

COLORADO GEOLOGICAL SURVEY
Open-file Report OF-01-15
Evaluation of Mineral and Mineral Fuel Potential of Jackson County State
Mineral Lands Administered by the Colorado State Land Board
19 July 2001

The Colorado Geological Survey (CGS) is releasing an evaluation of the mineral and mineral fuel resource potential of the nearly 129,400 acres of state mineral lands located in Fremont 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 160 acres to 77,890 acres. Senior author on this report is James A. Cappa, Chief of the CGS Mineral Resources Section. Nicole Koenig, Petroleum Geologist, authored the oil and gas evaluations of this report. Ms. Rachel Coursey, a consulting GIS analyst retained by the CGS, provided GIS production in the form of tract and index maps, as well as editing and documentation support.

This open file report includes an introduction to the geology and mineral resources of the county. A county reference map with tract locations is included, as well as maps of oil and gas test wells with oil field locations, coal resources, metallic mineral prospects, and industrial mineral prospects. The main body of the report is an evaluation of each individual tract, which includes text as well as corresponding topographic and geologic maps. A spreadsheet summary of the tract locations and commodity ratings is also included. Abbreviations used throughout the tract documentation are listed on the next page.

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.

The Abbreviations used in the tract documentation, with their definitions, are as follows:

MCF – thousand cubic feet
MMCF – million cubic feet
BCF – billion cubic feet
TCF – trillion cubic feet
BBL barrels
BO – barrels of oil
BW – barrels of water

MBO – thousand barrels of oil
MMBO – millions of barrels of oil
DST – drill stem test

Geological Overview

Jackson County lies between the Park Range on the west and the Independence Mountains, Medicine Bow Mountains and the Front Range on the north and on the east. Much of the county includes the North Park Basin, a Laramide-age basin with several west–northwest to northnorthwest-trending faults and anticlines. The Independence Mountain thrust fault trends mostly east-west and provides structural closure to the basin on its north end. The mountain ranges are composed of Precambrian igneous and metamorphic rocks. Permian through Mesozoic age sedimentary rocks overlie the Precambrian rocks around the edge of the North Park Basin. The vast area of the North Park Basin is covered with the early Tertiary sediments of the Coalmont and North Park Formations. Quaternary gravel deposits are found throughout the North Park Basin especially along the drainage system of the North Platte River. Eolian sand deposits in large dunes occur along the eastern edge of the basin.

Oil and Gas Resources

County Production Statistics

Jackson County produced 12,334,007 thousand cubic feet of gas, 1,452 barrels of oil and 680,593,236 thousand cubic feet of CO₂ in 1998 from 27 producing wells. This placed Jackson County 31st in annual gas and 14th in annual oil production among Colorado's 35 gas-producing and 30 oil-producing counties.

The cumulative production from 14 producing fields in Jackson County reached 12,334,007 thousand cubic feet of gas, 1,452 barrels of oil and 680,593,236 thousand cubic feet of CO₂ at the end of 1998. Jackson County was ranked 27th for cumulative gas production in 1998 and 12th for cumulative oil production among Colorado's producing counties.

Producing Horizons

There are eight individual formations/producing horizons that have produced gas and oil in Jackson County. These pay zones, with their accompanying lithologic descriptions and geologic age, are listed below in stratigraphic order.

Formation	Lithology	Age
Pierre	Interbedded Sand and Shale	Upper Cretaceous
Shannon S.S.	Sandstone	Upper Cretaceous
Niobrara	Limestone	Middle Cretaceous
Frontier	Sandstone	Middle Cretaceous
Dakota	Sandstone	Lower Cretaceous
Lakota	Sandstone	Lower Cretaceous
Muddy	Sandstone	Lower Cretaceous
Morrison	Sandstone	Upper Jurassic

Summary of production by fields

The following list contains the Jackson County oil and gas fields, their general locations, current status (producing, shut-in, or abandoned), producing formation(s), and cumulative oil and gas production at the end of 1998. Fields that had significant production are shown in bold print.

