Mineral Resources of the Horse Mountain and Continental Divide Wilderness Study Areas, Catron County, New Mexico

U.S. GEOLOGICAL SURVEY BULLETIN 1734–C

Chapter C

Mineral Resources of the Horse Mountain and Continental Divide Wilderness Study Areas, Catron County, New Mexico

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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 Horse Mountain (NM–020–043) and the Continental Divide (NM–020–044) Wilderness Study Areas, Catron County, New Mexico.

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SUMMARY

Abstract

The Horse Mountain (NM–020–043) and the Continental Divide (NM–020–044) Wilderness Study Areas include mountainous terrains that border the Plains of San Agustin in Catron County about 90 miles west of Socorro, N. Mex. (fig. 1). The areas studied consist of 4,432 acres on Horse Mountain in the Horse Mountain study area, north of the plains, and 37,599 acres around Pelona Mountain in the Continental Divide study area, south of the plains. There are no identified mineral resources in either wilderness study area. However, a moderate oil and gas potential applies to the entire Plains of San Agustin region, including both study areas (fig. 2). The mineral resource potential for metals (iron, manganese, zinc, lead, copper, molybdenum, gold, and silver) related to hydrothermal igneous systems is considered to be low in the study areas (fig. 2). The mineral resource potential for tin and uranium, geothermal energy, and sand and gravel is considered to be low.

Character and Setting

The Horse Mountain and Continental Divide Wilderness Study Areas include mountainous terrains on opposite sides of the Plains of San Agustin (called San Agustin Plains in this report), in Catron County about 90 mi (miles) west of Socorro, N. Mex. (fig. 1). Both study areas are underlain entirely by volcanic rocks of middle to late Tertiary age. The Horse Mountain Wilderness Study Area, north of the plains, consists almost wholly of a moderately dissected, rhyolitic volcano, a composite dome about 13 m.y. (million years) old. The Continental Divide Wilderness Study Area is dominated by lava flows from a broad, low-profile, andesitic shield volcano about 27 m.y. old, which is underlain peripherally by andesitic and rhyolitic lava flows, rhyolitic ash-flow tuffs (ignimbrites), and minor interlayered sedimentary conglomerates and sandstones derived by erosion of older volcanic rocks. Pre-Tertiary rocks, including Mesozoic and Paleozoic sedimentary rocks (see Time Chart in appendix) undoubtedly underlie the San Agustin Plains region at depths ranging perhaps from as little as a few hundred feet to several thousand feet.

Past mining activity near Horse Mountain has been limited to local-use, small-scale gravel quarrying from alluvial fan deposits adjacent to New Mexico Highway 12, a couple of miles east of the Horse Mountain Wilderness Study Area (fig. 1). Likewise, there is essentially no evidence of mining or prospecting in the Continental Divide Wilderness Study Area. The Taylor Creek tin district, several miles southeast of the study area, has been the object of extensive exploration for lode and placer tin deposits, but production of tin from such deposits has been economically insignificant over the past 60 years.

Identified Resources

There are no identified mineral resources in either the Horse Mountain or Continental Divide Wilderness Study Areas, and no mines, prospects, or mineralized areas were located during the investigations of the U.S. Bureau of Mines in either study area. There are no known leasable, locatable,

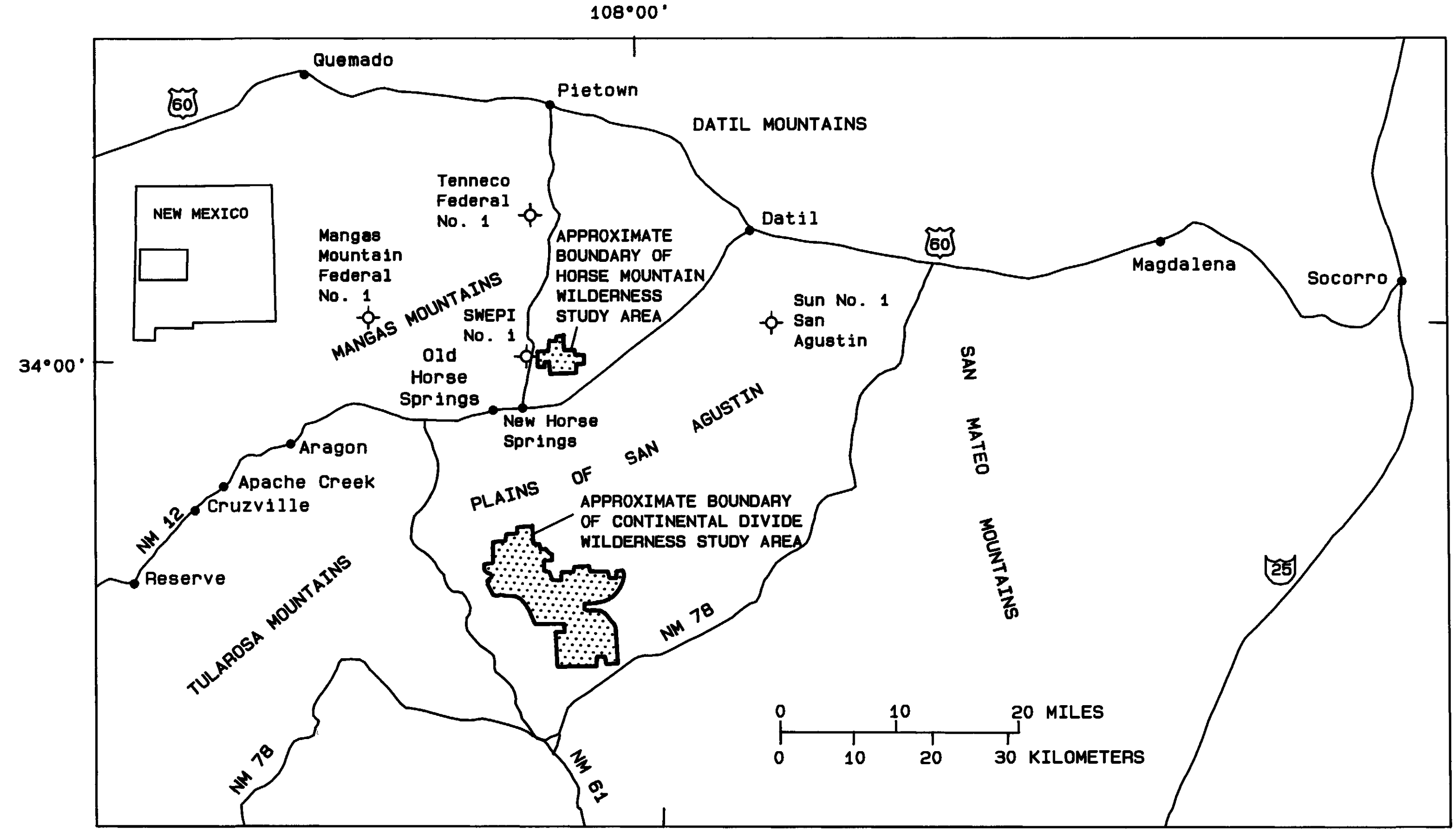


Figure 1. Index map showing location of the Horse Mountain and Continental Divide Wilderness Study Areas, Catron County, New Mexico, and the location of oil test wells near the study areas.

or salable mineral resources, no record of mining or prospecting, and as of November 15, 1985, no recorded mining claims or mineral leases in either study area. Tin, uranium, and thorium were detected in samples from the Continental Divide Wilderness Study Area; however, these elements were not found in sufficient quantities to indicate a resource. Similarly, silver and antimony were detected but do not represent a resource.

Mineral Resource Potential of the Horse Mountain Wilderness Study Area

A moderate mineral resource potential for oil and gas beneath the Horse Mountain Wilderness Study Area is related to indications of subsurface structures in Pre-Tertiary rocks that may contain hydrocarbons. The oil and gas prospects are sufficiently encouraging that a 7,000-ft wild-cat test well was drilled to economic basement bya consortium of major oil companies less than one mile west of the study area. The well, SWEPI No. 1 (fig. 1) completed in September 1987, was dry, but a second wildcat test well, Mangas Mountain Federal No. 1, is being drilled as of September 1987 about 15 miles west-northwest of the study area (fig. 1).

The potential for metallic mineral resources, including iron, manganese, zinc, lead, copper, molybdenum, silver, and gold is considered to be low in the Horse Mountain Wilderness Study Area because there are no manifestations of mineralization at the surface within the study area. However, the presence of an igneous system, represented by the Horse Mountain volcanic center, which, by most reasonable interpretations, must have risen to the surface through underlying pre-Tertiary sedimentary rocks, raises several possibilities for the formation of metal-bearing mineral deposits. Foremost would be contact metasomatic deposits that may have formed through interaction between igneous intrusions and carbonate and other sedimentary rocks, and related veins. The presence of a faulted(?) block of pre-Tertiary rocks about one-half mile long at the foot of Horse Mountain, south of the study area, and iron skarn mineralization in exotic blocks of pre-Tertiary rocks in a volcanic deposit several miles southwest of Horse Mountain (fig. 2) testify to this possibility. Thus the low potential for metallic mineral resources in the Horse Mountain Wilderness Study Area is offered at a low certainty level. The Horse Mountain Wilderness Study Area also has a low potential for geothermal resources, sand and gravel, tin, and uranium.

