Mineral Resources of the Brokeoff Mountains Wilderness Study Area, Otero County, New Mexico

U.S. GEOLOGICAL SURVEY BULLETIN 1735–E

Chapter E

Mineral Resources of the Brokeoff Mountains Wilderness Study Area, Otero County, New Mexico

By SAMUEL L. MOORE, M. DEAN KLEINKOPF,
and GARY A. NOWLAN
U.S. Geological Survey

PATRICIA A. CORBETTA
U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1735

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
SOUTHWESTERN NEW MEXICO

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

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

UNITED STATES GOVERNMENT PRINTING OFFICE: 1989

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

Library of Congress Cataloging-in-Publication Data

Mineral resources of the Brokeoff Mountains Wilderness Study Area, Otero County, New Mexico.

(Mineral resources of wilderness study areas—southwestern New Mexico ; ch. E) (Studies related to wilderness) (U.S. Geological Survey bulletin; 1735–E)
Bibliography: p.
Supt. of Docs. no.: I 19.3:1735–E
1. Mines and mineral resources—New Mexico—Brokeoff Mountains Wilderness. 2. Brokeoff Mountains Wilderness (N.M.) I. Moore, Samuel L. II. Series. III. Series: Studies related to wilderness. IV. Series: U.S. Geological Survey bulletin ; 1735–E.

QE75.B9	no. 1735–E	557.3 s	88–600458
[TN24.N6]		[553'.09789'65]	

STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of a part of the Brokeoff Mountains (NM-030-112) Wilderness Study Area, Otero County, New Mexico.

CONTENTS

PLATE

[Plate is in pocket]

FIGURES

TABLE

Mineral Resources of the Brokeoff Mountains Wilderness Study Area, Otero County, New Mexico

By Samuel L. Moore, M. Dean Kleinkopf, *and* Gary A. Nowlan
U.S. Geological Survey

Patricia A. Corbetta
U.S. Bureau of Mines

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 a part of the Brokeoff Mountains Wilderness Study Area (NM–030–112) in southern New Mexico. Inferred subeconomic mineral resources of gypsum, carbonate rocks, and sand and gravel are present; but these investigations revealed no metallic mineral resources. The assessed mineral resource potential for undiscovered resources in the study area is low for metals, coal, oil and gas, and geothermal energy.

SUMMARY

The Brokeoff Mountains Wilderness Study Area is located north of the Guadalupe National Park, Texas, along the boundary line between Texas and New Mexico in the southeasternmost part of Otero County, New Mexico (fig. 1). The U.S. Geological Survey and the U.S. Bureau of Mines studied 13,236 acres of the Brokeoff Mountains Wilderness Study Area (NM–030–112), at the request of the U.S. Bureau of Land Management. In this report the studied area is called the "wilderness study area" or simply the "study area." The boundaries of the wilderness study area encompass north-northwest-trending rugged hills and deeply incised canyons of the Brokeoff Mountains (pl. 1). The north-northwest-trending hills and canyons are underlain by faulted blocks of Lower Permian strata that dip southwestward along the southwestern and northeastern parts of the study area (pl. 1). The Brokeoff Mountains Wilderness Study Area lies southwest of the Guadalupe Mountain escarpment (Hayes, 1964) and is separated from the escarpment by the Big Dog Canyon graben (Hayes and Bigsby, 1983). The Brokeoff Mountains are flanked on the west by the Crow Flats drainage (pl. 1). The Brokeoff Mountains extend northward in New Mexico along the southwestern margin of the Guadalupe Mountains and southward from the study area into Texas.

The wilderness study area lies on the southwestern flanks of a northwest-trending regional gravity high that may encompass older structures in the high-density crystalline basement rocks of the Diablo platform to the west of the study area. The study area lies within the western flanks of a regional positive magnetic anomaly which indicates the presence of magnetic crystalline basement rock beneath the study area; however, the aeromagnetic profile is insufficiently resolved to support a mineral resource evaluation for the study area.

No metallic minerals were observed in the wilderness study area, and no alteration was noted; mineral potential is low for undiscovered resources of all metals. Nonmetallic mineral resources in the wilderness study area include thin beds of gypsum in the Lower Permian San Andres Limestone and sand and gravel in Crow Flats along the southwestern margin of the study area (pl. 1). The gypsum beds of the San Andres Limestone are a source of a small volume of gypsum that could possibly be used for the manufacture of wallboard. Carbonate rocks from the Grayburg Formation are suitable for agricultural and industrial uses. Gravel and sand deposits along the eastern margin of the Crow Flats could be mined, screened, and crushed for use as aggregate and road metal.

Manuscript approved for publication, October 5, 1988.

