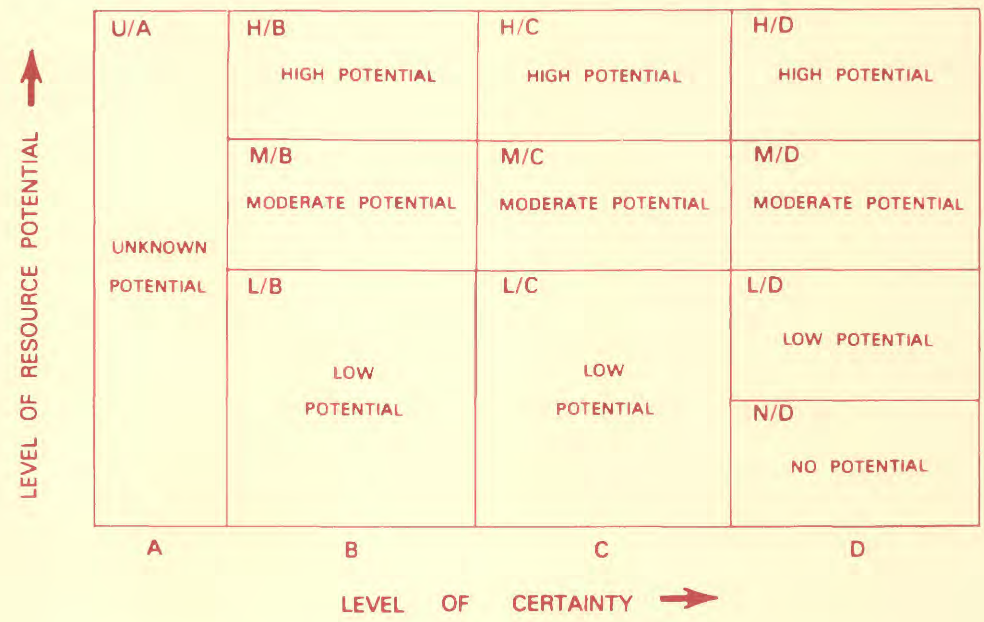
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application 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 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.

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



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.

Chapter D

Mineral Resources of the Dos Cabezas Mountains Wilderness Study Area, Cochise County, Arizona

By HARALD DREWES, GERDA A. ABRAMS, and
JERRY R. HASSEMER
U.S. Geological Survey

JEANNE E. ZELTEN
U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1703

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
SOUTHEASTERN ARIZONA

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON: 1986

Library of Congress Cataloging in Publication Data

Mineral resources of the Dos Cabezas Mountains Wilderness Study
Area, Cochise County, Arizona

(Mineral resources of wilderness study areas—Southeastern Arizona ;
ch. D) (U.S. Geological Survey bulletin ; 1703-D)
Bibliography: p.
Supt. of Docs. No.: I 19.3:1703-D
1. Mines and mineral resources—Arizona—Dos Cabezas Mountains
Wilderness. 2. Geology—Arizona—Dos Cabezas Mountains
Wilderness. 3. Dos Cabezas Mountains Wilderness (Ariz.)
I. Drewes, Harald, 1927- . II. Series. III. Series: U.S. Geological
Survey bulletin ; 1703-D.
QE75.B9 no. 1703-D 557.3 s 86-600381
[TN24.A6] [553'.09791'53]

For sale by
Books and Open-File Reports Section
U.S. Geological Survey
Federal Center
Box 25425
Denver, CO 80225

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 a part of the Dos Cabezas Mountains (AZ-040-065) Wilderness Study Area, Cochise County, Arizona.

RESOURCE / RESERVE CLASSIFICATION

	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Probability Range (or)	
	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.

CONTENTS

PLATE

FIGURES

Mineral Resources of the Dos Cabezas Mountains Wilderness Study Area, Cochise County, Arizona

By Harald Drewes, Gerda A. Abrams, *and*
Jerry R. Hassemer
U.S. Geological Survey

Jeanne E. Zelten
U.S. Bureau of Mines

SUMMARY

Abstract

The USGS (U.S. Geological Survey) and the USBM (U.S. Bureau of Mines) studied 11,921 acres of the Dos Cabezas Mountains Wilderness Study Area (AZ- 040-065) in Cochise County, Arizona. The study of this acreage was requested by the BLM (U.S. Bureau of Land Management). In this report, the studied area is called "wilderness study area" or just "study area." The wilderness study area covers about 18.6 sq mi (square miles) of the northeast flank of the Dos Cabezas Mountains in southeastern Arizona, where they lie just south of Interstate Highway 10 and 3–18 mi east and southeast of Willcox. Geologic, geochemical, geophysical, and mine and prospect studies were undertaken by the USGS and the USBM mainly during 1984. These followed more extensive geologic studies of the entire range, as well as studies of adjacent ranges. As a result of these investigations, about 3 sq mi of the study area is assigned a moderate mineral resource potential for porphyry, skarn, stockwork, massive-sulfide replacement, and vein deposits of copper, lead, zinc, molybdenum, tungsten, and silver. (In this report the term "deposit" does not carry a connotation of economic value.) Additionally, an identified resource of a silver- and gold-bearing quartz vein suitable for smelter flux is present. The rest of the area is assigned a low resource potential for both metallic and nonmetallic deposits.

Character and Setting

The study area is centered about Happy Camp Canyon on the northeast flank of the Dos Cabezas Mountains, about 6 mi southwest of Bowie and 18 mi east of Willcox in southeastern Arizona (fig. 1). The towns lie on Interstate Highway 10 and the main line of the Southern Pacific Railroad, which both skirt the northwest end of the mountains. Vehicular access to the study area extends to canyon mouths and to most of the larger, but now inoperative, mines. A few unmaintained jeep tracks and trails lead to old prospects and to cabins that are near springs. Scrubby forest, herbaceous plants, grasses, and cactus vegetation provide a substantial cover, but offer little hindrance to foot access.

The Teviston mining district occupies the northeast flank of the mountains and the Dos Cabezas mining district the southwest flank. Nearly $1.8 million of metals have been mined from mainly the Elma, Ivanhoe, Mascot, and Leroy mines in these districts, but outside the study area. Most properties were inactive at the time of this investigation.

The study area has geologic features and a geologic history considered favorable for the occurrence of certain kinds of mineral deposits, such as veins, replacement bodies, and stockworks or pipes. The geologic setting of the study area may also be favorable for disseminated deposits. However, these same features and this same history make the area unfavorable for the accumulation and preservation of hydrocarbon resources.

The key geologic features for this assessment of mineral resource potential include the known and inferred presence of sedimentary and volcanic rocks known to be favorable host rocks for mineral deposits elsewhere in the region. They also include the presence nearby of a master fault system (the Apache Pass fault zone) that was much used by rising fluids. The presence near the master fault of other faults and of steeply

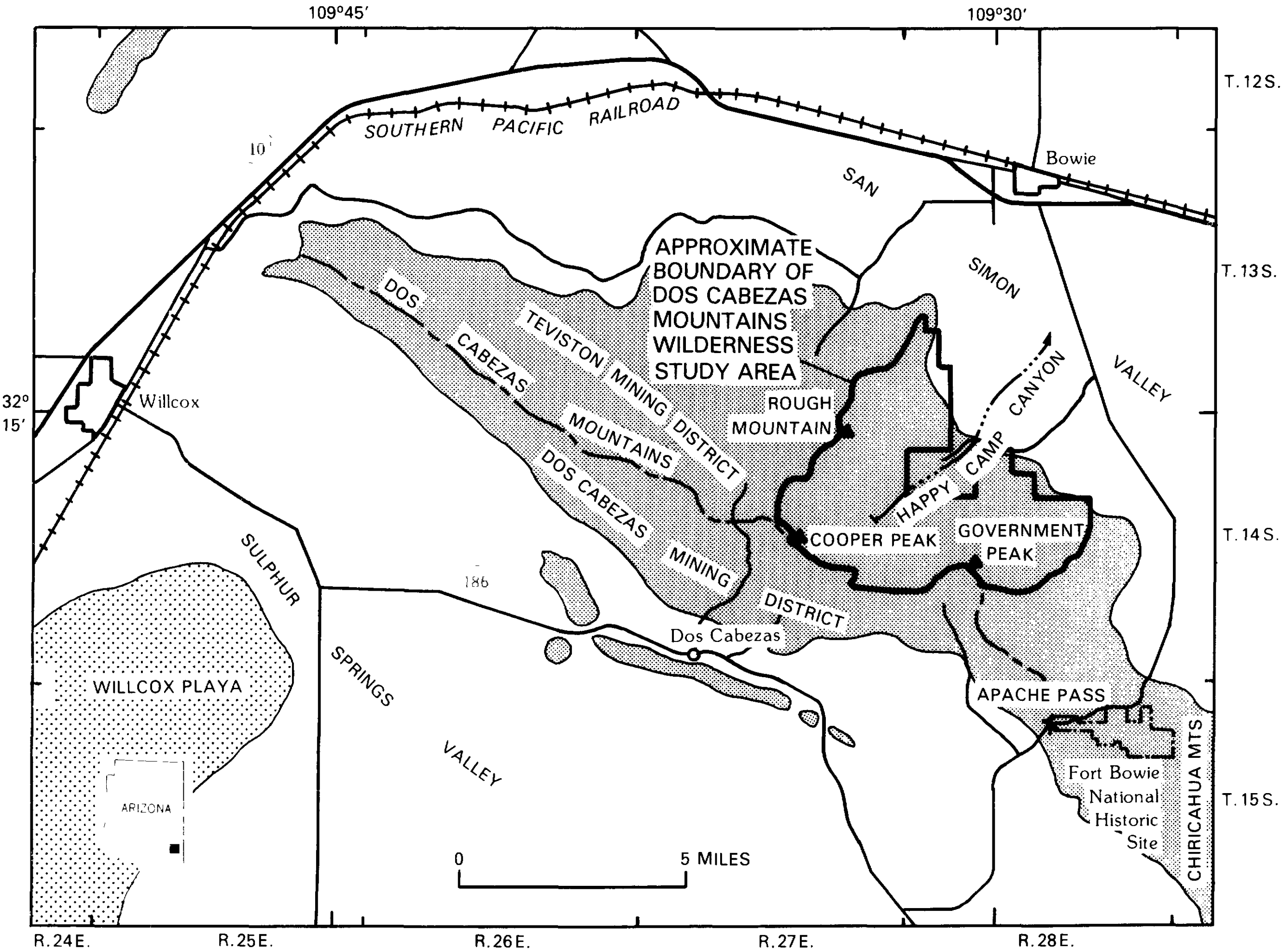
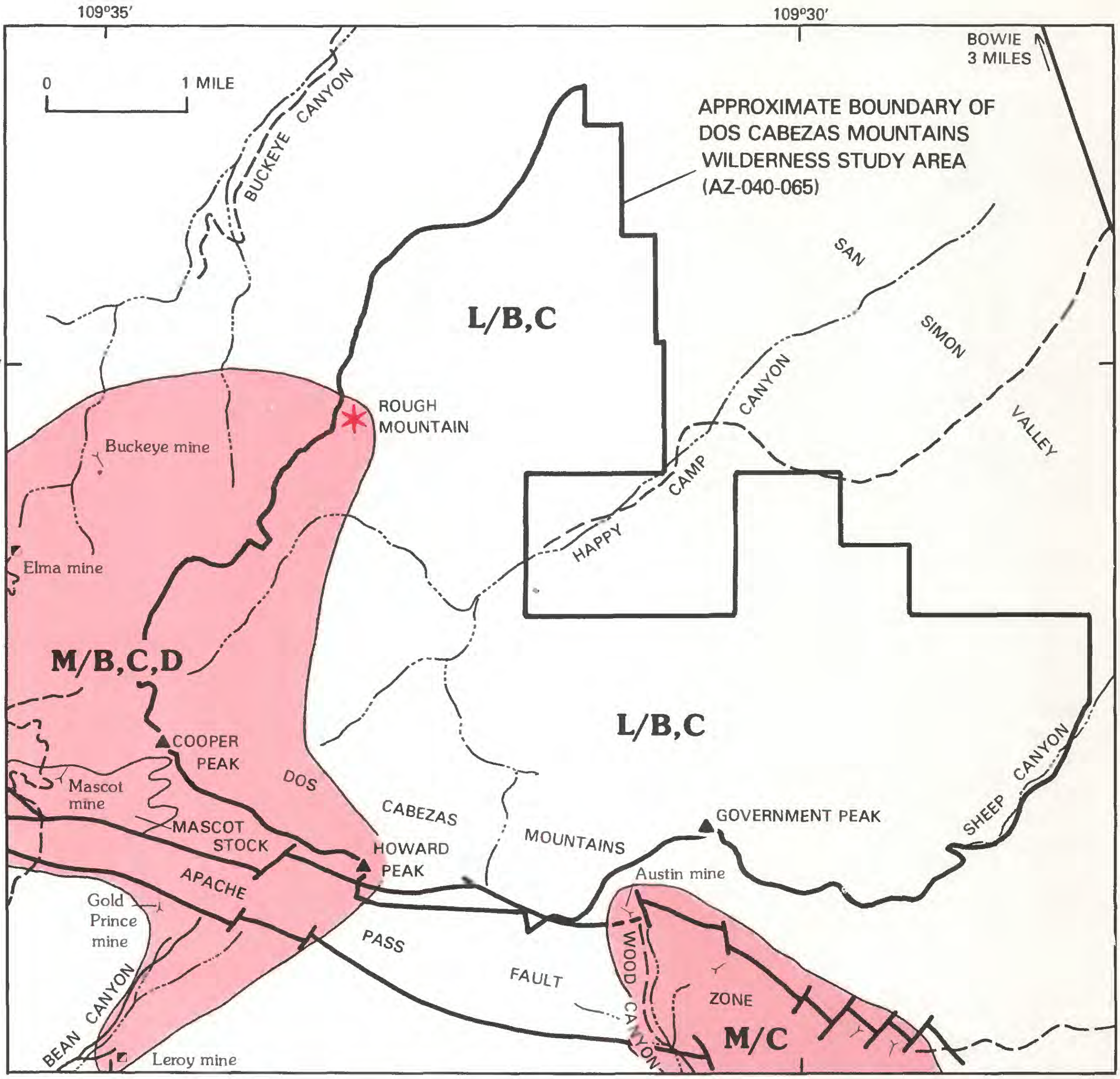


Figure 1. Index map showing location of the Dos Cabezas Mountains Wilderness Study Area, Cochise County, southeastern Arizona. Mountainous areas are shaded.

oriented features, such as breccia pipes and stock walls, is also an asset. Abundant and varied volcanic and plutonic rocks of late Laramide (Late Cretaceous to Paleocene) age are another favorable feature. (See geologic time chart at end of this report for relative geologic ages.) The area also had a favorable history of late uplift and erosion to a suitable level in the volcano-plutonic system for the exposure of deposits at the most likely position of accumulation. Finally, there are direct signs such as mineral deposits in and near the study area that base (copper, lead, zinc, molybdenum, and tungsten) and precious (gold, silver) metals were introduced. Such rocks, structures, geologic history, and mineralization occur in many mining districts of southeastern Arizona and southwestern New Mexico, and so they are viewed as favorable signs for mineralization in the study area.

The study area is underlain by (1) a basement of ancient crystalline rocks, (2) a fragmentary cover of sedimentary rocks, (3) a thick pile of volcanic rocks and related small masses of plutonic rocks, and (4) some younger intrusive rocks, including a large granite stock. Key rocks include certain of the sedimentary cover rocks, and part of the volcanic pile and a related intrusive rock.

