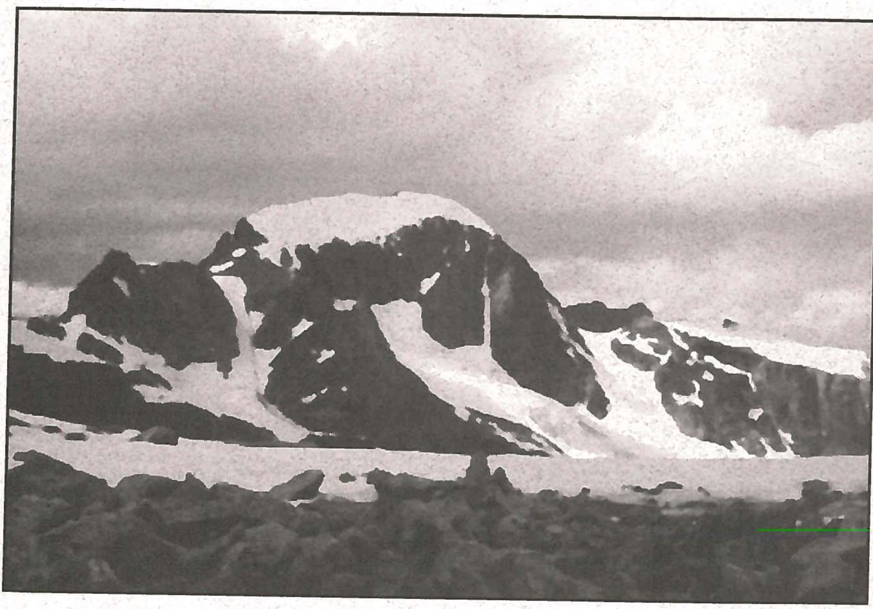
WYOMING STATE GEOLOGICAL SURVEY
Lance Cook, State Geologist

GEOLOGY OF WYOMING

by
Gary B. Glass
and
D.L. Blackstone, Jr.



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The Wyoming State Geological Survey
P.O. Box 3008
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PHONE: (307) 766-2286 Email: sales@wsgs.uwyo.edu
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Cover Photograph: Gannett Peak, at 13,804 feet above sea level, is the highest peak in Wyoming. View is from the top of Dinwoody Pass (photograph by Dianna Gentry, 1983).

Geology of Wyoming

When visitors first see Wyoming's vast prairies and mountain ranges, their interest is normally attracted to the spectacular views, the open space, the accompanying wildlife, and the sparse vegetation. Often, little if any thought is given to the geologic history that has produced much of what they are seeing. The State's present landscape is the product of a long series of events reaching back in geologic time almost to the inception of the earth as a planet and continuing to the present.

Scientists can determine the ages of rocks by measuring the radioactive decay of particular elements in the rocks. In Wyoming, the oldest dated rocks are certain granites and granite gneisses, which occur in the cores of the larger mountain ranges and are at least 2.8 billion years old. Relatively little, however, is known about these most ancient rocks.

The better documented geologic history of Wyoming dates back about 570 million years, to a time when sedimentary layers covered the ancient granite. The relationship of sediments overlying crystalline rocks is clearly evident around the margins of the mountains where erosion has exposed the interface between these rock units. The sedimentary layers are distinguishable from each other because they have different color, texture, and mineral composition, and because they often contain different assemblages of fossils (the preserved remains of animals and plants that lived during the time these rocks were deposited).

To understand the origin of the landforms in Wyoming, one must accept the fact that the Earth's crust, which is some 22 miles thick and composed of dense, crystalline igneous and metamorphic rocks, subsided relative to sea level for a long period of time. While Wyoming was below sea level, several thousand feet of relatively flat-lying sedimentary rock accumulated below the oceanic waters or along the shoreline areas.