Field Name	Section, Township and Range	Status	Year Disc.	Producing Formation	CUM OIL (BO)	CUM GAS (MCF)
Alkali Lake	30, T. 10 N., R. 80 W.	Abandoned	1982	Dakota	3,978	0
Alkali Lake	30, T. 10 N., R. 80 W.	Producing	1982	Niobrara	8,837	492
Battleship	23, T. 10 N., R. 79 W.	Producing	1954	Dakota-Lakota	48,995	0
Battleship	23, T. 10 N., R. 79 W.	Producing	1954	Dakota	294,701	0
Battleship	23, T. 10 N., R. 79 W.	Producing	1954	Frontier	31,871	1,390
Battleship	23, T. 10 N., R. 79 W.	Producing	1954	Lakota	2,640,179	0
Butler Creek	9, T. 8 N., R. 81 W.	Producing	1974	Frontier	27,157	14,871
Canadian River	11, T. 9 N., R. 78 W.	Abandoned	1956	Dakota-Lakota	462,035	4,705,446
Canadian River	11, T. 9 N., R. 78 W.	Abandoned	1956	Lakota	101	3,805,200
Canadian River	11, T. 9 N., R. 78 W.	Abandoned	1956	Muddy	0	247,667
Canadian River	11, T. 9 N., R. 78 W.	Producing	1956	Niobrara	36,238	176
Carlstrom	31, T. 10 N., R. 79 W.	Abandoned	1972	Niobrara	7,741	4,194
Coalmont	35, T. 7 N., R. 81 W.	Producing	1973	Niobrara	191,134	85,337
Delaney Butte	5, T. 8 N., R. 81 W.	Producing	1977	Dakota	9,737	0
Delaney Butte	5, T. 8 N., R. 81 W.	Abandoned	1977	Frontier	2,331	358
Delaney Butte	5, T. 8 N., R. 81 W.	Abandoned	1977	Niobrara	2,015	1,015
Grizzly Ckeek S.E.	8, T. 6 N., R. 80 W.	Producing	1993	Niobrara	1,612	0
Grizzly Creek	6, T. 6 N., R. 80 W.	Abandoned	1982	Niobrara	1,112	0
Grizzly Creek	6, T. 6 N., R. 80 W.	Abandoned	1982	Shannon S.S.	1,342	0
Johnny Moore Mtn	10, T. 8 N., R. 78 W.	Abandoned	1978	Niobrara	36,189	64,693
Lone Pine	27, T. 9 N., 81 W.	Producing	1971	Lakota	2,633,017	694,202
McCallum	2, T. 9 N., R. 79 W.	Producing	1928	Dakota-Lakota	4,826,712	176
McCallum	2, T. 9 N., R. 79 W.	Producing	1928	Dakota-Lakota	CO₂ =	360,869,437
McCallum	2, T. 9 N., R. 79 W.	Producing	1928	Lakota	38,583	919,320
McCallum	2, T. 9 N., R. 79 W.	Producing	1928	Muddy	52,230	0
McCallum	2, T. 9 N., R. 79 W.	Producing	1928	Muddy	CO ₂ =	276,313
McCallum	2, T. 9 N., R. 79 W.	Producing	1928	Morrison	2,041,892	0
McCallum	2, T. 9 N., R. 79 W.	Producing	1928	Morrison	CO₂ =	154,147,139
McCallum	2, T. 9 N., R. 79 W.	Abandoned	1928	Niobrara	231	0
McCallum	2, T. 9 N., R. 79 W.	Producing	1928	Pierre B	2,567,745	1,513,636

Field Name	Section, Township and Range	Status	Year Disc.	Producing Formation	CUM OIL (BO)	CUM GAS (MCF)
McCallum South	21, T. 9 N., R. 79 W.	Producing	1927	Lakota-Dakota-Muddy	CO₂ =	165,300,347
McCallum South	21, T. 9 N., R. 79 W.	Abandoned	1927	Niobrara	1,855	0
McCallum South	21, T. 9 N., R. 79 W.	Producing	1927	Pierre	39,932	0
McCallum South	21, T. 9 N., R. 79 W.	Producing	1927	Pierre B	810,541	119,958
Michigan River	29, T. 10 N., R. 79 W.	Abandoned	1975	Dakota	9,164	7,286
Michigan River	29, T. 10 N., R. 79 W.	Producing	1975	Lakota	155,526	148,590
Michigan River	29, T. 10 N., R. 79 W.	Abandoned	1975	Niobrara	588	0
				County Totals:	16,938,444	12,334,007
				CO₂ Total:		680,593,236

*BO = barrels of oil, MCF = thousand cubic feet

Structural and stratigraphic controls on production

Jackson County contains North Park Basin, a Laramide-age structural basin that plays a major role for hydrocarbon prospects. The extent of the basin was a positive structural feature along with Middle and South Park basins through much of the Paleozoic and developed into an elongated basin during the Late Cretaceous-Tertiary

Laramide Orogeny. North Park is separated from the Middle Park basin by Late Mesozoic and Tertiary intrusives. High-angle reverse faults on the east and high-angle normal faults on the west characterize the basin margins (Wandrey and Barker, 1996).

