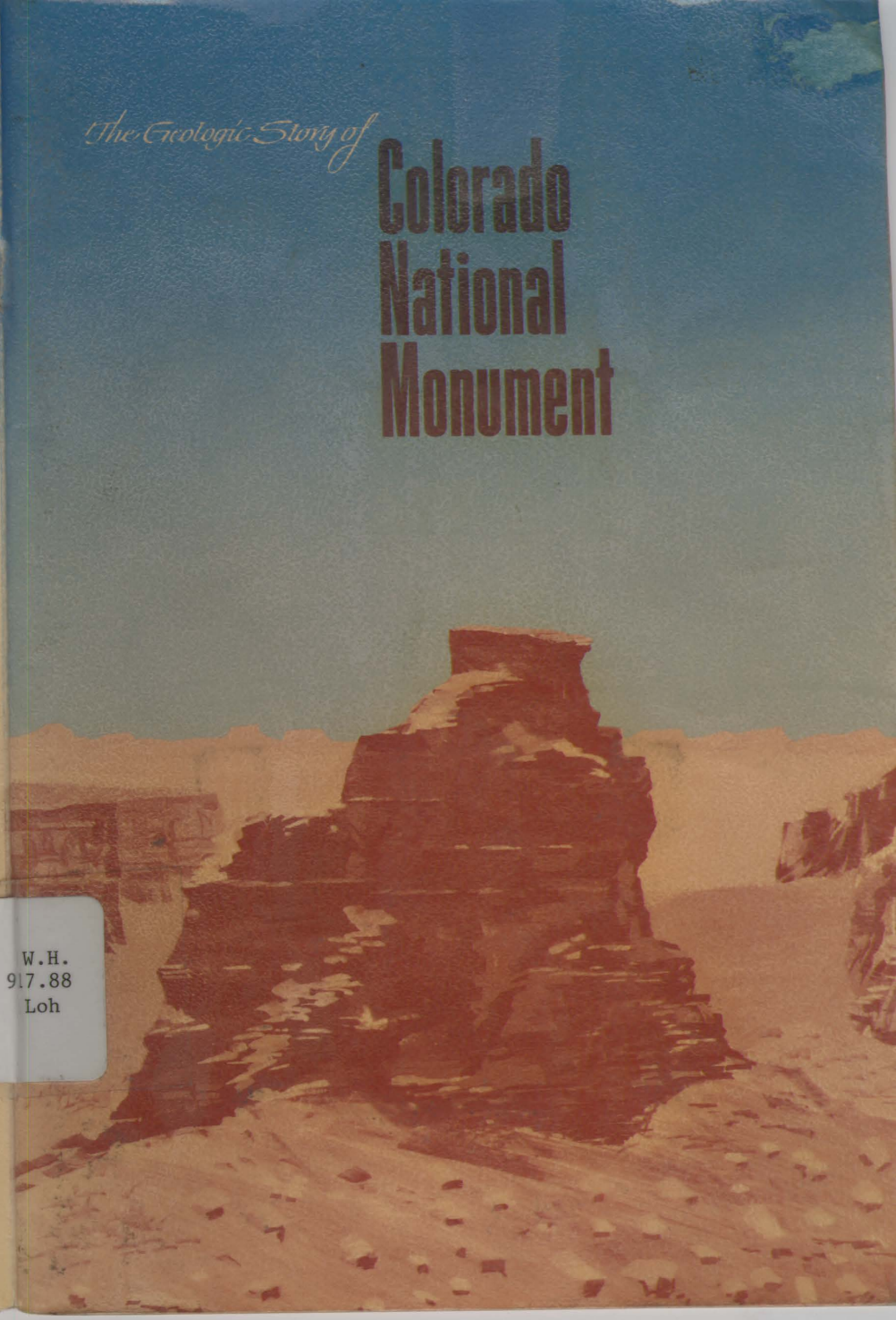
The Geologic Story of

Colorado National Monument



The Geologic Story of

Colorado National Monument

BY S. W. LOHMAN
U. S. GEOLOGICAL SURVEY

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The Colorado and Black Canyon Natural History Association is a nonprofit organization which assists the National Park Service in the development of a broad public understanding of the geology, plant and animal life, history, and related subjects pertaining to Black Canyon of the Gunnison and Colorado National Monuments.

It aids in the development of museums and wayside exhibits, offers publications on natural history for sale to the public, and cooperates with the Government in the interest of Black Canyon and Colorado National Monuments.

Contents

Independence Monument. *Infrared photo.*

Introduction

COLORADO NATIONAL MONUMENT IS A LAND of brightly colored cliff-walled canyons and towering monoliths – a majestic sample of mysterious canyonlands that stretch hundreds of miles to the west and south. Now a desert region more than a mile above the sea, it was not always so. More than a billion years ago the site of the Monument was deep beneath the sea. Later, lofty mountains were pushed up only to be obliterated eventually by the slow but relentless forces of erosion. Much later the earth shook to the stride of 10-ton dinosaurs – then the sea returned again and sharks swam over the region looking for food.

These are but a few samples of the interesting – even exciting – events in the long geologic history of the Monument. Many pages, indeed several whole chapters, of its history are missing and must be inferred from other regions where the story is more nearly complete. Thus the cliffs and canyons you are looking at did not get that way overnight. An understanding of the geologic processes and events that led to the scenic features of today should help you toward a clearer picture and greater appreciation of nature's handiworks.

Geologists have divided the United States into many provinces, each of which has distinctive geologic and topographic characteristics. Colorado National Monument is in the northeastern part of the Colorado Plateaus Province, which is referred to in this publication simply as the Colorado Plateau. This large, interesting province extends from Rifle, Colo. at the northeast to a little beyond Flagstaff, Ariz., at the southwest, and from Cedar City, Utah at the west nearly to Albuquerque, N. Mex., at the southeast.

