Mineral Resources of the Rimrock, Sand Canyon, Little Rimrock, and Pinyon Wilderness Study Areas, Cibola County, New Mexico

U.S. GEOLOGICAL SURVEY BULLETIN 1734–G

Chapter G

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MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
WEST-CENTRAL NEW MEXICO

DEPARTMENT OF THE INTERIOR
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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 Rimrock (NM–020–007), Sand Canyon (NM–020–008), Little Rimrock (NM–020–009), and Pinyon (NM–020–010) Wilderness Study Areas, Cibola County, New Mexico.

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PLATE

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FIGURES

Mineral Resources of the Rimrock, Sand Canyon, Little Rimrock, and Pinyon Wilderness Study Areas, Cibola County, New Mexico

By Charles H. Maxwell, Gary A. Nowlan, *and*
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ABSTRACT

In 1987 the U.S. Bureau of Mines and the U.S. Geological Survey conducted investigations to appraise the identified resources and assess the mineral resource potential of the Rimrock (NM–020–007), Sand Canyon (NM–020–008), Little Rimrock (NM–020–009), and Pinyon (NM–020–010) Wilderness Study Areas, Cibola County, N. Mex. These investigations showed that the study area contains no metallic mineral resources. Inferred subeconomic resources of sandstone and sand in the study areas have no unique characteristics and are not likely to be developed. Known coal beds are thin, impure, and subbituminous; they are not currently classified as a resource and are unlikely to be a resource in the future. The study areas have a low resource potential for undiscovered metals, oil and gas, coal, and geothermal energy.

SUMMARY

Character and Setting

The Rimrock, Sand Canyon, Little Rimrock, and Pinyon Wilderness Study Areas are discussed together in a single report because they are contiguous and have similar geology and resources. They are adjacent to El Malpais National Monument (fig. 1) and are part of the El Malpais National Conservation Area. The areas begin about 20 mi (miles) south of Grants, N. Mex., and continue southward for another 20 mi, south of Interstate Highway 40 and east of State Highway 117. The study areas contain a total of about 60,646 acres. The study areas are underlain by 1,000–1,500 ft (feet) of interfingering Cretaceous-age (see geologic time chart in Appendix) shale and sandstone, and as much as 500 ft of Jurassic eolian sandstone. The Jurassic sandstone forms the mesas and vertical cliffs along State Highway 117, and forms a natural arch in the Rimrock study area. The overlying shale and sandstone to the east form steep slopes covered by landslides, rising 1,000 ft to the basalt cap of Cebollita Mesa.

Identified Mineral Resources

A mineral survey of the areas by the U.S. Bureau of Mines found no mines, prospects, or mineralized areas. Coal beds in the Pinyon, Sand Canyon, and Little Rimrock study areas were tested. These known thin beds of impure subbituminous coal are not currently classified as a resource and are not likely to be a resource in the future. The sandstone in the study areas is classified as an inferred subeconomic resource suitable for use as crushed rock. The common variety sand in the study areas is also classified as an inferred subeconomic resource. Because vast quantities of similar sandstone and sand are available throughout the region, it is highly unlikely that these resources will ever be developed.

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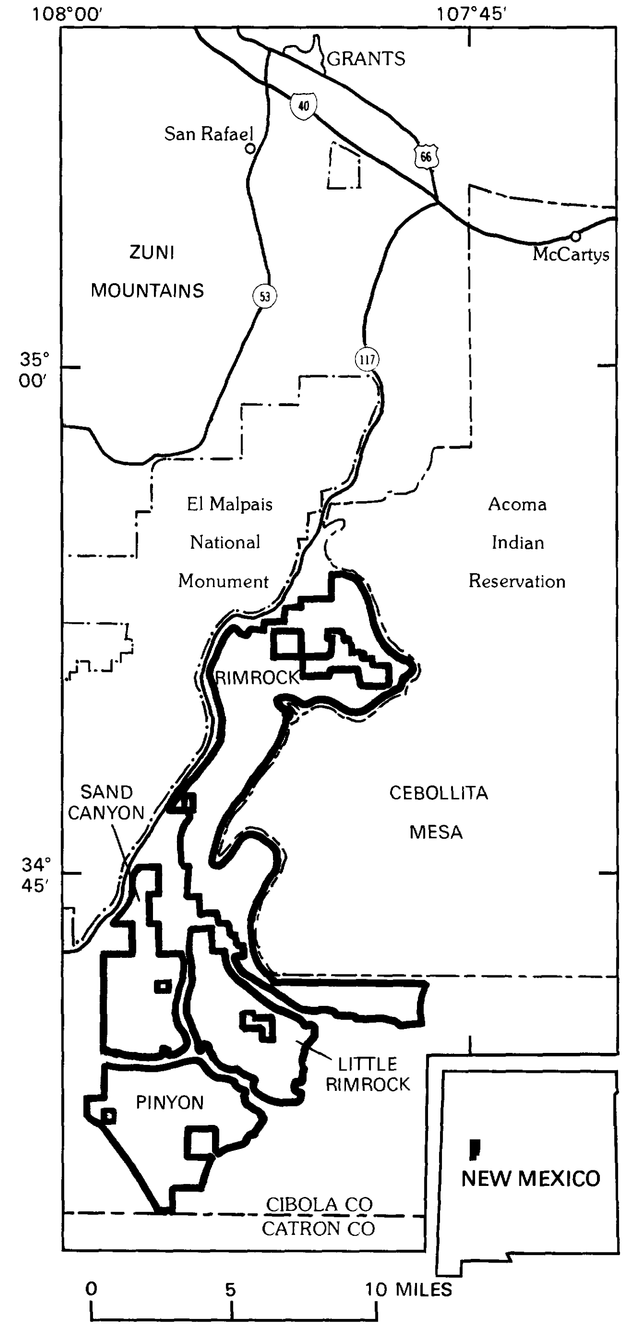


Figure 1. Location of the Rimrock, Sand Canyon, Little Rimrock, and Pinyon Wilderness Study Areas, Cibola County, N. Mex.