The first discovery was made in McCallum Field in 1926 with the drilling of the Continental Oil Company's Sherman A-1 discovery well on North McCallum Anticline. The well produced an estimated 500 barrels of 46o API gravity condensate per day and 30 MMCF of CO₂ until it was abandoned in 1943 (Wandrey and Barker, 1996).

Faulted basin-margin anticlines of the North Park Basin in Jackson County account for all of the commercial production of oil, gas, and CO₂. Lone Pine Field is an example of production from a faulted basin-margin anticline. The field was discovered in 1971 and has produced a significant amount of oil and gas. The field sits on top of a tightly folded, complexly faulted anticline with 24 to 45o dips on the eastern flank and 45 to 60o dips on the western flank (Wellborn, 1982). The field produces from the Lower Cretaceous Lakota Formation that has a 350-foot oil column with an average porosity of 18 percent (Wellborn, 1982).

Structural plays account for the majority of production in Jackson County although stratigraphic traps controlled by onlap and porosity pinchouts may be present. The best results from the three Laramide-age basins come from North Park Basin where the Cretaceous section is thickest and burial was deepest. The two types of plays that exist in Jackson County are the Cretaceous-Upper Jurassic Structural Play and the Subthrust Play (Wandrey and Barker, 1996).

Cretaceous-Upper Jurassic Structural Play

Late Laramide thrusts formed north-south-trending, faulted basin-margin anticlines in North Park Basin. Most surface structures have been tested with production from these structures and account for virtually all of the oil and gas production in Jackson County. All of the fields contain a structural component even though some may exist in combination with stratigraphic traps. Upper Jurassic through Cretaceous strata are the main reservoirs for these plays. The volcanic fields that separate North and Middle Park Basins may conceal similar traps, but no wells have produced from beneath these fields.

The reservoirs identified by the United States Geological Survey (1996) that produce from this play are the Upper Jurassic Morrison Formation, the Lower Cretaceous Dakota, Lakota and Muddy Sandstones and the Middle to Upper Cretaceous Frontier, Niobrara and Pierre Formations.

Upper Jurassic Reservoirs: The Morrison Formation consists of alluvial and lacustrine mudstone, siltstone, limestone, and sandstone. Reservoir thicknesses range from 15 to 140 feet with porosity averaging 15.7 percent and permeability averaging 31 millidarcies.

Lower Cretaceous Reservoirs: The Dakota Sandstone is the most prolific reservoir. It consists of intertongued beds of fluvial shoreline sandstone, conglomeratic sandstone, carbonaceous siltstone, claystone, and occasional thin coals. Thicknesses average 25 to 40 feet. Porosity and permeability values average 18 percent and 70 millidarcies, respectively. The Lakota Sandstone is a buff, medium- to coarse-grained sandstone and conglomerate. Reservoir thickness averages 70 feet and porosity and permeability values average 18.5 percent and 100 millidarcies, respectively. The Muddy Sandstone has an average thickness of 30 feet. This reservoir is a white to tan, very fine-grained sandstone with an average porosity of 24 percent and average permeability of 300 millidarcies.

Middle to Upper Cretaceous Reservoirs: Reservoirs in the Frontier Formation are very finegrained sandstones that form a continuous blanket across the basin. The average reservoir thickness is 35 feet with porosity values averaging 20 percent. The Niobrara Formation is a thinbedded calcareous claystone with limestone at its base. Reservoir thicknesses average 25 to 35 feet. Porosity and permeability values average 33 percent and 0.1 to 1.0 millidarcies, respectively. The Pierre Shale has an average thickness of 20 feet and is a dark-gray to brown fissile claystone or mudstone with occasional beds of sandstone, limestone, and thin beds of bentonite. Porosity values average 14 percent and permeability values average 7 millidarcies. The primary source rock for the above reservoirs is the Lower Cretaceous Mowry Shale. The Mowry Shale was deposited during the second major

Cretaceous sea transgression. Vitronite reflectance values (Ro) in the deepest part of North Park are within the thermal zone of oil and gas generation and total organic carbon (TOC) values averaging 1.5 percent. Burial history plots for North Park Basin indicate maximum burial depths of 20,000 feet. They also suggest that expulsion of hydrocarbons occurred approximately 45 to 40 million years ago. Migration was along open fracture systems and bedding planes over short distances vertically and updip (Wandrey and Barker, 1996). Laramide anticlines and faulted anticlines produced the oil and gas traps. A combination of structural and stratigraphic traps (e.g. onlap pinch-outs) also played a role in trapping oil and gas. These traps are generally small, but are relatively thick or stacked (Wandrey and Barker, 1996).

