Blackleaf Canyon

Montana Geology 2009

Madison Limestone

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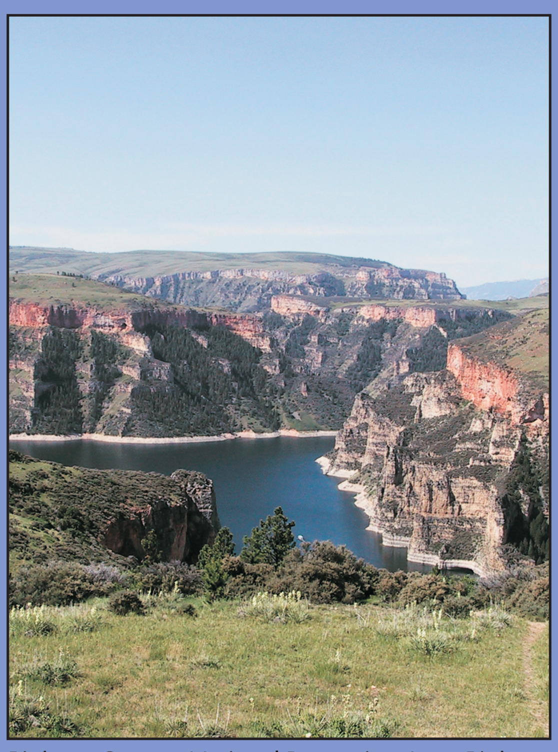

Bighorn Canyon National Recreation Area, Bighorn County; looking south from Pretty Eagle Point. Photo by David Lopez.

Lewis and Clark Caverns State Park, Jefferson County. Photo by Edmond Deal.

Gates of the Mountains, Lewis and Clark County. Photo by Susan Barth.

A natural bridge in Madison Limestone, Mission Canyon of the Little Rocky Mountains, Blaine County. Photo by John Wheaton.

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Madison Limestone in Montana

Traditionally, the Montana Bureau of Mines and Geology calendar has featured the geology of a particular scenic site in Montana. This year we feature a significant rock unit that is important throughout the entire state: the Madison Limestone.

Madison Limestone is composed of several formations, so its formal geologic name is *Madison Group*. The Madison produces some of Montana's most spectacular scenery as mountains, canyons, and caves. In Montana's semi-arid climate the limestone forms resistant peaks such as in the Bighorn, Big Snowy, and Little Belt Mountains, and the prominent ridges of the Rocky Mountain Front near Choteau (large front photo). Gates of the Mountains near Helena, Jefferson Canyon near Cardwell, and Bighorn Canyon near Billings are examples of scenic gorges cut into the relatively resistant limestone by rivers (see small photos on front and fig 1). Caves with exquisite stalactites, stalagmites, and other formations have formed in the limestone in areas such as Lewis and Clark Caverns State Park (photo on front).