The three older rock groups are cut by the Apache Pass fault zone. It is one of an extensive system of northwest-trending, steeply dipping faults that have been active at diverse times and have had a varied movement history. These faults were probably first active during Precambrian time and since then have remained major crustal zones of weakness up which magmas and hydrothermal fluids moved at deep crustal levels. Near the study area, the vents for the volcanic pile, small stocks, plugs and dikes, and occurrence of most mineral deposits of the Dos Cabezas mining district reflect a general control by the Apache Pass fault zone. Elsewhere along this fault zone are other volcanic fields, stocks, and mining camps, including those at Hilltop and Paradise. Other key structures in the study area are assorted vertical features, such as stock walls, breccia pipes, and faults that cut across (or branch from) the master fault, along which fluids may have spread at shal-



EXPLANATION

[No terrane having high mineral resource potential for any commodity was identified in this study]

*	**Site of identified mineral resource**—Quartz vein suitable for smelter flux, containing silver and gold
M/B, C,D	**Geologic terrane having moderate mineral resource potential with certainty levels B, C, and D for copper, lead, zinc, molybdenum, tungsten, and silver.** (See text and plate 1 for more detailed information)
L/B,C	**Geologic terrane having low mineral resource potential with certainty levels B and C for metals, nonmetals, and energy resources**
	Fault—Dashed where approximately located
	Mines and prospects
	Adit
	Inclined shaft

Figure 2. Summary map showing site of identified mineral resource and areas of moderate and low mineral resource potential, Dos Cabezas Mountains Wilderness Study Area, Cochise County, Arizona.

lower crustal levels. Similarly, the unconformity at the base of the volcanic pile rises away from the master fault and could have aided in dispersing fluids from that fault.

A history of Late Cretaceous–Paleocene volcanism, plutonism, and faulting along the Apache Pass fault zone is viewed as favorable because most mineral deposits of the region also have had such a history. These deposits typically were generated during the last stages of magmatic activity that mostly followed widespread compressional deformation. Then, beginning in mid-Tertiary time, the region was subjected to tensional, rather than compressional stress. Consequently, the upper rocks of the crust were faulted, alternating blocks were dropped and raised, and additional magmas moved upward. The Dos Cabezas block remained high relative to the adjacent intermontane blocks, and therefore deeply eroded to the root level of the volcanic pile and cap level of the related stocks. Such a structural level generally provides suitable pressure conditions for the deposition of mineral deposits.

Identified Mineral Resources

A large mineralized quartz vein on Rough Mountain in the northwest part of the study area constitutes an identified mineral resource (fig. 2). This vein is generally of high purity and so is suitable as flux in copper smelters. It contains small amounts of gold and silver, as well as some copper, which could be recovered as byproducts in the smelting process. The vein is flat lying, about 10 ft (feet) thick, and exposed near the top of a mountain, so that open-pit mining would be practical. At least 580,000 short tons of high-purity quartz is present. Other quartz veins nearby were also sampled but were not viewed as identified mineral resources because they are neither continuous nor exposed enough to determine resources.

Mineral Resource Potential

About 3 sq mi of the 18.6 sq mi comprising the study area have a moderate mineral resource potential for copper, lead, zinc, molybdenum, tungsten, and silver in porphyry, skarn, stockwork, massive-sulfide replacement, or vein deposits (fig. 2). Such deposits do not crop out in the study area but are likely to occur within a thousand feet of the surface.

These predictions of unexposed deposits are based on geologic mapping reinforced by geochemical and geophysical studies. There is much similarity between the geology of the core of the Dos Cabezas Mountains and that of many major mining districts of the region. All contain the same host rocks for certain mineral occurrences, represent the same level of exposure of a volcano-plutonic system, have igneous rocks of similar age and composition, and lie near a major northwest-trending fault zone. The Dos Cabezas Mountains contain base- and precious-metals deposits (as previously named), and there are good possibilities for additional discoveries.

The western part of the study area has a moderate resource potential for the named metallic mineral deposits. The ground near Cooper Peak (fig. 2) is near both the Apache Pass fault zone and the Mascot stock. It also has a breccia pipe containing blocks, as much as 10 ft across, of Paleozoic and Mesozoic rocks believed to have been derived from such a terrane beneath the volcanic pile or from larger blocks included within the volcanic pile.

Geophysical evidence and geologic mapping suggest the subsurface presence of a plug or stock near Howard Peak (fig. 2). Here, too, the contact of the intrusive body with sedimentary and volcanic rock is rated as having a moderate resource potential for the named metals.

The terrane between Cooper Peak, Howard Peak, and Rough Mountain is also rated as having a moderate resource potential for the same metals because of persistent metallic mineral accumulation in stream-sediment samples plus the presence of several prospects containing these metallic minerals. The area overlies a part of the volcanic pile in or beneath which favorable host rocks may occur, and also lies near the several plugs and the breccia pipe between the Elma mine, Cooper Peak, and Dos Cabezas Peaks (fig. 2).

The terrane of moderate resource potential for base and precious metals is extended to the Rough Mountain area because of the presence there of metalliferous quartz veins generally like those of the identified mineral resource.

The remainder of the study area is assigned a low mineral resource potential, particularly for base metals and gold and silver in veins or disseminated bodies. It is noteworthy, however, that a second area of moderate mineral resource potential lies south and southeast of Government Peak just outside the study area and extends almost to the southeast side of the study area (fig. 2).

INTRODUCTION

The Dos Cabezas Mountains Wilderness Study Area covers part of the Dos Cabezas Mountains, Cochise County, in the southeast corner of Arizona (fig. 1). At the request of the BLM, 11,921 acres of the Dos Cabezas Mountains Wilderness Study Area were studied. In this report the studied area is called "wilderness study area" or simply "the study area." The study area is centered about Happy Camp Canyon, enclosing a subcircular part of the crest and rugged northeast flank of the range. The center of the study area lies about 18 mi east of Willcox and 6 mi southwest of Bowie, towns which are both on Interstate Highway 10 and the main line of the Southern Pacific Railroad. State Highway 186 extends from near Willcox, through the nearly deserted mining village of Dos Cabezas, and along the southwest flank of the mountains. A county road extends from Bowie along the northeast end of the range, crosses Apache Pass, and joins

State Highway 186. Access to the study area is by way of ranch and mine roads from these secondary roads.

The Dos Cabezas Mountains are a typical range of the Basin and Range physiographic province. The range trends northwest, is about 22 mi long and 8 mi wide, and reaches an elevation of 8,354 ft at Dos Cabezas Peaks, about 2 mi west of the study area. To the northeast lies the broad intermontane San Simon Valley, which drains northward into the Gila River. To the southwest is the equally wide Sulphur Springs Valley, which drains internally into Willcox Playa. The San Simon Valley near the front of the Dos Cabezas Mountains is about 3,700 ft high, whereas the edge of the Sulphur Springs Valley across the range is about 4,200 ft high. As a result of this 500-ft difference in the local base level of erosion, the canyons on the northeast flank are deeper and longer than those on the southwest flank. This cross-range asymmetry has been a contributing factor in bringing access to the Elma mine (fig. 2), located at mid-flank on the northeast side, from Dos Cabezas village across the range to the southwest.

Although the terrain is decidedly rugged, the study area is everywhere accessible by foot from various roadheads. The main access is from a ranch road that extends up Happy Camp Canyon almost to the boundary of the wilderness study area. Above that roadhead, more or less washed-out trails extend up the tributary drainages of Tar Box and Howell Canyons (pl. 1) and up to some prospects on a high bench a mile east-northeast of Cooper Peak. Peripheral access is also provided from roadheads on the ridge crest northwest of Cooper Peak, site of a communications facility, and from roadheads in the lower part of Bean Canyon and upper reaches of Wood Canyon (pl. 1). Access on foot from these trails and roads is unhampered by the scrubby vegetation, except high on the northeast sides of Cooper and Howard Peaks. Typically, the lower spurs and hills are grassy and are dotted with low trees, shrubs, and cactus.

This evaluation of the mineral endowment (mineral resource potential and identified resources) is the product of several separate studies. Geologic, geochemical, and geophysical studies were undertaken by the USGS, and an evaluation of mines, prospects, and mineralized areas was done by the USBM. The studies led to independent results, which then were blended into a jointly derived evaluation of the mineral resource potential. This report presents summaries of the geophysical studies by G. A. Abrams, of the geochemical studies by J. R. Hassemer, of the geology by Harald Drewes, and of the mines, prospects, and mineralized areas by J. E. Zelten.

Mineral resource potential is the likelihood of occurrence of undiscovered concentrations of metals and nonmetals, of unappraised industrial rocks and minerals, and of undiscovered energy sources (coal, oil, gas, oil shale, geothermal sources). It is classified according to the system of Goudarzi (1984), which is shown on the inside front cover of this report. Identified resources are classified according to the system of the USBM and USGS (1980), which is shown on p. IV of this report.

Investigations by the U.S. Bureau of Mines

The USBM conducted a search of official records and a field study (Zelten, 1986). County, State, and BLM records of patented and unpatented mining claims and of mineral, oil, and gas leases were reviewed. Data on mining history were obtained from USBM records, geologic literature, and knowledgeable local people, geologists, and mining companies. Mines, prospects, and mineralized areas in and near the study area were examined in the field and were sampled to appraise the identified mineral resources. The 58 samples taken included grab or selected samples of mine and prospect dumps as well as chip samples of mineralized rock at mines or prospects. The samples were analyzed by fire assay or by fire assay–atomic absorption spectrophotometry for gold and silver, by X-ray fluorescence or colorimetry for tungsten, by ICP (inductively coupled plasma) spectrometry or atomic absorption for 11 elements, and by spectrographic methods for 40 elements, as described in detail by Zelten (1986). Complete analytical results are available for public inspection at the U.S. Bureau of Mines, Intermountain Field Operations Center, Denver Federal Center, Building 20, Denver, CO 80225. Tonnage calculations were made for a quartz vein on Rough Mountain.

Investigations by the U.S. Geological Survey

Conventional field-mapping procedures were used in the geologic study. Geologic features were mapped, mainly during 1979 and 1980, at 1:24,000 scale solely from ground surveys. Petrographic studies were made of igneous rocks, more to determine their general mineralogic composition and alteration than to result in a definitive study of a volcano-plutonic system. In connection with this mapping, mineralized rocks were taken from mine and prospect dumps to augment the geochemical study of the entire core of the range.

The geologic study was greatly facilitated by recently completed regional studies and by a considerable geologic literature on the Dos Cabezas Mountains. Most germane to this assessment is a range-wide study on volcanic and structural controls of mineralized rocks (Drewes and others, in press). Range-wide geologic-map coverage has also been completed, essentially by two generations of workers (Sabins, 1957a; Cooper, 1960; Erickson, 1968; Drewes, 1984, 1985, 1986; and Erickson and Drewes, 1984a and 1984b). Regional maps and reports bearing on the study area are also available (Gilluly, 1956; Drewes, 1980, 1981; and Drewes and others, 1985). A summary description of some mines is given by Richter and Lawrence (1983) and by others they cite. Several of the above reports provide citations to the literature of nearby ranges and mining camps that are not specifically referred to herein.

The geochemical evaluation was based mainly on stream-sediment samples, supplemented by chip samples taken from mine and prospect dumps and a few unworked outcrops. The stream-sediment samples were first pan concentrated, the heavy fraction was examined microscopically, and then the nonmagnetic fraction was analyzed spectrographically for 31 elements, as described in detail by J. R. Hassemer, D. E. Detra, and Harald Drewes (unpub. data). Results were of greater qualitative than quantitative value, but they permit comparisons between areas represented by individual sites and thus indicate normal versus anomalous areas. The chip samples were taken of mineralized rock to determine which metals not readily visible among the common minerals might be present. These samples were composited, pulverized, and analyzed spectrographically. Results again were of greater qualitative than quantitative value. Accordingly, the obtained values were generalized, generally to orders of magnitude of metal concentration, and attention was focused on such ore-deposit-indicator metals as silver, molybdenum, and bismuth.

The geophysical study was based on interpretations of a previously prepared aeromagnetic map (U.S. Geological Survey, 1980) and a complete Bouguer gravity map. The complete Bouguer gravity map consists of a compilation of data from Wynn (1981) plus 67 new stations (Abrams and others, 1985). The aeromagnetic data and Wynn's gravity data were previously interpreted in a regional study (Klein, 1985) and a range-wide study by Klein (*in* Drewes and others, in press).

Acknowledgments.—The geologic study benefited from a field visit by D. H. Richter, P. W. Lipman, and D. A. Sawyer, all of the USGS. Several mining companies also contributed some of their knowledge of the area. Each of the separate studies also benefited from frequent and, at times, searching collegial interaction.

APPRAISAL OF IDENTIFIED RESOURCES

By J. E. Zelten
U.S. Bureau of Mines

Lode and placer mining and prospecting have been carried out in the Dos Cabezas Mountains since the late 1800's, but there has been no mineral production recorded from within the study area. At least 580,000 short tons of high-purity gold- and silver-bearing quartz resource is present in a vein capping Rough Mountain, in the northwestern part of the study area (see resource/reserve classification chart on p. IV of this report). This quartz could be mined by surface methods and has resource value as silica smelter flux.

Mining and Mineral-Exploration History

Records of mineral, oil, and gas exploration activity and of mineral production in the study area and its surroundings provide useful insight on the mineral deposits of the study area. With the benefit of these data, examinations were made of sites of mineral occurrence within the study area. The field examinations were augmented by analyses designed to obtain quantitative data, in particular detailed analyses of key metals at sites where statistically significant sampling could be done. Gold, silver, copper, lead, and zinc were mined from lode and placer deposits since the late 1800's in the Teviston (or Tevis) mining district on the northeast flank of the Dos Cabezas Mountains and in the Dos Cabezas district on the southwest flank. Most mining in the Dos Cabezas district was done before 1970.

During 1973–75, U.S. Borax and Chemical Corp. explored an area between Dos Cabezas Peaks, Cooper Peak, the Mascot mine, and the Elma mine (fig. 2) for the possibility of a deeply buried porphyry copper deposit. Widely spaced drill sites occur 0.5–1.5 mi west of the study area and south of the Elma mine. The favorable signs that led to this drilling program were (1) surface exposure of copper-bearing massive sulfides, alteration, and mineral zoning, (2) the presence of breccia pipes, of specific types of porphyritic rock, and of andesitic volcanic rocks, and (3) the proximity to regional structures. Results of drilling in 1975 were not encouraging and the investigation was terminated (Michael Rauschkolb, U.S. Borax and Chemical Corp., Tucson, Ariz., oral and written communs., 1985).

The most recent mining activity is that of Phelps Dodge Corp., which has reopened the Gold Prince mine, on patented claims, about 1 mi south of the study area. As of May 1985, they were mining high-purity (80 percent or greater silica) vein quartz for use as smelter flux in their Douglas, Ariz., copper smelter. Gold in unreported quantities also is being recovered from this quartz vein (Michael Pawlowski, geologist, Phelps Dodge Corp., oral commun., 1984).

In May 1985, some of the western part of the study area was covered by unpatented mining claims, and several blocks of patented mining claims were along and within 1 mi of the western boundary (fig. 3). Oil and gas leases cover the eastern part of the study area (fig. 3). There is no record of oil or gas exploration or production in or near the study area.

