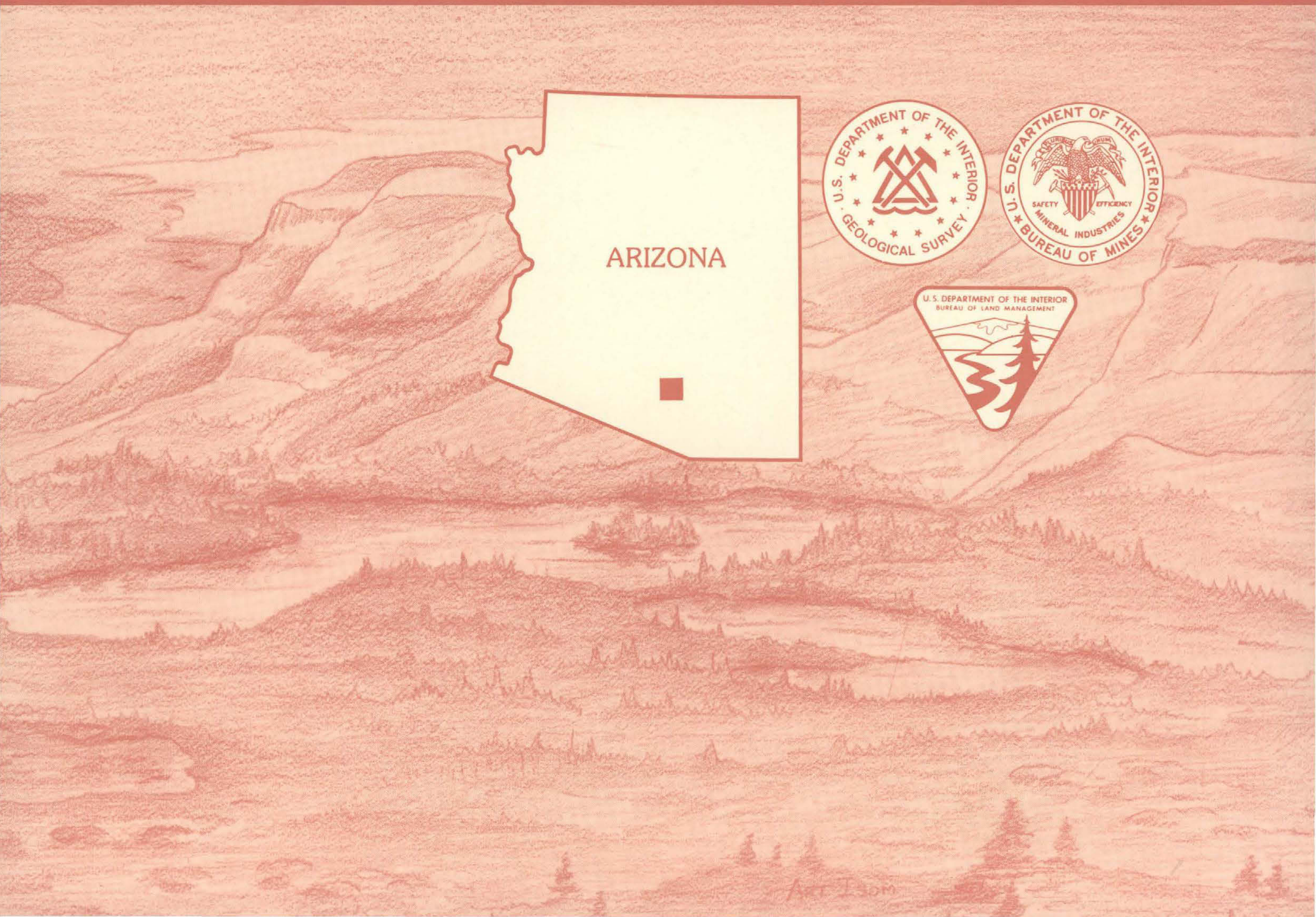
Mineral Resources of the Ragged Top Wilderness Study Area, Pima County, Arizona

U.S. GEOLOGICAL SURVEY BULLETIN 1702–H



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Chapter H

Mineral Resources of the Ragged Top Wilderness Study Area, Pima County, Arizona

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U.S. GEOLOGICAL SURVEY BULLETIN 1702

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

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of the Ragged Top Wilderness Study Area (AZ-020-197), Pima County, Arizona.

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Mineral Resources of the Ragged Top Wilderness Study Area, Pima County, Arizona

By Gary A. Nowlan, Jocelyn A. Peterson, James A. Pitkin, *and* William F. Hanna
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SUMMARY

Abstract

The Ragged Top Wilderness Study Area (AZ– 020–197), for which mineral surveys were requested by the U.S. Bureau of Land Management, encompasses 4,460 acres in south-central Arizona. Throughout this report, "study area" includes the wilderness study area and adjacent terrain where samples were collected. Field work was carried out in 1987 by the U.S. Bureau of Mines and the U.S. Geological Survey to appraise the identified (known) resources and assess the mineral resource potential (undiscovered) of the wilderness study area. The study area includes the northern part of a mineralized area that includes the Silver Bell porphyry copper deposits. Despite this proximity to a major mine and the presence of several mines and prospects within and near the study area, no metallic resources were identified; exposures of mineralized rock are generally erratic and small. Sand and gravel are present in minor amounts, but they have no unique qualities and other supplies are closer to markets.

Part of the southwest corner of the study area has high resource potential for gold, silver, lead, vanadium, barite, molybdenum, copper, and zinc in vein deposits. Adjacent parts of the study area to the north, west, and south have moderate resource potential for zinc, lead, barite, molybdenum, gold, silver, and copper in similar veins. Part of the east side of the study area has low resource potential for gold, barite, lead, silver, zinc, and copper in veins. The southern part of the study area has moderate resource potential for copper, silver, gold, and molybdenum in porphyry copper deposits. The east-central part of the study area has low resource potential for uranium deposits in veins and disseminated in Proterozoic sedimentary rocks. The northern part of the study area has low resource potential for thorium and rare-earth elements such as lanthanum in monazite or other accessory minerals in Proterozoic granite and for quartz, feldspar, and mica for industrial uses in pegmatites within granite. The study area has no potential for oil and gas or for geothermal energy resources.

Character and Setting

The Ragged Top Wilderness Study Area (AZ–020–197) (fig. 1) is located about 35 mi northwest of Tucson, Ariz., on the northeast side of the Silver Bell Mountains, a small range within the Basin and Range physiographic province. The study area lies partially in the northern part of the recently identified Silver Bell caldera, which provides the structural setting with which the Silver Bell porphyry copper deposits are associated (Sawyer, 1987). The study area is underlain by Proterozoic (see geologic time chart in "Appendixes") granitic and sedimentary rocks, Cretaceous volcanic rocks and granodiorite porphyry, and Tertiary rhyolite. A veneer of pediment gravels covers much of the granite north of Ragged Top.

Identified Resources

No metallic mineral resources were identified in the study area; exposures of mineralized rock are erratically distributed and small. The study area lies northeast of the Silver Bell mining district, which has produced copper since 1865, but little mining has occurred within the study area. Blocks of claims have been established in the study area and along the southwest boundary. Among these claims is the Ragged Top mine, which reportedly produced some zinc-lead-copper ore (Cruver and others, 1982). South-southwest of the Ragged Top mine are two barite prospects, and other small prospects are present in and near the west side of the study area.

