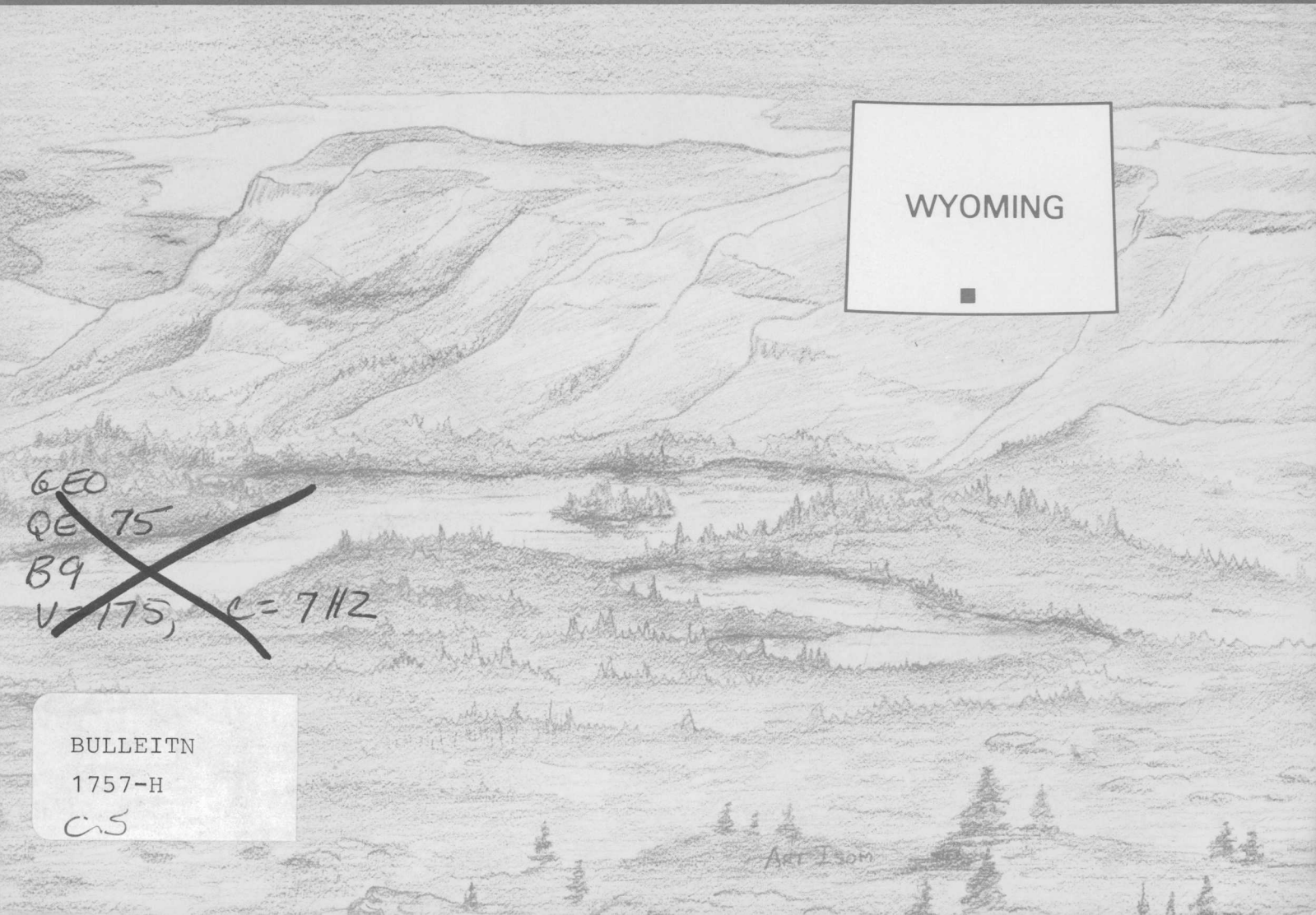
Mineral Resources of the Adobe Town Wilderness Study Area, Sweetwater County, Wyoming

U.S. GEOLOGICAL SURVEY BULLETIN 1757–H



Chapter H

Mineral Resources of the Adobe Town Wilderness Study Area, Sweetwater County, Wyoming

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MINERAL RESOURCES OF WILDERNESS STUDY AREAS—SOUTHERN WYOMING

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

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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 Adobe Town (WY–030–401/408) Wilderness Study Area, Sweetwater County, Wyoming.

CONTENTS

PLATE

[Plate is in pocket]

FIGURES

TABLE

Mineral Resources of the Adobe Town Wilderness Study Area, Sweetwater County, Wyoming

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ABSTRACT

In 1988 and 1989 the U.S. Geological Survey and the U.S. Bureau of Mines conducted a mineral resource appraisal of the Adobe Town Wilderness Study Area (WY–030–401/408). The study area consists of 10,920 acres in Sweetwater County in southwest Wyoming. There are no identified resources in the study area. The study area has high resource potential for undiscovered oil and gas and low resource potential for undiscovered oil shale, zeolites, uranium, coal, and metallic minerals.

SUMMARY

Character and Setting

The Adobe Town Wilderness Study Area (WY–030–401/408) lies in southwest Wyoming near the Colorado border about midway between Rock Springs, Wyo., and Craig, Colo. Baggs, Wyo., which is the closest town, is about 35 mi (miles) to the southeast (fig. 1). The U.S. Geological Survey (USGS) and the U.S. Bureau of Mines (USBM) studied 10,920 acres of the Adobe Town Wilderness Study Area at the request of the U.S. Bureau of Land Management (BLM). In this report the studied area is called the "wilderness study area" or simply the "study area." Oil and gas exploration has played a major role in development of this region since the discovery of natural gas at Powder Wash in 1930. Several wells have been drilled around the study area. Some of the roads leading to the drill sites are still usable, but most have been closed. Access to the study area from Craig, Colo., is via Colorado State Highway 13 north about 50 mi to a road that parallels the Little Snake River west to the Powder Wash gas field in Colorado. A gravel road heads north from the gas field and passes along the western part of the study area. This road continues north to Bitter Creek, Wyo., and then on to U.S. Interstate Highway 80.

The study area is in the Washakie basin, which is one of several basins in the Wyoming Basin Physiographic Province. The Washakie basin is a large sedimentary and structural basin about 50 mi across. Older strata, which are exposed around the edge of the basin, are tilted and dip toward the center, whereas younger strata in the central part are nearly flat lying. The basin is underlain by nearly 32,000 ft (feet) of sedimentary rock that ranges in age from Cambrian to Eocene; however the bulk of it is Cretaceous and Tertiary in age (see Geologic Time Chart in the Appendix). The only rock exposed in the study area is of middle and late Eocene age and belongs to the Adobe Town Member of the Washakie Formation. The Adobe Town Member is predominantly mudstone and sandstone with minor amounts of interlayered conglomerate, shale, limestone, and altered tuffs. There are several famous vertebrate fossil collecting sites in the Washakie basin, but none are within the study area. Fossil bones and petrified wood are, however, common in some strata in the study area.

The principal physiographic feature in the study area is the Skull Creek Rim. This rim and the cliffs below are an erosional escarpment of alcove lands. These landforms, which are carved in red and green mudstone and sandstone, form a picturesque setting. The elevation of Skull Creek Rim is about 7,000 ft and that of the flats occupied by Sand Creek