Appraisal of Examined Sites

A high-purity quartz vein containing minor amounts of gold and silver is the only identified mineral resource

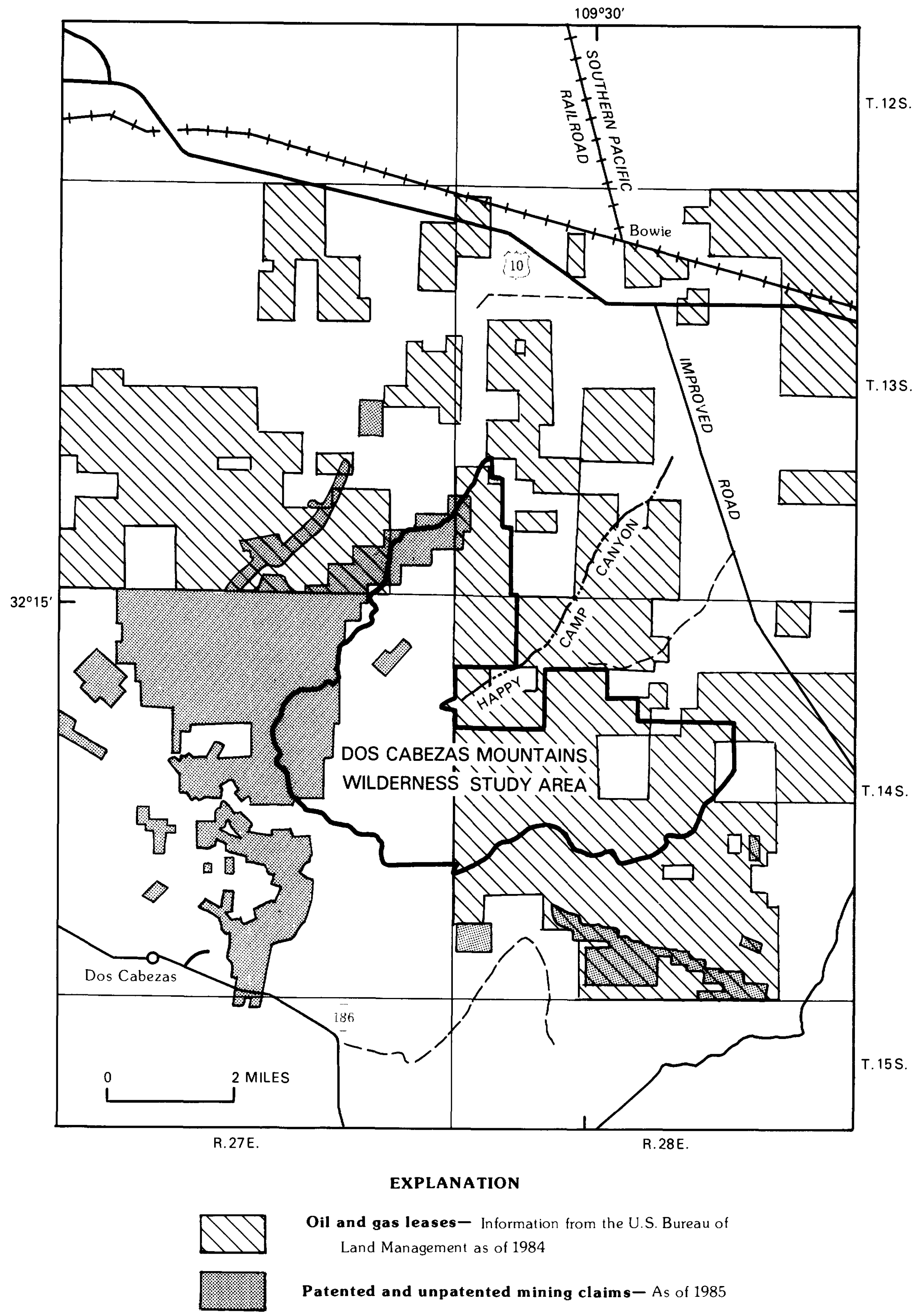


Figure 3. Distribution of oil and gas leases and mining claims in and near the Dos Cabezas Mountains Wilderness Study Area, Cochise County, Arizona.

in the Dos Cabezas Mountains Wilderness Study Area. This vein, on Rough Mountain in the northwestern part of the study area, has sufficient continuity and exposure to merit calculation of resources. Other quartz veins associated with the main vein, and the quartz veins south of Rough Mountain, are neither continuous nor exposed enough to warrant determination of resources. Rocks present in the study area could be used for construction purposes.

Quartz Veins in Rough Mountain

A flat-lying to gently dipping quartz vein in metarhyolite caps the southern part of Rough Mountain. Three associated steeply dipping feeder veins are exposed on the northern and southern slopes of the mountain.

The flat-lying vein forms an outcropping ledge that can be traced for at least 0.5 mi along the southwest side of the mountain. The vein averages about 10 ft in thickness and is covered at the summit by less than 20 ft of rock and detritus, a thickness permitting surface mining. This vein is estimated to contain at least 580,000 short tons of high-purity quartz. Three samples taken in a 70-ft-long adit driven into the east end of the vein contained azurite, malachite, pyrite, hematite staining, and chalcopyrite. Seven outcrop samples also were taken from along the main quartz vein. All 10 of these samples contained silver, ranging from 0.02 to 5.4 oz (ounces) per short ton, and trace amounts of gold. Silica content ranged from 74.8 to 100 percent.

Three smaller quartz veins believed to be feeders to the main flat-lying vein also were noted on Rough Mountain. All three dip steeply and so are not as readily mineable as the main vein. One of these feeder veins lies north of the main vein, is 4–6 ft thick, strikes N. 10° E., dips nearly vertically, and can be traced intermittently for a distance of about 600 ft from the main vein. Pyrite, limonite, hematite staining, and manganese oxide occur in two small prospects on the vein.

Another quartz feeder vein is intermittently exposed for a distance of about 1,500 ft on the southern slope of Rough Mountain. This vein is as much as 10 ft thick, strikes N. 10° E., and dips 54° SE. Small amounts of pyrite, chalcopyrite, malachite, galena, pyrophyllite, and hematite staining are present in the quartz.

The third quartz feeder vein is also present on the south side of Rough Mountain. This vein is 10 ft thick, strikes N. 10° E., dips vertically, and is exposed for a distance of about 100 ft. Pyrite, chalcopyrite, and galena are present in the quartz vein.

Samples of the three quartz feeder veins and adjacent country rock contained small amounts of gold and silver. Six of the 10 samples contained from 0.003 oz to 2.2 oz silver per short ton; five samples contained trace amounts of gold. Silica content of the five quartz samples ranged from 56.7 to 100 percent and averaged 85.8 percent (Zelten, 1986).

Quartz Veins in Other Areas

Other quartz veins were examined that may be genetically related to the veins on Rough Mountain but are far enough beneath the capping vein and its feeders so that their physical continuity is uncertain.

One such quartz vein of high purity occurs in brecciated rhyolite south of Rough Mountain, about 0.5 mi inside the western boundary of the study area. It is 2 ft thick, strikes N. 40° W., dips 30° SW., and is largely covered. Malachite, azurite, bornite, pyrite, chalcopyrite, galena, epidote, and hematite were present on the dump of a small opencut. Samples of the vein and of the rhyolite at the cut contained as much as 8.0 oz of silver per short ton, as much as 3 percent copper, as much as 6.2 percent lead, and trace amounts of gold.

Across the creek from this opencut is a collapsed adit, where a 7-in.-thick quartz vein is exposed in brecciated rhyolite in an opencut below the collapsed adit. The vein strikes N. 50° W. and dips 42° SW. Quartz-vein and country-rock samples contained trace amounts of gold and from 0.009 to 0.03 oz silver per short ton. Silica content of the quartz vein was 80.2 percent.

Two other quartz veins are south of Rough Mountain, well beneath the cap vein. They strike northeast to northwest, dip steeply to the west, are 3–10 ft thick, and are largely covered by surficial deposits. They are not exposed for more than a few tens of feet on the surface or in prospects. They contain a little pyrite and hematite staining, along with trace amounts of chalcopyrite, galena, malachite, pyrophyllite, and manganese oxide staining. Six samples from the veins contained silver, from 0.006 to 2.1 oz per short ton; five of them also had trace amounts of gold and one had 1 percent lead. Their silica content ranged from 54.3 to 97.1 percent (Zelten, 1986). The quartz veins could not be mined by surface methods and only limited exposures are present.

Because most quartz veins in the study area are of high purity and contain minor amounts of precious and base metals, the quartz could be used for smelter flux and some of the silver and gold could be recovered as byproducts at a smelter. Because the United States copper industry is currently (1986) depressed, the demand for smelter flux is low and is being satisfied by utilizing quartz veins with higher precious-metal content. The vein being mined by Phelps Dodge Corp. south of the study area is such an example. Quartz from the study area will not be in demand for use as silica flux unless economic conditions for copper mining in the United States improve.

Industrial Rocks

The Proterozoic igneous and metamorphic rocks and the Tertiary and Cretaceous sedimentary and igneous rocks that underlie the study area can be used for construction purposes. However, these rocks have no unique characteristics to make them more desirable than rocks elsewhere, closer to population centers and markets. (See further comments below.)

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By Harald Drewes, G. A. Abrams, and J. R. Hassemer
U.S. Geological Survey

Geology

In this section, we discuss the geologic setting, key formations and structures, and geologic history of the Dos Cabezas Mountains Wilderness Study Area, all of which contributed to our assessment of the mineral resource potential of the study area.

Through geologic time four major settings are recorded for the area, and each has left an important mark on the local geologic record. During the most ancient or Proterozoic time the area lay along the severely fractured southwest margin of the North American craton. The large amounts of cumulative movement along this ancient fault system give the region a subtle northwest-trending grain. Many younger igneous rocks and mineralized rocks were emplaced along or near these faults.

During Paleozoic time the region was alternately emergent and submergent, and thereby was covered by a sequence of marine sedimentary rocks having many disconformities. Deposition of sedimentary rocks continued during Cretaceous time, but the breaks in the continuity of deposition were larger and many nonmarine rocks were deposited. This geologic setting provided some of the favorable host rocks for mineral deposits of southeast Arizona and southwest New Mexico.

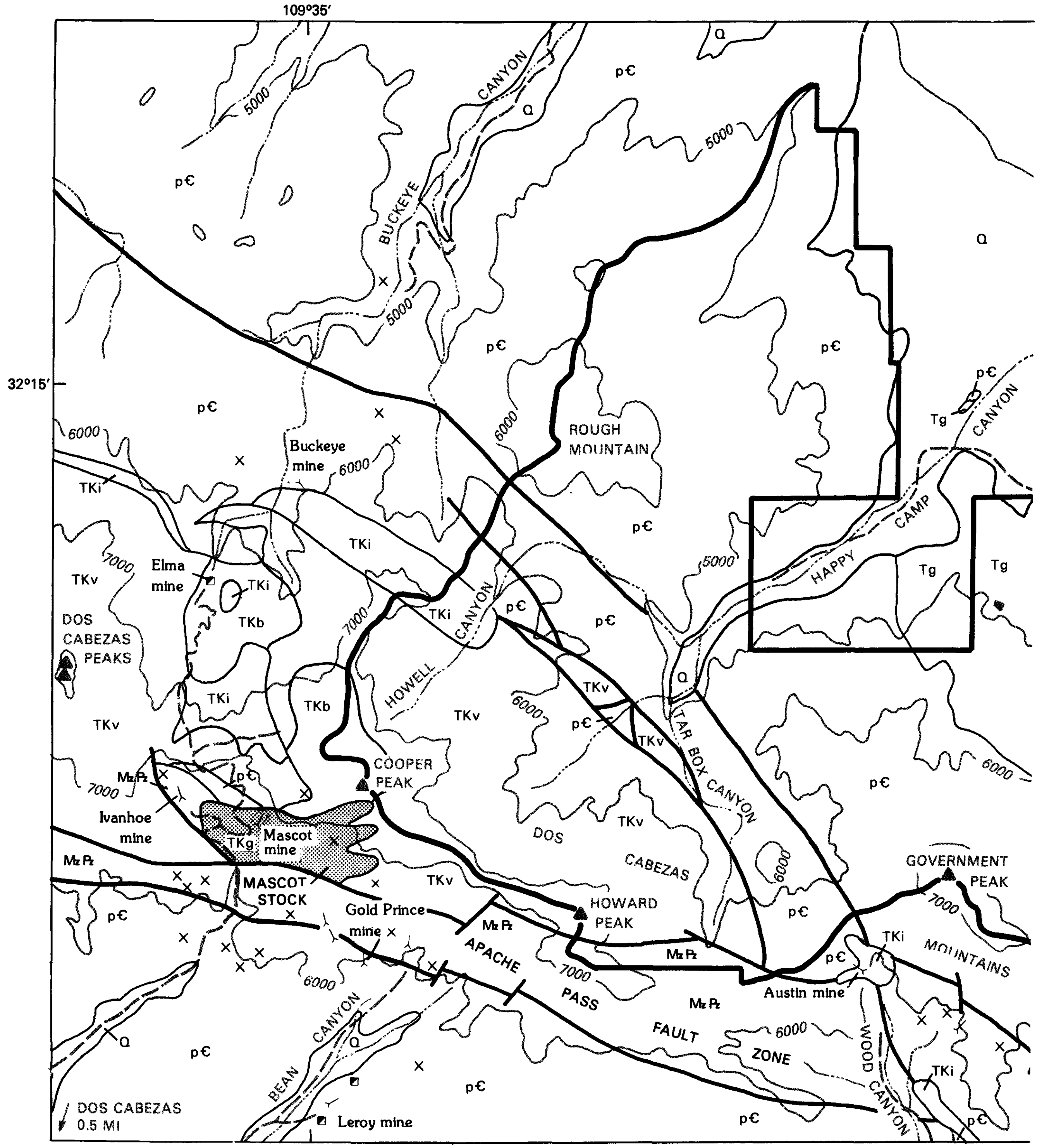
The study area next was involved in the development of the frontal edge of a belt of compressively deformed, massively intruded, and locally mineralized rocks known as the Cordilleran (or Laramide) orogenic belt, which extends virtually all along the west side of North America. The strongly deformed part of the belt at the present level of erosion probably reached within 4 mi of the study area (Drewes, 1980). Although the extent and style of this deformation have been variously interpreted, it is commonly accepted that most mineral deposits of the region were emplaced, in close association with magmas, toward the end of this orogenic period, during latest Cretaceous and Paleocene time.

Finally, the study area lies in a widespread terrane known as the Basin and Range province that was subjected to tension beginning in mid-Tertiary (Oligocene) time. Through this tensional setting, the region was broken up, mainly along north-trending normal faults, between which raised and dropped blocks alternated to make the linear ranges and valleys. Additional magmas moved upward in the crust to form stocks and abundant volcanic fields, and locally associated hydrothermal fluids formed mineral deposits. This setting was important to the study area mainly because the uplifted Dos Cabezas block was eroded to a structural level believed to be favorable for exposure of certain kinds of mineral deposits that may have been emplaced during the time of the third major setting.

Each major setting, then, contributed to the local geology an important feature considered favorable to the kinds of mineral deposits known in the region. Deeply rooted ancient faults provided the channel for fluid migration that led to the emplacement of a major volcano-plutonic system of late Cordilleran (Laramide) age in or upon mixed carbonate and clastic rocks of Paleozoic–Mesozoic age. These sedimentary rocks are optimally exposed in and near the study area by erosion that followed Basin and Range faulting that began in the Oligocene.

