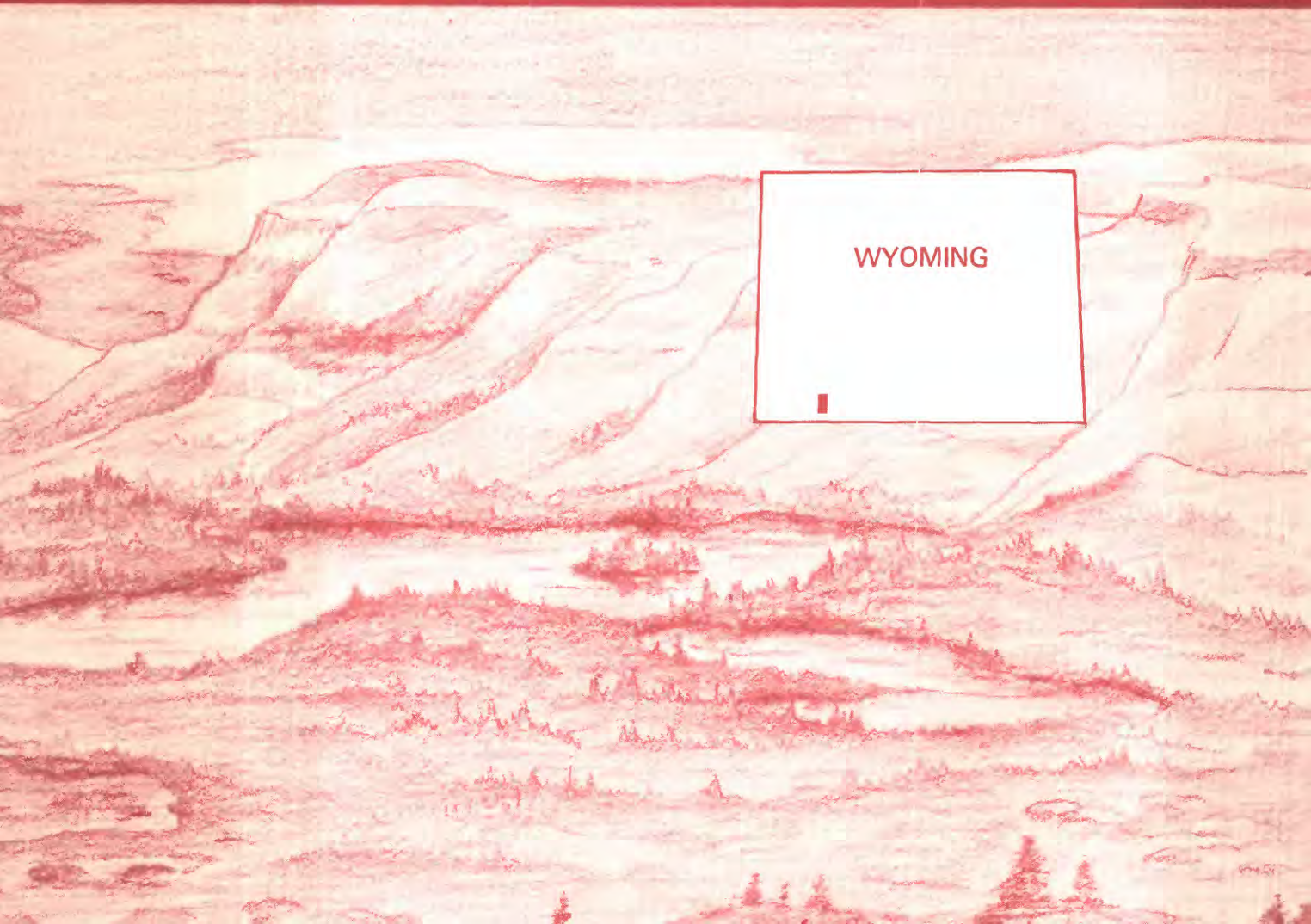
Mineral Resources of the Devils Playground and Twin Buttes Wilderness Study Areas, Sweetwater County, Wyoming

U.S. GEOLOGICAL SURVEY BULLETIN 1759–C



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Chapter C

Mineral Resources of the Devils Playground and Twin Buttes Wilderness Study Areas, Sweetwater County, Wyoming

By RICHARD E. VAN LOENEN and W. ANTHONY BRYANT
U.S. Geological Survey

MICHAEL E. LANE
U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1759

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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 Devils Playground (WY–040–401) and Twin Buttes (WY–040–402) Wilderness Study Areas, Sweetwater County, Wyoming.

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Mineral Resources of the Devils Playground and Twin Buttes Wilderness Study Areas, Sweetwater County, Wyoming

By Richard E. Van Loenen *and* W. Anthony Bryant
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ABSTRACT

In 1990 the U.S. Geological Survey and the U.S. Bureau of Mines conducted a mineral resource appraisal of the Devils Playground (WY–040–401) and the Twin Buttes (WY–040–402) Wilderness Study Areas in Sweetwater County in southwest Wyoming. The study areas contain 1.2 billion tons of inferred resources of trona (a mineral used in making soda ash). The study areas have high mineral resource potential for additional deposits of trona, high energy resource potential for natural gas and oil shale, moderate mineral resource potential for zeolites, and low energy and mineral resource potential for oil, coal, and metallic minerals.

SUMMARY

The Devils Playground and Twin Buttes Wilderness Study Areas lie in southwest Wyoming about 25 mi (miles) south of Green River. Flaming Gorge Reservoir is about 3 mi to the east. The study areas are contiguous, totaling about 26,800 acres, and unless specific mention is made to one or the other, the two areas are referred to as the "study areas" in this report. Access to the study areas is provided on the east by State Highway 530 and on the west by county highway 1 (fig. 1). The boundaries of the study areas are defined, for the most part, by jeep trails or four-wheel-drive roads.