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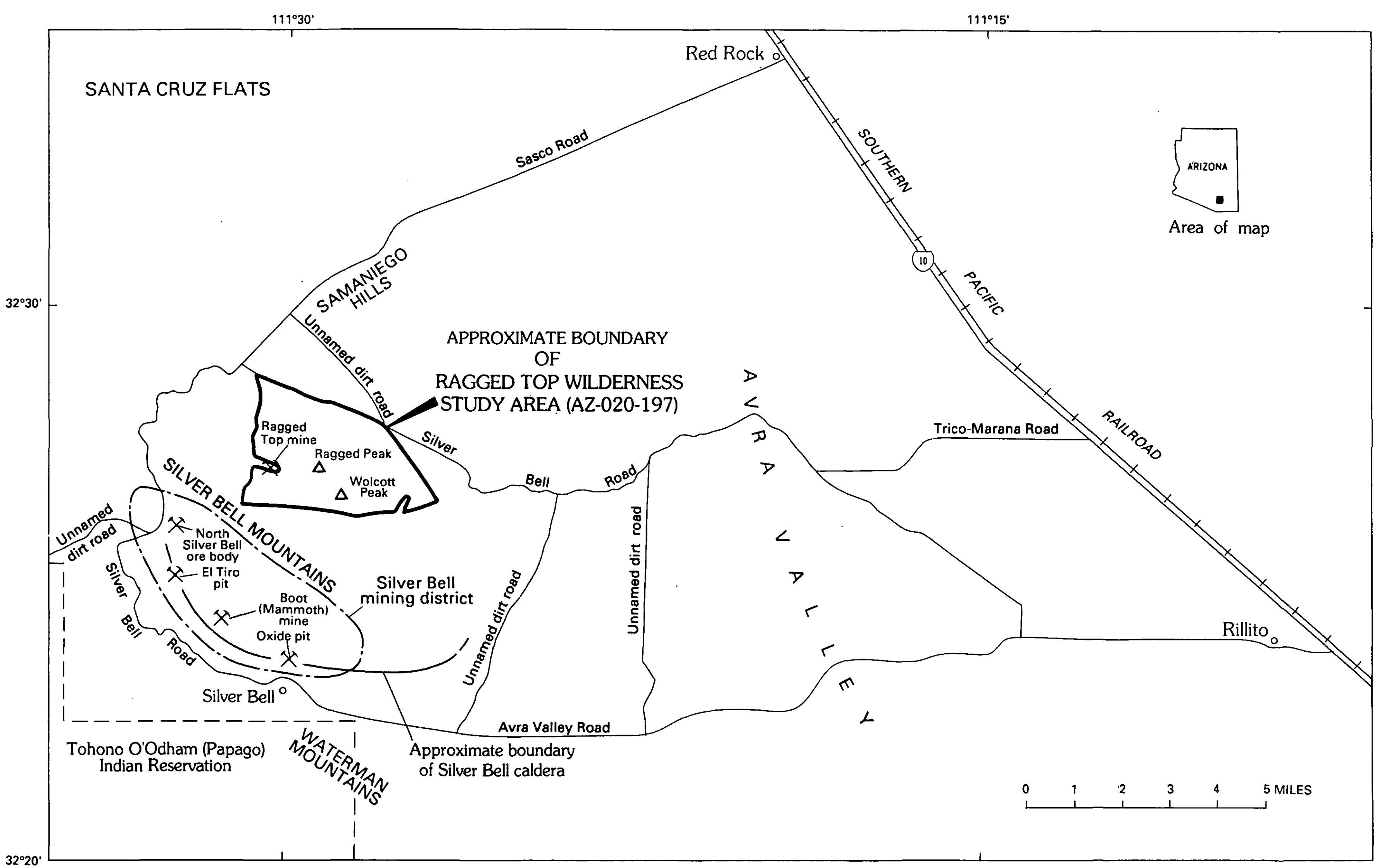

Figure 1. Index map showing location of Ragged Top Wilderness Study Area, Silver Bell mining district, southern boundary of Silver Bell caldera, and selected mines and prospects, Pima County, Arizona.

There are no oil and gas leases near the study area, and appropriate reservoir rocks are absent. Sand and gravel are not likely to be developed because other equally suitable material is present closer to markets.

Mineral Resource Potential

Primarily on the basis of strong geochemical anomalies, part of the southwest corner of the study area, which includes the Ragged Top mine area and known barite prospects, has high resource potential for gold, silver, lead, vanadium, barite, molybdenum, copper, and zinc in vein deposits (fig. 2). The adjacent parts of the study area to the north, west, and south, with less intense geochemical anomalies, have moderate resource potential for zinc, lead, barite, molybdenum, gold, silver, and copper in similar veins. An area of weak geochemical anomalies on the east side of the study area may also contain such veins; this area has low resource potential for gold, barite, lead, silver, zinc, and copper. The southern part of the study area has moderate resource potential for copper, silver, gold, and molybdenum in porphyry copper deposits; propylitic alteration is present in some rocks south of the Ragged Top fault, and three porphyry-copper ore bodies are known to the southwest within 2 mi of the study area. The east-central part of the study area has low resource potential for uranium, either in veins or disseminated throughout Proterozoic sedimentary rocks. Elsewhere in Arizona, similar Proterozoic rocks contain uranium. The northern part of the study area, underlain by granite, has low resource potential for thorium and rare-earth elements such as lanthanum in monazite or other accessory minerals and has low resource potential for quartz, feldspar, and mica for industrial uses in pegmatites. The study area has no potential for oil and gas or for geothermal energy resources.

INTRODUCTION

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

Character and Setting

The Ragged Top Wilderness Study Area (AZ–020–197) (fig. 1) is located in south-central Arizona about 35 mi northwest of Tucson. It covers 4,460 acres on the northeast side of the Silver Bell Mountains. The mountains are within the Sonora Desert region of the Basin and Range physiographic province, which in this part of Arizona is characterized by north- to northwest-trending mountain ranges separated by broad valleys. The valleys are made up of gravel-veneered pediments and local, deep, gravel-filled basins. The study area is underlain by two very different geologic terranes. The terrane north of the prominent Ragged Top fault (fig. 2) is composed of Proterozoic granitic and sedimentary rocks, and the terrane south of the fault is composed of Cretaceous volcanic, sedimentary, and intrusive rocks associated with the Silver Bell caldera and a later porphyry copper system. Extruded along the Ragged Top fault is a dome of Tertiary rhyolite that forms the rugged pinnacles of Ragged Top, for which the wilderness study area and the fault are named. Ragged Top is the collective name for 3,907-ft Ragged Peak, nearby 3,200-ft Wolcott Peak (U.S. Bureau of Land Management, 1987, p. 115), and adjacent lower peaks. The topography of Ragged Top is steep and rugged, while the wilderness study area elsewhere consists of relatively flat pediments or gentle hills.

The study area is accessible from Interstate 10 by the Avra Valley road from Rillito or by a gravel road running southwest from Red Rock, which is about 15 mi northwest of Rillito. Gravel roads providing easy access are present along the east, west, and north boundaries of the wilderness study area, and all parts of the study area are within walking distance of these roads. The climate is arid with hot summers and moderate winters; precipitation falls during summer thunder storms or winter rains.

The Ragged Top Wilderness Study Area lies in the Arizona upland subdivision of the Sonoran Desertscrub biotic community (Brown, 1982). The vegetation is dominated by shrubs; large intervening spaces contain layers of cacti. Trees found in the sudy area include the foothill palo verde (*Cercidium microphyllum*), cat-claw acacia (*Acacia greggii*), mesquites (*Prosopis* spp.), and ironwood (*Olneya tesota*). Most of the 20 species of cacti largely confined to, or best represented in, the Arizona upland subdivision are found here. The most spectacular cacti of the Sonoran Desert, the saguaro (*Carnegiea gigantea*), are found in large numbers in the study area and locally become a dense saguaro forest (Brown, 1982). The study area contains a population of Arizona rosewood (*Vauquelinia californica*) plants. Harris' hawks (*Parabuteo harrisii*) nest in the saguaro, and there is a small population of desert bighorn sheep (*Ovis canadensis nelsoni*) in the area.

Previous Investigations

Mining began in the Silver Bell Mountains in 1865, and by the early 1900's the disseminated copper mineralization within the district was recognized as having economic potential. Consequently, this area has received scrutiny by many people over the decades. Of particular note are the studies by Watson (1964), Richard and Courtright (1966), and Graybeal (1982), who described the porphyry copper deposits and discussed the structure and petrology of the Silver Bell Mountains. Recently, Sawyer (1987) interpreted the porphyry copper deposits as being structurally related to a Cretaceous caldera. Joseph (1982) described epithermal veins north of the main porphyry copper mineralization. Geologic quadrangle mapping of the Vaca Hills 15-minute quadrangle (Banks and Dockter, 1976) covers the west one-quarter of the study area.

Present Study

For the current study, USBM personnel reviewed sources of mineral information that include published and unpublished literature, USBM files, and mining claims and oil-and-gas lease records at the BLM State office in Phoenix, Ariz.

Field work by the USBM consisted of mapping and sampling mines and prospects. In all, 24 samples were collected: 16 from the Ragged Top mine, 4 from prospects within the wilderness study area, and 4 from prospects outside the area. All samples were analyzed for gold, silver, and 32 other elements by neutron activation; 4 of them were analyzed for copper, lead, zinc, manganese, molybdenum, and silver by direct coupled plasma emission spectroscopy, and 20 were analyzed for copper, lead, and zinc by wet chemistry and atomic absorption. Bondar-Clegg of Lakewood, Colo., performed the analyses; complete analytical data are available for inspection at the U.S. Bureau of Mines, Intermountain Field Operations Center, Building 20, Denver Federal Center, Denver, CO 80225.

Geologic interpretations of the study area and vicinity are based on dissertations by Watson (1964) and Sawyer (1987) and an unpublished map by D.A. Sawyer. Geologic interpretations of Precambrian rocks in the west one-quarter of the study area are based on mapping by Banks and Dockter (1976). USGS personnel conducted a reconnaissance geochemical survey of the study area in March 1987. On the basis of initial findings, more samples were collected in December 1987. Geophysical interpretations are based on published data.

Acknowledgments

We thank D.A. Sawyer for sharing information based on his Ph.D. study of the Silver Bell caldera and its relation to the porphyry copper mineralization and for assistance in sample collection; however, interpretations and conclusions are those of the authors. Personnel at the BLM Phoenix District Office provided helpful discussions on the mineral occurrences in the study area.