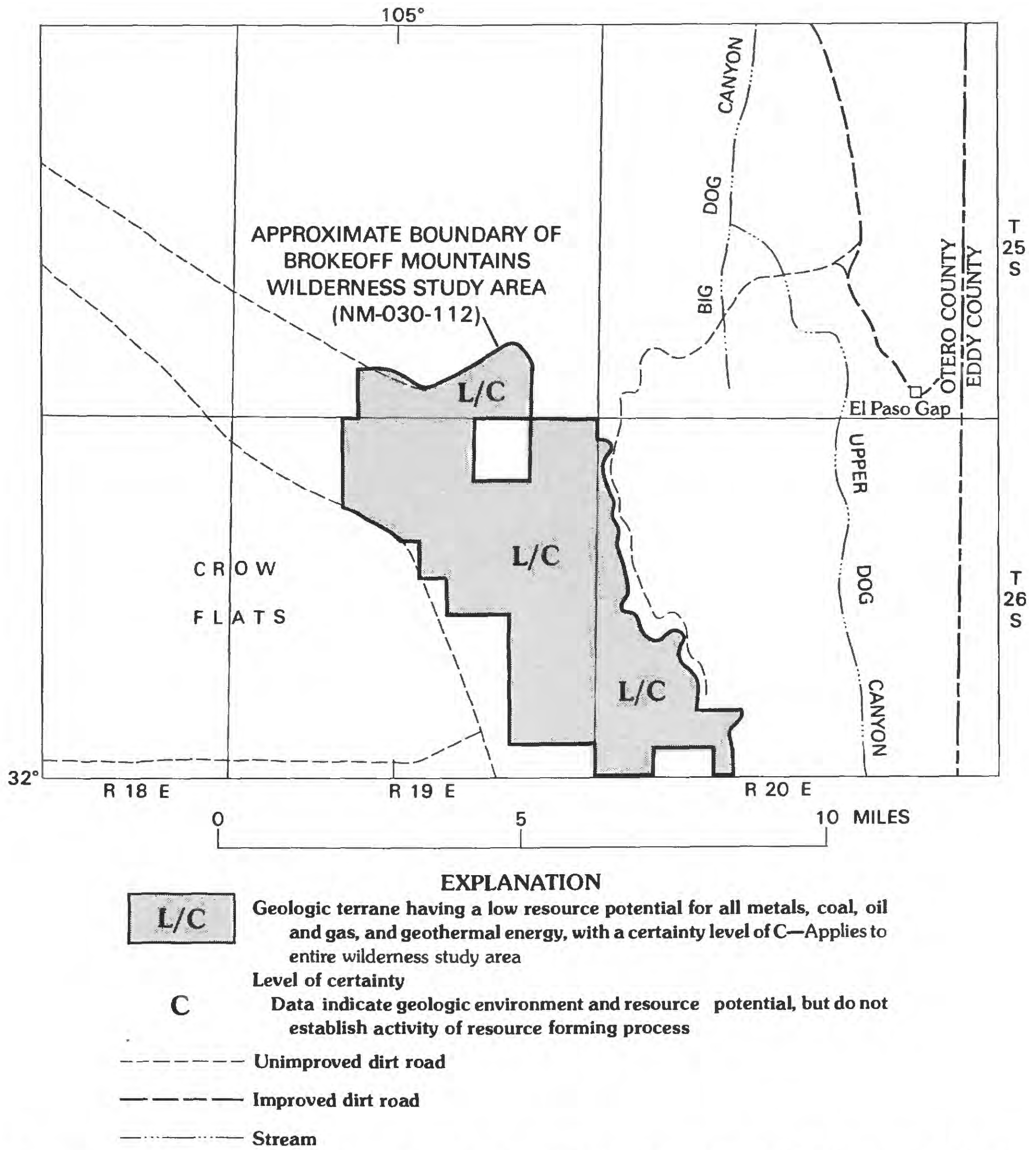


Figure 1. Summary map showing mineral resource potential of the Brokeoff Mountains Wilderness Study Area, Otero County, New Mexico.

The Permian strata that underlie the study area are all marine in origin and therefore are unlikely to contain coal; there is a low resource potential for coal in the study area. The oil and gas energy resource potential of the study area is low because extensive tilting and faulting of Permian strata have likely destroyed any petroleum traps. There are no warm springs or wells in the study area that would suggest a high geothermal gradient (heat flow); resource potential for geothermal energy is low.

INTRODUCTION

At the request of the Bureau of Land Management (BLM) 13,236 acres of the Brokeoff Mountains Wilderness Study Area were studied. The Brokeoff Mountains Wilderness Study Area (NM-030-112) is named for the Brokeoff Mountains which lie west of the Guadalupe Mountains and form rugged, prominent north-northwest-trending hills. Deeply incised canyons drain the map area north-northwestward through Humphrey Canyon to Crow Flats (pl. 1). Elevations of the map area range from about 3,700 ft along the northeastern part of Crow Flats to about 6,760 ft along the southernmost hills of the map area. The western parts of the area are accessible by unimproved dirt ranch roads that lead southeastward from New Mexico Highway 506. The eastern and northern boundaries of the study area are accessible by unimproved dirt ranch roads that lead southwestward and southward from the Big Dog Canyon road into the northern, central, and southern parts of the map area.

This report presents an evaluation of the mineral endowment (identified resources and mineral resource potential) of the study area 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 of undiscovered energy sources (coal, oil, gas, oil shale, and geothermal sources). It is classified according to the system of Goudarzi (1984) and is shown in the Appendix. Undiscovered resources are studied by the USGS.

Investigations by the U.S. Bureau of Mines

The USBM geologists conducted an 8-day field examination of the Brokeoff Mountains study area via unimproved-road and foot traverses (Corbetta, 1987). Five outcrop samples were collected from the Brokeoff Mountains study area (fig. 2). One jasperoid sample was analyzed for gold by fire assay–atomic absorption spectrophotometry, mercury by atomic absorption spectrophotometry, and 30 other elements by inductively coupled plasma–atomic emission spectrometry (ICP–AES). In addition to the jasperoid sample, five rock-chip samples of sedimentary units exposed in the study area were collected for whole-rock analysis by ICP–AES and for total sulphur analysis by chemical methods. Each of these five rock-chip samples was analyzed twice to determine precision.

Investigations by the U.S. Geological Survey

The geology of the Brokeoff Mountains Wilderness Study Area was mapped as part of a facies study of the Lower Permian strata in the El Paso Gap 15-minute quadrangle by Boyd (1958) for the New Mexico Bureau of Mines and Minerals, Socorro, N. Mex. The study area lies in the southeastern part of the El Paso Gap geologic map. Samuel L. Moore, in 1987, field checked Boyd's (1958) geologic map and found it to be of excellent quality; it was therefore used in this report (pl. 1). The northwestern 2 mi² of the study area, which lies outside Boyd's (1958) geologic map, was mapped in conjunction with field checking of Boyd's map (pl. 1).

