

COLORADO GEOLOGICAL SURVEY
Open-file Report OF-01-18
Evaluation of Mineral and Mineral Fuel Potential of
Montezuma and Dolores Counties
State Mineral Lands Administered by the Colorado State Land Board
18 August 2001

The Colorado Geological Survey (CGS) is releasing an evaluation of the mineral and mineral fuel resource potential of the nearly 59,970 acres of state mineral lands located in Montezuma and Dolores counties 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 108 individual tracts that range from 40 acres to 11,080 acres in size. Ms. Beth Widmann and Ms. Laura Wray, minerals geologist and petroleum geologist respectively for CGS, are the senior authors of this report. Ms. Widmann also created the mineral and mineral fuel reference maps for this evaluation. Ms. Rachel Garrison, a consulting GIS analyst retained by the CGS, provided GIS production in the form of geologic and topographic tract maps, as well as editing and documentation production.

This open file report includes an introduction to the geology and mineral resources of the two counties. The main body of the report includes evaluations of each individual tract, involving descriptive text as well as corresponding topographic and geologic maps. A summary of the tract locations and commodity ratings is included, as well as maps of oil and gas test wells with oil field locations, coal resources, and industrial mineral prospects.

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

Resource Overview

Montezuma and Dolores Counties occupy the southwest corner of Colorado and are bordered to the south by New Mexico, to the west by Utah, to the north by San Miguel County, and to the east by La Plata and San Juan Counties. Cortez and Dove Creek are the county seats for Montezuma and Dolores Counties, respectively. Together, these two counties encompass more than 3,100 square miles. Montezuma County has a population of 23,830, which is about a 28% increase from 1990 (U.S. Census 2000). The population for Dolores County has increased similarly in the past ten years and currently includes 1,844 residents.

Oil, gas, and carbon dioxide (CO₂) are the most economically significant resources in Montezuma and Dolores Counties. Together, the two counties produced 2.6 million MCF of gas, 18.8 million BO, and 3.3 billion MCF of CO₂ prior to 1999. Although there is currently no active coal mining in either county, most of the State Land Board tracts are located within either the Nucla-Naturita coal field or the Durango coal field. Numerous small coal mining operations produced more than 200,000 short tons of coal during the late 1800s and early 1900s. Similarly, there are no active metallic mining operations in either county despite fairly good resource potential in sandstone and siltstone deposits of the Jurassic Morrison and Entrada Formations throughout both counties. Dolores and Montezuma Counties together produced nearly \$50 million worth of silver, gold, copper, lead, and zinc prior to 1958 (Vanderwilt, 1947; Del Rio, 1960). Dolores and Montezuma Counties have produced only about one ton of uranium. Sand and gravel resources and building stone derived from the Cretaceous Dakota Sandstone are the most widespread and readily accessible mineral resources in both counties.

Geological Overview

Montezuma and Dolores Counties are adjacent to the Paradox Basin and the western portion of the Four Corners Platform (Figure 1). Sedimentologic and tectonic patterns in the greater Four Corners region have been controlled by northwest-southeast and northeast-southwest sets of lineaments that have created the Paradox pull-apart basin and its associated faults and folds. Elevations range from 4800 feet above sea level in the southwest part of Montezuma County to 14,246 feet in the northeast part of Dolores County. The topography in both counties comprises mesas and incised canyons developed primarily in Jurassic and Cretaceous sandstone. The rugged San Miguel, Rico, and La Plata Mountains are located on the eastern border of the two counties and are composed of Triassic, Jurassic, and Upper Cretaceous sedimentary rocks with Tertiary intrusive stocks, dikes, and sills. An early Tertiary intrusive complex is located in the central western part of Montezuma County and forms Sleeping Ute Mountain. Quaternary surficial deposits, such as stream alluvium and eolian sand, are widespread throughout both counties.