APPRAISAL OF IDENTIFIED RESOURCES

By Terry J. Kreidler
U.S. Bureau of Mines

Mining and Leasing Activity

The nearest mining district is the Silver Bell, about 1 mi southwest of the study area (fig. 1). The first production, in 1865, was oxidized copper ore that contained minor lead-silver concentrations and was mined from skarn at the Boot (Mammoth) mine, about 2 mi southwest of the study area. Production from vein and replacement ore bodies similar to those at the Boot mine continued intermittently until 1930. By 1909 the economic possibilities of low-grade disseminated copper in igneous rocks were recognized, and over the next 3 years extensive churn drilling partially delineated the Oxide and El Tiro ore bodies of the Silver Bell mine, 2 mi south and southwest of the study area, which at that time were subeconomic. ASARCO began further exploration drilling on the Silver Bell porphyry copper deposits in 1948 and started production in 1954 (Richard and Courtright, 1966, p. 157). The mine has not operated since 1984; the only production since then has been from precipitate recovery (ASARCO, annual report, 1986). Total production from the district between 1885 and 1981 was 1.3 billion lb of copper, about 50 million lb of lead, zinc, and molybdenum combined, about 6 million oz of silver, and about 2,000 oz of gold (Keith and others, 1983, p. 48). Another porphyry copper body, the North Silver Bell ore body, is in T. 11 S., R. 8 E., sec. 33, about 1 mi southwest of the study area (fig. 1). The company plans to develop the deposit pending higher copper prices (S.A. Anzalone, ASARCO, Inc., Tucson, Ariz., written commun., 1987).

Although 65 mining claims lie wholly or partly in the wilderness study area, little mining has taken place (fig. 1); 44 of those claims have been staked since the release of a USGS report in October 1988 (McHugh and others, 1988). The history of the Ragged Top mine, on the west boundary, is not known except that it was previously called the Franco Riqueza claims and reportedly produced some copper-lead-zinc ore (Cruver and others, 1982, p. 98). Two barite prospects, also near the west boundary, include one pit and one shallow shaft about 0.5 mi west-southwest of the Ragged Top mine.

There are no oil and gas leases in or near the study area. Ryder (1983) rated the petroleum potential of the study area as zero because the underlying Mesozoic and Tertiary igneous rocks are unsuitable source rocks; heat associated with them would have destroyed any hydrocarbons that may have existed.

Appraisal of Sites Examined

No metallic mineral resources were identified in the study area. The Ragged Top mine, two barite prospects, and five other prospect pits were examined. Geochemical anomalies in the samples from these sites (table 1) indicate that the southwestern part of the study area is possibly in the outer part of the propylitic alteration zone surrounding the three known ore bodies of the Silver Bell mine. However, the geochemical anomalies could also have resulted from a later, independent mineralizing hydrothermal event. The inferred subeconomic sand and gravel resources have no unique qualities, and similar materials are present closer to markets.

Ragged Top Mine

The Ragged Top mine is in an embayment on the west boundary of the wilderness study area (fig. 2). Workings consist of two adits and a shallow prospect shaft. The upper adit, 95 ft long, was driven along a mineralized zone and ends in a partially collapsed and filled winze, now only 30 ft deep. The lower adit, about 500 ft long and 70 ft below the upper adit, intersects the mineralized zone approximately 300 ft from the portal (Kreidler, 1987, fig. 2). Sixteen samples were taken in the adits, all but two from the mineralized zone.

A 200-ft-diameter alteration zone surrounds the deposit. From a distance, this zone appears yellowish orange because sulfide minerals, particularly pyrite, have been oxidized during weathering.

Sphalerite, galena, and minor amounts of chalcopyrite are present in the mineralized zone as small irregularly shaped pods and veinlets that fill fractures in a weathered and altered granodiorite porphyry. A select sample of sulfide minerals was taken from several veinlets and pods in both levels to ascertain the base-metal content of the ore minerals; the sample contains 29 percent zinc, 15.3 percent lead, and 1.56 percent copper (table 1, No. 3). However, the average metal content (0.95 percent lead, 0.82 percent zinc, and 0.24 percent copper) of the remaining 13 samples from the mineralized zone shows the low concentration of metals, even though lead and zinc contents are locally high (table 1).

Of the 13 mineralized samples, 3 contain concentrations of gold and silver much higher than the other samples (table 1, Nos. 8, 11, and 14). The 10 low-gold samples average about 140 parts per billion (ppb) gold, whereas the 3 anomalous samples average nearly 4,000 ppb. The 10 low-silver samples average about 12 parts per million (ppm) silver, while the 3 anomalous samples average 190 ppm.

Arsenic and barium, highly mobile elements in a mineralizing environment, are often used as geochemical-prospecting tools to locate deposits of base and precious metals. The arsenic content (8 to 41 ppm; table 1) of all samples from the Ragged Top mine is higher than average. The barium content (600 to 1,100 ppm; table 1) of 10 samples, including the two unmineralized ones, is higher than average. The average content for an igneous rock of intermediate composition is 2 ppm arsenic and 500 ppm barium (Levinson, 1980, p. 865).

The erratic distribution and small exposures of mineralized rock at the Ragged Top mine preclude the identification of base- or precious-metal resources.

Barite Prospects

Two barite prospects are approximately 2,500 ft west-southwest of the Ragged Top mine (fig. 2, Nos. 19–21).

The northernmost working, a partly collapsed shaft about 30 ft deep, was sunk on a 4.5-ft-wide, vuggy quartz vein that strikes N. 15°–20° E., dips vertically, and contains pods of barite. The barite pods vary from a few inches to about 1.5 ft long. Other minerals in the vein are pyrite, hematite, and limonite. The vein can be traced on the surface for about 20 ft before it disappears beneath alluvium. A select sample of barite pods contains 48.6 percent barium, equivalent to 82.6 percent barite, (table 1, No. 20); a grab sample of vein quartz collected from dump material contains 5,100 ppm barium (0.86 percent barite), less than 5 ppb gold, and 9 ppm silver (table 1, No. 19).

The second working, about 700 ft southwest of the shaft, is a prospect pit (fig. 2, No. 21) on a 2- to 6-ft-wide quartz-barite vein. Although not directly traceable on the surface, it appears to be an extension of the vein exposed at the shaft. The vein strikes N. 21° E. and dips vertically. Unlike the vein at the shaft, the quartz and barite here are more evenly distributed. A sample of the vein contains 4.8 percent barium (8.2 percent barite) (table 1, No. 21).

No barite resources were identified. The lowest commerical grade in use today is 92 percent barite ($BaSO_4$) (equivalent to a specific gravity of 4.2) for drilling fluids; other uses require grades between 95 and 98 percent (Brobst, 1983, p. 486, 496). Barite exposed in the prospect pit is too low grade to be of commercial interest. Selective mining of the vein and hand sorting of the barite pods at the shaft would yield concentrate containing about 80 percent $BaSO_4$ and would require further processing to reach minimum commercial grade. Even so, the limited exposure and unknown extent of the pod-bearing part of the vein indicate

Table 1. Selected geochemical data for U.S. Bureau of Mines samples from mines and prospects in and near Ragged Top Wilderness Study Area, Pima County, Arizona

[Gold (Au), silver (Ag), barium (Ba), and arsenic (As) determined by neutron activation, detection limits 5 parts per billion (ppb), 5 parts per million (ppm), 100 ppm, and 1 ppm, respectively; copper (Cu), lead (Pb), and zinc (Zn) determined by wet chemistry and atomic absorption, detection limits 0.01 percent for all elements; *, outside area boundary; —, not detected; na, not analyzed; >, greater than]

Sample									
Map No. (fig. 2)	Type or length (in.)	Au (ppb)	Ag (ppm)	Cu (percent)	Pb (percent)	Zn (percent)	Mn (percent)	Ba (ppm)	As (ppm)
North of wilderness study area									
*1	Grab	—	—	na	na	na	27.5	>3 pct	489
*2	26	—	—	0.14	0.02	0.01	.3	1,100	71
Ragged Top mine, mineralized zone									
*3	Select	58	8	1.56	15.3	29.0	—	760	20
*4	45	66	7	.08	.21	.49	—	820	34
*5	62	24	—	.01	.05	.08	—	1,100	24
*6	55	35	7	.01	.01	.14	—	890	33
*7	44	75	25	.13	1.12	1.39	—	250	28
*8	42	4,050	190	1.37	4.42	.98	—	390	35
*9	45	70	—	—	—	—	—	850	39
*10	38	84	10	.20	.56	.54	—	700	34
*11	48	3,660	140	.69	2.32	2.70	—	—	33
*12	30	597	36	.21	.41	1.06	—	380	41
*13	33	240	5	.19	3.15	1.65	—	600	39
*14	54	4,270	240	.04	.26	.22	—	—	29
*15	52	140	10	.06	.85	.83	—	300	33
*16	42	170	12	.16	.61	.58	—	850	38
Ragged Top mine, nonmineralized zone									
*17	37	64	—	—	—	.01	—	1,100	38
*18	39	11	—	.01	—	.01	—	880	8
Barite prospects									
19	Grab	—	9	—	.1	.02	na	5,100	27
20	Select	—	—	na	na	na	na	48.6 pct	45
21	35	—	—	na	na	na	na	4.8 pct	16
Near southwest corner of wilderness study area									
*22	27	170	63	1.3	4.2	3.1	na	1,400	10
23	55	220	—	.02	.23	.26	na	3,200	—
*24	42	34	280	1.8	3.3	4.5	na	1,800	—

that a drilling program would be required to evaluate the extent and grade of the barite deposit. The most crucial factor in any further development of this vein would be in establishing a local market for the final product. This seems unlikely as barite has not been mined in Arizona for several years and, as of September 1987, all domestic barite production comes from bedded and residual deposits (S.G. Ampian, U.S. Bureau of Mines, oral commun., 1987).