Mineral Resource Potential

Sediment samples from 116 sites on ephemeral streams were collected and analyzed by the U.S. Geological Survey for a reconnaissance geochemical survey. Analytical results show that very few samples had anomalous concentrations of any element. Most samples gave values near or below the average crustal abundance for shale and sandstone.

The study areas are on the northeast flank of a broad gravity low, which could reflect a deep magma chamber. A local negative deflection on the gravity low and a corresponding large magnetic low, just outside the southeast boundary of the Pinyon study area, may both be caused by a thick sedimentary section. However, magnetic highs circling the magnetic low could indicate a ring-shaped plutonic complex in the basement.

No mineralized areas or occurrences of metallic minerals were found in the study areas, and none of the geochemical samples had anomalous concentrations. Therefore the resource potential for undiscovered metals is low (fig. 2). The lack of source rocks in the region indicates that the potential for undiscovered oil and gas is low. The resource potential for the occurrence of coal beds other than those that are known in the areas is low. Heat flow in the study areas is only slightly above the continental average, and, hence, the resource potential for geothermal energy is low.

INTRODUCTION

The Rimrock (NM–020–007), Sand Canyon (NM–020–008), Little Rimrock (NM–020–009), and Pinyon (NM–020–010) Wilderness Study Areas are described together in a single report because they are contiguous, separated only by primitive roads, and have similar geology and resources. These areas are adjacent to the new El Malpais National Monument (fig. 1), created December 31, 1987, by House Resolution 403, which also included these wilderness study areas within the El Malpais National Conservation Area. The national monument area was previously designated El Malpais Wilderness Instant Study Area (Bigsby and Maxwell, 1981; Maxwell, 1981a, b, 1986).

The four study areas begin approximately 20 air miles south of Grants, N. Mex., and continue southward for another 20 miles. They are accessible from Interstate Highway 40 by way of paved State Highway 117 and numerous primitive roads (fig. 1). The Rimrock Wilderness Study Area contains 29,818 acres; Sand Canyon, 8,543 acres; Little Rimrock, 9,920 acres; and Pinyon, 12,365 acres, for a total of 60,646 acres.

This report presents an evaluation of the mineral endowment (identified resources and mineral resource potential) of the study areas and is the product of several separate studies by the U.S. Bureau of Mines (USBM) and the U.S. Geological Survey (USGS). Identified resources are classified according to the system of the U.S. Bureau of Mines and U.S. Geological Survey (1980), which is shown in the Appendix of this report. Identified resources are studied by the USBM. Mineral resource potential is the likelihood of occurrence of undiscovered metals and nonmetals, industrial rocks and minerals, and energy sources (coal, oil, gas, oil shale, and geothermal sources). It is classified according to the system of Goudarzi (1984), which is also shown in the Appendix. Undiscovered resources are studied by the USGS.

Investigations by the U.S. Bureau of Mines

A mineral survey of the Rimrock, Sand Canyon, and Little Rimrock Wilderness Study Areas and part of the Pinyon Wilderness Study Area was made in 1978 and 1979 as part of a mineral resource assessment of El Malpais Instant Study Area (Bigsby and Maxwell, 1981). Additional studies were made in August 1987, including a comprehensive literature search for information on mines, prospects, and mineralized areas, and a check of Bureau of Land Management files for any mining claim and oil and gas lease records pertaining to the study areas. A search was made for unreported prospects and mineralized areas, and four coal and three sandstone samples were taken for analysis (Hannigan, 1989).

Investigations by the U.S. Geological Survey

Most of the acreage in the four study areas was included in a comprehensive geologic study and mineral survey of the El Malpais Wilderness Instant Study Area in 1978–1980 (Bigsby and Maxwell, 1981; Maxwell, 1981a, b, 1986). Maxwell did additional geologic mapping in the Pinyon study area in 1987, Bankey evaluated relevant geophysical data, and Nowlan did geochemical sampling in the areas in 1987.

APPRAISAL OF IDENTIFIED RESOURCES

By Brian J. Hannigan U.S. Bureau of Mines

No mines, prospects or mineralized areas were seen in or near the Rimrock, Sand Canyon, Little Rimrock, or Pinyon Wilderness Study Areas during the field investigations. As of August 1987, Bureau of Land Management records show no mining claims in or near the study areas, but oil and gas leases cover about 3,600 acres in and within 1 mi of the study areas (pl. 1). No metallic mineral resources were identified in or near the study areas during the field investigations. Occurrences of coal, high-silica sandstone, and sand and gravel were suggested by literature pertaining to the area and were investigated.

Coal

Coal beds occur in the Crevasse Canyon Formation, principally in the Dilco Coal Member at the base. Four coal samples were collected in and near the Sand Canyon, Little Rimrock, and Pinyon study areas and were analyzed for moisture, ash, sulfur, and heat content. Coal that has a heat value of 8,300 to 11,500 Btu/lb (British thermal units/pound) on a moist, mineral-free basis is considered to be subbituminous; impure coal is defined as having an ash content of 25 percent or greater; subbituminous coal beds must be at least 30 inches thick to be considered resources (Wood and others, 1983). Heat values for the four samples (moist, ash-free basis) were between 8,538 and 10,718 Btu/lb. Ash content in the samples ranged from 23.27 to 27.30 percent (Hannigan, 1989). The coal beds range from 10 to 24 inches thick and are interbedded with shale. These thin beds of impure subbituminous coal are not classified as a resource.

