Mineral Resources of the West Potrillo Mountains–Mount Riley and the Aden Lava Flow Wilderness Study Areas, Dona Ana and Luna Counties, New Mexico

U.S. GEOLOGICAL SURVEY BULLETIN 1735–B

Chapter B

Mineral Resources of the West Potrillo Mountains–Mount Riley and the Aden Lava Flow Wilderness Study Areas, Dona Ana and Luna Counties, New Mexico

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U.S. GEOLOGICAL SURVEY BULLETIN 1735

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
SOUTHWESTERN NEW MEXICO

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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 West Potrillo Mountains–Mount Riley (NM–030–052) and the Aden Lava Flow (NM–030–053) Wilderness Study Areas, Dona Ana and Luna Counties, New Mexico.

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Mineral Resources of the West Potrillo Mountains-Mount Riley and the Aden Lava Flow Wilderness Study Areas, Dona Ana and Luna Counties, New Mexico

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ABSTRACT

In 1985, the USGS (U.S. Geological Survey) and the USBM (U.S. Bureau of Mines) conducted a mineral resource appraisal of part of the West Potrillo Mountains–Mount Riley Wilderness Study Area (NM–030–052) and the entire Aden Lava Flow Wilderness Study Area (NM–030–053), which encompass 148,540 and 25,287 acres, respectively, in southwestern New Mexico. This wide-ranging study included an examination of geologic, geochemical, and geophysical data, as well as a review and assessment of local mining activity. The West Potrillo Mountains–Mount Riley study area has identified resources of volcanic cinder at 21 individual sites (fig. 1). The rest of the West Potrillo Mountains–Mount Riley study area and the entire Aden Lava Flow study area have a low mineral resource potential for undiscovered volcanic cinder resources. Both study areas have a low mineral and energy resource potential for undiscovered, near-surface base (copper, lead, zinc, tin) and precious (gold, silver, platinum) metals, oil and gas, uranium, and geothermal energy resources. Based on currently available data, the mineral resource potential for undiscovered metallic resources in the underlying rocks at depth in both study areas is unknown.

SUMMARY

The West Potrillo Mountains–Mount Riley study area is roughly 30 mi (miles) southwest of Las Cruces, in Dona Ana and Luna Counties, N. Mex. (fig. 2). The Aden Lava Flow study area is east and northeast of the West Potrillo Mountains–Mount Riley study area, totally within Dona Ana County, about 20 mi southwest of Las Cruces. Access to and within both study areas is restricted to a number of improved and unimproved dirt roads. These unimproved roads may be approached from several locations off Interstate Highway 80, which passes a short distance from the study areas. Mount Riley, the Indian Basin depression, and the West Potrillo Mountains form the major topographic features of the West Potrillo Mountains–Mount Riley study area. Elevations range from a low of about 4,000 ft (feet) near the southwestern edge of the study area to nearly 6,000 ft at the summit of the Mount Riley intrusion. The terrain is marked by numerous intermittent drainages. Topographic relief is modest in the Aden Lava Flow study area. Elevations range from about 4,200 ft close to the eastern confines of the study area to roughly 4,400 ft at the crest of Aden Crater. A distinct drainage system is notably absent in the study area.

The West Potrillo Mountains–Mount Riley and the Aden Lava Flow Wilderness Study Areas are in the southernmost section of the Rio Grande rift, where the rift merges with the New Mexico portion of the Basin and Range province. Both study areas contain Quaternary basalt flows and cinder cones of the Potrillo basalt field (Hoffer, 1976a, b). The most prominent topographic feature in the region is Mount Riley. This felsic stock intrudes a series of Tertiary(?) volcaniclastic sedimentary and volcanic rocks, and marks the eastern edge of the West Potrillo Mountains–Mount Riley Wilderness Study Area.

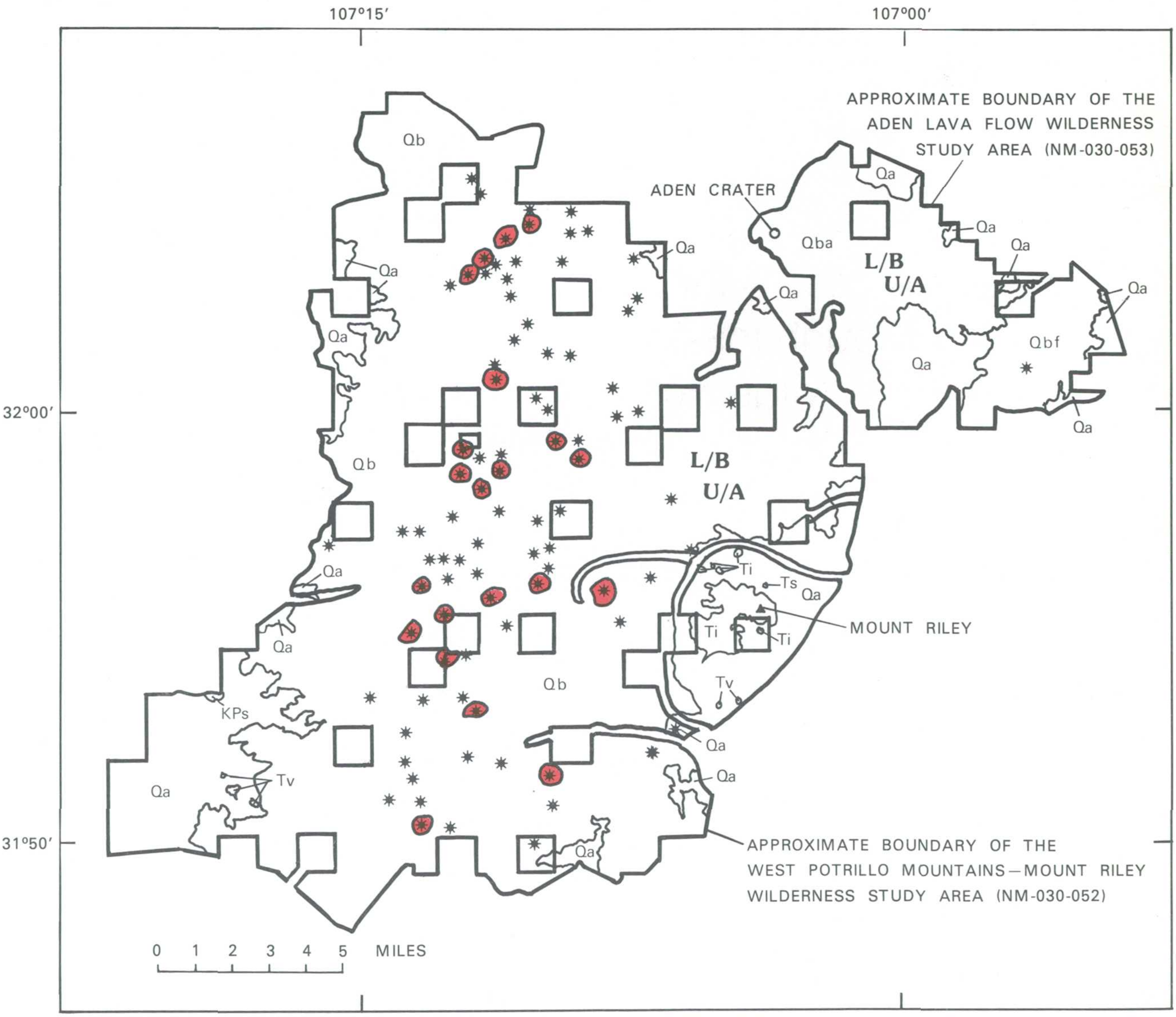

Figure 1 (above and facing page). Map showing identified resources, mineral resource potential, and generalized geology in the West Potrillo Mountains–Mount Riley and the Aden Lava Flow Wilderness Study Areas, New Mexico.