Other Prospects

Two prospect pits were found outside the northwest tip of the study area (fig. 2, Nos. 1, 2). At locality 1, psilomelane, a manganese mineral, covers the dump of a small pit dug in a volcanic rock of intermediate composition. None was seen in place, however, indicating that the manganese probably occurred in an isolated pod. A sample from the dump contains 27.5 percent manganese and more than 3 percent barium (table 1, No. 1). No resources were identified. The second pit, dug in an altered volcanic rock of intermediate composition, contains thin veinlets of quartz or calcite with no sulfides. A chip sample from the pit contains 1,100 ppm barium and 71 ppm arsenic but does not contain any appreciable metal concentrations (table 1, No. 2).

Three prospect pits are in or near the southwest corner of the wilderness study area. The northernmost pit (fig. 2, No. 22) is in highly altered granodiorite porphyry. No major structure is apparent. Malachite and azurite coat fractures, and the rock is heavily iron stained, but no sulfide minerals were seen. A chip sample from the pit contains anomalous concentrations of copper, lead, and zinc (table 1, No. 22). The two other prospect pits, along the south boundary of the wilderness study area (fig. 2, Nos. 23, 24), are in altered, highly fractured volcanic rocks of intermediate composition. At both localities, fracture surfaces are stained by iron oxides; at locality 24, malachite, azurite, and a black amorphous mineral, possibly an oxidized copper mineral, were also observed. Sample 23 does not contain any anomalous metal concentrations. Sample 24, however, contains anomalous concentrations of copper, lead, and zinc similar to those of sample 22 (table 1). Samples 22 to 24 contain 34 to 220 ppb gold, and samples 22 and 24 contain 63 and 280 ppm silver, respectively. No resources were identified.

All samples from the prospects discussed in this section contain anomalous amounts of barium, and all but two (Nos. 23, 24) contain anomalous arsenic.

Sand and Gravel

The Sonoran Desert is one of nature's great repositories of sand and gravel, and this study area is no exception. Sand and gravel are high-volume, low-unit-value commodities that require a local market for economic development. The occurrences in the Ragged Top Wilderness Study Area have no unique properties that would make them more valuable than other deposits closer to markets.

Summary

No unique mineral resources were identified in the Ragged Top Wilderness Study Area. The erratic distribution and generally small exposures of mineralized rock at the Ragged Top mine preclude the identification of resources. The barite-bearing quartz veins and the sand and gravel deposits are not now, or in the foreseeable future, of commercial value. There are no oil and gas leases.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

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Geology

The Ragged Top Wilderness Study Area can be evaluated for mineral resource potential only by considering the broader area that includes the Silver Bell porphyry copper deposits which are immediately to the south and which reflect geologic processes that have affected the study area. Thus, some geologic units are discussed below even though they do not crop out within the study area (fig. 2).

The study area is separated into two main geologic terranes by the major west-northwest-trending Ragged Top fault. Rocks north of the fault are correlated with the Middle Proterozoic granite and Middle Proterozoic sedimentary rocks of the Apache Group. South of the Ragged Top fault are Late Cretaceous volcanic, sedimentary, and intrusive rocks related to the formation of a caldera and the intrusion of rocks related to the porphyry copper system. Descriptions of the northern terrane are mainly from Watson (1964) and those of the southern terrane are mainly from Sawyer (1987).

The Proterozoic granite consists of porphyritic granite and cross-cutting, fine- to medium-grained granite (Banks and Dockter, 1976). The granite is composed mainly of quartz, orthoclase, plagioclase, and biotite and has minor chlorite, epidote, magnetite, apatite, and zircon. Near Ragged Top it has abundant iron-oxide minerals after magnetite and pyrite, and it contains some resistant quartz veins (Watson, 1964).

Proterozoic diabase is seen only in the granite as dikes and sills, too small to show at the map scale, and most likely predates deposition of the Apache Group. The rock consists mostly of small altered plagioclase laths and pyroxene, most of which have been altered to biotite, chlorite, and muscovite (Watson, 1964). The plagioclase and pyroxene form subophitic intergrowths. Quartz was introduced by later hydrothermal activity. These rocks contain veinlets of quartz, calcite, and iron-oxide minerals.

Sedimentary rocks of the Apache Group overlie the granite along an erosional unconformity. At the base of the Apache Group is a rounded pebble conglomerate of red to orange chert pebbles in a white siliceous matrix that is equivalent to the Barnes Conglomerate Member of the Dripping Spring Quartzite (Watson, 1964). Overlying the conglomerate are interbedded white quartzite and tan silty quartzite; one bed of silty rocks is colored red by hematite. These quartzite beds represent the upper part of the Dripping Spring Quartzite. No other formations of the Apache Group are present in the study area.

South of the Ragged Top fault (Sawyer, 1987) the oldest Late Cretaceous unit is the El Tiro biotite granite unit, containing perthitic potassium feldspar, quartz, plagioclase, and biotite. It predates formation of the Silver Bell caldera. This unit is present southwest of the study area, along the southwest side of the Silver Bell Mountains.

The Confidence Peak tuff unit consists of ash-flow tuff greater than 3,000 ft thick within the caldera. The tuff contains 5 to 20 percent lithic clasts and is compositionally a low-silica rhyolite. It contains abundant phenocrysts of plagioclase, quartz, and biotite plus a small amount of iron-titanium-oxide minerals. Large blocks of Paleozoic rocks