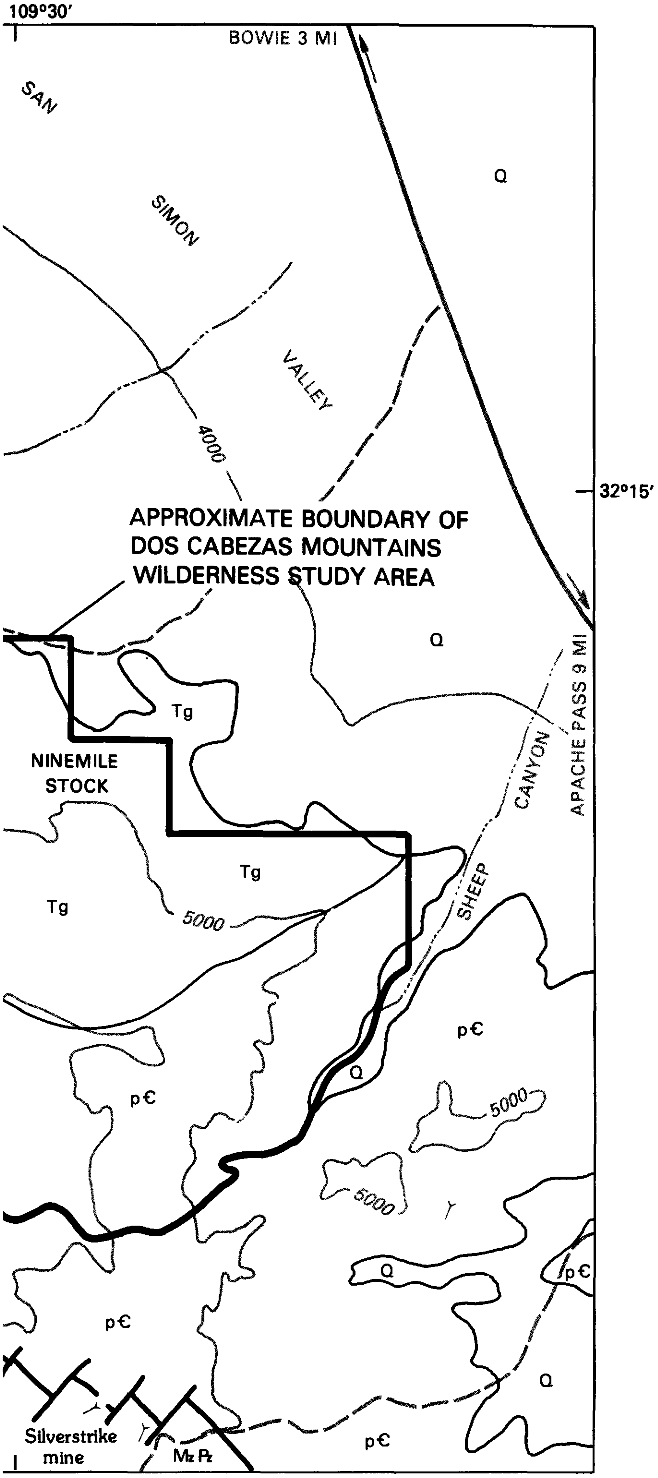
The study area is underlain by a variety of sedimentary, igneous, and metamorphic rocks that provide only a fragmentary record of geologic events between Proterozoic and Holocene times (fig. 4 and pl. 1). A suite of metamorphic and igneous (collectively, crystalline) rocks forms the basement terrane. Paleozoic and Mesozoic sedimentary rocks and some volcanic rocks overlie the basement rocks but are extensively eroded and may be covered. A pile of volcanic rocks of Late Cretaceous and Paleocene age caps the older rocks in much of the study area. Mid-Tertiary intrusive rocks underlie the eastern part of the area and occur in other widely scattered localities. Quaternary (including Holocene) gravel deposits occur in the major valleys and along the mountain front. Only those key formations bearing on our assessment are described briefly in this report. These key formations and most of the other formations of the study area are described more fully by Sabins (1957b) and Drewes (1985 and 1986).

Several formations of the study area have physical or chemical properties that are particularly favorable to the possible accumulation of mineral matter. One such key rock type is a sedimentary assemblage of interbedded carbonate and clastic units. In the study area, there are three of these mixed-lithology sedimentary assemblages. They are: (1) the upper part of the Upper Cambrian Coronado Sandstone (Bolsa Quartzite of some reports), part of the Lower Ordovician El Paso Formation, and the



Base from U.S. Geological Survey, 1:24,000,
Bowie, 1949, Cochise Head, 1950,
Dos Cabezas and Luzena, 1957

Figure 4 (above and facing page). Generalized geologic map of the Dos Cabezas Mountains Wilderness Study Area, Cochise County, Arizona. Topographic contour interval 1,000 feet.



Geology by Harald Drewes, 1979 and 1984, assisted by R. P Langford, R. C. Davies, and S. D. Birmingham, supplemented in Luzena quadrangle by Erickson and Drewes (1984b)

EXPLANATION

CORRELATION OF MAP UNITS

Q		QUATERNARY
Tg		TERTIARY
TKg	TKi	TERTIARY OR CRETACEOUS
TKb	TKv	
MzPz		PALEOZOIC
pЄ		PRECAMBRIAN

DESCRIPTION OF MAP UNITS

Q **Alluvium (Quaternary)**

Tg **Granite (Tertiary)**

TKg **Granite (Tertiary or Cretaceous)**—Stock

TKi **Intrusive rocks (Tertiary or Cretaceous)**—Aphanitic or porphyritic rhyolite plugs

TKb **Intrusive breccia (Tertiary or Cretaceous)**

TKv **Volcanic rocks (Tertiary or Cretaceous)**—Andesitic to rhyolitic breccia

MzPz **Sedimentary rocks (Mesozoic and Paleozoic)**

pЄ **Crystalline rocks (Precambrian; Proterozoic)**—Metasedimentary and metaigneous rocks, granite, and gneissic granite

Contact—Queried where doubtful

Fault

Mines and prospects

× **Prospect**

≻— **Adit**

Inclined shaft

0 2 MILES

Upper Devonian Portal Formation of Sabins (1957b), (2) the upper part of the Lower Permian and Pennsylvanian Horquilla Limestone, and (3) the middle part of the Lower Cretaceous Bisbee Group.

The upper part of the Coronado Sandstone comprises mainly siltstone, shale, and sandstone, but also has calcareous sandstone and thin limestone and dolomite beds. Most beds are thin and pale brown or yellowish brown; some are slightly greenish gray because of glauconite. The El Paso Formation is mainly dolomitic limestone and dolomite, but has some interbedded sandstone and siltstone and many carbonate beds with quartz grains. Light-gray to pale-brown colors and thin to moderately thick beds are common, and chert is sparse. The Portal consists of alternating thin units of light-gray limestone and dark-gray shale. Mixed reddish-gray siltstone and light-gray, slightly cherty, medium-bedded, micritic and bioclastic limestone make up the upper part of the Horquilla Limestone. The middle of the Bisbee Group has alternating beds of light-gray bioclastic limestone, siltstone, shale, sandstone, and some limestone-pebble conglomerate.

Locally, the Coronado, El Paso, and Portal Formations sequence is 700-1,500 ft thick, depending mainly on the amount of shearing and metamorphism along the Apache Pass fault zone. Each of the other two key sedimentary assemblages is several hundred feet thick, and grades upward or downward into less mixed rock.

These key sedimentary rocks are mineralized in some nearby mining camps, where the Coronado, El Paso, and Portal Formations sequence (or correlatives to the west, the Abrigo and Martin Formations) is the most attractive, possibly because of its lower stratigraphic position, which makes it the first of the three to be encountered by rising hydrothermal fluids. These rocks change readily to skarn minerals and may contain replacement stockwork and pipe deposits of copper, lead, zinc, molybdenum, gold, and silver. Such rocks are mineralized at the Ivanhoe mine (fig. 4), at Mineral Camp just west of Dos Cabezas Peaks (fig. 1), and at Johnson Camp, Courtland–Gleason, Tombstone, and Bisbee (not shown on maps of this report).

These key sedimentary rocks (included in MzPz, fig. 4) crop out along the Apache Pass fault zone (pl. 1) but do so in the study area only in a small area near Howard Peak. Within the study area, these rocks are upended or are shown to dip steeply southwest and away from the study area. Despite these attitudes, there is evidence to suggest that Paleozoic rocks may underlie some of the volcanic pile of the study area; hence, these buried masses of key rocks could be possible sites of mineral enrichment.

Andesitic or dacitic breccia of the Late Cretaceous or Paleocene volcanic sequence is another key rock type. Much of the volcanic pile that overlies chiefly the basement rocks of the central part of the Dos Cabezas Mountains is made up of andesitic or dacitic breccia. This breccia probably includes deposits formed both on the outer and inner slopes of a major volcanic composite cone, as well as flow breccia, nearly obscured ash-flow breccia, and some breccia pipes that may mark the sites of adventive cones (Drewes and others, in press). Inclusions of large blocks of Paleozoic and Mesozoic rocks are found in the breccia northwest of Dos Cabezas Peaks and near the Ivanhoe mine (Cooper, 1960; Drewes, 1985, 1986). Although some of these half-mile-long inclusions may have slid in from, or been faulted in from the Apache Pass fault zone side of the volcanic pile, they could also include blocks rafted up from the floor of the pile. Slide blocks of this size are usually much more shattered than these blocks are, so a rafting origin is favored.

The andesitic or dacitic breccia is readily fractured and is chemically favorable for some kinds of alteration and mineralization. The breccia at the Elma mine and at Cooper Peak, west of the study area (fig. 4), is believed to be a breccia pipe. Most clasts are mixed andesitic and rhyolitic types of the usual 1–4 in. size. In the Elma mine a large mineralized limestone mass is reported (Richter and Lawrence, 1983), presumably within the breccia but conceivably at its base. Some of the breccia is mineralized, and mineralized andesitic rocks of about this age also occur in the Lordsburg mining district (Thorman and Drewes, 1978) and at the Twin Buttes mine of the Sierrita district (Cooper, 1973), about 50 mi west of the study area. At Cooper Peak the core of the inferred breccia pipe has not only mixed volcanic clasts but 1- to 10-ft-long blocks of Paleozoic rocks. These likely were moved up the pipe and thus must have been torn loose from a blind subvolcanic-pile mass of Paleozoic rock. Several such masses have been shown schematically in the structure section of Drewes and others (in press). Inasmuch as this key rock type is mineralized, the inferred presence of blind masses of Paleozoic rock beneath part of the wilderness study area offers a possible site of mineral deposits. Andesitic rock in breccia pipes may be particularly favorable because their steep orientation offers channels for rising hydrothermal fluids, as well as their being suitable host rocks.

In several mining districts of the region, rhyolitic or latitic porphyry, commonly forming small irregular-shaped plugs or stocks, are a host rock for mineralization. Rocks near the intrusions may be even more mineralized where fluid movement was along the contacts of such plugs or stocks. Indeed, so common is this association that in the Sierrita and the nearby Helvetia mining districts the rock is referred to as the "ore porphyry." In the Dos Cabezas Mountains 0.5–1.0 mi northwest of Cooper Peak (fig. 4; Drewes, 1985), a biotite porphyry forms an irregular-shaped plug. Aside from its finer overall grain size, the rock seems to have petrographic similarities to the granitic rock of the nearby Mascot stock of Paleocene or Late Cretaceous age (fig. 4). The porphyry, however, is nearly as strongly altered as is the breccia it intrudes. The rock may be a late phase of the intrusive magma, and geophysical data suggest that the plug may extend into the study area near Cooper Peak according to Klein (*in* Drewes and others, in press).

Structural features key to the assessment of the mineral resource potential of the Dos Cabezas Mountains Wilderness Study Area are a major fault zone, and a variety of minor faults, steep stock walls, and breccia pipes, and an unconformity, which abut or cut across the major fault zone (pl. 1). The major fault zone may have guided the upward movement of ore fluids at deeper levels in the crust, and the other structures may have helped disperse these fluids at shallower levels. Many mining camps of the region are in or near such major faults (Drewes, 1981, fig. 2); their mineral deposits are locally controlled by minor structures.

The Apache Pass fault zone is the major structural feature in the study area, barely skirting its southwest side. It extends many miles to the northwest and tens of miles to the southeast, across the Chiricahua Mountains beyond Apache Pass (Sabins, 1957a; Cooper, 1960; Drewes, 1982, 1984, 1985, 1986). It is typically made up of a pair of bounding faults and some anastomosing faults between them. Most of the faults dip steeply or vertically. Near the study area the fault zone is half a mile wide; it narrows to the northwest and flares to the southeast.

Movement on the fault zone was recurrent, varied indirection and amount from time to time, and cumulatively was large (Drewes, 1981, 1982). Earliest movement was Precambrian, probably left lateral, and probably totalled many miles. During the Late Cretaceous, when the region to the south and west was being compressed, a segment of the fault zone may have been reactivated as a reverse fault that flattened downdip to the southwest and, thus, may have parted from the master fault (Drewes and others, in press). A segment of the fault zone near the study area was reactivated again during Paleocene(?) time and brought the volcanic pile down to the northeast, possibly emplacing a prong of Paleozoic and other rocks into the andesitic or dacitic breccia at the Ivanhoe mine through a left-lateral component of movement. The collapse of the central part of the volcanic sequence may have been part of this reactivation. Elsewhere along the Apache Pass fault zone still younger movement is recorded (Drewes, 1982).

The features of particular interest about the fault zone are its ancient origin, penetration deep into the basement terrane, and recurrent movement. These features are common to a system of northwest-trending faults that extend from West Texas to southern Nevada, although in many instances only a young phase of movement may be recorded. Magmas and hydrothermal fluids have moved along certain more shattered segments of these faults, and the Apache Pass fault zone has been no exception. In and near the study area along the andesitic-dacitic volcanic pile, the Mascot stock, many small plugs and dikes, and the main mineral occurrences of the Dos Cabezas mining district are all along or near the master fault zone (Drewes, 1986, fig. 1).

The assortment of minor structural features that abut or cut across the Apache Pass fault zone includes the basal unconformity of the volcanic sequence and the main breccia mass itself, which probably rise gradually from the fault zone to the northeast. The potential for fluid movement along this horizon and this permeable rock unit is indicated by the widespread propylitic alteration of these rocks. That some of these fluids carried base metals (copper, lead, zinc, and so forth) and silver is shown by the distribution of prospects along and near the base of the breccia mass (pl. 1).

The accumulation and upward dispersion of the fluids probably was facilitated where they reached steep-walled intrusive rocks or breccia pipes. Splay faults, such as those trending N. 45° W. through the center of the study area, also guided migrating fluids, as shown by several mineralized quartz veins in the splay fault zone in the Howell Canyon area (pl. 1). Cross faults, such as those offsetting the Apache Pass fault zone south and west of Howard Peak, likewise have influenced the movement of hydrothermal fluids, as indicated by the cluster of mines and prospects in that area. Possibly these cross faults extend farther into the adjacent terranes than the limited field evidence indicates, and thereby would further facilitate dispersion of the ore fluids to the area north and east of Howard Peak.

Finally, particular events of the geologic development of the study area are believed to be favorable to the possible accumulation of mineral deposits at accessible localities. A review of the regional setting illustrated that in and near the study area are (1) favorable associations of attractive potential host rocks, (2) a master fault up which magmas and ore fluids are known to have moved, and (3) diverse structures to aid in fluid dispersion. Here we (USBM and USGS authors, alike) point out that these favorable factors were developed in a suitable sequence, and that the optimum structural levels are exposed or within reasonable reach in the subsurface.

Most mineral deposits of the region were emplaced during the late phaseof the Cordilleran orogeny (Laramide). A few are older, such as the Jurassic copper deposit at Bisbee, or younger, such as the mid-Tertiary silver deposit at Pearce, respectively about 55 and 30 mi to the southwest of the study area. In the vicinity of the study area most of the known deposits are associated with igneous rocks of Late Cretaceous or Paleocene age. Only a little mineralization is associated with the mid-Tertiary rhyolite dikes of other parts of the Dos Cabezas Mountains (Drewes, 1985, 1986; Drewes and others, in press). Few such dikes occur within the study area, and all are small and seem barren, as is the Ninemile stock (fig. 3).

The favorable host rocks were in place and were severely eroded primarily during the Mesozoic Era; we suggest that they may underlie parts of the study area as blind masses of large inclusions. A master fault of the sort favored by rising magmas and ore fluids in other mining districts was present before mineralization. There also is evidence that such magmas and ore fluids were present during the Laramide event. Voluminous volcanic rocks were emplaced, several stocks and many dikes were intruded as high in the rocks as these volcanic rocks, and rock alteration attests to the availability of certain hydrothermal fluids. Direct and indirect signs of mineralization are numerous; a substantial production record is known from several nearby mines, and prospects occur at several places within the study area. Plate 1 shows more than a dozen small shafts, adits, and prospects, mainly in the area of moderate mineral resource potential.

One final condition of the geologic development is deemed favorable: the key rocks and structural features are exposed at a suitable level for the preservation and possible access to potential sites of mineralization. During post-Laramide time, the area was block faulted and the Dos Cabezas block was raised relative to the adjacent intermontane blocks. In consequence, any capping Tertiary volcanic rocks, such as those preserved in the nearby Fischer Hills, that may have been extruded near the mid-Tertiary igneous center of the Ninemile stock were removed. Additionally, the upper part of the Late Cretaceous–Paleocene volcanic sequence was eroded, to expose the root area of the volcanic structures and the top of the plutonic ones. Such a structural level is commonly optimal for the emplacement and preservation of hydrothermal ore deposits. Moreover, this structural level is just above the top of the crystalline basement, where again, rising fluids may undergo a rapid pressure loss.