In a later section, mention is made that fossils have been found in several of the rock formations in and near the Monument. Fossils, minerals, or rock specimens may not be collected in or removed from the Monument without prior written permission of the superintendent. However, few fossils have been found *in* the Monument – most of them come from the Redlands district between the Monument and the Colorado River.

I am indebted to many colleagues on the staffs of the U. S. Geological Survey and National Park Service, to friends of various ages and interests, and to my own family for reading all or parts of the manuscript and for material help in keeping the presentation clear and non-technical.

This account is dedicated to my wife, Ruth, and to my sons Bill, Terry, and Bob.

S. W. Lohman

ILLUSTRATIONS

Photographs by author unless otherwise credited.

The following by U. S. Geological Survey personnel:

Marginal sketches by John R. Stacy

Bird's-eye view of the Monument (in back pocket) by Fred A. Hostetler

Map of the Monument, rock column, and main kinds of rock folds by Robert H. Reilly

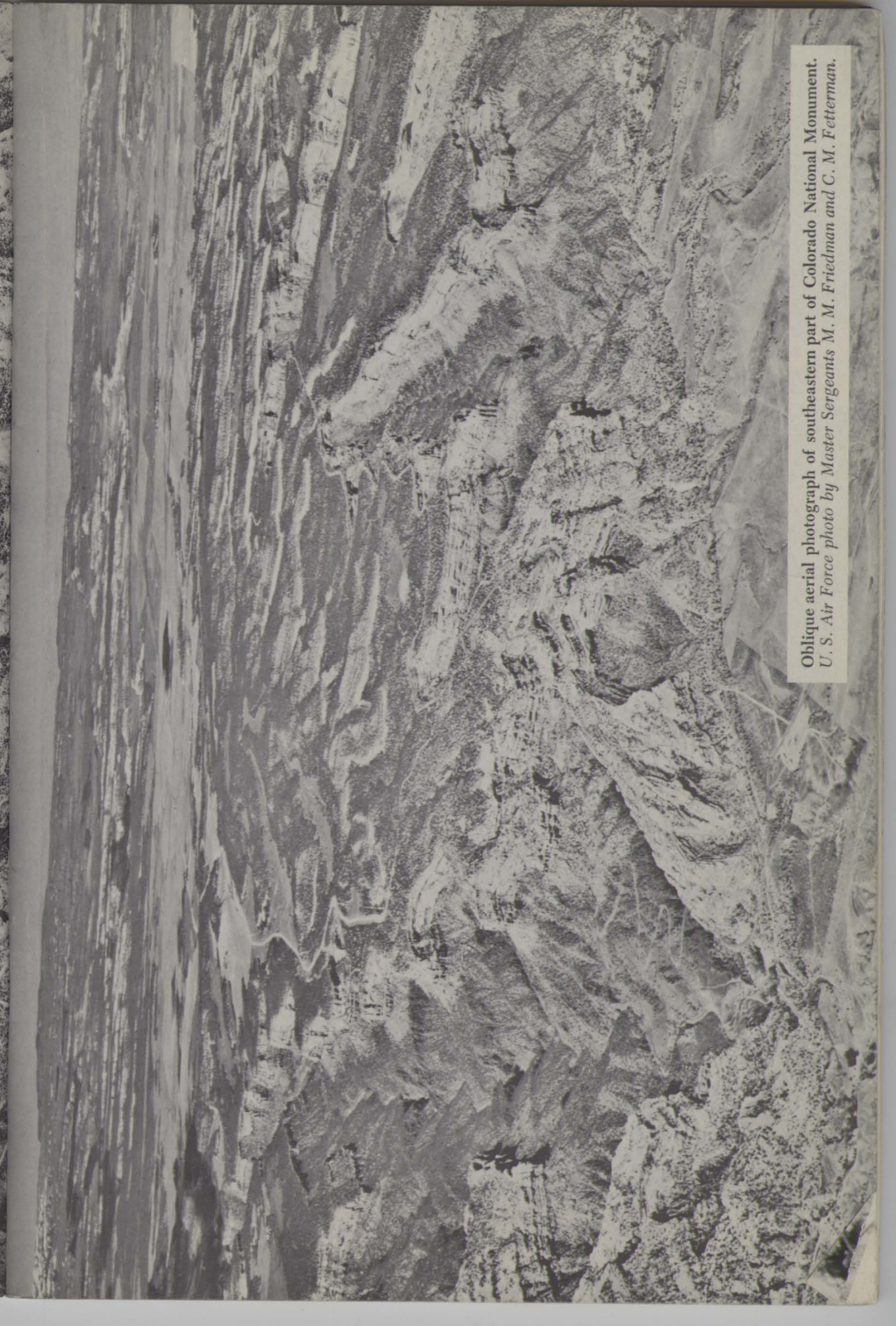
History of the Monument

THE STORY OF HOW COLORADO NATIONAL MONUMENT came into being is as colorful as the canyons and cliffs themselves. The fantastic canyon country had a magical attraction for John Otto who, in 1906, camped near the mouth of what is now called the east entrance of Monument Canyon and began building trails into the canyons and onto the mesas – the high tablelands that separate the deep canyons. He did this back-breaking work simply because he wanted to and so that others could share the beauty of this wild country.

In 1907, Otto got the Grand Junction Chamber of Commerce to petition Secretary of the Interior James A. Garfield to set aside the area as a National Monument. Otto's dream came true on May 24, 1911, when President William Howard Taft signed the proclamation creating the Monument. Shortly after that, Otto climbed to the top of Independence Monument where he placed the Stars and Stripes to celebrate Independence Day. The steps and holes he cut for climbing can still be seen and are used occasionally by a few fearless climbers of this 450-foot sandstone pinnacle.