Sandstone and Sand

The Zuni and Gallup Sandstones were examined to determine if they contained enough silica to be suitable for industrial uses. Visual inspection of these units indicated that they are generally too low in silica content to be suitable for any industrial purpose other than crushed rock. Three outcrop samples of the sandstone contained between 86.12 and 90.43 percent silica (Hannigan, 1989). The most common use of high-silica sand—the manufacture of glass—requires a minimum silica content of 95 percent (Buie and Robinson, 1958). Therefore, the sandstone in the study areas is classified as an inferred subeconomic resource suitable for use as crushed rock. The common-variety sand in the study areas is also classified as an inferred subeconomic resource. There are no gravel deposits in any of the areas. Because vast quantities of similar sandstone and sand are available throughout the region, it is highly unlikely that this subeconomic resource will ever be developed.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By Charles H. Maxwell, Gary A. Nowlan, and Viki Bankey U.S. Geological Survey

Geology

Bedrock in most of the four study areas is composed of interbedded and interfingering Cretaceous

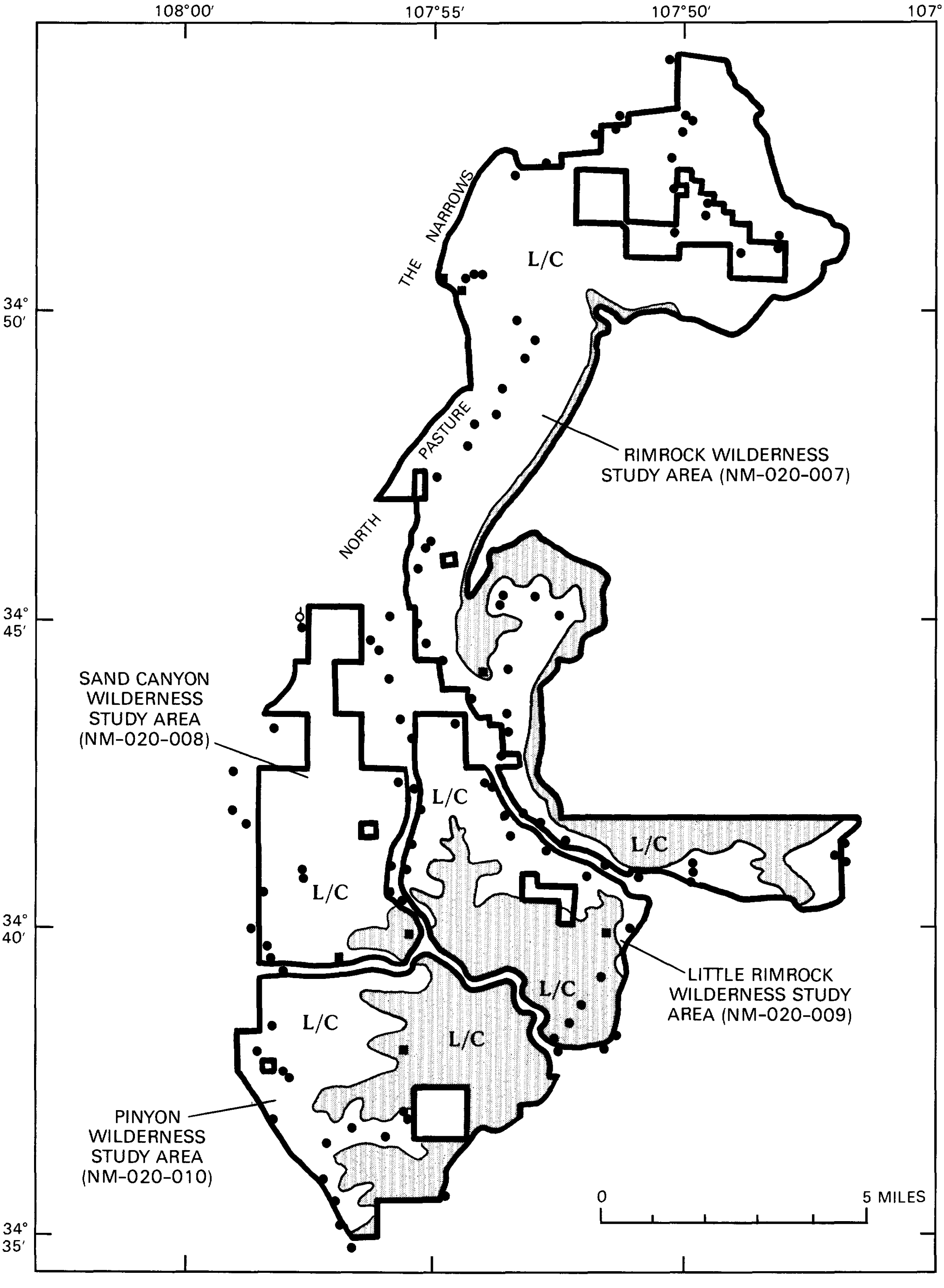


Figure 2 (above and facing page). Mineral resource potential, known coal occurrences, and geochemical sample sites in the Rimrock, Sand Canyon, Little Rimrock, and Pinyon Wilderness Study Areas, Cibola County, N. Mex.

shale and sandstone with a thickness of 1,000 to 1,500 ft, but as much as 500 ft of Jurassic eolian sandstone is exposed below the Cretaceous units in the northern part of the Rimrock study area. It forms the small mesas and vertical cliffs along State Highway 117, and the natural arch east of The Narrows (pl. 1). The overlying shale and

EXPLANATION

[pattern box]	Area having known coal occurrences—Thin beds of impure subbituminous coal, not classified as a resource
L/C	Geologic terrane having low resource potential for metals, oil and gas, coal, and geothermal energy, at certainty level C—Applies to all parts of all four study areas
	Level of certainty:
C	Data indicate geologic environment and give a good indication of the level of mineral resource potential
▬	Approximate boundary of wilderness study area
●	Stream-sediment sample site
■	Outcrop sample site
⌽	Test well for oil and gas

sandstone form steep slopes to the east, rising 1,000 ft to the basalt cap of Cebollita Mesa. These slopes are almost completely covered by landslides, tier upon tier of large slide blocks spanning a width of 1–2 mi. Only a few widely scattered outcrops of the underlying rocks show through the slides (pl. 1).