The study areas are along the southeastern edge of the Green River basin. The topography of the study areas is dominated by two prominent landmarks called Twin Buttes and Black Mountain. Colorful badlands are carved in the slopes of these topographic highs and the badlands that formed on the slopes of Black Mountain are called Devils Playground. Nearly 1,500 ft (feet) of flat-lying sedimentary rocks of Eocene age are exposed in the study areas. These rocks belong to the Bridger Formation and consist mainly of poorly consolidated mudstone and fine sandstone interbedded with sandstone, siltstone, claystone, and tuff beds. Minor amounts of indurated ledge- forming, commonly siliceous dolostone units form conspicuous stratigraphic markers that locally hold up prominent topographic benches in the study areas. Pyroclastic material is abundant throughout the Bridger Formation. The study areas lie over the deepest parts of the Green River basin where Phanerozoic rock may be as much as 30,000 ft thick.

No mines, prospects, or mining claims are known in the Devils Playground and Twin Buttes Wilderness Study Areas. The study areas were withdrawn from mining claim location because of the rich oil shale deposits in the region. The study areas are also considered by the Minerals Management Service to have moderate development potential for sodium (trona). Study of drill hole data for this investigation indicates as much as 1.2 billion tons of inferred trona resources may be present in the Green River Formation at depths of 2,200 ft to just over 3,000 ft beneath the study areas.

The study areas have a high resource potential for undiscovered natural gas in overpressured low-permeability Cretaceous sandstone reservoirs. Favorable reservoir rock for gas such as the Cloverly and Frontier Formations is thought to be present. The older Paleozoic rock beneath the study areas is unfavorable for oil and gas due to the absence of structural traps in the deeper parts of the basin; production from structurally controlled reservoirs in these rock comes from the nearby arched and uplifted terrane.

The study areas have high energy resource potential for oil shale deposits in the Green River Formation, although at depths of several thousand feet below the surface. The surface

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rock contains some very thin and low grade oil shales.

In addition to areas of inferred resources of trona, the study areas have high mineral resource potential for additional undiscovered deposits of trona in the Green River Formation.

The Bridger Formation, the rock unit exposed on the surface of the study areas, was deposited in a favorable environment for the formation of zeolites; however, such deposits were found to be very thin and impure. All tuff beds and other conspicuous rocks were examined for zeolite content. Traces of clinoptilolite, a common zeolite mineral, were found in some of the sampled beds in the study areas and major amounts were found in thin beds along the northeast and northwest boundary of the Devils Playground study area. The study areas, therefore, have a moderate potential for undiscovered deposits of zeolite; the resource potential is not high because of the very thin and impure nature of the beds.

The study areas have low potential for coal resources. Coal-bearing strata are probably present in the subsurface but are at great depths.

The study areas have low mineral resource potential for undiscovered metallic minerals. The Bridger Formation in its present geologic setting in the Green River basin is not a favorable environment for these types of mineral resources.

INTRODUCTION

This report discusses the mineral and energy resources of 26,800 acres in the Devils Playground (WY-040–401) and the Twin Buttes (WY–040–402) Wilderness Study Areas. The study areas are contiguous and unless specific mention is made to one or the other, the two areas are referred to as the "study areas" in this report. The study areas are in Sweetwater County in southwestern Wyoming about 25 mi (miles) south of Green River, Wyo., and 20 mi north of Manila, Utah (fig. 1). Flaming Gorge Reservoir is about 3 mi to the east. The boundaries of the study areas are defined, for the most part, by jeep trails or four-wheel-drive roads. These roads were built to serve, among others, livestock operations in the region, well-drilling projects, and pipeline maintenance. No established or marked hiking trails are within the study areas but bulldozer cuts traverse much of the terrain.

The road along the western boundary of the Devils Playground study area leads to Pine Springs. Pine Springs has been developed and a network of pipes connects the springs to water troughs several miles to the north. Pine Springs is also an important archaeological site that was examined by archaeologists from the University of Utah in the early 1960's. Their studies indicate that the site was occupied from 10,000 B.C. to A.D. 1,200.

Access to the study areas is provided on the east by State Highway 530 and on the west by county highway 1 (fig. 1). Roads to the study areas branch off of these highways at several different locations. The boundary roads, with the exception of the Pine Springs road, are in very poor condition.

The study areas are along the southeastern edge of the Green River basin, one of several basins in the Greater Green River basin of southwestern Wyoming (fig. 1). The topography of the study areas is dominated by two prominent landmarks called Twin Buttes and Black Mountain. They are capped by a hard and very resistant conglomerate that preserves the softer underlying rock. Colorful badlands are carved in the softer rock underlying Twin Buttes and Black Mountain. Nearly 1,500 ft (feet) of flat-lying sedimentary rocks of various shades of red, green, and gray are exposed in a picturesque landscape.

The study areas have a desert climate with most of the precipitation resulting from a few storms in summer and winter. All streams are ephemeral and drain eastward into Flaming Gorge Reservoir on the Green River. Drainage from the areas include Buckboard Wash, Squaw Hollow, Anvil Wash, Butte Wash, and several tributaries to Henry's Wash, which is south of the map of figure 2. Numerous small dams, many of which are within the study areas, have been built on the smaller tributaries for stock ponds. Strong winds are common in the region, but sparse patches of native grasses and sagebrush tend to stabilize older sand dunes and the thin veneer of soil that is characteristic of this type of terrain. The badlands are protected from wind erosion by a thin coating of a loosely cemented mixture of clay, fine sand, and rock fragments. Piñon pine and juniper are sparse and there is a grove of spruce trees at Pine Springs.