Volcanic cinder deposits in the West Potrillo Mountains–Mount Riley study area are the only resource identified by this investigation. Volcanic cinder or scoria is used for lightweight structural concrete, plaster aggregate, loose-fill insulator, roofing granules, riprap, railroad ballast, road surfacing, and landscaping. The volume of this resource is conservatively estimated at 400 million cubic yards. Distant markets make development of this commodity doubtful in the foreseeable future.

The mineral resource potential for volcanic cinder in the remainder of the West Potrillo Mountains–Mount Riley study area and the entire Aden Lava Flow study area is low. In spite of nearby subeconomic silver, lead, molybdenum, zinc, and copper occurrences, both study areas have low potential for undiscovered resources of near-surface base (copper, lead, zinc, tin) and precious (gold, silver, platinum) metals. Field observations and geophysical gravity data, however, suggest that carbonate-rich, slightly mineralized rocks that crop out locally may in fact extend beneath the surface into the West Potrillo Mountains–Mount Riley study area. In any case, the mineral resource potential for undiscovered metallic resources at depth in both study areas is unknown on the basis of currently available data. Accumulations of oil and gas are unlikely due to the unfavorable structural setting and pervasive volcanic activity in both study areas. The energy resource potential for undiscovered oil and gas resources is therefore low. No radioactive anomalies were detected in or near either study area, and the mineral resource potential for undiscovered uranium resources is considered low. The energy resource potential for undiscovered geothermal resources is regarded as low in both study areas because of generally low heat gradients and a deep-seated water table.

EXPLANATION OF IDENTIFIED RESOURCES AND MINERAL RESOURCE POTENTIAL

- ⊛ **Area having identified resources of volcanic cinder**
- L/B **Geologic terrane having low mineral resource potential for volcanic cinder, near-surface base (copper, lead, zinc, tin) and precious (gold, silver, platinum) metals, oil and gas, uranium, and geothermal energy, with certainty level B**—Applies to entire study areas; except that low potential for volcanic cinder does not apply to areas having identified resources of volcanic cinder
- U/A **Geologic terrane having unknown mineral resource potential for subsurface metals, with certainty level A**—Applies to entire study areas

Certainty levels

- A **Available data not adequate to determine level of resource potential**
- B **Data indicate geologic environment and suggest level of resource potential**

LIST OF MAP UNITS

- Qa **Alluvium, undifferentiated (Quaternary)**
- Qpab **Aden Basalt (Quaternary)**
- Qpaf **Afton Basalt (Quaternary)**
- Qpb **West Potrillo Basalt (Quaternary)**
- Ti **Intrusive rock (Tertiary?)**
- Tv **Volcanic rock (Tertiary?)**
- Ts **Sedimentary rock (Tertiary?)**
- KPs **Limestone (Cretaceous? or Permian)**

- ——— **Contact**
- * **Cinder cone**

INTRODUCTION

The West Potrillo Mountains–Mount Riley (NM–030–052) and the Aden Lava Flow (NM–030–053) Wilderness Study Areas encompass 148,540 and 25,287 acres, respectively. In this report, "study area" and "wilderness study area" refer to these acreages, which are the acreages on which mineral surveys were conducted. The West Potrillo Mountains–Mount Riley study area is roughly 30 mi southwest of Las Cruces, in Dona Ana and Luna Counties, N. Mex. (fig. 2). The Aden Lava Flow study area is totally within the confines of Dona Ana County, some 20 mi southwest of Las Cruces (fig. 2). Access to and within the study areas is limited to a number of improved and unimproved dirt roads. These unpaved roads may be accessed at several locations off Interstate Highway 80, which passes north and east of the study areas.

An arid, continental climate, with moderate winters and hot summers, characterizes this broad expanse in southwestern New Mexico. Both study areas contain locally abundant vegetation, including several species of range grass and a variety of desert shrubs such as mesquite and creosote bush. Mount Riley, the Indian Basin depression, and the volcanic cones of the West Potrillo Mountains (pl. 1) constitute the predominant topographic features of the West Potrillo Mountains–Mount Riley study area. Elevations range from a low of about 4,000 ft along the southwestern margin of the study area (Indian Basin) to almost 6,000 ft at the summit of the Mount Riley intrusion near the eastern periphery of the study area. Numerous minor intermittent drainages incise the landscape. The Aden Lava Flow study area is an almost level tract of basalt. Topographic relief is slight; elevations range from about 4,200 ft near the eastern edge of the study area to approximately 4,400 ft at the crest of Aden Crater, a small shield cone near the northwest margin of the study area. The study area has no distinct drainage system.

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 USBM and the USGS. Identified resources are classified according to the system of the USBM and USGS (1980), which is shown in the Appendix. 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), which is shown in the Appendix. The potential for undiscovered resources is studied by the USGS.

Investigations by the U.S. Bureau of Mines

In 1985, the USBM conducted a mineral survey of the West Potrillo Mountains–Mount Riley and the Aden Lava Flow Wilderness Study Areas in order to determine the nature and extent of known mineralization. Prior to field studies a literature search was undertaken and relevant published and unpublished information was