Mineral Resource Potential of the Continental Divide Wilderness Study Area

The same possibilities for oil and gas accumulation in suitable structures in pre-Tertiary rocks apply beneath the Continental Divide Wilderness Study Area as at Horse Mountain, and represent a moderate potential for petroleum resources.

The potential for metallic mineral resources associated with subvolcanic igneous intrusive activity is considered to be low in the Continental Divide Wilderness Study Area because of the lack of any significant indication of mineralized or altered rocks at the surface. However, the presence of an andesitic volcanic center, the Pelona Mountain volcano and its central plug, suggests the possibility of a replacement or skarn deposit at intrusive levels beneath this volcano. The mineral resource potential for iron, manganese, zinc, lead, copper, molybdenum, silver, and gold in such deposits is considered low.

The potential for rhyolite-hosted tin resources in the Taylor Creek Rhyolite in or adjacent to the Continental Divide study area is low. Tin values in sediment samples and panned concentrates derived from sediment samples do not exceed levels expected from terranes dominated by unaltered and unmineralized Taylor Creek-type rhyolites.

The potential for uranium resources in the Continental Divide study area is low. Although the rhyolitic tuffs and lava flows within the study area are likely source rocks for uranium, and suitable environments for its deposition and concentration by groundwaters might be found in the basin-fill of the San Agustin Plains between the Horse Mountain and Continental Divide Wilderness Study Areas (fig. 2), uranium deposits are not likely to occur within the study areas.

The potential for geothermal resources and sand and gravel resources is low within the Continental Divide Wilderness Study Area.

INTRODUCTION

Area Description

At the request of the U.S. Bureau of Land Management, the U.S. Geological Survey and the U.S. Bureau of Mines studied 4,732 acres of the Horse Mountain Wilderness Study Area and 37,599 acres of the Continental Divide Wilderness Study Area. In this report, the areas studied are called the "wilderness study areas"or simply "study areas." In addition, a somewhat larger area was mapped by the U.S. Geological Survey (pl. 1) in order to provide a more adequate geologic context for the assessment of the mineral resource potential of the combined study areas.

The Horse Mountain (NM–020–043) and Continental Divide (NM–020–044) Wilderness Study Areas are located on opposite sides of the Plains of San Agustin in Catron County, N. Mex. Both study areas are in a very sparsely populated region of widely scattered ranches and a few small towns about 90 mi west of Socorro, N. Mex. (fig. 1). U.S. Highway 60, between Socorro and Datil, and New Mexico Highway 12, which extends southwest from Datil, provide paved access to the San Agustin Plains region, from which the study areas can be reached by secondary gravel roads and unimproved roads. Most of the Horse Mountain Wilderness Study Area is roadless, but jeep trails and old logging roads provide limited access to the northern flanks of Horse Mountain. Jeep trails and old logging roads also lead to the boundaries of the Continental Divide Wilderness

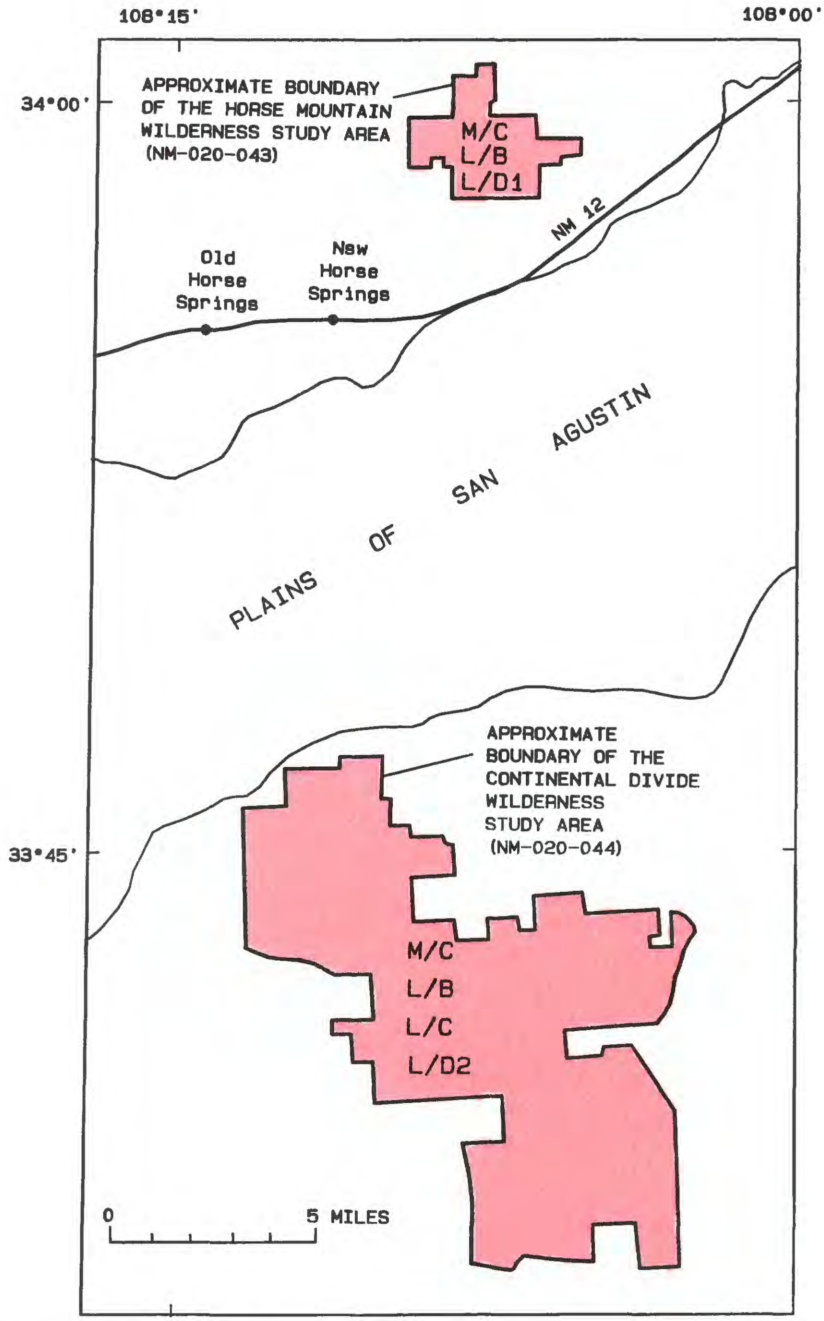


Figure 2 (above and facing page). Summary map showing mineral resource potential of the Horse Mountain and Continental Divide Wilderness Study Areas.

Study Area from all sides, and some give access to enclosures of state and private land holdings within the study area.

The Horse Mountain and Continental Divide study areas are local mountainous terrains that rise 2,500 to 2,700 ft (feet) above the adjacent San Agustin Plains. The Horse Mountain study area consists almost entirely of Horse Mountain, which has an elevation of 9,450 ft at the top of Horse Peak. The Continental Divide study area is dominated by Pelona Mountain, the top of which has an elevation of 9,212 ft. Both mountains are ancient volcanoes.

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)

EXPLANATION

M/C	**Geologic terrane having moderate mineral resource potential for oil and gas, with certainty level C**—Applies to entire study area
L/B	**Geologic terrane having low mineral resource potential for iron, manganese, zinc, lead, copper, molybdenum, silver, and gold, with certainty level B**—Applies to entire study area
L/C	**Geologic terrane having low mineral resource potential for tin, with certainty level C**—Applies to entire Continental Divide Wilderness Study Area
L/D1	**Geologic terrane having low mineral resource potential for tin, uranium, and geothermal energy, with certainty level D**—Applies to entire Horse Mountain Wilderness Study Area
L/D2	**Geologic terrane having low mineral resource potential for uranium and geothermal energy, with certainty level D**—Applies to entire Continental Divide Wilderness Study Area

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. The potential for undiscovered resources is studied by the U.S. Geological Survey.

Previous Studies

The most comprehensive previous study of the geology in the San Agustin Plains area is a report by Stearns (1962), which includes a geologic map of the north half of the Pelona 30-minute quadrangle. This report and map cover most of the Horse Mountain Wilderness Study Area and the northwestern part of the Continental Divide Wilderness Study Area. A reconnaissance geologic map of the entire Pelona 30-minute quadrangle (Willard and Stearns, 1971) includes most of both study areas. Other studies that provide a more regional perspective of the San Agustin region include collections of papers and generalized geologic maps in Chapin and Elston (1978), Elston and Northrup (1976), and Ratté and others (1984).

