

COLORADO GEOLOGICAL SURVEY

Open-file Report OF-99-12

Evaluation of Mineral and Mineral Fuel Potential of SW Moffat County State Mineral Lands Administered by the Colorado State Land Board

1 June 1999

The Colorado Geological Survey (CGS) is releasing an evaluation of the mineral and mineral fuel resource potential of the nearly 65,040 acres of state mineral lands located in SE Moffat County as part of its long-term evaluation of approximately 4,000,000 acres of state lands administered by the State Land Board. The CGS divided the lands, for evaluation purposes, into 57 individual tracts that range from approximately 320 acres to 11,960 acres. Mr. L.Alex Scarbrough Jr., a consulting minerals geologist retained by the CGS and Mr. Harry TerBest, a consulting petroleum and coal geologist also retained by the CGS, are the senior authors of this report while Mr. H. Thomas Hemborg, petroleum geologist and staff member of the CGS, assisted. Together these individuals have over 75 years of private sector experience in oil, gas, and minerals exploration, much of this in Colorado.

This open file report includes a general overview summary of the geology and mineral potential of the entire Moffat County along with maps of tract locations, oil and gas tests, and industrial mineral prospects. The main body of the report is an evaluation of each individual tract.

Four general categories of resources are included in this inventory:

- oil and gas
- coal
- metallic minerals
- industrial minerals and construction materials.

Each individual tract evaluation includes:

- A bar graph which ranks each tract's resource potential for each of the four mineral categories. An explanation of the categories may be found with the tract summaries.
- Tract identifier number, county name, and county location map.
- Tract location on a 7-1/2-minute United States Geologic Survey topographic map.
- Tract location on a United States Geologic Survey surface outcrop map.
- Location as to section, township, and range and approximate acreage.
- Overview of tract geology.
- Specific assessment of the resource potential for the four resource categories.
- References used in assessing tract potential.

All maps showing Moffat County tract boundaries were prepared by Mrs. Tiffany M. Lehart, a University of Colorado geology student serving an internship at the CGS. These maps were assembled by overlying the boundaries provided on a State Land Board computerized base map onto the United States Geologic Survey map bases in a Graphic Information System environment. Tract boundaries were not checked against the State Land Board's detailed land records because of time constraint considerations.

Introduction

Moffat County is situated in the extreme northwest corner of the state and has common borders with Wyoming to the north, Utah to the west and Rio Blanco and Routt counties in Colorado to the south and east. The county, which covers 4,761 square miles is the second largest in the state behind Las Animas County which covers 4,798

square miles. Surface elevations in the county varies from the summit of Middle Mountain at 9,559 feet, located in the northwest corner of the county (T. 12 N., R. 103 W.), to the Green River at 5,040 feet at the Utah-Colorado border (T. 7 N., R. 104 W.). Surface topography in the county generally varies from moderate-to rugged. Topography in the southwestern quarter of the county in places can be especially difficult.

The Green River enters Moffat County at the Utah-Colorado line some eight miles south of the northern Colorado boundary, flows south approximately 30 miles through the county along the county's western edge before egressing the county back into Utah at the county's topographic low point. The main drainage for Moffat County is the west flowing Yampa River which crosses the county near its southern boundary before joining the Green River about 4 miles from the point where the Green River exits the state. Nearly every drainage in the county is tributary to the Yampa.

Moffat County includes elements of three major Rocky Mountain Foreland structural features: Sand Wash Basin, Axial Basin Uplift, and Piceance Basin (Fig. 1).

Geological Overview

Surface mapping in Moffat County has identified 16 separate unconsolidated surficial deposits of Quaternary age, 27 Tertiary units, 17 Cretaceous units, 11 Jurassic and/or Triassic units, 7 Paleozoic units and 2 Precambrian units. Surface outcrops exposures in the eastern two thirds of the county are comprised predominately of Tertiary non-marine siliclastic units of the Browns Park, Bridger, Wasatch, Green River and Fort Union Formations and Cretaceous marine, nearshore-marine and delta-plain siliclastic deposits of the Mancos Shale, Mesaverde Group, Lewis Shale and Lance Formation. Predominate surface outcrop exposures in the western third of the county include Paleozoic carbonates and siliclastic units of the Cambrian, Mississippian, Pennsylvanian, and Permian periods as well as large areas of Precambrian Unita Mountain Group quartzite, conglomerate, and shale (age 950 —1,400 M.Y.) and the Tertiary Green River and Browns Park Formations. Of note in the county and present only in a small area at the Utah boarder in the Unita Mountains (T. 11 N., R. 104 W.) is the oldest rock in Colorado (probably > 2,500 m.y.). This unit, named the Red Creek Quartzite, is a complex of mica schist, amphibolite, and metaquartzite.

Moffat County includes elements of three major Rocky Mountain Foreland structural features: Sand Wash Basin, Axial Basin Uplift, and Piceance Basin.

Northern Moffat County includes the Sand Wash Basin which is a sub-basin of the Greater Green River Basin. The Greater Green River Basin, which is located east of the Wyoming-Idaho segment of the Cordilleran thrust belt is a composite of several basins and adjacent uplifts that resulted from latest Cretaceous to earliest Oligocene Laramide deformation. The Sand Wash Basin is essentially a southerly extension of the larger Washakie Basin of southern Wyoming. The east-west-trending Cherokee Arch, a complexly faulted anticline located along the Wyoming-Colorado state-line, separates the Sand Wash Basin from the Washakie Basin. In the Sand Wash Basin, basement rocks are as deep as 20,000 feet below sea level, and Cambrian through Tertiary-age rocks may be as much as 30,000 feet thick.

The Axial Uplift, which extends from the northwest corner of Moffat County to the southeast corner of the county is a southern extension of the Unita Mountain Uplift. The complex subsurface structure of this uplift is characterized by strong anticlinal folding of northwest-southeast, north-south, and east-west trends and important faulting of diverse trend. Dynamic analysis of these fault fold trends suggest they were produced by ENEWSW compression and lateral shearing at depth. Precambrian Unita Mountain Group basement is exposed at the surface along much of the western half of the uplift. Basement plunges into the subsurface along the eastern half of the uplift to a depth of approximately 14,000 feet.

The Laramide in age Piceance Basin of northwest Colorado is about 100 mile long and 40-50 miles wide, and bounded on the north by the Axial Uplift, and on the east by the White River uplift which is located in eastern Rio Blanco and Garfield Counties. Only the northernmost tip of this basin is located in Moffat County. The basin is asymmetrical and deepest along its east side near the White River Uplift, where more than 20,000 feet of

