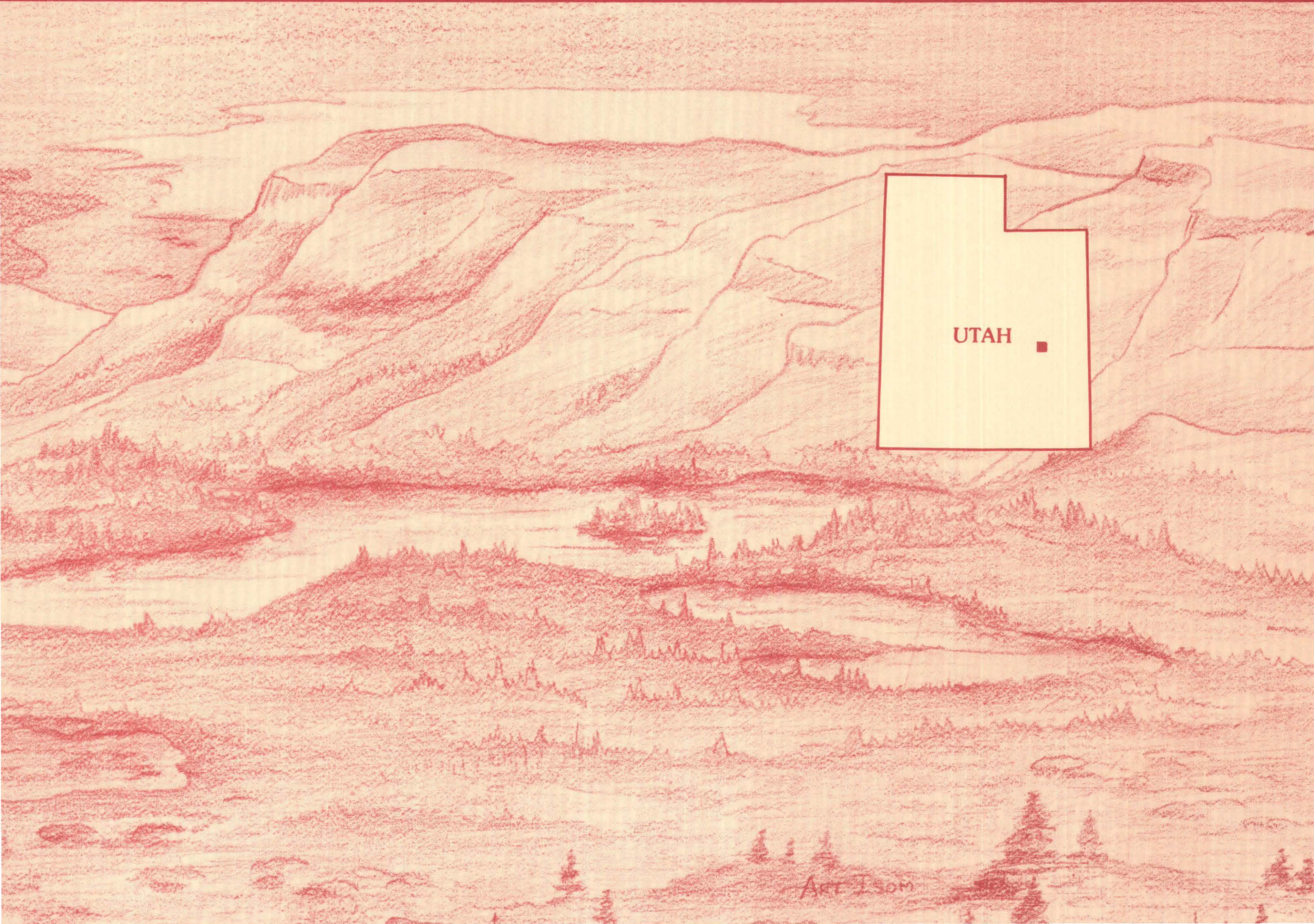
Mineral Resources of the Horseshoe Canyon North Wilderness Study Area, Emery and Wayne Counties, Utah

U.S. GEOLOGICAL SURVEY BULLETIN 1750



Mineral Resources of the Horseshoe Canyon North Wilderness Study Area, Emery and Wayne Counties, Utah

By SANDRA J. SOULLIERE and GREG K. LEE
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DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

UNITED STATES GOVERNMENT PRINTING OFFICE: 1988

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

Library of Congress Cataloging-in-Publication Data

Soulliere, Sandra J.
Mineral resources of the Horseshoe Canyon North Wilderness Study Area, Emery and Wayne Counties, Utah.

(U.S. Geological Survey bulletin ; 1750)
Bibliography: p.
1. Mines and mineral resources—Utah—Horseshoe Canyon North Wilderness. 2. Horseshoe Canyon North Wilderness (Utah) I. Lee, Greg K. II. Martin, Clay M. III. Title. IV. Series.
QE75.B9 no. 1750 557.3 s [553'.09792'57] 88-600369
[TN24.U8]

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 Horseshoe Canyon North Wilderness Study Area (UT-060-045), Emery and Wayne Counties, Utah.

CONTENTS

PLATE

[Plate is in pocket]

FIGURES

Mineral Resources of the Horseshoe Canyon North Wilderness Study Area, Emery and Wayne Counties, Utah

By Sandra J. Soulliere *and* Greg K. Lee
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ABSTRACT

The Horseshoe Canyon North (UT–060–045) Wilderness Study Area is in Emery and Wayne Counties, Utah, about 30 miles south of the town of Green River. Investigations by the U.S. Bureau of Mines and the U.S. Geological Survey indicate that the study area has no known economic resources, has inferred subeconomic resources of common variety sandstone, and has occurrences of common variety sand and gravel. The entire study area has moderate mineral resource potential for uranium, vanadium, and copper and for oil and gas; the northernmost part of the study area has moderate resource potential for potash. The entire study area also has low mineral resource potential for all other metals and geothermal energy.

SUMMARY

In 1986 and 1987, the U.S. Bureau of Mines and the U.S. Geological Survey conducted investigations to appraise the identified mineral resources (known) and assess the mineral resource potential (undiscovered) of the Horseshoe Canyon North (UT-060–045) Wilderness Study Area (fig. 1). The area is in Emery and Wayne Counties, about 30 mi (miles) south of Green River, Utah. Prominent cliffs and incised gulches characterize the study area. This topography was formed by the erosion of the flat-lying sedimentary rocks of Triassic and Jurassic age. (See geologic time chart in the Appendix.) Sedimentary rocks exposed in the study area are the Chinle Formation, Wingate Sandstone, Kayenta Formation, Navajo Sandstone, and Carmel Formation.