Drilling activity has decreased since the mid-1980s, probably due to very limited successes in finding fields of any size since the mid-1970s. Although North Park Basin in Jackson County can be considered as a mature petroleum play, further discoveries of small traps may be expected with continued drilling (Wandrey and Barker, 1996).

Subthrust Play (Hypothetical)

This play occurs under Laramide thrusts where pre-existing traps were preserved beneath the thrust or where the overthrust Precambrian rocks formed a trap in conjunction with a thick low-permeability shale seal. In Jackson County, the Independence Mountain Thrust is the largest thrust fault that can create traps of 1 MMBO. The rocks of the Cretaceous-Upper Jurassic Structural Play are typically under the thrust and are differentiated by the mechanism of trapping and greater burial depths. The source rocks remain the same but there is a potential for higher maturity levels resulting from increased heating in the subthrust. The traps may be created by the thrusts themselves, by Laramide anticlines and faulted anticlines, or by some combination of structural and stratigraphic traps that were preserved under the thrusts (Wandrey and Barker, 1996).

Coal Resources

Within the North Park Basin, the Coalmont Formation of Paleocene –Eocene age unconformably overlies the Upper Cretaceous Pierre Shale. The Coalmont Formation is composed of conglomerate, sandstone, siltstone, shale, carbonaceous shale and coal beds. Locally, the coal beds exceed 50 feet in thickness.

Significant subbituminous coal resources were recovered from the Riach coal bed of the lower Coalmont Formation in section 26, T. 7 N., R. 81 W. In the Coalmont quadrangle, the Riach coal bed ranges from 25 to 80 feet in thickness (AAA Engineering and Drafting, 1979a; Erdman, 1944).

Coal bed	BTU	C, %	O, %	H, %	N, %	S, %	Ash, %
Riach	9,570	54.98	29.75	5.99	1.21	0.74	7.33

Table 1. Chemical analysis of a Coalmont Formation coal bed (Henkes, 1957).

The Sudduth coal bed occurs near the base of the Coalmont Formation. The Marr Mine, the Marr No. 1, and the Canadian Strip Mine all produced from the Sudduth coal bed in and around T. 8 N., R. 78 W. The Marr and the Marr No. 1 both produced over 1.5 million tons of coal, especially during the 1974 to 1980 period. The Sudduth coal bed is 49-53 feet thick at the Marr mines, and 29-39 feet thick at the Canadian Mine. Proximate analyses of the Sudduth bed at the Kerr Strip Mine in section 2, T. 8 N., R. 78 W. indicate an average sulfur content of 0.2 %, ash content of 5.7%, and a heat value of 10,850 Btu/lb. There are several other named coalbeds that are of lesser economic significance.

Coal mining in the North Park Basin began in the late 1800s with small wagon mines. The Riach coal bed in the Coalmont district was exploited as early as the late 1800s. The most significant mining period was from 1909 to the end of World War II. As of 1941, total production from the Coalmont Mine was 1.5 million tons; remaining reserves were 177 million tons with 53 million being “recoverable” (Erdman, 1944). Coal was last produced in the district from the Grizzly Creek Strip, section 32, T. 7 N., R. 80 W; the mine operated for only one year, 1975, and produced 65,000 tons. The mines of the McCallum anticline district were opened in the 1970s through the 1990s. The Marr Mine was the largest producer with an estimated four million tons through 1993 when the mine

was closed and reclaimed. The Canadian Strip Mine produced 600,567 tons from 1975 to 1981. The mine was closed in 1985 (Roberts and Rossi, 1999).

Metallic Mineral Resources

There are no significant metallic mineral districts in Jackson County. There are a few isolated copper occurrences in pegmatites within the Proterozoic gneiss. These deposits rarely exceed a few feet in diameter and are of little economic importance.

There is a copper–molybdenum prospect, called the Kings Canyon Mine, in T. 11 N., R. 79 W. just to the east of the Northgate fluorspar district. This is probably the largest of the pegmatite hosted–copper deposits. The "vein" was about 300 feet long and had a width of about .5 foot to 2.5 feet. (Steven, 1960).