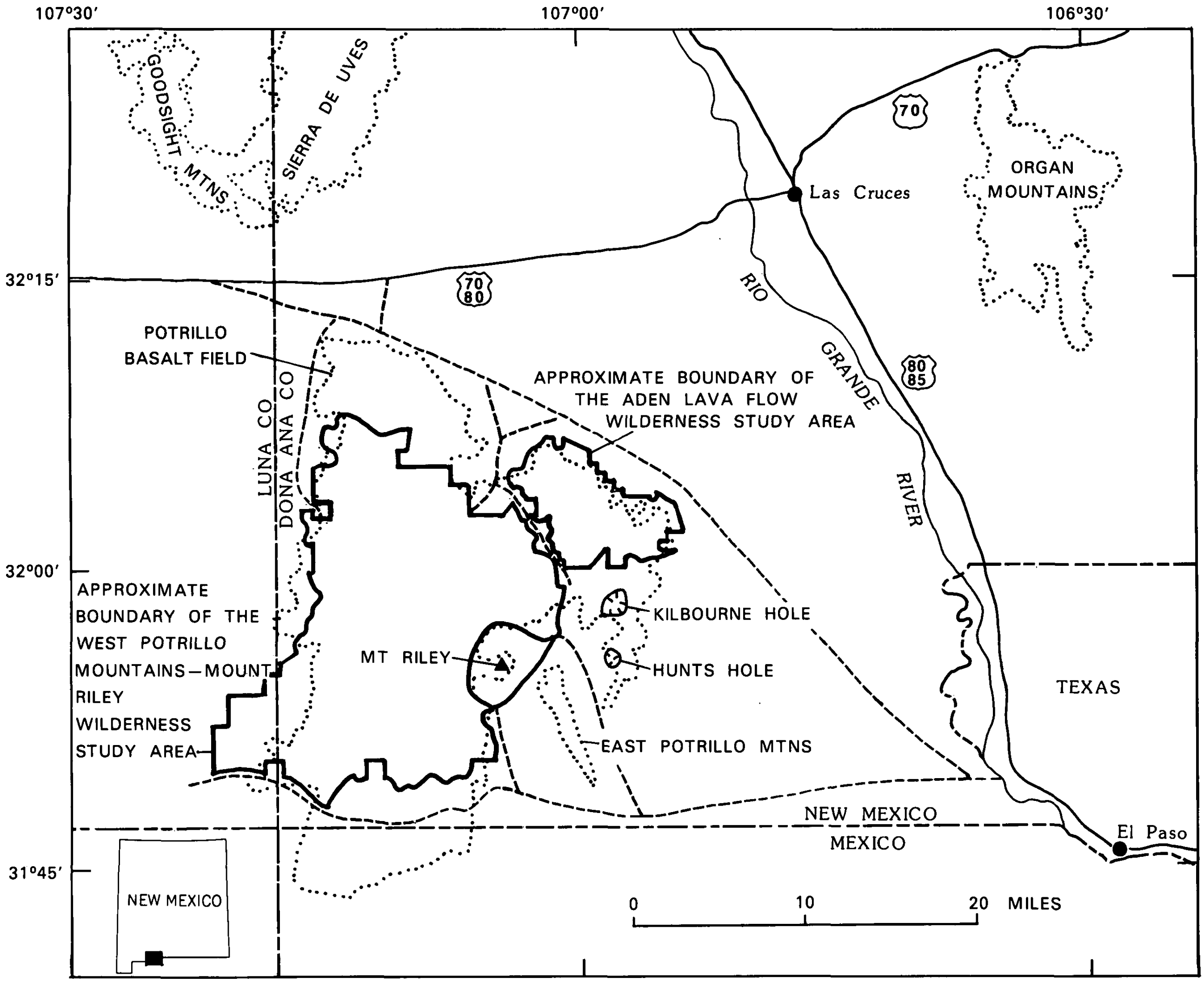

Figure 2. Index map showing the location of the West Potrillo Mountains–Mount Riley and the Aden Lava Flow Wilderness Study Areas, Dona Ana and Luna Counties, New Mexico. For simplicity, private and State inholdings are not shown. Dashed lines indicate unimproved roads.

carefully reviewed. This included a perusal of patented and unpatented claim records as well as a review of oil, gas, and geothermal leases. A summary of the results is presented here and in a more detailed report by Gese (1985).

Investigations by the U.S. Geological Survey

In 1985, the USGS carried out a mineral resource appraisal of the West Potrillo Mountains–Mount Riley and the Aden Lava Flow Wilderness Study Areas. This investigation involved a review of pertinent published and unpublished material, geologic mapping, collection of stream-sediment and rock samples for geochemical analyses, and the examination of regional gravity and aeromagnetic surveys.

APPRAISAL OF IDENTIFIED RESOURCES

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Methods of Investigation

Two USBM employees spent 17 days in the field and collected a total of 77 chip, grab, and stream-sediment samples. All 77 samples were fire assayed for gold and silver and analyzed by semiquantitative optical emission spectrographic methods for 40 elements. In addition, 17 samples were analyzed by atomic absorption spectrometry for barium, copper, lead, and zinc.

Complete analytical results for all samples are available for public inspection at the USBM, Intermountain Field Operations Center, Building 20, Denver Federal Center, Denver, CO 80225.

A volcanic cinder identified resource was determined for the West Potrillo Mountains–Mount Riley study area. Resource estimates were conservative and 20 percent of the calculated material was excluded to allow for waste. Aspect ratios (height over basal diameter), heights, radii, and resources for the 21 cones sampled are given in table 1. The color of the volcanic cinders was measured by comparing the sample with the Munsell soil color chart (Munsell Products, 1973).

Appraisal of Sites Examined

Red and black volcanic cinders have been mined intermittently from the Chaparral claims, located near the southern confines of the West Potrillo Mountains–Mount Riley study area, since the late 1940's. Black cinders were also mined from the deposit at Guzmans Lookout Mountain on the southern boundary of the West Potrillo Mountains–Mount Riley study area.

No mining districts are within the study areas. The West Potrillo Mountains–Mount Riley study area is less than 1 mi northwest of the Potrillo Mountains mining district, which includes the East Potrillo Mountains. The Aden Lava Flow study area is approximately 1 mi southwest of the Aden–Afton mining district. Gold, lead, barite, and marble were produced from the Potrillo Mountains district around 1900, and scoria was produced from the Aden–Afton district near the railroad siding of Afton (File and Northrop, 1966). The EPM block of lode claims, recently drilled by the Exxon Minerals Corp., and the Chaparral placer claims extend into the West Potrillo Mountains–Mount Riley study area (pl. 1).

Miscellaneous mineral occurrences near the study areas and not discussed in the text are summarized in Gese (1985).

Volcanic Cinder

Volcanic cinder is a rusty red to black, pyroclastic, scoriaceous material less than 1 in. (inch) in particle diameter that accumulates in cinder cones (Harben and Bates, 1984). More than 50 cinder cones occur within the West Potrillo Mountains–Mount Riley study area; 21 of these cones were examined and sampled (fig. 1, pl. 1). The cinder cones examined were limited to those having an aspect ratio (ratio of height to basal diameter) between 0.1 and 0.2 (Osburn, 1982). Osburn (1982) has suggested that all potentially commercial cinder cones fall within these limits. Mining cinder cones whose aspect ratios fall within this range should lower the amount of lava flows and ash encountered, thereby upgrading the material mined and lowering costs. All 21 cones were evaluated on the basis of color, texture, sorting, and grain size. Osburn (1980) also evaluated and calculated reserves for 3 of these 21 cinder cones. An inferred volcanic cinder resource of 400 million cubic yards was determined for the 21 cinder cones.

Chaparral Claims

The Chaparral block of six placer claims is located along and extends into the southern boundary of the West Potrillo Mountains–Mount Riley study area. Volcanic cinders have been extracted intermittently from these claims since they were first located in 1952. Two cinder pits are within the claims: one for the extraction of red cinders and one for the extraction of black cinders. Cinders were removed with front-end loaders and sorted and sized on site. Red cinders were being mined from the west pit in March 1985, approximately 2,000 ft south of the study area, for use in the construction industry. The claim holders plan on mining cinders from this deposit over the next 20 years. Although the Chaparral claims extend into the study area, both cinder deposits are outside the study area.

Guzmans Lookout Mountain

The volcanic cinder mine at Guzmans Lookout Mountain is on the southern boundary of the West Potrillo Mountains–Mount Riley study area in SW¼ sec. 35, T. 28 S., R. 4 W. Black cinders from the mine were used as ballast for the now abandoned Southern Pacific railroad bed. The southern and southwestern slopes of Guzmans Lookout Mountain have been almost completely removed but the northern slope is undisturbed. The deposit is approximately 350 ft thick and consists of well-sorted, black cinders. The mine has not been worked for several years, and because of the color of its cinders and remote location it will probably not be reopened in the near future.

EPM Claims

The EPM block of mining claims consists of 116 lode claims within and adjacent to the eastern part of the West Potrillo Mountains–Mount Riley study area. Barite prospects and jasperoid outcrops initially attracted William A. Bowes and Associates, the claim holder, to the area in 1970. The jasperoid outcrops are mainly along faults, fractures, and breccia zones in the Lower Permian Hueco Limestone. Several silver anomalies were delineated in the area as a result of a geologic mapping and geochemical sampling program, a shallow drilling program, and an induced polarization and resistivity survey (Jenkins, 1977).