Present Studies

As part of the appraisal process of the U.S. Bureau of Land Management (BLM), a preliminary mineral resources assessment of the study areas, based almost entirely on literature research, was prepared for the BLM by Geoexplorers International, Inc. (unpub., 1982). In addition, preliminary appraisals were published by the BLM for the Horse Mountain study area (1986,p. 20–1 to 20–24) and the Continental Divide study area (1986, p. 17–1 to 17–27).

Investigations by the U.S. Bureau of Mines

In the fall of 1984 and summer of 1985 the Bureau of Mines conducted an investigation of the parts of the Horse Mountain and Continental Divide Wilderness Study Areas designated preliminarily suitable for inclusion in the National Wilderness Preservation System by the BLM. The Horse Mountain Wilderness Study Area covers 5,032 acres, 4,432 acres of which were investigated by Almquist (1986); the Continental Divide Wilderness Study Area covers 68,761 acres, 37,599 acres of which were investigated by Wood (1986). Both investigations used the same general approach: literature and land status record reviews, followed by field examination, sampling, analysis, and data evaluation.

Investigations by the U.S. Geological Survey

Studies by the U.S. Geological Survey (1984–1986) included geologic, geophysical, and geochemical studies. A geologic map was prepared at 1:24,000 scale of about 65 square miles north of the San Agustin Plains, including and surrounding the Horse Mountain Wilderness Study Area, and about 200 square miles south of the plains, including and surrounding the Continental Divide Wilderness Study Area. The geology of both areas was compiled at 1:100,000 scale (pl. 1). Gravity and aeromagnetic surveys were completed for approximately the same area as the geologic map, but compiled at a much smaller scale (figs. 3 and 4). A geochemical survey of the study areas was based on analyses of 80 stream-sediment samples.

APPRAISAL OF IDENTIFIED RESOURCES

By Carl L. Almquist and Robert H. Wood, 2d U.S. Bureau of Mines

The U.S. Bureau of Mines surveys and studies mines, prospects, and mineralized areas to appraise mineral reserves and identified mineral resources.

Identified resources are those whose location, grade, quality, and quantity are known or can be estimated from specific geologic evidence. They include economic, marginally economic, and subeconomic components.

Horse Mountain

No mines, prospects, or mineralized areas were located during the Bureau's investigation of the Horse Mountain study area. None of the eight panned-concentrate samples and four rock chip samples collected contained anomalous element concentrations (Almquist, 1986, p. 7–8). Scintillometer readings, monitored during ground traverses, did not exceed the background of 25 cps (counts per second) by more than 50 percent.

Quaternary sand and gravel deposits that accumulated in the southwest corner of the study area represent a small fraction of the abundant supply present along State Highway 12 where several pits have been opened at more accessible sites. Development of this commodity within the area is therefore unlikely.

There are no known leasable, locatable, or salable mineral resources in the part of the Horse Mountain Wilderness Study Area investigated.

Continental Divide

There is no record of mining or prospecting, and as of November 15, 1985, there were no recorded mining claims or mineral leases in the Continental Divide study area. The nearest mining district is the Taylor Creek (Black Range) tin district and the nearest known deposit in the district is along Squaw Creek, about 10 mi to the southeast of the study area. However, the boundaries of this district are undefined, and location notices indicate that claims 1 mi south of the area studied are in this district (Wood, 1986, pl. 1). Cassiterite (an ore mineral of tin) occurs in the district as stringers in altered rhyolites and in placer deposits (see Fries, 1940).

The geologic setting (Roberts and others, unpub., 1982) suggests that tin, uranium, and thorium may occur within the study area. On the basis of this premise, the Bureau sampled the major drainages and the various rock units (primarily rhyolites) to determine whether tin, uranium, or thorium resources were present.

Tin values in 24 of the 52 panned-concentrate samples ranged between 48 and 660 ppm (parts per million) (0.0048 and 0.066 percent) (Wood, 1986, table 1). Seven of the 86 minus-80-mesh stream-sediment samples contained between 7 ppm (0.0007 percent) and 40 ppm (0.004 percent) tin (Wood, 1986, table 2). Tin was not detected in any of the rock samples analyzed (Wood, 1986, table 3). The Bureau's sample results do not identify any tin resources.

Uranium (0.6 to 18 ppm) was detected in all of the 178 samples analyzed (Wood, 1986, tables 1–3). Thorium (30 to 175 ppm) was detected in 16 of the panned-concentrate samples, in 2 of the minus-80-mesh stream-sediment samples, and in 3 of the rock samples (Wood, 1986, tables 1–3). The Bureau's sample results do not indicate any uranium or thorium resources.

Minor amounts of silver (0.1 oz/st (ounces per short ton) maximum) and antimony (110 ppm maximum) were present in six samples tested by fire assay for gold and silver and by atomic absorption for antimony (Wood, 1986, table 3). These values are slightly above the detection limits (0.05 oz/st and 50 ppm, respectively). Sample results and field observations do not suggest any near-surface silver or antimony resources.

Sand and gravel that occur in the drainages could be used as road metal, fill, or as aggregate. Transportation costs and low unit price limit the economic marketing range to local uses. No large, well-sorted, clean, or unique sand or gravel deposits were observed in the area and abundant supplies of similar material exist closer to possible markets.

There are no known mineral resources in the part of the Continental Divide Wilderness Study Area investigated. Tin, uranium, and thorium were detected in samples; however, these elements were not found in sufficient quantities to be classified as a resource. Similarly, silver and antimony were detected, but do not represent a resource. Sand and gravel could be suitable for local road construction.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By James C. Ratté, Richard W. Saltus, and Robert L. Turner, U.S. Geological Survey

Geology

The Horse Mountain and Continental Divide Wilderness Study Areas are underlain mainly by middle-Tertiary volcanic rocks of the Mogollon-Datil volcanic field. Pre-Tertiary rocks crop out only in one small area about ½ mi long and ⅛ mi wide at the base of Horse Mountain (pl. 1). However, a deep oil test well (Sun No. 1, San Agustin), about 20 miles northeast of the Horse Mountain study area on the San Agustin Plains (fig. 1), and inclusions of pre-Tertiary rocks in 33-m.y.-old pumice breccia near Old Horse Springs (pl. 1) indicate that Mesozoic and Paleozoic sedimentary rocks probably underlie both study areas.

Rocks of the Horse Mountain Study Area and Vicinity

The Horse Mountain study area, on the north side of the San Agustin Plains, consists almost entirely of dacitic to rhyolitic rocks of a composite volcanic dome (Horse Mountain) of late Miocene age (about 13 m.y. old) (pl. 1). The rocks of this moderately to deeply dissected ancient volcano presently cover an area about 4 mi in diameter. The rocks are mainly fine-grained porphyritic lava flows and flow breccia piled up around a northwest-southeast elongate zone, 1–2 mi long and ½-1 mi wide, of massive to brecciated, red to gray glassy rhyolite. Within this zone, several dikes of similar trend and composition extend out from a less brecciated central plug. The plug, elongate breccia zone, and dikes are interpreted as a central vent and associated linear fissure vent zone, essentially as previously reported by Stearns (1962). The rhyolite has been dated as about 13 m.y. by the potassium-argon method (R.F. Marvin, unpublished USGS biotite age, 1987) and by fission tracks in zircon (Jones, 1980).

The outer slopes of the Horse Mountain volcano are largely buried by talus and other surficial deposits, but scattered outcrops of older volcanic rocks and volcaniclastic sedimentary rocks crop out beneath the lava flows of the volcano. Most of these older rocks belong to the Datil Group (Osburn and Chapin, 1983), including round pebble conglomerates of the volcaniclastic Spears Formation, and interlayered ash-flow tuff outflow sheets, about 33–36 m.y. old, which are interlayered with the volcaniclastic sedimentary rocks. Pre-Tertiary sedimentary rocks crop out in a steeply tilted (about 40°) faulted block about 1 mi south of the study area boundary. The pre-Tertiary rocks are about 1 mi north of New Mexico Highway 12 at mileage marker 53, and are exposed for ½–¾ mile along the mountain front. They consist mainly of Permian rocks including, from bottom to top, Yeso Formation (201 ft), Glorieta Sandstone (95 ft), and San Andres Limestone (417 ft). The Permian rocks are overlain by unnamed Triassic(?) sandstone 114 ft thick (Stearns, 1962, p. 40-42). Tertiary conglomerates, dipping 10–15° north, appear to unconformably overlie the pre-Tertiary rocks, but the contact is not exposed (Stearns, 1962, p. 6).

In the Horse Springs area, west and southwest of Horse Mountain, a more complete section of the volcanic rocks that preceded the formation of Horse Mountain volcano is present. Above the Datil Group, the Horse Springs sequence includes rhyolitic lava flows of Bat Cave Wells—formerly the rhyolite of Wye Hill of Bornhorst (1980)—the thin distal edges of three regional ash-flow tuffs (Vicks Peak, Shelley Peak, and Bloodgood Canyon Tuffs), and andesitic lava flows of the Squirrel Springs Canyon and Bearwallow Mountain Andesites (pl. 1), all between about 24 and 29 m.y. old. Of particular interest in the Horse Springs area is the dacitic pumice breccia of Old Horse Springs, formerly the tuff breccia of Horse Springs Canyon of Bornhorst (1980), because it marks a probable vent, or at least a vent facies accumulation of pyroclastic flows. Some of the breccia contains abundant inclusions of porphyritic quartz monzonite and clasts of altered and mineralized pre-Tertiary sedimentary rocks.