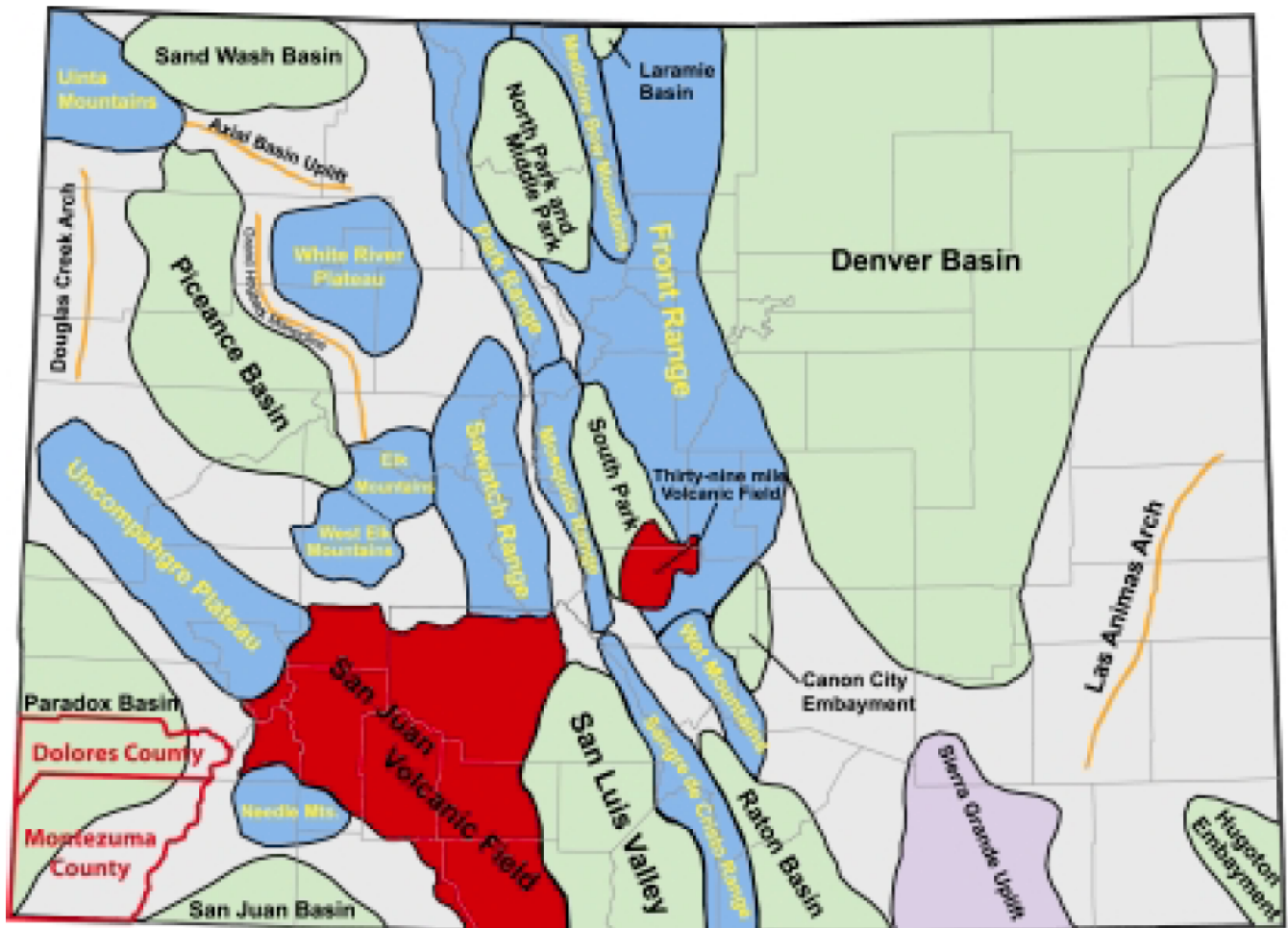


Figure 1. Major Tectonic and Physiographic Features of Colorado, showing the locations of Custer and Huerfano Counties (map modified after Tweto, 1979).

Oil and Gas Resources

County production statistics for Montezuma County

Montezuma County produced 2,480,919 MCF of gas, 481,334 BO, and 315,307,694 MCF of carbon dioxide (CO₂) in 1998 from 53 producing wells. This placed the county 15th in annual gas, 6th in annual oil production, and 1st in CO₂ among Colorado's 35 gas-producing, 30 oil-producing, and 3 CO₂-producing counties.

The cumulative production from 20 producing fields in Montezuma County reached 44, 254,049 MCF of gas, 18,279,625 BO, and 3,028,887,272 MCF of CO₂ at the end of 1998. At the end of 1998, the county was ranked 22nd for cumulative gas production, 18th for cumulative oil production, and 1st in CO₂ production among Colorado's producing counties.