Geochemistry

A reconnaissance geochemical survey was undertaken to help determine the kind and extent of mineralized ground that may be present in the Dos Cabezas Mountains Wilderness Study Area. Results of this survey, summarized in this section, indicate that the entire study area is geochemically anomalous. Although signs of mineralized rocks are widespread, the available data do not support the presence everywhere of actual mineral deposits. Rather, in all parts of the study area some elements of interest in mineral-deposit assessment occur in abnormally high concentrations.

Part of the geochemical survey was made by sampling stream sediments from the sites shown on figures 5 and 6, using standard geochemical exploration techniques. These entail the collection of a pair of samples at each site, the one a composite sample of stream sand and silt that was pan concentrated and further separated by weight and magnetic properties, and the other a composite sample of stream silt and clay that was sieved (minus 80 mesh) to retain the fine fraction. After a visual inspection under a microscope, all samples were analyzed semiquantitatively for 31 elements by the spectrographic method described by Grimes and Marranzino (1968). Uranium analyses of the sieved samples were made by a neutron activation method described by Millard and Keaton (1982). Selected data from these reports are used in this section of our report.

Some rock-chip samples of mineralized material were taken for the range-wide study of Drewes and others (in press). In addition to spectrographic analyses, these samples were also tested for arsenic, gold, bismuth, copper, antimony, and zinc by the atomic-absorption method described by Viets (1978) and Ward and others (1969). Data from the present study's chip samples of mineralized sites were augmented by a few additional analyses of rock float found in stream drainages (J. R. Hassemer, D. E. Detra, and Harald Drewes, unpub. data); those collection sites, however, are not shown on figures 5 and 6.

Other geochemical studies have also been made of the Dos Cabezas Mountains area and the adjacent terrane, and their results were considered in this study. Results of a regional geochemical reconnaissance of the Silver City $1° \times 2°$ quadrangle, which encompasses the Dos Cabezas Mountains, are presented by McDanal and others (1983) and are summarized by Watts and Hassemer (1986). Data on the metals content from a few drill holes in breccia pipes and from "soil" (colluvium) surveys of an area just northwest of the study area were made available for inspection only, by the U.S. Borax Corp., and thus are not shown here, but the information entered into our appraisal.

Microscopic check of all the samples before analysis provides some key observations on the minerals that probably produced the anomalous element concentrations. Minerals of the scheelite-powellite series (calcium tungstate—calcium molybdate) occur in most samples. Pyrite (iron sulfide) and limonite (hydrated iron oxide) derived from pyrite or other sulfides are also common. Epidote (hydrated calcium, iron, aluminum silicate), which is a common alteration mineral, occurs in most samples and is found as stringers and joint coatings of clasts from the upper tributaries of Happy Camp Canyon. Fluorite (calcium fluoride) also was found in a few samples and in some of these formed a large part of the nonmagnetic fraction. A few fluorite grains were violet, a fluorite variety typically showing radioactivity damage, as reported by Watts and Hassemer (1986). Some samples contained bismutite (bismuth carbonate) and thorite (thorium silicate); the visual identification of these minerals was verified by X-ray diffraction (S. J. Sutley, 1985, oral commun.).

Of the 31 elements analyzed for, 22 were found in anomalous concentrations at one or more sites each. These include antimony, arsenic, barium, beryllium, bismuth, cadmium, chromium, cobalt, copper, fluorine, gold, lead, manganese, molybdenum, nickel, niobium, silver, thorium, tin, tungsten, uranium, and zinc. Each of these is either an indicator of or a pathfinder to mineralized rock, and each may occur in association with one or more other significant elements. At each site at least four of these elements occurred in anomalous concentrations. Only seven elements (copper, lead, zinc, molybdenum, tungsten, bismuth, and silver) and fluorite are shown on figures 5 and 6; these give the most useful information as to the possible occurrence of mineral-deposit types. Because the study area is small, the determination of what is anomalous, as shown on figures 5 and 6, depends largely on comparison with thousands of samples from other studies throughout the region.

The distribution of copper in anomalous amounts is widespread in the study area (fig. 5), but generally is at a low level of enrichment in stream-sediment samples. Away from sites of known mineralization, anomalously abundant copper commonly occurs in the paramagnetic (slightly magnetic) fraction of the heavy-mineral concentrates, presumably in the limonitic material derived from sulfide minerals. In the Dos Cabezas Wilderness Study Area anomalous concentrations of copper occur near the much-faulted central part, suggesting a structural control of the copper mineralization.

Lead in anomalous amounts is nearly ubiquitous in the stream-sediment samples and the rock-chip samples (fig. 5). Lead in the heavy-mineral concentrates is most abundant in the upper reaches of Happy Camp Canyon and in some adjoining areas to the west and southwest in which there are mining camps.

Silver is also anomalous in quantity in much of the study area (fig. 5), and is closely associated with high levels of lead. Silver is most abundant in Howell Canyon and adjacent drainages outside the study area, in Tar Box and adjacent Wood Canyons, in a small drainage on the southeast flank of Rough Mountain known to have mineralized quartz veins, and in a drainage on the east side of Ninemile stock. The silver from the east side of the Ninemile stock probably is from the peripheral host rocks.

Zinc occurs in anomalous amounts in stream-sediment samples just outside the study area, rather than inside it (fig. 5). Anomalous amounts of zinc were found near mines and prospects where zinc minerals are exposed at the surface but not in areas of few or no mines. Zinc concentrations were moderately high in the "soil" or colluvium study by the U.S. Borax Corp., around the breccia pipes just northwest of the study area. Zinc is notably a mobile element, implying that it may have moved, through either primary or secondary processes, away from sources of mineralization. Consequently, zinc may only be of limited value in a geochemical search for concealed mineral deposits within the study area, although in a general way a zinc halo may flag a broad center of mineralization.

Bismuth (fig. 6), molybdenum (fig. 5), and tungsten (fig. 6) occur in high concentrations in drainages on the block northeast of the Cretaceous–Tertiary volcanic pile and the Apache Pass fault zone. Niobium and thorium also occur in high concentrations in this area, but as their distribution mirrors that of bismuth, molybdenum, and tungsten, they are not separately illustrated. The bismuth is probably from bismutite. Scheelite, molybdenum-rich scheelite, and powellite form several percent of the nonmagnetic heavy-mineral fraction of scattered samples and more than 10 percent of samples from tributaries of the lower reaches of Happy Camp Canyon. However, powellite and molybdenum-rich scheelite are scarce or absent from drainages around Cooper Peak and the Elma mine, where molybdenum is present in anomalous amounts; as sulfides are common in these areas, a molybdenite (molybdenum sulfide) may be expected but was not recognized in the panned-concentrate samples.

Fluorine, occurring in fluorite, the calcium fluoride mineral, is present in relatively few samples (fig. 6). Where it occurs, however, fluorite can be fairly abundant, accounting for as much as 70 percent of the nonmagmatic concentrate fraction.

Other elements occur in anomalous concentrations mostly just outside the study area. With two exceptions, in Howell Canyon and Sheep Canyon, gold was not found in the stream-sediment samples, but it is present in some of the rock-chip samples and is known to occur in many of the nearby mines (Richter and Lawrence, 1983). In the rock-chip samples gold is seen to occur chiefly with silver, copper, lead, and zinc. Beryllium occurs in weakly anomalous amounts southeast and northwest of the study area. Uranium is most abundant (40 ppm) in stream drainages on the north flank of Rough Mountain, just outside the study area. Barium, cadmium, cobalt, nickel, and tin are so sporadically present that they seem to offer little significance as indicator elements.

In conclusion, the reconnaissance geochemical study shows that many elements are present in abnormally great abundance. Some of these occur together in mineral assemblages found on mine and prospect dumps in and near the study area. These typically are sulfides, which seem centered around the northwest part of the study area. Others occur as molybdates, tungstates, carbonates, and silicates, typical of the northeastern part of the area. The native metal, gold, is apparently most common northwest of the study area.

These element and mineral assemblages may reflect various levels of exposure to a large complex mineralized system. In this system, the scheelite-powellite, bismuth, uranium, niobium, and thorium of the northeastern basement terrane may be a deep-level root zone. The sulfide assemblage (minerals containing copper, molybdenum, lead, zinc, and silver) of the volcanic pile is typical of mineralization at an intermediate level. The gold occur-

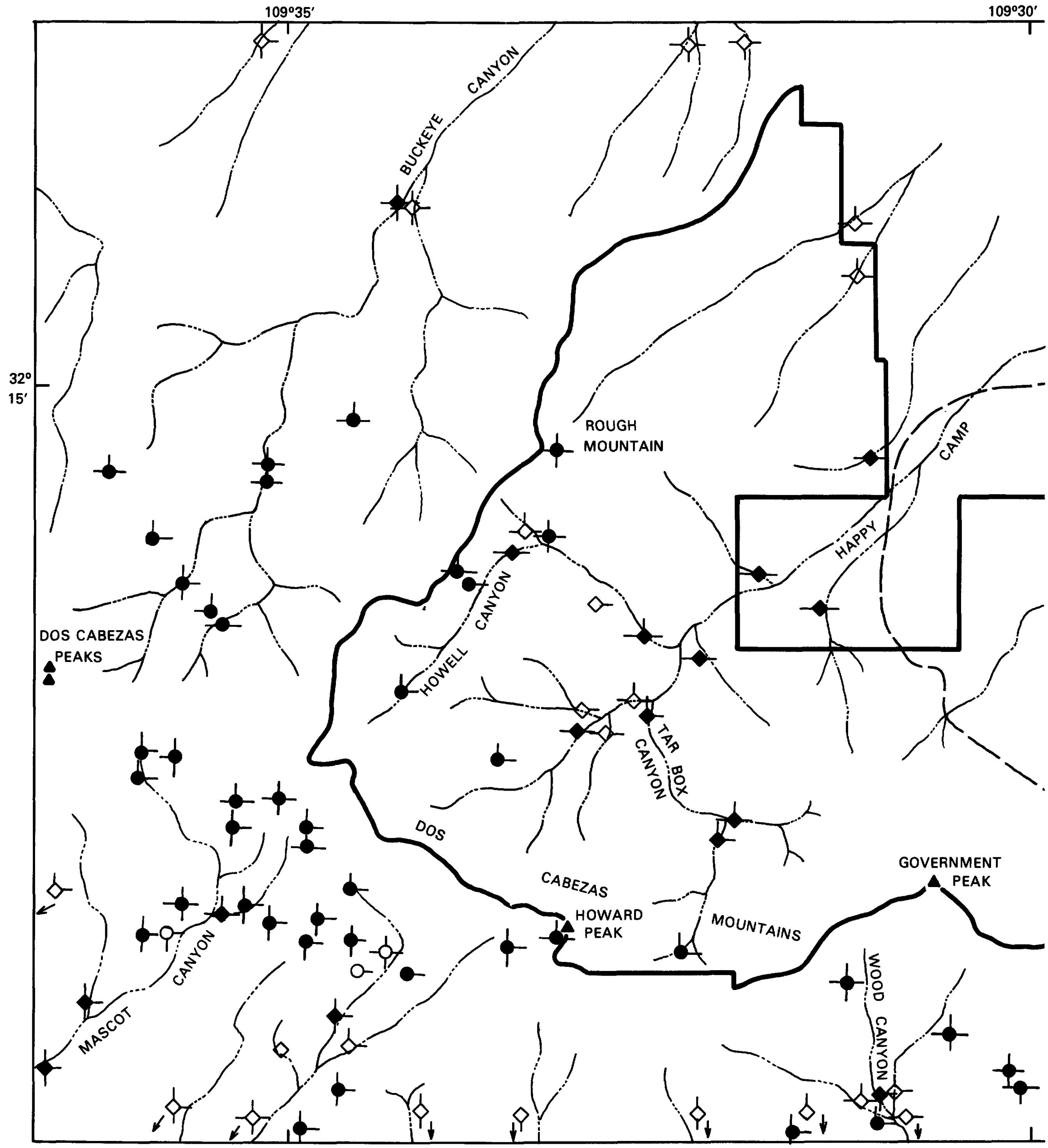
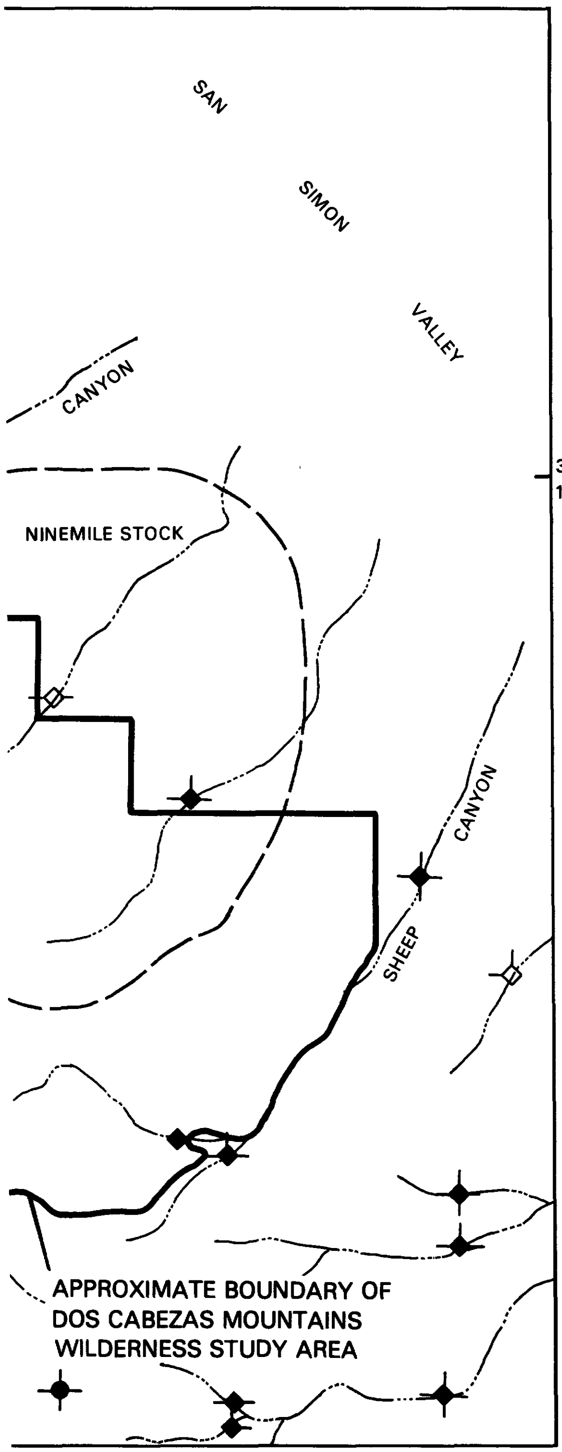


Figure 5 (above and facing page). Distribution and abundance of silver, copper, lead, zinc, and molybdenum in stream-sediment and rock-chip samples of the Dos Cabezas Mountains Wilderness Study Area, Cochise County, Arizona.

rences northwest of the study area may represent deposition at the highest levels present in this system. (See also the preceding discussion of the geology.)

In effect, then, the geochemical study indicates that the Dos Cabezas Mountains Wilderness Study Area has many signs favorable to a terrane having likely mineral deposits, but no signs that define what model might be appropriate at some particular site.



EXPLANATION

[≥, greater than or equal to; ppm, parts per million]

Stream-sediment sample locality and element concentration—Symbols are combined where a locality contained more than one element. Arrow indicates sample locality is outside map area

- **Silver, ≥ 1 ppm**
- **Copper, ≥ 150 ppm**
- **Lead, ≥ 150 ppm**
- **Zinc, ≥ 500 ppm**
- **Molybdenum, ≥ 10 ppm**

Rock-chip sample locality and element concentration—Symbols are combined where a locality contained more than one element

- **Silver, ≥ 0.5 ppm**
- **Copper, ≥ 70 ppm**
- **Lead, ≥ 50 ppm**
- **Zinc, ≥ 200 ppm**
- **Molybdenum, ≥ 5 ppm**
- **No anomalous concentration**

0 2 MILES

Geophysics

Gravity and aeromagnetic data were analyzed to complement geologic mapping by providing information on concealed rocks and structures, but no magnetic and gravity anomalies are considered to be directly related to possibly mineralized rock.