Until about 1921 the only routes into the Monument proper were John Otto's trails, but in that year the ranchers of Glade Park joined with Otto in building the steep, twisting Serpents Trail from No Thoroughfare Canyon to the mesa above – a much shorter route to Grand Junction. It had 54 switchbacks and climbed about 1,500 feet in 2½ miles. The Serpents Trail was included in the Monument in 1933 and was used until 1950 when an easier route was built up the west side of No Thoroughfare Canyon and through a tunnel to the top of the mesa.

Monument Canyon. *U. S. Soil Conservation Service photo.*



Oblique aerial photograph of southeastern part of Colorado National Monument. *U. S. Air Force photo by Master Sergeants M. M. Friedman and C. M. Fetterman.*

Tunnel in Wingate Sandstone near top of No Thoroughfare Canyon entrance. *Photo by John R. Stacy.*

Construction of the scenic Rim Rock Drive through the Monument was begun by the National Park Service about 1931, and the drive eventually was completed to join roads from Fruita and Grand Junction. The route from Fruita includes a winding road up Fruita Canyon and through two tunnels to the mesa.

The Monument originally included 13,749 acres, but later boundary changes increased the total to 17,606 acres, or nearly 28 square miles.

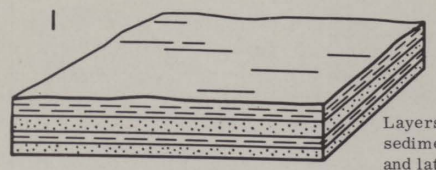
LOOK ALMOST ANYWHERE IN THE Monument and you will see that the rocks are piled up in layers of different color, thickness, and hardness – much like a vast layer cake. In most of the Monument, these layers are flat or slope gently down to the northeast, but along the northeastern boundary they are sharply bent or broken as though the cake had been carelessly placed over the edge of a table and had sagged.

Let us consider these layers one by one, beginning with the oldest at the bottom, for each is a partial record of events long past. Layers of rock that can be easily recognized and distinguished from other layers are called formations, and are named after a place where they are well exposed and first described. The places after which the sedimentary formations of the Monument were named are given in the rock column illustrated on page 9. Geologic formations include some very soft rocks such as shale or hardened mud.

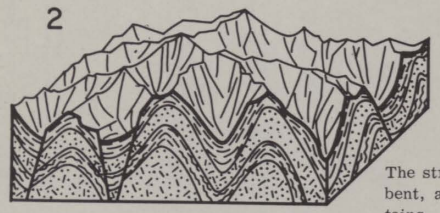
Oblique aerial photograph of northwestern part of Colorado National Monument.
U. S. Air Force photo by Master Sergeants M. M. Friedman and C. M. Fetterman.

AGE (millions of years)	GEOLOGIC AGE	NAME OF ROCK FORMATION	KIND OF ROCK AND HOW IT IS SCULPTURED BY EROSION	THICKNESS (feet)	NAMED FOR OCCURRENCE AT OR NEAR
100	LATE CRETACEOUS	MANCOS SHALE	Gray and black shale, and thin beds of sandstone and limestone. Contains sea shells. Eroded from Monument, but underlies Grand Valley and forms lower part of Book Cliffs.	3,800	MANCOS, COLO.
		DAKOTA SANDSTONE	Coaly shale, sandstone, conglomerate, and lignite coal. Contains plant remains. Forms benches and slopes. Caps highest hill in Monument.	150	DAKOTA, NEBR.
125	EARLY CRETACEOUS	BURRO CANYON FORMATION	*EROSIONAL UNCONFORMITY* — Green siltstone and shale, and sandstone and conglomerate. Forms benches and slopes. Crops out on highest hill in Monument.	60	BURRO CANYON SAN MIGUEL CO., COLO.
150	LATE JURASSIC	MORRISON FORMATION	Brightly colored siltstone and mudstone, and sandstone and limestone. Contains dinosaur bones and fresh-water shells. Forms slopes and badlands.	600	MORRISON, COLO.
		SUMMERVILLE FORMATION	Brightly colored siltstone and mudstone, and thin sandstones. Forms slopes.	54	SUMMERVILLE POINT SAN RAFAEL SWELL, UTAH
		ENTRADA SANDSTONE	White and salmon-red sandstone. Upper level-bedded part forms stair steps, lower mostly cross-bedded part forms cliffs.	150	ENTRADA POINT SAN RAFAEL SWELL, UTAH
175	JURASSIC AND TRIASSIC(?) (missing)		*EROSIONAL UNCONFORMITY*		
	LATE TRIASSIC(?)	KAYENTA FORMATION	Red and purple siltstone and shale, and sandstone and conglomerate. Forms bench between two cliffs and mesas between canyons.	45–80	KAYENTA, ARIZ.
200	LATE TRIASSIC	WINGATE SANDSTONE	Buff and light red sandstone. Cross-bedded and level-bedded. Forms highest cliffs and most of named rock features in Monument.	350	FT. WINGATE NEW MEX.
		CHINLE FORMATION	Red siltstone and shale, and some limestone conglomerate. Forms steep slopes at foot of cliffs.	80–100	CHINLE VALLEY N. E. ARIZ.
230–1000	TRIASSIC, PALEOZOIC, YOUNGER PRECAMBRIAN (missing)		*GREAT UNCONFORMITY*		
1,500	OLDER PRECAMBRIAN	UNNAMED	Schist, gneiss, granite, and pegmatite dikes. Floors main canyons and forms high bluff above the Redlands.	UNKNOWN	

ROCK COLUMN OF THE MONUMENT



Layers of sand, mud, and other sediment accumulated in the sea and later were hardened into sedimentary rocks.