Rocks of the Continental Divide Study Area and Vicinity

South of the San Agustin plains, about 80 percent of the Continental Divide study area is underlain by lava flows of the Bearwallow Mountain Andesite of the Pelona Mountain shield volcano of late Oligocene age. The volcano consists mainly of a sequence of hypersthene andesite lava flows about 1,500 ft thick. The flows are piled up around a central plug, which is exposed in a craterlike amphitheater about ½ mi in diameter, just north of the top of Pelona Mountain (pl. 1). The plug consists of finely granular hypabyssal andesite, which has given a plagioclase potassium-argon age of 26.6±1.0 m.y. (Marvin and others, in press). The plug probably fills the main vent of the volcano, although there is evidence of other, smaller satellite vents on its flanks.

The older rocks that underlie the Bearwallow Mountain Andesite and crop out around the margins of the Pelona Mountain volcano are mainly rhyolitic ash-flow tuffs and lava flows, some lava flows of intermediate to mafic composition, and minor volcaniclastic sedimentary rocks, much like the upper part of the volcanic sequence north of the San Agustin Plains in the Horse Springs area. The oldest volcanic rocks of the Datil Group north of the plains are not exposed in the Continental Divide study area. However, the Rock House Canyon Tuff of the Datil Group has been tentatively identified northeast of the study area on the north side of Shaw Mountain and farther northeast (pl. 1), where it is associated with round pebble volcaniclastic conglomerate typical of the Spears Formation. Otherwise, the oldest exposed rock unit south of the plains (pl. 1) is the rhyolite of Bat Cave Wells; north of the plains, this rhyolite overlies the tuff breccia of Old Horse Springs.

Taylor Creek Rhyolite, which contains tin-bearing veins and associated placer tin southeast of the study area (Maxwell and others, 1986; Eggleston and Norman, 1986; Lawrence, 1985; Rye and others, 1984), crops out extensively along the eastern side of the Continental Divide study area. This rhyolite characteristically forms coalescing flow-dome complexes, which erupted from many separate centers in the northern Black Range and adjacent areas (Lawrence, 1986; Lawrence and Richter, 1986; Duffield, 1986). Rhyolite along the eastern side of the study area was erupted from centers near Shaw Canyon, outside the northeast corner of the study area, from centers in the Indian Peaks southeast of the study area, and probably from a center in the low hills east of Pelona Well, south of the Continental Divide between Shaw Canyon and Indian Peaks. Taylor Creek Rhyolite from the Shaw Canyon center covers about 2 sq mi in the northeast corner of the study area, where rhyolite breccias along Shaw Canyon indicate the approximate margins of the flows from that center and suggest that they do not extend far beneath the Bearwallow Mountain Andesite from Pelona Mountain. Rhyolite flows between Shaw Canyon and Indian Peaks are not so well exposed and could extend a short distance beneath Bearwallow Mountain Andesite and the eastern boundary of the study area. Taylor Creek Rhyolite is absent in the western part of the study area, where it would be beneath Bloodgood Canyon Tuff, if present. Rocks shown as Taylor Creek-type rhyolite (unit Tdr) near the top of Pelona Mountain and on the northwest flanks of Pelona Mountain on the reconnaissance map of Willard and Stearns (1971) are here identified as an intrusive plug of Bearwallow Mountain Andesite, which has a light-colored granophyric groundmass, and rhyolitic Bloodgood Canyon Tuff, respectively.

Rocks Beneath the San Agustin Plains

There are no truly deep wells in the part of the San Agustin Plains between the study areas, but several wells drilled for climate research and uranium exploration have sampled the rocks beneath the plains to as deep as about 2,100 ft (C.S. Wallis, Noranda Exploration, Inc., oral commun., 1987). Tertiary volcanic basement in drill holes beneath the central part of the plains is apparently at a depth of about 2,000 ft. The Tertiary volcanic sequence observed at the surface can be correlated across the plains, but there is little direct information concerning the identity and thickness of individual units beneath the plains. However, geophysical data indicate no unusual thickening of silicic ash-flow tuffs, as might accompany a major volcanic center beneath the plains, or that might indicate that the downdropped San Agustin graben formed contemporaneously with Oligocene ash-flow tuff volcanism.

Pre-Tertiary rocks are known at the surface in the vicinity of the study areas only from the tilted block at the base of Horse Mountain and the exotic clasts included in the pumice breccia near Old Horse Springs. However, a deep oil test well (Sun No. 1, San Agustin) is located near the center of the San Agustin Plains, about 20 mi east-northeast of Horse Mountain, in sec. 29,T. 3 S., R. 9 W. According to a stratigraphic log of the well by Roy Foster (New Mexico Bureau of Mines and Mineral Resources, 1966) the well penetrated 230 ft of basin fill, 6,385 ft of Tertiary volcanic and volcaniclastic rocks, and 5,550 ft of pre-Tertiary sedimentary rocks and Tertiary(?) intrusive rocks, as follows: about 1,480 ft of Cretaceous, including 225 ft of Tertiary(?) intrusive; 105 ft of Triassic; 3,932 ft of Permian, including 1,400 ft of Tertiary(?) intrusive; and 138 ft of Pennsylvanian rocks above Precambrian gneiss. Thus, surface exposures and drill-hole data indicate that significant thicknesses of pre-Tertiary rocks underlie the Tertiary volcanic rocks in both study areas as well as under the San Agustin Plains.

Geologic Structure

The Horse Mountain and Continental Divide study areas are near the northwestern margins of the Mogollon-Datil volcanic field, which is part of the widespread volcanism produced between about 40 and 25 m.y. ago by plate tectonic processes. The later relaxation of tectonic forces initiated extensional stresses that caused pull-apart fragmentation, or extension, of the Earth's crust. In the Mogollon–Datil volcanic field, extension was concentrated in areas peripheral to the main eruptive centers in the central part of the field, which lie east and south of the San Agustin Plains. Thus, the study areas are located in an area where extension has created structures that provided access to the surface for volcanism. The Pelona Mountain volcano (26–27 m.y.), the San Agustin graben beneath the San Agustin Plains (26–27 m.y.?), and the Horse Mountain volcano (about 13 m.y.) are all manifestations of the extensional, pull-apart tectonics that followed the volcanism which created the Mogollon–Datil volcanic field.

Faults mapped in bedrock on both sides of the plains, and parallel to its edges, support the graben or downdropped fault block model of the San Agustin basin (Stearns, 1962; Willard and Stearns, 1971; pl. 1, this report). The principal development of the graben was believed by Stearns to postdate the Horse Mountain volcano (about 13 m.y. old), and there is presently no evidence to dispute that interpretation. Minimum late Miocene displacement of at least 800 ft is shown by downdropped lava flows from the Horse Mountain volcano along the southeast front of Horse Mountain (pl. 1), on the northern edge of the graben. However, the alignment of several late Oligocene andesitic volcanoes, of which Pelona Mountain in the Continental Divide study area is one, suggests at least incipient, deep-seated fracturing along the future trend of the graben at a much earlier time. In addition to faults that parallel the edges of the plain, other faults, probably mostly older than the graben, belong to sets having regional counterparts and trends that are mainly northwest and west-northwest, and a few that are north-northeast.

Besides the San Agustin graben, the major structures in and near the wilderness study areas are constructional volcanic features such as the Pelona Mountain and Horse Mountain volcanoes, the flow dome complexes of Taylor Creek Rhyolite, and the near-vent accumulation of the pumice breccia of Old Horse Springs. Little evidence was found to support the concept of the Crosby Mountains depression (Bornhorst, 1980), a large volcano-tectonic subsidence structure attributed to eruption of the pumice breccia of Old Horse Springs (Elston, 1984). Given the relatively small volume (on the order of 10 cubic miles), indicated by the distribution and thickness of the pumice breccia, and the lack of any definitive geophysical expression of a cauldron beneath the San Agustin Plains, the existence of a large collapsed eruptive center here on the northwest fringes of the Mogollon–Datil volcanic field is viewed with skepticism. However, during this study we have tried to test the possibility that a somewhat smaller eruptive center for the Blue Canyon Tuff might be concealed beneath the San Agustin Plains between the Horse Mountain and Continental Divide study areas, because of its bearing on the chance of related ore deposits. The Blue Canyon Tuff is very similar chemically and petrographically to the pumice breccia of Old Horse Springs, and the two units are probably very close in age. Therefore it is reasonable that the Blue Canyon Tuff, like the pumice breccia, is locally derived. A small collapsed source area could be present beneath the adjacent San Agustin Plains, but a gravity low, the expected geophysical expression of such a center, might be masked by the low density sedimentary fill of the San Agustin graben. (See discussion of gravity anomaly 2 in the "Geophysics"section of this report.)