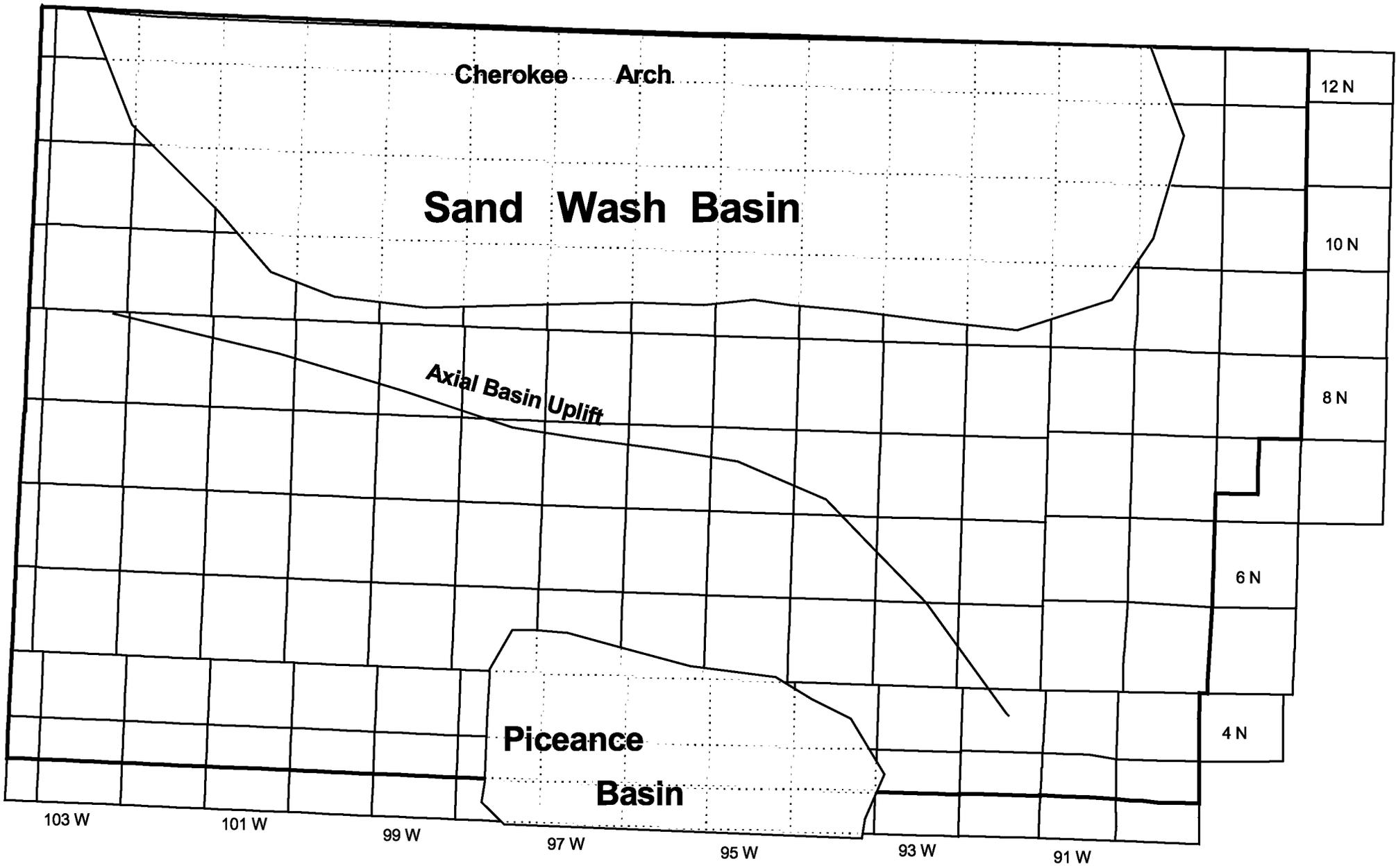


Figure 1 - Major tectonic feaures in Moffat County.

Phanerozoic sedimentary rocks may be present. Depth to basement in the Moffat County portion of the Piceance Basin is estimated to be as deep as 20,000 feet.

State owned mineral acreage in Moffat County totals 209,318.99 acres. For evaluation purposes, the CGS divided these lands into four quadrants approximately equal in size. The four quadrants were further subdivided into 238 individual tracts ranging from less than 100 acres to over 10,000 acres. The northeast quadrant includes 77 tracts, the southeast quadrant includes 57 tracts, the southwest quadrant includes 45 tracts, and the northwest quadrant includes 59 tracts.

Oil and Gas Resources

Moffat County in 1997 produced 430,524 barrels of oil (BO) and 21,139,485,000 thousand cubic feet (MCF) of natural gas from 30 individual fields. The number of producing wells in Moffat County that supplied this volume of production totaled 311. Moffat County in 1997 ranked fifth among Colorado's counties in natural gas production and seventh in oil production.

Cumulative oil production in Moffat County at the end of December 1997 totaled 66,453,579 BO. Cumulative natural gas production in the county at the end of 1997 totaled 823,859,259 Mcf. Moffat County ranked seventh in cumulative oil production and fourth in cumulative natural gas production among the state's counties at the end of 1997. Forty six individual oil and gas fields contributed to this volume. Three of the county's fields are now abandoned and thirteen are currently shut-in.

Twenty two individual formations/horizons have produced oil and/or natural gas in Moffat County. Listed below from youngest to oldest are the respective pay zones. Also included in this listing is a lithologic characterization of the productive formations as well as the geologic age of the productive units.

Wasatch Formation; Sandstone; Lower Eocene-Upper Paleocene Fort Union Formation; Sandstone; Paleocene Lance Formation Sandstone; Upper Cretaceous Fox Hills Sandstone Upper Cretaceous Lewis Shale Sandstone Upper Cretaceous Mesaverde Sandstone Upper Cretaceous Mesaverde Coal Coal Upper Cretaceous Mancos Shale Fractured Shale Upper Cretaceous Niobrara Formation Fractured Shale Upper Cretaceous Frontier Formation Sandstone Upper Cretaceous Mowry Shale Fractured Shale Upper Cretaceous Dakota Sandstone Sandstone Lower Cretaceous Morrison Sandstone Upper Jurassic Curtis Sandstone Upper and Middle Jurassic Entrada Sandstone Middle Jurassic Sundance Sandstone Middle Jurassic Nugget Sandstone Sandstone Lower Jurassic-Upper Triassic Shinarump Sandstone Middle Triassic Moenkopi Sandstone Lower Triassic Phosphoria Formation Dolomite Permian Weber Sandstone Sandstone Lower Permian-Middle Pennsylvanian Minturn Sandstone Middle Pennsylvanian

Oil and gas production in Moffat County occurs within two of the three major Rocky Mountain Foreland structural features that are present within the county: Sand Wash Basin with its associated Cherokee Arch and the Axial Uplift. The small portion of the Piceance Basin that is present in the county is not productive.

Cherokee Arch

The Cherokee Arch is essentially a structural play located along the Wyoming Colorado State line. The Cherokee Ridge Arch separates the Washakie Basin in Wyoming from the Sand Wash Basin in Colorado. The area is characterized by an east-west-trending zone of en echelon faults and folds that are believed to be due to wrenching. Structural deformation occurred during the Laramide orogeny.

Colorado's 3rd, 6th, 7th, and 9th largest gas fields are located on the arch. The fields are Powder Wash (cumulative production at the end of 1997 – 254.7 billion cubic feet {Bcf} of natural gas and 7.9 million barrels of oil {Mmbo}), Hiawatha (231.1 Bcf and 4.5 Mmbo), Hiawatha West (130.7 Bcf and 0.2 Mmbo), and Sugar Loaf (76.3 Bcf and 0.3 Mmbo).

Reservoirs in the Cherokee Arch Play include the Jurassic Nugget Sandstone, Lower Cretaceous Dakota Sandstone, Upper Cretaceous Mesaverde Formation, Lewis Shale sandstones, Lance Formation, Paleocene Fort

Union Formation, and Eocene Wasatch Formation. Porosity ranges from 10 to 30 percent and permeability ranges from 0.1 to 500 mD. Reservoir thickness is highly variable, ranging from 10 to 40 ft. Cretaceous reservoirs in the deeper part of the play area are low permeability reservoirs.

Although there are no oil or gas analyses from fields in the play area, it is likely that the oils are sourced from Cretaceous rocks and the gases are sourced from Cretaceous and older rocks. Based on thermal maturity mapping Cretaceous and older rocks are thermally mature to overmature with respect to the oil window. When Cretaceous and older rocks entered their oil window (0.6 percent vitrinite reflectance) is not known, but it is likely that structural traps were in existence when Cretaceous source rocks entered the oil window. Older source rocks, such as the Permian Phosphoria Formation may have passed through the oil window (1.3 percent vitrinite reflectance) prior to the formation of structural traps. The trapping mechanism for nearly all accumulations is structural. Existing fields are anticlinal folds that are commonly faulted. Impermeable shales and/or faults provide the seals. Depth of occurrence: 2,000 to 15,000 ft. This area is maturely explored. Deep drilling to the Mississippian Madison Limestone at depths of about 23,000 ft has not encouraged the hope of any pre-Mesozoic reservoirs. Discovery of any fields larger than 1 MMBO is unlikely, however, it is likely that gas fields larger than 6 BCF will be discovered in the future. The gas potential is probably greatest in pre-Cretaceous reservoirs in buried structural traps.