Table 1. Resource data an d descriptions of samples from 21 cinder cones inside the West Potrillo Mountains–Mount Riley Wilderness Study Area, New Mexico

[Data from Gese, 1985]

Sample No.	Aspect ratio	Radius of base (feet)	Height (feet)	Inferred resources (million cubic yards)	Description
9	0.11	1,000	225	7.0	Grayish-red cinders, abundant agglutinate on surface.
10	.13	1,700	450	40.3	Dark-gray cinders, moderate amount of agglutinate.
11	.10	1,200	250	11.2	Dark-gray cinders, well sorted, very little agglutinate on surface.
13	.14	1,250	350	17.0	Black cinders, well sorted, little agglutinate on surface.
19	.12	1,650	275	23.2	Brownish-black cinders, well sorted, very little agglutinate on surface.
20	.11	800	170	3.4	Medium-gray and dark-reddish-brown cinders, poorly sorted, moderate amount of agglutinate on surface.
21	.13	550	150	1.4	Pale-red cinders, moderately sorted, moderate amount of agglutinate on surface.
22	.10	1,100	230	8.6	Dark-reddish-brown cinders, poorly sorted, moderate amount of agglutinate on surface.
23	.12	1,200	290	13.0	Very dusky red cinders, poorly sorted, moderate amount of agglutinate on surface.
24	.14	800	230	4.6	Very dusky red to black cinders, poorly sorted, moderate amount of agglutinate on surface.
25	.12	950	230	6.4	Moderate-red cinders, poorly sorted, abundant agglutinate on surface.
36	.13	1,650	450	38.0	Dusky red cinders, well sorted, very little agglutinate on surface.
37	.12	1,650	400	33.8	Grayish-red cinders, well sorted, little agglutinate on surface.
38	.14	1,100	320	12.0	Dusky red cinders, well sorted, very little agglutinate on surface.
39	.11	1,150	250	10.2	Dark-reddish-brown cinders, moderately sorted, moderate amount of agglutinate on surface.
40	.12	1,350	320	18.1	Same as sample number 39 but no agglutinate on surface.
41	.13	1,400	380	23.1	Grayish-black to grayish-red cinders, moderately sorted, moderate amount of agglutinate on surface.
42	.17	1,250	430	20.8	Grayish-black cinders, well sorted, little agglutinate on surface.
60	.11	2,150	480	68.8	Pale-brown to grayish-red cinders, moderately well sorted, moderate amount of agglutinate on surface.
62	.15	1,375	400	23.4	Grayish-black cinders, moderately sorted, moderate amount of agglutinate on surface.
63	.12	1,300	310	16.2	Moderate-reddish-brown cinders, moderately sorted, cinders loosely cemented in outcrop, moderate amount of agglutinate on surface.

In 1983 and 1984, Exxon Minerals Corp. drilled 10 holes within the claim block 1,500–7,000 ft southeast of the study area. Total depths of the drill holes ranged from 25 to 465 ft; all but two of the drill holes were at least 175 ft deep. Silver values of 2–27 ppm (parts per million) were found in drill cuttings from six of the drill holes (Gese, 1985).

USBM personnel took 12 samples from brecciated and silicified Hueco Limestone outcrops on the EPM claims. Six samples contained from 0.1 to 0.3 oz (ounces) silver/ton (3.4 to 10.2 ppm) and two samples contained a trace amount of gold (Gese, 1985, table 2). Barite was visible in most of the samples. All of the claims that were inside the study area boundary were recently abandoned by the claim holder (Steve Aacher, Bowes and Associates, oral commun., October 1985).

Geothermal Energy

Geothermal resources have been of interest in both study areas since approximately 1975. Interest was initially based on the large amount of Quaternary volcanic activity in the area and on local reports of warm water (80–100 °F) in wells. The Kilbourne Hole KGRA (Known Geothermal Resource Area) was established in 1975 by the USGS and was located south of the Aden Lava Flow study area.

The following information was supplied by Roger Bowers, Hunt Energy Corp., Dallas, Texas (oral commun., October 1985). Hunt Energy Corp. was engaged in numerous geothermal exploration activities around the Kilbourne Hole KGRA and within the Aden Lava Flow study area. Their exploration activities included mapping geologic structural trends from aerial photographs, a roving-dipole resistivity study, a shallow (300–500 ft) drilling program, and a deeper (2,000 ft) more detailed drilling program. Anadarko Production Corp. also held geothermal leases in the area and their exploration activities were limited to shallow (300–500 ft) drilling within the Kilbourne Hole KGRA.

Subsurface temperatures within and near the study areas are too low (less than 250 °F) to be of commercial interest due to the remoteness of the area and the depth to the water table (250–300 ft). Both Hunt Energy Corp. and Anadarko Production Corp. dropped their geothermal leases and the Kilbourne Hole KGRA was declassified.

Oil and Gas

Oil and gas leases cover the southern part of the West Potrillo Mountains–Mount Riley study area and most of the Aden Lava Flow study area. One oil and gas test well has been drilled within the West Potrillo Mountains–Mount Riley study area (pl. 1) and two wells have been drilled within 5 mi of the study area. None of the wells had oil or gas shows (Thompson and Bieberman, 1975; Kottlowski and others, 1969).

The Aden lava flow is situated on the northern limb of the Pedrogosa basin, a basin in which oil and gas is known to occur in Mexico (Landes, 1970). Hydrocarbon shows were found in Paleozoic, Cretaceous, and Tertiary strata in the Grimm, Hunt, Brown, and American Arctic Ltd. No. 1 Mobile-32 test well, approximately 2.5 mi northeast of the study area (Thompson and Bieberman, 1975).

Recommendations for Further Studies

The volume of the volcanic cinders could be calculated with a higher degree of certainty, and the quality of the cinders could be determined with more accuracy, if exploration cuts were made to expose the internal material of the cinder cones.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

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Geology

Geologic Setting

The West Potrillo Mountains–Mount Riley and the Aden Lava Flow Wilderness Study Areas are in the southernmost part of the Rio Grande rift, where it merges with the New Mexico portion of the Basin and Range province (Seager and Morgan, 1979). The West Potrillo Mountains–Mount Riley Wilderness Study Area contains mainly Quaternary basaltic lava flows and cinder cones, although in the southwestern part of the study area a few isolated outcrops of Tertiary volcanic rocks and one outcrop of silicified carbonate rock also occur (pl. 1). Mount Riley is a felsic pluton that intrudes a series of Tertiary(?) volcaniclastic sedimentary and volcanic rocks near the eastern confines of the study area (pl. 1). The Aden Lava Flow study area contains two Quaternary basalt flows, the Aden lava flow and the Afton lava flow, both of which rest on unconsolidated sedimentary basin fill of the Miocene to Pleistocene Santa Fe Group.

Description of Rock Units

Permian and Cretaceous carbonate and clastic sedimentary rocks are abundant in the region and crop out near the southeastern, southwestern, and western boundary of the West Potrillo Mountains–Mount Riley study area. The most prominent of these outcroppings are those of the East Potrillo Mountains, a basin-and-range uplifted fault block. It seems reasonable to suspect that these units may underlie much of the West Potrillo Mountains–Mount Riley study area and possibly the Aden Lava Flow study area as part of a corresponding downthrown fault block.

Undated but probably Tertiary intermediate to silicic composition volcanic and volcaniclastic sedimentary rocks occur in isolated outcrops west and north of the West Potrillo Mountains (Seager, 1987) and in the vicinity of and south of the Mount Riley intrusion (Millican, 1971; Seager, 1987) (pl. 1). According to Hoffer (1986), much of the region is underlain by calc-alkaline andesitic to dacitic volcanic rocks and volcaniclastic tuffs and sediments.

Also undated but probably associated with the foregoing intermediate to silicic magmatic suite is the Mount Riley pluton (Tri unit of pl. 1). This intrusion is a complex of light-tan fine-grained felsic rocks. Host rocks near the contact with the Mount Riley intrusion are brown, maroon, green, and dark-gray siltstone and sandstone, water-laid tuff, volcaniclastic sandstone, and conglomerate (Ts unit of pl. 1).