No mines, prospects, or mining claims are in the study areas, but rock and fossil collecting has taken place. Chert beds are common and some of it is prized by collectors for its banded appearance. These beds were the source of chert used by the Indians at Pine Springs for thousands of years.

Many famous collecting sites for vertebrate fossils are in the Green River basin. The study areas are classic sites of vertebrate fossil collecting and have yielded specimens now found in the collections of the American Museum of Natural History, the United States National Museum, and the Yale Peabody Museum. Thousands of fossil specimens have been collected for study. Fossil mammals include primates, carnivores, rodents, insectivores, marsupials, and ungulates; fossil amphibians are represented by salamanders; and fossil reptiles include snakes, lizards, turtles, alligators, and crocodiles. In addition to the terrestrial vertebrate faunas, fossil aquatic animals include gastropods, pelecypods, ostracodes, and fish. Fossil wood, leaf, and algal remains also occur. The fossil vertebrate mammal faunas provided the basis for the recognition and definition of the North American middle Eocene Bridgerian land-mammal age (Wood and others, 1941).

This report presents an evaluation of the mineral endowment (identified resources and mineral resource potential) of the study area and is the product of several separate studies by the U.S. Bureau of Mines (USBM) and the U.S. Geological Survey (USGS). Identified resources

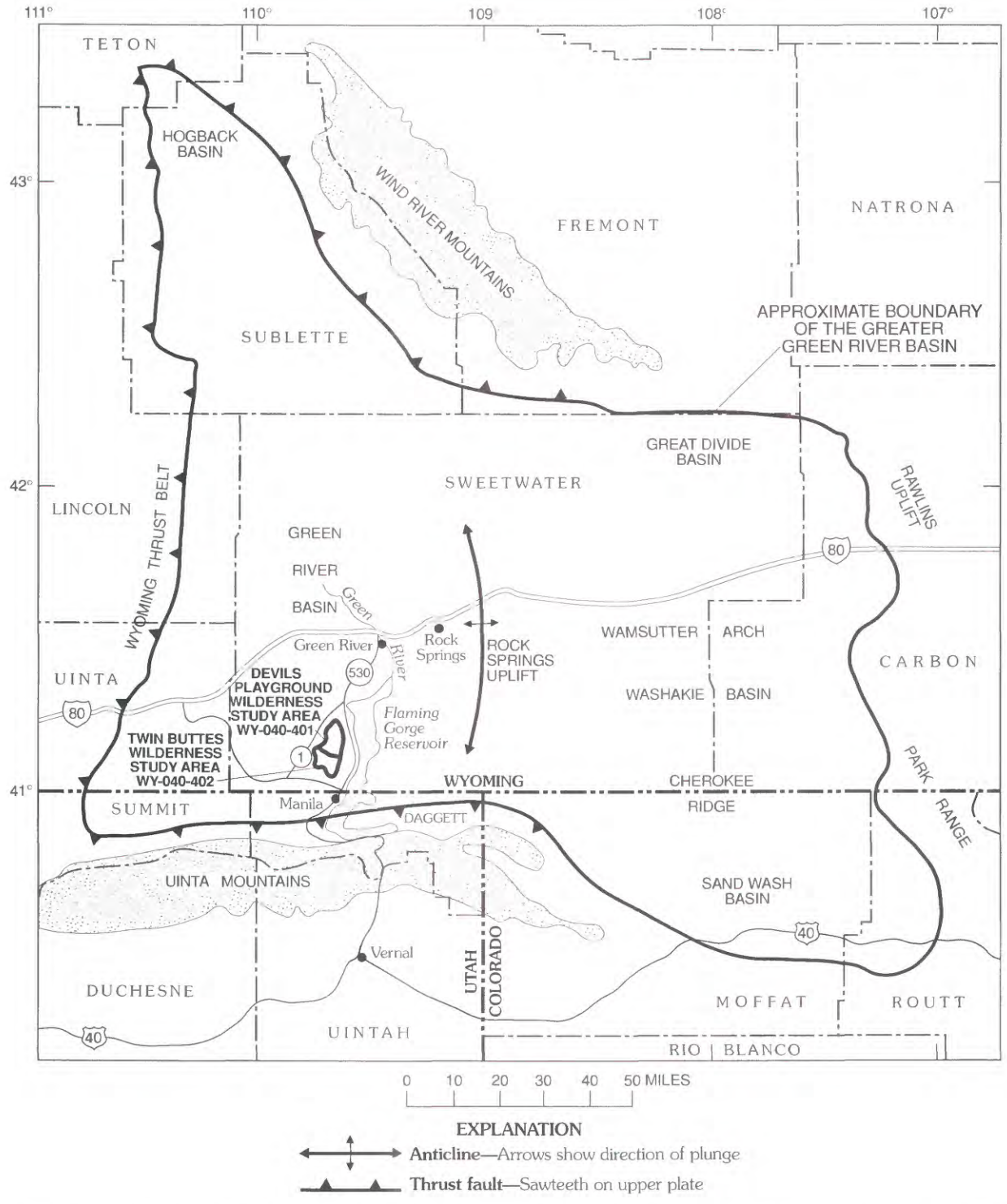
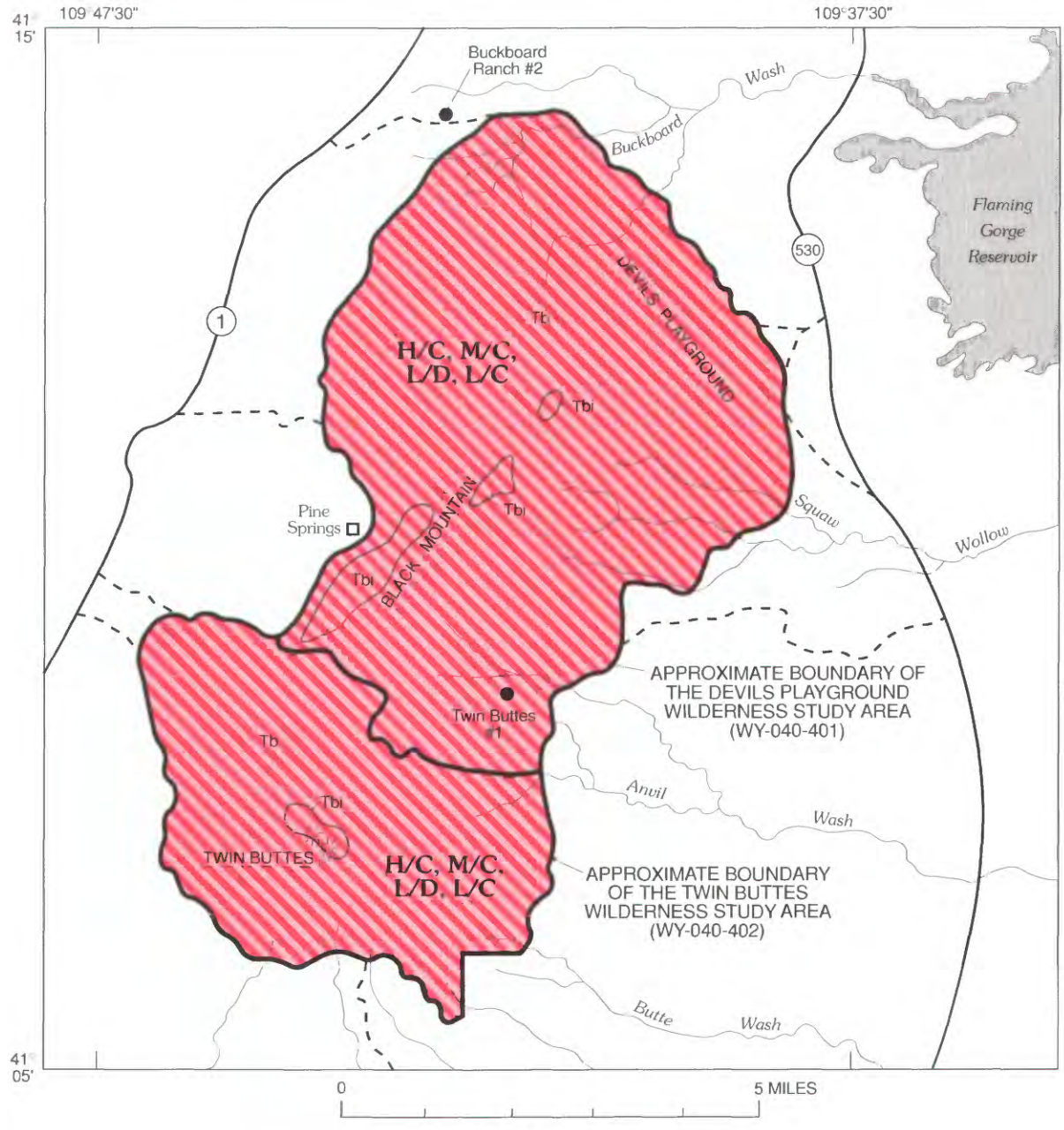