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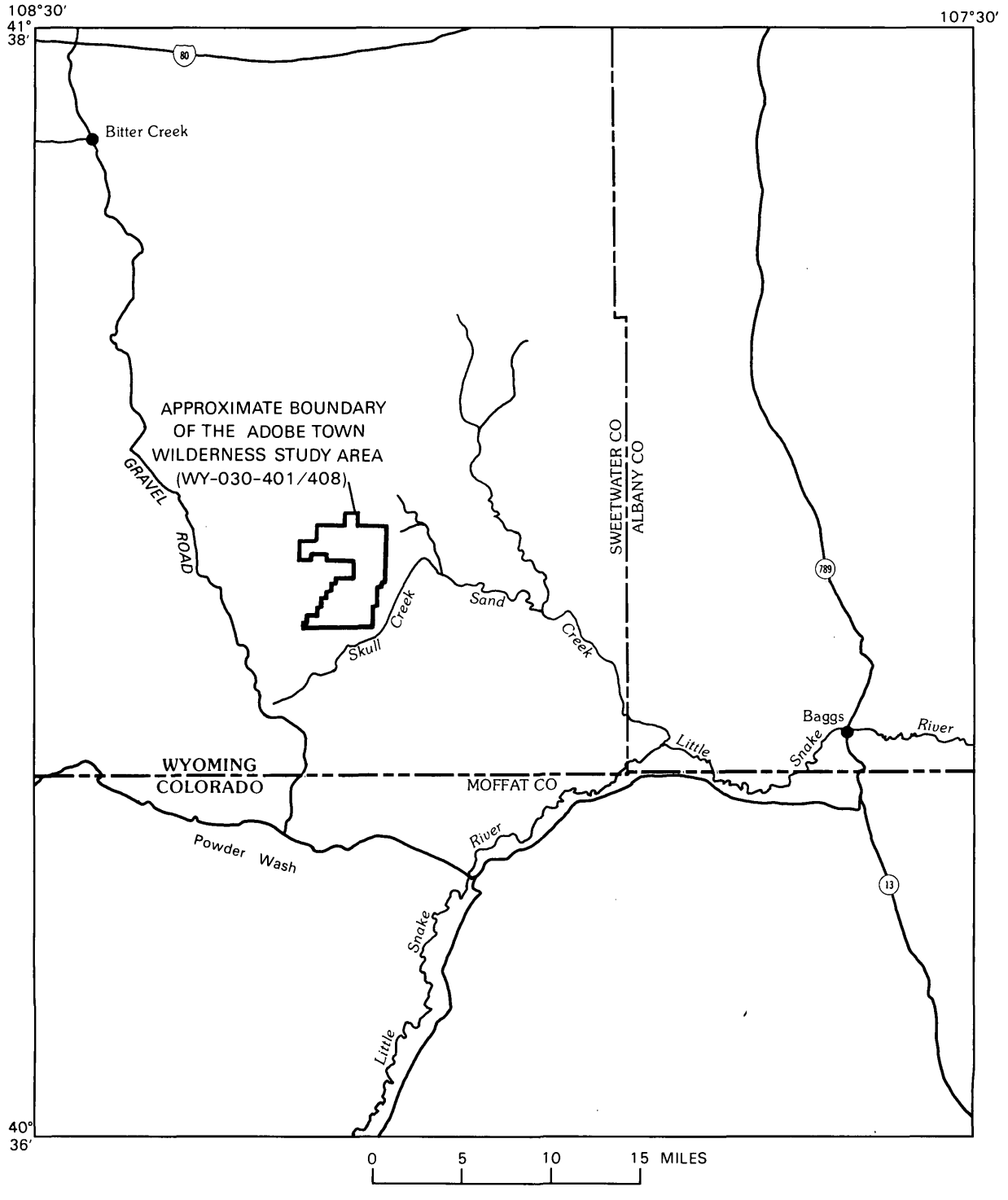

Figure 1. Index map showing location of the Adobe Town Wilderness Study Area, Sweetwater County, Wyoming.

to the east is 6,500 ft. The study area has a desert climate with most of the precipitation from a few storms. All streams in the region are ephemeral. Strong winds are prevalent in this region as evidenced by the sand dunes that cover the plains above and below the cliffs. The dunes are elongate and locally several miles long. They are partially stabilized by sparse vegetation and are separated by interdune areas that are covered by very coarse lag gravels.

Identified Resources

There has been no mining and there is no evidence that prospecting occurred in the Adobe Town Wilderness Study

Area. There are no mining claims in the study area because it was withdrawn from mining claim location in 1930.

Exploration for oil and gas by drilling has taken place near the study area. Nearly one-half of the study area is under lease for oil and gas (fig. 2), and additional lease acreage has been applied for. Upper Cretaceous and lower Tertiary reservoir rocks that contain hydrocarbon resources elsewhere in the Washakie basin are present in the study area. Source rocks such as carbonaceous shales and coal beds are at the optimum depth for natural gas generation. Natural gas was present in three wells near the study area. Recoverable natural gas reserves that underlie the study area are estimated to be 1–2 TCF (trillion cubic feet). Eocene vertebrate fossils and petrified wood are present locally in the Washakie Formation.

Mineral Resource Potential

The Adobe Town Wilderness Study Area has high resource potential for undiscovered oil and gas (fig. 2). The study area lies within an area of existing gas production. Recent studies have shown that much of the Greater Green River basin, including the study area, contains very large amounts of natural gas in overpressured low-permeability Cretaceous and Tertiary sandstone reservoirs. More than 15,000 ft of overpressured rocks may be present beneath the study area.

The Washakie basin generally contains, in outcrop or near the surface, resources of oil shale, zeolites, uranium, and coal. However, the study area has low potential for these resources (fig. 2) due to the great depth of burial. Formations that could contain these resources occur from 600 to several thousand feet below the surface of the study area.

The study area has low resource potential for metallic minerals (fig. 2). No geochemical anomalies were detected, and no evidence of mineralization was observed. The geologic setting of the fluvial and lacustrine sedimentary rocks, combined with the absence of hydrothermal systems or other related igneous activity, is not favorable for the formation of metallic mineral deposits.

INTRODUCTION

This report discusses the mineral resources of 10,920 acres of the Adobe Town Wilderness Study Area. The original study area consisted of 85,710 acres, but it was reduced in size to allow for development and production of natural gas resources. In this report "study area" refers to the smaller area. The Adobe Town Wilderness Study Area is located in southwest Wyoming near the Colorado border, about midway between Rock Springs, Wyo., and Craig, Colo. Baggs, Wyo., which is the nearest town, is about 35 mi southeast of the study area (fig. 1). This very remote part of Wyoming is used primarily for livestock grazing and deer and antelope hunting. Oil and gas exploration companies have conducted seismic surveys throughout the region, and most of the secondary roads were built to serve drill sites. Access to the study area from Craig, Colo., is north via Colorado State Highway 13 about 50 mi to a road that parallels the Little Snake River west to the Powder Wash gas field in Colorado. A gravel road heads north from the gas field and passes along the western part of the study area. This road continues north to Bitter Creek, Wyo., and then on to U.S. Interstate Highway 80. Several jeep trails exist in the region around the study area, however most are in very poor condition. There are no established hiking trails in the study area, although game trails are common.

The study area is in the Washakie basin, which is one of several basins in the Wyoming Basin Physiographic Province. The study area is near the center of this basin where the terrain is dominated by badlands topography and sand-dune-covered plains. The topography in this part of the Washakie basin consists of a series of rims or cliffs that drop in elevation from about 7,200 ft in the west to 6,500 ft in the east. The Adobe Town Rim is to the west of the study area, the Skull Creek Rim makes up the study area, and the Prehistoric Rim is about 5 mi to the east. The Adobe Town Rim was included in the original study area. Adobe Town was named for the shapes of weathered rock formations, some of which resemble adobe buildings. These features are also common in the western part of the study area and in Monument Valley, which is adjacent to the northwestern part of the study area.

The cliffs of Skull Creek Rim are a 500-ft-high erosional escarpment of alcove lands. This type of terrain makes up the bulk of the study area along with a small part of the dune-covered plains above and below the cliffs. The cliff faces east and overall trends northeasterly. These landforms, which are carved mainly in pale-red and pale-green mudstone and sandstone, form a picturesque setting when viewed from the east.

The study area has a desert climate with most of its precipitation from a few storms in winter and summer. Annual precipitation is about 10 in. (inches) (Turnbull, 1978). Vegetation is limited to sparse patches of native grasses and sagebrush. Streams in the study area are ephemeral, and flooding is common. Extensive flood plains have developed along the larger drainages. Most of the study area drains to the east into Skull Creek and other small tributaries of Sand Creek, which empties into the Little Snake River near Baggs, Wyo. Terrain above Skull Creek Rim along the western part of the study area drains southwest into Shell Creek. Both the Little Snake River and Shell Creek empty into the Yampa River to the south in Colorado.