Producing horizons in Montezuma County

There are ten individual formations/producing horizons that have produced gas and oil in Montezuma County. These pay zones, with their accompanying lithologic descriptions and geologic age, are discussed below.

By far, the highest volumes of gas and oil are produced from the carbonates in the Paradox Formation, deposited

during the Desmoinesian Age of the Pennsylvanian Period. At that time, the Paradox Basin existed as a broad, asymmetrical sag oriented northwest-southeast. Repeated marine transgressions and regressions caused the cyclic deposition of various lithologies within the basin. The central portion of the basin was filled with up to 2000 meters of evaporites, both salt and anhydrite, with interstratified black shales known as the Paradox Formation. Concurrently, along the southwest margin of the basin, cyclic algal reef-mound deposits and thin dark shales accumulated in thicknesses up to 700 meters. These carbonate mound buildups and organic rich dolomitic muds resulted from deposition during marine transgressions, while the evaporitic facies characterized regressive phases.

CO₂ production in the county is derived from the Leadville Limestone of Mississippian age (Kinderhookian to Osagean). The largest Leadville accumulation of oil is from Lisbon Field in San Juan County, Utah. Dolomite reservoirs with moldic and intercrystalline porosities are most prolific; the productive facies include dolomitic mudstones, karstified grainstones, and moldic wackestones (Fourer, 1996, p. 129-138).

Several clastic reservoirs contribute to minor gas and oil production and include: the Honaker Trail Formation of the Hermosa Group; the Permian Cutler Formation; the Triassic Shinarump Member of the Chinle Formation; the Upper Cretaceous Dakota Sandstone; and the Upper Cretaceous Gallup and Tootie Sandstones of the Mancos Shale.

Summary of production by fields in Montezuma County

The following table contains the Montezuma County oil and gas fields with corresponding general location, current status (producing, shut in, or abandoned), production formation(s), and cumulative oil and gas production at the end of 1998. Significant production for a field is shown in bold type.

Field Name	Section, Township and Range	Status	Producing Formation	CUM OIL (BO)	CUM GAS (MCF)
Desert Canyon	11-34N-20W	Abandoned	Ismay	60,741	132,098
Dove Creek	3-38N-19W	Producing	Molas	84,313	946,234
Flodine Park	15-35N-20W	Producing	Ismay	2,263,022	8,281,718
Flodine Park	15-35N-20W	Producing	Paradox	2,535,315	9,492,561
Flodine Park E.	26-35N-20W	Producing	Ismay	209,110	928,850
Goodman Point	6-36N-18W	Abandoned	Desert Creek	1,401	552
House Creek	20-38N-15W	Abandoned	Cutler	0	25,383
Island Butte	20-38N-19W	Producing	Desert Creek	2,106,777	5,685,407
Kernan Canyon	25-36N-15W	Abandoned	Dakota	150	0
LittleUte	11-34N-20W	Producing	Ismay	140,886	358,639
Mancos River	15-32N-18W	Abandoned*	Gallup	166	0
Mancos River	15-32N-18W	Abandoned*	Mancos	26,017	0
Marble Wash	15-33N-20W	Abandoned	Hermosa	19,978	54,772
MarbleWash	15-33N-20W	Producing	Ismay	950,560	1,615,114
Marble Wash	15-33N-20W	Producing	L. Ismay	991,284	1,679,941
McClean	15-37N-19W	Producing	Desert Creek	4,107,345	10,555,419
McElmo (CO2)	24-36N-18W	Producing	Leadville	0	3,007,427,209**
McElmo (CO2)	24-36N-18W	Producing	Mississippian	0	20,963,979
McElmo (CO2)	24-36N-18W	Producing	Shinarump	47,958	908,913
Menefee Mtn.	16-35N-13W	Abandoned	Dakota	49,230	255
Point Lookout	29-36N-14W	Abandoned	Dakota	0	23,000
Ramona	15-33N-18W	Abandoned	Gallup	1,392	0
Roadrunner	14-33N-20W	Producing	Ismay	1,483,353	2,933,077
Roadrunner	14-33N-20W	Producing	L. Ismay	2,061,899	4,069,695
Sage	22-33N-20W	Producing	Ismay	259,491	497,347
Sagehen	16-33N-20W	Shut in	Ismay	44,354	59,592
Sierra	5-35N-13W	Abandoned	Dakota	131,478	29,021
Sleeping Ute	10-34N-20W	Producing	Ismay	121,686	254,742
Towaoc	21-33N-20W	Producing	Ismay	244,008	538,890
Towaoc	21-33N-20W	Producing	Molas	719,595	918,445
Total				18,279,625	44,254,949
Total (CO2)					3,028,887,272

* First field discovery in 1927; first production from this field in 1931.