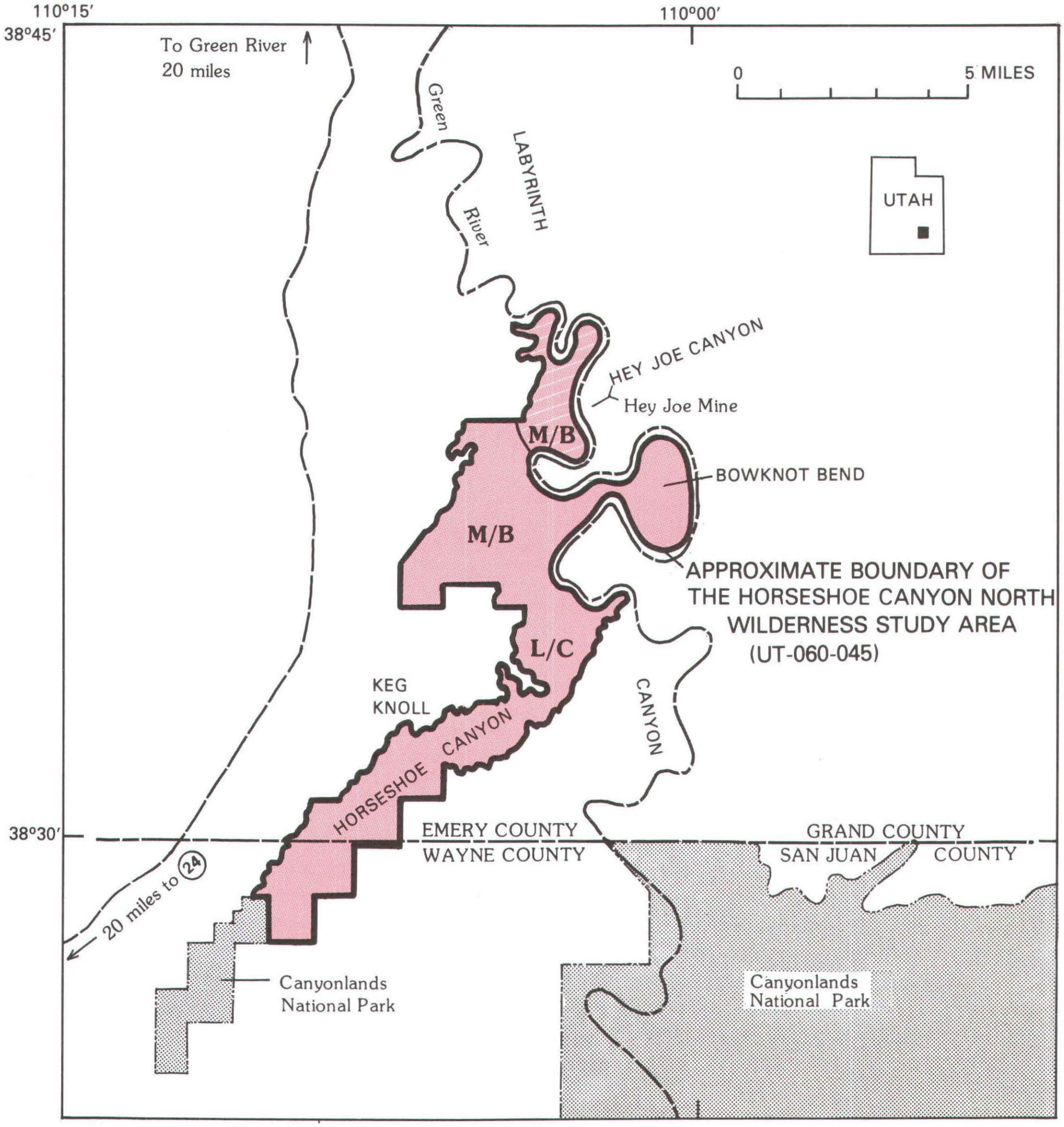
U.S. Geological Survey researchers collected and analyzed 31 stream-sediment samples, 18 heavy-mineral panned-concentrate samples, and 9 rock samples from the study area. Workers from the U.S. Bureau of Mines collected and analyzed 45 rock samples, 10 stream-sediment samples, and 1 panned-concentrate sample. Analyses of these samples reveal the presence of concentrations of elements that may be related to mineral deposits. Gravity, magnetic, and radiometric data were used to determine the regional rock distribution and geologic structure of the area.

Six lode claim blocks for uranium are located in or near the study area; there are no patented claims in the vicinity. Approximately 1 mi^2 (square mile) of the study area is under lease application for potash. Most of the study area is under lease for oil and gas. Oil and gas have been produced within 12 mi of the study area, but not within the study area. Uranium prospecting and limited mining have occurred in the eastern part of the study area near Bowknot Bend, where 12 short adits (3 of which are inaccessible) are located in the Moss Back Member of the Chinle Formation. No resources of uranium were identified in this area.

Inferred subeconomic resources of sandstone and occurrences of sand and gravel are common in the study area. However, development is unlikely because ample resources of these materials are available elsewhere in the region at locations closer to local markets.

The entire study area has a moderate mineral resource potential for undiscovered uranium, vanadium, and copper in the Moss Back Member of the Chinle Formation. Uranium deposits containing variable but small amounts of copper occur in the Moss Back Member of the Chinle Formation in the vicinity of the study area. Uranium and vanadium minerals (carnotite and uraninite) are found in adits and prospects in and near the study area and in the Hey Joe Mine just east of the study area. Exposures of the Moss Back Member near Bowknot Bend are unoxidized and contain carbonaceous material, indicating a favorable environment

Publication approved by the Director, U.S. Geological Survey, March 29, 1988.



EXPLANATION

M/B **Geologic terrane having moderate mineral resource potential for uranium, vanadium, and copper in the Moss Back Member of the Chinle Formation and for oil and gas, with certainty level B**—Applies to entire study area

M/B (hatched) **Geologic terrane having moderate mineral resource potential for uranium, vanadium, and copper in the Moss Back Member of the Chinle Formation and for oil and gas and potash, with certainty level B**

L/C **Geologic terrane having low mineral resource potential for all metals, except as noted above, and for geothermal energy, with certainty level C**—Applies to entire study area

Certainty levels:

B **Data indicate geologic environment and suggest level of resource potential**

C **Data indicate geologic environment and indicate resource potential, but do not establish activity of resource-forming processes**

Figure 1. Mineral resource potential and location of the Horseshoe Canyon North Wilderness Study Area, Emery and Wayne Counties, Utah.

for possible precipitation of uranium-vanadium minerals. Samples of unoxidized sandstone contained more than 100 parts per million uranium, but geochemical analyses of stream-sediment samples from the study area revealed no anomalous concentrations of uranium, vanadium, or copper.

The potential for undiscovered potash resources in the northernmost part of the study area is moderate. Potash is found in the Paradox Member of the Hermosa Formation, which underlies the study area at a depth of approximately 5,000–6,500 ft. The northern part of the study area is in a zone inferred to contain potash based on geologic mapping and gravity data. A decrease in gravity recorded at the northern end of the study area may be due to an increase in the thickness of low-density evaporites, including potash. No test wells have been drilled in the study area, and the quality and thickness of the potash are unknown.