In this region of the United States the typical surface expression of an aeromagnetic anomaly is approximately half a mile south and west of its source due to the inclination and declination of the Earth's magnetic field.

The Apache Pass fault zone generally coincides with a magnetic low (fig. 7). This magnetic low is probably

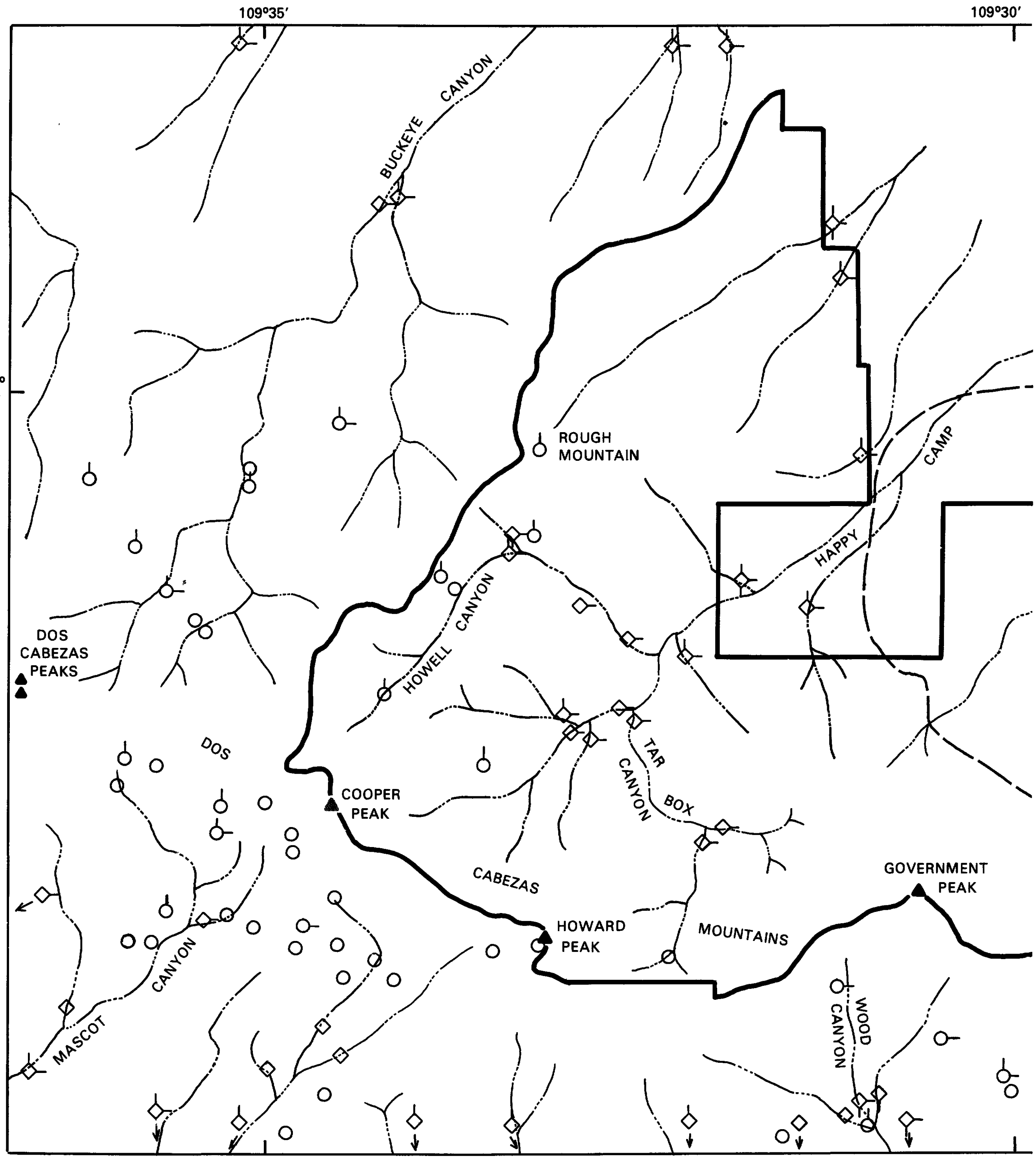
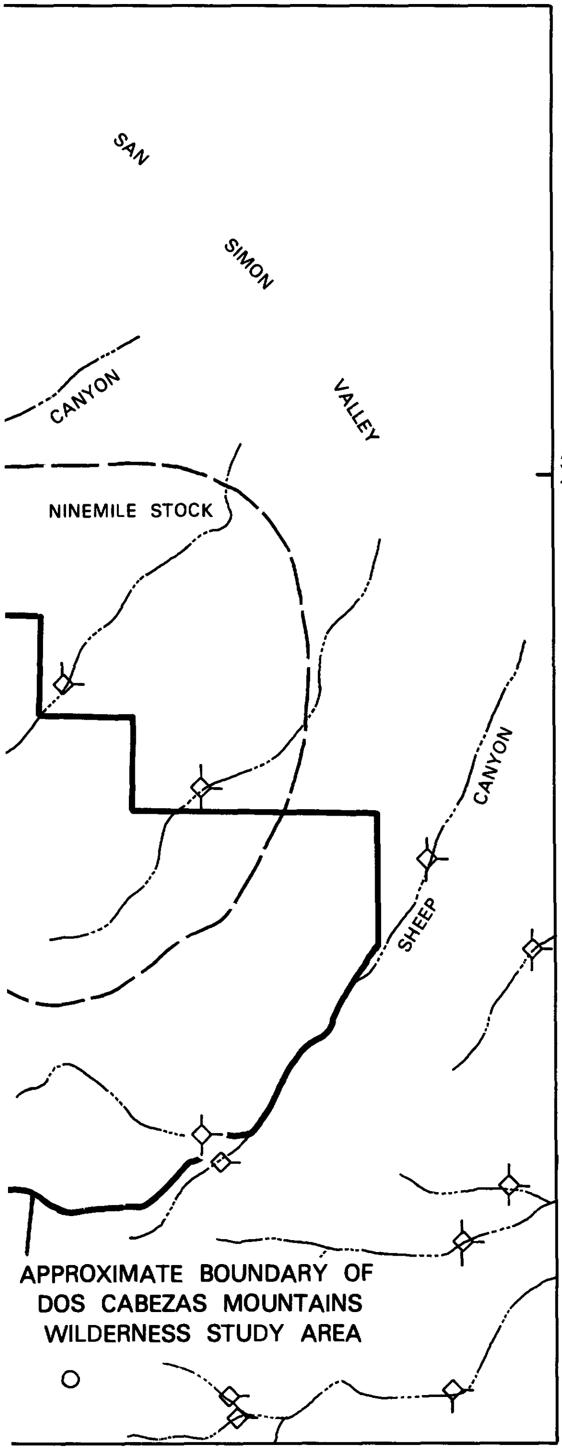


Figure 6 (above and facing page). Distribution and abundance of tungsten, bismuth, and fluorite in stream-sediment and rock-chip samples of the Dos Cabezas Mountains Wilderness Study Area, Cochise County, Arizona.

due to a narrow belt of Paleozoic and Mesozoic sedimentary rocks dipping southwest (Drewes, 1986). West of Howard Peak the magnetic low bends south of the Apache Pass fault zone. This abrupt offset of the low is probably a geophysical expression of the cross faults shown on plate 1. The magnetic high at the offset (fig. 7, site A) may represent a granitic stock concealed near Howard Peak. The surface occurrence of some small rhyolite intru-



EXPLANATION

[≥, greater than or equal to; ppm, parts per million]

Stream-sediment sample locality and element concentration—Symbols are combined where a locality contained more than one element. Arrow indicates sample locality is outside map area

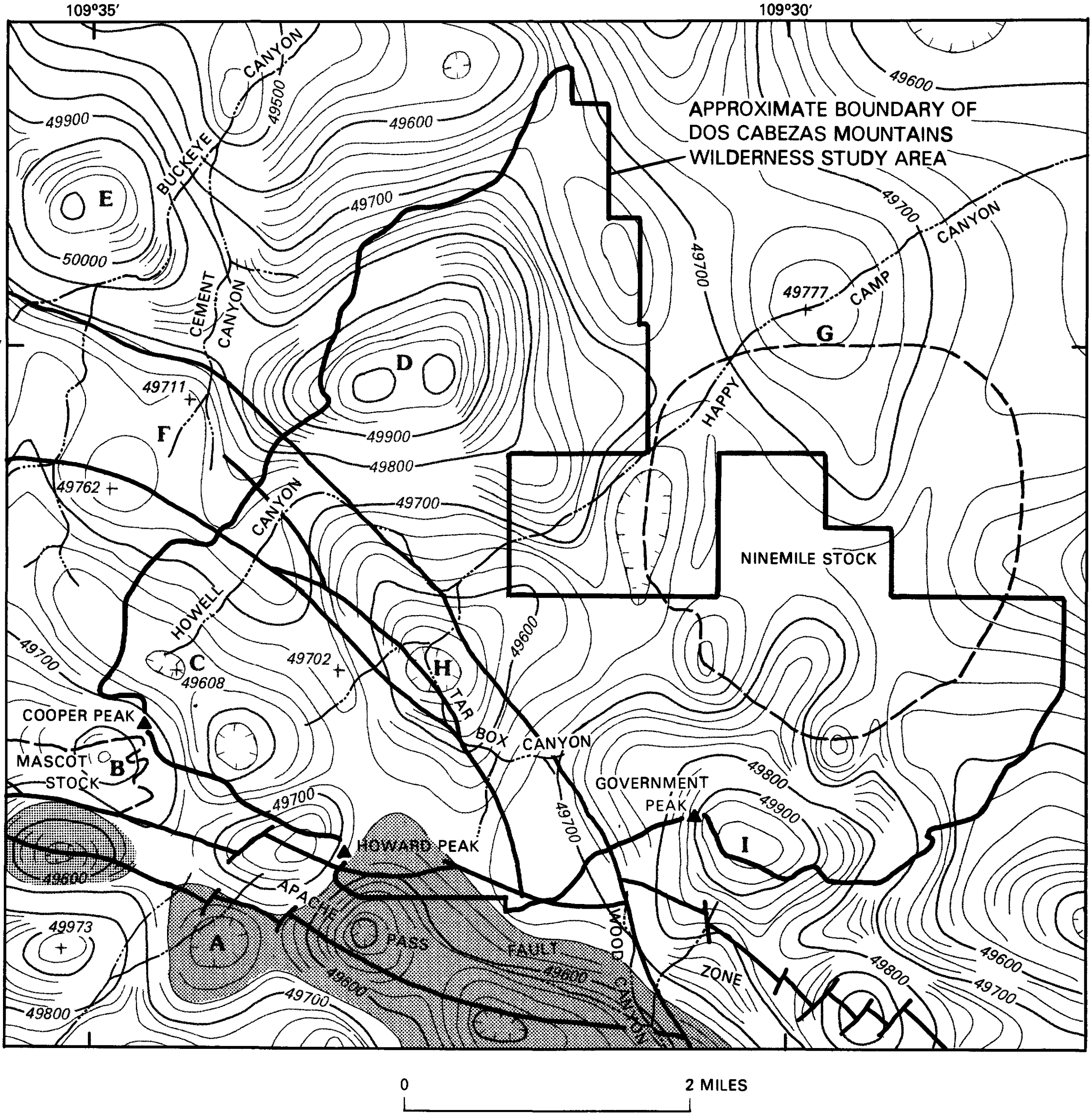
- **Bismuth, ≥ 20 ppm**
- **Tungsten, ≥ 100 ppm**
- **Fluorite, ≥ 5 percent**
- **No anomalous concentration**

Rock-chip sample locality and element concentration—Symbols are combined where a locality contained more than one element

- **Bismuth, ≥ 10 ppm**
- **Tungsten, ≥ 50 ppm**
- **No anomalous concentration**

sive bodies on the geologic map lends support to this conclusion. A similar magnetic high near Cooper Peak (fig. 7, site B) may also be related to an intrusive body.

An elongate magnetic low lies just north of Cooper and Howard Peaks (fig. 7, site C). This low lies in the area where the volcanic pile of the Dos Cabezas Mountains area is believed to be thickest (Drewes and others, in press). This area may be a fault-bounded collapsed structure (Drewes and others, in press). The magnetic low is interpreted as reflecting either reverse polarization of the ash-flow sheet or an extensive area of propylitized or otherwise altered rock. No magnetic-property measurements are available from samples of the ash-flow rock to discriminate between these possibilities. Geologic infer-



EXPLANATION

— 49700 — **Magnetic contours**—Showing total-intensity magnetic field. Contour interval 20 gammas; index (heavy) contours 100 gammas; hachures indicate closed contours of magnetic low; +, selected site showing specific magnetic value. [Flight elevation 500 ft above terrain along east-west flight lines spaced 0.6 mi apart]

49608 +

Magnetic low associated with the Apache Pass fault zone

A, B **Site of specific magnetic anomaly**—A through I, referred to in text

Fault

Contact—Showing general outline of granitic stocks

Figure 7. Total-intensity aeromagnetic map of the Dos Cabezas Mountains Wilderness Study Area, Cochise County, Arizona.

ence (Drewes, in press) suggests that the ash-flow sheet may be 1,500 ft thick in some areas; a thickness of about 1,000 ft may be reasonable over other substantial areas. A gravity high over the same area (fig. 8, site C) indicates a relatively shallow crystalline basement, but consistent with the previously estimated thickness (Drewes, in press) of the volcanic rock.

Two magnetic highs in an area of Proterozoic rocks at Rough Mountain and Maverick Mountain (fig. 7, sites D and E, respectively) seem to coincide with topographic highs.

A small magnetic low (fig. 7, site F) at the southwest side of Rough Mountain is in an area underlain by a wide fault zone (Drewes, in press). This anomaly could reflect locally strong alteration, and possible associated mineralization, or it may be caused by a rhyolitic body perhaps related to the broad dike (Drewes, in press) that extends along the northeastern margin of the volcanic field.

A magnetic high along Happy Camp Canyon northeast of the study area (fig. 7, site G) reflects unknown lithologic changes or structure beneath the alluvium.

A T-shaped magnetic low (fig. 7, site H) lies in the area of the intersection of the branch faults off the Apache Pass fault zone and the upper reaches of Happy Camp Canyon. The area is underlain mainly by Proterozoic metasedimentary and metavolcanic rocks. The anomaly is probably caused by a reduction in rock magnetic properties and by high terrain clearance.

In the area of Government Peak there are both magnetic and gravity highs (figs. 7 and 8, site I). The gravity high of this area persists at a Bouguer reduction density of 3.00 grams per cubic centimeter, which indicates that the gravity anomaly is not caused solely by topography. These gravity and magnetic anomalies are inferred to be caused by dense and strongly magnetic rocks. Rock of these similar characteristics appears to protrude northeastward in the Ninemile stock area due to the extension of the magnetic high there. Low-density granitic rocks crop out in this region. The lack of any gravity expression in the Ninemile stock area suggests that the granitic rocks do not extend to any appreciable depths.

Mines, Prospects, and Mineralized Areas

The production history and the description of identified mineral resources and other mines and prospects, given by Zelten in a preceding section, provide important insight for the assessment of mineral resource potential.

Mines and prospects are common along the Apache Pass fault zone. Sulfide mineral deposits commonly occur in the fault zone in the Dos Cabezas Mountains and many of these workings have produced substantial amounts of base and precious metals, predominantly copper and gold. Mines and other known mineral occurrences are along strands in the fault zone itself, in breccia pipes, in small stocks, or in quartz veins, most of which dip away from the study area. However, there are no mines in that part of the fault zone which extends through a small part of the southwestern side of the study area. Mines in and associated with the fault zone were not examined to define and categorize the deposits because the mineralized structures do not trend toward the study area. Furthermore, a heavy colluvial or talus cover conceals bedrock in most places around the examined workings.