There is no evidence of prospecting and there are no mining claims in the study area. The area was withdrawn from mining claim location in 1930 (U.S. Bureau of Land Management, 1987). Several drill sites used in the past for natural gas exploration and

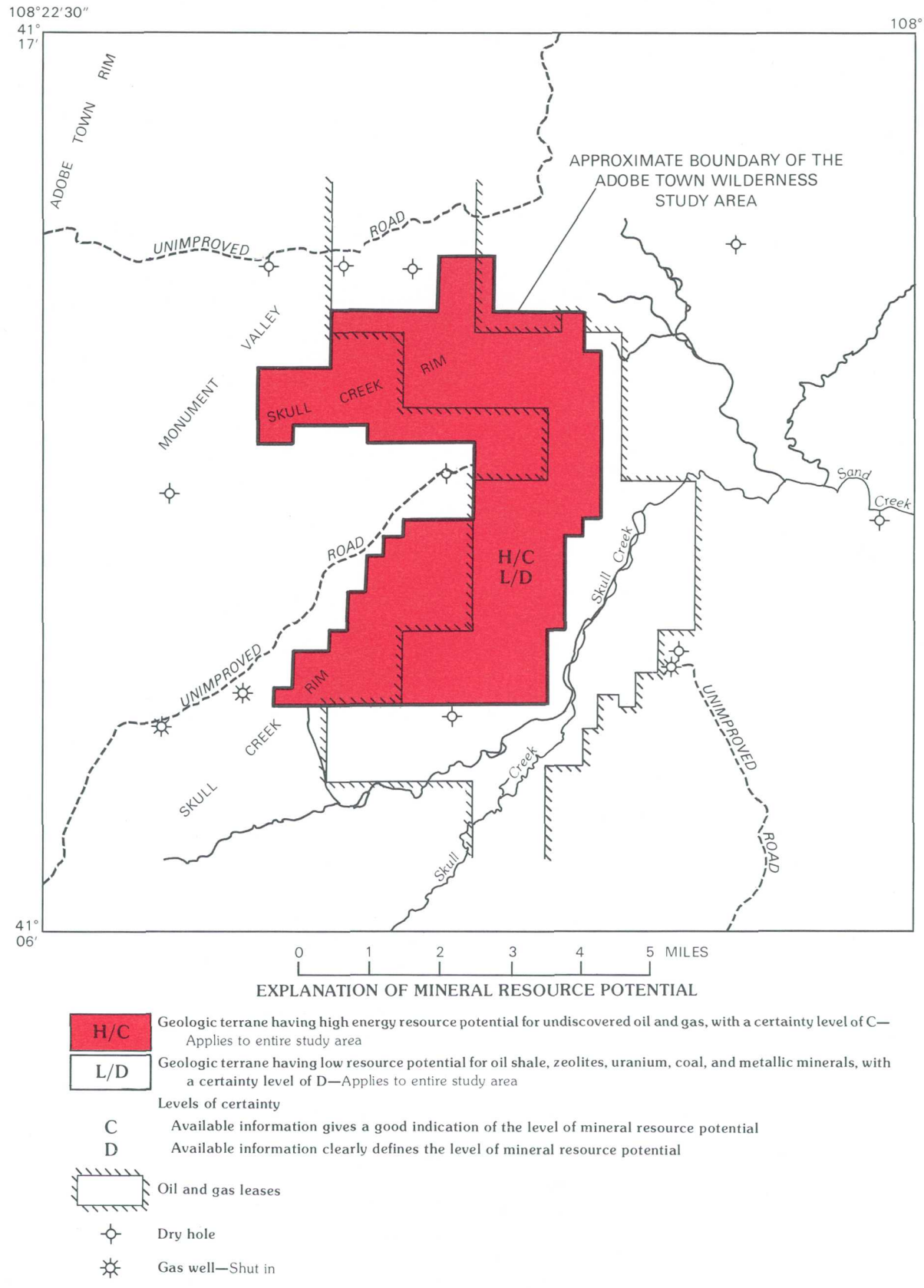

Figure 2. Mineral resources of the Adobe Town Wilderness Study Area, Sweetwater County, Wyoming.

production and roads to serve these sites are just outside the study area. A christmas tree (an assemblage of valves, pipes, guages, and fittings) is still in place on a well just west of the study area, but most of the holes nearby have been abandoned and nothing remains above ground. The only evidence of anthropogenic activity within the study area is scraps of wire and cable used in the past to construct enclosures for the capture of wild horses.

There are many famous collecting sites for vertebrate fossils in the Washakie basin. Although none are within the study area, several sites were included in the original, larger proposed study area. Fossil mammal bones, turtle shells, and petrified wood are common in the study area.

Visitors to this region are seasonal. Among them are ranchers who utilize the grazing allotments, personnel who service gas wells, hunters, and government workers.

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 USBM and USGS. Identified resources are classified according to the system of the U.S. Bureau of Mines and U.S. Geological Survey (1980), which is shown in the Appendix of this report. Identified resources are studied by the USBM. Mineral resource potential is the likelihood of occurrence of undiscovered metals and nonmetals, industrial rocks and minerals, and of undiscovered energy sources (coal, oil, gas, oil shale, and geothermal sources). It is classified according to the system of Goudarzi (1984) and is shown in the Appendix. Undiscovered resources are studied by the USGS.

Investigations by the U.S. Bureau of Mines

Appraisal of identified resources in the Adobe Town Wilderness Study Area included literature searches and field work by the USBM. A detailed literature search was made for geologic and mining information pertinent to the study area, and BLM records were examined for mining claims, land status, and oil and gas leases. Two USBM geologists spent 5 days in the field in July 1988 in and near the study area.

Fifteen stream-sediment samples were collected, and the samples were analyzed, some by inductively coupled plasma atomic emission spectroscopy and others by fire-assay atomic absorption methods. The results of the analyses are given in entirety in Kness (1989).

Investigations by the U.S. Geological Survey

Assessment of the potential for undiscovered resources in the Adobe Town Wilderness Study Area is based largely on the geologic setting, geochemical and geophysical data collected for this study, and consideration of the production history of similar rocks in surrounding areas. Field work for the geologic mapping and sampling was done in August and September of 1988. A geologic map of the study area and vicinity was compiled at 1:24,000 scale using aerial photographs. Fifteen stream-sediment and 10 rock samples were collected and analyzed. Geophysical interpretations were made of gravity, magnetic, and radiometric anomalies by Bankey and Kulik (1989). Information used in assessing oil and gas potential is taken largely from Spencer (1983) who rated the petroleum potential of Wyoming, Law (1988) who discussed hydrocarbon plays in southwestern Wyoming basins, Law and others (1989) who estimated gas resources in the Greater Green River basin, and McPeek (1981) who discussed gas in the Eastern Green River basin. Roehler (1973a) discussed the stratigraphy of the Eocene Washakie Formation and in another report (1973b) summarized the mineral resources of the Washakie basin. The surface geology of much of the Washakie basin is shown by Roehler (1985); map scale is 1:100,000.

APPRAISAL OF IDENTIFIED RESOURCES

By R.F. Kness
U.S. Bureau of Mines

Mining History

There has been no mining and there is no evidence that prospecting occurred in the Adobe Town Wilderness Study Area. There are no mining claims in the study area. A large part of the Washakie basin, including the study area, was withdrawn from mining claim location because oil shale deposits occur at depth in the basin (Executive Order 5327, April 15, 1930). The U.S. Minerals Management Service classified extensive acreage, including the study area, as prospectively valuable for oil shale (oil shale land classification order Wyoming No. 1, Sept. 26, 1982).

The only mines in the region are coal mines in the Rock Springs coal field about 30 mi to the northwest and the Little Snake River coal field 30 mi to the east and a uranium mine in the Poison basin area 25 mi southeast of the study area.

Oil and Gas

No drilling has been done in the study area, but 12 holes have been drilled in nearby areas (fig. 2). Two of these wells yielded 1,200 and 1,760 MCF (million cubic feet) gas per day from Upper Cretaceous reservoirs. Another well, which bottomed in the Paleocene Fort Union Formation, had initial production of 3,700 MCF gas per day (Kness, 1989). Recoverable natural gas reserves that underlie the study area are estimated to be 1–2 TCF (U.S. Bureau of Land Management, 1987, p. 29). About one-half of the study area is currently (January 1989) under lease for oil and gas (fig. 2).

Uranium

Eocene sandstones, such as those exposed in the study area, host uranium deposits in many Wyoming uranium mining districts such as Gas Hills, Shirley Basin, and Red Desert. Stream-sediment samples were collected in and near the study area and analyzed for uranium and (or) pathfinder elements for uranium deposits that might be present in the Washakie Formation. No significant amounts of uranium or pathfinder elements were found (Kness, 1989).

Collectible Commodities

Eocene mammal fossils are numerous and widely distributed in the Washakie Formation in the Washakie basin. Roehler (1973a, p. 25) tabulated vertebrate collecting localities in the Washakie Formation. The nearest site (locality 17) is 1.75 mi northeast of the study area where a Titanothere skull and jaw fragments were collected.

Conclusions

Exposed Eocene rocks in the study area are barren of metallic mineral occurrences. Analytical data do not show uranium or consistent pathfinder-element concentrations that are indicative of sandstone-type uranium deposits like those that occur in similar-age rocks elsewhere in the Wyoming basins.

Upper Cretaceous and lower Tertiary reservoir rocks that contain hydrocarbon resources elsewhere in the Washakie basin are present at depth in the study area (Law and others, 1989). Source rocks such as carbonaceous shales and coal beds are at the optimum depth for natural gas generation (Law and others, 1989). Natural gas was present in three wells near the study area (Kness, 1989). Recoverable natural gas reserves that underlie the study area are estimated to be 1–2 TCF.