Before the eruption of the Quaternary volcanic rocks in the study areas, the Potrillo region was faulted during the formation of the Rio Grande rift. As a result, the region between the East and West Potrillo Mountains is a north-trending upthrown block (Seager, 1987) with downthrown blocks on either side forming topographic basins.

The West Potrillo Mountains–Mount Riley and the Aden Lava Flow study areas are largely underlain by Quaternary basalt lava flows and cinder cones of the Potrillo basalt field (Hoffer, 1976a, b). Within the study areas, Hoffer recognized three main basaltic units, the West Potrillo Basalt found within the West Potrillo Mountains, and the Afton Basalt and Aden Basalt, which are found within and south of the Aden Lava Flow study area. All of these basalts are interpreted to be younger than middle Pleistocene (Hoffer, 1976a).

The youngest recognized geologic units in the study areas are localized Quaternary alluvium.

Geochemistry

A reconnaissance geochemical survey was conducted in the West Potrillo Mountains–Mount Riley Wilderness Study Area in the winter of 1985 to aid in the mineral resource assessment of the area. Geochemical sampling in the Aden Lava Flow Wilderness Study Area was not done because stream drainages are virtually nonexistent. In addition, the underlying basalts are very young and fractures, joints, and faults, where leakage of metals from buried or concealed deposits might occur, are not sufficiently developed near the surface to serve as outlets for migrating metals in solution.

Nonmagnetic heavy-mineral concentrates in the West Potrillo Mountains–Mount Riley Wilderness Study Area and rocks in both study areas were selected as appropriate sample media. All samples were analyzed by a six-step semiquantitative emission spectrographic method (Grimes and Marranzino, 1968) for 31 elements. A complete listing of the analytical results and a concise description of the sampling and analytical techniques are given in Jones and others (1987).

Nonmagnetic heavy-mineral concentrates have proven remarkably effective in delineating mineralized systems in the arid or desert environments of the southwestern United States. This sample medium provides a representative cross section of the transported heavy-mineral components of a stream or drainage basin. Rock samples were collected from unaltered and altered outcrops in order to determine background levels and suites of elements associated with bedrock alteration. This survey was augmented by rock and concentrate samples collected just beyond the eastern and western confines of the West Potrillo Mountains–Mount Riley study area. These particular samples were gathered from mines, prospects, and areas of observed alteration (Jenkins, 1977; Broderick, 1984) for use as a comparative reference or guideline concerning mineralization within the study areas.

The samples collected outside the study areas had prominent geochemical anomalies in both sample media, reflecting localized silver, lead, molybdenum, zinc, and copper mineralization. Geochemical evidence for deposits of a similar nature or any mineralized system is notably absent within the West Potrillo Mountains–Mount Riley study area. Concentrate anomalies within the study area include silver, lead, tin, tungsten, barium, and strontium. By virtue of their isolated and widely scattered occurrences, however, any association with mineral deposits is unlikely, and no significance is perceived. Rock anomalies are localized about the Mount Riley pluton, where traces of silver and molybdenum were noted in a small number of samples. Although no definitive interpretation can be made of these few generally single-element anomalies, it seems reasonable to suspect that they represent little more than high background levels unrelated to mineralized rock.

Calcite veins and heavily stained pyrite-bearing fault gouge were also sampled from the Mount Riley stock. Although these samples proved to be barren of geochemical anomalies, the calcite veins may be of some interest. The size of some of the veins, a few of which attain thicknesses of greater than 6 ft, may indicate replacement of carbonate-bearing rocks below the present erosional surface. If, and to what degree, this possible zone(s) of replacement is (are) mineralized is not known.

Geophysics

The West Potrillo Mountains–Mount Riley and the Aden Lava Flow Wilderness Study Areas are covered by regional gravity and aeromagnetic surveys having sufficient resolution to define anomalies of 1.9 mi^2 or more in areal extent. Gravity data are in the form of a complete (terrain-corrected) Bouguer gravity anomaly map (fig. 3) (Cordell and others, 1982), based on 55 observation points within or immediately adjacent to the study areas. The aeromagnetic data are in the form of an anomaly map (fig. 4) contoured by hand (F.E. Riggle, USGS, oral commun., 1987). The aeromagnetic data are based on measurements made along nine flight lines in an east-west direction and three tie lines in a north-south direction, spaced 3 mi and 11 mi apart, respectively, at an average altitude of 400 ft above ground (Carson Helicopters, Inc., 1981a, b). This aeromagnetic map agrees generally with the regional compilation of Cordell (1983), but does not reflect the detailed signatures of near-surface sources, as does a smaller survey of the Kilbourne Hole area (Cordell, 1975), flown at a line spacing of 1 mi.

Assumed contrasts of rock density and total magnetization (sum of remanent and induced magnetization or average dipole moment per unit volume) are based on measurements made in nearby areas (Ramberg and others, 1978; Klein and Wynn, 1984; Bath, 1976; Klein and Johnson, 1983), including the Gila Lower Box Wilderness Study Area, N. Mex. In order of increasing density, the groupings of interest are: (1) Quaternary basin fill and Tertiary unconsolidated sediments, (2) Quaternary basalt, which has a high vesicle content and consequent high porosity, Tertiary volcanic rocks and consolidated sedimentary rocks, and Mesozoic sedimentary rocks, (3) Tertiary intrusive rocks, and (4) Paleozoic sedimentary rocks, which are carbonate rich, and Precambrian granitic rocks. In order of increasing magnetization, the groupings are: (1) all sediments and sedimentary rocks of a non-volcanic origin, which are assumed to be relatively nonmagnetic, (2) Tertiary volcanic and intrusive rocks and Precambrian granitic rocks, which are assumed to be weakly to moderately magnetic, and (3) Quaternary basalt, known to be strongly magnetic.

The gravity data (fig. 3) show three prominent anomalies that are along the southern two-thirds of the West Potrillo Mountains–Mount Riley study area: a northwest-trending high (C) centered over Mount Riley; a north-trending low (B) southwest of this high and over the southern extremity of the study area; and a lower amplitude north-trending high (A) just west of the low, marked by a pair of separated contour closures. All of these features occur over various parts of the Potrillo basalt field and are inferred to have sources that underlie the basalt.

The northwest-trending gravity high (C) is associated in part with relatively dense Paleozoic sedimentary rocks of the East Potrillo Mountains and moderately dense Tertiary intrusive rocks of the Mount Riley region. This high is inferred to be caused mainly by an uplifted block of Phanerozoic sedimentary rocks, intruded by igneous rocks, and perhaps underlain by Precambrian metamorphic rocks. The lower amplitude north-trending gravity high (A) to the west is associated in part with relatively dense Precambrian granitic rocks and Paleozoic sedimentary rocks and moderately dense Tertiary intrusive rocks, similar to the association noted for the northwest-trending high. This high, like the one previously discussed, is inferred to be caused principally by an uplifted block of Precambrian and Phanerozoic rocks. The north-trending gravity low (B) is inferred to be generated by Tertiary sedimentary and volcanic graben fill.