Using the erosional surface that separates underlying Precambrian rocks from overlying sedimentary rocks as a datum plane, the following events can be deduced. The greatest subsidence below sea level occurred in western Wyoming, as evidenced by the 30,000 feet of sediment that accumulated in a north-south-trending trough since the beginning of Cambrian time. A broad area east of this trough on a shelf adjacent to the deeper water areas received much less sediment, perhaps 10,000 feet, during the same time interval. Throughout this long period of time, there were minor upward and downward oscillations of the crust, but the principal activity in

GEOLOGIC TIME SCALE

TIME[1]	ERA	PERIOD		SOME MINERAL RESOURCES IN WYOMING[2]
0	CENOZOIC	Quaternary	Holocene	Sand and gravel, placer gold, travertine, sulfur, diatomite, clinker, sodium sulfate, epsomite.
1.6			Pleistocene	
5.3			Pliocene	Diatomite, pumicite, agate.
23.7			Miocene	Agate.
36.6			Oligocene	Copper-molybdenum porphyries, paleoplacer gold.
57.8			Eocene	Uranium, coal, trona, oil shale, zeolites, gold paleoplacers, rare earths, fluorite, thorium, copper-molybdenum porphyries.
66.4			Paleocene	Uranium, coal, natural gas.
144	MESOZOIC	Cretaceous		Oil and gas, coal, bentonite, silica sand, titaniferous black sandstone paleoplacers, uranium.
208		Jurassic		Gypsum, oil and gas, silica sand, copper-silver-zinc.
245		Triassic		Gypsum, oil and gas.
286	PALEOZOIC	Permian		Phosphate rock and associated vanadium, oil and gas, gypsum.
320		Pennsylvanian		Limestone, oil and gas, silica sand, copper.
360		Mississippian		Limestone, oil and gas (including helium and carbon dioxide), hematitic quartzites ("Rawlins red").
408		Devonian		Limestone, oil and gas, diamond-bearing kimberlites.
438		Silurian		
505		Ordovician		Oil and natural gas, dolomite, and limestone.
570		Cambrian		Silica sand; paleoplacer gold, thorium, and rare earths; oil reservoir rocks.
				Major unconformity
2,500	PRECAMBRIAN	PROTEROZOIC[3]		Anorthosite. Gold, copper, platinum. Copper and gold. Volcanogenic copper-silver-zinc. Tantulum- and niobium-bearing mafic dikes. Gold-bearing quartz veins. Copper-bearing quartzite. Uranium paleoplacers. Railroad ballast from quartzofeldspathic rocks and metadolomites. Hematite iron ore (probable Proterozoic age).
4,600		ARCHEAN[3]		Pegmatites containing beryl, lepidolite, feldspar, and copper sulfides. Jade, sapphires, rubies. Banded magnetite iron formation. Uranium paleoplacers. Gold-bearing veins and shears. Talc and asbestos.

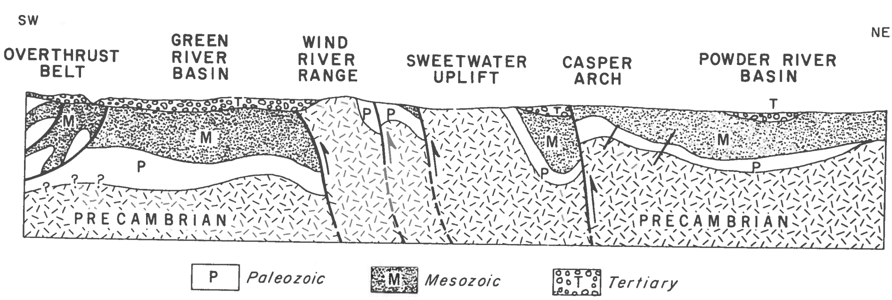
[1] In millions of years before present (from Geological Society of America 1983 Geologic time scale).
[2] In addition, in different areas of Wyoming, rocks of nearly all ages act as aquifers for ground water.
[3] Resources not necessarily in chronological order.

Wyoming was subsidence and accumulation of sediments. Wyoming was last at or near sea level during the close of the Cretaceous Period approximately 66 million years ago.

The geological time chart of Wyoming (facing page) is complete with names depicting the time intervals and their relative positions to each other. A few radiometrically determined dates, in millions of years, are shown to indicate the total time expanse of the calendar as well as the age of certain important geological events. Wyoming is very fortunate in having at least some geological evidence of events that happened during each time period.

In addition, the age relationships of some of Wyoming's important mineral resources are shown.