** CO2 production

County production statistics for Dolores County

Dolores County produced 984,176 MCF of gas and 186,743 BO in 1998 from 27 producing wells. This placed the county 22nd in annual gas and 11th in annual oil production among Colorado's 35 gas-producing and 30 oil-producing counties.

The cumulative production from four producing fields in Dolores County reached 34,198,502 MCF of gas and 6,160,139 BO at the end of 1998. Dolores County was ranked 22nd for cumulative gas production and 18th for cumulative oil production among Colorado's producing counties.

Producing horizons for Dolores County

There are two producing oil and gas horizons in Dolores County, the Ismay Stage and the Desert Creek Stage,

both of which belong to the Pennsylvanian Paradox Formation of the Hermosa Group. The Paradox Formation was deposited during the Desmoinesian Age of the Pennsylvanian Period. At that time, the Paradox Basin existed as a broad, asymmetrical sag oriented northwest-southeast. Repeated marine transgressions and regressions caused the cyclic deposition of various lithologies within the basin. The central portion of the basin was filled with up to 2000 meters of evaporites, both salt and anhydrite, with interstratified black shales known as the Paradox Formation. Concurrently, along the southwest margin of the basin, cyclic algal reef-mound deposits and thin dark shales accumulated in thicknesses up to 700 meters. These carbonate mound buildups and organic rich dolomitic muds resulted from deposition during marine transgressions, while the evaporitic facies characterized regressive phases. The producing formations in Dolores County are found exclusively in the algal mound carbonate facies.

Summary of production by fields in Dolores County

The following table contains the Dolores County oil and gas fields with corresponding general location, current status (producing, shut in, or abandoned), production formation(s), and cumulative oil and gas production at the end of 1998. Significant production for a field is shown in bold type.

Field Name	Section, Township and Range	Status	Producing Formation	CUM OIL (BO)	CUM GAS (MCF)
Papoose Canyon	19-39N-19W	Producing	Desert Creek	5,749,952	30,353,681
Papoose Canyon	19-39N-19W	Abandoned	Hermosa	10,315	52,051
Papoose Canyon	19-39N-19W	Producing	Ismay-Desert Cr.	379,175	1,231,026
Papoose Canyon	19-39N-19W	Producing	Ismay	3,987	1,884,196
Squaw Creek	3-39N-20W	Abandoned	Desert Creek	11,189	24,332
Stone Pony	23-38N-20W	Producing	Ismay	5,500	575,710
Total				6,160,118	34,120,996

Structural and stratigraphic controls on production in Montezuma and Dolores Counties

The present-day structural configuration of Montezuma and Dolores Counties has been shaped by tectonic events ranging from Precambrian through Cenozoic times. Located along the eastern side of the Colorado Plateau, the present-day topography and structure of both surface and subsurface rocks in Montezuma and Dolores counties records a long and complicated history of sedimentation and tectonic activity. The western portions of these counties lie within the Paradox Basin. Deposition of sediments within the Paradox began in Late Cambrian times and continued sporadically until the present with both clastic and marine deposition. Periodic tectonism and uplift removed a significant quantity of both Paleozoic and Mesozoic sediments.

The Paradox Basin is an intercratonic evaporite basin of Pennsylvanian age, but is cored by Lower Paleozoic sediments whose accumulations were controlled by recurrent basement lineaments that bounded the Colorado Plateau. These lineaments controlled Pennsylvanian sedimentation as Precambrian wrench faults were reactivated, causing both uplifted and downdropped blocks. Clastics shed from highlands to the northeast formed fan deltaic deposits on the northeast edge of the basin. Concurrently, the rapidly subsiding Paradox Basin was being filled by cyclic sequences of evaporites, shallow marine carbonates, organic dolomites, and fine-grained siliciclastics. Depositional cycles, present in the thick accumulations of Pennsylvanian sediments, are bounded by recognizable, transgressive black shales that are regionally extensive across the basin.