The aeromagnetic data (fig. 4) disclose large anomalies associated with much of the Potrillo basalt field. The data indicate that the magnetization of much, if not most, of the basalt is reversed in polarity because of a high content of reversed remanent magnetization. The thickest part of the basalt, and perhaps the most magnetic part, is inferred to underlie the deepest magnetic low in the central part of the map area. This low is nested within a northeast-trending zone of lows extending from a circular depression at its southwestern extremity about 24 mi northeastward to the heart-shaped depression immediately north of the Aden Lava Flow Wilderness Study Area. This zone of lows may be underlain by a linear fracture zone marked by crustal weakness through which much of the basalt has been extruded. This feature is shown in the gravity data only by a subtle termination of the most prominent gravity high and its adjacent low. The magnetically reversed subsurface basalt within the inferred fracture zone predates the Aden and Afton Basalts of the Potrillo basalt field, known to be normally magnetized in conformity to their young ages. Tertiary intrusive rocks of the Mount Riley region do not generate a significant regional anomaly because they are weakly magnetic, limited in volume, or both. Similar intrusive rocks near the southwestern margin of the West Potrillo Mountains–Mount Riley study area have a little more magnetic expression, as part of a low that covers the northernmost exposures of Tertiary intrusive and Precam-

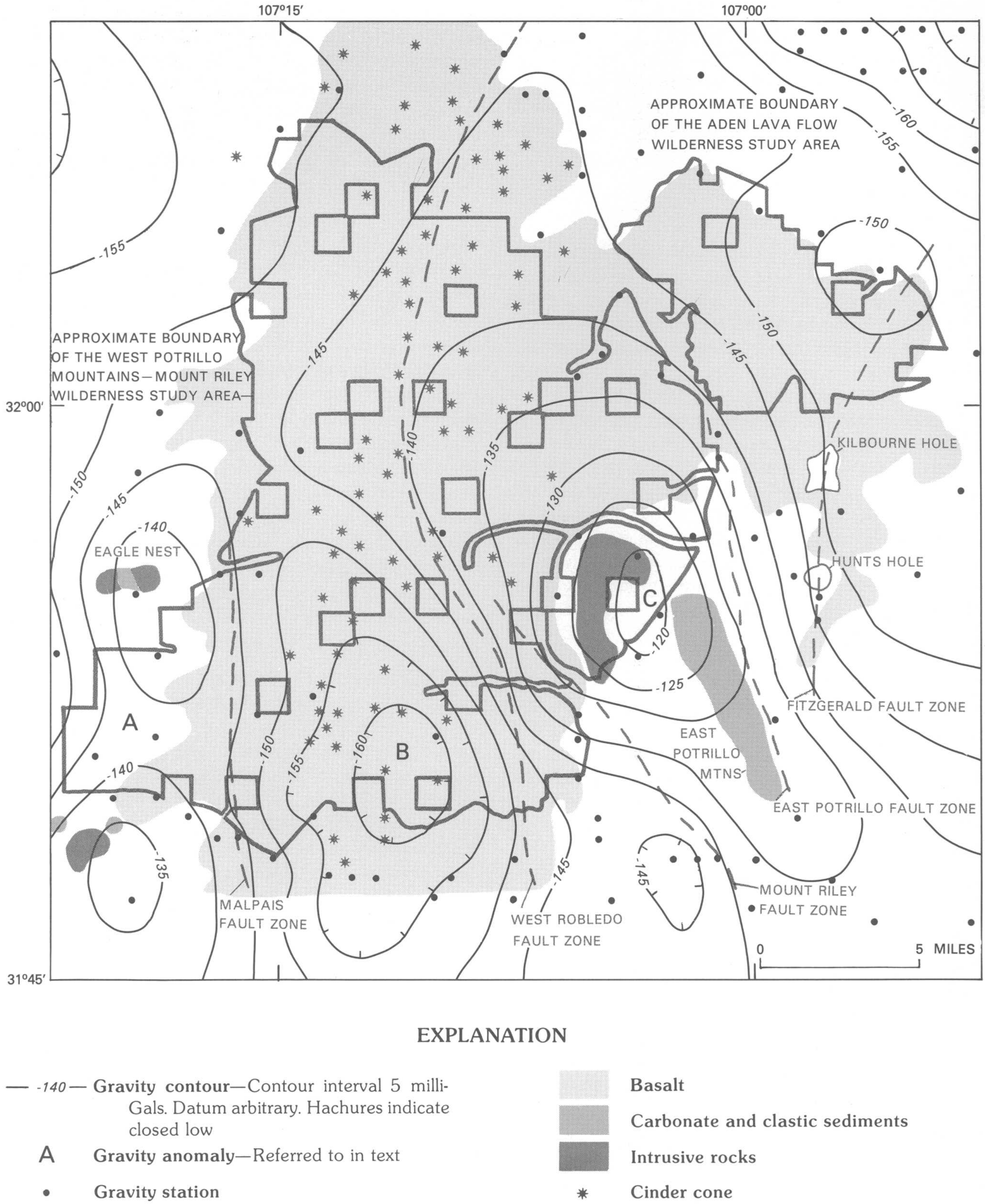


Figure 3. Bouguer gravity and generalized geology map of the West Potrillo Mountains–Mount Riley and the Aden Lava Flow Wilderness Study Areas, New Mexico.

brian granitic rocks at Eagle Nest. It is not known whether this magnetic low is caused by basalt hidden beneath alluvium or by intrusive and granitic rocks at depth.

With regard to mineral resource assessment, it is of interest to note gravity anomalies in the vicinity of Eagle Nest, where silver, lead, and zinc have been prospected in Precambrian and Paleozoic carbonate rocks, as well as in the East Potrillo Mountains, where silver occurrences and barite are known to be associated with carbonate rocks. Although the regional magnetic anomaly data are of little value in this respect, the gravity data clearly show that the carbonate-rich rocks at Eagle Nest may extend southward beneath that part of the West Potrillo Mountains–Mount Riley study area west of long 107° 15′ W. The gravity anomaly data also indicate that carbonate-rich rocks of the East Potrillo Mountains may extend northwestward beneath Mount Riley for about 6 mi into the eastern part of the West Potrillo Mountains–Mount Riley study area.

Aerial gamma-ray spectroscopy data indicate low levels of radioactivity in the Aden Lava Flow study area and moderate radioactivity levels in the West Potrillo Mountains–Mount Riley study area. No anomalies were detected within or near either study area (J.S. Duval, written commun., 1985).