Sand Wash Basin

The Sand Wash basin includes some minor gas production from conventional strat traps in Cretaceous sandstone. However, it is believed that the major opportunity to expand production in the basin will be from basin-centered accumulations in Cretaceous and lower Tertiary rocks.

Basin-centered gas accumulations are a type of unconventional gas accumulations that differ significantly from conventional gas accumulations. They have the following attributes : (1) generally, very large accumulations occupying the more central, deeper parts of basins, (2) absence of down-dip water contacts, (3) abnormally over- or underpressured, (4) gas is the pressuring phase, (5) produce little or no water, (6) permeability less than 0.1 mD, (7) overlain by a normally pressured transition zone containing gas and water, (8) contain thermogenic gas, (9) source of gas is local – either from interbedded or adjacent lithologies, (10) gas is thermogenic, (11) top of accumulations occur at 0.75 to 0.9 percent vitrinite reflectance, (12) structural and stratigraphic trapping aspects are of secondary importance, (13) the "seal" for these gas accumulations is due to the presence of multiple fluid phases in low-permeability reservoirs; it is a relative permeability barrier

The basin-centered gas plays in the Sand Wash Basin are subdivided into three reservoir sequences: (1) Mesaverde, (2) Lewis, and (3) Fox Hills-Lance.

Mesaverde Play – The play area extends through the deeper parts of Sand Wash Basin. The Mesaverde Play includes the Mesaverde Group Almond, Williams Fork and Iles Formations. The thickness of the stratigraphic interval averages 3,000 ft, and the cumulative thickness of individual reservoirs ranges from less than 450 ft to 1,000 ft. Individual reservoirs range in thickness from 10 to 75 ft. The most likely source rocks are coal and carbonaceous shale within the play interval. Gas began to be generated from the Mesaverde interval in late Eocene or Oligocene time. The depth to the top of reservoirs in the Mesaverde Play ranges from 8,000 to 14,000 ft. The play is immaturely explored. Most of the Mesaverde Play remains unevaluated and it is likely that several accumulations larger than 6 Bcf could be developed.

Lewis Play – This play includes the stratigraphic interval of the Lewis Shale. The play area is restricted to the deeper parts of the eastern flank of the Sand Wash Basin. Reservoirs in the Lewis occur as isolated sandstones bounded above and below by shale. The cumulative thickness of reservoirs in the play ranges from less than 40 ft to more than 150 ft. Individual sandstone reservoirs range in thickness from 10 to 30 ft. Sources of gas are from the marine shales of the Lewis Shale . Gas began to be generated from shales in the Lewis Shale in Oligocene time. The depth to the top of reservoirs in the Lewis Play ranges from 5,000 to 12,000 ft. The play is moderately explored. Productive examples in the basin include the Windsock and parts of the West Side Canal fields. However, a large area is undrilled and untested

Fox Hills—Lance Play – The play includes the stratigraphic interval from the base of the Fox Hills Sandstone to the top of the Lance Formation. The play area encompasses the deeper parts of the Sand Wash Basin. The reservoirs in the Fox Hills part of the play are represented by deltaic sandstones. In contrast, reservoirs in the Lance part of the play were deposited in fluvial dominated systems and are more lenticular than those in the Fox Hills. The average cumulative thickness of reservoirs in the play ranges from 800 to greater than 1,200 ft, with a median thickness of 1,000 ft. Individual reservoirs range in thickness from 10 to 60 ft. Sources of gas are from coal and carbonaceous shale in the Fox Hills Sandstone and Lance Formation. The depth to the top of reservoirs within the play area ranges from 4,500 to 11,000 ft. The play has been very sparsely tested.

The Four Mile Creek Lance Formation reservoir gas field located in T11-12 N and R91W on the shallow east flank of the basin is a conventional strat trap.

Coal Bed Methane (CBM) Plays

Coals in the Mesaverde and Lance have productive potential. Currently only minor volumes of CBM production has been established from the Mesaverde.

Mesaverde CBM Play – This play includes coals within the Iles and Williams Fork Formations. The Iles play encompasses an area located in the southeastern part of the Sand Wash Basin. The Iles coal zone contains up to 7 coal beds with an aggregate thickness of as much as 50 ft. Individual coal beds are as thick as 15 ft. Coal beds in the Iles were deposited in a deltaic environment. On the basis of depositional environments similar to that of coals in the Williams Fork Formations, the coal beds in the Iles are most likely a humic type and composed mainly of vitrinite. Thermal maturity ranges from 0.45 to 0.7 percent Ro. This play is immaturely explored and has not been tested. The Williams Fork play encompasses an area of about 650 sq mi in the southeastern part of the Sand Wash Basin. There are two coal zones within the Williams Fork Formation; an upper zone containing as many as 12 coal beds and a lower coal zone containing as many as 18 coal beds. The aggregate thickness of coals in both zones is as much as 220 ft. Individual coal beds are as thick as 45 ft. Coal beds within the Williams Fork Formation are the principal coalbed gas objectives in the Sand Wash Basin. Gas content ranges from less than 1 to more than 540 scf/ton and averages 147 scf/ton. Thermal maturity of Williams Fork coal beds ranges from 0.4 to 0.7 percent Ro. At this level of thermal maturity, the gases generated from the coal beds might be expected to be both thermogenic and biogenic. The play area is lightly to moderately explored. About 7 wells have been drilled and tested the production potential of Williams Fork coal beds. To date, there is no commercial production. Potentially good areas for reserves may occur along the crests of folds where gas can accumulate by buoyancy or in areas where the flow of water in the coals is impeded by a permeability discontinuity, such as a fault. Other potentially good areas for gas production include areas where the water table has been lowered, such as wells located in close proximity to surface mining. In these areas, gas begins to desorb from the coal matrix because of the reduction in pressure caused by the dewatering process and gas then flows to the well bore along the cleat system.

Lance CBM Play – The Play area is in the southeast part of the basin. The more laterally persistent coal zone occurs in the lower part of the Lance Formation. Stray coals occur mainly in the middle part of the Lance. The main coal zone ranges in thickness from 100 to 400 ft. There are 1 to 8 coal beds in the Lance that have a cumulative thickness of as much as 85 ft. Individual coal beds are as thick as 13 ft.

Coal beds in the Lance Formation were deposited in fluvial dominated systems. Thermal maturity of coal beds in the Sand Wash Basin–Lance Play ranges from 0.4 to 0.65 percent Ro. Organic thermal maturation was achieved in Oligocene time, during maximum burial. The coals are inferred to be vitrinite rich coals with ash contents of 3-20 percent. Gas content of these coals is unknown, but they are assumed to be comparable to coals of similar rank and quality elsewhere. The level of thermal maturity of Lance coal beds indicates that the sorbed gas may be a mixture of thermogenic and biogenic gas. The Sand Wash Basin–Lance Play is immaturely explored, and there have not been any tests of the coalbed methane potential.

Axial Basin Arch

The Axial Arch Play in central Moffat is bounded on the south by the Piceance Basin and on the north by the Sand Wash Basin. It is a southeast extension of the eastern end of the Uinta Mountains Uplift. During much of Paleozoic time, the Axial Arch area was a structurally depressed area referred to as the Colorado Trough. Most structural features are the result of Laramide orogeny, although there is evidence of recurrent movement on pre-Laramide features. The principal reservoirs in the Axial Arch Play area include the Pennsylvanian Minturn Formation and Weber Sandstone; Triassic Shinarump Sandstone, and Moenkopi Formation; Jurassic Entrada Sandstone and Morrison Formation; Lower Cretaceous Dakota Sandstone; and Upper Cretaceous Frontier Formation, Niobrara Formation, and Marapos Sandstone Member of the Mancos Shale. Porosity ranges from 12 to 20 percent and permeability ranges from 0.1 to 300 mD. Reservoir thickness ranges from 8 to 65 ft. Fractured shale reservoirs are also present in a few fields. Possible hydrocarbon source rocks include the Pennsylvanian Belden, Permian Phosphoria Formation, and various Cretaceous rocks. In part of the play area, the Belden is probably thermally overmature, whereas Cretaceous source rocks are in the oil window. Timing The present levels of thermal maturity were probably achieved in the Oligocene. Structural traps were most likely formed as early as Pennsylvanian time and later during the Laramide orogeny. Consequently, the temporal relationships between hydrocarbon generation, migration, and structural development were favorable. Most hydrocarbon accumulations are in structural traps although reservoirs such as the Weber, Entrada, Shinarump, Dakota and Frontier have stratigraphic aspects. Seals are provided by shales. Depth of occurrence: 2,000 to 12,000 ft.