The landslides are generally older than the alluvium in the adjacent valleys. They were formed during an early wet period, which was followed by progressive changes in climate to the present-day arid conditions. During the wet period, large amounts of water percolated through the porous basalt and sandstone, soaked and weakened the underlying shales, and produced the numerous slide blocks, which migrated down either to the base of the slope or to the top of a stable block. As the volume of precipitation lessened, landslides occurred less frequently and less alluvial material was carried away. Eventually the slides stabilized, and alluvium filled the valleys and covered many of the lower slides to form broad, flat floors. Flash flooding, characteristic of the present-day arid conditions, has locally eroded deep gullies in the alluvium, partly uncovering some landslide blocks.

Recent accumulations of windblown sand and silt form several large and many small dune fields in the study areas. Only the most prominent of these are shown on the geologic map (pl. 1). They are most common on the lee sides of mesas and ridges, but are also prominent east of The Narrows on the windward side of the ridge. Thin longitudinal dunes and sheets with a west-southwest trend occur throughout the western lowland areas.

The study areas are on the eastern edge of the Zuni Mountains high, which was an island area where no sediments were deposited during Pennsylvanian time. The oldest sedimentary rocks on this high, west of the study areas, are sandstones of the Permian Abo Formation, which rest on an undulating surface of Precambrian granite. However, a test well south of North Pasture, near the north end of the Sand Canyon study area (fig. 2), penetrated 120 feet of Pennsylvanian limestone and shale (in addition to about 4,000 ft of younger strata), and other wells about 30 mi north (near Grants) and 30 mi southeast intersected, respectively, about 480 and about 500 ft of Pennsylvanian rocks (Wengerd, 1959).

New names and correlations are being considered for Jurassic units in the region to the north and west of the study area, but the existing names for the units (Maxwell, 1986) are retained for this report. The Zuni Sandstone map unit includes about 60 ft of fluviatile sandstone at the base, which is an equivalent of the Wanakah Formation to the north, and which grades upward into the eolian Zuni Sandstone. The Zuni is about 500 ft thick at The Narrows and thins to the south. The underlying Entrada Sandstone is exposed only at The Narrows, thins to the south, and is probably truncated by the unconformity at the base of the Zuni map unit a few miles to the south, as it is in the next band of outcrops about 25 mi to the east (Maxwell, 1976).

Pre-Dakota erosion has truncated the Jurassic units from north to south so that the Dakota rests on Triassic units a few miles south of the Pinyon study area. The Dakota Sandstone and most of the Mancos Shale are combined into one map unit for this report (Kmd, pl 1). The map unit includes, from the base up, the basal unit of the Dakota, the Oak Canyon Member and lateral equivalents of the Cubero Tongue of the Dakota, the Clay Mesa Tongue of the Mancos, the Paguate Tongue of the Dakota, the Whitewater Arroyo Tongue of the Mancos, the Twowells Tongue of the Dakota, and the Rio Salado Tongue of the Mancos. The basal unit of the Dakota, 0–65 ft thick, is light-gray to white, medium- to coarse-grained, poorly sorted, crossbedded sandstone and conglomerate with siliceous cement. Lenses of conglomerate in the basal part of the unit have prominent scour and fill structures. The Oak Canyon Member consists of 60–90 ft of light-gray and grayish-tan, locally calcareous or carbonaceous sandstone and siltstone with numerous brown-weathering fossiliferous limestone lenses and concretions. The overlying tongues of the Dakota Sandstone are light gray, brown, and tan, fine to very fine grained, locally silty, and locally fossiliferous. The tongues of the Mancos Shale are all light- to dark-gray, friable shale and silty shale, locally fossiliferous.

The Tres Hermanos Sandstone, above the Dakota-Mancos map unit, is mapped with the overlying D-Cross Tongue of the Mancos Shale (Kth, pl 1). The D-Cross Tongue has the same lithology as the other Mancos units. The Tres Hermanos is composed of three units: upper and lower sandstone units similar to those of the Dakota, and a middle unit of light-gray and brown interbedded carbonaceous shale, sandstone, and siltstone, which includes a few thin coal lenses and, in the southern part of the area, interbeds of dark-gray fossiliferous shale.

The Gallup Sandstone consists of three members: a massive sandstone at the top, a middle silty shale, and a lower silty sandstone. The upper sandstone forms the prominent cliffs near the top of Cebollita Mesa, and the uppermost cliffs in the southern part of the study areas. It is light brown to light gray, fine to medium grained, thin to massive bedded and includes local areas of cross-bedding and lenses of dark-brown-weathering sandy limestone. The middle shale pinches out to the south. The lower sandstone is light gray to yellowish gray, thin bedded, and silty, grading southward into interbedded thin sandstone and dark-gray shale with thin coaly lenses. Total thickness of the Gallup is 260–330 ft.