Figure 1. Map showing location of the Devils Playground and Twin Buttes Wilderness Study Areas, Sweetwater County, Wyoming, and major structural elements and subbasins of the Greater Green River basin.

are classified according to the system of the USBM and USGS (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 USGS.



EXPLANATION

H/C	**Geologic terrane having high resource potential for natural gas, oil shale, and trona**—Applies to both areas
M/C	**Geologic terrane having moderate resource potential for zeolite**—Applies to both areas
L/D	**Geologic terrane having low resource potential for coal and metallic metals**—Applies to both areas
L/C	**Geologic terrane having low resource potential for oil**—Applies to both areas
Tbi	**Bishop Conglomerate**
Tb	**Bridger Formation**
●	**Drill Holes**—Refer to table 1

Figure 2. Summary map showing mineral and energy resource potential of the Devils Playground and Twin Buttes Wilderness Study Areas.

Investigations by the U.S. Bureau of Mines

Appraisal of identified resources in the Devils Playground and Twin Buttes Wilderness Study Areas included literature searches and field work. A detailed literature search was made for geologic and mining information pertinent to the study areas, and BLM records were examined for mining claims, land status, and oil and gas leases. Two USBM geologists spent 7 days in the field in June 1990 in and near the study areas.

Investigations by the U.S. Geological Survey

Assessment of the potential for undiscovered mineral and energy resources in the Devils Playground and Twin Buttes Wilderness Study Areas is based largely on the geologic setting, geochemical data from rocks and stream sediments, and consideration of the production history of similar rocks in the surrounding areas. The field work for this assessment was done in July 1990. No new information or data were obtained during this study for the subsurface geology. Information used in assessing oil and gas potential is taken largely from Spencer (1983) who rated the petroleum potential of Wyoming, Law and others (1989) who discussed hydrocarbon plays and estimated gas resources in the Greater Green River basin, Root and others (1973) who summarized the mineral resources of Sweetwater County, and Bradley (1964) who provided a comprehensive description of the Eocene rocks in the Green River basin.

APPRAISAL OF IDENTIFIED RESOURCES

By Michael E. Lane
U.S. Bureau of Mines

Mining History

No mines, prospects, or mining claims are in the Devils Playground and Twin Buttes Wilderness Study Areas. There are no mining claims in the study areas as of June 1990. Both study areas were withdrawn from mining claim location because oil shale deposits occur at depth in the Green River basin (Executive Order 5327, May 20, 1930, and Public Land Order 45, 1967). The study areas are almost entirely within the boundaries of the Green River Basin Known Sodium Leasing Area as delineated by the Minerals Management Service (MMS) and are considered by the MMS to have moderate development potential for sodium (trona).