CROSS SECTION AT CLOSE OF MARINE CRETACEOUS



STRUCTURAL CROSS SECTION OF WYOMING TODAY

These diagrammatic cross sections show the development of structures across Wyoming. The upper diagram is a southwest-northeast cross section through Wyoming at the close of the Cretaceous Period (about 66 million years ago). The lower diagram is a cross section of the same area after the episode of mountain building that followed the Cretaceous Period, and in a broad way, this lower diagram reflects the present configuration of the crust.

Today, most of the sedimentary rock units have been tilted from their originally horizontal positions by large scale crustal movements described under the terms *diastrophism* and *tectonic activity*. A major period of crustal activity began in the Late Cretaceous and has continued intermittently until the present. This crustal unrest warped and fractured the crust and the overlying sediments, outlining the mountain ranges and basins and establishing the geologic framework that we see today.

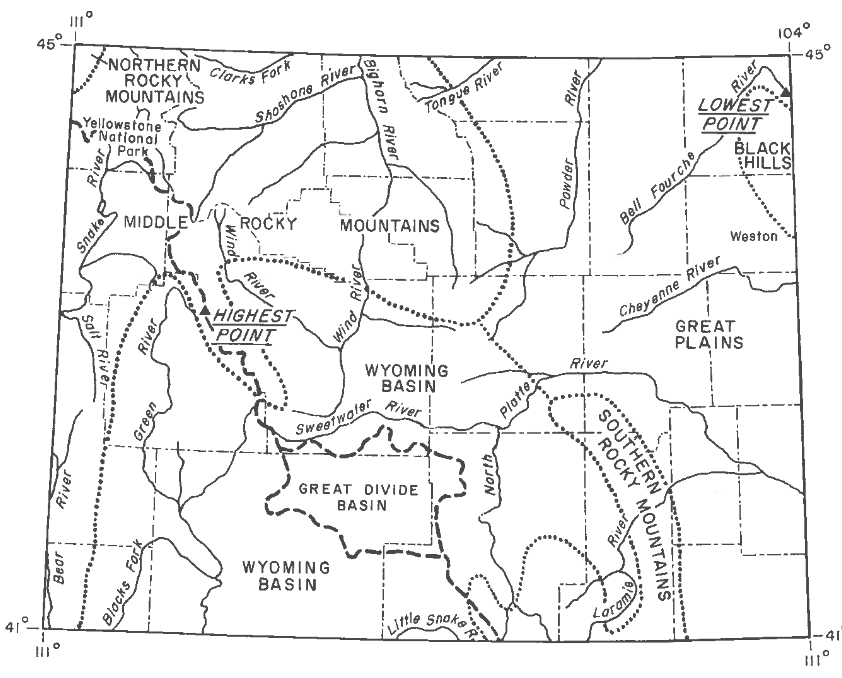
This episode of mountain building elevated the rocks above sea level and, together with further elevation in late Tertiary time, provided the necessary stream gradients whereby the streams of the region could proceed to dissect the rocks into the existing landforms. The major event that ultimately governed the position of most larger streams in Wyoming was the accumulation of a vast sheet of younger sedimentary rocks in the basin areas, climaxed by a widespread sheet of volcanically-derived fine-grained sediments. The major streams developed on this aggraded surface. Later,

Map of major drainages in Wyoming.

as these streams cut downward, their courses were locked into the harder underlying rocks and, as a result, such great canyons as the Wind River, the Bighorn, and the Platte evolved.

As a result of this geologic history, Wyoming is now divisible into three major physiographic categories: mountains, the Great Plains of eastern Wyoming, and basins. The landscape and underlying geology of features in each of these categories are very different.

In most of Wyoming's mountainous areas, the difference of elevation is in part due to uplift of large segments of the Earth's crust in the form of folds