APPRAISAL OF IDENTIFIED RESOURCES

By Patricia A. Corbetta
U.S. Bureau of Mines

Methods of Investigation

Information pertaining to the geology and its economic significance, mining, and oil and gas activity was obtained from a literature search and discussions with personnel at the BLM district offices. Mining claim, oil and gas lease, and lease application records were provided by the BLM State Office in Santa Fe, N. Mex.

Mining and Oil and Gas Activity

No mining districts or claims are in the Brokeoff Mountain area. Sand and gravel deposits are present within 1 mi west of the study area. Production from these deposits is unknown.

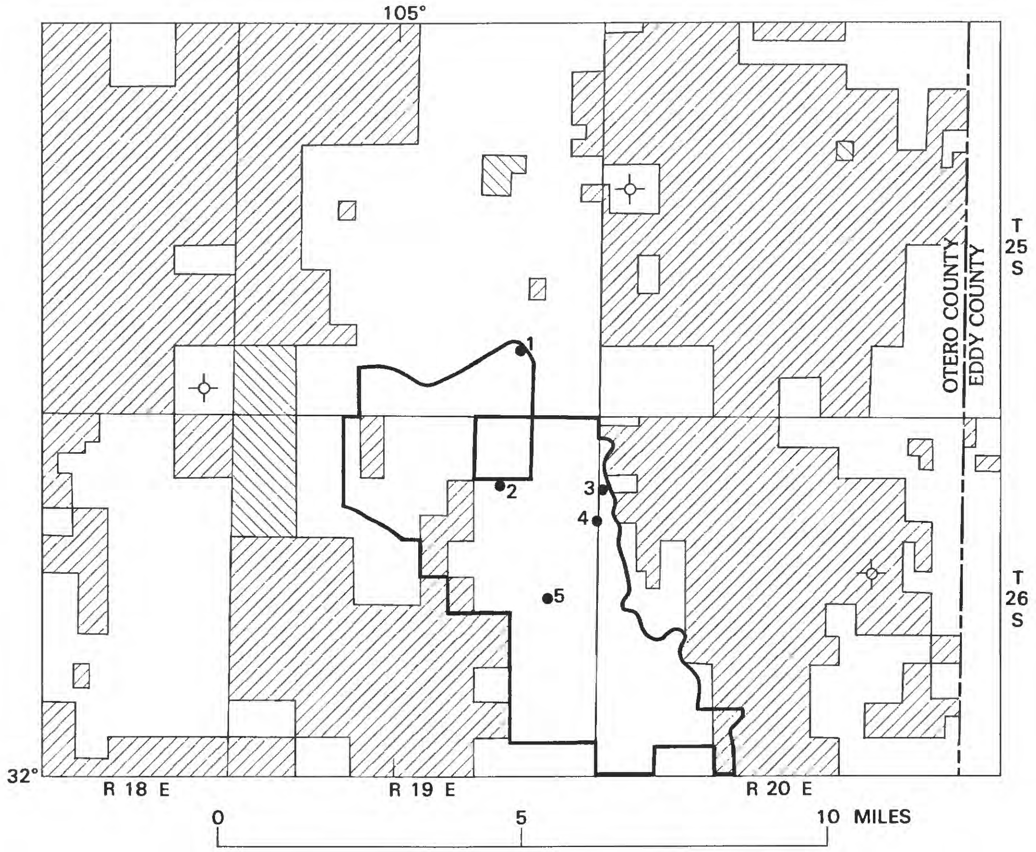
Oil and gas leases and lease applications cover extensive areas in the southwestern corner of Eddy County and the southeastern corner of Otero County (fig. 2). Three test wells were drilled within 3 mi of the study area; all wells were dry and abandoned (Cruver and others, 1982).

Mineral Appraisal

No metallic mineral occurrences were found in the study area.

Three samples of carbonate rocks (samples 1, 2, and 4) from the study area have total carbonate ($CaCO_3$ plus $MgCO_3$) contents greater than 80 percent which make them suitable for agricultural uses. Because these are low-unit-value commodities, local markets would need to be established for the dolomite and limestone to be of economic value. Outcrops of carbonate beds that would meet the local demand are present closer to local markets.

Sample 1 from the study area (fig. 2) is a dolomitic shelf facies in the Grayburg Formation. Sample 1 contained more than the minimum required concentration of MgO (16 percent) and less than the maximum allowable concentrations of SiO_2 (1.75 percent) and Al_2O_3 plus TiO_2 (1.50 percent) for the manufacture of refractory dolomite, which indicates that the Grayburg Formation is a source of magnesium



EXPLANATION

Approximate boundary of the Brokeoff Mountains Wilderness Study Area

●1 Locality of rock sample—Showing sample number

Oil and gas leases

Oil and gas lease applications

Dry and abandoned oil and gas well

Figure 2. Map showing U.S. Bureau of Mines sample localities, oil and gas leases, and lease applications in and near the Brokeoff Mountains Wilderness Study Area, Otero County, New Mexico.

compounds for refractory uses. However, the shelf facies in the reef complex typically grade laterally into and are interbedded with sandstone units that could significantly decrease the suitability of the formation for use as refractory dolomite. Gypsum occurs as a few thin beds in the San Andres Limestone. Development of this subeconomic resource is unlikely.

Alluvial deposits are present along the western side of the Brokeoff Mountains. Cruver and others (1982, p. 41–42) identified this area as a possible sand and gravel resource. However, the defined area lies predominantly outside the study area.