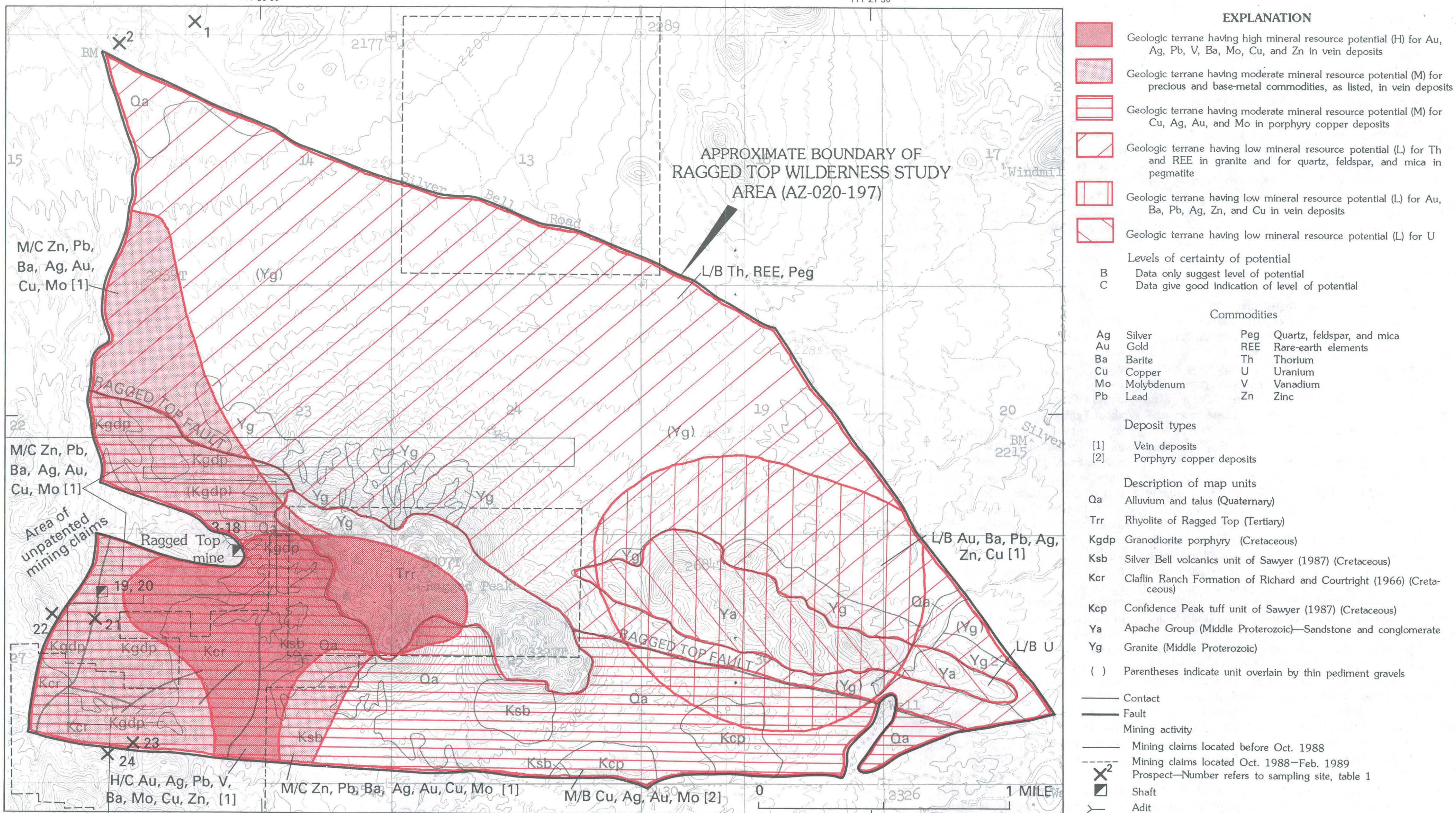

Figure 2. Mineral resource potential, geology, U.S. Bureau of Mines sampling sites, and locations of mines and prospects of Ragged Top Wilderness Study Area, Pima County, Arizona. Mineral resource data compiled by Gary A. Nowlan and Jocelyn A. Peterson, 1988. Geology modified from David A. Sawyer (written commun., 1987). Base from U.S. Geological Survey, 1:24,000 Silver Bell East and Silver Bell West quadrangles, 1988.

in a matrix of the Confidence Peak tuff unit are present locally. This unit extends into the southern part of the wilderness study area (fig. 2).

Overlying the Confidence Peak tuff unit is the Claflin Ranch Formation (Richard and Courtright, 1966) consisting of volcaniclastic sedimentary rocks. The Claflin Ranch Formation is more than 2,300 ft thick at its type section in the study area (sec. 26, T. 11 S., R. 8 E., Silver Bell West quadrangle) (Sawyer, 1987), where it is composed of volcaniclastic sedimentary rocks, debris-flow deposits, and primary pyroclastic ash-fall and ash-flow deposits. Elsewhere in the Silver Bell Mountains it is mostly composed of primary and reworked pyroclastic flow and fall deposits and minor intercalated sedimentary rocks. This unit covers about 0.5 mi^2 in the southwest corner of the wilderness study area.

The Silver Bell volcanics unit is a diverse sequence of andesitic and dacitic rocks that overlie and locally interfinger with the Claflin Ranch Formation. These volcanic rocks include flows, domes, hypabyssal intrusions, and related volcaniclastic debris-flow deposits and sedimentary rocks. The volcaniclastic rocks include heterogeneous matrix-supported mudflow deposits and monolithologic clast-supported traction breccias of andesite and dacite composition. Flows and domes are high-potassium dacites containing phenocrysts of plagioclase and biotite with quartz, hornblende, or pyroxene locally. These rocks represent deposits from a postcollapse composite volcano. They are present in the southern part of the wilderness study area, directly south of Ragged Top.

Granodiorite porphyry intrudes both the Confidence Peak tuff unit and the Claflin Ranch Formation. The largest intrusion is southwest of Ragged Top, partly within the wilderness study area, where it is largely truncated by the Ragged Top fault. The mineralogy of these intrusions is similar to that of the dacite in the Silver Bell volcanics unit, but the plutons are more phenocryst rich. The granodiorite porphyry has undergone strong propylitic alteration with the development of epidote. These plutons may be the cores of andesitic stratovolcanoes of the Silver Bell volcanics unit.

The youngest Late Cretaceous volcanic unit is the Mount Lord Volcanics, a densely welded tuff containing phenocrysts of sanidine, plagioclase, and quartz. The tuff is a compound cooling unit as thick as 650 ft. Field evidence suggests that this unit is an outflow facies from a source outside the Silver Bell caldera, and geochemical considerations support the conclusion that these rocks are unrelated to the caldera. This unit is found south and west of the study area.

The last Cretaceous igneous event was intrusion of the plutons and dikes associated with the porphyry copper deposits. These rocks range from monzodiorite to granodiorite to quartz monzodiorite porphyry; porphyry copper mineralization is most closely related to the quartz monzodiorite porphyry. These plutons were intruded along an arc on the southwest side of the Silver Bell Mountains along the exposed caldera ring faults. They do not crop out within the wilderness study area.

The jagged pinnacles of Ragged Top represent an eroded Oligocene flow-banded rhyolite dome extruded along the Ragged Top fault. The rhyolite contains sanidine, plagioclase, and biotite phenocrysts. Lithologically similar dikes found south of Ragged Top, nearer the porphyry copper deposits, are probably coeval. This rhyolite postdates movement on the Ragged Top fault, as it exhibits no displacement.

Pediment gravels and alluvium consist of poorly sorted, unconsolidated sand and gravel of local derivation. They primarily form a thin veneer over Middle Proterozoic granite in the northern part of the study area.

The major structures and lithologies of the southern part of the wilderness study area resulted from Late Cretaceous caldera volcanism. The following interpretations are from Sawyer (1987). The El Tiro biotite granite unit was intruded 73 million years ago (E.W. James and D.A. Sawyer, unpub. data cited by Sawyer, 1987, p. 32), prior to formation of the caldera. Collapse of the caldera coincided with the eruption of the Confidence Peak tuff unit, which formed a thick tuff sequence within the caldera and a thin outflow facies exposed in the West Silver Bell Mountains about 7 mi west of the study area. Large blocks of Paleozoic sedimentary rocks were enclosed within parts of the intracaldera tuff during caldera collapse. The volcaniclastic sediments of the Claflin Ranch Formation were derived from the reworking of unconsolidated tuff in the uppermost part of the Confidence Peak tuff unit. Pyroclastic flows and fallout materials higher in the Claflin Ranch Formation indicate the close temporal and genetic ties between the intracaldera tuff of the Confidence Peak tuff unit and the Claflin Ranch Formation. Thus, the Claflin Ranch Formation is considered the moat-filling sedimentary material of the caldera. Ring faults outline the structural margin of the caldera and controlled the emplacement of several plutons of the porphyry-copper-forming system. These may have been preexisting regional faults that were reactivated during caldera formation. The Silver Bell volcanics unit forms a post-collapse composite volcano and associated rocks that were deposited on the intracaldera accumulation. Granodiorite porphyry intrusions may be the roots of such composite volcanoes or may have formed during magmatic resurgence following caldera collapse. After intrusion of the granodiorite porphyry, but before intrusion of the quartz monzodiorite porphyry suite, the Mount Lord Volcanics were deposited from a source outside the Silver Bell Mountains. Monzodiorite porphyry intrusions predate the mineralization, but grade into later porphyry-copper-related quartz monzodiorite porphyries. The hydrothermal activity associated with the porphyry copper mineralization accompanied the final Late Cretaceous intrusive activity.

The Ragged Top fault is a major structural feature that bisects the study area. Movement along the fault was largely strike slip and truncated the north edge of the caldera structure.

Geochemistry

Stream-sediment samples represent a composite of material eroded from all parts of the drainage basin of the stream sampled. Panned-concentrate samples derived from stream sediment contain selectively concentrated minerals that may include ore-related elements that are not easily detected in stream-sediment samples. Samples of drainage sediment were collected in March 1987 at 11 sites on ephemeral streams in the study area (fig. 3). At each stream site three samples were collected . One, here called a stream-sediment sample, was air dried and then sieved through a 30-mesh stainless-steel sieve. A 30-mesh, rather than the more conventional 80-mesh, sieve was used to lessen the possible dilution effects of wind-blown material in this desert environment. The other two samples, each derived from 20 lb of stream sediment, were panned until 1 to 4 oz remained and are here called concentrate samples. One of these samples was further concentrated by heavy liquids and magnetic separations to produce a nonmagnetic heavy-mineral-concentrate sample consisting of accessory minerals such as zircon, sphene, and apatite, and nonmagnetic ore minerals. The other concentrate sample received no further treatment before chemical analysis for gold and is here called a raw panned-concentrate sample.

The stream-sediment samples and nonmagnetic heavy-mineral-concentrate samples were analyzed by emission spectrography for more than 30 elements. The stream-sediment samples were also analyzed (1) for gold by graphite-furnace atomic absorption, (2) for arsenic, bismuth, cadmium, antimony, and zinc by inductively coupled plasma spectroscopy, and (3) for uranium by fluorimetry. The raw panned-concentrate samples were analyzed for gold by flame atomic absorption.