EXPLANATION

·········· Generalized boundary of major physiographic province

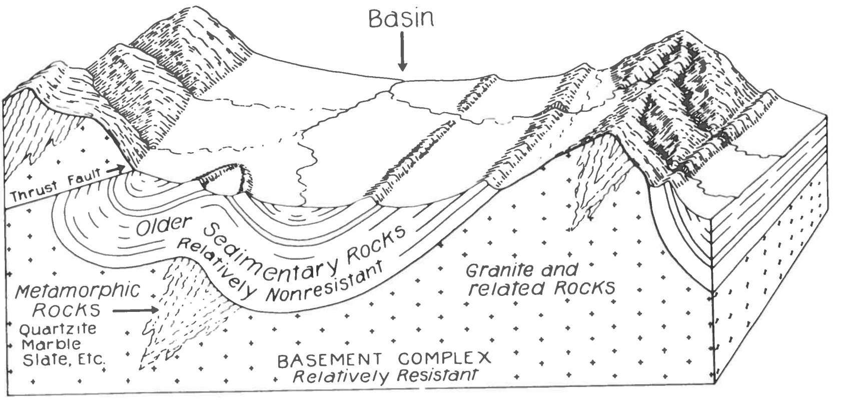
– – – – Continental Divide

–·–·–·– County boundary

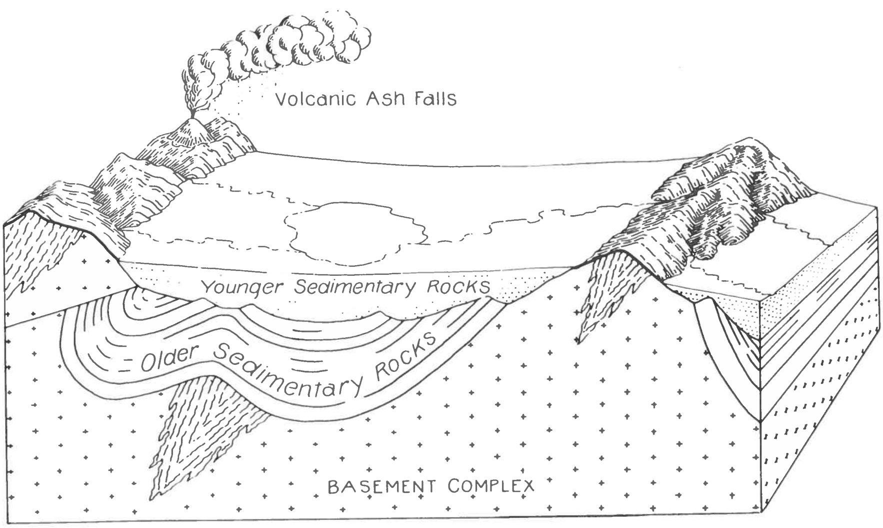
▲ Highest and lowest elevations in the state

Physiographic provinces of Wyoming. Major drainages, the Continental Divide, and the highest and lowest points in the State are shown.

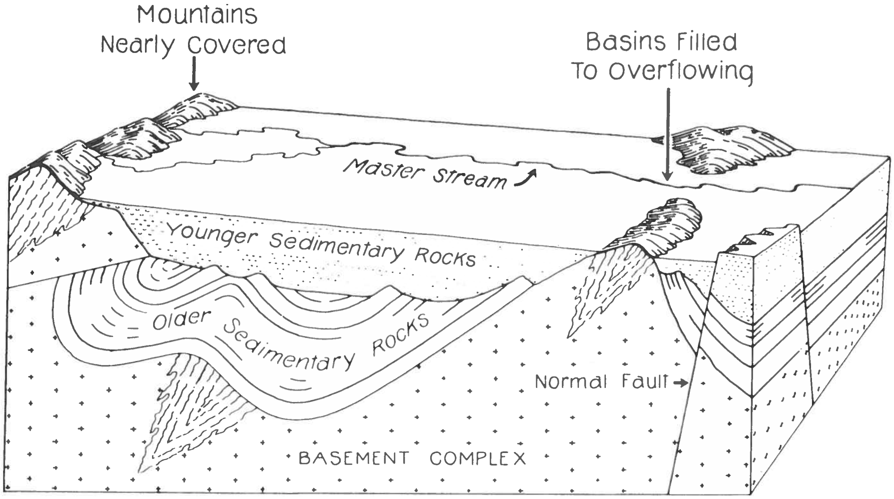
To illustrate the evolution of a typical Wyoming landscape, the late Dr. S.H. Knight, former Wyoming State Geologist and Professor of Geology at the University of Wyoming, prepared these four block diagrams.