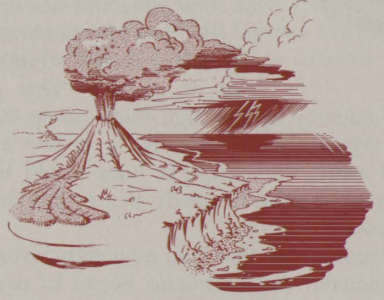
The strata were compressed, bent, and uplifted into high mountains. Heat and pressure at great depth changed the sediments into banded schist and gneiss.

Molten rock flowed upward along cracks or faults. Upon cooling it formed lava at the surface and granite or pegmatite beneath.

During eons of time the forces of erosion wore down the mountains to a nearly level plain.

Block diagram of early Precambrian events *(after Edwin D. McKee).*

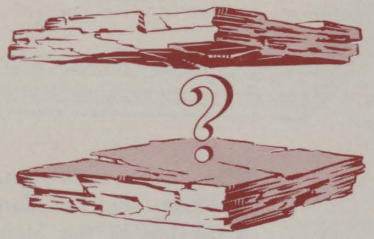
ANCIENT ROCKS AND EVENTS



THE DARK ROCKS THAT FLOOR all the large canyons of the Monument and form the high bluffs along the northeastern boundary are of early Precambrian age – among the oldest known rocks of the earth. Most were once sand, mud, and other sediment that piled up in the sea and later hardened into sedimentary rocks. After thousands of feet of such rocks had accumulated, they were squeezed, bent, and lifted up by slow but mighty movements of the earth's crust to form high mountains like the Rockies. Heat and pressure that developed at great depth in the roots of these mountains changed the sedimentary rocks into types known as schist (finely banded) and gneiss (coarsely banded). Rocks changed in this way are called metamorphic.

Later in Precambrian time, molten material from below was forced upward along cracks or faults and cooled slowly to form thin seams or dikes and irregular bodies of granite. Rocks that once were molten are known as igneous. Dikes that contain large crystals of pink feldspar, white or clear quartz, black tourmaline, and large flakes of white mica are called pegmatite. Small pegmatite dikes pass through the older schist and gneiss along roadcuts in Fruita and No Thoroughfare Canyons.

A GREAT GAP IN THE ROCK RECORD



IF YOU LOOK DOWN INTO any of the large canyons in the Monument, you will notice a brick-red formation, which forms steep slopes at the foot of the high cliffs and lies upon the dark Precambrian rocks along nearly straight lines of contact. This is particularly well shown about midway up the high bluffs along the northeastern boundary of the Monument. If the red layer and all overlying rocks were stripped away, these straight lines would be the exposed edges of a remarkably smooth, nearly flat surface on top of the dark Precambrian rocks.

After the old rocks were squeezed up into high mountains, what became of them? From the moment the mountains began to rise, their rocks were buffeted by wind, pounded by rain, pried open by frost, scoured by debris-laden streams and, perhaps, by glaciers, and the loosened rock particles were dissolved or carried to the sea. Most rocks are brittle enough to crack when bent by earth forces. Such cracks, called joints, are easy targets for erosion. The freezing of water in joints tends to pry the rocks apart. Their breakup was hastened by the chemical attack on rock minerals by water charged with oxygen and carbon dioxide. When land plants became established in later geologic eras, soil acids formed from decaying vegetation also assisted materially in breaking up the rocks.

These same erosion processes are going on today, but their effects are scarcely noticeable from year to year except in soft earth after storms or floods. During eons of time, however, the mountains were worn down to a nearly level plain.

But the story is not quite so simple. Missing between the red and dark layers are many thousands of feet of rocks, some of which once covered this surface and still occur in other regions less affected by erosion. This gap in the rock record, which represents more than a billion years, is known to geologists as an unconformity. Missing are later Precambrian rocks, all those of the Paleozoic Era, and part of those of the Mesozoic Era.

Traces of primitive life have been found in some Precambrian rocks in the form of lime-secreting algae and casts of worms, but no fossils of more advanced types have been found because at that time the primitive animals seemingly had not yet developed shells or skeletons. The ensuing Paleozoic Era saw the appearance and great development of shellfish, fish, amphibians, reptiles, and primitive plants.

Some of the rock layers of ages missing at the Monument may be seen as near as Glenwood Springs to the northeast and Gateway to the southwest. Rocks probably were deposited in the Monument during this long interval but were subsequently stripped off, along with much of the dark Precambrian rock, late in the Paleozoic when the earth's crust again became restless and another mountain range was formed and exposed to erosion.

The Age of Reptiles

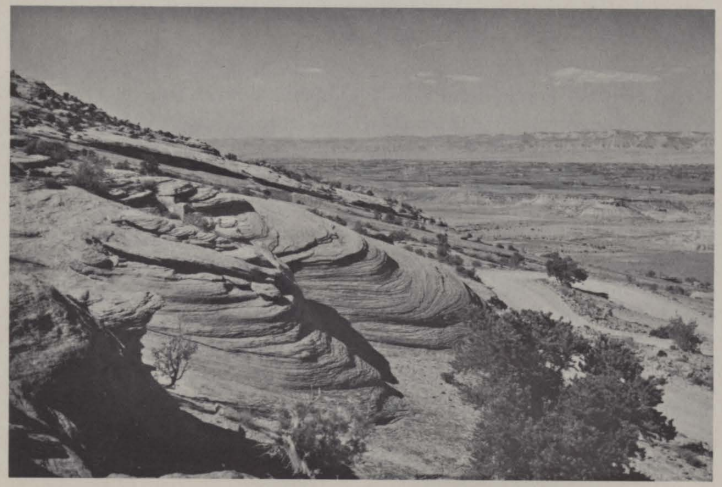
ALL THE LAYERS OF SEDIMENTARY rocks in the Monument above the dark Precambrian were deposited by wind and water during the Mesozoic Era. This long era has been called the Age of Reptiles, for reptiles, including dinosaurs (meaning terrible lizards), were then the dominant land animals. The Mesozoic Era, like ancient Gaul, has been divided into three parts – the Triassic, Jurassic, and Cretaceous Periods. Rocks of each of these periods crop out in the Monument.