The resource potential for oil and gas is moderate in the study area. Favorable reservoir and source rocks of Mississippian through Permian age underlie the study area and have yielded oil and gas elsewhere in the region. However, test wells drilled within 5 mi of the study area were dry.

The study area lacks a favorable geologic environment for any metallic mineral resources other than uranium, vanadium, and copper. No minerals have been produced and no surface evidence was found to indicate the presence of metallic mineral resources. The study area has a low mineral resource potential for all metals except uranium, vanadium, and copper. No evidence for geothermal resources is present in the study area, and the potential for geothermal resources is low.

INTRODUCTION

The Horseshoe Canyon North (UT-060–045) Wilderness Study Area covers approximately 20,500 acres in Emery and Wayne Counties, Utah (fig. 1), about 30 mi south of the town of Green River. In this report the studied area is called the "wilderness study area" or simply the "study area." Access is provided by unimproved roads east of Utah Highway 24 and from unimproved roads south of Green River, Utah. Intermittent streams drain the study area and flow east into the Green River, which forms part of the eastern boundary of the study area. Elevations range from 4,000 ft (feet) at the Green River to more than 5,400 ft at the top of Horseshoe Canyon. The prominent cliffs and incised canyons that characterize the topography of the study area are the result of erosion of the flat-lying Triassic and Jurassic sedimentary rocks.

This report presents an evaluation of the mineral endowment (identified resources and mineral resource potential) of the study area and was the product of several separate studies by the U.S. Bureau of Mines (USBM) and the U.S. Geological Survey (USGS). Identified resources are classified according to the system of the U.S. Bureau of Mines and the 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), which is also shown in the Appendix of this report. Undiscovered resources are studied by the USGS.

Investigations by the U.S. Bureau of Mines

In October 1985 and May 1986, the USBM conducted a mineral investigation of the Horseshoe Canyon North Wilderness Study Area. The field investigation was preceded by a literature survey of the region. Information regarding surface and mineral ownership, oil and gas leases, mining claims, and prospecting activity was researched from records of the Bureau of Land Management (BLM).

The field investigation included the examination and sampling of mineralized areas in and near the study area boundaries, scintillometer surveys to detect anomalous radioactivity at sample sites and during foot traverses, the collection of minus-80-mesh stream-sediment sample fractions to determine the extent of mineralized areas, and placer sampling of a stream bar along the Green River. Altogether, 56 samples were taken: 45 rock samples, 10 stream-sediment samples, and 1 panned-concentrate sample (Martin, 1987). All rock and stream-sediment samples were analyzed for uranium by fluorometry by Bondar-Clegg, Inc., Lakewood, Colo. Stream-sediment samples and the panned-concentrate sample were analyzed for gold by fire assay/atomic absorption spectrometry and for silver by atomic absorption spectrometry, also by Bondar-Clegg. In addition, all stream-sediment samples and selected rock samples underwent semiquantitative optical emission spectrographic analysis for 40 elements at the USBM Reno Research Center, Reno, Nev. Results of the analyses are in Martin (1987). Additional information is available from the U.S. Bureau of Mines, Intermountain Field Operations Center, Building 20, Denver Federal Center, Denver, CO 80225.

Investigations by the U.S. Geological Survey

In 1986 and 1987, the USGS conducted investigations to assess the potential for undiscovered mineral resources of the Horseshoe Canyon North

Wilderness Study Area. The investigations included a search for published and unpublished information about the area, a field verification of previous geologic mapping (Huntoon and others, 1982), collection of stream-sediment and rock samples for geochemical analysis, a review of existing geophysical information, and a search for mineralized and altered areas. Robert Jachens reviewed the gravity and aeromagnetic data of Case and Joesting (1972) and incorporated the information into the geophysical section of this report. Geochemical analyses of all USGS samples were performed by R.T. Hopkins, Jr., J.D. Sharkey, and D.L. Fey.

APPRAISAL OF IDENTIFIED RESOURCES

By Clay M. Martin, U.S. Bureau of Mines

Mining and Leasing Activity

Uranium is the only commodity produced or prospected for in the Horseshoe Canyon North Wilderness Study Area. Some ore was produced from adits in the Bowknot Bend area, although no records of production were located during this investigation. The Hey Joe Mine, about 0.75 mi east of the study area (fig. 1), produced about 10,000 pounds of U_3O_8 and 13,000 pounds of V_2O_5 in the 1950's and 1960's. According to the property owners, ore grade at the mine was about 0.22 percent U_3O_8 and 6 percent V_2O_5. (See Trimble, 1976.)

As of October 1985, six blocks of lode claims for uranium were located in or near the study area, mostly along outcrops of the Chinle Formation in Labyrinth Canyon (pl. 1). No patented claims exist in or near the study area.

Small amounts of placer gold were produced from terrace and stream bar gravels along the Green and Colorado Rivers in southeastern Utah in the late 19th and early 20th centuries, but no production is known from the Green River gravels in or near the study area and there are no placer claims nearby.

A small part of the study area is under lease for oil and gas (fig. 2), but no exploration holes have been drilled within the study area boundary. Approximately 1 mi^2 of the study area is under lease application for potash (fig. 2); other potash lease applications, 2 mi to the north and 10 mi to the east of the area, are pending with the BLM.

Hey Joe Mine

The largest mine in the vicinity of the study area is the Hey Joe Mine, now inactive, about 0.75 mi east of the study area in Hey Joe Canyon on the east side of the Green River. All production was from the Chinle Formation; ore minerals at the mine were mainly carnotite and uraninite (Trimble, 1976). The Hey Joe Mine was not examined extensively or sampled during the USBM investigation because levels of radon gas in the mine are as high as 12 times the amount considered acceptable by the U.S. Mine Safety and Health Administration. Outcrops of the Moss Back Member of the Chinle Formation near the mine, however, are similar to those near uranium prospects in the study area along Bowknot Bend, about 2 to 3 mi to the southeast, where the Moss Back is composed of crossbedded, lenticular beds of medium-grained sandstone grading into conglomerate.

Bowknot Bend Mines and Prospects

The Moss Back Member of the Chinle Formation, which is host to many of the known uranium deposits in the region, has been prospected extensively along Bowknot Bend in the eastern part of the study area. Workings in the study area consist of 12 short adits in the Moss Back Member on the east side of Bowknot Bend (Martin, 1987). At the time of this field investigation, three of the adits were inaccessible due to collapse. The nine accessible adits range from 40 to 150 ft in length and appear to be exploratory in nature for the most part. Uranium concentrations in samples from these adits were generally low, ranging from 5 ppm (parts per million) to 1,200 ppm, except for two samples from small, highly localized pockets that exceeded 2,000 ppm uranium, the upper limit for the analysis method used. Radiometric readings in the adits ranged from a low of 420 cps (counts per second; within the general background level of the area of 250–450 cps) to a high of 32,000 cps.