Conclusions

No metallic mineral occurrences were found in the Brokeoff Mountains Wilderness Study Area. Limestone and dolomite from the study area are suitable for agricultural and industrial uses. Small amounts of inferred subeconomic gypsum resources occur in the area. Sand and gravel accumulations are present in the study area, but they have no unique qualities. Development and use of these industrial minerals, which are also commonly available outside the study area, are dependent upon local demand.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By Samuel L. Moore, Gary A. Nowlan, and M. Dean Kleinkopf

Geology

Structure

The geographic features of the Brokeoff Mountains Wilderness Study Area are north-northwest-trending hills and canyons that are drained northwestward through the major tributaries of Humphrey Canyon into the Crow Flats drainage (pl. 1). The Lower Permian rocks in the central part of the Brokeoff Mountains are displaced by north-northwest-trending, branching and anastomosing, vertical to steeply dipping faults that have broken the Permian strata into east-northeast- and west-southwest-tilted fault blocks (pl. 1). The Brokeoff Mountains are flanked on the southwest by Crow Flats and on the northeast by a graben in Big Dog Canyon which lies southwest of the Guadalupe Mountains (Hayes, 1964).

Stratigraphy

The sedimentary rocks of the study area range in age from Early Permian to Quaternary.

In the study area, the Lower Permian Yeso Formation is exposed in a horst block in Panther Canyon in the northern part of the study area and along upthrown fault blocks in the southwestern and southern parts of the study area (pl. 1). The Yeso Formation exposures include the upper 150–200 ft of the formation and are composed of medium-gray, medium-grained, thick-bedded, fossiliferous, cherty, bioclastic, ledge-forming dolomite.

The San Andres Limestone, which conformably overlies the Yeso Formation, is widely exposed in the study area and is composed of light-olive-gray, fine- to medium-grained, thin- to medium-bedded dolomite and dolomitic limestone; locally the dolomite beds are thinly laminated and crossbedded and contain chert and small amounts of gypsum occur as thin beds in the limestone.

The Grayburg Formation, which conformably overlies the San Andres Limestone, is present throughout the study area and is made up mostly of grayish-orange to light and very light orange, and light- to medium-gray, fine-grained, medium-bedded dolomite and dolomitic limestone and some interbeds of dolomitic sandstone. The formation is resistant to erosion and underlies the higher ridges of the study area (pl. 1).

Quaternary alluvium is made up of poorly sorted stream gravels and fan deposits derived from the Lower Permian dolomites, limestones, and sandstones that underlie the map area. In the upper and intermediate parts of the major tributary drainages of Humphrey Canyon, the alluvium is composed of poorly sorted sand, silt, pebbles, and cobbles. In the lower part and mouth of Humphrey Canyon, and along the southwestern front of the Brokeoff Mountains, the alluvium and alluvial fans are made up mostly of unsorted boulders, cobbles, pebbles, and sand.

Geophysics

The only known geophysical coverage of the Brokeoff Mountains region is reconnaissance gravity and aeromagnetic anomaly maps (Bond and Zietz, 1987; an airborne reconnaissance survey by Carson Helicopters, Inc., 1981; Cordell and others, 1982). The control is so widely spaced that the data are of insufficient resolution to detect and delineate details of local structures and igneous intrusions that might influence mineral resource evaluations. The only control established within the boundaries of the Brokeoff Mountains Wilderness Study Area is one magnetic profile from the National Uranium Resource Evaluation (NURE), which was carried out in 1981 as part of an airborne reconnaissance survey (Carson Helicopters, Inc., 1981). No new geophysical surveys were made for this study.

A reconnaissance gravity anomaly map taken from Cordell and others (1982) is included to show the location of the wilderness study area relative to major gravity features in the Brokeoff Mountains region (fig. 3). Interpretation of these features provides some clues about the subsurface structure and lithology of buried sedimentary and crystalline rocks of the region. The wilderness study area lies on the southwestern flank of a northwest-trending regional gravity high that indicates the presence of high-density crystalline rocks beneath the Brokeoff Mountains. Northwest of the wilderness study area, northwest and north-northwest gravity trends intersect a major north-trending regional gravity high that likely is associated with high-density crystalline basement rocks underlying the Diablo Platform west of the study area.

In addition to the strong north and northwest trends, discontinuous northeasterly regional trends are clearly discernible, mostly around the edges of the gravity anomaly (fig. 3). These trends may reflect older structure that predates the north- to northwest-trending geologic structure that is mapped at the surface. It is not known whether this northeasterly grain is pervasive across the wilderness study area, or what influence it might have on the evaluation of the mineral potential.