Geochemistry

A reconnaissance geochemical survey of the Horse Mountain and Continental Divide study areas was completed in the spring of 1985. Minus-80-mesh stream sediments and heavy-mineral concentrates of stream sediment were the primary sample media used because they represent a composite of the rock and soil upstream from the sample sites. Eight sites were sampled along the major drainages that radiate from the Horse Mountain study area, and 59 sites were sampled in and adjacent to the Continental Divide study area. The samples were collected from alluvium in the active stream channels. Each sample was composited from several localities along a channel length of approximately 50 ft. Analytical data and a description of the sampling and analytical techniques are available from B.M. Adrian (USGS, written commun., 1987).

Analytical results of the minus-80-mesh stream-sediment samples showed no anomalous concentrations of any metals, with the possible exception of one tin value of 15 ppm in the northwest corner of the Continental Divide study area, south of Fullerton Canyon in the southwest corner of section 34, T. 6 S., R. 13 W. This site is near the intersection of two faults and near the head of a draw that drains an area underlain mainly by high-silica rhyolite Bloodgood Canyon Tuff, which could be the source of the tin. The weakly anomalous tin concentration is not significant in the absence of some other indications of tin mineralization in the area.

Heavy-mineral concentrates obtained from stream-sediment samples were split into a nonmagnetic fraction and a slightly magnetic fraction from which magnetite and ilmenite had been removed by use of a hand magnet. Seventy-five percent of the nonmagnetic samples contained insufficient material for analysis, reflecting a relative absence of heavy minerals, such as cassiterite (tin oxide) and most sulfides, in the rocks from which the sediment samples were derived. Of the 15 nonmagnetic samples that contained enough material for analysis, 12 contained tin between 20 and 2,000 ppm. Results of analysis of the slightly magnetic fraction, in which tin may be largely in magnetite, showed tin ranging between 20 and 300 ppm in 25 of the 59 samples from the Continental Divide study area.

Unaltered and unmineralized Taylor Creek Rhyolite may contain an average of 5–10 ppm tin (Maxwell and others, 1986) and a heavy-mineral content of 1 percent or less; thus a heavy-mineral concentrate sample of sediment derived from an area underlain by Taylor Creek Rhyolite can contain 1,000–2,000 ppm tin and should not be designated as anomalous. Such values serve mainly to identify source terranes consisting predominantly of tin-bearing, high-silica rhyolite, rather than being indicative of a tin resource.

Geophysics

An isostatic residual gravity map (fig. 3) of an area about 20 by 40 mi containing the wilderness study areas was compiled from 136 measured gravity values, 50 established in March 1986 for this study, the remainder from data assembled and edited for regional gravity maps of New Mexico (Cordell and others, 1982). To minimize the inverse correlation of gravity with topography, a Bouguer reduction density of 2.5 g/cm^3 (grams/cubic centimeter) was used. This is the assumed average bulk density of the volcanic rocks which make up most of the topographic relief in the area (Krohn, 1976). Details of the standard Bouguer gravity reduction procedure are in Cordell and others (1982). As a final step in the gravity reduction process, a broad regional gradient based on the gravitational effect of Airy isostatic roots (Simpson and others, 1983) was removed from the data. The resultant isostatic residual anomaly emphasizes the gravity effect of the rock density distribution in the upper 7 to 15 mi (Simpson and others, 1986).

An aeromagnetic survey of a similar but somewhat smaller area than that of the gravity map was flown in December 1985 by Airborne Geophysics, Inc., and compiled by EG & G Geometrics under contract to the U.S. Geological Survey. The flight lines are east-west and have a ½-mi spacing; the survey was flown at a constant 300 ft above the ground. North-south tie lines were flown every 9 mi. The 1980 International Geomagnetic Reference Field, updated to September 1985, was removed from the flight line data by EG & G Geometrics. To smooth the magnetic field for plotting at the small scale of figure 4, and to facilitate comparison with calculated magnetic models, the original 300-ft draped survey was upward-continued to an 11,500-ft level surface using an unpublished computer program by Grauch, based on a technique by Cordell (1985). Upward continuation is a mathematical method for removing the magnetic noise of the low-level survey in order to better define broad regional features.

The purpose of geophysical surveys related to mineral resource appraisal is to identify rock bodies or structural features in the subsurface that are not evident from surface examination, and to extend surface data into the subsurface. The gravity method utilizes differences in the density of rock bodies for this purpose, and, in this region, is most helpful in characterizing major structural features based on density contrasts between pre-Tertiary sedimentary rocks, particularly carbonate rocks, Tertiary volcanic and volcaniclastic rocks, and alluvium. The aeromagnetic survey on the other hand is responsive to differences in the magnetic properties of rocks and is applied in the search for buried igneous intrusions that may be related to metallic mineral resources. In this area the highly magnetic volcanic rocks, exposed at or near the surface in much of the area, hampers the identification of buried plutons.

The most striking feature of the gravity map is the steep gravity gradient of 8 mGal/mi (milligals per mile) that trends northeast-southwest along the northern edge of the San Agustin Plains (gravity anomaly 1, fig. 3). The gradient marks the inferred fault contact between a down-dropped block, or graben, beneath the plains and an uplifted block, or horst, north of the plains. Modelling this gradient, using the best available density data on the local rock sequence, suggests that the alluvial fill of the San Agustin graben, which has a surface elevation of about 6,900 ft, is underlain by middle Tertiary volcanic rocks to a depth about 900 ft above sea level. Expressed another way, the Paleozoic sedimentary rocks that crop out at the base of Horse Mountain in the uplifted block north of the plains, which may or may not be in an unfaulted stratigraphic sequence with the overlying volcanic rocks there, are probably about 6,000 ft beneath the surface of the San Agustin Plains. The absence of a similar gravity gradient on the south side of the plains suggests that the graben is highly asymmetric and has the form of a highly tilted block that is strongly downfaulted only on one side.

The closed gravity low over the San Agustin Plains is bounded approximately by the zero gravity contour (gravity anomaly 2, fig. 3), and reaches a depth between minus-8 and minus-10 mGal. A low of this magnitude can be explained by as little as about 1,300 ft of alluvium, but the alluvium is known to be at least 2,000 ft thick in this area from a research drill hole cored near the center of the San Agustin playa (Foreman and others, 1959). Thus the gravity anomaly is not as low as expected for the determined amount of fill. This discrepancy could be accounted for by a thick section of at least 6,500 ft of higher density pre-Tertiary rocks beneath the plains, or alternatively, the density of the alluvial fill may exceed the assumed 2.0 g/cm^3. The nearest control point is a deep oil test well (Sun No. 1, San Agustin) about 20 mi to the northeast of Horse Mountain near the center of the plains, where 5,500 ft of pre-Tertiary rocks consist of about 3,800 ft of Mesozoic and Paleozoic sedimentary rocks and about 1,700 ft of interlayered Tertiary(?) intrusive rocks. The top of the Paleozoic rocks in the well is at about 1,000 ft below sea level.

If the maximum estimated structural relief of about 4,000 ft is assumed, on the basis of offset of the volcanic rocks north of the plains under Horse Mountain and the same rocks assumed to be under the plains (Stearns, 1962), then the Paleozoic rocks may be at about sea level, or about 6,900 ft deep beneath the plains. This agrees reasonably well with the estimate, derived in analysis of the gravity gradient (anomaly 1, fig. 3), of an elevation at the top of Paleozoic rocks of about 900 ft above sea level.

A broad, low amplitude gravity ridge (gravity anomaly 3, fig. 3) delineates the southern edge of the plains. If this gravity ridge also represents a horst of Paleozoic rocks, the horst here is narrower and much deeper than the horst north of the plains. Southeast of this anomaly, the gravity field decreases toward a shallow low near the southeast corner of the Continental Divide study area (anomaly 4, fig. 3) where Taylor Creek Rhyolite and other silicic volcanic and volcaniclastic rocks may overlie deeper or thinner pre-volcanic strata.