Uranium content and radioactivity levels in the three inaccessible adits are unknown, but a sample from the dump of the adits contained 210 ppm uranium. From surface evidence these caved adits appear to be more extensive than the others; whatever ore was produced in the Bowknot Bend area may have come from these caved adits.

The Bowknot Bend prospects show only low concentrations of uranium, and no resource is indicated for them as a result of this field investigation. The study also indicates no uranium occurrences anywhere else in the Horseshoe Canyon North study area; no significant uranium or other metal content was detected in stream-sediment samples from study area drainages.

Placer Gold

Prospectors of the late 19th and early 20th centuries made sporadic attempts to recover placer gold from the Green and Colorado Rivers in the region

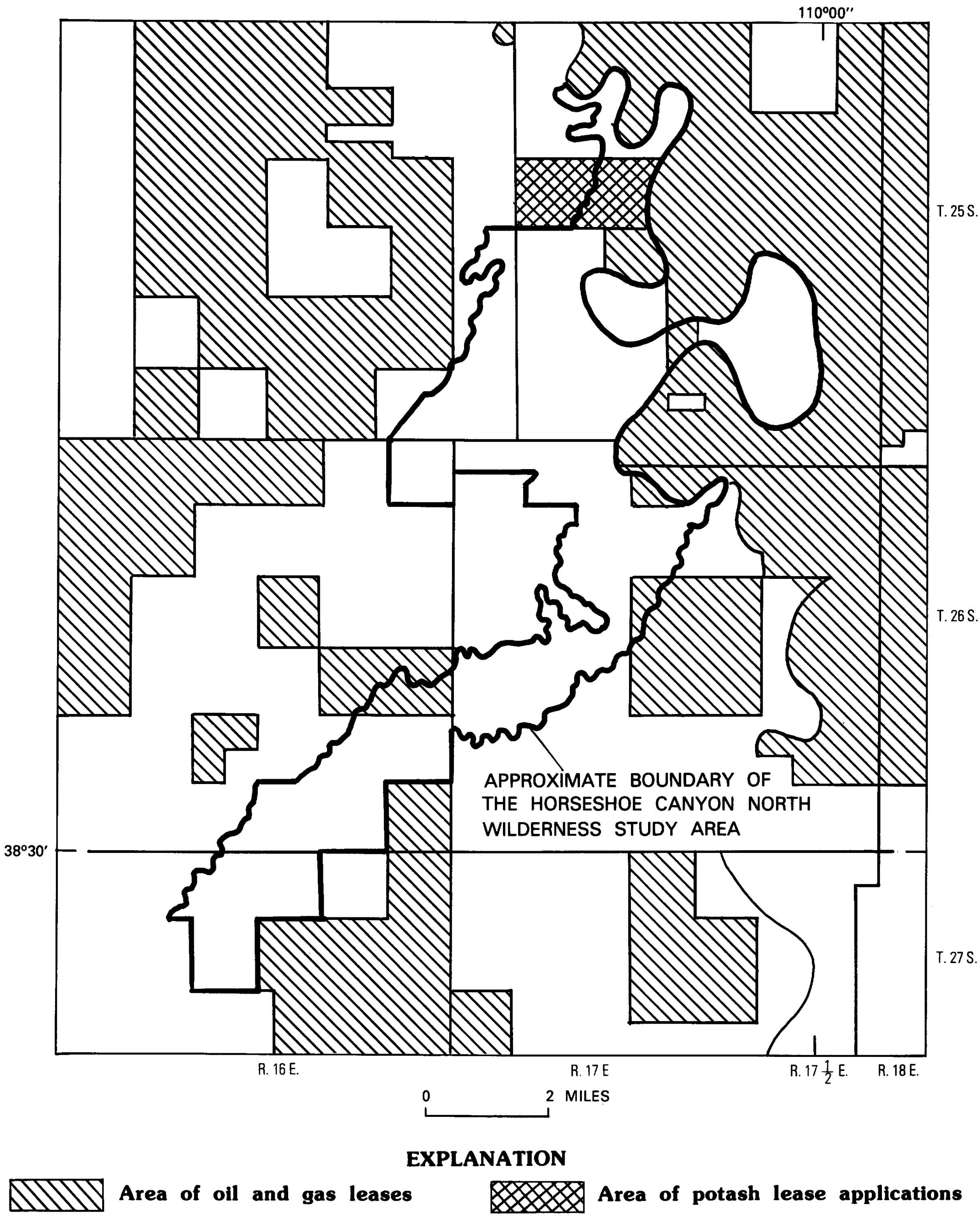


Figure 2. Oil and gas leases and potash lease applications in and near the Horseshoe Canyon North Wilderness Study Area, Emery and Wayne Counties, Utah (from BLM files as of July 1987).

including the study area. The USBM field investigation sought to evaluate placer gold occurrences in the bed of the Green River, just outside the eastern boundary of the study area. A single panned-concentrate sample taken from a gravel bar in the river channel contained 85 parts per billion gold; silver was not detected. This amount of gold does not indicate a placer gold resource in the Green River adjacent to the study area.

Potash

The Paradox Member of the Hermosa Formation underlies the entire study area at depths of 5,000 to 6,500 ft (Hite, 1976). This unit contains large amounts of evaporitic gypsum, anhydrite, and potash in much of the Paradox basin (a depositional basin that includes the study area and extends about 150 mi to the southeast). The Paradox Member has been profitably mined for potash within 20 mi of the study area. Resources of various evaporite minerals may underlie the study area (see assessment of mineral resources, this report), but potash is probably the only one of these that could conceivably be profitably mined at great depth, using solution-mining techniques. It is more likely, however, that the potash beds east of the Green River, which are thicker and much more accessible by highway and rail, would be developed before any attempt would be made to recover potash in the study area vicinity.

Mineral Occurrences

Inferred subeconomic resources of common variety sandstone occur in the study area in a wide range of textures, colors, cementations, and bedding thickness. Many of the sandstone units would be suitable for use as dimension stone, flagstone, or concrete aggregate; however, vast quantities of sandstone of equal or higher quality are available throughout the region at locations closer to markets.

Occurrences of common variety sand and gravel are common in canyon bottoms in the study area, particularly in Labyrinth and Horseshoe Canyons, where primary and secondary alluvial terraces are developed. None of these occurrences are easily accessible, and they are far from potential markets. Ample resources of similar sand and gravel are available elsewhere in the region at locations closer to markets.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By Sandra J. Soulliere and Greg K. Lee
U.S. Geological Survey

Geology

The geology of a major portion of the study area was mapped and described by Huntoon and others (1982) during a study of Canyonlands National Park and vicinity. After a field check, we chose to use a portion of this map (pl. 1) and its descriptions of rock units for this investigation. The northern part of the study area, which was not mapped by Huntoon and others (1982), was mapped in the field by S.J. Soulliere and A.M. Leibold. Flat-lying sedimentary rocks of Triassic and Jurassic age are exposed in the study area and represent deposition in marine and continental environments.