The Crevasse Canyon Formation and related rocks overlie the Gallup Sandstone and comprise a sequence of nonmarine sandstone, siltstone, carbonaceous shale, and coal beds. The separate members of this map unit are well defined to the north but become increasingly difficult to differentiate toward the southern part of the study areas. Units, starting at the base, include the Dilco Coal Member and the Borrego Pass Lentil of the Crevasse Canyon Formation, the Mulatto Tongue of the Mancos Shale, the Dalton Sandstone and Gibson Coal Members of the Crevasse Canyon Formation, the Point Lookout(?) Sandstone, and the Cleary(?) Coal Member of the Menefee(?) Formation. The contact of the Gallup Sandstone with the Dilco is well defined in the northern part of the Rimrock area but becomes gradational to the south and is arbitrarily placed below the lowest coal beds. The Dilco is composed of light-yellowish-gray to white, thin-bedded sandstone and siltstone interbedded with light- to dark-gray carbonaceous shale and thin coal beds. The Borrego Pass Lentil and the Mulatto Tongue grade southward into yellowish gray siltstone and sandstone and pinch out. The Dalton Sandstone Member is composed of light-gray and yellowish-gray, fine- to medium-grained, thin-bedded to massive sandstone that grades southward into thin-bedded silty sandstone interbedded with carbonaceous shale indistinguishable from the Dilco Coal Member. The Gibson Coal Member is identical to the Dilco but thins and grades southward in the area to marginal marine shale and sandy limestone. The overlying Point Lookout(?) Sandstone apparently pinches out north of the study areas, but it may grade southward into rocks indistinguishable from the Gibson. The Crevasse Canyon Formation is much thicker in the southern part of the study areas and therefore may include equivalents of the Point Lookout and possibly the overlying Cleary Coal Member of the Menefee Formation. Lithologies are so similar that separating the members is difficult.

The structure of the study areas is relatively simple; the northern part of the Rimrock Wilderness Study Area is on the crest of a regional east-southeast-trending anticline, and a gentle regional dip to the south extends through the other study areas. A few very shallow northwest-trending folds occur in the southern part of the Pinyon study area. Several prominent faults are shown on plate 1. The faults at the south end of Cebollita Mesa are the northern terminus of a zone of faulting that extends southeastward for 20 mi or more. The many small fault scarps in the alluvium along the western edge of the Sand Canyon and Pinyon study areas are very young. These are part of a complex fault zone to the west that trends north-northeast, west side generally down, and that has a postulated right-lateral component of movement. The wedge-shaped block of Tres Hermanos Sandstone at the south end of North Pasture (pl. 1) has been downfaulted about 650 feet relative to the surrounding Dakota Sandstone (Maxwell, 1986).

Geochemistry

A reconnaissance geochemical survey of the Rimrock, Sand Canyon, Little Rimrock, and Pinyon Wilderness Study Areas was conducted from June to September 1987. Samples of stream sediment were collected at 116 sites on streams draining the study areas and vicinity (fig. 2). Stream-sediment samples represent a composite of material eroded from the drainage basin of the stream sampled. Samples of water were collected from 18 wells and 3 springs in or near the study area.

Methods

Two stream-sediment samples were collected at each site. One of the samples was air dried and sieved through an 80-mesh (0.18-mm or 0.007-inch) screen. For the second sample at each site, about 20 pounds of sediment was collected and panned to remove most of the quartz, feldspar, clay-sized material, and organic matter. Treatment with bromoform removed the remaining low-density minerals, and a magnetic separation removed the magnetite and any other strongly magnetic material to produce a concentrate sample. The concentrate samples may consist of nonmagnetic ore minerals, ferromagnesian silicates, iron and manganese oxides, barite, and accessory minerals such as sphene, zircon, apatite, and rutile.

The sieved stream-sediment samples were analyzed for 35 elements, and concentrate samples were analyzed for 37 elements by a semiquantitative emission spectrographic method. In addition, the sieved samples were analyzed for uranium by fluorometry and for arsenic, bismuth, cadmium, antimony, and zinc by inductively coupled plasma spectroscopy. Analytical data, sampling sites, and references to analytical methods are presented in Bullock and others (1989).

Water samples were analyzed for calcium, magnesium, sodium, potassium, silica, iron, and manganese by flame atomic absorption; for zinc, copper, arsenic, molybdenum, and cobalt by cold-vapor atomic absorption; for sulfate, chloride, fluoride, and nitrate by ion chromatography; for uranium by laser-excited fluorometry; and for alkalinity by Gran's plot titration. The temperature and pH of the samples were measured at the time of collection. Analytical data, sampling sites, and references to analytical methods are presented in McHugh and Nowlan (1989).

Results

Results from the geochemical studies show that very few distinctly anomalous concentrations of any element are present in the study areas. Most concentrations are near or below the average crustal abundance for shale and sandstone (Rose and others, 1979). Molybdenum was detected at 10 ppm (parts per million) in two concentrate samples. Two stream-sediment samples from the southern part of the study area contained 0.5 and 2 ppm silver; none was detected in the corresponding concentrate samples. Three concentrate samples in the central part of the area contained 20–50 ppm tin, and two in the southern part contained 500 ppm zinc. These anomalous concentrations seem incompatible with the geology and probably represent contamination caused by human activity.

The water samples were slightly alkaline (pH generally about 7.5), had about 200–2,000 ppm total dissolved solids, and contained more sulfate than chloride. Several well-water samples contained 0.6–1.4 ppm zinc, probably from galvanized pipe in the well.

The geochemical studies give no indication that any mineralized rocks might be present.

Geophysics

Gravity Data

The complete Bouguer gravity anomaly map (fig. 3) was made from data for 60 stations extracted from the Defense Mapping Agency gravity data base. Data from these stations were reduced using a density of 2.67 grams per cubic centimeter and were corrected for terrain to a radius of 103.6 mi from each station. The map shows anomalies in the gravity field that are associated with changing rock densities or structure. The gravity anomaly map shows many subsurface structural details more clearly than the magnetic anomaly map, and it is less weighted toward compositional changes. However, the large station spacing (no closer than 2 mi and sometimes as great as 12 mi) gives the gravity map a regional character only; broad or deep features are enhanced and shallow, high-frequency anomalies are not detected. The study areas are on the northeastern flank of a broad 15-milligal negative gravity anomaly. This anomaly trends north-south, is centered near the southern contact of Quaternary basalt and Cretaceous sedimentary rocks, and measures roughly 45 mi long and 25 mi wide (Keller and Cordell, 1984). The lack of good geologic correspondence makes interpretation difficult, but this feature could reflect a deep magma chamber that is the source of the basalt of El Malpais. A local negative deflection superimposed on this larger feature corresponds with a large magnetic low south of the study areas.