The area is maturely explored. However, the area is structurally complex and has experienced a long history of structural deformation dating back to Precambrian time. Accordingly opportunity still exist to discover new accumulations in complex structural settings.

Coal Resources

Coal mines and prospects dominate the natural resource occurrences in the Southeast Quadrant of Moffat County but are also present in the Southwest Quadrant and to a much lesser extent in the Northeast Quadrant. Parts of three coal fields underlie portions of county. A large portion of the Yampa coal field, within the Green River Coal Region, underlies northern and eastern Moffat County. The southern and western part of the county contains portions of the Danforth Hills and Lower White River coal fields of the Uinta Coal region. Landis (1959) estimates the following original in-place resources to a depth of 6,000 feet for these coal fields: Danforth Hills (partly in Rio Blanco County also) – 10.5 billion tons; Lower White River (primarily in Rio Blanco County) – 11.8 billion tons; and Yampa (with a significant part in Routt County) – more than 300 billion tons. For the entire county, Landis estimated demonstrated resources (those within 1/2- mile of a data point) to a maximum depth of 3,000 feet at 2.7 billion tons. Inferred resources (those within 3 miles of a data point) to a depth of 3,000 feet are estimated to be 13 billion tons.

Coal beds of economic interest are present only in strata of Late Cretaceous and Tertiary age. Tracts in Moffat County are underlain by coal from one or more of three formations: the Tertiary Fort Union Formation, the Cretaceous Lance Formation, and the Cretaceous Mesaverde Group (bituminous coal), which includes the Williams Fork and Iles Formations.

Hundreds of coal mines have operated within Moffat County. These mines were documented in a Colorado Geological Survey open file report from a coal reserve base update of the 1970s (Boreck and others, 1979). Previously operated mines in the vicinity of specific tracts have been identified from this report. At the present time, only two coal mines, the Colowyo Mine and the Trapper Mine, are operating within the county. Both are surface mines whose production has been generally increasing in recent years. The Colowyo Mine, in the Danforth Hills coal field, produced 5.5 million tons in 1997. This mine has recently introduced larger-scale mining equipment in efforts to further increase productivity. The Trapper Mine, in the Yampa coal field, produced 2 million tons in 1997 to supply a nearby power plant. The Empire Mine, an underground mine just southwest of the Trapper Mine, closed in 1996. This mine closure is part of a statewide trend of mine closures, as economic conditions force smaller, less productive mines out of business.

Specific reports used in estimating the coal resources of individual tracts are listed at the end of each section on coal. Open file reports have been abbreviated as OFR and coal. Coal Resource Occurrence/Coal Development Potential (CROCDP) reports, published as USGS open-file reports (OFRs), and other USGS open-file reports which document coal drilling projects are available for areas that include many of the tracts in Moffat County, both in the Danforth Hills coal field and the Yampa coal field. Some U.S. Geological Survey coal investigations maps (“C” series) and miscellaneous investigations maps (“MF” series) and various other references provided information used in the resource estimates. A primary source of data on coal zone thickness in the Yampa coal field is Colorado Geological Survey Open File Report 81-6, The Coal Bed Methane Potential of the Sand Wash Basin, Green River Coal Region, Colorado (Boreck and others, 1981). In that report, coals four feet or more thick were identified on logs of oil and gas test holes and data was compiled on maps for each of the three coal zones. Another source of coal zone thickness data for the Yampa coal field is unpublished thickness picks by CGS geologists on Mesaverde coals for more recently drilled oil and gas wells. These sources of data from oil and gas wells are not listed for individual tracts, since they apply to numerous tracts within the Yampa coal field.

Additional references are contained in CGS Information Series 25 – Selected References on the Geology and Coal Resources of Central and Western Colorado Coal Fields and Regions, published in 1988. Separate chapters on the Danforth Hills coal field, the Yampa coal field and the Uinta Coal Region are applicable to Moffat County.

Tonnage factors used in resource calculations are 1770 tons/acre-foot for subbituminous coal and 1800 tons/acre-foot for bituminous coal. Fort Union coals are considered to be subbituminous, while all other coals are assumed to be bituminous (although Mesaverde Group coals of the Upper Coal Group may be subbituminous.)

Metallic Mineral Resources

Uranium prospects and/or mines occur in all four quadrants of Moffat County but are vastly more numerous in its southeastern quadrant. During the uranium boom of the 1970’s, the county was one of the largest producers of uranium in the state. Although the Tertiary Browns Park Formation which hosts the Maybell District is the most prolific host, small deposits and/or mineralized areas also occur in the following:

- Precambrian Uinta Mountain Formation
- Pennsylvanian Weber Formation
- Triassic Chinle Formation
- Jurassic Morrison Formation, Entrada Sandstone, and Curtis Member of Stump Formation
- Cretaceous Iles and Williams Fork Formations and Mancos Shale
- Tertiary Green River and Wasatch Formations

Additionally, other formations of various ages exhibit sedimentologic characteristics similar to those listed above and may therefore possess hypothetical potential for hosting uranium deposits as well.

The Maybell and Skull Creek Districts, which are respectively located in the Southeast and Southwest Quadrant, are the largest in the county. Additionally, there is also a significant concentration of prospects in the vicinity of the town of Great Divide in the Northeast Quadrant; a synopsis of the first two districts is presented in the ensuing paragraphs.

The Maybell District is located along the east-west-trending Lay Syncline. Mines and prospects here have exploited tabular ore lenses up to 8.0 feet thick composed of uranophane, meta-autinite, and coffinite (Beroni and McKeown, 1952; Isachsen, 1955, Cadigan, 1972; Lewis, 1978; and Collier, Hornbaker, and Chenoweth, 1978; and Nelson-Moore, Collier, and Hornbaker, 1978). These are hosted by arkosic, locally tuffaceous, sandstones and some conglomerates which occur only 10 to 70 feet below the surface. Mineralization, which appears to have been localized to a certain degree by small faults, consists of both unoxidized coffinite and uraninite and their oxidized products, meta-autinite and uranophane; substantial vanadium and minor molybdenum, silver, and gold

are commonly present in some ores (MRDS database). Fourteen mines in the district produced an aggregate of 1,609,200 tons of ore averaging 0.13% U₃O₈ through the mid-1970's (Chenoweth, 1978). The largest mines in the district are the Rob Rollo, Marge, Gertrude, Sage-Buella, and the Johnson Lease. Numerous mines and prospects are present within 1.0 to 5.0 miles of the large 12,000 acre state tract centered around the town of Maybell; these are particularly abundant to the north and east of the property (Beroni and McKeown, 1952; Isachsen, 1955, Cadigan, 1972; Lewis, 1978; and Collier, Hornbaker, and Chenoweth, 1978; and Nelson-Moore, Collier, and Hornbaker, 1978). Almost this entire publicly owned parcel is underlain by the district's primary ore-host, the Tertiary Browns Park Formation.