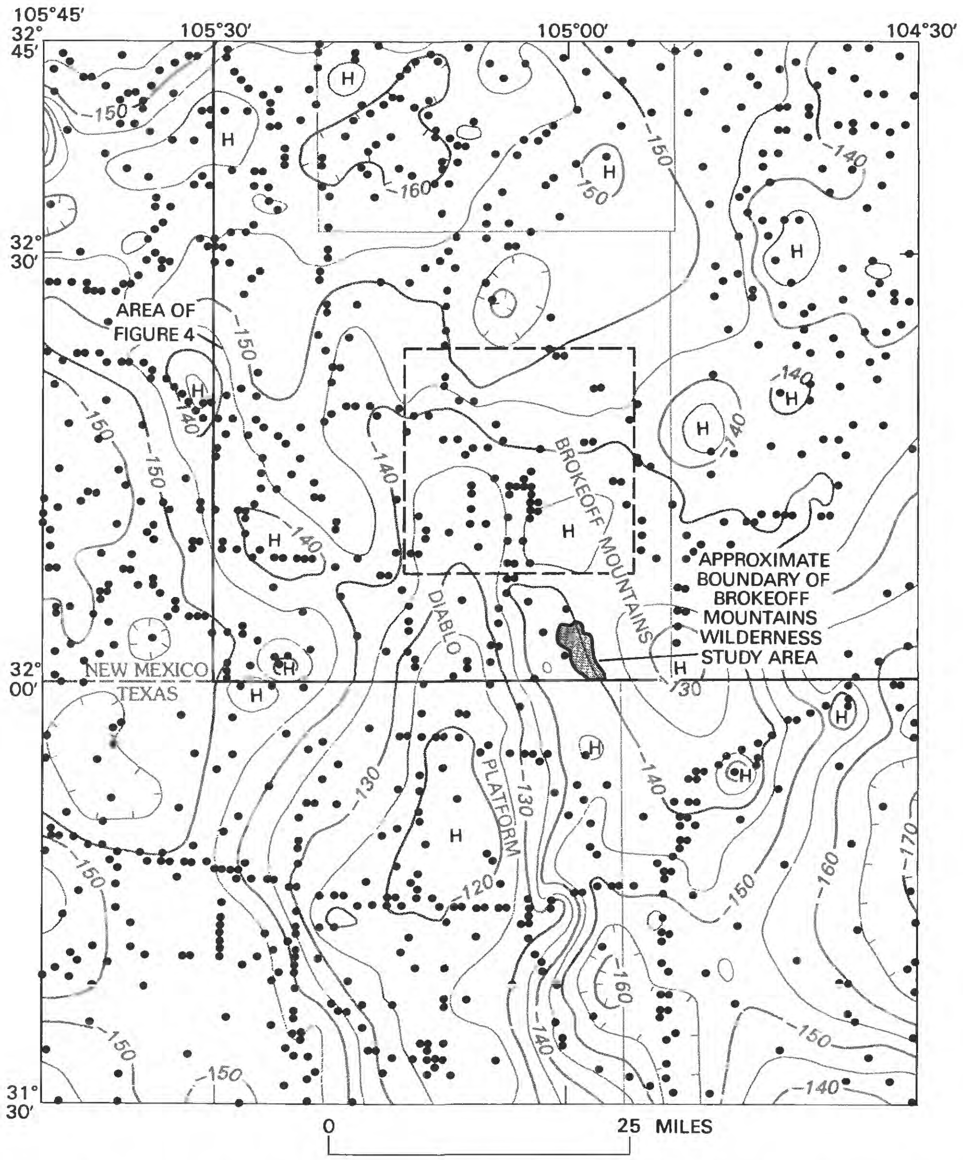


Figure 3. Bouguer gravity anomaly map of the Brokeoff Mountains, New Mexico, and adjacent areas. Brokeoff Mountains Wilderness Study Area shown by pattern. Contour interval 5 mGals. Map abstracted from Cordell and others (1982). Location of gravity stations shown by dots. Contours defining gravity lows are hachured; H, gravity high. Dashed lines delineate area of aeromagnetic anomaly map shown on figure 5.

A reconnaissance magnetic anomaly map taken from the U.S. Geological Survey (1980) illustrates the regional magnetic setting of the wilderness study area (fig. 4). The wilderness study area is on the western flank of a positive anomaly that indicates the presence of magnetic rocks beneath the Brokeoff Mountains. The reconnaissance nature of the data and the single aeromagnetic profile that crosses the study area yield insufficient resolution to provide information applicable to the mineral resource evaluations.

There is evidence that more detailed, thus higher resolution, magnetic anomaly data might provide information about buried geologic features useful in the mineral resource studies of the wilderness study area. Magnetic anomaly data from a 0.5-mi-spaced survey of an area located about 4 mi north of the wilderness study area show a variety of magnetic anomalies and steep gradient zones. These zones probably depict some local geologic features in the subsurface, such as faulting and intrusions, that could be of use in mineral resource evaluations (fig. 5). The series of positive and negative anomalies west of Crow Flats appear to have shallow sources which may occur within the sedimentary section. There are discontinuous northeasterly magnetic trends,