Sedimentary formations range in age from Cambrian to Holocene. Gas and oil production is derived from strata of Devonian, Mississippian, Pennsylvanian, Permian, Triassic, Jurassic and Cretaceous ages.

Pennsylvanian Carbonate Reservoirs

The Pennsylvanian Hermosa Group Paradox Formation carbonates account for the majority of the hydrocarbon

production in the Paradox Basin. Vuggy limestone and dolomite reservoirs, with porosities ranging from 5% to 20% and net pay thicknesses of up to 50 feet commonly, were developed in algal mounds in association with organic-rich dolomitic shales and mudstones that rimmed the evaporite sequences in the basin. The biohermal carbonate mounds of the Ismay and Desert Creek intervals of the Paradox Formation, in particular, represent deposition during highstand system tracts. These interbedded organic dolomitic shales and mudstones, with up to 5% total organic carbon (TOC), are the source beds for Pennsylvanian oil and gas. These source rocks entered the oil generation window during late Cretaceous to Paleocene time and the gas generation window during Eocene to Oligocene time (Huffman, 1996, p. 3). Pennsylvanian-age structures probably controlled sites of mound-building and Laramide structural events produced structural traps, while facies differentiation created stratigraphic traps components. Seals were formed by impermeable evaporites, carbonates, and shales.

Devonian – Mississippian Carbonate and Clastic Reservoirs

Devonian to Mississippian Elbert and Leadville Formations produce oil from porous sandstones and dolomites or dolomitic limestones respectively. Reservoir thicknesses may be as great as 200 feet with porosities ranging from 5% to 25%. Hydrocarbon generation, sourced from the organic-rich dolomitic shales of the Pennsylvanian Paradox Formation discussed above, began in Permian time and may be continuing even today. Traps exist on uplifted fault blocks adjacent to salt anticlines, and the seals are the Paradox Formation evaporites that either overlay or are in fault contact with the reservoirs (Huffman, 1996, p. 2). Carbon dioxide (CO₂) and helium are also produced from these reservoirs.

Additional reservoirs

There are other reservoirs of varying ages representing a variety of play types that exist in the greater Paradox Basin of Utah. However, for the purposes of the State lands in Colorado, only the major producing reservoirs and accumulation types have been listed above. One new play, however, is worth mentioning because it may eventually impact Colorado. There are reports of gas wells being drilled and completed in the numerous sands that are either in the upper part of the Hermosa Group or in the arkosic sandstones of the Cutler Formation. This information has been confidential; reports of productive zones, rates, and pay thicknesses have not yet been released to the public.

Coal Resources

Coal resources in Dolores and Montezuma Counties are found within the Upper Cretaceous Dakota Sandstone and Menefee Formation. Both counties are within the San Juan River Coal Region. State Land Board tracts in Dolores County lie within the Nucla-Naturita field. Montezuma State Land Board tracts lie within either the Nucla-Naturita field to the north or the Durango field to the south. Although there is currently no active coal mining in either county, several small coal mining operations were active during the late 1800s and early 1900s. Production figures were recorded for 26 known mines in Montezuma County and one mine in Dolores County (Eakins, 1986), but numerous other small mines most certainly contributed to county production. Cumulative production through 1976 is estimated at 74,481 and 139,018 short tons for Dolores and Montezuma Counties, respectively (Borek and Murray, 1979).

Metallic Mineral Resources

Currently, no metal mining is being done in Montezuma or Dolores County, although resources such as uranium, silver, gold, copper, lead, and zinc do exist and have been mined in the past.

Dolores and Montezuma Counties together produced \$47,710,342 worth of silver, gold, copper, lead, and zinc from 1878 to 1958 (Vanderwilt, 1947; Del Rio, 1960). Much of this production was from the Rico District in eastern Dolores County and the La Plata District in eastern Montezuma County. The western part of Dolores County is adjacent to the southern boundary of the Uravan District, which has been the primary producer of uranium in Colorado. Prior to 1970, Dolores and Montezuma Counties produced about one ton of uranium and about ten tons of vanadium, primarily from the area south of the Uravan District (Dolores County) and from the

McElmo Creek District to the south (Montezuma County). In comparison, the Sunday Mine complex in San Miguel County produced more than 200 tons of uranium and 1.3 million tons of vanadium from 1997 to 1999. Colorado did not produce any uranium or vanadium in 2000 due to low commodity prices and increasingly expensive mining costs. Although there are no State Land Board tracts within the mining districts of Dolores and Montezuma Counties, geologic conditions underlying many of the tracts are favorable for metallic reserves. The principal metallic mining districts in Dolores and Montezuma Counties are described below.