The Independence Mountain gold placer district is located in T. 11 N., R. 81 W. There is a gold placer occurrence in California Gulch (Mason and Arndt, 1996). Very little information regarding grade, tonnage, or production is available on these placers (Parker, 1974). There are no known bedrock gold deposits on Independence Mountain. High level Pleistocene gravels (not shown on geological map) are thought to be the source of the gold (Parker, 1974).

The Pearl district is in the Precambrian terrain of the northwest part of Jackson County in T. 11 N., R. 82 W. These copper deposits occur as either small massive sulfide deposits or as disseminated minerals in the Proterozoic gneiss. The usual copper minerals are chalcopyrite with lesser amounts of chalcocite and bornite. Sphalerite and galena are present in small amounts (Hail, 1965).

There are a few isolated uranium occurrences in Jackson County; however, none of these have ever been mined.

Prospecting in the district began around 1899 and continued until 1911. A smelter was built but never used. A few tons of ore was shipped from the Wolverine Mine in 1916 and 1917 (Hail, 1965). There has been no recent activity in this area.

Industrial Mineral Resources

The only significant industrial mineral occurrence in Jackson County is the fluorite deposits of the Northgate district. Fluorite occurs in veins and fractures in Precambrian rocks, especially the granitic rocks. Mineralization is mostly confined to north-northwest and northwest trending late Tertiary faults of Pinkham Mountain (Steven, 1960). These faults appear to be related to the east-west trending Independence Mountain Fault. Fluorspar production at the Northgate district began in 1922, and continued intermittently until World War II when production was sharply increased. In 1951, a new mill was built and production continued until late 1973. The amount of production is not reported.

There are a few reported vermiculite occurrences in ultramafic hornblendites rocks of Precambrian age. All of the vermiculite occurrences are associated with pegmatites. These occurrences are all very small and have probably never been commercially exploited (Steven, 1960).

The Proterozoic rocks of Jackson County can be used for crushed stone. Several of the Cretaceous age Formations can be used for construction material purposes. The Dakota Sandstone can be used for decorative stone, aggregate, or rip rap. The Pierre Shale can be a source for lightweight aggregate. Sand and gravel deposits occur throughout the North Park in the North Platte River drainage. Nearly pure quartz sand is found in large sand dunes in the eastern part of the basin along the mountain front.

Stratigraphic Units Occurring on State Land Board Tracts

Listed below are geologic descriptions of the Kiowa County map units.

Surficial Units:

- (Qa) Quaternary Alluvium – Gravel, sand, silt, and clay in stream valleys and alluvial fans.
- (Ql) Quaternary Landslide (Holocene and Pleistocene) – Shaly material with or without boulders of sandstone or basalt
- (Qgo) Old Gravels and Alluvium – Terrace, outwash, alluvial fan, and pediment gravels
- (Qg) Young Gravels (Pleistocene) – Stream, terrace, and outwash gravels.
- (Qe) Eolian deposits (Holocene) – Windblown sand and silt
- (Qdo) Old Glacial Drift (Pleistocene) – Unsorted bouldery till, morainal form is subdued or lacking; may include some deposits of pre-Quaternary diamicton.; probably pre-Bull Lake in age.
- (Qd) Glacial Drift (Pleistocene) – Deposits of Pinedale and Bull Lake ages.

Bedrock Units:

- (Xb) Biotite Gneiss, Schist, and Migmatite (Precambrian X) – Locally containing hornblende gneiss, calc-silicate rock, quartz rich rock and metaconglomerate.
- (Xfh) Interlayered Felsic and Hornblendic Gneisses (Precambrian X) – Probably mainly metavolcanic but includes some interlayers of pelitic biotite-sillimanite gneiss and schist and local pods of calc-silicate gneiss.
- (Xg) Granitic Rocks (Precambrian X) – Quartz monzonite, granodiorite, and quartz diorite compositions; in part migmatitic.
- (Yg) Granitic rocks (Precambrian Y) – No detailed description available on 1°x 2° geologic map.
- (TrPr) Chugwater Formation and thin units of Forelle and Satanka in northeastern North Park – Chugwater Formation (Upper Triassic) – Red and gray sandstone, siltstone, shale, and conglomerate. Thickness in North Park is 800 feet. Forelle Limestone Member (Permian) – Gray limestone. Thickness is <20 feet. Satanka Shale (Permian) – Red shale. Maximum thickness is 135 feet.
- (Trr) Chinle and Chugwater Formations (Triassic) – Chinle Formation (Upper Triassic) – Brownish- and purplish-red calcareous siltstone, mudstone, and sandstone; limestone-pellet conglomerate in lower part. Chugwater Formation (Upper Triassic) – Red and gray sandstone, siltstone, shale, and conglomerate. Thickness in North Park is 800 feet.
- (KJds) Dakota, Morrison and Sundance Formations (Upper Jurassic-Lower Cretaceous): – Morrison Formation – Variegated shale and mudstone, light-gray sandstone, and beds of fine-grained gray limestone; locally conglomeratic near base. Thickness is 300-500 feet. Sundance Formation – Yellowish-gray to pale green glauconitic and oolitic marine limestone and sandstone and cross-bedded light gray to orange sandstone containing local intervening red and yellow siltstone beds. Thickness is 100-300 feet. Dakota Sandstone – Light gray and tan sandstone or quartzite; some interbedded darkshale and shaly sandstone. Thickness is 100-250 feet.
- (Kc) Colorado Group (Upper and Lower Cretaceous) – Consists of the Upper Cretaceous Niobrara Formation (calcareous shale and marly limestone) and Upper and Lower Cretaceous Benton Shale (dark bentonitic shale, calcareous sandstone, and siliceous shale near base). Thickness is 1,000 to 1,300 feet.
- (Kp) Pierre Shale (Upper Cretaceous) – Dark gray, marine shale and a few thick beds of fine-grained sandstone. Maximum preserved thickness is 5,300 feet.
- (Mzu) Mesozoic Rocks Undivided – Consist mainly of the Mesozoic units below the Pierre Shale: – Chinle Formation (Upper Triassic) – Brownish and purplish-red calcareous siltstone, mudstone, and sandstone; limestone pellet conglomerate in lower part; Garta Sandstone Member present at base in most places (grayish-purple to white coarse-grained sandstone and conglomeratic sandstone, 25 feet thick). Thickness

up to 600 feet. Chugwater Formation – Red sandstone, siltstone, and shale; locally contains gypsum. Thickness is 300–800 feet. Morrison Formation (Upper Jurassic) – Variegated shale and mudstone, light-graysandstone, and beds of fine-grained gray limestone; locally conglomeratic near base. Thickness is 300–500 feet. Sundance Formation – Yellowish-gray to pale green glauconitic and oolitic marine limestone and sandstone and cross-bedded light gray to orange sandstone containing local intervening red and yellow siltstone beds. Thickness is 100–300 feet. Dakota Sandstone (Lower Cretaceous) – Light gray and tan sandstone or quartzite; some interbedded dark shale and shaly sandstone. Thickness is 100–250 feet. Colorado Group (Upper and Lower Cretaceous) – Consists of the Upper Cretaceous Niobrara Formation (calcareous shale and marly limestone) and Upper and Lower Cretaceous Benton Shale (dark bentonitic shale, calcareous sandstone, and siliceous shale near base). Thickness is 1,000 to 1,300 feet. Pierre Shale (Upper Cretaceous) – Dark gray, marine shale and a few thick beds of finegrained sandstone. Maximum preserved thickness is 5,300 feet.

- (Tc) Coalmont Formation (Eocene and Paleocene) – Sandstone, conglomerate, and carbonaceous shale; contains coalbeds. Estimated maximum thickness is 11,000 feet.
- (Twr) White River Formation (Oligocene) – Light gray to white soft tuffaceous siltstone and claystone. Thickness is < 200 feet. (Taf) Ash-flow tuff (Oligocene) – Near Cameron Pass; about 28 Ma.
- (Tv) Volcanic Rocks (Pliocene, Miocene, and Oligocene) – Principally volcanic rocks of intermediate composition; includes some basalt, light-colored tuffs, and bouldery volcanic breccia.
- (Tnp) North Park Formation (Miocene) – Fluvial ashy sandstone, conglomerate, sandstone, limestone, claystone, and volcanic ash; loosely consolidated. Maximum thickness is about 1,800 feet.
- (Tv) Volcanic Rocks (Pliocene, Miocene, and Oligocene) – Principally volcanic rocks of intermediate composition; includes some basalt, light-colored tuffs, and bouldery volcanic breccia.
- (Tmi) Middle Tertiary Intrusive Rocks (Miocene and Oligocene –20--35 Ma) – Porphyries of intermediate composition; dikes and sills.

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