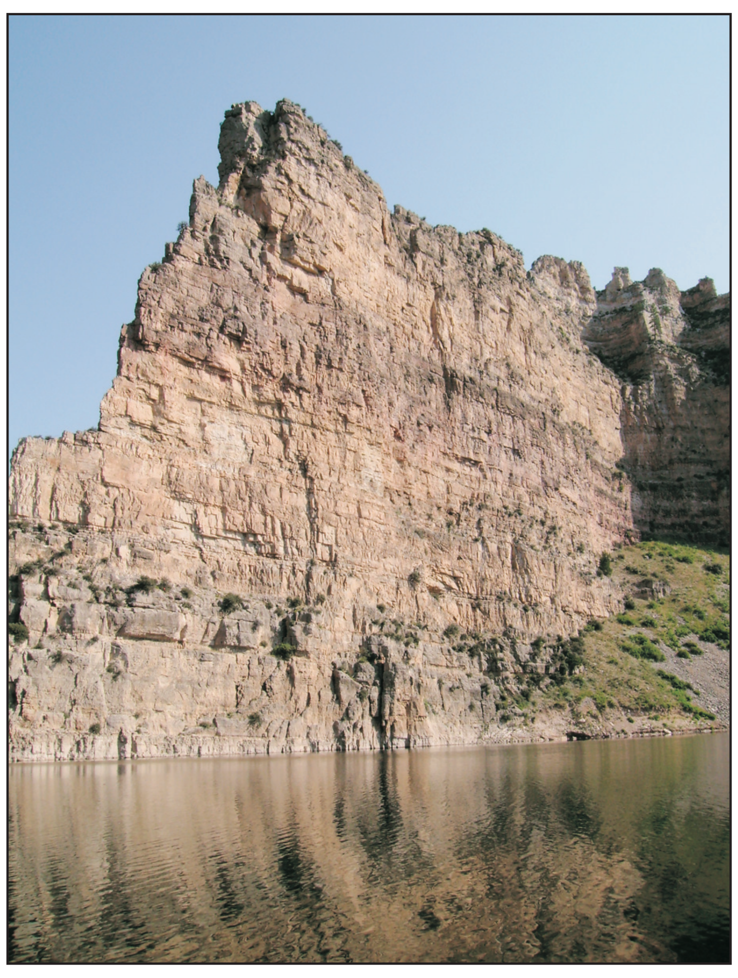


Figure 1. Madison Limestone column, north end of Bighorn Canyon. Photo by Clay Schwartz.

Economic Importance

Madison Limestone is Montana's most important bedrock fresh-water aquifer, hosts numerous oil and gas reservoirs, is a source of limestone ($CaCO_3$) for cement and aggregate for concrete and construction, and locally hosts numerous deposits of economically significant metals such as gold, zinc, lead, and tungsten (fig. 2).

Figure 2. Graymont's Indian Creek lime plant near Townsend produces lime that supplies customers in Montana and several other western states. All cement and lime production in Montana is sourced from rocks of the Madison Group. In particular, the thick beds of the Mission Canyon Limestone are a significant source of high-purity limestone. Photo by Robin McCulloch.

The Madison's prominence as an aquifer and underground reservoir is a result of the excellent porosity and permeability present in many areas. Holes in the limestone are its porosity; the interconnections between those spaces provide permeability, which allows fluids to move through the rock. Some of that porosity and permeability were created as the components of the limestone were deposited, but much developed long after the deposits became rock. Carbon dioxide in shallow ground water dissolves limestone, creating voids ranging from pinholes to large caverns.

Permeability in the Madison can be extraordinary. For example, water that enters Madison Limestone outcrops in the northern Little Belt Mountains travels into the subsurface for great distances underground, well into Canada. Along the way cracks in the overlying rock allow it to reach the surface as springs, such as at Giant Springs State Park (fig. 3). There are many other areas where surface water drains into Madison outcrops and recharges the shallow subsurface with abundant, high-quality ground water, making it Montana's most valuable and reliable bedrock aquifer.

Figure 3. Upwelling water ripples the pool at Giant Springs, Great Falls, Montana. Water escaping from the Madison Limestone 300 feet below the surface moves upward through nearly vertical fractures and discharges to the Missouri River at about 300 cubic feet per second (~135,000 gallons per minute). Photo by Tom Patton.

Oil and gas are produced from porous and permeable zones originally present in rocks such as reef deposits, as well as those originating from secondary processes. In 2007, Montana had 2,650 oil and gas wells that produced from reservoirs in the Madison Group. Total production from these wells for the year was ~2.9 million barrels of oil and ~1.5 billion cubic feet of natural gas (data from the Montana Board of Oil and Gas Conservation).

Recent trends and technology changes are generating new interest in the Madison Limestone. Current investigations include its potential for permanently storing carbon dioxide to keep that greenhouse gas from reaching the atmosphere, and as a "battery" for wind-generated electricity by storing compressed air that could later turn turbines to generate electricity as needed. It also has considerable geothermal potential. In eastern Montana the Madison is deeply buried (fig. 4) and water quality is generally not acceptable for potable use, but water temperatures over vast areas are warm, and locally are hotter than most near-surface natural hot springs in Montana.

Acknowledgments

Front photo: Blackleaf Canyon (Rocky Mountain Front, north of Choteau) by Chuck Haney. Other photos by MBMG staff David Lopez, Edmond Deal, Susan Barth, John Wheaton, Clay Schwartz, Robin McCulloch, and Tom Patton. Paleogeographic maps courtesy of Ron Blakey, Northern Arizona University Geology. Cross section adapted from the Geologic Atlas of the Rocky Mountain Region, Rocky Mountain Association of Geologists. Calendar text and map by MBMG staff. Layout and editing by Susan Barth and Susan Smith.