Upper Cretaceous and Tertiary sedimentary rocks that contain oil shale, zeolite, and coal resources elsewhere in the Washakie basin are present beneath the study area (Kness, 1989). Large inferred resources may be present, but at depths that preclude economic recovery. Eocene fossils are present in the study area.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By R.E. Van Loenen, R.H. Hill, Viki Bankey, and W.A. Bryant
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Geologic Setting

The Adobe Town Wilderness Study Area lies near the center of the Washakie basin. The Washakie basin, along with the Green River, Great Divide, Hoback, and Sand Wash basins, makes up the Greater Green River basin of southwest Wyoming (this terminology is from Law and others, 1989). These basins are separated by minor uplifts or arches. The Wamsutter arch is to the north of the Washakie basin, the Rock Springs uplift is to the west, the Cherokee Ridge is to the south, and the Park Range is to the east (fig. 3). The Washakie basin is a deep sedimentary and structural basin about 50 mi across; the study area is nearly centered over the deepest part.

The study area is underlain by more than 32,000 ft of Phanerozoic sedimentary rocks that range in age from Cambrian to Tertiary (McPeek, 1981). These rocks probably rest on rocks of the Middle Proterozoic Uinta Mountain Group. Table 1 (compiled from Rocky Mountain Association of Geologists, 1972) lists all rock units that underlie the study area. The upper part of the Washakie Formation is the only rock exposed in the study area. Older strata are exposed along the edge of the Washakie basin, and they dip gently toward the center of the basin. Rock formations of economic interest in the region include Upper Cretaceous rocks for oil and gas and Tertiary rocks for gas, oil shale, zeolites, uranium and coal.

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. After Cretaceous sediments were deposited over this region and over much of the continent, mountain ranges were uplifted by compressional forces and the intermontane basins between the ranges began to fill with sediment. At the onset of the Paleocene Epoch the Greater Green River intermontane basin received

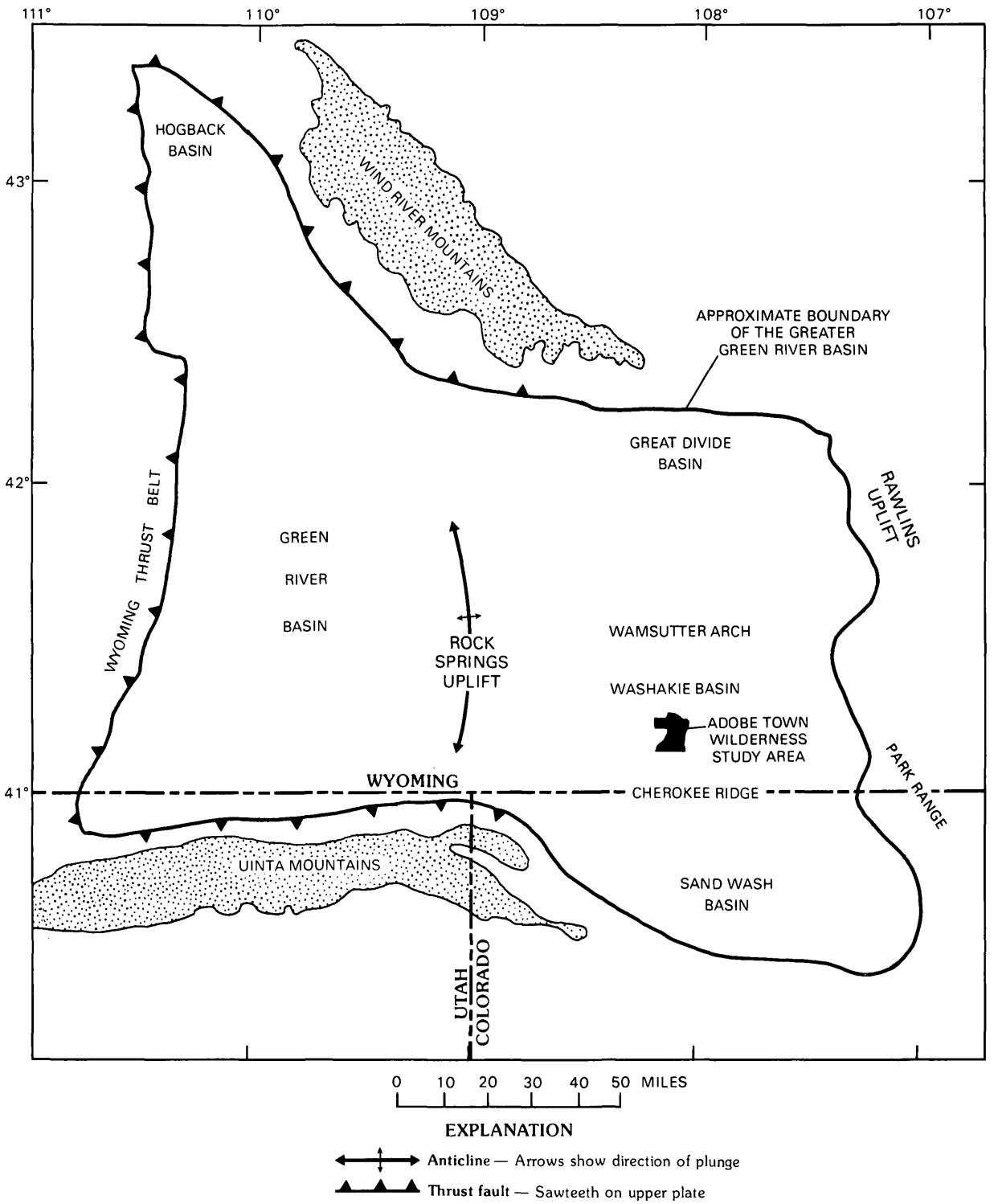


Figure 3. Map of Greater Green River basin showing major structural elements and subbasins. Modified from Law and others (1989).

sediments from the thrust belt to the west and from the Uinta Mountains to the south (fig. 3) (McDonald, 1972). These sediments, which compose the Fort Union Formation, were deposited on flood plains in fluvial, lacustrine, and paludal environments. Late Paleocene swamps were especially dominant in the area of the present Washakie basin. Coal beds that formed from these swamps have been mined around the margin of the Washakie basin where the Fort Union is exposed, for example, in the Rock Springs coal field, west of the study

Table 1. Stratigraphic list of Phanerozoic formations that underlie the Adobe Town Wilderness Study Area

[Compiled from information in Rocky Mountain Association of Geologists, 1972]

Washakie Formation (upper and middle Eocene)
Green River Formation (middle and lower Eocene)
Wasatch Formation (lower Eocene and upper Paleocene)
Fort Union Formation (Paleocene)
Lance Formation (Upper Cretaceous)
Fox Hills Sandstone (Upper Cretaceous)
Lewis Shale (Upper Cretaceous)
Almond Formation (Upper Cretaceous)
Pine Ridge Sandstone (Upper Cretaceous)
Allen Ridge Formation (Upper Cretaceous)
Haystack Mountains Formation (Upper Cretaceous)
Steele Shale (Upper Cretaceous)
Frontier Formation (Upper Cretaceous)
Mowry Shale (Upper Cretaceous)
Muddy Sandstone (Lower Cretaceous)
Thermopolis Shale (Lower Cretaceous)
Cloverly Formation (Lower Cretaceous)
Morrison Formation (Upper Jurassic)
Sundance Formation (Upper and Middle Jurassic)
Nugget Sandstone (Jurassic? and Triassic?)
Ankareh Formation (Upper and Lower Triassic)
Dinwoody Formation (Lower Triassic)
Park City Formation (Lower Permian)
Tensleep Sandstone (Upper and Middle Pennsylvanian)
Amsden Formation (Middle and Lower Pennsylvanian)
Madison Limestone (Lower Mississippian)
Unnamed sandstone (Cambrian)

area (Roehler, 1973a, b). The Fort Union is present beneath the study area but at depths that exceed 7,500 ft (as determined from drill-hole data; Kness, 1989).

Downwarping of the Greater Green River basin and uplift of the adjoining mountain ranges continued through Paleocene and into Eocene time (McDonald, 1972). The Fort Union was tilted up along the edges of the basin and eroded. The Wasatch Formation was deposited during the late Paleocene and early Eocene unconformably on the Fort Union as rapid downwarping of the basins continued. Eocene rocks were deposited in the Greater Green River basin continuously as minor uplifts and arching began to separate the basin into subbasins. In the Washakie basin, Wasatch rocks consist of sandy mudstone, sandstone, coal, and carbonaceous shale. The depositional environment of the Wasatch was similar to that of much of the underlying Fort Union. Coal has been mined from the Wasatch around the edges of the Washakie basin, and the first wells drilled in the region produced gas from the Wasatch (Roehler, 1973b). Uraniferous phosphate beds occur locally in the Wasatch about 40 mi southwest of the study area (Roehler, 1973b). The Wasatch lies about 5,000 ft beneath the study area and, as recorded in a test well 2 mi east of the study area, it is about 2,700 ft thick (Kness, 1989).