Analysis of the anomalies on the aeromagnetic map (fig. 4) indicates that they are largely the result of topography (pl. 1) and the distribution of volcanic rocks at the surface. The outstanding anomaly in the map area is the deep low (more than 300 nanoTeslas) on the

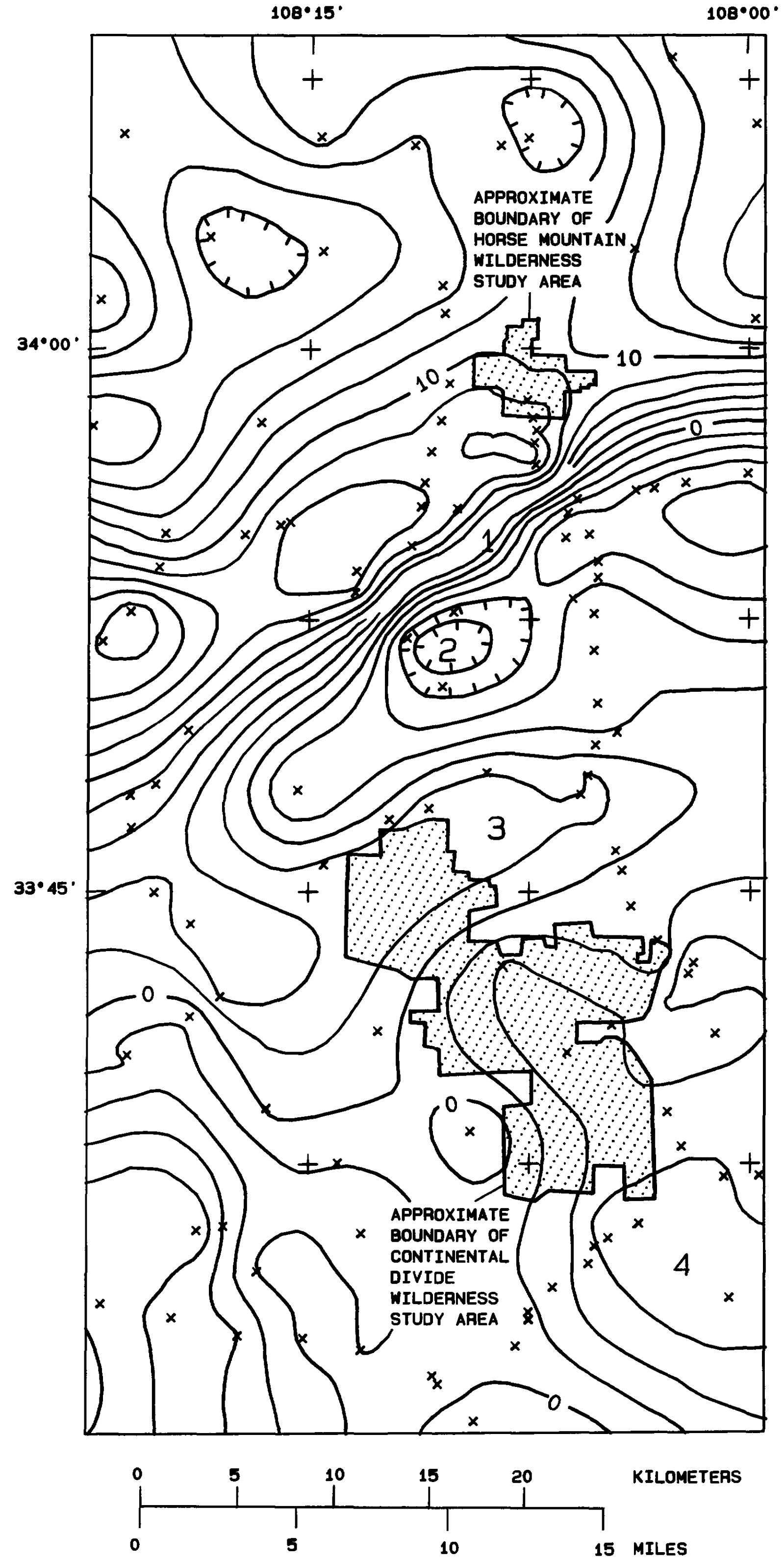


Figure 3. Isostatic residual gravity map of the Horse Mountain and Continental Divide Wilderness Study Areas and vicinity, New Mexico. A reduction density of 2.5 g/cm^3 was used. Contour interval 2 mGal; hachured in areas of closed gravity lows; x, gravity station; 1, anomaly discussed in test.

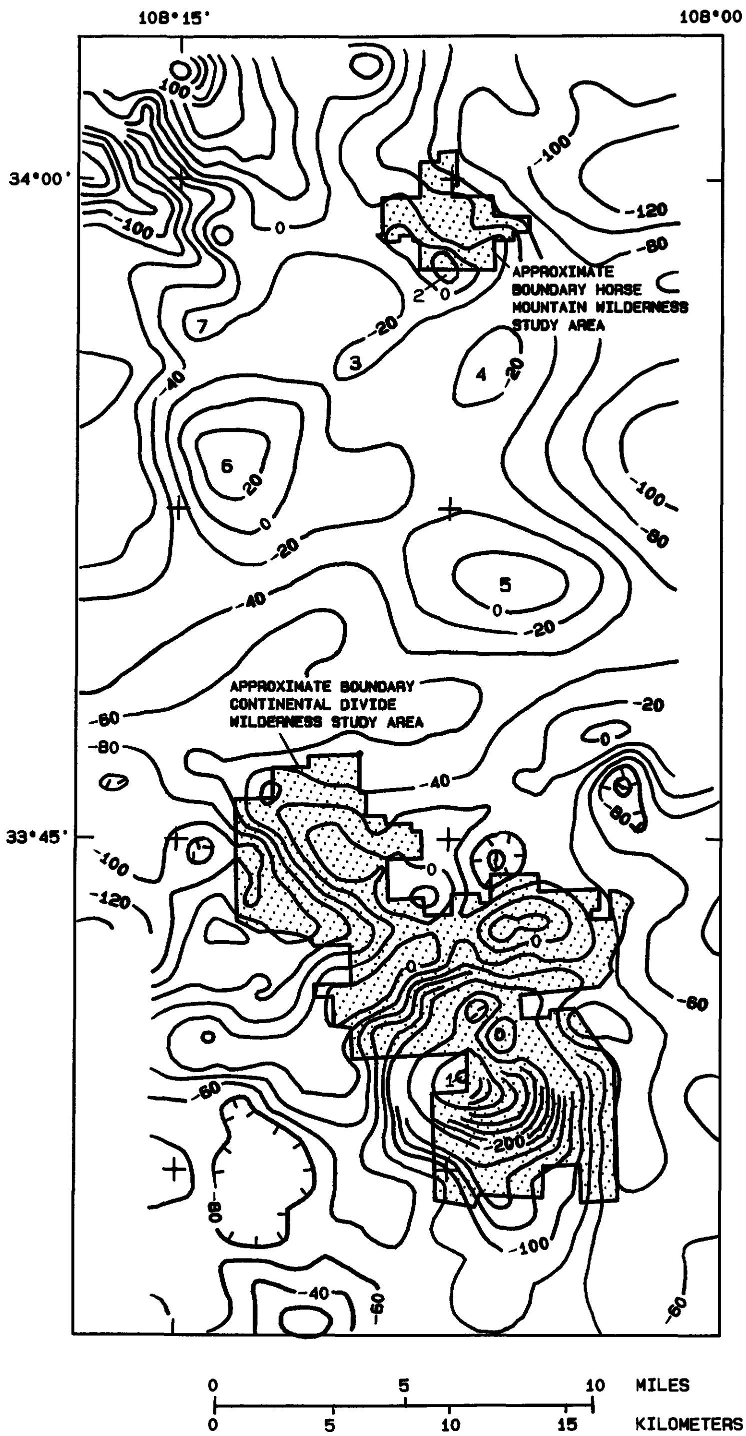


Figure 4. Upward-continued aeromagnetic map of the Horse Mountain and Continental Divide Wilderness Study Areas, New Mexico. The original 400-ft draped survey has been upward-continued to a level of 11,500 ft for this map. Contour intervals 20 and 100 nanoTeslas; hachured in areas of closed magnetic lows; 1, anomaly discussed in text.

southern flank of Pelona Mountain (anomaly 1, fig. 4). This anomaly has a high negative correlation with topography implying that the Bearwallow Mountain Andesite of the Pelona Mountain volcano is reversely magnetized relative to the earth's present magnetic field. However, the central plug of the Pelona Mountain volcano (pl. 1) appears to be either normally magnetized, or has a much lower intensity reversed remanent magnetism that is overwhelmed by the normal magnetism induced by the earth's present magnetic field.

The 20 nanoTesla closed magnetic high near the south edge of the Horse Mountain study area (anomaly 2, fig. 4) has a high positive correlation with topography that is consistent with normal magnetization of the rhyolitic rocks of the Horse Mountain volcano. Anomaly 3 (fig. 4) is a linear magnetic gradient that is coincident with the steep gravity gradient (anomaly 1, fig. 3) that parallels the northern edge of the plains. It is interpreted as the magnetic expression of the faulted northern margin of the San Agustin graben, along which the volcanic rocks exposed on the north side of the plains are buried to the south beneath nonmagnetic alluvial graben fill. Anomaly 4 is also a magnetic feature that is parallel to the axis of the plains. It probably represents an elongate intragraben horst, or upfaulted block, with the same trend as the graben. Anomaly 5 may be another concealed fault-bounded horst block of volcanic rocks beneath the plains, but one that trends perpendicular to the axis of the San Agustin graben. Corresponding east-west faults in the volcanic rocks bordering the east edge of the plains (pl. 1) support this interpretation.