Gold analyses of raw panned-concentrate samples have several advantages over gold analyses of nonmagnetic heavy-mineral-concentrate samples. The first advantage is that a large sample of raw panned-concentrate (from 6 to 27 g in this study) is analyzed, and thus problems of inhomogeneity are lessened. In contrast, only 5 mg of nonmagnetic heavy-mineral concentrate are analyzed. The second advantage is that preparation of raw panned-concentrate samples for analysis takes only a few simple steps, so chances of losing gold particles are minimized. The third advantage is that the analytical sensitivity for gold is less than its average bedrock crustal abundance (0.002–0.005 ppm, Rose and others, 1979, p. 557) if the gold concentration of the raw panned-concentrate sample is converted to its concentration in the original stream sediment. The analytical method used in the analysis of raw panned-concentrate samples will detect 0.05 ppm gold in a 10-g sample (table 2).

Additional concentrate samples were collected at 15 sites in December 1987, and 28 samples of mineralized and altered bedrock were also collected then. The concentrate samples were collected and treated in the same manner as the previous ones except that, in most cases, only 10 lb of stream sediment were panned. To establish bedrock background concentrations, analysis of the mineralized and altered rocks was supplemented by the analysis of seven samples of relatively unaltered bedrock that had been collected in 1982 by D.A. Sawyer. Rock samples were analyzed by semiquantitative direct-current arc emission spectrography for more than 30 elements. In addition, they were analyzed for arsenic, bismuth, cadmium, antimony, and zinc by inductively coupled plasma–atomic emission spectroscopy, for mecury by cold-vapor atomic absorption, for telllurium and thallium by flame atomic absorption, for fluorine by ion selective electrode, and for tungsten by visible spectrophotometry.

Sampling locations, tabulations of the analytical results, descriptions of sample preparation methods, descriptions of rock samples, and descriptions and references for the analytical methods are given by McHugh and others (1988).

Table 2 lists selected elements determined in each type of drainage sample, the lower and upper limits of determination, the range of concentrations, the 50th percentile value, and the threshold (highest background) concentrations. Threshold values were established by both subjectively and statistically examining the data and by comparing the data with geochemical data from mineral resource assessments of the Ajo and Lukeville 1° by 2° quadrangles (Theobald and Barton, 1983, 1987) and the Table Top Mountain, Baboquivari Peak, and Coyote Mountains Wilderness Study Areas (Peterson and others, 1988; Nowlan and others, 1989).

Three geochemically anomalous areas were delineated on the basis of analyses of concentrate and stream-sediment samples (fig. 3). Extremely high concentrations of gold, silver, lead, vanadium, barium, and strontium characterize most concentrate samples from area A (McHugh and others, 1988). Some concentrate samples also contain anomalous concentrations of molybdenum, copper, zinc, cadmium, and bismuth. Concentrations of lead, vanadium, barium, and strontium are as high as 1 percent (10,000 ppm) or greater. Concentrations of gold, silver, and copper are 1,000 ppm or greater. Concentrations of zinc, molybdenum, and bismuth are as high as 300–700 ppm, and the concentration of cadmium is as high as 70 ppm. The most intensely anomalous part of area A is on the southwest slopes of Ragged Top. The relative significance of the anomalous elements (listed above) in area A, as judged from the number and magnitude of anomalous concentrations, is Au=Ag>Pb=V>Ba=Sr>(Mo>Cu>Zn>Cd=Bi).

Only minimal prospecting has occurred near the most intensely anomalous part of area A, and the source of the anomaly is unknown.

Anomalous area B adjoins the north, west, and south margins of area A. The intensity of the geochemical anomalies is less in area B than in area A, and there are no anomalous concentrations of vanadium, cadmium, and bismuth. Area B is divided into two parts, B-north and B-south. The suites of anomalous elements in B-north and B-south are similar except that B-north lacks anomalous concentrations of strontium and B-south lacks anomalous concentrations of copper, and the order of importance of anomalous elements is essentially the opposite. The relative significance of anomalous elements in B-north is Zn=Pb>Ba> (Ag=Au>Cu>Mo), and that in area B-south is Mo>Sr>Ba>(Ag=Au>Pb=Zn). The geochemistry of drainage samples from anomalous area B is consistent with the mineralogy of veins that have been prospected or mined in that area. Mineralized rock samples collected by the USBM from the Ragged Top mine in area B-north contain as much as 4 ppm gold (Kreidler, 1987). Mineralized and altered rocks collected in area B by the USGS contain from 0.002 ppm to as much as 0.38 ppm gold (McHugh and others, 1988). Seven samples of relatively least altered Upper Cretaceous rocks collected in and near area B contain less than 0.001 ppm gold.

Anomalous area C lacks the geochemical intensity of areas A and B. Concentrations of gold and silver are generally near the lower limits of determination, and concentrations of barium are not universally greater than

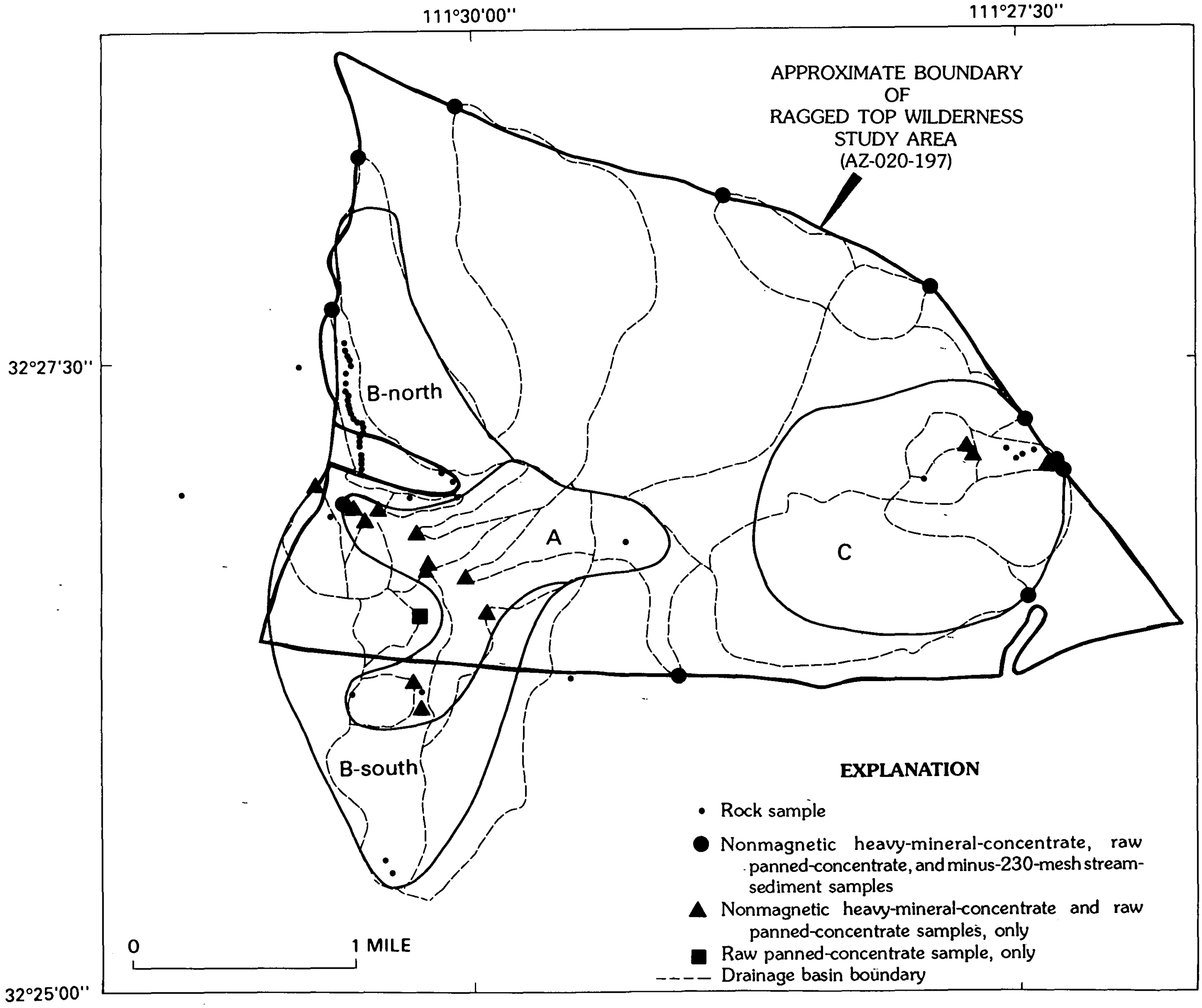

Figure 3. Stream-sediment and rock sample sites and areas of geochemical anomalies in Ragged Top Wilderness Study Area, Pima County, Arizona. Anomalous area A, B, and C discussed in geochemistry section of text.