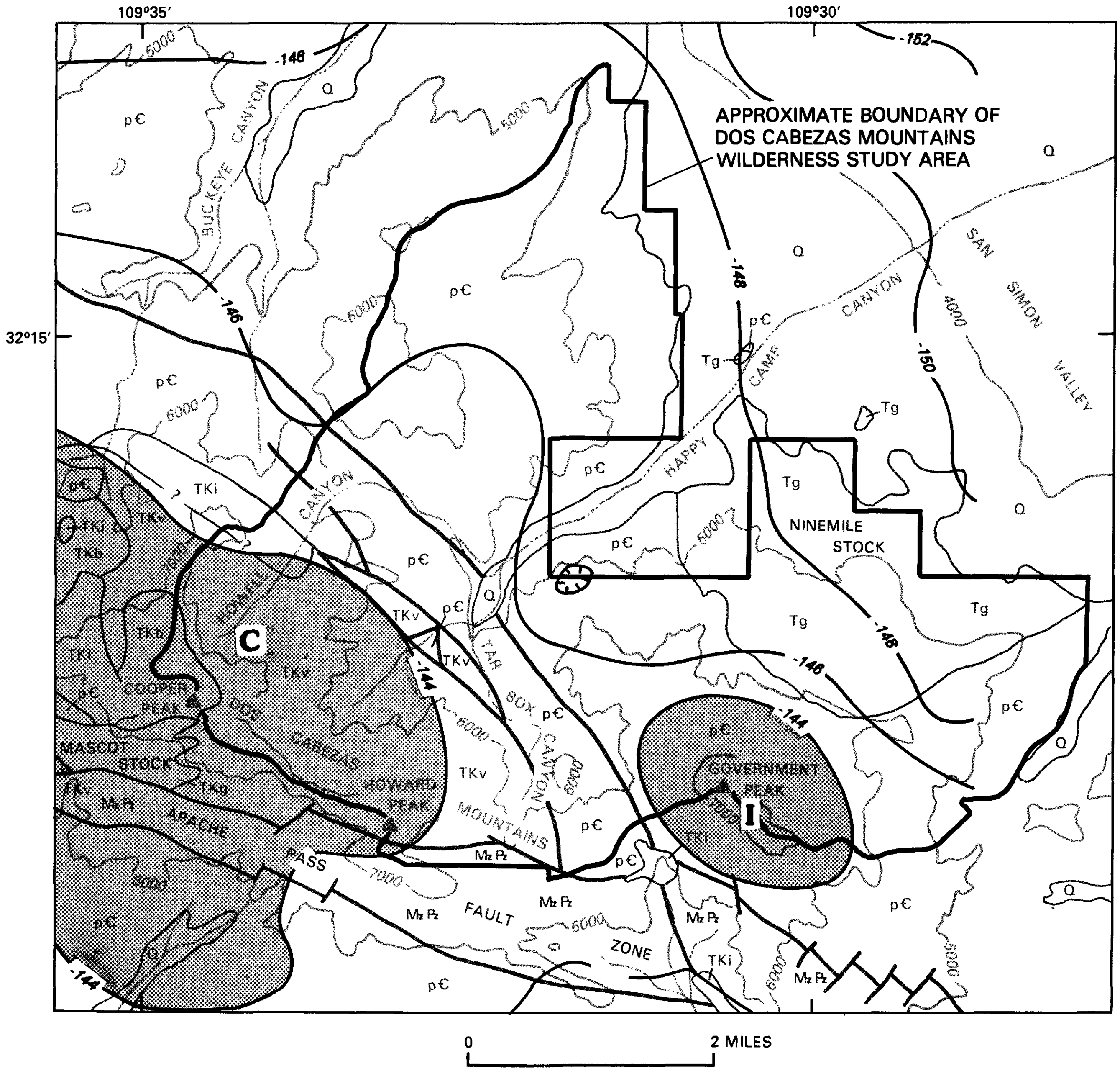
In the study area itself none of the workings have led to recorded production, but quartz veins, volcanic rocks, and dikes have been prospected. There is no evidence of placer mining in the study area and only a few signs that placer prospecting may have occurred. Beyond the establishment of oil and gas leases (fig. 3), there is no sign of oil and gas exploration in or near the area. More detailed assessments are here withheld because, although deep Vibroseis[1] lines were run near the study area, we have had no access to them.

A quartz vein at Rough Mountain was described in a preceding section as an identified resource; a few other mineral deposits a short distance outside the study area also were examined to see whether the deposits could project into the area. In none of these cases was such a projection judged likely.

Tungsten ore, occurring as scheelite in shear zones, veins, volcanic rocks, favorable sedimentary beds, and skarn deposits of tactite zones, was produced in unrecorded quantity from small mines within 2 mi south of the study area in and near Wood Canyon (Dale and others, 1960, p. 6–26). The Austin mine, which is the mine nearest to the study area, has an adit about on the contact of the Paleozoic and Mesozoic sedimentary rocks (pl. 1); the other mines and prospects are in the Paleozoic formations of mixed carbonate and clastic rock types. Geologic mapping of the area (Sabins, 1957a; Drewes, 1985) indicates that these favorable rock types have been removed by faulting between the Austin mine and the study area, and that the general zone of these sedimentary rocks follows the Apache Pass fault zone, which only barely enters the area and there dips away from it.

Much of the area within 3 mi south of the study area has been claimed for uranium. Prospects at a claim about 1.5 mi south of the study area (NW¼ sec. 32, T. 14 S., R. 28 E.) are on radioactive quartz-fluorite veins in Proterozoic granite. Drill-core samples of the veins assayed 0.3 and 1.09 percent uranium oxide (Richter and Lawrence, 1983, p. 52). Production has not been recorded from any of the claims in this area. These uranium-bearing structures and formations are truncated by the Apache Pass fault zone and do not extend into the study area (Drewes, 1985).

[1]Any use of trade names in this report is for descriptive purposes only and does not imply endorsement by the USGS.



EXPLANATION

—-146— Gravity contour—Contour interval 2 milligals; hachures indicate closed contours of gravity low

Gravity high within regional high of the Dos Cabezas Mountains

C, I Site of specific gravity anomaly—Referred to in text, and keyed to magnetic anomalies

Contact

Fault

Placer gold has been mined intermittently from small gulches in the Teviston and Dos Cabezas mining districts, which extend well beyond the study area, with a recorded production of more than 1,000 oz (Johnson, 1972, p. 84). This gold was probably derived from gold-bearing quartz veins and stringers in the Mesozoic and older rocks (Wilson, 1937, p. 69, and also the studies on Rough Mountain, this report). Whereas quartz veins as large as those on Rough Mountain are not common in the study area, quartz stringers may be present in significant number in some of the Proterozoic rocks. Recorded placer claims nearest to the study area lie in Buckeye Canyon. Prospecting may have occurred in Happy Camp Canyon below a cabin on the main fork, above the junction of Tar Box Canyon, where an alluvial terrace has some unexplained surface irregularities. Prospecting signs along the present washes would, in any case, have been obliterated by the occasional heavy runoff common to the Dos Cabezas Mountains.

Mineral Resource Potential

The mineral resource potential of the Dos Cabezas Mountains Wilderness Study Area is moderate in one area, and is low elsewhere (fig. 2 and pl. 1). Areas of high potential for any commodity are not recognized, although one quartz vein has been described as an identified mineral resource.

Areas of Moderate Mineral Resource Potential for Metals

About 3 sq mi along the western side of the study area are assigned a moderate resource potential (M) for mineral accumulation. These accumulations probably include, in various parts of this "western moderate terrane," disseminated porphyry copper or copper-molybdenum, copper-lead-molybdenum-tungsten skarn, and copper-lead-silver vein types of deposits. They may also include stockwork and massive-sulfide deposits. The basis for inferring a reasonable likelihood of occurrence of at least some of these kinds of mineral deposits is a highly favorable geologic environment plus strong support from the geochemical, geophysical, and mining-history studies. Within the western moderate terrane (fig. 2 and pl. 1), however, different levels of certainty are assigned to separate parts of the terrane, based on the particular mix of direct observation versus indirect projections inherent in the rationale for our judgment. To a lesser extent, this range of certainty is also reflected in the varying breadth of support from the separate studies. Consequently, the western moderate terrane is subdivided into three subterranes reflecting the certainty level by letter designations, indicating that the available information either suggests (M/B) or gives good indication (M/C) or clearly defines (M/D) the assigned level of mineral resource potential (certainty level A is not here recognized). Further subdivision, indicated by numerical subscripts, delineates areas in which various types of mineral accumulations may be expected.

A second moderate terrane is outside (southeast of) the study area near Wood Canyon; copper, lead, zinc, molybdenum, tungsten, and silver are possible in stratabound, vein, or skarn deposits. The terrane is both smaller in extent and more uniform in geologic environment, and therefore is undivided; its certainty level is C.

Western Moderate Terrane

The western moderate terrane is divided into five subterranes, differentiated on the basis of certainty levels, kinds of metals, and types of deposits:

- M/D_1: Copper, lead, zinc, molybdenum, tungsten, and silver in skarns, stockworks, veins, and breccia pipes.
- M/D_2: Copper, lead, and silver in veins.
- M/C_1: Copper, lead, molybdenum, tungsten, and silver in veins.
- M/C_2: Copper, lead, and silver in veins.
- M/B_1: Copper, molybdenum, lead, and zinc in stock works, replacements, and veins.

Terrane M/D_1 contains (1) three key geologic features favorable for accumulations of mineral deposits, (2) favorable geochemical anomalies, (3) geophysical evidence of the subsurface extension of a key stock, and (4) direct signs that at least copper has been introduced; there is also a record of mineral production from similar terranes nearby. The Mascot stock is a key geologic feature because it is of a kind and age found in other nearby mineralized areas. North of the stock is a breccia-pipe system (second key geologic feature) inferred to be the vent for an ancient volcanic center, probably a minor vent flanking the main source site of the extensive andesitic-dacitic volcanic field. The central breccia phase (third key geologic feature) of this minor vent contains large blocks

Figure 8 (facing page). Complete Bouguer gravity anomaly map of the Dos Cabezas Mountains Wilderness Study Area, Cochise County, Arizona. Data compiled from Wynn (1981) and Abrams and others (1985). Reduction density is 2.67 grams per cubic centimeter. Q, alluvium (Quaternary); Tg, granite (Tertiary); TKg, granite (Tertiary or Cretaceous); TKi, intrusive rocks (Tertiary or Cretaceous); TKb, intrusive breccia (Tertiary or Cretaceous); TKv, volcanic rocks (Tertiary or Cretaceous); MzPz, sedimentary rocks (Mesozoic and Paleozoic); p€, crystalline rocks (Precambrian; Proterozoic).

of Paleozoic and Mesozoic sedimentary rocks that were probably derived from the subvolcanic host rock. Details of these structural relations and rock types are described in Drewes (1985) and Drewes and others (in press).

Skarn-type deposits and vein deposits are commonly found in the host rocks of Paleocene ore-related granite stocks such as the Mascot stock. Rocks favorable for such deposits occur in the Paleozoic and Mesozoic sequences, which are known from direct evidence to occur along the Apache Pass fault zone and, from indirect evidence, to underlie the breccia pipe area at Cooper Hill. Aeromagnetic data show this stock to extend into the study area east of Cooper Peak (fig. 7), where it probably has the shape of a shoulder flanking the main stock mass. Such shoulders are deemed favorable sites for ore accumulation.

Breccia pipes offer easy egress to ore fluids and may host stockwork deposits or ore pipes. Favorable sedimentary host rocks, either forming large inclusions within the breccia or as subvolcanic beds, may be sites of massive-sulfide replacement, as occurs at the Elma mine. Furthermore, the andesitic to dacitic terrane itself is a moderately favorable terrane for Late Cretaceous–Paleocene-aged ore deposits of southeast Arizona and southwest New Mexico. And, indeed, these rocks are widely altered and are in many places seen to contain copper and lead minerals. In fact, the alteration is so strong that precise placement of the contact between granodiorite or quartz monzonite of the Mascot stock and the andesitic breccia is difficult to make and, hence, segments of the contact are queried. Much of the alteration is propylitic, some may be a clay-mineral alteration related to hydrothermal activity but our studies did not venture farther in this phase of rock chemistry. The decrease in concentration of copper and zinc northeast of Cooper Peak may indicate a wider dispersion of geochemically mobile metals from a hydrothermal center.

Terrane M/D_2 lies south and east of M/D_1, along the Apache Pass fault zone and, thus, largely just outside the study area. This terrane also has been assigned, with a high degree of certainty, a moderate mineral resource potential because of favorable geologic features whose surface and subsurface positions are well defined, and because of supporting favorable geochemical, geophysical, and mining-history data. Copper-lead-silver veins are found along many segments of the fault zone, not only nearby but throughout its length of about 30 mi (Drewes and others, 1983; Drewes and others, in press). From surface observation and airborne magnetic data alike, the fault zone is seen to dip steeply southwest, probably branching at depth to a vertical fault zone and a more gently dipping zone of sedimentary rocks that may show signs of a mild compressive deformation. The Apache Pass fault zone hosted intrusive rocks as well as quartz veins. The localization of the entire andesitic-dacitic volcanic field is controlled by this fault zone. The Mascot stock and others are found along this zone and its splays, and similar associations occur along other such master faults (Drewes, 1980, 1981). Therefore, conditions are favorable for the presence of blind quartz veins bearing copper, lead, and silver at deeper levels of the fault zone, particularly near the stock and other smaller intrusive bodies.

Terrane M/C_1 is underlain mainly by Proterozoic granitic rock that is cut by a few faults and mineralized quartz veins. Although the granitic rock itself is unlikely to be mineralized, the veins, with their considerable copper, lead, and silver content, offer attractive targets. The veins along Howell Canyon are controlled by northwest-trending faults, part of a splay fault system of the Apache Pass fault zone. The veins on Round Mountain and Virginia Hill dip gently northward, probably guided locally by a foliation or sheeting in the granitic rocks. There is a good likelihood that blind veins of this type remain to be found in this terrane, guided by the same sorts of structures as are the veins at the surface. The dispersal of these veins is, however, less precisely controlled and, thus, less certain than are the veins along the Apache Pass fault zone.

Terrane M/C_2 forms a prong southwest of the Apache Pass fault zone and the study area proper, following a quartz-vein system along which the Leroy mine is located. This vein trends northeast, is about vertical, and is as much as 3 ft wide. Similarly oriented but commonly smaller veins are scattered throughout the Proterozoic terrane southwest of the fault zone. The Leroy mine has been a producer of copper, lead, and silver, all of which are also found in the rock samples taken from several mine dumps (Drewes and others, in press).

There is a strong likelihood that this vein, or closely related nearby veins, could occur, particularly northeast of the mine, at a depth at which they may merge with the southwest-dipping Apache Pass fault zone. Other concentrations of copper, lead, and silver comparable to those of the Leroy mine may be expected. With so specific an exploration target in mind, detailed geophysical studies, such as an induced polarization survey taken along the vein and its proposed northeastern subsurface extension, may be desirable.

Terrane M/B_1 covers much of the western moderate terrane and extends west of the study area at least half a mile and possibly 2 mi or more, to, or beyond the Dos Cabezas Peaks (figs. 1 and 2; Drewes and others, in press). This terrane is underlain mainly by altered andesitic to rhyolitic breccia of the Late Cretaceous to early Tertiary volcanic pile that caps much of the range. These volcanic rocks are believed to dip gently southwest and, although they generally overlie crystalline basement rocks, in some places they probably overlie Paleozoic or Mesozoic sedimentary rocks like those found in the Apache Pass fault zone (Drewes, 1985; Erickson and Drewes, 1984a). Additionally, some zones of the volcanic breccia may be more thoroughly fractured than others and thus have a permeability favorable to the outward migration of hydrothermal solutions from such sites as the Apache Pass fault zone, the Mascot stock, and the breccia pipe at Cooper Peak. The geochemical study confirms that a wide area north of Cooper Peak contains source rocks for anomalous concentration of bismuth, copper, lead, zinc, molybdenum, and silver but offers only general support of the geologic targets proposed. Geophysical study likewise indicates the general distribution of volcanic terrane but gives no basis for judging its thickness or for testing its underlying rocks. The geologic target, then, offers a likelihood of concealed replacement type of deposits and veins in blind masses of subvolcanic sedimentary rocks, and disseminated porphyry copper-molybdenum type deposits somewhere in the subterrane, but the certainty level is only suggestive.