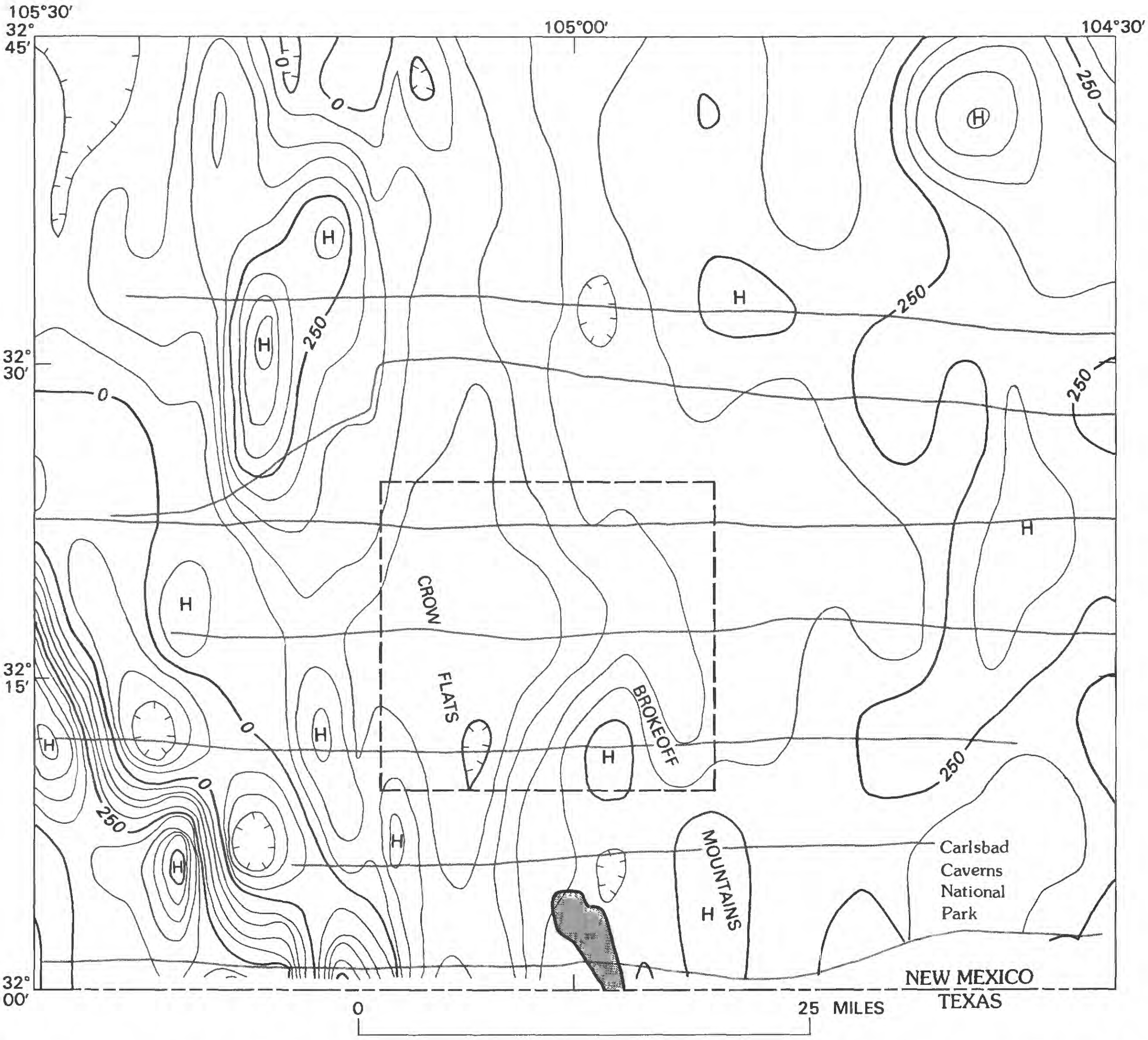


Figure 4. Residual intensity magnetic anomaly map of the Brokeoff Mountains, New Mexico, and adjacent areas. Map taken from National Uranium Resource Evaluation (NURE) by Carson Helicopters, Inc. (1981) and from survey by Bond and Zietz (1987). Brokeoff Mountains Wilderness Study Area shown by pattern. Contour interval 50 gammas. Flight lines shown by screened east-west lines: interval 6 miles, altitude 500 feet above terrain. Contours defining magnetic lows are hachured; H, magnetic high. Dashed lines delineate area of aeromagnetic anomaly map shown on figure 5.

similar to the gravity trends noted above, that are further evidence for the presence of an older northeast-trending structure.

Geochemistry

A reconnaissance geochemical survey of the Brokeoff Mountains Wilderness Study Area was conducted in July and September 1987. Samples of drainage sediment were collected at 27 sites on ephemeral streams that drain the wilderness study area. Stream-sediment and panned-concentrate samples derived from stream sediments represent a composite of material eroded from the drainage basins of the sampled streams.

Methods

Two samples were collected at each site. One of the samples was air dried and then sieved through an 80-mesh (0.177 mm) stainless-steel sieve to obtain a "stream-sediment sample." The portion that passed