The only mines in the region are trona mines about 25 mi northwest of the study areas near Green River, Wyo., and coal mines around the Rock Springs uplift to the northeast and in the Henrys Fork coal field to the south.

Table 1. Data and analyses for the Twin Buttes #1 and the Buckboard Ranch #2 drill holes

[na, not analyzed; ?, not known. BLM file data, Rock Springs District Office]

Depth to top of bed (ft)	Bed number	Thickness of bed (ft)	% Trona
Twin Buttes #1 drill hole			
2664	18	3	na
2710	17	4.5	na
2762	16	10	na
2781	15	6.5	na
2836	14	11	na
2854	?	3	na
2881	13	10	na
2902	12	6	na
2951	9	9	na
3008	4	2.5	na
3020	3	3	na
3034	2	2	na
3079	1	3	na
Buckboard Ranch #2 drill hole			
2222	18	6	na
2259	17	11	81.9
2311	16	9	42.5
2329	15	14	21.5
2381	14	10	46.1

Several drill holes are near the wilderness study areas. Two holes are adjacent to or within the present study area boundaries; the Twin Buttes #1 (T. 14 N., R. 109 W., sec. 33) and the Buckboard Ranch #2 (T. 15 N., R. 109 W., sec. 32), intercepted trona beds in the Green River Formation at 2,664 ft and 2,222 ft, respectively (BLM file data) (fig. 2). The Buckboard Ranch #2 hole was drilled for trona by Joseph Perkins in July 1959, five trona beds were intersected (table 1; 14, 15, 16, 17, and 18). The Twin Buttes #1 hole was drilled in July 1975 by Farmers Union Central Petroleum Company to search for oil and gas. Twelve trona beds (1, 2, 3, 4, 9, 12, 13, 14, 15, 16, 17, and 18) were encountered. The Twin Buttes #1 hole was not cored or analyzed. (See Lane, 1990.)

Trona

Trona ($Na_2CO_3NaHCO_3 \cdot H_2O$) is an evaporite mineral formed in nonmarine alkaline lakes and marshes. These types of deposits are rarely economic (Lefond, 1983, p. 1188); however, the world's largest trona deposits are being mined west of Green River (U.S. Bureau of Mines, 1989, p. 149). These deposits occur as numerous beds in the Wilkins Peak Member of the Green River Formation (Eocene). Culbertson (1966) assigned numbers to 25 trona beds that exceeded 3 ft in maximum thickness and have an areal extent of 100 sq mi or more; these reference numbers are used in this report. Trona bed 17 is being mined by FMC Corporation and is 8–14 ft thick, about 1,600 ft deep, and

has purity of 80–90 percent trona and 10–20 percent halite and insolubles (shale stringers and other impurities) (Dave Hutcheson, FMC Corporation, oral commun., 1990).

Trona is readily processed to form soda ash (sodium bicarbonate). Soda ash is mostly used in making glass and paper, but it is also used in soaps, detergents, and pharmaceuticals. Thirteen trona beds, projected to extend beneath the wilderness study areas, have been identified from drill-hole data (table 1). The beds range in thickness from 2 to 14 ft. Using drill-hole data and computer-generated isopach maps supplied by the BLM, about 1.2 billion tons of inferred trona resources were calculated for beds 17, 14, and 12 underlying the wilderness study areas. These calculations do not contain purity estimates because of limited data. The calculations were done using a tonnage factor of 15 ft3 per ton and maps that showed outlines and thicknesses of projected trona beds. Additional data, including drilling, would be needed to verify and more accurately delineate trona beds and determine the quality of the resources. Table 1 shows drill-hole data for the two drill holes. Existing trona reserves under lease, in the region, are projected to meet market demands for hundreds of years (U.S. Bureau of Land Management, 1982); thus, development of trona beds in the near future beneath the study areas is unlikely.

Zeolite

Occurrences of zeolite in the study areas have been reported by Harris and others (1985), but no zeolite resources were identified in the study areas.

Sand and Gravel

The Bishop Conglomerate (Oligocene) on Black Mountain is considered a major gravel deposit (Root and others, 1973); however, it is not accessible. The State Highway Department has developed two gravel pits along the west boundary of the study areas (Root and others, 1973). Material from these pits was used locally for road construction. This and similar material in the study areas is very common in the region and it possesses no special qualities.

Collectible Commodities

With the exception of fossil turtles, the vertebrate fossils that were abundant on or near the surface in the past have been largely removed by collectors from the study areas. Nonmarine invertebrates and plant fossils are common throughout the Bridger Formation (Eocene), which is exposed in the study area. Black, brown, and banded cherts, common in outcrop and as float in the study areas are prized by rock collectors.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By Richard E. Van Loenen and W. Anthony Bryant
U.S. Geological Survey

Geologic Setting

The Devils Playground and Twin Buttes Wilderness Study Areas are within the deepest part of Green River basin, a deep structural and sedimentary basin containing over 25,000 ft of Phanerozoic rock. The structural and stratigraphic history of the Greater Green River basin began near the end of the Cretaceous Period, at the onset of the Laramide orogeny. Paleocene sediments that now comprise the Fort Union Formation were deposited in the basin. These sediments were derived from the newly formed mountain ranges surrounding the basin, and the sediments were deposited on flood plains in fluvial, lacustrine, and paludal (marsh) environments. Late Paleocene swamps were especially dominant, and later formed coal beds. These coal beds have been mined around the margin of the Rock Springs uplift where Fort Union rocks are exposed. The Fort Union is not exposed in the study areas but is present in the subsurface at depths exceeding 5,000 ft.