During Pennsylvanian time a thick sequence of marine sediments, mainly evaporites, filled the Paradox depositional basin in southeast Utah and southwest Colorado (Hite and Buckner, 1981). The study area lies on the northwestern edge of the Paradox basin. Pennsylvanian and Permian rocks of the basin consist of interbedded sandstones, siltstones, shales, conglomerates, and evaporites. Rocks of this age are not exposed in the study area, but projection of surface geologic mapping indicates that they may be present in the subsurface. The Lower Permian White Rim Sandstone Member of the Cutler Formation in particular is important to this study because it has reservoir characteristics favorable for the entrapment of oil and gas (Molenaar and Sandberg, 1983; Baars and Seager, 1970). The Paradox Member of the Middle and Upper Pennsylvanian Hermosa Formation also underlies the study area and may have reservoir characteristics for oil and gas. It has also been mined locally for potash (Hite, 1976).

Mesozoic-age sedimentary rocks exposed in the study area are (oldest to youngest) the Chinle Formation, Wingate Sandstone, Kayenta Formation, Navajo Sandstone, and Carmel Formation. The Upper Triassic Chinle Formation generally forms slopes of variegated red, purple, green, and yellow bentonitic sandstones and siltstones. Ledges of conglomeratic sandstones occur locally. The Chinle has been divided into six members (Stewart and others, 1972), but only the Moss Back, Owl Rock, and Church Rock Members are present in the study area. The Moss Back Member is about 25 ft thick and consists of yellowish-gray, fine- to medium-grained, lenticular-bedded, conglomeratic sandstone and minor mudstone and siltstone beds (Johnson, 1959). The Owl Rock Member is as much as 60 ft thick in the study area and is composed of pale-reddish-brown, coarse-grained siltstone with interbedded limestone (Stewart and others, 1972). The Church Rock Member consists of pale-reddish-brown, coarse- to fine-grained siltstone with sandstone lenses. The Upper Triassic Wingate Sandstone unconformably overlies the Chinle and consists of approximately 200 to 250 ft of reddish-brown, thick-bedded, cross-stratified, fine-grained, well-sorted sandstone that forms a steep cliff. The Upper Triassic(?) Kayenta Formation conformably overlies the Wingate and is divided into a lower cliff-forming unit and an upper slope-forming unit having a total thickness of 250–450 ft. The Kayenta consists of reddish-brown to lavender, fine-to medium-grained sandstone with subordinate siltstone, limestone, and shale interbeds. The Upper Triassic(?) and Jurassic Navajo Sandstone forms cliffs and hummocky knobs. The Navajo conformably overlies the Kayenta Formation and consists of buff to pale-orange, well-sorted, fine- to medium-grained, thick-bedded sandstone and thin-bedded, sandy limestone with stringers of red chert. The Navajo is approximately 250 to 450 ft thick. The Middle Jurassic Carmel Formation unconformably overlies the Navajo Sandstone and forms a rounded slope. The Carmel is composed of red, muddy siltstones and shaly sandstones approximately 20 to 130 ft thick.

Geochemistry

A reconnaissance geochemical survey was conducted in the Horseshoe Canyon North Wilderness Study Area in 1987. For this study, 31 stream-sediment samples, 18 heavy-mineral panned-concentrate samples, and 9 rock samples were collected and analyzed (pl. 1).

Analyses of stream-sediment samples represent the chemistry of the rock material eroded from the drainage basin upstream from each sample site. In addition, the fine (silt) fraction of the sediment provides nuclei for the adsorption of dissolved metals contained in the stream water. Analyses of these materials are useful in identifying those drainage basins that contain concentrations of elements that may be derived from mineral deposits. Coarse stream sediment was panned to reduce the amount of common rock-forming minerals, such as quartz and feldspar, and to create a concentrated sample. The selective concentration of minerals, many of which may be ore-related, permits determination of some elements that are not readily detected in stream-sediment samples.

Analyses of unaltered or unmineralized rocks provide background geochemical data for individual rock units. Analyses of altered or mineralized rocks, where present, may provide useful geochemical information about the major- and trace-element assemblages associated with a mineralizing system.

Methods

Stream-sediment samples were collected from active stream drainages in the study area. At each sample site a composite of fine material from several localities within the stream was collected and air dried prior to sieving and subsequent analysis.

Panned concentrates derived from stream sediments were collected from drainages large enough to deposit gravel-size and coarser sediment. These samples were generally taken close to the stream-sediment sample localities but were derived from coarser material representing a higher energy depositional environment in the stream. A heavy-mineral concentrate was obtained by panning and was then submitted to the laboratory for drying and analysis.

Some rock samples were collected where the rock was visibly altered or mineralized, and the most mineralized or altered material observed was collected preferentially. Other rock samples were collected at random from unmineralized rock units.

All rock samples were crushed, ground, split, and analyzed. Stream-sediment samples were dried and sieved through an 80-mesh (177-micrometer) screen, and the fraction finer than 80 mesh was analyzed. Panned concentrates were dried and a small split of each sample was separated for spectrographic analysis. The remainder was weighed and chemically analyzed for gold.

Six-step semiquantitative emission spectrographic analyses were made of all samples using the method of Grimes and Marranzino (1968). Each spectrographic analysis included determinations of 35 elements. Atomic-absorption spectrophotometric analysis for gold was performed on every panned-concentrate sample using the method of Thompson and others (1968). All rock samples were analyzed for antimony, arsenic, bismuth, cadmium, and zinc by the inductively coupled plasma, atomic-emission spectrometric method of Crock and others (1987). All stream-sediment and rock samples were analyzed for uranium using a modification of the fluorometric method described by Centanni and others (1956).

Results

Inspection of the statistical distributions of the analytical data and consideration of average crustal abundances of the elements in comparable lithologic terrains (Rose and others, 1979) suggest that the study area is, for the most part, generally lacking in mineral enrichment. The stream-sediment and panned-concentrate samples gave almost no indication of anomalous geochemical concentrations, with the possible exceptions of low-level (1 ppm) silver determined in a single sample (location 10, pl. 1) in Keg Spring Canyon, and minor chromium (1,000 ppm) in a northern tributary of lower Barrier Creek at location 26 (pl. 1).

However, each of the Chinle Formation rock samples that were collected because of apparent mineralization were found to have anomalous concentrations of several elements. Most noteworthy are the two samples collected at location 17 at Bowknot Bend at the northeastern edge of the study area. This site is the location of previous uranium mining, and the samples were collected from an adit in apparently mineralized sandstone. In addition to high uranium concentrations (greater than 100 ppm), the samples were found to be enriched in copper (500 and 10,000 ppm), molybdenum (50 and 2,000 ppm), lead (100 and 1,000 ppm), and zinc (1,000 ppm) with minor silver (700 ppm) and arsenic (340 ppm). The samples are from a localized bed of the Moss Back Member of the Chinle Formation that pinches out to the south.

Two samples from location 16, west of Bowknot Bend, were also from the Moss Back Member. An unaltered sample from this site showed no enrichment, but the other, altered sample, in which iron replaced carbonaceous material, contained minor molybdenum in addition to iron.