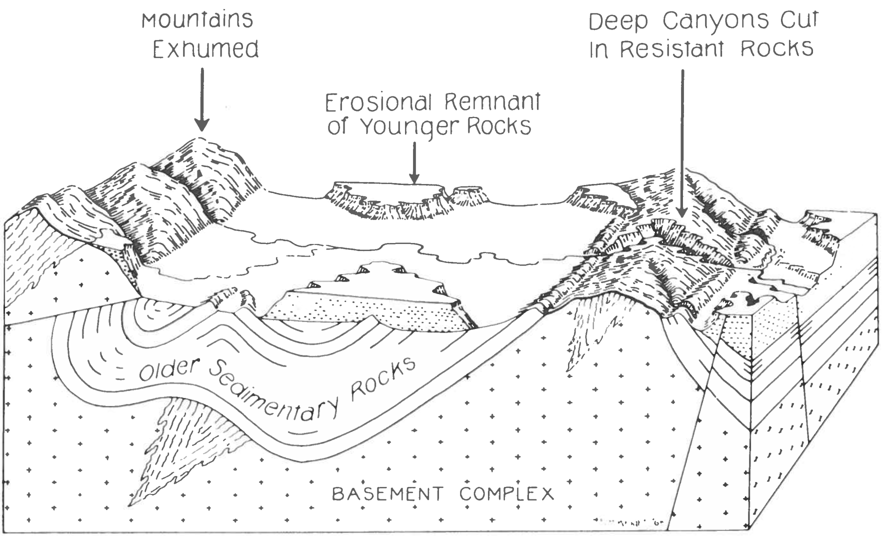
Stage I. Mountains and basins formed by folding and faulting. Extensively modified by erosion.



Stage 2. Basins partially filled with younger sediments derived from adjacent mountains and intermittent volcanic ash falls.



Stage 3. Basins filled to overflowing at low places on divides, followed by regional uplift with tilting and faulting. Present master streams developed on rejuvenated surfaces.



Stage 4. Present cycle of erosion - basins partially excavated. Youthful canyons cut across resistant cores of mountains. Basin floors are lowered as canyons are deepened.

or wrinkles, or blocks bounded by fractures, or a combination of both. Most of Wyoming's larger mountain ranges also have an exposed core of very ancient Precambrian metamorphic and igneous rocks.

The frequently asked question, "How old are the mountains?" may be answered in two ways. We might consider that the age of the oldest rocks exposed to the elements and in the process of being eroded is the age of the mountains. In another sense we might consider the time elapsed since the rocks were elevated so that they began to be carved by erosion.