Downwarping of the basin and uplift of the adjoining mountain ranges continued through Paleocene and into Eocene time. Sediments of the Wasatch Formation were deposited on the Fort Union in a depositional environment similar to that of the Fort Union. The Wasatch also contains coal.

During the early and middle Eocene, prehistoric Lake Gosiute flooded the basin several times resulting in the deposition of an alternating sequence of lacustrine and fluvial sediments. These sediments now comprise the Green River Formation, which contains rich oil shale and trona deposits. The Green River Formation is present at depths of 100 to 3,000 ft beneath the study areas.

During middle Eocene time, the prevailing lacustrine environment changed back to mainly fluvial with the deposition of the Bridger Formation. Nearby volcanic centers also supplied voluminous pyroclastic material to the basin during this time. The material makes up much of the Bridger Formation, and it is also the source rock for zeolite.

About 1,400 ft of the middle and upper parts of the Bridger Formation are exposed in the study areas. This includes strata of the uppermost part of the Blacks Fork and Twin Buttes Members as recognized by Wood (1934) and the Cedar Mountain Member of West and Hutchison (1981). The rocks are mostly poorly consolidated mudstone and fine sandstone with the amount of pyroclastic material increasing upward in the section. Indurated ledge-forming, commonly siliceous dolostone units are minor, but conspicuous

stratigraphic markers that locally hold up prominent topographic benches in the study areas. Coarse sandstone, siltstone, claystone, and tuff beds are interbedded throughout the section in lesser amounts. Some of the more pronounced light-colored beds, referred to in previous studies as "white layers," are used as time- stratigraphic marker beds. The clastic sedimentary rocks, as exposed in the steep slopes and cliffs, are green, gray, olive, and red; and these sediments were deposited in fluvial flood plain, channel, and marginal lacustrine settings. The indurated carbonate rocks are pale brown, light gray, grayish orange, and grayish black; and they represent lacustrine deposition.

In this area the uppermost part of the Bridger was removed by erosion, and later the Bishop Conglomerate was deposited during the Oligocene. The Bishop Conglomerate, the youngest formation in the study areas, consists of coarse debris derived mainly from the Uinta Mountains. Erosion has since removed all but a few small remnants of Bishop Conglomerate that cap Twin Buttes and Black Mountain. On both mountain slopes large blocks of Bishop Conglomerate have broken loose and have been rafted downslope on the Bridger Formation.

The Bishop Conglomerate is 75–100 ft thick and is comprised of loosely cemented bouldery, cobbly conglomerate and coarse- to medium-grained, poorly sorted, pebbly, friable sandstone. The Bishop is light gray, light brown, red, and white; it was probably deposited as part of a continuous alluvial slope around the flanks of the Uinta Mountains and was subsequently eroded. Faults and fold structures are absent in the rock exposed in the study areas; the beds dip gently to the west at about 3 degrees, exposing older rock along the east side of the study areas.

Geochemistry

Six stream-sediment samples were collected and analyzed for forty-six elements, including base and precious metals, arsenic, uranium, and thorium. These samples represent material derived from sedimentary rock exposed in the study areas and deposited by the major streams. Analysis of these samples did not reveal any anomalous concentrations of any important elements indicative of mineral resources. The samples were analyzed for 44 elements that included base and precious metals by the ICP method by P.H. Briggs and for uranium and thorium by delayed neutron counting by R.E. McGregor and D.M. McKown of the U.S. Geological Survey. These data are available for public inspection at the U.S. Geological Survey, MS 973, 25046 Federal Center, Denver, CO 80225, under job no. UB76.

The tuffaceous rocks in the study areas are known to contain zeolite, and 35 rock samples were collected and analyzed to evaluate this potential resource. The samples were analyzed for zeolite by X-ray diffraction methods. The zeolite content of the samples was estimated by comparing X-ray traces of the samples to X-ray traces of samples containing known amounts of zeolites. Ten samples contain clinoptilolite (a common zeolite mineral) ranging from trace amounts to 10 percent, with one sample containing as much as 80 percent. No other zeolite minerals were detected. Other material in the samples consists of varying amounts of quartz, micas, feldspars, clays, and carbonate minerals. The locations of the clinoptilolite-bearing samples are on plate 1 of Lane (1990).

Mineral and Energy Resources

The geologic setting of the study areas is not favorable for metallic mineral resources, and the strata exposed there are not known to contain such resources anywhere in the region. The study areas are, however, within a large natural gas province; and oil shale, coal, and evaporite minerals (trona) occur at depth beneath the study areas.

Oil and Gas

The Greater Green River basin is considered an oil and gas producing province. Oil and gas have been produced from many fields in different stratigraphically and structurally controlled reservoirs throughout the province. The major producing reservoirs are Cretaceous and Tertiary sandstones, but production has also come from Cambrian sandstone, Mississippian carbonate rocks, Pennsylvanian carbonate rocks and sandstone, and Jurassic sandstone (Spencer, 1983). The majority of the oil and gas fields in Sweetwater County are along the crest and the eastern flank of the Rock Springs uplift, some 50 to 75 mi east of the study areas. The Church Buttes field on the Moxa Arch is about 20 mi northwest and the Clay basin field is about 25 mi to the southeast of both study areas. All land adjoining the study areas is currently under lease for oil and gas and approximately 20 percent of the study areas are covered by oil and gas leases (Lane, 1990). Bulldozer-cuttrails, which were probably used for seismic surveys, are evident throughout much of the study areas. These surveys illustrate past interest for oil and gas by private companies. Two holes, one to a depth of 5,000 ft and one to nearly 20,000 feet, were drilled prior to 1975 within the study areas. The locations of these holes were not determined. The deeper well recovered gas from Jurassic and Cretaceous reservoirs, but it is currently shut in (U.S. Bureau of Land Management, 1988).