Mineral and Energy Resources

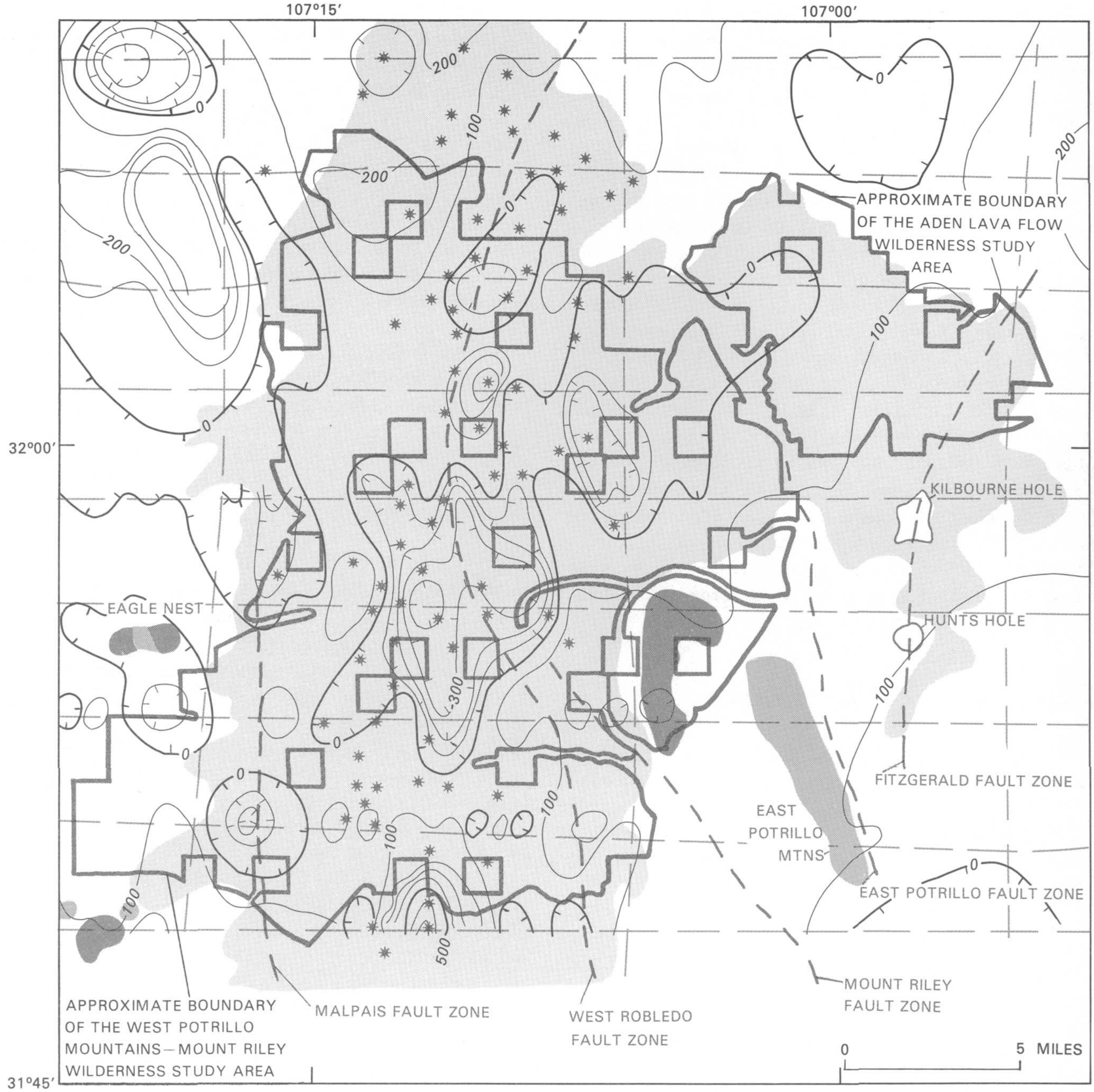
As previously mentioned, the West Potrillo Mountains–Mount Riley study area has identified resources of volcanic cinder at 21 individual cinder cones (fig. 1, pl. 1) having favorable aspect ratios (ratio of height to basal diameter) between 0.1 and 0.2. The mineral resource potential for volcanic cinder in the remainder of the West Potrillo Mountains–Mount Riley study area and the entire Aden Lava Flow study area is low, with certainty level B. This assessment is due to the large volume of lava and volcanic ash associated with cinder cones whose aspect ratios fall outside the previously mentioned range.

The mineral resource potential for near-surface base (copper, lead, zinc, tin) and precious (gold, silver, platinum) metals within the West Potrillo Mountains–Mount Riley and the Aden Lava Flow Wilderness Study Areas is low, with certainty level B. Available geologic and geochemical data coupled with a lack of mineralized outcrop constitute the basis for this assessment. A veneer of basalt overlies most of both study areas, and the basalt's barren nature relative to metallic mineralization is borne out by geochemical studies in the West Potrillo Mountains–Mount Riley study area (a geochemical survey was not conducted in the Aden Lava Flow study area). Geochemmical anomalies are restricted to a few widely scattered, generally solitary concentrations, and any association with mineralized rock seems unlikely. Whether mineralization of any metals is concealed beneath the volcanic field is unknown based on currently available data, with certainty level A. It is conceivable that favorable host rocks for mineralization may in fact underlie much of the West Potrillo Mountains–Mount Riley study area and perhaps the Aden Lava Flow study area as well. Mineralized and altered Permian and Cretaceous carbonate units crop out immediately east of the Mount Riley stock in the East Potrillo Mountains. Similar, though less prominent, carbonate-rich units are found just outside the southwestern boundary of the West Potrillo Mountains–Mount Riley study area, most notably at Eagle Nest. Geophysical gravity data suggest that these carbonate rocks may actually extend beneath the surface northwestward from the East Potrillo Mountains and southward from the Eagle Nest area into the adjacent West Potrillo Mountains–Mount Riley study area. Tangible evidence of these inferred subsurface units may include the lone outcrop of silicified carbonate rock found south of Eagle Nest as well as the large calcite veins and localized limestone outcrops noted in and about the complex at Mount Riley. In any case, if favorable or reactive host rocks do exist beneath the surface, it is unknown if and to what extent mineralization has taken place.

Despite ongoing exploration and some localized potential for oil and gas, no producing wells are currently in operation in southwestern New Mexico (Broadhead, 1985). Ryder (1983) projected oil and gas possibilities in the Aden Lava Flow Wilderness Study Area as medium by virtue of promising hydrocarbon shows and indications of favorable sedimentary rocks in an exploratory well several miles east of the study area. Although no exploratory wells are actually within the Aden Lava Flow study area, it would seem logical that oil and gas deposits have probably been lost or destroyed, if they were ever present in the first place. Volcanic activity and resultant thermal effects as well as the tectonic setting (on the flank of a recently active rift system) could destroy reservoir capabilities. If favorable reservoir and (or) source rocks or any accumulations of oil or gas underlie the study area, local igneous and tectonic effects such as high temperatures and leakage would certainly inhibit the preservation of developed hydrocarbons. The energy resource potential for oil and gas is therefore low, with certainty level B.

The energy resource potential for oil and gas in the West Potrillo Mountains–Mount Riley Wilderness Study Area is also low, with certainty level B. This concurs with Ryder's (1983) low assessment, which was founded on the unsettled structural character and recent volcanic activity in and around the study area. One test well within and two test wells adjacent to the study area contained no oil or gas shows (Thompson and Bieberman, 1975; Kottlowski and others, 1969).

The mineral resource potential for uranium is low, with certainty level B, for both study areas. Gamma-ray



EXPLANATION

— *100* — **Aeromagnetic contour**—Contour interval 100 nanoTeslas. Datum arbitrary. Hachures indicate closed low

— — - **Flight lines**

Basalt

Carbonate and clastic sediments

Intrusive rocks

✱ **Cinder cone**

Figure 4. Aeromagnetic and generalized geology map of the West Potrillo Mountains–Mount Riley and the Aden Lava Flow Wilderness Study Areas, New Mexico.

surveys failed to detect near-surface radioactive anomalies in or near either study area (J.S. Duval, written commun., 1985).

Despite the large amount of Quaternary volcanic activity in the region and local reports of warm water in wells, the geothermal resource potential for both study areas is low, with certainty level B. Test-well data reveal generally low heat gradients and a deep-seated water table.

REFERENCES CITED

Bath, G.O., 1976, Interpretation of magnetic surveys in intermontane valleys of Nevada and southern New Mexico: U.S. Geological Survey Open-File Report 76–440, 37 p.

Broadhead, R.F., 1985, Oil and gas discovery wells drilled in New Mexico in 1984: New Mexico Geology, v. 7, p. 35–39.

Broderick, J.C., 1984, The geology of Granite Hill, Luna County, New Mexico: University of Texas at El Paso, M.S. thesis, 90 p.

Carson Helicopters, Inc., 1981a, National Uranium Resource Evaluation aerial gamma-ray and magnetic reconnaissance survey of portions of New Mexico, Arizona, and Texas—Final report—Volume I, New Mexico, Las Cruces NI 13–10 quadrangle: U.S. Department of Energy Open-File Report GJBX–412(81), 18 p. [Available from U.S. Geological Survey, Open-File Services Section, P.O. Box 25425, Denver, CO 80225.]