EARLY LANDSCAPE

BY LATE TRIASSIC TIME the Monument was part of a nearly flat plain, but there were hills or low mountains just to the northeast. Streams from these hills dropped silt and mud on this plain and into many small lakes. Later these deposits gradually hardened into the red siltstone and shale of the Chinle Formation, which is about 100 feet thick. The red color of this formation and of some of the overlying rocks is caused by small amounts of iron oxide – the same pigment used in rouge and red barn paint.

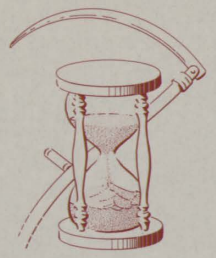
Because it is soft, the Chinle is easily eroded into steep slopes at the foot of high sandstone cliffs in all canyons of the Monument and on top of the high bluffs that face the Redlands. It also forms the broad base of Independence Monument. Rim Rock Drive crosses the Chinle three times in the lower part of Fruita Canyon and twice in No Thoroughfare Canyon.

Fossil reptile bones, petrified wood, and fresh-water shells come from the Chinle in parts of Arizona and Utah. Reptiles probably roamed the Monument in Chinle time, but their remains have not been reported. But fossils may be found in it someday – perhaps you will find the first one!



Petrified sand dunes. Wingate Sandstone along old Serpents Trail.

ANCIENT SAND DUNES



STILL LATER IN THE TRIASSIC PERIOD the Monument became part of a vast desert. Winds blowing from the northwest brought great quantities of fine sand and piled them up into large dunes like those in the Sahara Desert or in Great Sand Dunes National Monument in Colorado. But, like all deserts, it was not always dry – occasional rainstorms produced many small lakes and ponds. Some of the sand was washed into these lakes or ponds and settled in level layers. This huge sandpile eventually hardened into the buff and light-red sandstone that we now know as the Wingate. The shapes of the old dunes are indicated by the steep dips of sand layers, called cross beds, which stand out in sharp contrast to the nearly level layers formed in the lakes and ponds.

The spectacular scenery of Colorado National Monument owes its existence to the 350-foot cliffs of the Wingate Sandstone. Many of the cliff walls are vertical – some even overhang. Eroded remnants of the Wingate form most of the named rock features of the Monument. The bird's-eye view of the Monument (in pocket inside back cover) clearly shows these and other features.

Red Canyon.

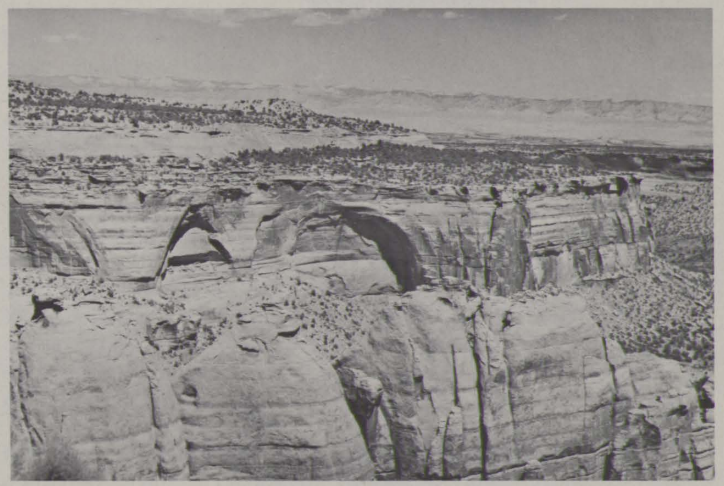
Ute Canyon.

Independence Monument – a towering slab of sandstone that resembles a bridge pier – is all that is left of a high narrow wall that once connected Independence View with the high mesa north of the slab and which once separated east and north entrances of Monument Canyon. In a few thousand years this remnant, too, may be gone.

Vertical cliffs and shafts of the Wingate Sandstone endure only where the top of the formation is capped by beds of the next younger rock unit – the Kayenta Formation. The Kayenta is much more resistant than the Wingate, so even a few feet of the Kayenta, such as cap Independence Monument, protect the rock beneath. Once this cap has been eroded away, the underlying Wingate is weathered into rounded domes, such as the Coke Ovens and Balanced Rock.

Cold Shivers Point – a toadstool shaped cap of sandstone of the Kayenta above a vertical cliff of the Wingate – is perhaps the most aptly titled feature of the Monument.

The Coke Ovens and Squaw Fingers were formed partly because most of the caprock of Kayenta has been weathered away and also because the brittle rocks were cracked along an evenly spaced set of vertical joints. These joints trend northward between the two named features. More rapid weathering along these joints helped form the separate rounded domes or spires between them.



The Coke Ovens. Note the arches in the middle background and the piñon- and juniper-covered slope between the cliffs of the Wingate below and the Entrada Sandstone above.

Similarly, northwestward-trending vertical joints connect and helped shape the Kissing Couple, Pipe Organ, and Sentinel Spire.

Arches or shallow caves weathered out of some cliff faces of the Wingate, particularly where the underlying Chinle Formation has been partly scoured away. Although there are no large caves within the Monument, there are three in a row along the road 3 miles west of the Glade Park Post Office. One of these was inhabited until 1958.