The Green River Formation (lower and middle Eocene) overlies and intertongues with the Wasatch. The Green River is largely composed of lacustrine deposits laid down when prehistoric Lake Gosiute inundated the Greater Green River basin or parts of it during several filling cycles. Changing lake levels along with different sources of sediments caused the intertonguing of the lacustrine and fluvial sediments in the upper part of the Wasatch and throughout the Green River Formation. The Greater Green River basin eventually filled with lake sediments, the lake dried up, and fluvial conditions returned to the basin. The Green River Formation is best known for its rich deposits of oil shale. Trona (an evaporite sodium mineral) occurs locally (McDonald, 1972). The Green River Formation crops out along the edges of the Washakie basin, and it is present beneath the study area at depths of 1,000–2,000 ft; it is at least 4,000 ft thick (drill-hole data; Kness, 1989).

The youngest rock in the Washakie basin, and the only rock exposed in the Adobe Town Wilderness Study Area, is the Washakie Formation of middle to late Eocene age. The Washakie Formation was divided into the Kinney Rim and Adobe Town Members by Roehler (1973a). The Kinney Rim Member is 880 ft thick, and the Adobe Town Member is 2,300 ft thick (Roehler, 1973a). The Kinney Rim Member is exposed 10–20 mi from the study area, and the Adobe Town Member covers the center of the Washakie basin, including the study area. The Washakie Formation was deposited in a mixed fluvial environment that included local areas of lacustrine and paludal deposits. Volcanic ash was deposited over the region during this period, and locally, ash may comprise as much as 20 percent of the total formation (McDonald, 1972). Alteration of the ash to zeolite minerals has occurred in many parts in the formation; some of these zeolites may have commercial uses (Roehler, 1973b).

Description of Map Units

Exposed bedrock and surficial deposits mapped in the study area and shown on plate 1 are the Adobe Town Member (Twa) of the Washakie Formation, the rose-red marker bed (Twar) (a chromostratigraphic unit within the Adobe Town Member), eolian deposits (Qe), alluvium (Qa), and landslide deposits (Qls).

Tertiary Rocks

About 600 ft of the Adobe Town Member (Twa) is exposed in the study area. This stratigraphic section is near the middle of the Washakie Formation. The rocks are largely distributary stream deposits of mudstone and sandstone; mudstone is about twice as abundant as sandstone. Interbedded throughout the section, in lesser amounts, are conglomerate, siltstone, shale, claystone, limestone, and volcanic ash beds. These rocks, as exposed in the cliffs, are pale green, red, and brown. Several distinctive chromostratigraphic rock units that have been used for mapping in the Washakie basin were identified by early-day mappers as "marker beds" and labeled by number and, in some cases, by color. Roehler (1985) mapped six marker beds in the Washakie Formation, including bed 644 which he called the "upper red marker" ("rose-red marker bed" of Roehler, 1973a). This bed is exposed in the Skull Creek Cliffs along the eastern part of the study area, and it is shown on the geologic map (pl. 1) as map unit Twar. It was separated from the main body of the Adobe Town Member on the map to illustrate the flat-lying nature of the beds in the study area, the rather constant thickness of marker beds, and the nature of displacement along faults. The rose-red marker bed is tilted very slightly down to the northwest, which causes it to dip beneath the surface north of the study area. South of the study area, where it had been elevated slightly, it has been eroded away. The marker bed is about 80 ft thick and consists mainly of variegated pale-green and pale-red mudstone with minor amounts of interbedded claystone and sandstone. When viewed from a distance the bed overall appears moderate to pale red, which contrasts with the olive-green sandstone units that lie below and above.

Sandstone beds in the Adobe Town Member in the study area are various shades of red and green, and they range from less than 1 ft to more than 40 ft thick. They are generally lenticular. Most of the sandstones are hard ledge-formers, and they tend to preserve the softer mudstones thus contributing to the badland topography. The outcrop pattern of some of the sandstones when viewed on aerial photographs resembles that of meandering streams. This pattern is probably caused by differential weathering within the thicker fossil stream channel deposits. The sandstone beds are commonly crossbedded and fine grained to conglomeratic; some are tuffaceous. Fining upward sequences are common.

Pyroclastic material is distributed throughout much of the Washakie Formation. It occurs in most of the rocks, and locally it can be a major component (McDonald, 1972). Volcanic ash commonly accumulated on lake bottoms; it was preserved in situ or was later reworked and redeposited by streams. Several thin, lenticular ash beds occur in the study area; they are conspicuous because of their white color.

A white tuff bed (bed 664 of Roehler, 1973a) occurs about 375 ft above marker bed 644 (rose-red marker bed). Mauger (1977) reported a potassium-argon date of 44–43 million years on biotite (corrected for 4 percent extraneous Cretaceous biotite) from bed 664. Krishtalka and others (1987) considered the recalibrated date of 45–44 million years to be reasonably accurate. They assigned an early Uintan land-mammal age to the middle part of the Adobe Town Member (beds 622–675 of Roehler, 1973a) based on a fossil vertebrate assemblage that includes *Protoplychus*, *Eobasileus*, *Dolichorhinus*, *Eomoropus*, *Triplopus*, *Amkynodon*, *Achaenodon*, and *Protylopus*.

Quaternary Deposits

Eolian deposits (Qe) of dune sand cover nearly one-half of the map area but only a small part of the study area. The dunes are partially stablized by sparse vegetation. They are narrow and elongate and generally have a ragged and patchwork pattern that trends easterly. The dunes are separated by barren areas which are covered with very coarse lag gravel. These interdune areas are flat and devoid of vegetation. Large dunes, some as high as 50 ft, parallel the stream channels along the flood plains of Sand Creek and its tributaries.

Alluvium (Qa) includes unconsolidated clay, sand, gravel, and silt that occur in the stream channels and on flood plains. These deposits are subject to wind erosion except during the short periods of flooding or spring runoff.

Landslide deposits (Qls) are large-scale slumps that occur along Skull Creek Rim. Large chunks of the rock formation, some nearly ¼ mi wide, have broken free along the cliffs and slid partway down as coherent masses.

Structure

The Washakie basin is a deep sedimentary and structural basin that simply subsided as it received sediment and was unaffected by other tectonic deformation. Bedrock structures in the Adobe Town Wilderness Study Area are minimal. The edges of the basin were faulted and tilted, but the center of the basin remains relatively flat lying and unchanged. The rose-red marker bed as mapped does not change in elevation appreciably across the 6-mi length of the study area. Two minor northwest-trending normal faults dissect the formation in the southern part of the study area. Displacement along these faults is about 50 ft.

Geophysics

Available geophysical data, which include gravity, aeromagnetic, and radiometric data, were analyzed for

the region of the study area. No new data were obtained for the study. Due to the lack of detailed geophysical data, only a regional interpretation is possible.

Gravity Data

Gravity stations are too sparsely scattered to define or locate small mineral deposits. On a regional scale, however, gravity can be a useful mapping tool for pinpointing structural breaks and folds and for delineating shallowly buried plutons.

Gravity data (fig. 4) used in this report are a subset of the data used for a larger regional map of southwestern Wyoming (Bankey and Kulik, 1989). No gravity stations are located in the study area. The contour lines represent contrasts in rock densities associated with changes in geologic structure or lithology. A density of 2.67 grams per cubic centimeter was used to reduce data to the Bouguer anomaly. The regional gravity field shows the study area as nearly overlying the deepest part of the northeast-trending Washakie basin. The circular gravity low to the northeast of the study area marks basin shallowing and may show a possible structural trap for oil and gas; however, the circular gravity low is outside the study area.

Aeromagnetic and Radiometric Data

Aeromagnetic and radiometric data for the study area (fig. 5) are taken from a regional survey flown in 1979 for the National Uranium Resource Evaluation (NURE) Program. The survey (Bendix Field Engineering Corporation, 1979) was flown using a fixed-wing aircraft at a nominal ground clearance of 400 ft, and east-west flight lines were spaced 3 mi apart. The aeromagnetic and radiometric instruments in the aircraft can detect point sources in a swath on the ground that extends as far as 45° to each side of the flight line. At 3-mi spacing and 400 ft above ground, 6 percent of magnetic and radiometric sources at the surface should be detected. One hundred percent coverage of magnetic sources is theoretically achieved at 7,500 ft below the surface, whereas radiometric measurements are restricted to near-surface (less than 20 inches deep) sources.

The aeromagnetic contours primarily represent changes in the Earth's magnetic field due to variations in the magnetic properties of rocks. The aeromagnetic field measured by the NURE survey in the study area consists of an east-west-trending, south-dipping gradient of 8–10 nT/mi (nanoTeslas per mile). The broad, long-wavelength anomalies arise from deep, intrabasement magnetic sources. A slight magnetic basement high shown to the west of the study area was inferred by the contractor (Bendix Field Engineering Corporation, 1979). There is no evidence of shallow intrusions in the data set. The aeromagnetic and gravity fields show little correlation.