In the Skull Creek District the host of most of the uranium mineralization is the basal portion of Curtis Member of the Stump Formation and the upper portion of the Entrada Sandstone (Beroni and McKeown, 1952; Isachsen, 1955; Lewis, 1978; Nelson-Moore, Collins, and Hornbaker, 1978; and Collier, Hornbaker, and Chenoweth, 1978); both are of Jurassic age. The primary past production (254 tons of 0.21% U₃O₈, 1.02% V₂O₅) was from the Blue Mountain Group Claims in the N1/2, NE1/4, Section 35, T. 4 N., R. 101 W on the south flank of the Skull Creek anticline; high-grade radium was mined in 1903 while uranium ores were exploited in the 1950's (Isachsen, 1955; Cadigan, 1972; Nelson-Moore, Collins, and Hornbaker, 1978). The U.S. Atomic Energy Commission conducted a drilling program in the vicinity of the preceding but a copy of the report was not accessible (McDougald, 1955). Ore minerals are chiefly carnotite with some uraninite, malachite, azurite, brochantite, and copper vanadate which occur in lenses averaging two feet in thickness thick within massive sandstones; selected samples ran 0.004 to 0.16% U₃O₈, 0.59 to 1.89% V₂O₅, and 0.68 to 2.35% Cu (Beroni and McKeown, 1952). Mineralization is most abundant around carbonized wood and carbonaceous shale. A second small uranium orebody hosted by the Pennsylvanian Weber Sandstone is located approximately 1.0 to 1.5 miles northwest of the Blue Mountain Group workings on the north flank of the Skull Creek anticline. This deposit was discovered in 1954 but is now mined-out; grade and tonnages are unknown (Isachsen, 1955). Other prospects located in the sections bordering the Skull Creek State Land Tract include the following (Nelson-Moore, Collins, and Hornbaker, 1978):

- Biles Shaft - Sec. 31, T. 4 N., R. 100 W. (no production, mineralization at Jurassic Curtis-Entrada contact)
- Bozo #1 - Section 35, T. 4 N., R. 101 W. (no production, mineralization in Jurassic Curtis Mbr.).
- Cleta Croup - Sec. 26, T. 4 N., R. 101 W. (19 tons 0.11% U₃O₈ in Jurassic Carmel Fm.).
- Coal Ridge - T. 4 N., R. 101 W. (samples avg. 0.081% U₃O₈ from Cretaceous Iles Fm.).
- Unnamed Prospect - Section 2, T. 3 N., R. 101 W. (no data available).

Metallic Minerals - Gold

Gold prospects and/or mines are found in all quadrants of Moffat County and exploited the metal primarily from placer and, in some instances, paleoplacer sources (Davis and Strufert, 1990 and Parker, 1992). Occurrences are by far most numerous in the county's Northeast Quadrant and include at least ten significant placer mines as well as a number of minor prospects (Davis and Streufert, 1990). A few similar deposits, most notably the Round Bottom and Big Bottom Mines, also known as the Yampa River Placers, are present in the county's Southeast Quadrant; these exploited low grade gold from both the present day and terrace gravels of the Yampa River. Placers of similar tenor also exist near Browns Park in the county's Northwest Quadrant. At the Douglas Mountain Mine located in the county's Southwest Quadrant, gold is associated with copper, lead, and zinc mineralization in fault and fracture-controlled vein deposits (Davis and Streufert, 1990).

The most productive gold deposits in Moffat County are situated in its Northeast Quadrant and constitute placers located primarily in the present day floodplain and terraces of Fourmile Creek, Timberlake Creek, Lay Creek, and the Little Snake River (Davis and Streufert, 1990). This area is collectively known as the Iron Divide District. Placer gold has also been found in Fortification, Housel, Dressler, and Blue Gravel Creeks as well as Pole, Dry, Scandinavian, and Bighole Gulches which are also part of the afore mentioned district. The headwaters of all of the preceding originate in the Iron Springs Divide area where drift mining has exploited gold from fossil placer

channels in bedrock variously interpreted to be either the Tipton Tongue of the Green River Formation and/or the Cathedral Bluffs Member of the Wasatch Formation (Parker, 1992 and MRDS database). The original source of the gold in these paleoplacers was probably from crystalline rocks in the Park Range (MRDS database). Gold was first discovered in the area on Fortification Creek in 1882 and through at least 1939 methods of exploitation at the previously discussed occurrences have included hand placering, ground sluicing, dry-land washing, hydraulicking, bucketline dredging, and underground drifting (Parker, 1992). The gold from the Iron Divide District is rounded rather than flaky, very finegrained (67 colors/milligram = 2,067,000 colors/ounce), and exhibits a pureness of about 885 to 935 fine (Parker, 1992). The gold-bearing alluvium in stream bottoms and terraces in the area is up to 12 to 20 feet thick but averages about 6 to 9 feet thick; areas worked are up to at least 700 acres in size (MRDS database). The Fourmile Creek/Timberlake Creek area of the district produced an unknown but substantial amount of gold between 1892 and 1910 and at least 4,800 ounces of gold between 1911 and 1940 (MRDS database). Information on the tenor of the placers is sparse but grades appear to range from 0.013 to 0.025 oz./cubic yard and 0.007 to 0.014 oz./cubic yard depending on what gold price (\$20.00 to \$35.00/oz.) is used to calculate the tenor which between 1900 and 1939 was reported as the dollar amount (\$0.26 to \$0.50) of gold/cubic yard obtained from the processed sand and gravel (Parker, 1992). Data from more recent operations give gold values ranging from 0.044 to 0.06 oz/cubic yard and 0.10 to 0.104 oz/cubic yard (unpublished information, Marathon Gold Corp., 1984). The MRDS database reports the following in the Fourmile Creek workings:

- \$3.37 (0.096 oz./cubic yard @ \$35/oz. Au)
- 11.5 lbs/cubic yard combined illmenite, euxenite, columbite, and rutile
- 6.8 lbs/cubic yard monazite
- 3.6 lbs/cubic yard garnet
- 3.4 lbs/cubic yard magnetite

Metallic Minerals - Zinc and Lead

There are two oxidized zinc-lead prospects located in the Southwest Quadrant of Moffat County within the boundaries of Dinosaur National Monument approximately 1.0 to 3.0 miles north of Tanks Peak (Untermann and Untermann, 1954; Heyl, 1964; Hansen and Carrara, 1980; MRDS database). These are hosted by the Permian Park City Formation, Mississippian Madison Limestone, and Cambrian Lodore Formation (Heyl, 1964 and MRDS database). At the Mantle Mine where the carbonates of the Madison and quartzites of the Lodore are in fault contact, the deposit occurs in a northeasterly striking weak shearzone of vertical fractures containing veinlets and breccia mineralized by hydrozincite, hemimorphite, cerussite, lead arsenate and ocher, and malachite and azurite (MRDS database). A 4.5 foot channel sample here yielded 27.45% zinc, 0.8% lead, 0.35% copper, 0.01 opt gold, trace silver, 2.4% iron, 7.2% silica, and 34.10% carbonate (Heyl, 1964). One shaft and several adits are present but production was small (MRDS database). A nearby sister prospect, the Jameson Mine, is reported to host similar mineralization in the Park City Formation (MRDS database).

Metallic Minerals - Copper and Silver

All of the copper prospects located in Moffat County occur in its Southwest Quadrant. Two bonafide and five questionable copper and/or copper-lead-silver-gold prospects are located on and in the vicinity of Douglas Mountain; these occur in the Cambrian Lodore Formation. Two other questionable prospects occur on or in the vicinity of Cross Mountain (Streufert and Cappa, 1994); these are located in sandstones of both the Cambrian Lodore Formation and the Middle Pennsylvanian Morgan Formation (Dyni, 1968 and Kanizay, 1955). In all of the preceding areas disseminated glauconite may have been mistaken for oxidized (green) copper mineralization. However, verified copper mineralization in the form of chalcocite is present at the Bromide Mine in the Douglas Mountain area as well as at several prospects in the nearby Blue Mountains; thus some of the mineralization at the questionable occurrences may actually be oxidized copper (MRDS database). At the Bromide Mine and

surrounding claims argentiferous and auriferous chalcocite and galena occur in up to 15 inch thick veins hosted by the Cambrian Lodore Formation and the Precambrian Uinta Mountain Formation (MRDS database). Production amounted to approximately 565 tons of ore between 1912 and the late 1970's. Elsewhere in the Southwest Quadrant of Moffat County, bonafide copper mineralization is associated with several uranium-vanadium occurrences in the Skull Creek Uranium District which is located between the town of Blue Mountain and Massadona. These are hosted by the Jurassic Curtis Member of the Stump Formation and the Pennsylvanian Weber Sandstone (Beroni and McKeown, 1952; Isachsen, 1955; Lewis, 1978; Nelson-Moore, Collins, and Hornbaker, 1978; and Collier, Hornbaker, and Chenoweth, 1978).