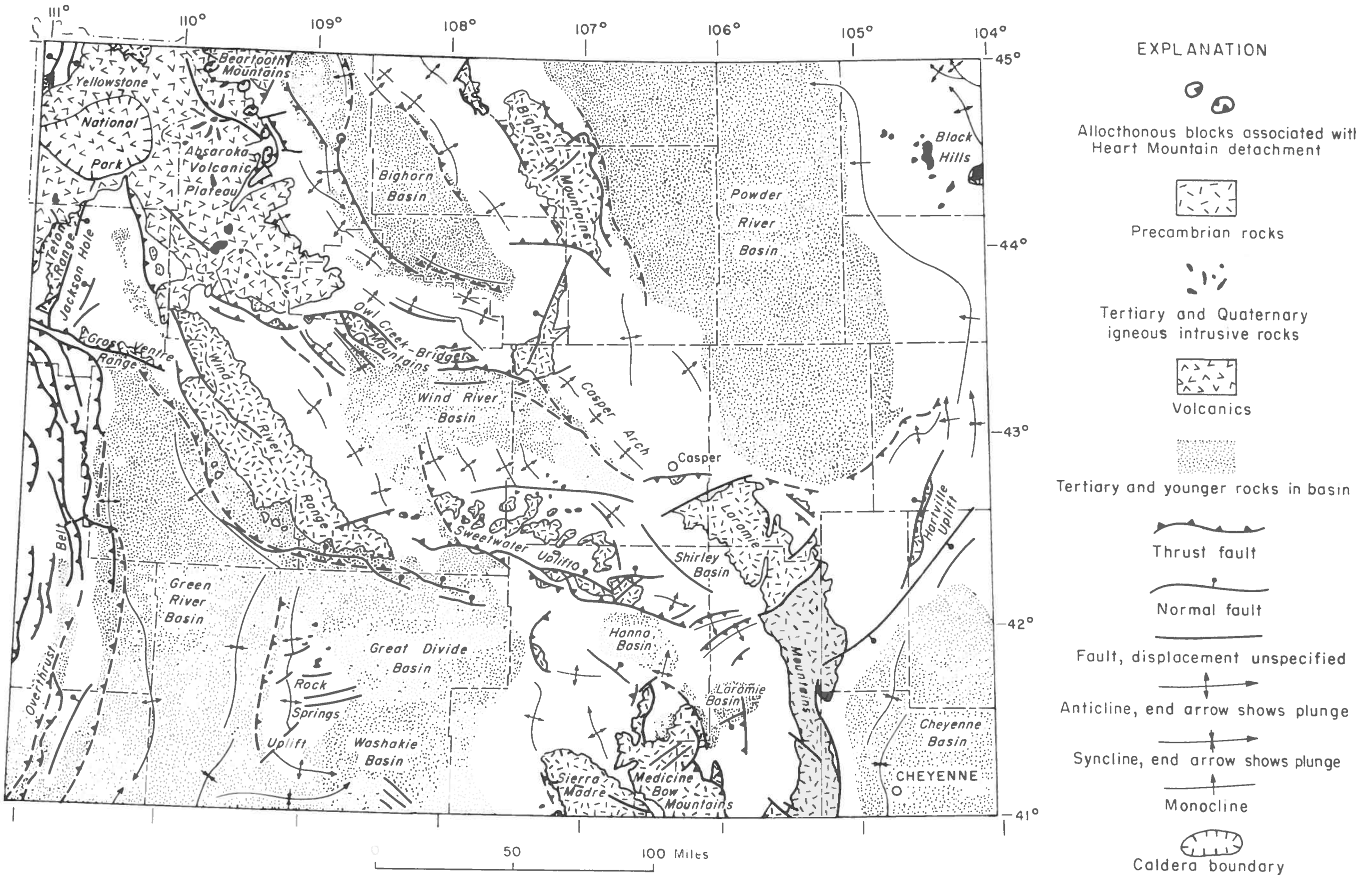
Most mountains in Wyoming were elevated about 60 million years ago, which is quite recent by geologic standards, since the oldest rocks in the cores of these mountains are about 2.8 billion years old.

The Teton Mountain range, which rises with spectacular grandeur from the floor of Jackson Hole, is a medium sized but unique mountain range. The bold east front, which stands above the glacial lakes at the base, is a result of intermittent but major movement of more than 20,000 feet on a steeply inclined fracture plane that slopes to the east. The rugged mountain peaks have been carved from the elevated segment of the crust. Glacial processes have produced the matterhorns and U-shaped valleys that are the characteristic landforms.

The Tetons are extremely young by geologic standards, having attained their height less than 10 million years ago. This fact places them among the youngest ranges in the Rocky Mountains. Numerous minor earthquakes within historic time in Jackson Hole attest to the fact that these mountains may still be growing.

Although the high Yellowstone Plateau and Absaroka Range of northwestern Wyoming present a mountainous terrain, these areas are remnants of a plateau that coincided with the top of a vast pile of nearly horizontal sheets of rock materials derived from nearby volcanic vents in the Yellowstone area. Once the pile of volcanic debris had accumulated, the region was subjected to the ever present forces of erosion, which cut deep valleys. The mountains are those of erosion - the deep dissection of relatively flat-lying rock layers - and are a classic example of this type of development.

Even now the Yellowstone Plateau is a thermally and seismically active area with molten rock perhaps no more than 1.9 miles beneath the surface in some places. While the geysers of Yellowstone also attest to the relatively shallow thermal activity beneath the plateau, researchers have documented recent uplift of portions of the Yellowstone Caldera (remnants of a large



Map of major structural elements in Wyoming.

volcano), rising at rates up to 15 millimeters per year. The most recent volcanic activity on the plateau, however, has been dated at 600,000 years before the present.

Scenically, the basins of Wyoming are less satisfying than the other two geologic provinces, and some persons may feel that the long, rather monotonous vistas of low buttes and mesas and sparse vegetation are like a lost world. A trip across the basins during the heat of the day in August can be a less than exciting experience, but if the same trip is made in early morning or early evening, the landscape has a very different appearance. At these times of the day, low-level lighting can accentuate the landscape and make it very beautiful.