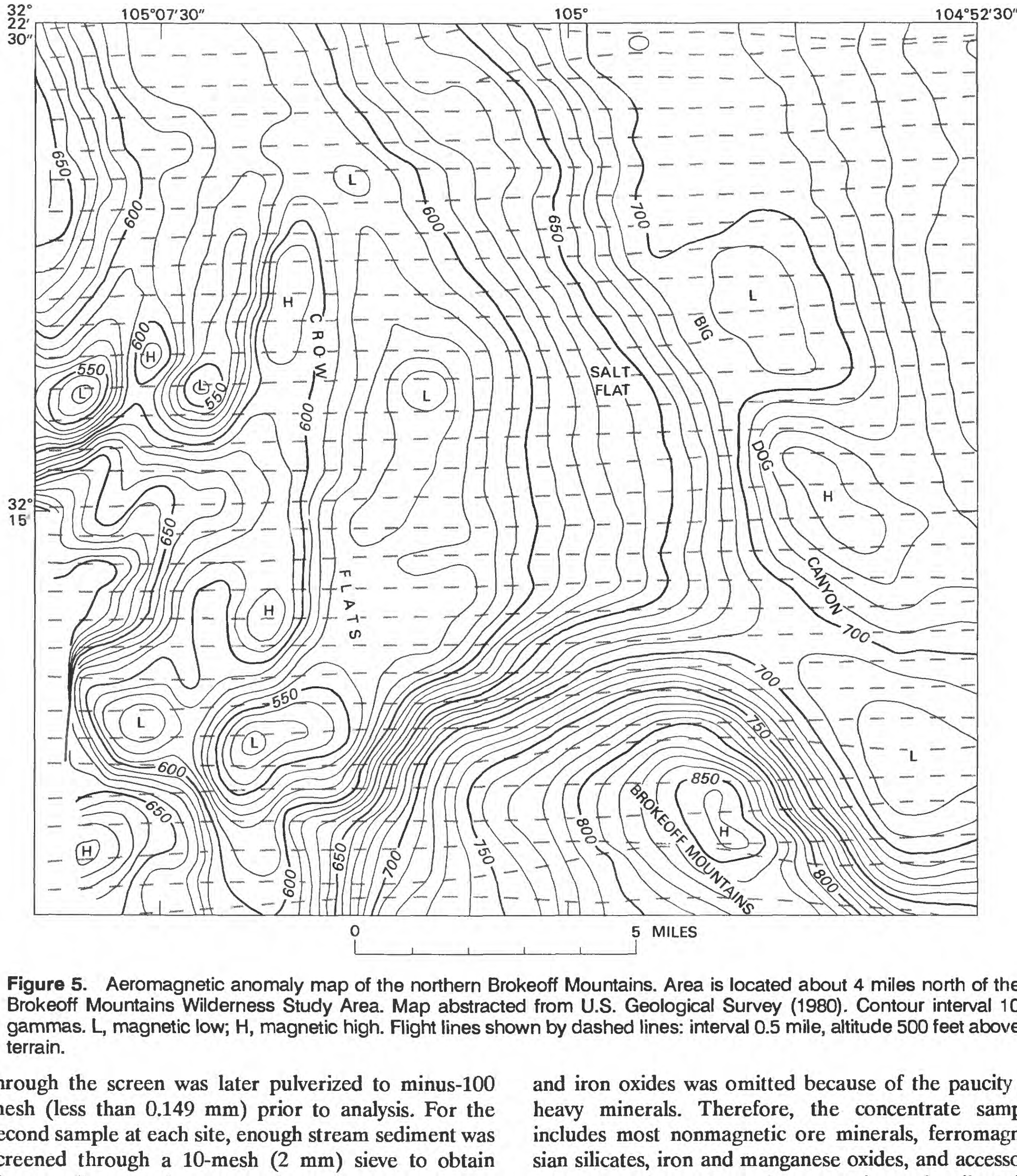


Figure 5. Aeromagnetic anomaly map of the northern Brokeoff Mountains. Area is located about 4 miles north of the Brokeoff Mountains Wilderness Study Area. Map abstracted from U.S. Geological Survey (1980). Contour interval 10 gammas. L, magnetic low; H, magnetic high. Flight lines shown by dashed lines: interval 0.5 mile, altitude 500 feet above terrain.

through the screen was later pulverized to minus-100 mesh (less than 0.149 mm) prior to analysis. For the second sample at each site, enough stream sediment was screened through a 10-mesh (2 mm) sieve to obtain about 20 lb. The minus-10-mesh sample was panned to remove most of the carbonate rock material, quartz, feldspar, clay-sized material, and organic matter. Treatment with bromoform (specific gravity 2.8) removed the remaining light minerals. Finally, a magnetic separation removed the magnetite and any other naturally magnetic minerals to produce a "concentrate sample." A magnetic separation to remove paramagnetic minerals such as ferromagnesian silicates and iron oxides was omitted because of the paucity of heavy minerals. Therefore, the concentrate sample includes most nonmagnetic ore minerals, ferromagnesian silicates, iron and manganese oxides, and accessory minerals such as sphene, zircon, apatite, and rutile. Prior to analysis the concentrate sample was pulverized to minus-100 mesh.

The stream-sediment and concentrate samples were analyzed by emission spectrography for 35 elements. In addition, the concentrate samples were analyzed by emission spectrography for platinum and palladium. Also, the stream-sediment samples were analyzed for uranium by ultraviolet fluorometry and for

Table 1. Statistics for selected elements in panned-concentrate samples from stream sediments of the Brokeoff Mountains Wilderness Study Area, Otero County, New Mexico

[Samples collected and analyzed by the U.S. Geological Survey. Results based on 27 samples of unseparated paramagnetic-nonmagnetic fractions. Concentrations determined by emission spectrography. All concentrations are reported in parts per million, except iron, which is reported in percent. N, not detected; L, detected below lower limit of determination]

Element	Lower limit of determination	Upper limit of determination	Range		50th percentile
			Minimum	Maximum	
Iron	0.1	50	10	30	20
Boron	20	5,000	70	300	150
Cobalt	20	5,000	L	70	50
Chromium	20	10,000	200	2,000	700
Copper	10	50,000	30	300	150
Lanthanum	100	2,000	N	500	100
Molybdenum	10	5,000	10	70	20
Nickel	10	10,000	15	500	100
Strontium	200	10,000	N	10,000	N
Zinc	500	20,000	N	1,500	N

arsenic, bismuth, cadmium, antimony, and zinc by inductively coupled plasma spectroscopy. Analytical data, sampling sites, and references to analytical methods are presented by Bullock and others (1988).

Results

Concentrate samples appear to be more useful than stream-sediment samples for a geochemical evaluation of the Brokeoff Mountains Wilderness Study Area. One stream-sediment sample contains 7 ppm (parts per million) silver and 150 ppm lead, which are both anomalous concentrations. However, the concentrate sample from the same site has no detectable silver at 1 ppm and an average concentration of lead (50 ppm). This anomalous stream-sediment sample (111, pl. 1) was collected in a southern tributary of Cork Draw. The source of the silver and lead is unknown.

Results of the analyses of the concentrate samples from the Brokeoff Mountains Wilderness Study Area were compared with those of the Guadalupe Escarpment Wilderness Study Area (Light and others, 1985), which lies about 5 mi east of the Brokeoff Mountains Wilderness Study Area. Concentrate samples from both study areas showed similar anomalous element contents which include zinc and molybdenum (table 1). Zinc and molybdenum are the only elements listed in table 1 that occur in anomalous amounts. The anomalous amounts of zinc and molybdenum were probably derived from weathered, permeable iron-rich dolomitic sandstone beds that served as aquifers for the lateral migration of weakly mineralized fluids westward into the study area from the Guadalupe Escarpment (Light and others, 1985).

Mineral and Energy Resources

Metals

There are no mines or exploration prospects in the Brokeoff Mountains Wilderness Study Area (fig. 2). Although the Permian strata of the study area have been extensively faulted, no visible evidence of base- or precious-metal mineralization was observed in the dolomite breccia and gouge zones along these faults. This study includes 27 stream-sediment samples that were processed to panned-concentrate samples (table 1), and the only anomalous elements found in the panned-concentrates were zinc and molybdenum. The zinc and molybdenum were probably derived from minor concentrations of these elements in connate waters that migrated laterally, resulting in the deposition of zinc and molybdenum in the Permian dolomite, dolomitic limestone, and dolomitic sandstone of the study area (Light and others, 1985). These geochemical data in the study area, in conjunction with the lack of visible evidence of mineralized fault zones and (or) hydrothermally altered wallrock along the faults, strongly indicate that it is improbable that any significant amounts of metallic minerals underlie the study area. Supporting this conclusion is the general lack of mineralized rocks in the Little Dog and Pup Canyons Roadless Area (Hayes and Bigsby, 1983; Hayes and others, 1983) and in the Guadalupe Mountains east of the study area (Hayes, 1964). The closest known mineralized rocks to the Brokeoff Mountains Wilderness Study Area occur about 5 mi east in a prospect in the Devil's Den Wilderness Study Area (Corbetta, 1987; Light and others, 1985). Minerals of possible economic importance that occur in the Devil's Den prospect are azurite, malachite, and hematite (Corbetta, 1987). There is no record of production from the Devil's Den prospect (Corbetta, 1987).