The samples from locations 29 and 30, near Keg Knoll, are directly related because the sample collected at locality 29 consists of mineralized float chips derived from the outcrop at locality 30 (3 samples). Although samples from locality 30 are quite highly enriched in copper (15,000 and >20,000 ppm) and a sample from locality 29 has moderately anomalous contents of silver (300 ppm), arsenic (700 ppm), bismuth (15 ppm), molybdenum (20 ppm), lead (300 ppm), and uranium (20 ppm), the actual extent of the outcrop that produced these samples was only approximately 10 ft by 15 ft at the ground surface. The samples reflect the geology at the surface and do not give an indication of mineralization at depth.

Geophysics

Three types of geophysical data (gravity, magnetic, and radiometric) that cover the study area and its vicinity were compiled and examined. The three data sets are adequate for addressing the regional structural and tectonic setting of the study area, but their sampling intervals are too wide to permit detailed statements about mineral resource potential at deposit scale except in small areas directly beneath detailed profiles.

Gravity Data

Gravity data from the study area and surrounding region were from Case and Joesting (1972) and the National Geophysical Data Center of the National Oceanic and Atmospheric Administration, Boulder, Colo. Data points are separated at 2–4 mi spacing in the region, and only a few stations are located within the study area boundary. The observed gravity data, based on the International Standardization Net datum (Morelli, 1974) were reduced to free-air gravity anomalies using standard formulas (Telford and others, 1976). Bouguer, curvature, and terrain corrections (from about 0.4 mi out to a distance of about 104 mi from each station), using a reduction density of 2.67 grams per cubic centimeter, were added to the free-air anomaly at each station to determine complete Bouguer gravity anomalies (fig. 3).

The gravity field over the northern half of the study area is characterized by a general east-northeastward decrease in values from about -200 milligals in the southwest to about -215 milligals in the northeast. The southern half of the study area appears to lie along the southern edge of a gravity trough that extends westward across the center of figure 3, but gravity data near the study area are sparse, and the gravity contours are not closely controlled. Case and Joesting (1972) attribute the decrease in gravity to a combination of three factors: (1) an increase in depth to the Precambrian basement surface, from about 2,500 ft below sea level near the southwest end of the study area to nearly 5,000 ft below sea level near its northeast end; (2) an increase in thickness of low-density Paradox Member evaporites toward the northeast; and, possibly, (3) a northward decrease in average density of the Precambrian basement. They further speculate that the gravity trough may be related to local depositional thickening of salt in the Fremont accessway of Wengerd (1962).

Aeromagnetic Data

Aeromagnetic surveys of the Paradox basin and vicinity were made between 1953 and 1959 with a continuously recording fluxgate magnetometer (Case and Joesting, 1972). Total-field magnetic data over the study area were measured at 8,500 ft barometric elevation along east-west flight lines spaced 1–1.5 mi apart. Figure 4 is a contour map of the total-intensity magnetic field of the Earth relative to an arbitrary datum.

The most pertinent anomalies in the vicinity of the study area are two roughly circular magnetic highs about 8–10 mi in diameter, one located about 10 mi northwest of the center of the study area and the other about 10 mi to the southeast. A weak magnetic high, expressed primarily as a south-pointing deflection of the magnetic contours, lies over the central part of the study area. The shape and magnitude of the southeastern anomaly, coupled with a coincident gravity high, led Case and Joesting (1972) to infer its source to be a mafic intrusion into the Precambrian basement. This anomaly and the other high lie along a band of magnetic highs that extends from the San Rafael Swell, 40 mi northwest of the study area, to the Colorado River, 20 mi southeast of the area. These anomalies were interpreted by Case and Joesting (1972) to represent a continuous line of basically flat-lying mafic Precambrian(?) intrusions. If their interpretation is correct, the source of the weak magnetic high over the study area lies at an estimated depth of 8,000–9,000 ft beneath the general land surface.

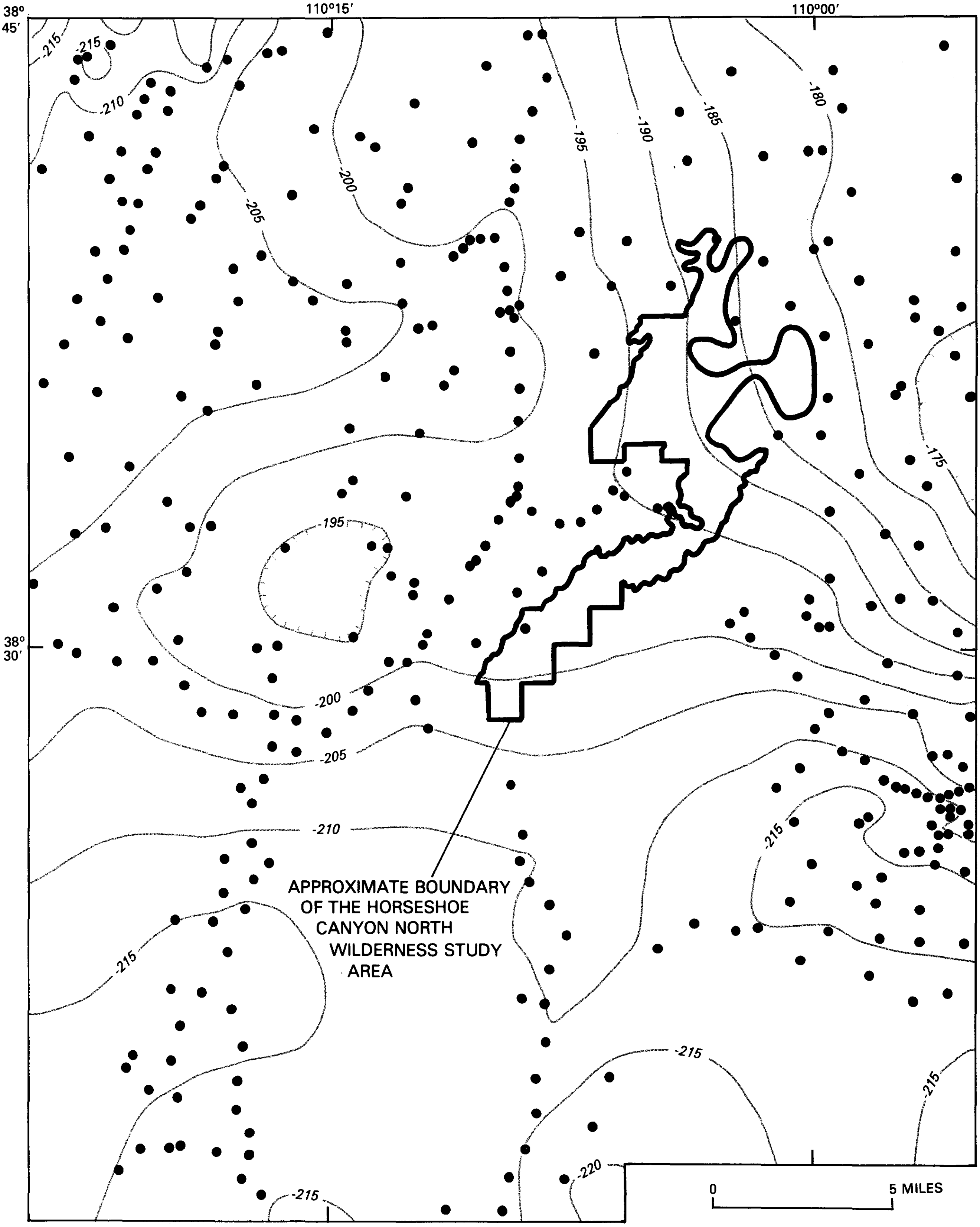


Figure 3. Complete Bouguer gravity map of the Horseshoe Canyon North Wilderness Study Area and vicinity. Contour interval 5 milligals. Hachures indicate gravity lows; dots indicate locations of gravity observations.