The study areas were rated by Spencer (1983) as having high potential for gas in Cretaceous and Tertiary sandstones and low potential for structurally controlled oil and gas accumulations in Jurassic sandstone and Permian and Pennsylvanian sandstones and carbonates. Recent studies by Law and others (1989) have shown that much of the Greater Green River basin contains large amounts of

Znatural gas in overpressured low-permeability Cretaceous and Tertiary sandstone reservoirs. Generation and accumulation of gas in low-permeability rock at rates greater than the gas can escape causes overpressuring. Natural gas is generated from organic matter in the interbedded coal, marine shale, and carbonaceous lithologies contained in the Cretaceous and Tertiary rock (Law and others, 1989; McPeek, 1981). These gas-bearing sandstones occupy the deeper parts of the basins. Five stratigraphic plays were assessed in the Greater Green River basin by Law and others (1989) and these include Cloverly-Frontier, Mesaverde, Lewis, Fox Hills-Lance, and Fort Union Formations. Of these the only play that may be present beneath the Devils Playground/Twin Buttes study areas is the Cloverly-Frontier. The other formations are either absent from the study areas or they lack the basic attributes required for gas accumulation (Law and others, 1989).

The study areas, therefore, have a high energy resource potential, with a certainty level C, for undiscovered natural gas and a low potential for oil at a C level of certainty. The older Paleozoic rock are unfavorable for oil and gas due to the absence of structural traps in the deeper parts of the basin; production from structurally controlled reservoirs in these rock comes from the arched and uplifted terrane.

Oil Shale

Oil shale is widespread in Eocene lacustrine sediments of the Green River basin. Oil shales are typically finely laminated, brown, kerogen- bearing calcareous sedimentary rocks. They occur, in descending order, in the Laney, Wilkins Peak, and Tipton Shale Members of the Green River Formation. H.W. Roehler (written commun., 1990) estimated oil yields for beds in the three members in the Green River basin as ranging from 2–30 gallons of oil per ton (gpt).

The depth to the oil shales in the top of the Laney Member ranges from 1,000 to 3,000 ft below the surface of the study areas and with greater depths to the lower oil shale-bearing members. Oil shales occur on the surface in the Bridger Formation in the study areas, but they are thin and of low grade. The Bridger was not deposited in a favorable environment for the accumulation of rich or high grade oil shales. The study areas have high energy resource potential for oil shale deposits in the Green River Formation, although at depths that would require in-situ methods of extraction. This assessment is made with a C level of certainty.

Trona

Trona occurs in the Wilkins Peak Member of the Green River Formation. Drill-hole data confirm the presence of trona in the subsurface of the study areas (table 1 and Lane, 1990). In addition to areas of inferred resources of trona, the study areas have high mineral resource potential for undiscovered deposits of trona, with certainty level C.

Zeolite

Zeolites are hydrous aluminosilicate minerals, many of which have commercial applications as they have the ability to selectively remove specific ions from solutions to which they are exposed, either by absorption, by ion exchange, or by acting as molecular sieves. Most zeolites of commercial importance occur as authigenic minerals in sediments of saline and alkaline lakes. The minerals form from vitric volcanic ash that has been deposited by air fall or by streams in lakes. The ash is devitrified or altered during diagenesis, by saline and alkaline waters, to clay and other minerals including zeolites. Commercial deposits of zeolite can form if the volcanic ash occurs in significant quantities, is not greatly diluted with other detrital material, and if the composition of the enclosing water is maintained long enough to convert the ash to zeolite.

Zeolite minerals are common in the middle and upper Eocene rocks of the Greater Green River basin (R.A. Sheppard, written commun., 1990). These rocks include the Bridger Formation, which is exposed in most of the study areas. During deposition of the Bridger Formation, large amounts of pyroclastic material, supplied from nearby volcanic centers, were added to the basin. Although most of this volcanogenic material was probably reworked and deposited along with other material in a fluvial environment, some ash fell and accumulated in more favorable lacustrine (lake) deposits. Trace amounts of clinoptilolite (a common zeolite mineral) were found in selected samples of the Bridger Formation in the study areas, and major amounts occur in thin beds along the northeast and northwest boundary of the Devils Playground study area. The geologic setting is, therefore, favorable for the occurrence of zeolites, but the resource potential is not high because the zeolite-bearing beds are usually thin and impure. Thus, the study areas have moderate mineral resource potential for zeolite minerals with a certainty level of C.

Coal

Coal occurs in the Fort Union and Wasatch Formations and in several Upper Cretaceous formations in Sweetwater County. Coal is mined from these rocks where they are exposed or occur near the surface around the Rocks Springs uplift and about 10 mi south of the study areas in the Henrys Fork coal field. Coal-bearing Fort Union and Wasatch rocks are probably present beneath the study areas but at great depths. Due to the depth of burial, the study areas have low energy potential for coal with a certainty level of D.

Metallic Minerals

No evidence, such as mineralization, rock alteration, or geochemical anomalies, was found that indicates the presence of base or precious metal resources in the study areas. Furthermore, the Bridger Formation in its present geologic setting in the Green River basin is not a favorable environment for these types of mineral resources. Therefore, the study areas have low mineral resource potential for undiscovered metallic minerals, with a certainty level of D.

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APPENDIX

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

LEVELS OF RESOURCE POTENTIAL

H **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.

M **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 reasonable likelihood for resource accumulation, and (or) where an application of mineral-deposit models indicates favorable ground for the specified type(s) of deposits.

L **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 permissive. This broad category embraces areas with dispersed but insignificantly mineralized rock, as well as areas with little or no indication of having been mineralized.

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

U **UNKNOWN** mineral resource potential is assigned to areas where information is inadequate to assign a low, moderate, or high level of resource potential.