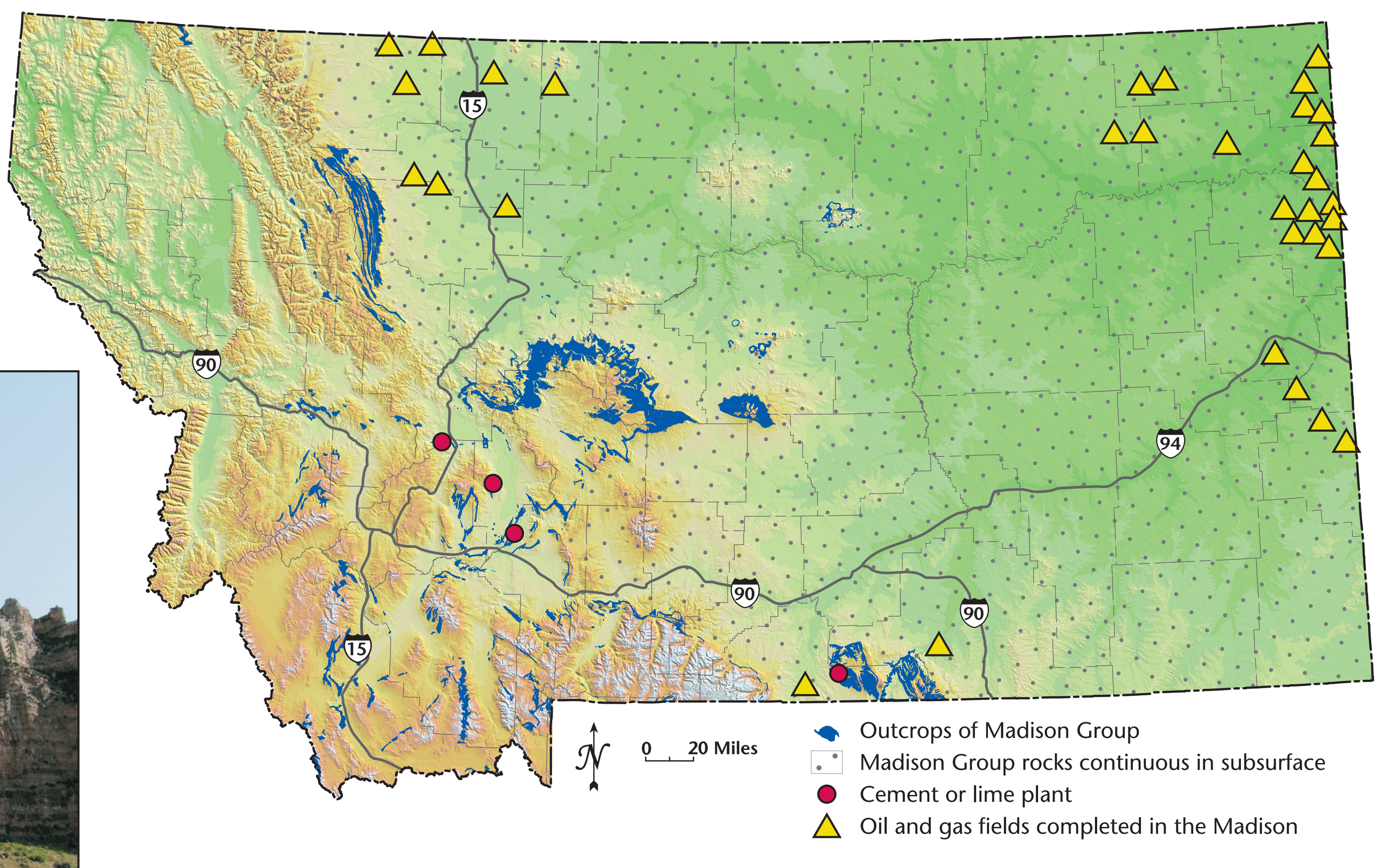


Figure 4. The Madison Limestone crops out widely in the mountains of western and central Montana. East of these outcrops, it is usually present but buried beneath younger rocks. Madison outcrops are locally mined for both metals and industrial minerals, and those along the flanks of mountains are recharged by surface water. In the subsurface, the Madison offers resources as an aquifer, a hydrocarbon trap, low-grade geothermal potential, and fluid storage.