Several areas of anomalously high uranium values were detected by the radiometric survey and are shown on figure 5. No areas of anomalously high uranium values occur in the study area. Areas of anomalously high uranium values occur outside the study area in the Washakie basin where badland topography exposes the Wasatch, Green River, and Washakie Formations. Uranium anomalies 1 and 2 measure 9–10 ppm eU (parts per million equivalent uranium) and have low Th/U ratios (Bendix Field Engineering Corporation, 1979), which suggest uranium enrichment in the mudstone units of the Washakie Formation. However, the measured values alone do not suggest resource potential. There are no significant thorium or potassium anomalies in the study area.

Geochemistry

A reconnaissance geochemical survey was conducted in the Adobe Town Wilderness Study Area in September 1988. Fifteen stream-sediment samples were collected from dry stream beds. Stream sediments represent a composite of the rock and soil that are exposed in drainage basins upstream from a sample site. Chemical analyses of stream sediments may provide data useful in identifying basins that contain unusually high concentrations of elements that may be related to ore deposits. The samples were sieved through 60-mesh stainless-steel sieves. The minus-60-mesh material was pulverized with ceramic plates and then analyzed for 35 elements using a semiquantitative, direct-current arc emission spectrographic method (Grimes and Marranzino, 1968). In addition, the samples were analyzed for arsenic, antimony, and zinc by atomic absorption spectroscopy (O'Leary and Meier, 1984) and uranium and thorium by delayed neutron counting (McKown and Millard, 1987).

A threshold value, which is defined as the upper limit of normal background values, was determined for each element by inspection of frequency distribution histograms. Only one sample collected in the study area was found to be anomalous in that it contained an element in an amount that exceeded its threshold value. This sample contained 10 ppm molybdenum and was not anomalous in any other elements. It is from the northern part of the study area near the site of gas exploration and production, and the sample may have been contaminated by such activities. Uranium, thorium, arsenic, antimony, and zinc are not present in anomalous amounts in the study area. The absence or low values of these elements are common in this type of geologic environment.

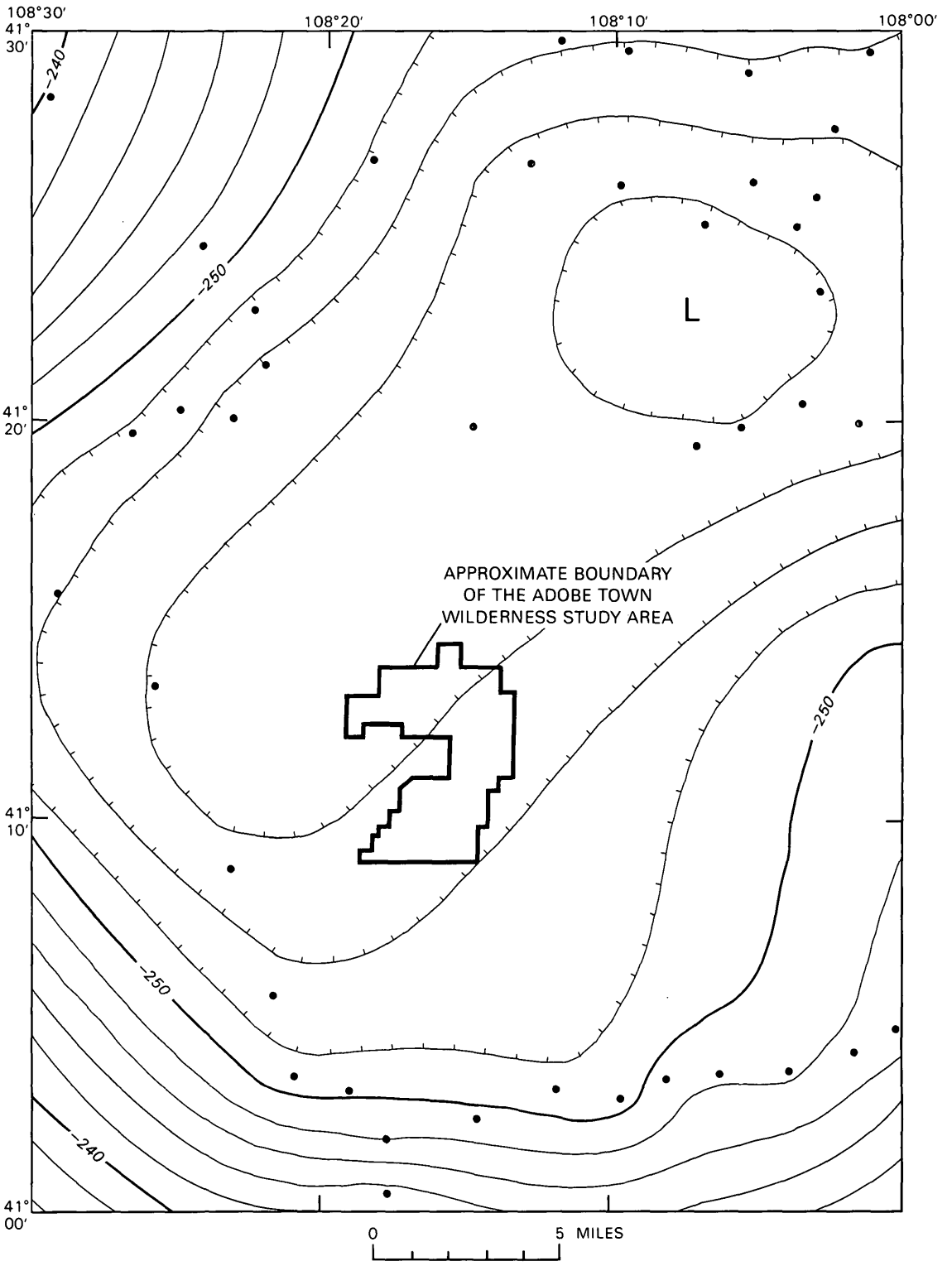


Figure 4. Bouguer gravity map of the Adobe Town Wilderness Study Area and vicinity. Contour interval is 2 milligals. Contours hachured in area of closed gravity low (L). Dots indicate location of gravity stations.