Table 2. Geochemical statistics for elements present in anomalous amounts in drainage-basin samples collected in 1987 in and near the Ragged Top Wilderness Study Area, Pima County, Arizona

[Results based on 26 raw panned-concentrate samples, 25 nonmagnetic heavy-mineral-concentrate samples, and 11 stream-sediment samples, except as noted. Concentration determined by emission spectrographic methods except that Au-a was determined by atomic absorption and Sb-i and Zn-i were determined by inductively coupled plasma spectroscopy. ppm, parts per million; 50th percentile, concentrations in one-half of samples were equal to or lower than this number; N, not detected; G, greater than upper limit of determination; L, detected below lower limit of determination; <, less than value shown]

Element	Limits of Determination (ppm)		Concentration (ppm)			
	Lower	Upper	Minimum	Maximum	50th percentile	Threshold
Raw panned concentrate						
Gold (Au-a)	[1]0.05	([2])	<0.02	150	<0.05	<0.05
Nonmagnetic heavy-mineral concentrate						
Gold (Au)	20	1,000	N	G	N	N
Silver (Ag)	1	10,000	N	1,000	N	N
Barium (Ba)	50	10,000	700	G	G	3,000
Bismuth (Bi)	20	2,000	N	300	N	N
Cadmium (Cd)	50	1,000	N	70	N	N
Copper (Cu)	10	50,000	N	1,000	20	30
Molybdenum (Mo)	10	5,000	N	500	N	N
Lead (Pb)	20	50,000	L	G	700	700
Strontium (Sr)	200	10,000	N	G	700	1,500
Vanadium (V)	20	20,000	30	15,000	150	500
Zinc (Zn)	500	20,000	N	700	N	N
Minus-30-mesh stream sediment						
Gold (Au)[3]	0.001	([2])	<0.001	0.01	0.001	<0.001
Silver (Ag)	.5	5,000	N	.5	N	N
Barium (Ba)	20	5,000	300	1,500	500	500
Copper (Cu)	5	20,000	20	70	30	30
Lead (Pb)	10	20,000	30	300	50	50
Antimony (Sb-i)	2	([2])	<2	14	<2	<2
Zinc (Zn)	200	10,000	N	200	N	N
Zinc (Zn-i)	2	([2])	31	150	77	60

[1] Based on 10-gram sample.
[2] Upper limit is open ended.
[3] Based on eight samples.

10,000 ppm as is the case in areas A and B. Area C is unique in that antimony is anomalous in several samples of stream sediment; concentrations are as high as 14 ppm. The relative significance of anomalous elements in area C is Au=Sb>Ba>Pb>(Ag=Bi>Zn=Cu). Samples of quartz veins, diabase, and altered granite from area C contain from less than 0.001 ppm to 0.044 ppm gold.

The Proterozoic igneous and sedimentary terrane north of the Ragged Top fault is geochemically different from the Late Cretaceous volcanic-intrusive-sedimentary terrane south of the fault. Area A and most of area B are south of the Ragged Top fault. Mildly anomalous area C, which lies mostly north of the Ragged Top fault, is primarily underlain by Proterozoic granite, diabase, and sedimentary rocks. Drainage samples from areas north of the Ragged Top fault have high, but not anomalous concentrations of beryllium, boron, gallium, scandium, tin, uranium, and yttrium.

The suites of elements found in anomalous concentrations in samples from areas A, B, and C are consistent with an interpreted occurrence of polymetallic or epithermal veins conforming to one or more of several mineral deposit models (Cox, 1986; Mosier and others, 1986a, b, c). The geochemical patterns of areas A and B (fig. 3) suggest zoning related to a mineralized area southwest of Ragged Top. Another possiblity is that multiple independent stages of vein mineralization may have occurred. Such veins may have resulted from the mineralizing processes that produced the nearby Late Cretaceous North Silver Bell porphyry copper deposit, from processes associated with the Oligocene extrusion of the rhyolite of Ragged Top, or both.

More work is needed to determine the temporal relation of mineralization in and near the study area.

Geophysics

Gravity and Aeromagnetic Data

The Ragged Top Wilderness Study Area is covered by regional gravity (Lysonski and others, 1980; Defense Mapping Agency Aerospace Center, 1974, 1975) and aeromagnetic (U.S. Geological Survey, 1980) surveys having sufficient resolution to define anomalies with areas of several square miles. Complete (terrain-corrected) Bouguer gravity anomalies were determined from 13 observation points immediately surrounding the study area and from about 15 additional points outside of but within 1.2 mi of the area shown in figure 4. Magnetic anomalies were determined from total-field measurements made along seven east-west flightlines, three of which intersect the study area itself (fig. 5), spaced 1 mi apart at a nominal altitude of 4,000 ft above sea level.

The Bouguer gravity anomaly map (fig. 4) is dominated by a quasi-linear gradient of almost 3.2 milligals/mi. Anomaly values decrease southwestward along the common flank of a broad high centered north of the study area and a local low centered about 3 mi southwest of the area. The high is probably associated with the moderately dense Proterozoic granite that extends in the subsurface northeast of the study area and the Cretaceous granodiorite porphyry that extends to the south-southwest. Alternatively, the high may be associated with the Tertiary rhyolite. Anomaly values decline northwest of the high to a region about 6 mi northwest of the study area where low-density basin fill is at least 2 mi thick. Likewise, anomaly values decrease east of the high to a region 10 mi east of the study area where similar basin fill reaches a thickness of about 2 mi (Oppenheimer and Sumner, 1980). The low in the southwest corner of figure 4 is unusual in that it is a local small-amplitude feature that owes its geometry partly to a small-amplitude high farther southwest, which may be associated with moderately dense Paleozoic sedimentary rocks. Thus, the low is attributable to a veneer of low-density sediments that abut sedimentary rocks to the southwest. The region of most intensive mining and prospecting in the Silver Bell district underlies the dominant gradient rather than a high or low. Unfortunately, the gravity observation points are too sparsely distributed to determine whether a characteristic microgravimetric signature has been superposed on this gradient in this region.

The magnetic anomaly map (fig. 5) is characterized by four main features: (1) a prominent east-trending high that transects the center of the study area and extends discontinuously to a high in the northeast corner of the figure; (2) a large-amplitude northwest-striking low immediately southeast of the area; (3) a cluster of circular highs southwest of this low; and (4) a broad low that occupies the

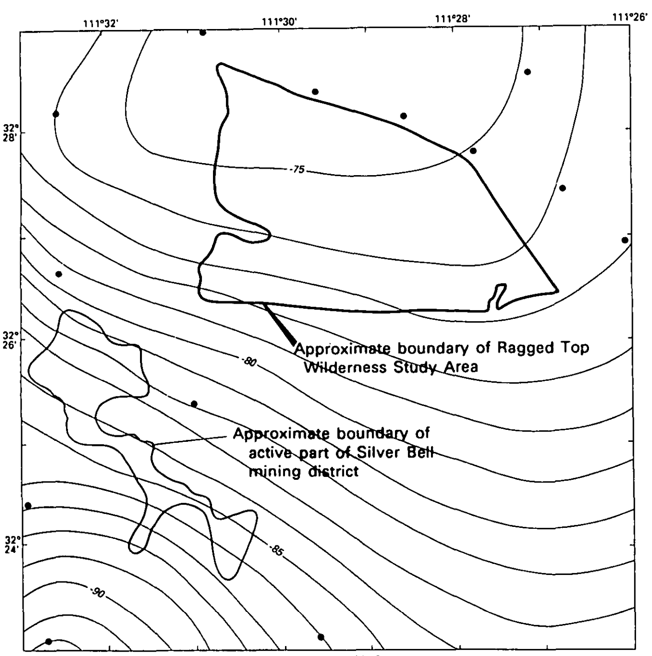

Figure 4. Bouguer gravity anomaly map of vicinity of Ragged Top Wilderness Study Area, Pima County, Arizona. Contour interval 1 milligal. Dots represent gravity observation points.

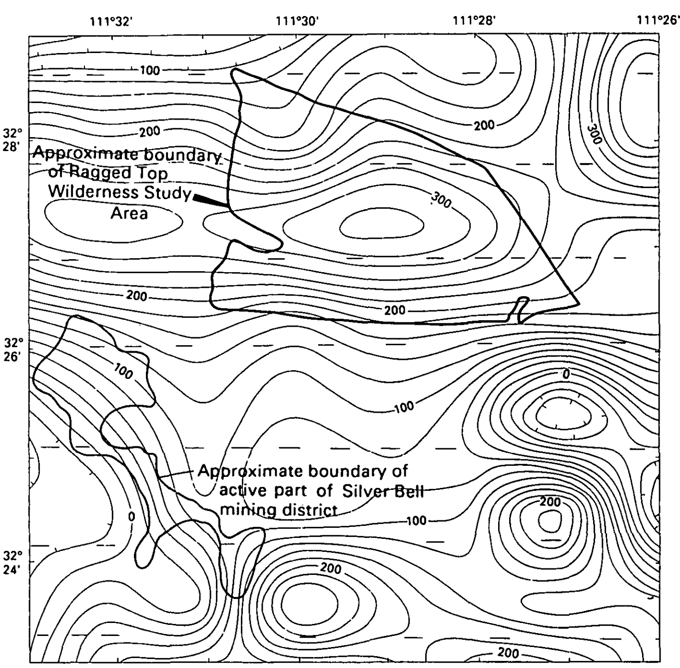

Figure 5. Aeromagnetic anomaly map of vicinity of Ragged Top Wilderness Study Area, Pima County, Arizona. Contour interval 20 nanoteslas; hachures indicate closed area of lower anomaly value. Flightline traces are dashed.

southwest corner of the figure and is directly west of the large-amplitude low and its neighboring cluster of circular highs. Two caveats should be noted: (1) these magnetic anomalies are strongly influenced by the topography of exposed magnetic rocks because the survey was flown at a constant barometric elevation, and (2) many of the contours defining anomaly shape near maximums or minimums are between flightlines and are inferred by interpolation. However, the anomaly map remains useful for correlating anomalies to known or inferred sources.