Aeromagnetic Data

The total intensity aeromagnetic anomaly map (fig. 4) was produced from a survey flown at 8,500 ft barometric elevation along east-west flight lines spaced 1 mi apart (U.S. Geological Survey, 1979). The 1975 International Geomagnetic Reference Field, updated to the year and month of the survey, was subtracted from the survey data.

The aeromagnetic map shows anomalies in the magnetic field that result from the distribution of magnetic minerals in the rocks, measured as magnetic susceptibility. Magnetic anomalies caused by varying magnetic susceptibilities in the rocks are commonly of much greater magnitude than anomalies caused by significant structural offset. This effect can limit structural interpretation but enhance separation of sources having different compositions. Many of the rock units in and near the study areas are associated with distinct anomaly patterns in the magnetic field. Nonmagnetic Cretaceous sedimentary rocks and recent alluvium underlie the area of gradual magnetic gradients between the Tertiary basalt of Cebollita Mesa and the Quaternary basalt of El Malpais. The Tertiary basalt flows that cap Cebollita Mesa exhibit high-frequency magnetic highs and lows that are associated with lava cones and vents (Maxwell, 1981b). The Quaternary basalts of El Malpais exhibit broader low-frequency highs and lows. On a regional scale, Tertiary basalts appear less magnetic overall than Quaternary basalts in northwestern New Mexico (Cordell, 1983). This difference is probably the result of different compositions of the magma sources for these basalts.

A broad, circular 200-nanotesla magnetic low (L1, fig. 4) dominates the magnetic field southeast of the Pinyon and Little Rimrock study areas. It is about 10 mi in diameter, coincides with extensive outcrops of the Crevasse Canyon Formation, and is surrounded by a ring of broad magnetic highs (H1a–H1e, fig. 4). The magnetic low is in the same place as a minor gravity low shown on figure 3. The magnetic and gravity lows may be caused by thickened sedimentary rocks filling a basement

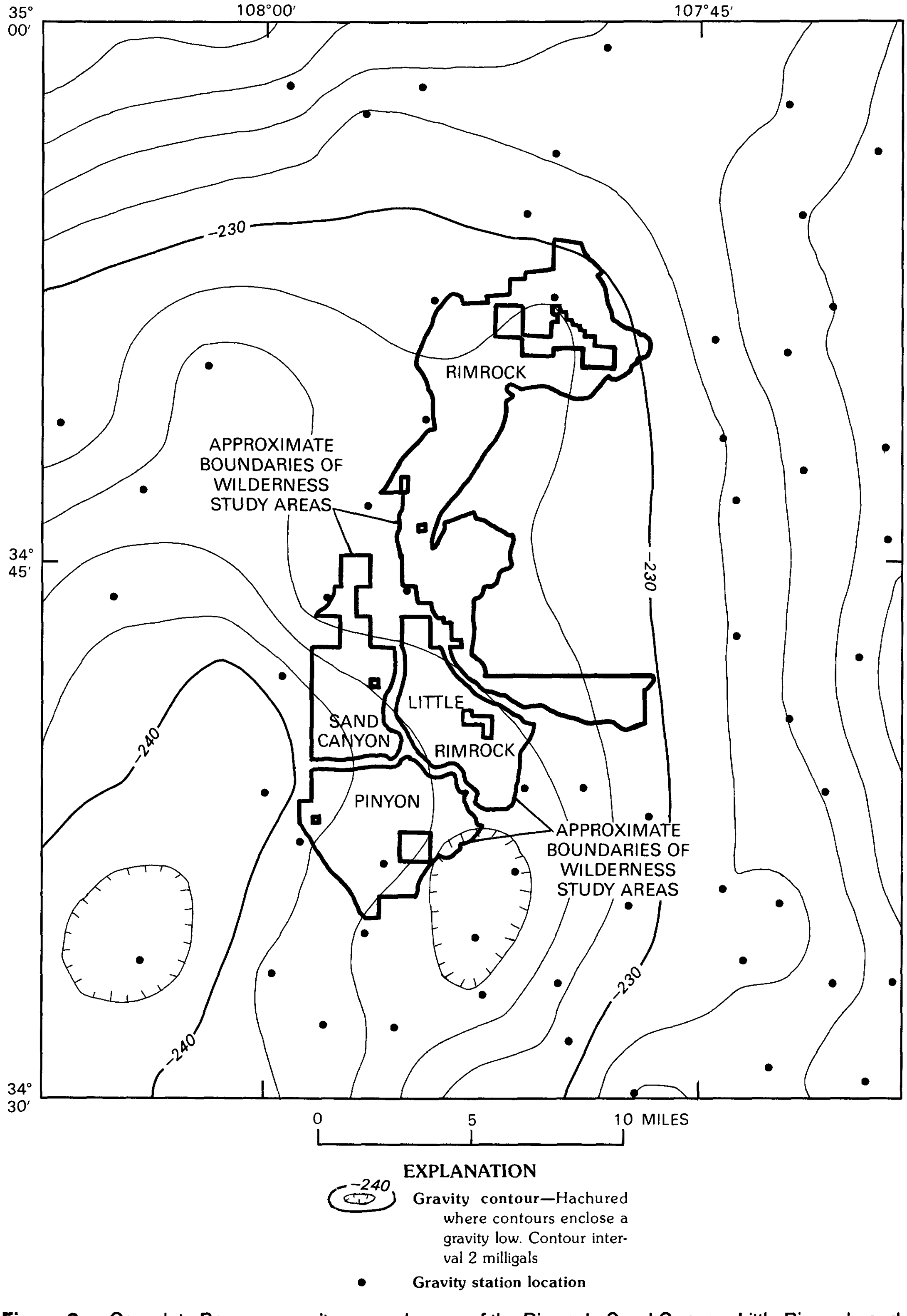


Figure 3. Complete Bouguer gravity anomaly map of the Rimrock, Sand Canyon, Little Rimrock, and Pinyon Wilderness Study Areas and vicinity, New Mexico.