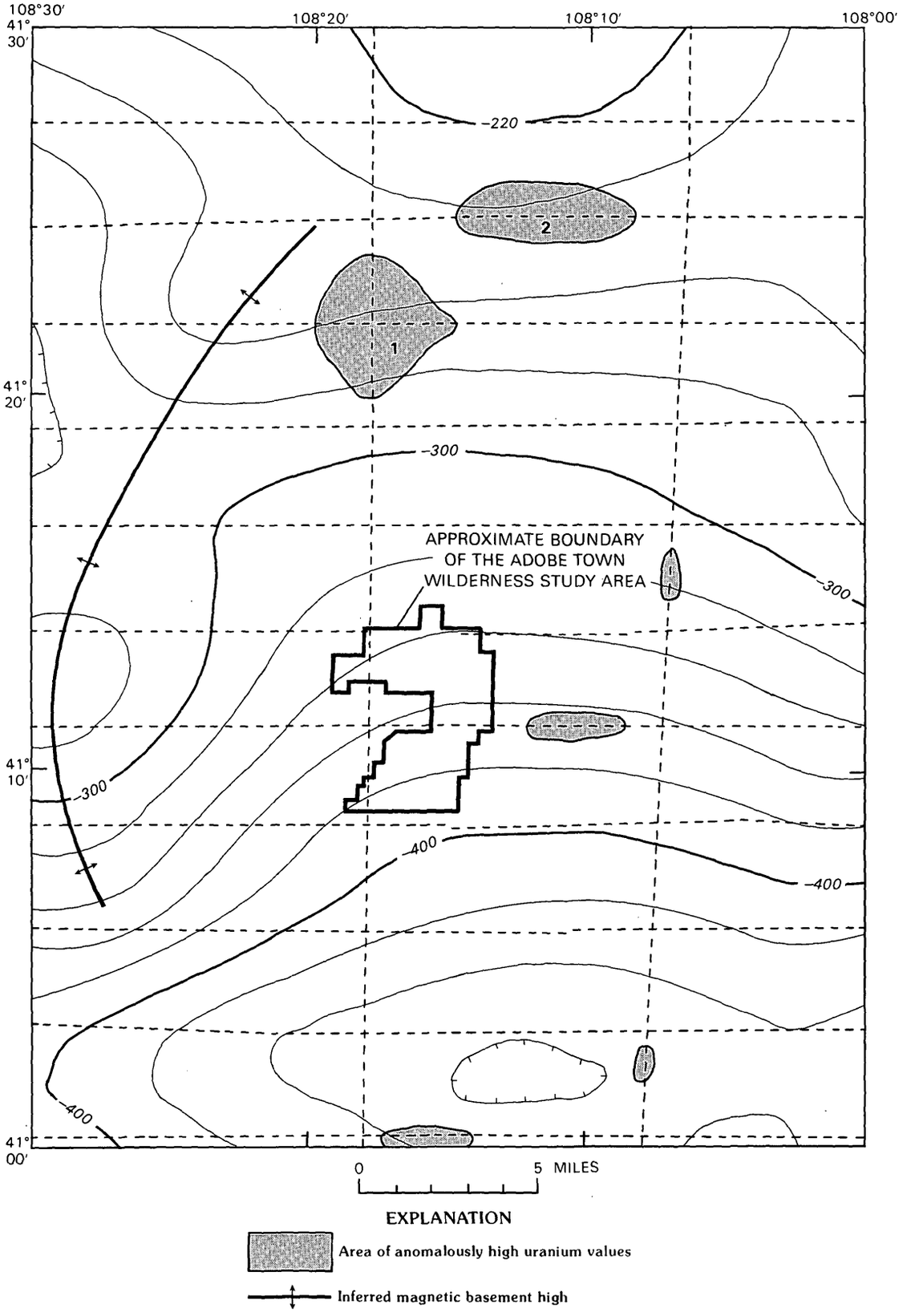


Figure 5. Residual total-field aeromagnetic and uranium anomaly map of the Adobe Town Wilderness Study area and vicinity. Contour interval is 20 nanoteslas. Contours hachured in area of closed magnetic low. Flight lines shown by dashed lines.

Mineral and Energy Resources

There has been no mining in the Adobe Town Wilderness Study Area although there are coal mines within 10 mi. The geologic setting of the study area is not favorable for metallic mineral deposits, and the strata exposed there are not known to contain such deposits anywhere in the region. The study area is within a large natural gas province, however.

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 reservoirs throughout the province. Cumulative production of the major fields averages nearly 10 million barrels of oil and 180 MCF of gas per field. This production has been mainly from Cretaceous and Tertiary reservoirs. Gas was first discovered in the Sand Wash basin about 30 mi southwest of the study area at Hiawatha field in 1926. The Powder Wash field, which is about 15 mi south of the study area, was discovered and developed in the early 1930's. Hiawatha and Powder Wash fields contain mostly shallow wells, and production is from Tertiary reservoirs.

Although there has been exploration activity near the study area, there are no drill holes within the study area. Twelve holes were drilled within 2 mi of the study area between 1952 and 1985 (fig. 2). The location of these holes and (or) the roads leading to them played a role in defining the boundary of the study area. Five holes were relatively deep (more than 10,000 ft), and three of the deep wells have recorded gas production (Kness, 1989). All but one of the wells have been plugged and abandoned.

Spencer (1983) rated the study area as having high potential for gas in Cretaceous and Tertiary sandstones. The study area lies within an area of existing production. Furthermore, recent studies by McPeek (1981) and Law and others (1989) have shown that much of the Greater Green River basin, including the study area, contains large amounts of natural gas in overpressured low-permeability Cretaceous and Tertiary sandstone reservoirs. The generation and accumulation of gas in low-permeability rock at rates greater than the gas can escape causes overpressuring. These gas-bearing sandstones occupy the deeper parts of the basins and may occur throughout a 14,000-ft-thick sequence. Natural gas is generated from organic matter in the interbedded coal, marine shale, and carbonaceous lithologies contained in Cretaceous and Tertiary rock (Law and others, 1989; McPeek, 1981). Beneath the study area, this thick sequence of rock includes the Lower Cretaceous Cloverly Formation through the lower Tertiary Fort Union Formation (table 1). The Cloverly could be as deep as 25,000 ft, and the top of the gas-bearing overpressured rocks is about 8,000 below the study area (Law and others, 1989). This interval represents a very thick section of rock with natural gas potential in the study area but, due to the low permeability of these reservoirs, much of the gas may not be recoverable without fracturing or some other type of reservoir stimulation to free the gas. Oil was discovered about 30 mi northwest of the study area in 1972 in Paleozoic rock (Roehler, 1973b) along the edge of the Washakie basin, but similar Paleozoic reservoirs in the subsurface of the study area have low potential for oil due to high temperatures caused by their depth of burial. The entire study area has high resource potential, with a certainty level of C, for undiscovered oil and gas.

Oil Shale

Oil shale is widespread in the Greater Green River basin; it is common in the Green River Formation and less common in the Wasatch Formation (Roehler, 1973b). Rich oil shale may contain as much as 60 gal (gallons) oil per ton. Oil shale that contains more than 15 gal oil per ton may be of economic importance depending on accessibility, thickness, and the price of oil. The Wasatch and Green River Formations crop out nearly continuously around the edge of the Washakie basin but no closer than 10 mi to the study area. Roehler (1973b) noted that two sites in the Green River Formation, about 15 mi southwest of the study area, were sufficiently rich in oil that they could be included in the U.S. Department of Interior oil-shale lease program.

The Wasatch and Green River Formations do not crop out in the study area but are several thousand feet below the surface. The same strata that host the rich oil shale to the southwest may be as much as 3,000 ft below the study area (Kness, 1989). There is no oil shale in the Adobe Town Member of the Washakie Formation, which is the rock exposed on the surface of the study area. The entire study area has low resource potential for undiscovered oil shale, with a certainty level of D. A certainty level of D was assigned because the Wasatch and Green River oil shales are buried deeply beneath the study area.

Zeolites

Zeolites are common in the Wasatch, Green River, and Washakie Formations in the Washakie basin (Roehler, 1973b). These zeolite minerals result from devitrification or alteration of vitric volcanic ash by ground waters. Many zeolites have the ability to remove selectively specific ions from solutions to which they are exposed, either by adsorption, by ion exchange, or by acting as molecular sieves.

Zeolites occur locally in the study area in altered ash beds in the Adobe Town Member of the Washakie Formation. These beds are thin, lenticular, and usually white to light gray; they range from 1 to 8 ft in thickness and extend for no more than ¼ mi. They are relatively hard and form ledges in the predominantly mudstone cliffs of the study area. An ash bed was sampled in sec. 8, R. 96 W., T. 14 N. (eastern part of the study area), and the samples were analyzed for zeolite content by X-ray diffraction. This bed contains major amounts of clinoptilolite, which is a common zeolite mineral. Other minerals found in the samples were quartz, mica, and clays, and these minerals tend to increase in amounts toward the top of the bed. A thin bed to the south contained only minor amounts of clinoptilolite.

Zeolite resources exist in strata exposed nearby, but outside the study area, in the "robins-egg-blue" marker bed (Roehler, 1973b). This marker bed crops out continously around the study area but nowhere closer than about 10 mi. It has been estimated to contain over 5 billion tons of clinoptilolite (Roehler, 1973b).

The zeolite-bearing marker bed probably exists in the subsurface below the study area but at depths exceeding several hundred feet. Its quality is unknown, and at this depth of burial it has low resource potential. The zeolite-bearing tuffs that are exposed in the study area are too limited in size and overall do not have the qualities needed to be considered a zeolite resource. The entire study area has low resource potential for undiscovered zeolites, with a certainty level of D.

Uranium

There are no known resources of uranium in the Adobe Town Member of the Washakie Formation. Uranium was mined from the upper Oligocene and Miocene Browns Park Formation east of the study area near Baggs, Wyo. (Roehler, 1973b); however, the Browns Park has been eroded from the study area. Uraniferous phosphate occurs in the Wasatch Formation west of the study area (Roehler, 1973b), and the beds there reportedly contain 0.3 percent uranium and 19 percent phosphate. The Wasatch is present beneath the study area but at depths that exceed 5,000 ft. Anomalous amounts of uranium were not found during the geochemical survey of the study area, and the uranium anomalies detected by the NURE survey are too low to indicate a resource. The entire study area has low resource potential for undiscovered uranium, with a certainty level of D.

Coal

Roehler (1973a) did not find coal beds in the Washakie Formation, and none were found in the Washakie Formation during this study. The coal-bearing formations that crop out around the edge of the Washakie basin are several thousand feet below the surface of the study area. The entire study area has low resource potential for undiscovered coal, with a certainty level of D.

Metallic Minerals

No evidence, including mineralization, rock alteration, or geochemical or geophysical anomalies, was found that indicates the presence of base or precious metals. The entire study area has low resource potential for undiscovered metallic minerals, with a certainty level of D.

REFERENCES CITED

Bankey, Viki, and Kulik, D.M., 1989, Gravity survey data and Bouguer gravity anomaly map of southwestern Wyoming, northeastern Utah, and northwestern Colorado: U.S. Geological Survey Open-File Report 89–175–A–B, 31 p., 1 diskette.