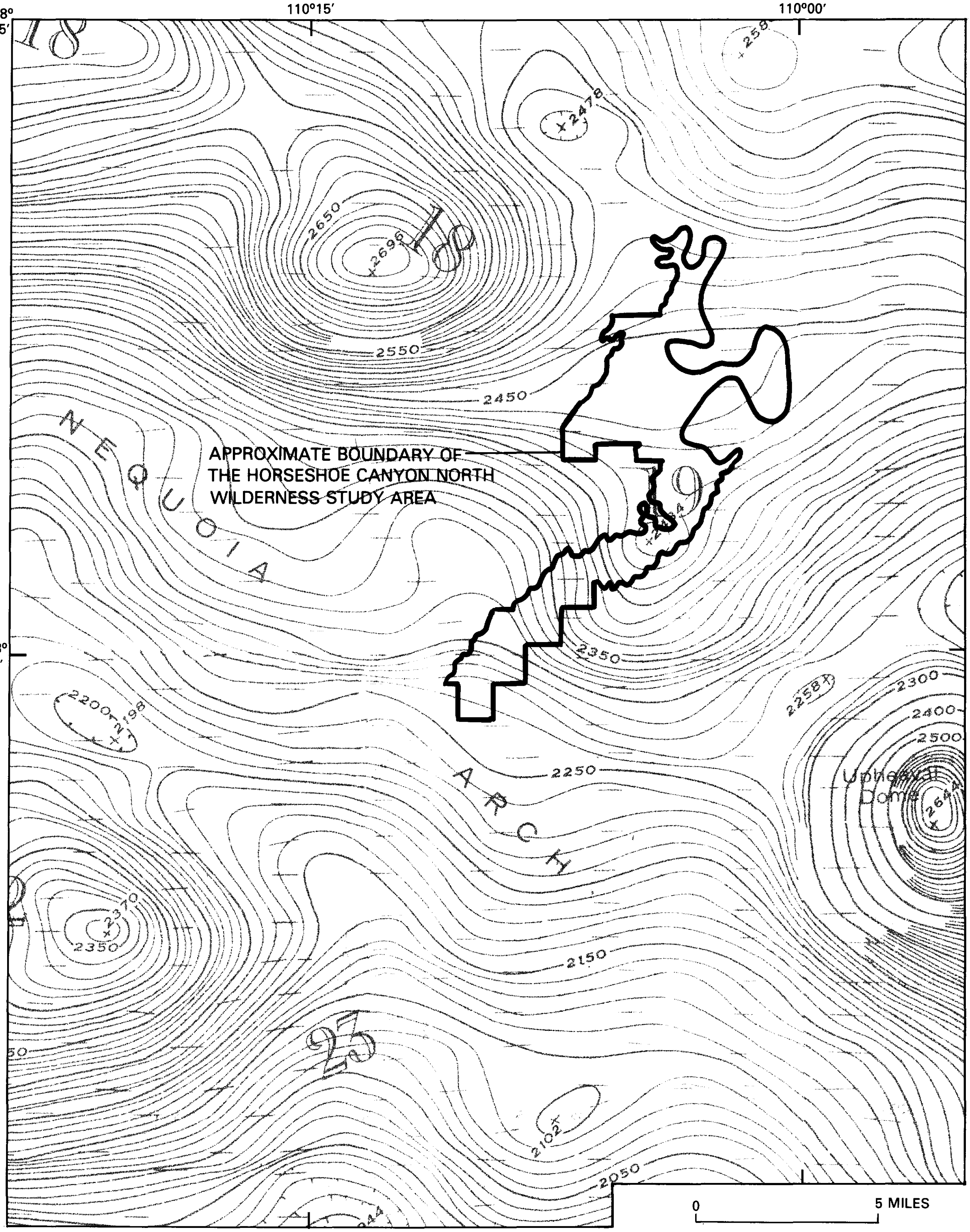


Figure 4. Total magnetic intensity map of the Horseshoe Canyon North Wilderness Study Area and vicinity (from Case and Joesting, 1972). Contour interval 10 gammas (nanoteslas). Hachures indicate magnetic lows; horizontal dashes represent flight lines for data collection.

Radiometric Data

A radiometric survey of the Salina 1°×2° quadrangle, Utah, was flown and compiled under contract to the U.S. Department of Energy as part of the National Uranium Resource Evaluation (NURE) program (GeoMetrics, 1979). Data were collected at an elevation of 400 ft above average terrain along east-west flight lines spaced about 3 mi apart and north-south flight lines spaced about 12 mi apart. The survey recorded gamma-ray flux from radioactive isotopes indicative of the presence of uranium, thorium, and potassium. Count rates along parts of the six flight lines that crossed the study area give no indication of anomalous amounts of radioactive elements. However, two anomalies indicative of uranium were identified close to the study area boundary just south of Keg Knoll, two others between 1 and 3 mi east of the east boundary at latitude 38°32.4' N., and a fifth about 1 mi south of the extreme southwest corner of the study area (GeoMetrics, 1979). Because the flight lines are widely spaced and because gamma rays are strongly attenuated by passage through earth materials, these data do not preclude the presence of anomalous amounts of radioactive elements within the study area between flight lines or buried a few feet or more beneath the ground surface.

Mineral and Energy Resources

Metallic Minerals

Known uranium deposits in the region, containing varied but small amounts of vanadium and copper, are localized in fluvial sandstone beds in the Moss Back Member of the Chinle Formation. Johnson (1959) studied uranium and vanadium mineralization in the Green River district, an area that includes the Horseshoe Canyon North Wilderness Study Area. He found that ore deposits in the Chinle in the district are, with few exceptions, classed as uranium deposits with minor amounts of vanadium and (or) copper. The Moss Back Member of the Chinle Formation is exposed in the northern half of the study area and underlies the rest of the study area. It is a favorable host for uranium with minor vanadium and copper. Thick beds of fluvial sandstone and carbon-rich black mudstone of the Moss Back Member interfinger and provide traps for ore-bearing solutions. Carbonaceous material in the mudstone provides a chemically reducing environment for the precipitation of uranium, vanadium, and copper minerals into sandstone paleochannels. Ore-bearing units are generally light gray to buff near ore deposits and are red or brown away from ore.