Metallic Minerals - Manganese

Three manganese prospects are located 1.0 to 3.0 miles east of MF Mountain in the Southwest Quadrant of the county; these appear to be hosted by siltstones, claystones, and sandstones of the Jurassic Morrison Formation (MRDS database).

Metallic Minerals - Miscellaneous

Blue-black hematite mixed with limonite and ocher occur in a 6.0 to 7.0 foot thick sandstone unit within the Mississippian Madison Limestone at the Paint Iron Mine on Douglas Mountain in the Southwest Quadrant of Moffat County (Hansen, 1978). Channel samples over the mineralized interval in the short tunnel on the property ran 35% iron, 0.08% phosphorous, 0.12% sulphur, 0.1% manganese, and 5.1% loss on ignition (Harrer, C.M. and Tesch, W.J., Jr., 1959, Reconnaissance of iron occurrences in Colorado: USBM IC-7919, p. 49-51). Petrographic analysis showed 0.001 to 0.01% copper, gallium, yitrium, vanadium, and chromium and 0.01 to 0.1% lead, zinc, manganese, and nickel as well as 0.1 to 1.0% titanium. Material from the mine was reportedly processed for paint pigment but is of too low grade and remote to be mined for iron (MRDS database).

Industrial Mineral Resources

Industrial Minerals - Sand and Gravel

Sand and gravel deposits occur in every quadrant of Moffat County with the most prospective resources being associated with the Recent and Pleistocene floodplain and terrace alluvium (Qa, Qal, and Qr) of the Yampa, Green, and Little Snake River as well as large creeks such as Vermillion, Fourmile, Timberlake, Fortification, Lay, and Elkhead Creeks and Bighole, Big, Mud Spring, and Morgan Gulches. Additional prospective resources are contained in Quaternary and Tertiary gravels mantling old pediment surfaces (Qop, Qp, and Qtg, etc.) and glacial outwash (Qtp, Qgp, Qgo, etc.); these occur at numerous locations in the county but are most widespread in the Northeast and Northwest quadrants. There were seven licensed sand and gravel pits and one clay pit operating in the county in 1996 (Hemborg, 1996).

The primary use of sand and gravel in Colorado is as a road base material and as an aggregate in asphalt and cement. The composition, hardness of pebbles and cobbles, and color variations are directly related to the source from which the sand and gravel has been derived. In Moffat County the sources may be multiple and diverse as in the Southwest and Northwest quadrants as well as monotonous and uniform as in the Northeast and Southeast quadrants. Sorting, roundness, and size of pebbles and cobbles are interrelated to the source from which the material originated, distance the material has been transported, and method of transport. The viability of any given deposit is predicated on its quality and proximity to markets and transportation routes. With regard to quality of a deposit, a high amount of interstitial clay requiring substantial washing would greatly diminish the likelihood of its being commercially developed.

Industrial Minerals - Crushed Aggregate and Building Stone

Moffat County contains a number of formations whose rocks qualify as resources of crushed aggregate and

building stone. However, only two licensed operating stone product quarries, both apparently producing limestone products, were operating in the county in 1996 (Hemborg, 1996). Other similar resources not currently being exploited include the following:

- Sandstones of the Cretaceous Williams Fork and Iles Formation of the Mesaverde Group, Cretaceous Frontier Sandstone, Cretaceous Dakota Sandstone, Jurassic Entrada Sandstone, Triassic-Jurassic Glen Canyon Sandstone, Pennsylvanian Weber Sandstone, Cambrian Lodore Formation, and Middle Proterozoic Unita Mountain Group
- Limestones of the Permian Park City Formation, Pennsylvanian Morgan Formation, Pennsylvanian Round Valley Formation, Mississippian Madison Limestone, and Middle Proterozoic Unita Mountain Group.
- Quartzite and marble of the Early Proterozoic Red Creek Quartzite.

Industrial Minerals - Gypsum

The Jurassic Carmel Formation contains gypsum beds which may constitute a potential source of the commodity for the production of wallboard, plaster, and filler material. Commercial viability is dependent on the individual deposit's size, quality, and proximity to markets and transportation routes. Resources are located in both the Northwest and Southwest Quadrants of the County.

Stratigraphic Units Occurring on State Land Board Tracts

- Qa - Alluvium (Holocene) - Silt, sand, and gravel in stream channels and floodplains.
- Qac - Alluvium and Colluvium (Holocene) - Bedded clay, silt, sand, and gravel in stream channel's and floodplains as well as slope wash and colluvium.
- Qe - Eolian Deposits (Holocene and Pleistocene) - Windblown silt and sand.
- Qp - Deposits on Pediment Surfaces (Holocene and Pleistocene) - Silty sand and gravel on pediment surfaces and broad alluvial fans.
- Qf - Fan Deposits and Colluvium (Holocene and Pleistocene) - Silty sand and gravel in alluvial fans and talus cones.
- Ql - Landslide Deposits (Holocene and Pleistocene) - Earth flows and rotational slumps.
- Qr - River Terrace Deposits (Pleistocene) - Gravel and subordinate sand on benches adjacent to rivers; locally includes sheet wash and pediment deposits.
- Qtp - Till of Pinedale Age (Pleistocene) - Gravel and sand deposited by receding glaciers.
- Qgp - Glacial Outwash of Pinedale Age (Pleistocene) - Gravel and sand deposited by glacial meltwater.
- Qtb - Till of Bull Lake Age (Pleistocene) - Gravel and sand deposited by receding glaciers.
- Qgb - Glacial Outwash of Bull Lake Age (Pleistocene) - Gravel and sand deposited by glacial meltwater.
- Qg - Gravels and Alluviums of Pinedale and Bull Lake Age (Pleistocene) - Includes Broadway and Louviers alluviums.
- Qop - Deposits on Older Pediment Surfaces (Pleistocene) - Silty sand and gravel.
- Qto - Old Till (Pleistocene) - Gravel and sand deposited by receding glaciers.
- QTg - Old Gravel Deposits (Pleistocene to Oligocene) - Gravel and sand deposits capping high level erosion surfaces.
- Qgo - Old gravels and alluvium (pre-Bull Lake Pleistocene) - Terrace, outwash, alluvial fan, and pediment gravels.
- Tbp - Browns Park Fm. (Miocene) - White, light gray, and tan, generally crossbedded, partly tuffaceous sandstone with subordinate conglomerate, siltstone, rhyolitic air-fall tuff, and minor limestone.
- Tbc - Bishop Cng. (Oligocene) - Light-gray and pink, partly tuffaceous conglomerate sandstone, and minor light-gray to light-pinkish-gray biotitic air-fall tuff.
- Tds - Starr Flatt Mbr. of Duchesne River Fm. (Oligocene? and Eocene) - Light to medium-red and tan sandstone, mudstone, and sub-ordinate conglomerate.
- Tdl - Lapoint Mbr. of Duchesne River Fm. (Oligocene? and Eocene) - Light red, tan, and yellow sandstone, siltstone, mudstone, and minor conglomerate with bentonite beds.
- Tdd - Dry Gulch Mbr. of Duchesne River Fm. (Oligocene? and Eocene) - Light to medium-gray, medium-red, purplish-gray, and yellow sandstone, mudstone, shale, and conglomerate.
- Tdb - Brennan Basin Mbr. of Duchesne River Fm. (Oligocene? and Eocene) - Light to medium-red, light-gray, light-brown, yellow, and tan sandstone, mudstone, conglomerate, shale, and siltstone. Locally impregnated with oil.
- Tu - Unita Fm. (Eocene) - Greenish-gray, dirty yellow, grayish-orange, and purple shale, marlstone,