Despite the rather limited vegetative cover, the wide lonesome stretches of Wyoming's basins provide pasturage for a large number of cattle, sheep, and wildlife, particularly in the winter months when snow melt provides water for animals.

Viewed from a geological perspective, these same basins are much more stimulating than some of the uplifts, and are just as profound in terms of the movements of the Earth's crust. In fact, the amount of down folding of the crust usually exceeds the uplift of the adjacent mountains if sea level is used as a datum. The basins, which are surface topographic depressions, are at the same time compound downfolds in which the layered sedimentary rocks dip toward the lowest point or trough. Many of the exciting aspects of these downwarps are hidden from the eye because they lie at great depths.

In terms of economics and natural resources, Wyoming would not be as prosperous without the raw materials that exist in the rocks of these basins (see page 2). Along the basin margins, the sedimentary strata often crop out in hogbacks, exposing limestone, gypsum, bentonite, phosphate rock, and building stone. Farther out in the basin, at the surface, one finds some of the great coal fields of Wyoming and uranium deposits. The rock units that extend under the basins at depth act as the reservoirs for oil and gas accumulations. Special rocks such as trona and oil shale are found in the central part of one of the basins (Green River Basin).

A discussion of Wyoming's geology would not be complete without elaborating on the treasure house of valuable minerals and rocks located in the State. Wyoming is perhaps best known for its abundance of energy minerals. Vast reserves of oil, natural gas, coal, and uranium underlie many areas of the State. Wyoming's nearly 1,000 oil and gas fields account for more than 100 million barrels of oil and more than 700 billion cubic feet of natural gas each year. With this production, the State ranks 6th in the Nation and first in the Rocky Mountain area. Recent oil and gas activity in Wyoming's Overthrust Belt makes that area one of the largest and most active new discoveries in the lower forty-eight states. The State's petroleum industry is also producing large quantities of helium and carbon dioxide as well as by-product sulfur from sour-gas processing plants.

The State is also fortunate in having twenty-five percent of the Nation's coal resources, or more than one trillion tons of coal. From this resource, coal companies mine more than 165 million tons of coal each year, ranking Wyoming first in coal production since 1988. More than 83 percent of Wyoming's coal production comes from Campbell County in northeastern Wyoming's Powder River Basin. All this Campbell County production comes from mines on the Wyodak coal bed, which is the thickest coal mined in the United States. This bed is 50 to 110 feet thick where it is mined.

Although Wyoming's annual uranium production has declined substantially, the State is still a major uranium-producing state. In addition to these actively mined energy resources, Wyoming has a vast untapped resource of oil shale beneath the Green River and Washakie Basins of southwestern Wyoming.

Wyoming's mineral wealth does not stop at energy resources. The largest known trona resource in the world is found in the Green River Basin of southwestern Wyoming. Trona is a naturally occurring hydrated sodium carbonate and sodium bicarbonate used to produce industrial soda ash. Soda ash is vitally important in the glass, paper, soap, petroleum-refining, and textile industries. Baking soda is also a product of soda ash. Presently, five underground trona mines in Wyoming produce approximately 15 million tons of trona a year. Trona from these mines supplies more than 90 percent of the Nation's demand for soda ash. Soda ash is also exported to a number of countries.

Wyoming is also the leading producer of bentonite, which is a commercial term used for valuable expanding clays. When mixed with water, Wyoming bentonites expand up to 15 times their dry volume. This unique clay is very useful in drilling muds used by the petroleum industry, for pelletizing taconite in the iron ore industry, and for binding foundry sands.

Limestone, gypsum, crushed rock, jade, sand, gravel, and some placer gold are also mined in Wyoming. There are a host of other valuable mineral resources that occur in Wyoming. These include copper, iron ore, silica sand, molybdenum, feldspar, phosphate rock, anorthosite (an aluminumrich rock), and diamond to name a few. Although the first seven of these mineral resources have been mined in the past, the economic value of Wyoming's diamond occurrences is still under evaluation.

The diversity of Wyoming's mineral resources constitutes one of the State's greatest long-term economic assets. Few other states have such a variety of presently or potentially economic resources with which to adjust to changing market demand.

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