The prominent east-trending magnetic high appears to correlate spatially much more with mapped Cretaceous granodiorite porphyry, presumed to be moderately to strongly magnetic, than with mapped Proterozoic granite, known to be weakly to moderately magnetic elsewhere in central and southern Arizona. However, the anomaly closely parallels the trace of the Ragged Top fault and the outcrop of the rhyolite emplaced along the fault. If the rhyolite is magnetic, the somewhat discontinuous extension of this high northeast of the study area raises the possibility that intrusive equivalents of the rhyolite may underlie the region in the northeast corner of the figure. Geologic mapping indicates that the Cretaceous granodiorite does not extend into the subsurface north of the Ragged Top fault. The large-amplitude northwest-trending magnetic low probably is not associated with reversely magnetized volcanic or intrusive rocks as are many other lows in southern Arizona. Rather, it appears to be a polarization feature over relatively nonmagnetic tuffs and sedimentary rocks, coupled to the cluster of circular highs south of the low. The cluster of highs is caused by normally magnetized intrusive rocks of intermediate composition. The region of intensive mining and prospecting in the Silver Bell district underlies a magnetic gradient rather than a high or low, just as is the case with the gravity anomaly map. It is possible that this magnetic gradient, forming the northeast margin of the broad low in the southwest corner of figure 5, is underlain by pervasively altered rocks associated with the porphyry copper mineralization.

The regional geophysical data do not suggest regional evidence that anomaly features, and thus causative sources, of the Silver Bell mining district extend northeastward into the wilderness study area. Rather, these gradients extend only to areas southwest and immediately south of the study area.

Aerial Gamma-Ray Spectrometry

Aerial gamma-ray spectrometry measures the near-surface (less than 2 ft) distribution of potassium (K), uranium (eU), and thorium (eTh). The e (for equivalent) prefix denotes the potential for disequilibrium in the uranium and thorium decay series. Because the distribution of these elements is controlled by geologic processes, aerial gamma-ray measurements can be used in geologic mapping, mineral exploration, and understanding of geologic processes.

The spectrometry data used for this report were obtained between 1974 and 1981 for the National Uranium Resource Evaluation (NURE) program of the U.S. Department of Energy. Flightline spacing was usually at 3- to 6-mi intervals, which yields data suitable for producing contour and other maps at scales of 1:500,000 and smaller. All NURE flights were 400 ft above ground level. At this altitude, terrestrial gamma radiation can be detected along a swath 800 ft wide along the flightline. One north-south flightline crosses the east side of the study area. Spectrometry data that include the study area are presented on contour maps and color-composite image maps (Duval, 1983) at scales of 1:500,000 and 1:1,000,000. The data described below were derived from the NURE report for the Tucson 1° by 2° quadrangle (Texas Instruments, Inc., 1978).

Radioelement maps that include the Ragged Top Wilderness Study Area indicate that it is characterized by radioelement concentrations of 2.0 to 2.5 percent K, 3 to 4 ppm eU, and 8 to 12 ppm eTh. These concentrations are probably of reasonable (not anomalous) levels for the Proterozoic crystalline rocks, Cretaceous volcanic, sedimentary, and intrusive rocks, and Tertiary intrusive rocks that are present in the study area. There is no indication that these concentrations relate in any way to alteration patterns of the Silver Bell porphyry copper system. The sparse flightline coverage of the study area precludes deriving any direct information on mineral resource potential from the aerial gamma-ray data.

Mineral and Energy Resource Potential

Vein Deposits

An area near the southwest corner of the Ragged Top Wilderness Study Area has high resource potential, certainty level C, for gold, silver, lead, vanadium, barite, molybdenum, copper, and zinc in vein deposits (fig. 2). An area north, west, and south of this area of high potential has moderate resource potential, certainty level C, for barite, copper, gold, lead, molybdenum, silver, and zinc. These two areas have been distinguished primarily on the basis of geochemical anomalies found during this study. Known mines and prospects in that part of the study area, however, already indicate possible mineral resource potential. An additional area on the east side of the study area has low resource potential, certainty level B, for gold, barite, lead, silver, zinc, and copper in vein deposits on the basis of geochemical studies.

Deposits at the Ragged Top mine and the barite prospects lie within areas designated here for vein deposits. Joseph (1982) conducted a detailed study of the barite and base-metal veins and concluded that they were formed by a hydrothermal system younger than, and distinct from, the system that formed the Silver Bell porphyry copper deposits. Joseph determined that an early stage of quartz deposition that cemented breccias was followed by quartz-calcite-hematite-barite-fluorite-vein mineralization. This early mineralization is cut by late-stage fluorite-barite-galena-sphalerite-quartz-calcite veins. Outcrop patterns suggested to Joseph (1982) that the early veins fill fault zones and fractures that show right-lateral offsets, whereas the later veins are present along normal faults. Her fluid-inclusion studies indicate that the hydrothermal fluids ranged from 370 to 160 °C and that mineral deposition probably was a result of simple cooling. Whether the possible hydrothermal system on the east side of the study area is related to the veins on the west side is unknown.

Porphyry Copper Deposits

The part of the study area south of the Ragged Top fault has moderate resource potential for copper, silver, gold, and molybdenum, certainty level B, in porphyry copper deposits. The known porphyry copper ore bodies in the mining district have been emplaced along bounding faults on the southwest side of the caldera structure, which the Ragged Top fault truncates on the north. Although no porphyry copper deposits have been found to date in the study area, the margin of the North Silver Bell deposit is about 1 mi southwest of the study area. Propylitic alteration in the southwestern part of the study area could be related to the known porphyry ore bodies or possibly to a buried, as yet undiscovered, ore body. Without detailed mapping of the alteration, sophisticated geophysical studies, and a drilling program, it is difficult to determine whether or not a porphyry copper deposit might lie buried beneath the volcanic and sedimentary rocks of the study area.

Uranium in the Apache Group

Outcrops of the Apache Group, here solely composed of Dripping Spring Quartzite, have low resource potential, certainty level B, for uranium. One stream-sediment sample from the northeast side of the wilderness study area contains a threshold concentration of 7.5 ppm uranium. In Gila County, Ariz., the Dripping Spring Quartzite hosts uranium deposits (Granger and Raup, 1959; Nutt, 1982). The uranium-bearing stratiform disseminated ore bodies were formed during diagenesis of volcaniclastic potassium-rich carbonaceous siltstone deposited in an intertidal environment (Nutt, 1982). Later intrusion of diabase sills remobilized the uranium into veins. The rocks of the study area have been given only low resource potential for uranium for several reasons. First, the closest known deposits are in Gila County, more than 50 mi away. Second, most of the exposed rocks are coarser than siltstone and appear to be clastic rather than volcaniclastic. Third, the diabase in this area intrudes only the Proterozoic granite and thus may be older than the Apache Group in this region (Watson, 1964). Fourth, uranium concentrations in stream-sediment samples from near outcrops of the Apache Group are generally within the normal range for granite, sandstone, and shale (1.7–3.9 ppm; Rose and others, 1979, p. 578).

Thorium, Rare-Earth Elements, Quartz, Feldspar, and Mica in Granite

The Proterozoic granite north of the Ragged Top fault has low resource potential, certainty level B, for thorium and rare-earth elements such as lanthanum in monazite or other accessory minerals and for industrial quartz, feldspar, and mica in pegmatites. There is little evidence within the study area that the granite contains these commodities because geochemical indications of rare-earth elements and thorium are slight and because the pegmatites in the granite are very small and uncommon relative to pegmatites seen elsewhere in Proterozoic rocks of southern Arizona (Peterson and others, 1988).

Energy Resources

The Ragged Top Wilderness Study Area has no potential, certainty level D, for oil and gas or for geothermal energy resources because the area lacks suitable reservoir rocks and because, in the case of oil and gas, any hydrocarbons would likely have been destroyed by heat generated during the Cretaceous igneous activity.

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APPENDIXES

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

LEVELS OF RESOURCE POTENTIAL

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

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

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

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

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

LEVELS OF CERTAINTY

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

LEVEL OF RESOURCE POTENTIAL ↑

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

LEVEL OF CERTAINTY →

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.
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RESOURCE/RESERVE CLASSIFICATION

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

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

GEOLOGIC TIME CHART

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

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

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

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