The Uravan Mineral Belt is a generally north-striking narrow zone of mineralization adjacent to the Dolores River Valley that extends from near Gateway in Montrose County to Egnar in San Miguel County. Although the southern end of the belt is loosely defined as being in San Miguel County, mineralization extends into Dolores County along the Dolores River as far as Dove Creek. The Barlow Mine (section 10, T. 40 N., R. 10 W.) and the Blue Eagle Mine (section 36, T. 41 N., R. 11 W.) were the most significant producers of uranium and vanadium in Dolores County. In Montezuma County, the Roberta Jean Mine (section 8, T. 38 N., R. 19 W.) was the leading producer of uranium and vanadium. Most of the ore deposits are found in Mesozoic rocks consisting chiefly of sandstone and siltstone. The Salt Wash Member of the Jurassic Morrison Formation contains the most extensive deposits. However, the Brushy Basin Member of the Morrison Formation and the Entrada Sandstone are also known to contain uranium resources (Haynes and others, 1972).

The Rico District is in the eastern part of Dolores County. The district is characterized by a low structural dome of Precambrian to Jurassic rocks that were intruded by Tertiary dikes, sills, and stocks. Faulting subsequent to the Tertiary intrusive event provided channels for circulating thermal waters and served to localize mineralization. Ore is concentrated in veins coincident with, parallel to, or branching from these faults. The Rico District is known to have produced gold, silver, lead, zinc, copper, uranium, vanadium, bismuth, tellurium, manganese, and molybdenum. Total production value from 1879 to 1944 for gold, silver, copper, lead, and zinc is estimated at \$26,279,454 (Vanderwilt, 1947).

The La Plata District in eastern Montezuma County is also known for its gold, silver, lead, zinc, copper, and numerous other metallic minerals production. Like the Rico District, the La Plata District is characterized by a low structural dome consisting of Pennsylvanian to Cretaceous sedimentary rocks intruded by Tertiary rocks then faulted. Veins associated with the faults host the ore deposits. Prior to World War II, the district produced over 2,000,000 ounces of silver and several hundred thousand pounds of lead and copper (Vanderwilt, 1974).

The McElmo Creek, Cross Canyon and Chimney Rock Districts are smaller regions known primarily for their uranium and vanadium production, although other ore metals such as gold, silver, and copper were secondarily produced from these localities. Ore deposits are hosted primarily by Mesozoic sandstone and siltstone deposits. The McElmo Creek District is located around McElmo Dome, about ten miles west of Cortez. The Cross Canyon District is a minor district in northwestern Montezuma County. The Chimney Rock District is about 12 miles south-southwest of Cortez, on the eastern side of U.S. Highway 666.

Industrial Mineral Resources

The most readily available resource in either Montezuma or Dolores County is sand and gravel. Alluvial deposits containing sand and gravel underlie the Dolores River valley and its many tributary drainages. Several of the plateau regions in both counties are overlain by eolian sand. These deposits are used primarily as road base and fill material for local roads and highways. Clean eolian sands are a potential source of silica that may be used in industries such as glass and ceramic manufacturing. Currently there are no active gravel mines in Dolores County. There are six permitted gravel pits in Montezuma County, three near Dolores and three west of Mancos (Lawson, 1998).

The Cretaceous Dakota Sandstone is typically a good source of building stone. It is currently mined at a quarry about three miles east of Cortez in Montezuma County. Dakota Sandstone is also quarried north of Dove Creek in Dolores County. Dakota Sandstone may also be of use to specialized industries requiring high-silica content in their manufacturing processes.

Minor amounts of clay were mined from the Cretaceous Mancos Shale near the town of Dolores in Montezuma County, although it is not clear for what purpose the material was used. Elsewhere in the state, similar clay deposits are used primarily in the manufacture of brick.

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