Magnetic anomaly 6 (fig. 4) is a 20–40 nanoTesla magnetic high on the northern edge of the plains and is centered approximately on Jack Peak (pl. 1). This anomaly and the magnetic nose (anomaly 7, fig. 4) to the north correspond more or less to the distribution of silicic volcanic rocks, particularly the pumice breccia of Old Horse Springs (pl. 1) and its iron-rich mineralized inclusions. Anomaly 6 could be an indication of an iron-rich skarn deposit at depth. Alternatively, anomalies 5 and 6, which are separated by the graben-bounding fault, may represent offset parts of the same northwest-trending fault block.

Mineral and Energy Resources

The mineral resource potential of both the Horse Mountain and Continental Divide study areas, as outlined in figure 2 and plate 1, are assessed as shown in table 1. Modifications to the assessments given in table 1 that apply to areas outside the boundaries of the study areas, but within the area of the geologic map, include a moderate potential at certainty level C for base and ferrous metals, particularly lead, zinc, copper and iron and possible associated gold and silver, related to the near vent accumulation of the pumice breccia of Old Horse Springs, and moderate potential for uranium and geothermal energy in the San Agustin graben, both at certainty level B.

Table 1. Assessment of mineral resource potential for Horse Mountain and Continental Divide Wilderness Study Areas, New Mexico

[HM, Horse Mountain; CD, Continental Divide]

Commodity	Potential	Level
Oil and gas	Moderate	C
Fe, Mn, Zn, Pb, Cu, Mo, Ag, Au	Low	B
Uranium	Low	D
Tin (HM)	Low	D
(CD)	Low	C
Geothermal energy	Low	D
Sand and gravel	Low	D

Oil and Gas

The moderate oil and gas potential assigned to the Horse Mountain and Continental Divide study areas is based on the presence of pre-Tertiary sedimentary rocks known to be favorable as petroleum source rocks or reservoir rocks elsewhere. The favorable rocks, which include Cretaceous, Permian, and Pennsylvanian formations, are all present in a dry hole (the Sun No. 1, San Agustin Plains Unit, about 20 mi northeast of Horse Mountain) drilled more than 12,000 ft into Precambrian basement rocks in 1966 (fig. 1). The Permian rocks, which may be the most favorable for oil and gas exploration, also crop out at the base of Horse Mountain, and are present as inclusions in the dacitic pumice breccia of Old Horse Springs (plate 1), indicating that they occur beneath the Old Horse Springs area.

Perhaps most significant is the fact that the country surrounding the wilderness study areas is part of a much larger region that is the object of a major oil exploration play by several major and numerous smaller oil companies (Pankonien, 1985; McCaslin, 1985, p. 111). The attraction of the region is the existence of a large tract, in east-central Arizona and west-central New Mexico, which is relatively unexplored because of the extensive cover of volcanic rocks. However, previous exploration has shown oil in Permian rocks in the area in Tenneco's Federal No. 1 well, drilled in 1967 in sec. 35, T. 1 S., R. 13 W., about 13 mi north of Horse Mountain (fig. 1).

Successful petroleum exploration depends not only upon having the appropriate source and host rocks, but also upon finding suitable structures for trapping and accumulating concentrations of oil and gas. The present oil company exploration is largely an attempt, using various geophysical methods, to identify such structures as targets for drilling. With the present information available for this assessment, favorable structures for oil and gas accumulation could underlie the wilderness study areas. Analysis of the thermal maturation of carbonate rock from the San Andres Formation at the foot of Horse Mountain indicates that the rocks are in the petroleum window, that is, they have been heated sufficiently for oil maturation but not to the point where petroleum products would have been driven out of the rocks (Anita Harris, written commun., 1986). The energy resource potential for oil and gas in both study areas and the San Agustin Plains is moderate, with certainty level C.

Metals in Hydrothermal Deposits

The absence of hydrothermally altered or mineralized rocks in the Horse Mountain and Continental Divide study areas, and most of the surrounding region, attests to a low mineral resource potential for all metals. However, the occurrence of mineralized jasperoid and other mineralized inclusions of pre-Tertiary sedimentary rocks in the dacitic pumice breccia of Old Horse Springs, about 5–8 mi southwest of the Horse Mountain study area, indicates a potential for mineralization associated with igneous intrusions in the Paleozoic sedimentary rocks that also underlie the Horse Mountain study area. The mineralized inclusions in the dacitic pumice breccia consist mainly of hematite and zinc-bearing magnesioferrite, and quartz and calcite gangue; they contain as much as 10,000 ppm (1 percent) zinc, 3,000 ppm manganese, 300 ppm copper, 300 ppm vanadium, 100 ppm nickel, and 70 ppm lead (Ratté and Modreski, 1987). A contact metasomatic iron skarn may be present at depths outside the Horse Mountain study area; such a deposit is likely to be localized where the intrusion invaded pre-Tertiary carbonate and other sedimentary rocks.

Although there are no indications of this type of mineralization in the Horse Mountain study area, the Horse Mountain volcano must have been fed by a conduit of some type, such as a dike or dike swarm, connected with a body of dacitic to rhyolitic magma that also must have come up through the pre-Tertiary rocks. Thus there is a low potential for iron, manganese, lead, zinc, copper, molybdenum, gold, and silver in contact metasomatic deposits associated with the Horse Mountain silicic volcanic system, similar to that associated with the pumice breccia southwest of Horse Springs, at a certainty level B. Similarly there is the possibility that mineralization occurred at depth in the Pelona Mountain volcanic system and the sedimentary rocks that presumably underlie the Continental Divide study area. Thus the potential for iron, manganese, lead, zinc, copper, molybdenum, gold, and silver mineralization beneath the Continental Divide study area also is considered to be low at a certainty level B.

Uranium

The potential for uranium deposits in both the Horse Mountain and Continental Divide study areas is considered to be low at a high level of certainty, D. Although there has been uranium exploration in the San Agustin Plains area, it has been based on a model in which uranium is leached by groundwater from potential source rocks (rhyolite tuffs and lava flows) around the margins of the plains and is precipitated under suitable conditions within the lacustrine and other fluvial sediments of the basin fill. The environment suitable for such deposits lies entirely outside the wilderness study areas.

Results of an aerial gamma-ray survey showed overall low radioactivity and overall moderate radioactivity in the Horse Mountain and Continental Divide study areas, respectively, and no radioactivity anomalies within or near either study area (J.S. Duval, U.S. Geological Survey, written commun., 1986).

Tin

The Horse Mountain and Continental Divide study areas have low potential for both tin placer deposits and rhyolite-hosted tin lode deposits as defined by Reed and others (1986) at certainty levels D and C, respectively. The Taylor Creek Rhyolite, host for the tin deposits in the Taylor Creek district, is absent north of the San Agustin Plains, but does crop out in the northeast corner of, and along the east side of, the Continental Divide study area, where it could extend a short distance beneath the alluvium and andesite at the east edge of the study area (pl. 1). Some rocks previously identified in the study areas as tin-bearing rhyolite like the Taylor Creek (Willard and Stearns, 1971; Roberts and others, 1982; U.S. Bureau of Land Management, 1986) are shown by this study to be rhyolite tuffs (Bloodgood Canyon Tuff and Shelley Peak Tuff, plate 1) and low silica rhyolite lavas of Bat Cave Wells, not Taylor Creek Rhyolite.

There are no known tin deposits or prospects within the study areas and geochemical studies have given no other indications of possible tin resources therein.

Geothermal Energy

No new information was developed from this study to assess the geothermal energy potential of the study areas, which is considered to be low at a low level of certainty, B. That a geothermal energy potential exists in the San Agustin region is indicated by several wells that produce point-of-discharge temperatures equal to or exceeding 21 °C (R.G. Myers, U.S. Geological Survey, written commun., 1986). Two of these wells are within bedrock areas south of the plains, but none are within the wilderness study area boundaries. Chimney Well, in Shaw Canyon at the northeast corner of the Continental Divide study area (pl. 1), has a point-of-discharge temperature of 26 °C, and Coyote Well about 2 mi west of the southwest corner of the study area (pl. 1) has a point-of-discharge temperature of 28 °C. Both are deep wells, 750 ft and 1200 ft, respectively, and thus normal geothermal gradient may account, at least in part, for the apparently anomalous temperatures.

Sand and Gravel

The potential for sand and gravel deposits within the wilderness study areas is low at a high level of certainty, D. The poorly sorted landslide debris and colluvium that is present locally in small areas on the flanks of Horse Mountain within the study area, and similar material along some drainageways in the Continental Divide study area, are largely unsuitable as resources of sand and gravel.

REFERENCES CITED

Almquist, C.L., 1986, Mineral investigation of a part of the Horse Mountain Wilderness Study Area (NM–020–043), Catron County, New Mexico: U.S. Bureau of Mines Open-file Report MLA 39–86.