Deposition of Madison Limestone

Seas advanced into and retreated from Montana repeatedly throughout geologic time. The Madison Limestone was deposited during one of those cycles between about 360 and 320 million years ago in the Mississippian geologic time period, when much of the United States was submerged (fig. 5). As the sea spread across the continent, mud, sand, and silt initially dominated the sediments that accumulated on the sea floor, but with time the supplies of mud and sand decreased and carbonate deposits dominated. Marine animals thrived in the seawater that advanced into the area. Shells and other hard body parts from animals such as clams, brachiopods, crinoids, and corals accumulated along with calcite "mud" that precipitated from the seawater to form great thicknesses of limestone that commonly contains abundant fossils. In Montana the Mississippian limestones accumulated across the entire state, locally reaching a thickness of more than 1000 feet. When the sea withdrew temporarily from Montana, it left behind many shallow, restricted bodies of water in which chemical precipitates such as gypsum formed. Upon exposure to erosion, most of the precipitates dissolved and cavernous topography developed on the limestone. Younger sediments, commonly including abundant amounts of red mud, were eventually deposited on this erosional surface and now stain outcrops of the underlying gray limestone.

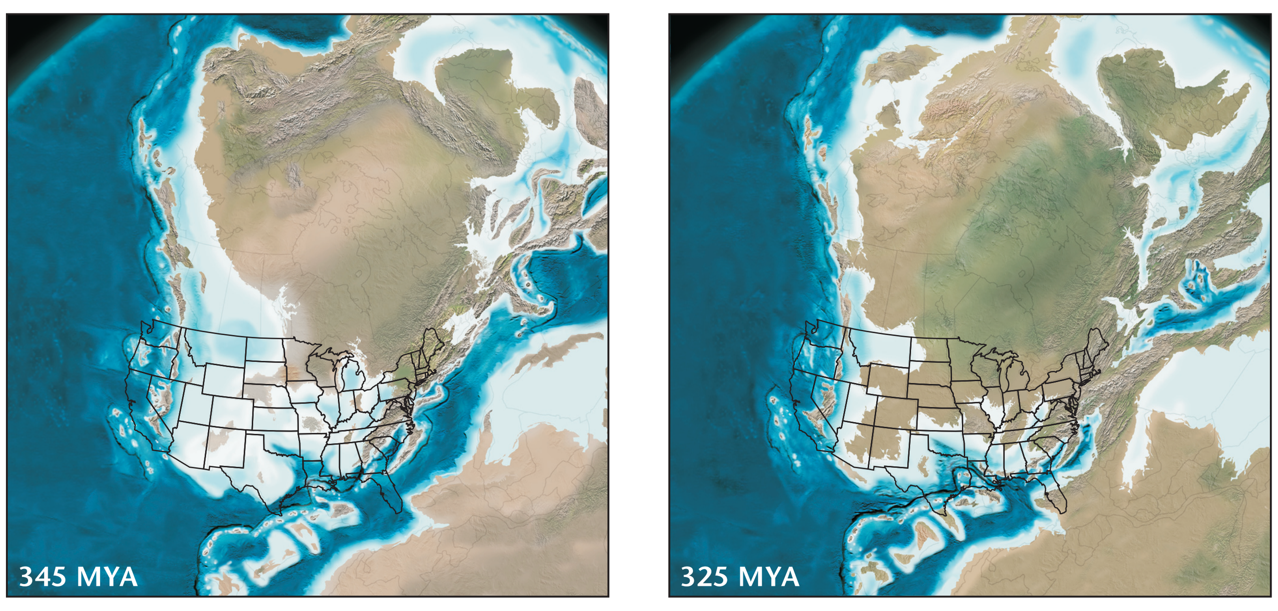
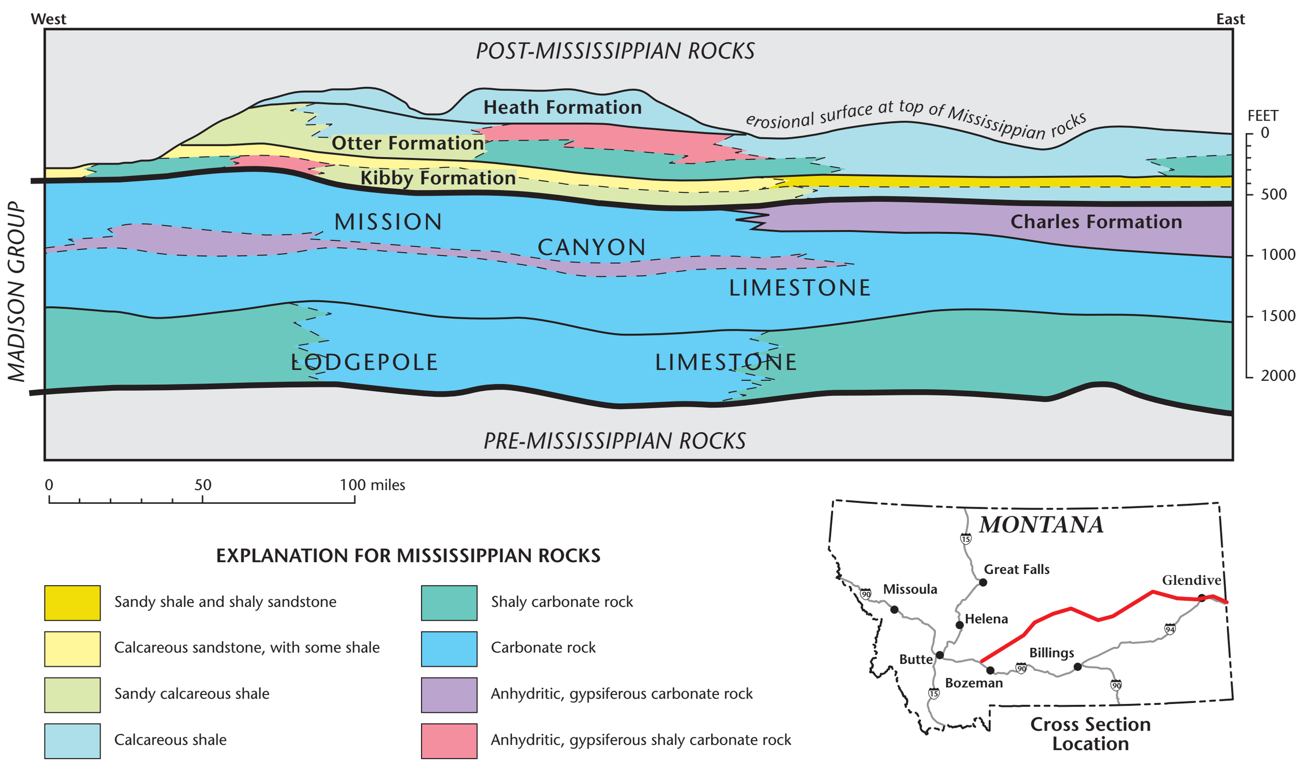