Many of the cliff faces of the Wingate are darkened or blackened by desert varnish – a natural pigment of iron and manganese oxides.

Dinosaurs left their footprints in the sands of the Wingate in parts of the Colorado Plateau, but no tracks or fossils have yet been found in this formation in or near the Monument.

THE RAINS CAME

THE ARID CLIMATE OF WINGATE time was followed by a wet period, when streams from the northeast gradually covered the sand dunes with mud, sand, and some gravel. The sand and gravel of the stream channels were cemented into sandstone and conglomerate, and the mud of the flood plains hardened into red and purple siltstone and shale. The resulting Kayenta Formation makes up the bench between two cliffs upon which the Monument headquarters and most of scenic Rim Rock Drive were built. Here nature was kind, for this gently sloping bench was an ideal place to build the road from which to look down into the deep chasms. The Kayenta also caps the broad mesas between the canyons. It is only 45 to 80 feet thick in the Monument, but is about 350 feet thick in eastern Utah.

The Kayenta has yielded fossil bones of dinosaurs and other reptiles in northeastern Arizona and fresh-water shells in eastern Utah. As yet, however, no fossils have been reported from it in or near the Monument.

Balanced Rock. *Photo by John R. Stacy.*

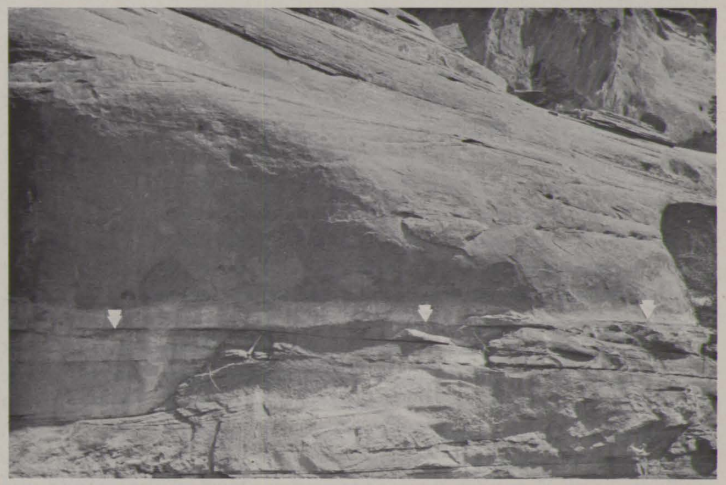
Cold Shivers Point. *Photo by John R. Stacy.*

BIGGER AND BETTER SAND DUNES

ONCE AGAIN THE COLORADO PLATEAU became a desert, and this time the dry climate persisted from probably the Late Triassic into the Jurassic. The howling winds piled up enormous sand dunes, layer upon layer, to a total thickness of 2,000 feet at Zion National Park and as much as 500 feet in eastern Utah and parts of southwestern Colorado. This immense sandpile eventually was cemented into the Navajo Sandstone.

Beautifully sculptured remains of the Navajo are featured at Zion National Park and at Capitol Reef, Rainbow Bridge, Navajo, and Dinosaur National Monuments, and can be seen in many other parts of the Colorado Plateau.

This sandstone extends to within about 35 miles southwest of Colorado National Monument, but the Navajo and a considerable thickness of younger deposits are missing in and near the Monument. Thus we have another gap in the rock record marking the absence from the Monument of much of the Kayenta, all the Navajo and



A gap in the rock record between the Kayenta Formation below and the Entrada Sandstone above. Geologist's pick and white arrows point to the old erosion surface.

overlying Carmel Formation, and part of the Entrada Sandstone. Some of the rocks now missing probably were deposited and later stripped off so that in the Monument the top of the Kayenta is another erosion surface. This old surface is clearly visible in many places along the cliff wall on the southwest side of Rim Rock Drive between the visitor center and Kissing Couple.

Because of this gap in the rock record of the Monument, we will continue our story farther west where it is more nearly complete.

THE SEA TO THE WEST

IN MIDDLE JURASSIC TIME THE LAND now called central Utah sank beneath an arm of the sea that came in from the north, and the area remained beneath this sea until Late Jurassic time. Sediment carried into this sea and into bordering lagoons by streams later hardened into the sedimentary rocks of the Carmel Formation, Entrada Sandstone, and Curtis and Summerville Formations. This sea probably did not quite reach the Monument, but some of the formations were laid down close to it, either on its eastern beaches or in lagoons near the eastern coast.

On the eastern shore of this sea, sand dunes were piled up by winds blowing from the northeast. Occasional rainy spells created lakes and ponds in which some of the sand was deposited in level beds. This pile of sand later hardened into the lower cliff-forming part of the Entrada Sandstone, which looks something like the Wingate, but is generally only half as thick, weathers into less abrupt cliffs, is mostly salmon-red, and is almost free of joints.

The upper part of the Entrada is a white level-bedded sandstone which generally weathers into stairsteps or benches but in some places forms cliffs. It appears to consist of hardened beach or lagoon sand which was deposited along the eastern shore of the sea.

The Entrada Sandstone forms a line of cliffs and isolated rock forms that are second in height and grandeur only to those of the Wingate. It is best displayed southwest of Rim Rock Drive between the visitor center and the Coke Ovens and along the western arm of Ute Canyon. It also forms the Saddlehorn just south of the camp and picnic grounds near the visitor center. Most of the smooth cliff faces show both the steeply dipping crossbeds of the old sand dunes and the flat-lying beds of the lake or pond deposits.

Entrada Sandstone along the western arm of Ute Canyon.