The Brokeoff Mountains Wilderness Study Area, for the above reasons, is given a low mineral resource potential for all metals, with a certainty level of C.

Coal

The Permian strata that underlie the study area are all marine in origin and therefore unlikely to contain coal; there is a low energy potential for coal in the study area, with a certainty level of C.

Oil and Gas

Oil and gas lease applications overlap into the study area in the southwestern margin and the southeastern parts of the map area (fig. 2). Test wells were drilled within 3 mi of the study area; all were dry and abandoned (Corbetta, 1987). The oil and gas potential of the Brokeoff Mountains is low because of the extensive faulting and tilting of Permian strata in the shelf facies of the rocks of the Delaware Basin that likely destroyed any petroleum trap that may have been present (Cruver and others, 1982; Ryder, 1983). Thus the Brokeoff Mountains Wilderness Study Area has a low energy resource potential for oil and gas, with a certainty level of C. The geologic terrane east of the study area has a high potential for oil and gas, because it is on the northwest shelf of the Delaware Basin in geologic terrane similar to that of productive wells in the Delaware Basin and the northwestern shelf areas of the basin (Ryder, 1983).

Geothermal Energy

The Brokeoff Mountains Wilderness Study Area has not been leased for geothermal energy exploration, and there are no warm springs or wells in the area that would suggest a high geothermal gradient (heat flow). The Brokeoff Mountains Wilderness Study Area is therefore given a low resource potential for geothermal energy, with a certainty level of C.

REFERENCES CITED

Bond, K.R., and Zietz, Isidore, 1987, Composite magnetic anomaly map of the conterminous United States west of 96° longitude: U.S. Geological Survey Geophysical Investigations Map GP-977, 2 sheets, scale 1:2,500,000.

Boyd, D.W., 1958, Permian sedimentary facies, central Guadalupe Mountains, New Mexico: New Mexico Bureau of Mines and Mineral Resources Bulletin 49, 100 p.

Bullock, J.H., Jr., Roemer, T.A., and Nowlan, G.A., 1988, Analytical results and sample locality map for stream-sediment and heavy-mineral-concentrate samples from the Brokeoff Mountains Wilderness Study Area (NM–030–112), Otero County, New Mexico: U.S. Geological Survey Open-File Report 88–574, 11 p., 1 pl.

Carson Helicopters, Inc., 1981, National Uranium Resource Evaluation aerial reconnaissance survey of portions of New Mexico, Arizona, and Texas (Fort Sumner, Roswell, Carlsbad, Las Cruces, El Paso, and Holbrook quadrangles)—Final report: U.S. Department of Energy Grand Junction Office (report) GJBX 412–81, v. 2, scale 1:500,000

Corbetta, P.A., 1987, Mineral investigation of a part of the Brokeoff Mountains (NM–030–112) Wilderness Study Area, Otero County, New Mexico, and the Lonesome Ridge (NM–060–801) and a part of the Devil's Den (NM–060–145) Wilderness Study Areas, Eddy County, New Mexico: U.S. Bureau of Mines Open-File Report MLA–43–87, 17 p.

Cordell, Lindrith, Keller, G.R., and Hildenbrand, T.G., 1982, Bouguer gravity map of the Rio Grande Rift, Colorado, New Mexico, and Texas: U.S. Geological Survey Geophysical Investigations Series Map GP–949, scale 1:1,000,000

Cruver, S.K., Wodzicki, Antoni, and Krason, Jan, 1982, Geology, energy, and mineral resource assessment of the Humphrey Canyon Area, New Mexico: Unpublished report prepared for the U.S. Bureau of Land Management, Las Cruces District, 47 p.

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

Hayes, P.T., 1964, Geology of the Guadalupe Mountains, New Mexico: U.S. Geological Survey Professional Paper 446, 69 p.

Hayes, P.T., and Bigsby, P.R., 1983, Mineral resource potential and geologic map of the Little Dog and Pup Canyons roadless area, Otero County, New Mexico: U.S. Geological Survey Miscellaneous Field Studies Map MF–1468, scale 1:50,000.

Hayes, P.T., Light, T.D., and Thompson, J.R., 1983, Mineral resource potential and geology of Guadalupe Escarpment Wilderness Study Area, Eddy County, New Mexico: U.S. Geological Survey Miscellaneous Field Studies Map MF–1560–A, scale 1:24,000, and pamphlet, 6 p.

Light, T.D., Domenico, J.A., and Smith, S.M., 1985, Geochemical map of the Guadalupe Escarpment Wilderness Study Area, Eddy County, New Mexico: U.S. Geological Survey Miscellaneous Field Studies Map MF–1560–B, scale 1:24,000

Ryder, R.T., 1983, Petroleum potential of wilderness lands in New Mexico, *in* Miller, B.W., ed., Petroleum potential of wilderness lands in the western United States: U.S. Geological Survey Circular 902–A–P, p. I1–I33.

U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, 5 p.

U.S. Geological Survey, 1980, Aeromagnetic map of the Little Dog–Pup Canyon area, New Mexico: U.S. Geological Survey Open-File Report 80–997, scale 1:62,500.

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 →

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
A	B	C	D

LEVEL OF CERTAINTY →

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

Abstracted with minor modifications from:

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

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

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

RESOURCE/RESERVE CLASSIFICATION

	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Probability Range (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.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1989—673-047/86,071 REGION NO. 8