Bendix Field Engineering Corporation, 1979, Aerial gamma ray and magnetic survey, Rock Springs, Rawlins, and Cheyenne quadrangles, Wyoming, and Greeley quadrangle, Colorado: U.S. Department of Energy Report GJBX–17(79).

Goudarzi, G.H., compiler, 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84–787, 42 p.

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

Kness, R.F., 1989, Mineral investigation of the Adobe Town Wilderness Study Area, Sweetwater County, Wyoming: U.S. Bureau of Mines Open File Report MLA 33–89.

Krishtalka, L., West, R.M., Black, C.C., Dawson, M.R., Flynn, J.J., Turnbull, W.D., Stucky, R.K., McKenna, M.C., Bown, T.M., Golz, D.J., and Lillefraven, J.A., 1987, Eocene (Wasatchian through Duchesnean) biochronology of North America, *in* Woodburne, M.O., ed., Cenozoic mammals of North America: Berkeley, University of California Press, p. 77–117.

Law, B.E., 1988, Geologic framework and hydrocarbon plays in the southwestern Wyoming Basins Province: U.S. Geological Survey Open-File Report 88–450–F, 29 p.

Law, B.E., Spencer, C.W., Charpentier, R.R., Crovelli, R.A., Mast, R.F., Dolton, G.L., and Wandrey, C.J., 1989, Estimates of gas resources in overpressured low-

permeability Cretaceous and Tertiary sandstone reservoirs, Greater Green River Basin, Wyoming, Colorado, and Utah: Wyoming Geological Association Guide Book, 40th Annual Field Conference, p. 39–61.

Mauger, R.L., 1977, K–Ar ages of biotites from tuffs in Eocene rocks of the Green River, Washakie, and Uinta basins, Utah, Wyoming, and Colorado: Laramie, University of Wyoming, Contributions to Geology, v. 15, no. 1, p. 17–41.

McDonald, R.E., 1972, Eocene and Paleocene rocks of the Southern and Central Basins: Denver, Rocky Mountain Association of Geologists, Geologic Atlas of the Rocky Mountain region, p. 243–256.

McKown, D.M., and Millard, H.T., Jr., 1987, Determination of uranium and thorium by delayed neutron counting, *in* Baedecker, P.A., ed., Methods for geochemical analysis: U.S. Geological Survey Bulletin 1770–I, p. I1–I12.

McPeek, L.A., 1981, Eastern Green River Basin—A developing giant gas supply from deep, overpressured Upper Cretaceous sandstones: American Associaton of Petroleum Geologists Bulletin, v. 65, p. 1078–1098.

O'Leary, R.M., and Meier, A.L., 1984, Analytical methods used in geochemical exploration: U.S. Geological Survey Circular 948, p. 18–25.

Rocky Mountain Association of Geologists, 1972, Geologic Atlas of the Rocky Mountain Region: Denver, 331 p.

Roehler, H.W., 1973a, Stratigraphy of the Washakie Formation in the Washakie Basin, Wyoming: U.S. Geological Survey Bulletin 1369, 40 p.

_____ 1973b, Mineral resources in the Washakie Basin, Wyoming, and Sand Wash Basin, Colorado: Wyoming Geological Association, 25th Field Conference Guidebook, p. 47–56.

_____ 1985, Geologic map of the Kinney Rim 30 × 60 minute quadrangle, Wyoming and Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I–1615, scale 1:100,000.

Spencer, C.W., 1983, Petroleum potential of wilderness lands in Wyoming, *in* Miller, B.W., ed., Petroleum potential of wilderness lands in the Western United States: U.S. Geological Survey Circular 902–M, p. M1–M10.

Turnbull, W.D., 1978, The mammalian fanuas of the Washakie Formation, Eocene age, of southern Wyoming, Part 1; Introduction—The geology, history, and setting: Fieldiana, Geology, v. 33, no. 30, p. 569–601.

U.S. Bureau of Land Management, 1987, Final Adobe Town–Ferris Mountain Wilderness environmental impact statement, Rawlins District Office, Wyoming: 119 p.

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

APPENDIX

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

Definitions of Mineral Resource Potential

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

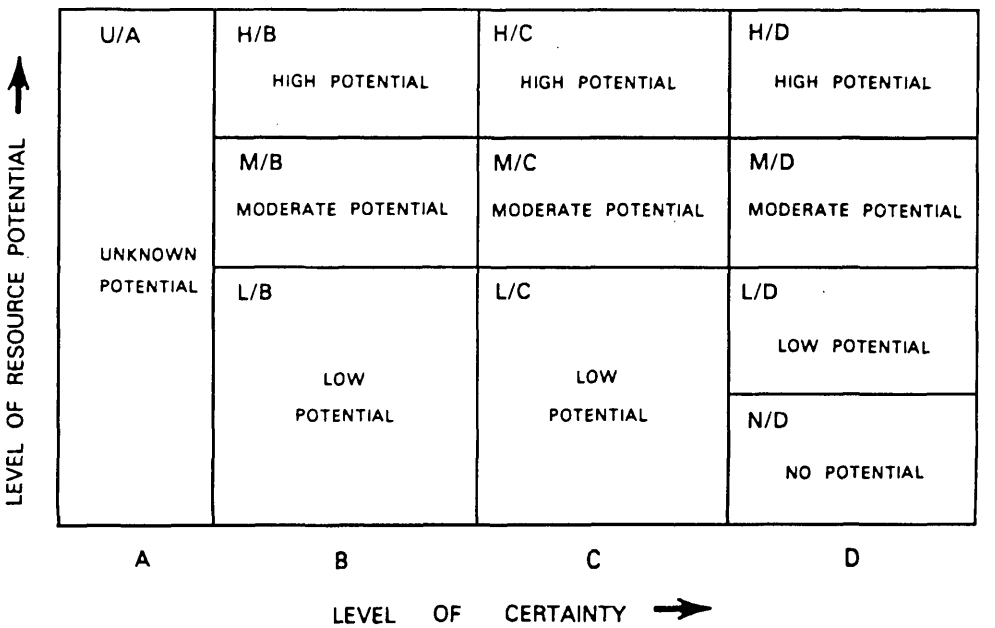
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application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

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

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

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

Levels of Certainty



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

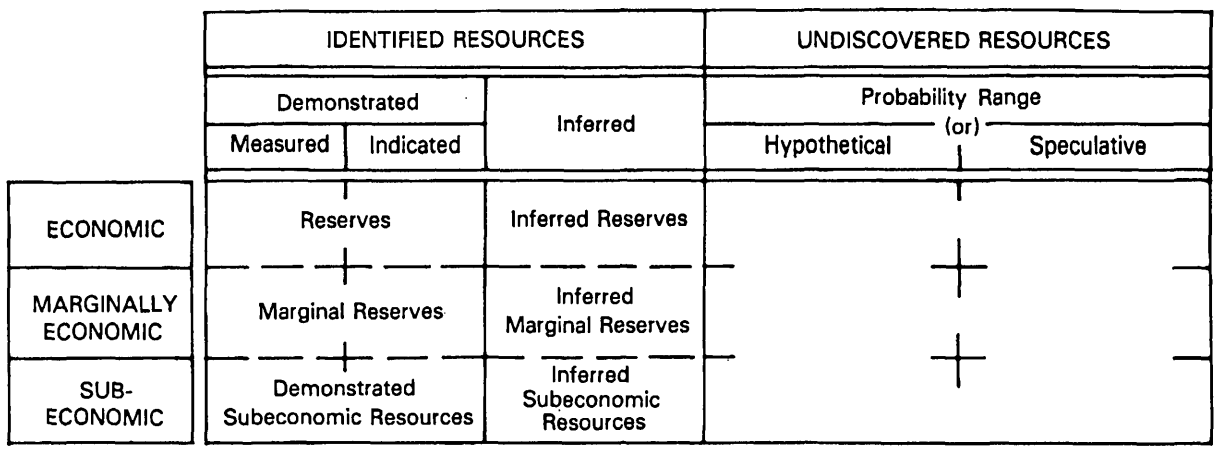
Abstracted with minor modifications from:

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

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

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

RESOURCE/RESERVE CLASSIFICATION



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

GEOLOGIC TIME CHART

Terms and boundary ages used in this report

EON	ERA	PERIOD		EPOCH	BOUNDARY AGE IN MILLION YEARS
Phanerozoic	Cenozoic	Quaternary		Holocene	0.010
				Pleistocene	1.7
		Tertiary	Neogene Subperiod	Pliocene	5
				Miocene	24
			Paleogene Subperiod	Oligocene	38
				Eocene	55
				Paleocene	66
	Mesozoic	Cretaceous		Late Early	96 138
		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				
pre-Archean[2]		3800?			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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