- siltstone, and sandstone. Locally tuffaceous.
- Tuu - Upper part of Unita Fm. (Eocene) - Light-gray, white, greenish-gray, maroon, grayish-purple, red, tan, and yellow shale, mudstone, claystone, and minor sandstone.
- Tul - Lower part of Unita Fm. (Eocene) - Upper unit of light-gray and light-purple claystone and sandstone containing interbedded greenish-gray, light-green, brown, and yellow shoestring sandstone and conglomerate. Lower unit is pale-yellow, brown, or red sandstone and minor conglomerate and shale.
- Tb - Bridger Fm. (Eocene) - Gray, green, tan, red, brown, white, yellow, and turquoise shale, mudstone, claystone, siltstone, and minor sandstone and limestone. Locally tuffaceous.
- Tbu - Upper part of Bridger Fm. (Eocene) - Light-gray, tan, and yellow conglomerate, sandstone, and limestone.
- Tbl - Lower part of Bridger Fm. (Eocene) - Tan, pale-yellow, light-gray, and light-green sandstone, shale, and limestone.
- Tg - Green River Fm. (Eocene) - Light-gray and buff marlstone, oil shale, limestone, siltstone, sandstone, and conglomerate
- Tgp - Parachute Creek Mbr. of Green River Fm. (Eocene) - Light-gray, dark-tan, white, light-yellow, thin-bedded fissile oil shale, marlstone, limestone, oolite, siltstone, sandstone, and air-fall tuff.
- Tgl - Lower part of Green River Fm. - Undivided Garden Gulch, Douglas Creek, and Anvil Points Mbrs. (Eocene) -Light-gray, light-yellow, and tan siltstone, shale, sandstone, marlstone, limestone, oil shale, and conglomerate.
- Tgla - Laney Mbr. of Green River Fm. (Eocene) - Light to medium-brown, tan, yellowish tan, and light-yellow thin-bedded fissile oil shale, claystone, sandstone, marlstone, siltstone, limestone, and air-fall tuff.
- Tgw - Wilkins Peak Mbr. of Green River Fm. (Eocene) - Light to medium-gray fissile saline oil shale, shale, siltstone, sandstone, and minor white beds of algal limestone and air-fall tuff.
- Tgt - Tipton Tongue of Green River Fm. (Eocene) - Brown oil shale, light-gray sandstone, and greenish-gray claystone and siltstone.
- Tglu - Luman Tongue of Green River Fm. (Eocene) - Light to medium brown fissile oil shale, siltstone, sandstone, limestone, carbonaceous shale, coal, and conglomerate.
- Tui - Upper Tertiary Intrusive Rocks (Pliocene and Miocene) - Porphyries of intermediate and basaltic composition.
- Tv - Volcanic Rocks (Pliocene, Miocene, and Oligocene) - Primarily volcanic rocks of intermediate composition; some basalts, light-colored tuffs, and bouldery volcanic breccia.
- Tbb - Basalt of Bimodal Volcanic Suite (Pliocene and Miocene) - Dense black lava rock
- Tw - Wasatch Fm. (Eocene and Paleocene) - Light-gray, red, green, white, yellow, and purple claystone, shale, sandstone, siltstone, and conglomeratic sandstone.
- Twc - Cathedral Bluffs Tongue (Eocene) of Wasatch Fm. - Light to medium-gray, red, pink, yellow, and maroon shale, claystone, and minor lenticular sandstone and oil shale.
- Twn - Niland Tongue (Eocene) of Wasatch Fm. - Tan, light to dark-gray, brown, red, and yellow sandstone, shale, siltstone, oil shale, carbonaceous shale, and coal.
- Twm - Main body (Eocene and Paleocene) of Wasatch Fm. - Tan, gray, yellow, and red shale, claystone,

- sandstone, conglomeratic sandstone, and marly limestone.
- Tf - Fort Union Fm. (Paleocene) - Light-gray, white, tan, light-green, and brown sandstone, shale, claystone and subordinate carbonaceous shale, coal, siltstone, and conglomerate.
- Kmvg - Mesaverde Group (Upper Cretaceous) - Light-gray, tan, yellow, purplish-brown cross-bedded sandstone, dark-gray shale, and minor coal.
- Kmvu - Upper Unit of Mesaverde Grp. (Upper Cretaceous) - Tan, light-gray, and yellow cross-bedded sandstone and subordinate shale, carbonaceous shale, and minor coal.
- Kmvc - Coal Unit of Mesaverde Grp. (Upper Cretaceous) - Light to medium-gray, light-yellow, light-orange, and tan crossbedded sandstone, carbonaceous shale, and coal.
- Kmvl - Lower Unit of Mesaverde Grp. (Upper Cretaceous) - Tan, light to medium-gray, and light yellow cross-bedded sandstone and subordinate shale, carbonaceous shale, and coal.
- Kmv - Upper, Coal, and Lower Units of Mesaverde Grp., Undivided (Upper Cretaceous) - Upper Unit is tan, light-gray, and yellow cross-bedded sandstone and subordinate shale, carbonaceous shale, and minor coal. Coal Unit is light to medium-gray, light-yellow, light-orange, and tan crossbedded sandstone, carbonaceous shale, and coal. Lower Unit is tan, light to medium-gray, and light yellow cross-bedded sandstone and subordinate shale, carbonaceous shale, and coal.
- Ksc - Segoe Sandstone, Buck Tongue of Mancos Shale, and Castlegate Sandstone. of Mesaverde Grp. (Upper Cretaceous) - Segoe Sandstone is light-gray, tan, buff, and orange marine sandstone and shale. Buck Tongue is medium to dark-gray marine shale. Castlegate Sandstone is light-gray, yellow, and tan marine sandstone and minor shale.
- Kbc - Buck Tongue of Mancos Shale and Castlegate Sandstone of Mesaverde Grp. (Upper Cretaceous) - Buck Tongue is medium to dark-gray marine shale. Castlegate Sandstone is light-gray, yellow, and tan marine sandstone and minor shale.
- Kw - Williams Fork Fm. of Mesaverde Grp. (Upper Cretaceous) - Light to medium-brown, orange, tan, and gray beds of sandstone, shale, claystone, carbonaceous shale, and coal.
- Ki - Iles Fm. of Mesaverde Grp. (Upper Cretaceous) - Light-gray, tan, and orange sandstone, shale, claystone, carbonaceous shale, and coal.
- Kl - Lance Fm. (Upper Cretaceous) - Gray shale, light brown sandstone, and a few coal beds.
- Kla - Lance Fm. and Fox Hills Sandstone (Upper Cretaceous) - Lance Formation is light-gray and yellowish-brown sandstone, siltstone, shale, and coal. Fox Hills Sandstone is gray and buff sandstone.
- Kls - Lewis Shale (Upper Cretaceous) - Dark-gray limy marine shale and subordinate sandstone.
- Km - Mancos Shale (Upper Cretaceous) - Medium to dark-gray marine bentonitic fossiliferous shale and minor siltstone and sandstone.
- Kh - Hilliard Shale (Upper Cretaceous) - Medium to dark-gray marine shale and minor siltstone and sandstone.
- Kfd - Frontier Sandstone, and Mowry Shale Mbrs. of Mancos Shale and Dakota Sandstone (Upper and Lower Cretaceous) - Frontier Sandstone is yellow and tan, fossiliferous, locally crossbedded marine sandstone and minor continental shale and coal. Mowry Shale is silver-gray and bluish-gray, siliceous marine shale and bentonite. Dakota Sandstone is yellow and light-gray, cross-bedded, mostly fluvial sandstone and subordinate pebble conglomerate, shale, and coal.
- Kjcm - Cedar Mountain Fm. (Lower Cretaceous) and Morrison Fm. (Upper Jurassic) - Cedar Mountain