Figure 5. Oceans covered most of the U.S. during the early part of the Mississippian Period (345 million years ago), but 20 million years later shorelines had receded, exposing most of the central and Rocky Mountain regions. Nearly all of Montana remained covered by ocean waters throughout the Mississippian. Maps used with permission from Ron Blakey, Northern Arizona University Geology.

The Mississippian limestones are not unique to Montana. They were deposited widely across the western and central United States, but geologists in other states sometimes applied different names to these rocks. In Colorado it is the Leadville Limestone; in parts of South Dakota it is known as the Pahasapa Limestone; and in the Grand Canyon of Arizona the Redwall Limestone forms sheer cliffs 400–500 feet high. Even the well-known Salem Limestone, quarried in Indiana and used to build the Washington Monument and other prominent buildings, was deposited in the Mississippian seas.



STRATIGRAPHIC SECTION THROUGH MISSISSIPPIAN ROCKS IN MONTANA

Figure 6. Well logs reveal compositional differences in subsurface rocks that reflect changes through time and geographical area. High-purity carbonate rocks accumulated in open ocean waters with limited sediment input from streams; anhydrite and gypsum were deposited in a highly saline environment having restricted circulation, such as lagoons; and in near-shore environments wave energy winnowed sedimentary particles by size, leaving the sand grains behind and the finer muds deposited in deeper water as shales. Cross section modified with permission from the Geologic Atlas of the Rocky Mountain Region, Rocky Mountain Association of Geologists, 1972.

Fundamental to Montana's Land and Economy

Where exposed, the Madison Limestone may form majestic mountain peaks, ridges, and massive cliffs, but in much of Montana it is buried below the surface. Although it is out of sight, it is even more valuable there for the water and mineral resources it contains, or for uses yet to be developed. Some recent ideas such as storing carbon dioxide in the Madison Limestone would not have been considered just a few years ago. Who knows what other new uses we will find for this ancient limestone deposit?

Montana Bureau of Mines and Geology

Montana Tech of The University of Montana

Scope and Organization

The Montana Bureau of Mines and Geology (MBMG) was established in 1919 as a public service agency and research entity for the State of Montana, to conduct and publish investigations of Montana geology, including mineral and fuel resources, geologic mapping, and ground-water quality and quantity. In accordance with the enabling act, the MBMG conducts research and provides information but has no regulatory functions.

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