Shortly before the Jurassic sea to the west dried up, silt, mud, and some sand were carried into either a shallow arm of it or a broad bay or lagoon near it, and later hardened to become the Summerville Formation. The Summerville is only 50 to 60 feet thick in the Monument but is much thicker in Utah.

The Summerville Formation is so soft that it weathers very rapidly and hence is exposed at only a few places. It is best displayed in the high roadcut at Artist Point and along the road to the south for the next mile. In this exposure even the thinnest beds can be traced for hundreds of yards, and individual beds have a nearly constant thickness for such distances. Thin sedimentary beds of such uniform thickness are thought to have accumulated in relatively quiet bodies of water. If you look at the underside of some of the blocks of hard light-gray sandstone that have broken off, you may see corrugations like those on some metal barn roofs. These are ripplemarks produced by wave or current action while the sand was still loose, indicating that the water was not always entirely quiet. Although much of the Summerville is red, you will see beds of many other colors including gray, blue gray, greenish gray, chocolate brown, and reddish brown.

The Summerville is exposed also in roadcuts along the upper part of the west arm of Ute Canyon. Your chances of finding any fossils in this formation are pretty slim. You will have a much better chance below the Monument in the overlying Morrison Formation.

Summerville Formation at Artist Point. Camera case is 7½ inches high.

DINOSAURS ROAM THE MONUMENT

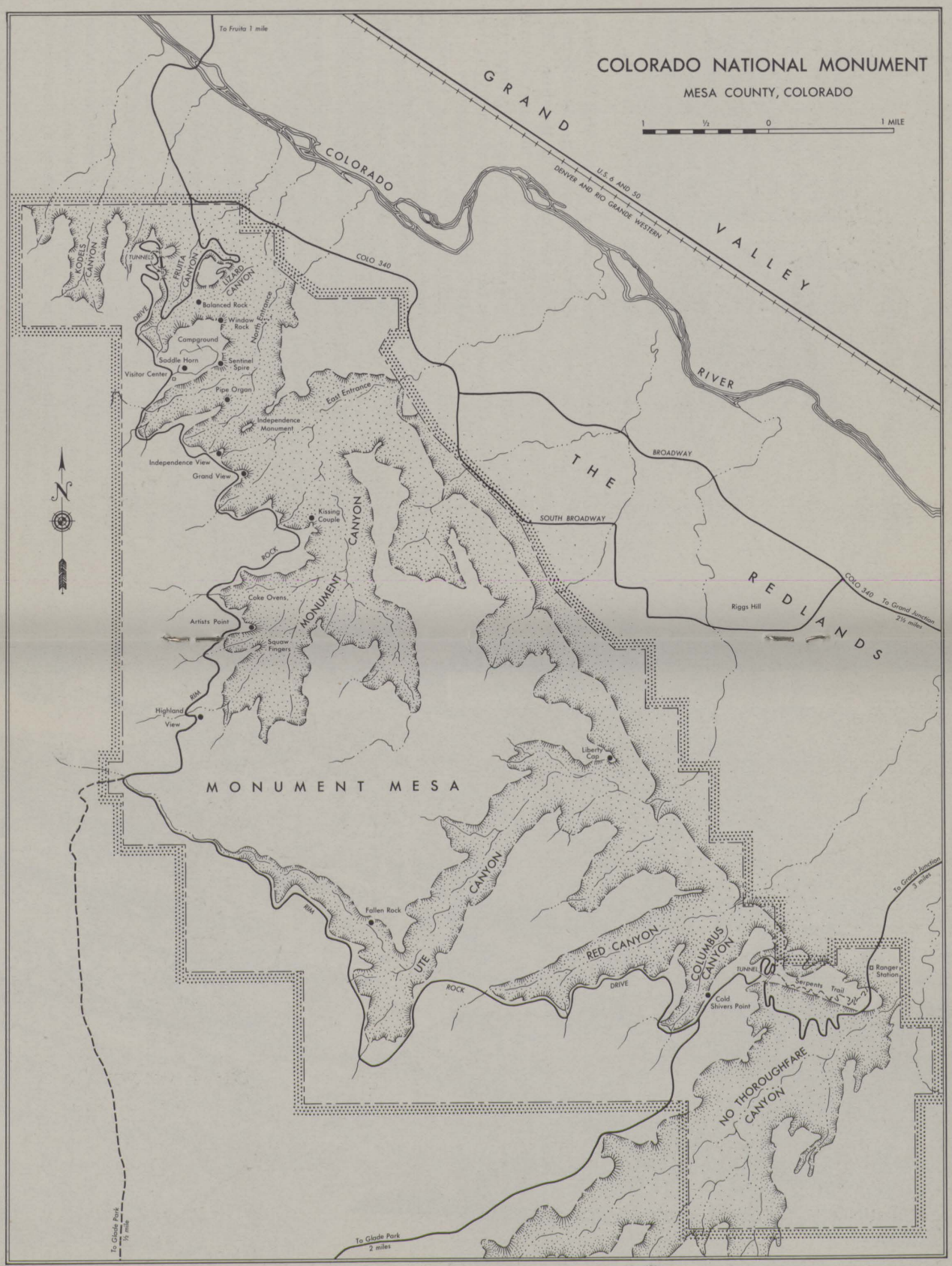
IN LATE JURASSIC TIME THE SEA to the west eventually dried up, either because it was filled with sediments or because the land rose above sea level, or both. Streams from higher lands to the south brought in mud, silt, and sand that piled up hundreds of feet thick over thousands of square miles, including the Monument.

These sediments were later compacted into the brightly colored siltstone, mudstone, and sandstone now known as the Morrison Formation. Some of the sediment accumulated in the many lakes that dotted the landscape. The colors are about the same as those of the Summerville. Algae and other microscopic organisms extracted calcium carbonate from the lake waters, and when they died this material settled on the lake bottoms to make limestone.