- Fm. consists of Upper Member of purple, gray, and greenish-gray shale, mudstone, siltstone, and minor limestone and Lower Member of medium to dark-gray and tan crossbedded conglomerate and sandstone constituting the discontinuous Buckhorn Conglomerate Member. Morrison Fm. is light-gray, olive-red and light purple shale, claystone, siltstone, and minor interbedded sandstone and bentonite; some mudstone.
- Kc - Cedar Mountain Fm. (Lower Cretaceous) - Upper Member is purple, gray, and greenish-gray shale, mudstone, siltstone, and minor limestone. Lower Member is medium to dark-gray and tan crossbedded conglomerate and sandstone constituting the discontinuous Buckhorn Conglomerate Member.
- Jmsc - Cedar Mountain Fm. (Lower Cretaceous), Morrison Fm., Stump Fm., Entrada Sandstone, and Carmel Fm. (Upper and Middle Jurassic) - Cedar Mountain Fm. comprised by Upper Member of purple, gray, and greenish-gray shale, mudstone, siltstone, and minor limestone; Lower Member is medium to dark-gray and tan crossbedded conglomerate and sandstone constituting the discontinuous Buckhorn Conglomerate Member. Morrison Fm. is light-gray, olive-red and light purple shale, claystone, siltstone, and minor interbedded sandstone and bentonite; some mudstone. Stump Fm. consists of Redwater Mbr. comprised of olive-green and light-green shale and siltstone sparsely interbedded with limestone and sandstone; Curtis Mbr. consists of light gray crossbedded sandstone. Entrada Sandstone comprised by light-gray, buff, or pink crossbedded sandstone. Carmel Formation comprised by medium to dark-red and green sandy shale, sandstone, siltstone, mudstone, limestone, and gypsum.
- Jm - Morrison Fm. (Upper Jurassic) - Light-gray, olive-red and light purple shale, claystone, siltstone, and minor interbedded sandstone and bentonite; some mudstone.
- Jmse - Morrison Fm., Stump Fm., and Entrada Sandstone (Upper and Middle Jurassic) - Morrison Fm. is light-gray, olive-red and light purple shale, claystone, siltstone, and minor interbedded sandstone and bentonite; some mudstone. Stump Fm. consists of Redwater Mbr. comprised of olive-green and light-green shale and siltstone sparsely interbedded with limestone and sandstone; Curtis Mbr. consists of light gray crossbedded sandstone. Entrada Sandstone comprised by light-gray, buff, or pink crossbedded sandstone.
- Jsc - Stump Fm., Entrada Sandstone, and Carmel Fm. (Upper and Middle Jurassic) - Stump Fm. consists of Redwater Mbr. comprised of olive-green and light-green shale and siltstone sparsely interbedded with limestone and sandstone; Curtis Member consists of light gray crossbedded sandstone. Entrada Sandstone comprised by light-gray, buff, or pink crossbedded sandstone. Carmel Formation comprised by medium to dark-red and green sandy shale, sandstone, siltstone, mudstone, limestone, and gypsum.
- Jse - Stump Fm. and Entrada Sandstone (Upper and Middle Jurassic) - Stump Fm. consists of Redwater Mbr. comprised of olive-green and light-green shale and siltstone sparsely interbedded with limestone and sandstone; Curtis Member consists of light gray crossbedded sandstone. Entrada Sandstone comprised by light-gray, buff, or pink crossbedded sandstone.
- JTrgc - Glen Canyon Sandstone (Lower Jurassic, and Upper Triassic) and Chinle Fm. (Upper Triassic) - Glen Canyon Sandstone is Pink, light-gray, and buff crossbedded sandstone. Chinle Fm. is Medium to dark-red, light-gray, purple, and light-green siltstone, sandstone, claystone, shale, and conglomerate.
- JTrg - Glen Canyon Sandstone (Lower Jurassic and Upper Triassic) - Pink, light-gray, and buff crossbedded sandstone.
- Trc - Chinle Fm. (Upper Triassic) - Medium to dark-red, light-gray, purple, and light-green siltstone, sandstone, claystone, shale, and conglomerate.

- TrPmp - Moenkopi Fm. (Lower Triassic) and Park City Fm. (Permian) - Moenkopi Fm. is medium to dark-red, reddish-brown, green, and gray siltstone and shale. Park City Fm. is light-gray, light-greenish-gray, gray, light-yellow, and red siltstone, sandstone, dolomite, limestone and shale underlain by light-gray, tan, and light-yellow, sandstone, sandy cherty limestone, dolomite, claystone, and phosphatic shale.
- Trm - Moenkopi Fm. (Lower Triassic) - Medium to dark-red, reddish-brown, green, and gray siltstone and shale.
- Trmd - Moenkopi Fm. and Dinwoody Fm. (Lower Triassic) - Moenkopi Fm. is medium to dark-red, reddish-brown, green, and gray siltstone and shale. Dinwoody Fm. is light-gray, greenish-gray or white shale, siltstone, sandstone, and minor limestone.
- Trd - Dinwoody Fm. (Lower Triassic) - Light-gray, greenish-gray or white shale, siltstone, sandstone, and minor limestone.
- Pp - Park City Fm. (Lower Permian) - Light-gray, light-greenish-gray, gray, light-yellow, and red siltstone, sandstone, dolomite, limestone and shale underlain by light-gray, tan, and light-yellow, sandstone, sandy cherty limestone, dolomite, claystone, and phosphatic shale.
- PIPw - Weber Sandstone (Permian and Pennsylvanian) - Light-gray and buff crossbedded sandstone.
- IPm - Morgan Fm. (Middle Pennsylvanian) - Light to medium-red, yellow, and gray locally crossbedded sandstone interbedded with light to medium-gray limestone, and minor soft red shale; underlain by light-gray, red, and green shale, siltstone, sandstone, and limestone.
- IPmr - Morgan Fm. (Middle Pennsylvanian) and Round Valley Limestone (Pennsylvanian) - Morgan Fm. is light to medium-red, yellow, and gray locally crossbedded sandstone interbedded with light to medium-gray limestone, and minor soft red shale; underlain by light-gray, red, and green shale, siltstone, sandstone, and limestone. Round Valley Limestone is light to medium-gray and bluish-gray limestone and interbedded light-gray and red shale.
- Mr - Mississippian Rocks (includes Doughnut Shale, Humbug Fm., Madison Limestone, and correlative rocks - Doughnut Shale comprised of dark-gray, light-green, and red clay shale and light-gray and light yellow sandstone and limestone. Humbug Fm. comprised by tan, pink, light-gray, and red locally crossbedded sandstone, limestone, and red and black shale. Madison Limestone comprised by tan, light-yellow, and light to dark-gray limestone, locally dolomitic.
- MCr - Mississippian and Cambrian Rocks - Gray limestone assignable to the Madison or Leadville Limestone underlain by sandstone, quartzite, and shale of the Sawatch Quartzite or Lodore Formation. Lodore Formation is light-brown, pink, and greenish-gray sandstone and pebble conglomerate; overlain by pink, tan, and light-greenish-gray shale and interbedded tan and light-green crossbedded sandstone.
- Cl - Lodore Fm. (Upper Cambrian) - Light-brown, pink, and greenish-gray sandstone and pebble conglomerate; overlain by pink, tan, and light-greenish-gray shale and interbedded tan and light-green crossbedded sandstone.
- Yu - Uinta Mountain Grp. (Middle Proterozoic) - Light to dark-red, crossbedded, locally pebbly sandstone and locally gray, green, and red silty shale.
- Xwr - Red Creek Quartzite (Early Proterozoic? and Archean) - White, gray, tan, and light-green meta-quartzite, subordinate quartz-muscovite schist and ortho-amphibolite, and minor marble.