Bornhorst, T.J., 1980, Major and trace element geochemistry and mineralogy of upper Eocene to Quaternary volcanic rocks of the Mogollon–Datil volcanic field, southwestern New Mexico: Albuquerque, N. Mex., University of New Mexico, Ph.D. dissertation, 500 p.

Chapin, C.E., and Elston, W.E., eds., 1978, Field guide to selected cauldrons and mining districts of the Datil–Mogollon volcanic field: New Mexico Geological Society Special Publication 7, 149 p.

Cordell, Lindrith, 1985, Techniques, applications, and problems of analytical continuation of New Mexico aeromagnetic data between arbitrary surfaces of very high relief (abs.); *in* Proceedings of the International Meeting on Potential Fields in Rugged Topography: Institut de Géophysique Université de Lausanne Bulletin 7, p. 96–101.

Cordell, Lindrith, Keller, G.R., and Hildebrand, T.G., 1982, Bouguer gravity 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.

Duffield, W.A., 1986, Preliminary interpretation of field and chemical characteristics of the Taylor Creek Rhyolite, New Mexico (abs.): Geological Society of America Abstracts with Programs, v. 18, no. 5, p. 352–353.

Eggleston, T.L., and Norman, D.I., 1986, A summary of the geology, geochemistry and tin occurrences in the Black Range, New Mexico: New Mexico Geological Society, 37th Guidebook, Truth or Consequences Region, p. 173–178.

Elston, W.E., 1984, Mid-Tertiary ash-flow tuff cauldrons, southwestern New Mexico: Journal of Geophysical Research, v. 89, no. B10, p. 8733–8750.

Elston, W.E., and Northrup, S.A., eds., 1976, Cenozoic volcanism in southwestern New Mexico: New Mexico Geological Society Special Publication 5, 151 p.

Foreman, F., Clisby, K.H., and Sears, P.B., 1959, Plio-Pleistocene sediments and climates of the San Agustin Plains, New Mexico: New Mexico Geological Society Guidebook 10, p. 117–120.

Fries, Carl, Jr., 1940, Tin deposits of the Black Range, Catron and Sierra Counties, New Mexico: U.S. Geological Survey Bulletin 922–M, p. 355–370.

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.

Jones, D.P., 1980, Volcanic geology of the Alegros Mountain area, Catron County, New Mexico: Albuquerque, N. Mex., University of New Mexico, M.S. thesis, 76 p.

Krohn, D.H., 1976, Gravity survey of the Mogollon Plateau volcanic province, southwestern New Mexico; *in* Elston, W.E., Northrup, S.A., eds., Cenozoic volcanism in southwestern New Mexico: New Mexico Geological Society Special Publication 5, p. 113–116.

Lawrence, V.A., 1985, A study of the Indian Peaks tin-bearing rhyolite dome-flow complex, northern Black Range, New Mexico: Boulder, Colo., University of Colorado, M.S. thesis, 112 p.

______ 1986, Developments in the Cenozoic volcanic stratigraphy of the Indian Peaks area, northern Black Range, New Mexico: New Mexico Geological Society Guidebook, 37th Field Conference, Truth or Consequences Region, p. 179–182.

Lawrence, V.A., and Richter, D.H., 1986, Geologic map of the Indian Peaks West quadrangle, Catron County, New Mexico: U.S. Geological Survey Miscellaneous Field Studies Map MF–1849, scale 1:24,000.

McCaslin, J.C., 1985, Holbrook basin area awaits drill bit: Oil and Gas Journal, v. 83, no. 32, p. 111.

Marvin, R.F., Naeser, C.W., Bikerman, M., Mehnert, H.H., and Ratté, J.C., in press, Isotopic ages of post-Paleocene igneous rocks within and bordering the Clifton 1°×2° quadrangle, Arizona-New Mexico: New Mexico Bureau of Mines and Mineral Resources Bulletin 118.

Maxwell, C.H., Foord, E.E., Oakman, M.R., and Harvey, D.B., 1986, Tin deposits in the Black Range tin district: New Mexico Geological Society, 37th Guidebook, Truth or Consequences Region, p. 273–282.

Osburn, G.R., and Chapin, C.E., 1983, Nomenclature for Cenozoic volcanic rocks of northeast Mogollon–Datil volcanic field, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Stratigraphic Chart No. 1.

Pankonien, L.J., 1985, What's happening in the United States: World Oil, v. 203, no. 2, p. 19.

Ratté, J.C., Marvin, R.F., Naeser, C.W., and Bikerman, M., 1984, Calderas and ash flow tuffs of the Mogollon Mountains, southwestern New Mexico: Journal of Geophysical Research, v. 89, no. B10, p. 8713–8732.

Ratté, J.C., and Modreski, P.J., 1987, Origin and significance of mineralized pre-Tertiary xenoliths in pumice breccia at Old Horse Springs, Mogollon–Datil volcanic field, Catron County, New Mexico (abs.): Geological Society of America Abstracts with Programs, v. 19, no. 5, p. 328.

Reed, B.L., Duffield, Wendell, Ludington, S.D., Maxwell, C.H., and Richter, D.H., 1986, Descriptive model of rhyolite hosted Sn, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 168.

Roberts, D.B., Krason, J., and Rizo, J.A., 1982, Geology, energy, and mineral resources assessment of the San Agustin area, New Mexico: Unpublished report prepared for U.S. Department of the Interior, Bureau of Land Management.

Rye, R.O., Lufkin, J.L., and Wasserman, M.D., 1984, Genesis of tin occurrences in the Black Range, New Mexico, as indicated by oxygen isotope studies (abs.): Geological Society of America Abstracts with Programs, v. 16, no. 6, p. 642.

Simpson, R.W., Jachens, R.C., and Blakely, R.J., 1983, AIRYROOT—A Fortran program for calculating the gravitational attraction of an Airy isostatic root out to 166.7 km: U.S. Geological Survey Open-File Report 83–883, 66 p.

Simpson, R.W., Jachens, R.C., Blakely, R.J., and Saltus, R.W., 1986, A new isostatic residual gravity map for the conterminous United States with a discussion on the significance of isostatic anomalies: Journal of Geophysical Research, v. 91, no. B8, p. 8348–8372.

Stearns, C.E., 1962, Geology of the north half of the Pelona quadrangle, Catron County, New Mexico: New Mexico Bureau of Mines and Mineral Resources Bulletin 78, 46 p. (includes geologic map, scale 1:63,360).

U.S. Bureau of Land Management, New Mexico State Office, 1986, New Mexico Statewide Wilderness Study, 1986: 4 v. (v. 3, Appendices-Wilderness Analysis Reports).

Willard, M.E., and Stearns, C.E., 1971, Reconnaissance geologic map of the Pelona 30-minute quadrangle: New Mexico Bureau of Mines and Mineral Resources, Geologic Map 23, scale 1:126,720.

Wood, R.H., II, 1986, Mineral investigation of a part of the Continental Divide Wilderness Study Area (NM–020–044), Catron County, New Mexico: U.S. Bureau of Mines Open-file Report MLA 53–86.

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.

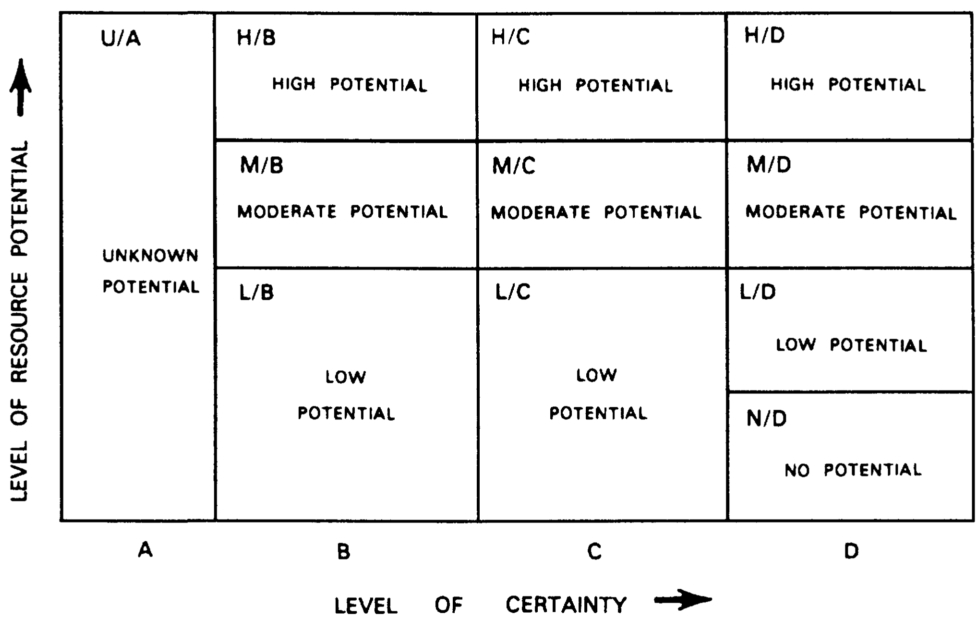
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application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