depression, but the magnetic highs circling the low are not associated with any particular formation, and the sedimentary rocks are relatively flat-lying and undisturbed. The lack of surface geologic correlations and the long wavelength of the anomalies suggest that the source of these anomalies is deep; they could indicate a ring-shaped plutonic complex in the basement. The high-frequency anomalies on southern Cebollita Mesa interrupt the ring of magnetic highs and may represent the surface expression of a basement-controlled weakness in the crust. A second magnetic low (L2, fig. 4) correlates with ridges of Jurassic and Cretaceous sandstones that abut the basalt flows of El Malpais. The magnitude of L2 is lowest at the contact rather than at the valley center, suggesting that the mapped fault to the south continues northward through this area. The magnetic field is flat across the northern part of the Rimrock study area, except for the high-frequency magnetic highs caused by lava cones on Cebollita Mesa.

Radiometric Data

Aerial gamma-ray spectroscopy is a technique that provides estimates of the near-surface (0 to 20 inches depth) concentrations of potassium (K), equivalent uranium (eU), and equivalent thorium (eTh). The uranium and thorium data are described as equivalent concentrations because the technique measures radioactive daughter nuclei that are chemically distinct from the parent nuclei. These data (K, eU, eTh) provide a partial geochemical representation of the near-surface materials. In a typical aerial survey, each measurement reflects average concentrations for a surface area on the order of 15 acres to an average depth of about 1 ft.

From 1975 to 1983 the U.S. Department of Energy contracted for aerial gamma-ray surveys that covered almost all of the conterminous United States and much of Alaska. The flight-line spacings of these surveys vary from 1 to 10 mi and are, in general, only suitable for producing regional scale maps.

As part of a state mapping project, the data for New Mexico were compiled and processed to produce a series of maps at a scale of 1:1,000,000. These maps include the composite-color maps described by Duval (1983). The maps were examined to estimate the K, eU, and eTh concentrations for each wilderness study area and the presence or absence of anomalous radioelement concentrations was noted. The definition of anomaly requires that the element concentration and its ratios to the other two elements all be high values in the context of the map.

Overall radioactivity is moderate in all of the study areas, which had the following concentrations:

Study area	K (percent)	eU (ppm)	eTh (ppm)
Rimrock	1.4–2.0	1.0–2.5	4–10
Sand Canyon	1.5–2.5	1.6–2.0	7–10
Little Rimrock	1.0–1.5	2.0–2.5	8–10
Pinyon	1.5–2.5	1.6–2.5	7–11

No uranium or thorium anomalies are within or near any of the study areas. There is a subtle potassium anomaly to the west of the study areas, which appears to be an extension of a large area of elevated potassium concentrations to the southwest that correlates mostly with volcanic rocks of the Datil Group.

Mineral and Energy Resources

Metals

No mineralized areas or occurrences of metallic minerals were found in the wilderness study areas. No significant anomalies were found in the stream-sediment and concentrate samples. Two apparent silver anomalies in stream-sediment samples were not substantiated by the concentrate samples nor by the presence of commonly associated elements. Other slight anomalies of tin and zinc are probably due to contamination. The study areas have a low potential for the occurrence of metallic mineral resources, with a certainty level of C.