______ 1981b, National Uranium Resource Evaluation aerial gamma-ray and magnetic reconnaissance survey of portions of New Mexico, Arizona, and Texas—Final report—Volume II, Texas–New Mexico–El Paso NH 13–1 quadrangle: U.S. Department of Energy Open-File Report GJBX–412(81), 14 p. [Available from U.S. Geological Survey, Open-File Services Section, P.O. Box 25425, Denver, CO 80225.]

Cordell, L.E., 1975, Combined geophysical studies at Kilbourne Hole maar, New Mexico, *in* Seager, W.R., Clemons, R.E., and Callender, J.F., eds., Guidebook of the Las Cruces Country: New Mexico Geological Society, 26th Field Conference, p. 269–271.

______ 1983, Composite residual total intensity aeromagnetic map of New Mexico: New Mexico State University Energy Institute, Geothermal Resources of New Mexico, Scientific Map Series, scale 1:500,000.

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

File, Lucien, and Northrop, S.A., 1966, County, township, and range locations of New Mexico's mining districts: New Mexico Bureau of Mines and Mineral Resources Circular 84, 66 p.

Gese, D.D., 1985, Mineral resources of the West Potrillo Mountains/Mt. Riley Study Area and the Aden Lava Flow Wilderness Study Area, Dona Ana and Luna Counties, New Mexico: U.S. Bureau of Mines Open-File Report MLA 74–85, 19 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, 42 p.

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

Harben, P.W., and Bates, R.L., 1984, Pumice and scoria, *in* Geology of the nonmetallics: New York, Metal Bulletin Inc., p. 64–68.

Hoffer, J.M., 1976a, Geology of Potrillo basalt field, south-central New Mexico: New Mexico Bureau of Mines and Mineral Resources Circular 149, 30 p.

______ 1976b, The Potrillo basalt field, south-central New Mexico, *in* Elston, W.E., and Northrop, S.A., eds., Cenozoic volcanism in southwestern New Mexico: New Mexico Geological Society Special Publication No. 5, p. 89–92.

______ 1986, Subsurface volcanic stratigraphy southern New Mexico, *in* Hoffer, J.M., ed., Geology of southcentral New Mexico: El Paso Geological Society Field Trip Guidebook, April 11, 1986, p. 119–122.

Jenkins, D.A., 1977, Geologic evaluation of the EPM mining claims, East Potrillo Mountains, Dona Ana County, New Mexico: Socorro, N. Mex., New Mexico Institute of Mining and Technology, M.S. thesis, 109 p.

Jones, J.L., Kilburn, J.E., Zimbelman, D.R., and Siems, D.F., 1987, Analytical results and sample locality maps of heavy-mineral-concentrate and rock samples from the West Potrillo Mountains/Mt. Riley Wilderness Study Area (030–052), Luna and Dona Ana Counties, New Mexico: U.S. Geological Survey Open-File Report 87–265.

Klein, D.P., and Johnson, G.R., 1983, Density, porosity, and magnetic properties of rock specimens from southwestern Arizona: U.S. Geological Survey Open-File Report 83–808, 31 p.

Klein, D.P., and Wynn, J.C., 1984, Density, porosity, and magnetic susceptibility of rocks from the Silver City 1° × 2° quadrangle, Arizona and New Mexico: U.S. Geological Survey Open-File Report 84–17, 11 p.

Kottlowski, F.E., Foster, R.W., and Wengerd, S.A., 1969, Key oil tests and stratigraphic sections in southwest New Mexico, *in* Cordoba, D.A., Wengerd, S.A., and Shomaker, J.W., eds., Guidebook of the border region: New Mexico Geological Society, 20th Field Conference, p. 186–196.

Millican, R.S., 1971, Geology and petrography of the Tertiary Riley–Cox pluton, Dona Ana County, New Mexico: University of Texas at El Paso, M.S. thesis, 87 p.

Munsell Products, 1973, Munsell soil color chart: Baltimore, Md.

Osburn, J.C., 1980, Evaluation of scoria deposits in New Mexico: New Mexico Bureau of Mines and Mineral Resources Annual Report, 1978–1979, p. 75–80.

______ 1982, Scoria exploration and utilization in New Mexico, *in* Industrial rocks and minerals of the Southwest: New Mexico Bureau of Mines and Minerals Circular 182, p. 57–59.

Ramberg, I.B., Cook, F.A., and Smithson, S.B., 1978, Structure of the Rio Grande rift in southern New Mexico and West Texas based on gravity interpretation: Geological Society of America Bulletin, v. 89, p. 107–123.

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

Seager, W.R., 1987, Geologic map of the southwest quarter of the Las Cruces and northwest part of the El Paso 1°×2° sheets: New Mexico Bureau of Mines and Mineral Resources Geologic Map 57, scale 1:100,000.

Seager, W.R., and Morgan, P., 1979, Rio Grande Rift in southern New Mexico, West Texas, and northern Chihuahua, *in* Riecker, R.E., ed., Rio Grande Rift—Tectonics and magmatism: American Geophysical Union, p. 87–106.

Thompson, Sam, III, and Bieberman, R.A., 1975, Oil and gas exploration wells in Dona Ana County, New Mexico, *in* Seager, W.R., Clemons, R.E., and Callender, J.F., eds., Guidebook of the Las Cruces Country: New Mexico Geological Society, 26th Field Conference, p. 171–175.

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.

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.

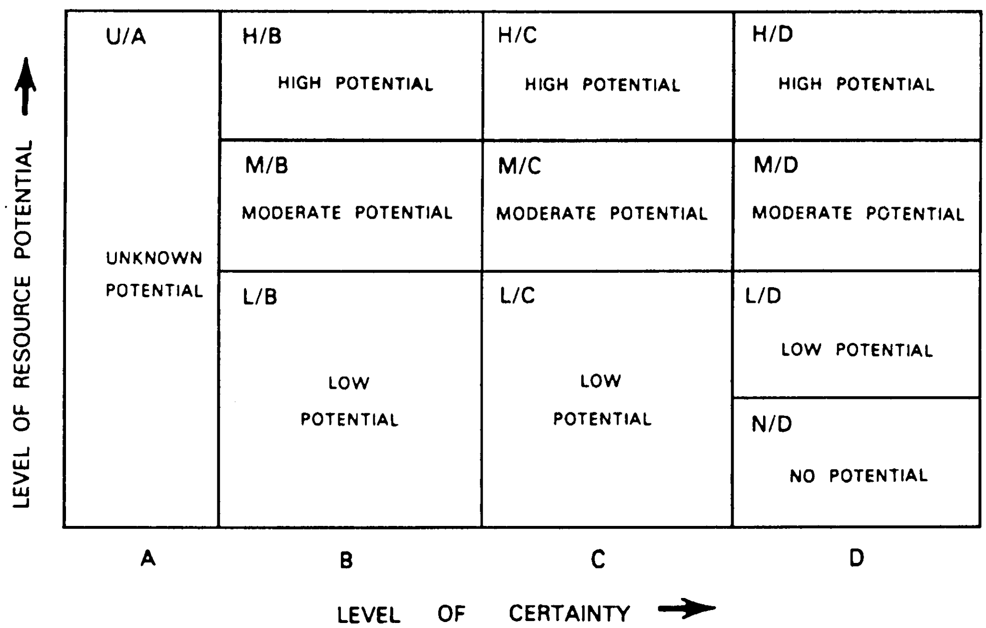
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application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



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 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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March 3, 1849

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