Sandstone and mudstone beds of the Moss Back Member near Bowknot Bend are light gray and contain carbonaceous material suggestive of possible uranium-vanadium mineralization. These beds tend to be lenticular and pinch out over short distances. Geochemical analyses of some gray sandstones revealed more than 100 ppm uranium, and stream-sediment samples from the northern half of the study area showed concentrations of 0.35–0.75 ppm uranium. Uranium and vanadium minerals are found at the Hey Joe Mine and in mines and prospects in and near the study area (Trimble, 1976). Although this evidence indicates some uranium mineralization at the surface, more detailed studies of the Moss Back fluvial systems are needed in order to project sandstone paleochannel and carbon-rich mudstone trends in the subsurface. Therefore, the potential for undiscovered resources of uranium, vanadium, and copper in the Moss Back Member of the Chinle Formation in the study area is moderate with a certainty level of B. (See Appendix for explanation of certainty levels.) This rating is based on the known occurrence of uranium and vanadium minerals in prospect pits in the study area, the presence of favorable host rocks, and the uncertainty of projected trends favorable for the deposition of uranium and vanadium.

Anomalous amounts of very fine grained gold and mercury have been reported in the Petrified Forest Member of the Chinle Formation in northern Arizona and southern Utah (Lawson, 1913; Lausen, 1936; L.L. Patten, unpub. data, 1968). However, the Petrified Forest Member is not present in the study area, and geochemical sampling has not revealed any anomalous concentrations of gold or mercury from outcrops of the Chinle in the study area.

The geologic environment of the study area is not favorable for the presence of any other metallic minerals. In addition, geochemical evidence does not indicate abnormally high concentrations of metals in the study area. No minerals have been produced, and no surface evidence was found to indicate metallic mineral resources. Therefore, the study area is assigned a low potential for all metals other than uranium, vanadium, and copper, with a certainty level of C.

Potash

Evaporite and potash deposits in the Paradox basin occur in the Middle Pennsylvanian Paradox Member of the Hermosa Formation. The Paradox underlies the study area at a depth of approximately 6,000 ft. Hite (1961; 1976) delineated the limits of major potash zones in the Paradox Member, and the northern part of the study area is within one of these zones. Geophysical data indicate a decrease in gravity at the northern end of the study area, which may be due to an increase in thickness of low-density evaporites or potash. Because no test wells have been drilled in the study area, the occurrence, the quality, and the thickness of any potash are not known with certainty. The mineral resource potential for potash is therefore moderate in the northernmost part of the study area with a certainty level of B.

Oil and Gas

The Horseshoe Canyon North Wilderness Study Area is underlain by rock units that produce oil and gas elsewhere in the Paradox basin. Reservoir rocks include Mississippian carbonate rocks and clastic rocks in the Pennsylvanian Paradox Member of the Hermosa Formation. Source rocks are the black, organic-rich shales also found in the Paradox Member. The Lower Permian White Rim Sandstone Member of the Cutler Formation is also a favorable reservoir for oil and gas in the region (Baars and Seager, 1970) and is present beneath the study area, where it probably intertongues with the Cedar Mesa Sandstone Member of the Cutler (Baars, 1975). Source rocks are the marine sedimentary rocks further down in the Cutler Formation. Molenaar and Sandberg (1983) rated the potential for oil and gas in the study area as medium (roughly equivalent to the moderate potential rating of Goudarzi, 1984). Their rating is based on the facts that the area is adjacent to a large heavy-oil deposit in the White Rim and that test wells drilled within 5 mi of the study area were dry. The presence of favorable source and reservoir beds, with no production from drill holes, indicates a resource potential rating of moderate for oil and gas in the study area. This rating has a certainty level of B, due to difficulty in seismic profiling of subsurface structure and sparse drill hole data.

Geothermal Resources

No hot springs or other geothermal sources were noted during this investigation. The energy resource potential is low for geothermal energy in the study area, with a certainty level of C.

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APPENDIX

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

Definitions of Mineral Resource Potential

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

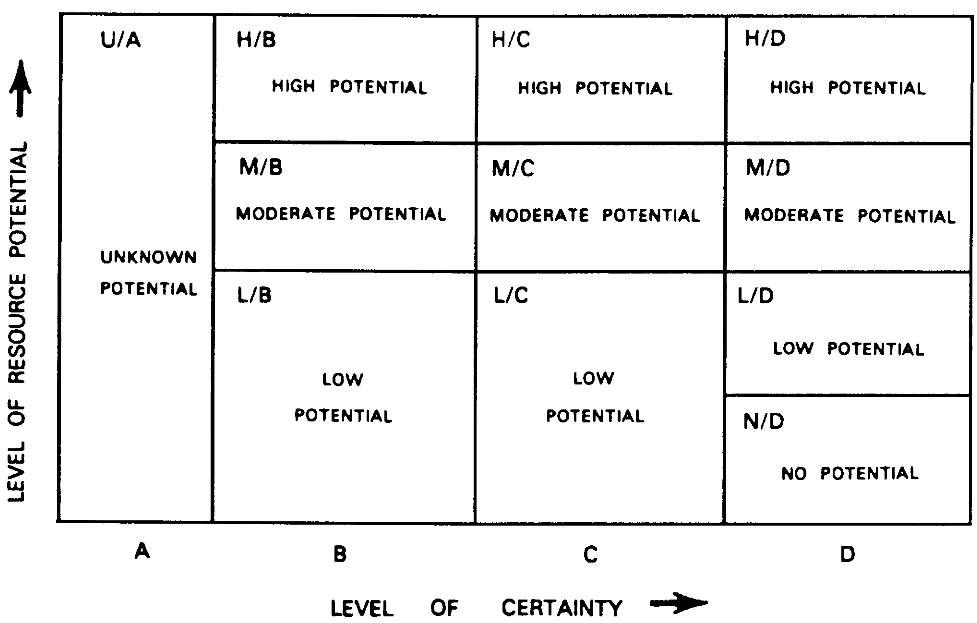
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application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

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

UNKNOWN mineral resource potential is assigned to areas where information is inadequate to assign low, moderate, or high levels of resource potential.

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

Levels of Certainty



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:

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RESOURCE / RESERVE CLASSIFICATION

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

Major elements of mineral resource classification, excluding reserve base and inferred reserve base. Modified from U. S. Bureau of Mines and U. S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U. S. Geological Survey Circular 831, p. 5.

GEOLOGIC TIME CHART

Terms and boundary ages used in this report

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

[1] Rocks older than 570 m.y. also called Precambrian, a time term without specific rank.

[2] Informal time term without specific rank.

U.S. GOVERNMENT PRINTING OFFICE: 1988—573-047 66.083 REGION NO. 8