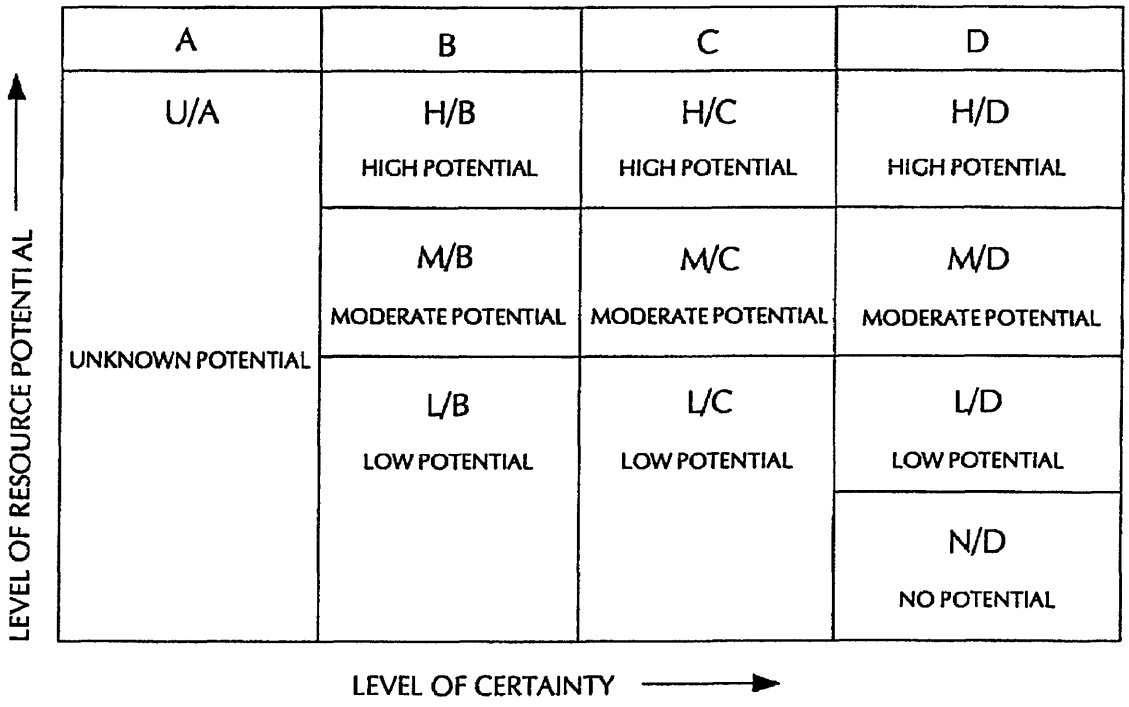
LEVELS OF CERTAINTY

A Available information is not adequate for determination of the level of mineral resource potential.

B Available information only 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.



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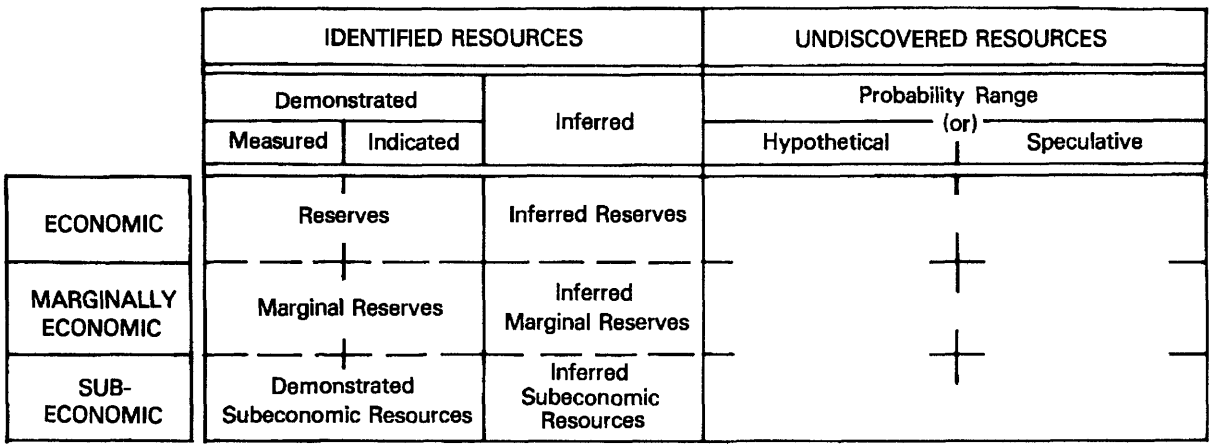
RESOURCE/RESERVE CLASSIFICATION



Major elements of mineral resource classification, excluding reserve base and inferred reserve base. Modified from McKelvey, 1972, Mineral resource estimates and public policy: American Scientist, v.60, p.32-40, and U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, p.5.

GEOLOGIC TIME CHART

Terms and boundary ages used by the U.S. Geological Survey in this report

EON	ERA	PERIOD		EPOCH	AGE ESTIMATES OF BOUNDARIES (Ma[1])
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		Lake Middle Early	500
		Cambrian		Late Middle Early	~[2]570
Proterozoic	Late Proterozoic				900
	Middle Proterozoic				1600
	Early Proterozoic				2500
Archean	Late Archean				3000
	Middle Archean				3400
	Early Archean				
pre-Archean[3]		3800?			4550

[1]Millions of years prior to A.D. 1950.
[2]Rocks older than 570 m.y. also called Precambrian, a time term without specific rank.
[3]Informal time term without specific rank.

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Mineral Resources of Wilderness Study Areas—Miscellaneous States

This volume was published
as separate chapters A, B, and C

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[Letters designate the chapters]

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