Wood Canyon Moderate Terrane

The small area southeast of the study area assigned a moderate mineral resource potential, terrane M/C_3, also lies along the Apache Pass fault zone. This terrane, near Wood Canyon, is underlain chiefly by Paleozoic sedimentary and Mesozoic sedimentary and volcanic rocks. These rocks dip steeply southwest, are intruded by several plugs and many dikes, and are cut by faults adjacent to and within the Apache Pass fault zone. Several old mines and many prospects occur near faults or along favorable stratigraphic zones, some of which are altered and have skarn minerals. Copper, lead, zinc, molybdenum, silver, tungsten, and fluorite show up in these rocks, and the geochemistry of the alluvium and the sparse records of mine production also indicate the presence of tungsten and molybdenum, along with the more ubiquitous copper, lead, zinc, and silver. Geophysical data confirm only the presence of terrane typical of the Apache Pass fault zone.

Terrane M/C_3 has a moderate likelihood of containing copper, lead, zinc, molybdenum, tungsten, and silver in stratabound, vein, or skarn deposits. From geologic indications alone—the many intrusive rocks plus the altered condition of some rocks—there is a likelihood of finding a larger granitic plug or stock beneath the surface that may be associated with contact deposits. Thus, the available data give a good indication of the moderate level of mineral potential of the terrane.

Areas of Low Mineral Resource Potential for Metals

Areas of low mineral resource potential (L) have geologic, geochemical, and geophysical characteristics not particularly favorable, or even unfavorable, for the occurrence of mineral deposits. The assessment of these areas as having this low potential is made with greater certainty in two geologic terranes than in two others, reflecting differences in the quality and kind of available geologic information. Two certainty levels are used, by letter designations, indicating that the available information either suggests (L/B) or gives good indication (L/C) of the assigned level of mineral resource potential (certainty levels A and D are not here recognized). Further subdivision, indicated by numerical subscripts, delineates areas in which various types of mineral accumulations may be expected. In essence, we see little likelihood that any serious exploration effort should be directed toward the areas of low potential, given the presently available geologic and technologic knowledge.

Terrane L/C_1 lies between the Apache Pass fault zone and its splay fault system, which runs through the middle reaches of Happy Camp Canyon. This terrane occupies much of the central and southern parts of the study area. It is underlain by andesitic to dacitic rocks of the east end of the Late Cretaceous–early Tertiary volcanic pile, some Cretaceous sedimentary and volcanic rocks beneath the pile, and much Proterozoic crystalline rock (pl. 1).

All of our studies support this assignment of low potential. The geophysical study corroborates the position of larger faults and the distribution of some major rock types, the volcanic pile to the west, and some amphibolitic masses in the Proterozoic basement to the east. The history of mining shows that only a few veins were prospected, apparently without achieving anticipated results. The geochemical study indicates the continued presence of the base metals copper, lead, zinc, and molybdenum, as well as the occurrence of tungsten in anomalous amounts in stream sediments. However, the tungsten occurrence is of lesser abundance and more spotty distribution than is characteristic of the terranes of moderate mineral resource potential. Above all, there is no clear-cut geologic rationale for the distribution of these metals that could lead to a possible site or model of mineral accumulation, and thus a low potential is assigned this terrane. The available geologic control of this area provides a good basis for this assignment of potential, especially so along the fault zone through the center of the terrane, that might attract the prospector.

Terrane L/C_2 is a relatively barren segment of the Apache Pass fault zone. It is underlain by the same Paleozoic and Mesozoic rocks found in the other segments, but has few intrusive bodies, skarn masses, and prospects. Geologic and geophysical studies show the Apache Pass fault zone to run through the terrane, and geochemical indicators show the continued, although more spotty or lower concentration of copper, lead, and silver. Quartz veins are few or so small and erratically distributed as to have escaped notice during the geologic study. Consequently, there is little likelihood of blind mineralized veins, unless geologic conditions change at greater depth. This alteration of barren and mineralized segments is typical of conditions along the Apache Pass fault zone. Again, the available information gives a good indication that the mineral resource potential is low for all metals.

Terrane L/B_1 covers much of the eastern and northern arms of the study area. The terrane is underlain mainly by Proterozoic crystalline rock, of which metasedimentary and metaigneous rocks are about as extensive as granitoid rocks. Part of the eastern arm is underlain by the mid-Tertiary Ninemile granite stock, and a few rhyolite dikes of similar age occur at wide intervals. Younger alluvium covers the bedrock of the larger valley floors and fringes of the San Simon Valley.

Terrane L/B_1 has few geologic features favorable to the accumulation of any base or precious metals. The young stock is barren; veins are few and small but probably are mineralized; hydrothermally altered rocks are rare; and other direct signs of mineral accumulation are nearly absent. The geophysical and mining-history studies give no favorable signs of possible mineral deposits. Geochemical anomalies occur over various parts of the terrane for bismuth, tungsten, fluorite, and thorium, an assemblage resembling that occurring in quartz veins in the basement rocks at Apache Pass, some 4 mi to the southeast of Wood Canyon. Lacking specific geologic sources, the mineral resource potential of the area for base- or precious-metal deposits (copper, lead, zinc, gold, silver) is judged to be low.

Terrane L/B_2 lies southwest of the southwest strand of the Apache Pass fault zone and adjoining terrane M/C_2. Like terrane M/C_2, terrane L/B_2 is underlain by Proterozoic granitic rock, but unlike M/C_2, there is no prominent vein set with mineralized quartz like that at the Leroy mine. The mineral resource potential of terrane L/B_2 is thus low for all metals. Because the veins here are small or even absent in much of the terrane, the other studies have not been able to contribute supporting data of particular help, and thus the certainty level is only suggestive.

Areas of Low Mineral Resource Potential for Energy Resources

In the study area, the mineral resource potential for energy sources is low with certainty level A. The rocks of the area contain no coal and are unlikely to contain oil and gas, inasmuch as most of the rocks are igneous or metamorphic and inasmuch as the few known sedimentary rocks are strongly faulted and have been heated by nearby igneous rocks. Furthermore, these rocks are not likely to form a major thrust plate, overlying rocks at greater depth that are more suitable for oil or gas accumulation. Such overthrust plates are inferred to lie south and west of the study area, but even there the likelihood of occurrence is low.

Areas of Low Mineral Resource Potential for Sand and Gravel

Gravel deposits lap against the northeast flank of the range and may have some industrial usefulness. Such deposits have been worked along Happy Camp Canyon about a half mile northeast of the map area of plate 1, where they were fairly fine-grained (cobble-pebble) gravel and sand suitable for road metal. The deposits extending into the study area are coarse-grained (bouldery cobble) gravel and pebbley sand beds, probably less suitable for industrial use. Furthermore, finer grained, more suitable gravel deposits derived from similar source rocks should be abundant along much of the Dos Cabezas and nearby mountains.

Much of terrane L/B_1 is underlain by rocks of no known commercial value, but near the range front are a granite mass and gravel deposits. The granite of the Ninemile stock is pinkish gray, medium coarse grained, and unaltered. Steep fractures are widely spaced; subhorizontal ones are moderately spaced to give many of the bold outcrops a subtle sheeted or layered appearance. Even though such fractures are likely to become fewer, deeper in the body, the stock is relatively small and is exposed near its original cap. Consequently, the fractures may persist downward for a considerable distance. No granite has been commercially quarried from southeastern Arizona.

REFERENCES CITED

Abrams, G. A., 1986, Geophysical maps of the Dos Cabezas Mountains Wilderness Study Area, Cochise County, Arizona: U.S. Geological Survey Miscellaneous Field Studies Map MF–1873–A, scale 1:62:500.

Abrams, G. A., Moss, C. K., and Schutter, T. A., 1985, Principal facts for gravity stations in the Dos Cabezas Mountains, Cochise County, Arizona: U.S. Geological Survey Open-File Report 85–222, 10 p.

Cooper, J. R., 1960, Reconnaissance geology map of Willcox, Fisher Hills, Cochise, and Dos Cabezas quadrangles, Cochise and Graham Counties, Arizona: U.S. Geological Survey Mineral Investigations Field Studies Map MF–231, scale 1:62,500.

———1973, Geologic map of the Twin Buttes quadrangle, southwest of Tucson, Pima County, Arizona: U.S. Geological Survey Miscellaneous Investigations Series Map I–745, scale 1:48,000.

Dale, V. B., Stewart, L. A., and McKinney, W. A., 1960, Tungsten deposits of Cochise, Pima, and Santa Cruz Counties, Arizona: U.S. Bureau of Mines Report of Investigations RI5650, 132 p.

Drewes, Harald, 1980, Tectonic map of southeastern Arizona: U.S. Geological Survey Miscellaneous Investigations Series Map I–1109, scale 1:125,000.

———1981, Tectonics of southeastern Arizona: U.S. Geological Survey Professional Paper 1144, 96 p.

———1982, Geologic map of the Cochise Head quadrangle and adjacent areas, southeastern Arizona: U.S. Geological Survey Miscellaneous Investigations Series Map I–1312, scale 1:24,000.

———1984, Geologic map and sections of the Bowie Mountain North quadrangle, Cochise County, Arizona: U.S. Geological Survey Miscellaneous Investigations Series Map I–1492, scale 1:24,000.

———1985, Geologic map and structure sections of the Dos Cabezas quadrangle, Cochise County, Arizona: U.S. Geological Survey Miscellaneous Investigations Series Map I–1570, scale 1:24,000.

———1986, Geologic map and structure sections of the Simmons Peak quadrangle, Cochise County, Arizona: U.S. Geological Survey Miscellaneous Investigations Series Map I–1569, scale 1:24,000.

Drewes, Harald, Houser, B. B., Hedlund, D. C., Richter, D. H., Thorman, C. H., and Finnell, T. L., 1985, Geologic map of the Silver City 1°×2° quadrangle, New Mexico and Arizona: U.S. Geological Survey Miscellaneous Investigations Series Map I–1310–C, scale 1:250,000.

Drewes, Harald, Klein, D. P., and Birmingham, S. D., in press, Volcanic and structural controls of mineralization in the Dos Cabezas Mountains of southeastern Arizona: U.S. Geological Survey Bulletin 1676.

Drewes, Harald, Moss, C. K., Watts, K. C., Jr., Forn, C. L., and Bigsby, P. R., 1983, Mineral resource potential map of the North End Roadless Area, Chiricahua Mountains, Cochise County, Arizona: U.S. Geological Survey Miscellaneous Field Studies Map MF–1412–D, scale 1:50,000.

Erickson, R. C., 1968, Geology and geochronology of the Dos Cabezas Mountains, Cochise County, Arizona, *in* Southern Arizona Guidebook 3: Tucson, Ariz., Arizona Geological Society, p. 192–198.

Erickson, R. C., and Drewes, Harald, 1984a, Geologic map of the Railroad Pass quadrangle, Cochise County, Arizona: U.S. Geological Survey Miscellaneous Field Studies Map MF–1688, scale 1:24,000.

———1984b, Geologic map of the Luzena quadrangle, Cochise County, Arizona: U.S. Geological Survey Miscellaneous Field Studies Map MF–1721, scale 1:24,000.

Gilluly, James, 1956, General geology of central Cochise County, Arizona, *with sections on* Age and correlation by A. R. Palmer, J. S. Williams, and J. B. Reeside, Jr.: U.S. Geological Survey Professional Paper 281, 169 p.

Goudarzi, G. H., 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84–787, 42 p.

Grimes, D. J., and Marranzino, A. P., 1968, Direct-current arc and alternating-current spark emission spectrographic field methods for the semiquantitative analysis of geologic materials: U.S. Geological Survey Circular 591, 6 p.

Johnson, M. G., 1972, Placer gold deposits of Arizona: U.S. Geological Survey Bulletin 1355, 103 p.

Klein, D. P., 1986, Aeromagnetic map of the Silver City 1°×2° quadrangle, Arizona and New Mexico: U.S. Geological Survey Miscellaneous Investigations Series Map I–1310–D, scale 1:250,000.

McDanal, S. K., Forn, C. L., Hassemer, J. R., and Watts, K. C., 1983, Analytical results for stream-sediment concentrate, sieved stream-sediment, rock, and water samples from the Silver City 1°×2° quadrangle, New Mexico and Arizona: U.S. Geological Survey Report NTIS PB–83 220 863 [computer tape available from U.S. Department of Commerce, National Technical Information Service, Springfield, VA 22161].

Millard, H. T., Jr., and Keaton, B. A., 1982, Precision of uranium and thorium determinations by delayed neutron counting: Journal of Radioanalytical Chemistry, v. 72, p. 489–500.

Richter, D. H., and Lawrence, V. A., 1983, Mineral deposit map of the Silver City 1°×2° quadrangle, New Mexico and Arizona: U.S. Geological Survey Miscellaneous Investigations Series Map I–1310–B, scale 1:250,000.

Sabins, F. F., Jr., 1957a, Geology of the Cochise Head and western part of the Vanar quadrangles, Arizona: Geological Society of America Bulletin, v. 68, no. 10, p. 1315–1341.

———1957b, Stratigraphic relations in the Chiricahua and Dos Cabezas Mountains, Arizona: American Association of Petroleum Geologists Bulletin, v. 41, no. 3, p. 466–510.

Thorman, C. H., and Drewes, Harald, 1978, Geologic map of the Gary and Lordsburg quadrangles, Hidalgo County, New Mexico: U.S. Geological Survey Miscellaneous Investigations Series Map I–1151, scale 1:24,000.

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. Geological Survey, 1980, Aeromagnetic map of the southern part of the Silver City 1°×2° quadrangle, Arizona and New Mexico: U.S. Geological Survey Open-File Report 80–1128, scale 1:62,500.

Viets, J. G., 1978, Determination of silver, bismuth, cadmium, copper, lead, and zinc in geologic materials by atomic absorption spectrometry with tricaprylylmethylammonium chloride: Analytical Chemistry, v. 50, p. 1097–1101.

Ward, F. N., Nakagawa, H. M., Harms, T. F., and Van Sickle, G. H., 1969, Atomic-absorption methods useful in geochemical exploration: U.S. Geological Survey Bulletin 1289, 45 p.

Watts, K. C., and Hassemer, J. R., 1986, Geochemical interpretive and summary maps, Silver City 1°×2° quadrangle, New Mexico and Arizona: U.S. Geological Survey Miscellaneous Investigations Map I–1310–E, scale: plate 1, 1:250,000; plate 2, 1:500,000.

Wilson, E. D., 1937, Arizona gold placers, *in* Arizona gold placers and placering: Arizona Bureau of Mines, Mineral Technology Series no. 38, Bulletin no. 142, p. 9–90.

Wynn, J. C., 1981, Complete Bouguer gravity map of the Silver City 1°×2° quadrangle, New Mexico–Arizona: U.S. Geological Survey Miscellaneous Investigations Series Map I–1310–A, scale 1:250,000.

Zelten, J. E., 1986, Mineral resources of a part of the Dos Cabezas Mountains Wilderness Study Area (AZ–040–065), Cochise County, Arizona: U.S. Bureau of Mines Mineral Land Assessment Open File Report MLA 2–86, 31 p.

GEOLOGIC TIME CHART

Terms and boundary ages used by the U. S. Geological Survey, 1986

EON	ERA	PERIOD		EPOCH	BOUNDARY AGE IN MILLION YEARS
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 m.y. also called Precambrian, a time term without specific rank.

[2] Informal time term without specific rank.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1987—773-047/46,017 REGION NO. 8