Oil and Gas

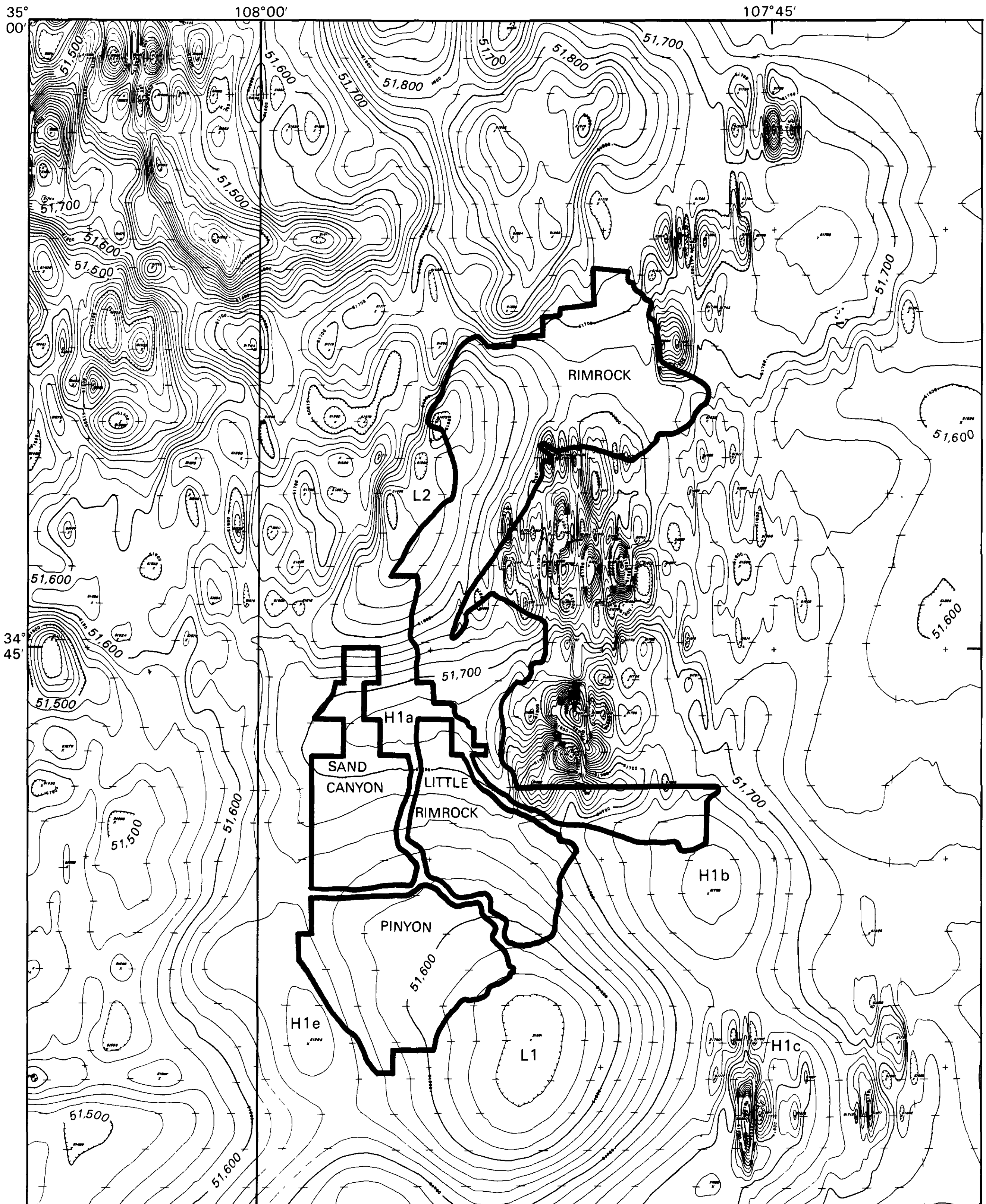
The areas are classified by the U.S. Bureau of Land Management (1986) as having a moderate potential for the occurrence of oil, natural gas, and carbon dioxide. One test well at the northwest edge of the Sand Canyon study area (fig. 2) had only 120 ft of Pennsylvanian rocks and no shows of oil or gas. Results from other wells to the north and south of the study areas and from gravity measurements indicate that the Pennsylvanian rocks, the only potential source rocks in the region, are thin shelf deposits with little potential for the accumulation of oil and gas. The wilderness study areas are therefore given a low energy resource potential for oil and gas, with certainty level C.

Coal

Coal occurs in the Crevasse Canyon Formation in the southern part of the wilderness study areas, in several beds that range from 10 to 24 inches in thickness and are interbedded with shale. The known coal beds were sampled and tested, but no indications of other coal beds were seen during the studies. Additional coal beds are not likely to be present in the study areas. The wilderness study areas have a low energy resource potential for coal, with certainty level C.

Geothermal Energy

The study areas lie within an area of anomalously high heat flow (Reiter and others, 1975). Intermittent volcanic activity has occurred in the El Malpais lava field north and west of the study areas over a 3-million-year


35° 00′
108°00′
107°45′
34° 45′
34° 30′
51,500
51,600
51,700
51,800
RIMROCK
L2
H1a
SAND CANYON
LITTLE RIMROCK
PINYON
H1b
H1c
H1d
H1e
L1
0
5
10 MILES

EXPLANATION

—51,700— Aeromagnetic contour—Number shows residual intensity anomaly in gammas; contour interval 20 gammas

Aeromagnetic low

- - - - Flight line location

Approximate boundary of wilderness study area

Figure 4 (above and facing). Aeromagnetic map of the Rimrock, Sand Canyon, Little Rimrock, and Pinyon Wilderness Study Areas and vicinity, New Mexico (from U.S. Geological Survey, 1979). Anomalies L1, L2, and H1a–H1e are discussed in text.

period, ending with the eruption of the McCartys flow less than 1,000 years ago. A range of tholeiitic to alkalic compositions within short distances in the basalt flows may indicate heating from individual geothermal conduits at diverse depths beneath the field. Ultramafic inclusions and strontium isotope ratios indicate deep origins for the basalt. Local hot spots may occur within the broad area of high heat flow (Laughlin and West, 1976). The only known geothermal test work in the region was the drilling of four shallow test wells on the west side of El Malpais for the Sunoco Energy Development Company; these wells reportedly yielded inconclusive data (Bigsby and Maxwell, 1981). Heat flow in the study areas appears to be only slightly above the continental average; it indicates only a low potential for geothermal resources, with certainty level C.

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APPENDIX

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

LEVEL OF RESOURCE POTENTIAL →

<table>
<tr><td rowspan="4">U/A
UNKNOWN POTENTIAL</td><td>H/B
HIGH POTENTIAL</td><td>H/C
HIGH POTENTIAL</td><td>H/D
HIGH POTENTIAL</td></tr>
<tr><td>M/B
MODERATE POTENTIAL</td><td>M/C
MODERATE POTENTIAL</td><td>M/D
MODERATE POTENTIAL</td></tr>
<tr><td rowspan="2">L/B
LOW POTENTIAL</td><td rowspan="2">L/C
LOW POTENTIAL</td><td>L/D
LOW POTENTIAL</td></tr>
<tr><td>N/D
NO POTENTIAL</td></tr>
<tr><td>A</td><td>B</td><td>C</td><td>D</td></tr>
</table>

LEVEL OF CERTAINTY →

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

Abstracted with minor modifications from:

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

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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 McKelvey, 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 in this report

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.

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