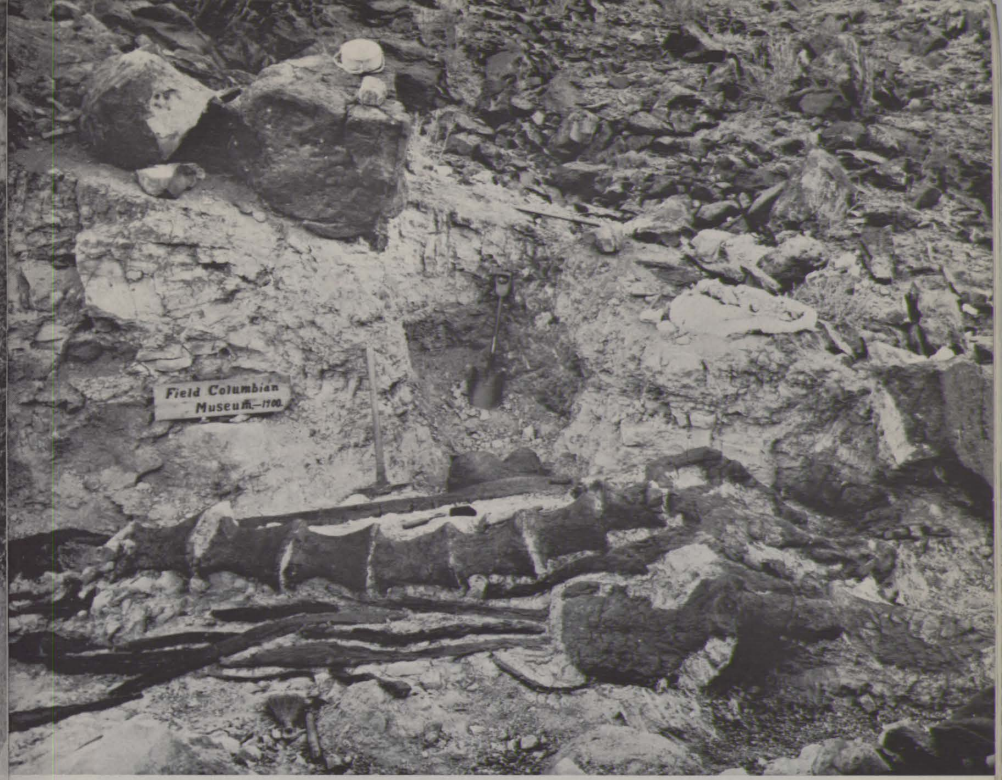
The soft siltstone and mudstone of the Morrison Formation weather rapidly into steep or fairly steep slopes, but the harder beds of sandstone, most of which are in the lower third of the formation, are sculptured into bold ledges or low cliffs. The Morrison is best exposed in and east of the Redlands, where the bare rocks are carved into badlands like the famous ones of South Dakota. Both the Fruita and No Thoroughfare Canyon approaches to the Monument wind past typical badlands in the Morrison. The entire 600 feet of this formation is best seen in the high bluff east of No Thoroughfare Canyon ranger station.

The Morrison is not well exposed in the Monument as it is restricted to the higher parts where most of it is hidden by vegetation. The lower part is seen in roadcuts and outcropping ledges along Rim Rock Drive between Artist Point and the head of the west arm of Ute Canyon.

The climate during Morrison time was wet enough to support abundant vegetation along the many lakes and streams – at least enough to feed the hungry dinosaurs and other reptiles that roamed the area. Many bones and parts of several skeletons of dinosaurs have been found in the Morrison at several places in the Redlands not far below the Monument.


COLORADO NATIONAL MONUMENT
MESA COUNTY, COLORADO
1 ½ 0 1 MILE
To Fruita 1 mile
GRAND VALLEY
COLORADO RIVER
U.S. 6 AND 50
DENVER AND RIO GRANDE WESTERN
COLO 340
KODELS CANYON
TUNNEL
FRUITA CANYON
LIZARD CANYON
DRIVE
North Entrance
Balanced Rock
Window Rock
Campground
Saddle Horn
Sentinel Spire
Visitor Center
Pipe Organ
East Entrance
Independence Monument
Independence View
Grand View
N
Kissing Couple
ROCK
MONUMENT CANYON
Coke Ovens
Artists Point
Squaw Fingers
RIM
Highland View
THE REDLANDS
BROADWAY
SOUTH BROADWAY
Riggs Hill
COLO 340 To Grand Junction 2½ miles
Liberty Cap
MONUMENT MESA
Fallen Rock
UTE CANYON
RED CANYON
DRIVE
COLUMBUS CANYON
TUNNEL
Serpents Trail
Ranger Station
To Grand Junction 3 miles
Cold Shivers Point
NO THOROUGHFARE CANYON
To Glade Park 2 miles
To Glade Park 2 miles

Morrison Formation and older rocks. Looking east across No Thoroughfare Canyon.



Excavating type specimen of *Brachiosaurus altithorax*, from south side of Riggs Hill. *Photo taken in 1900, reproduced by permission of Chicago Natural History Museum.*

The most famous dinosaur locality near the Monument is Riggs Hill where, in 1900, the late Elmer S. Riggs of the Field Columbian Museum (now Chicago Natural History Museum) dug out part of the first known skeleton of *Brachiosaurus*. This discovery made quite a splash in the scientific world, for it is the first and only type of dinosaur found whose front legs were longer than its hind legs. The fossilized thigh bone (femur) alone is 6 feet 8 inches long and weighs 549 pounds; the arm bone (humerus), though incomplete, is even longer. The ribs are 9 feet long. A brass plaque now marks the site of the excavation.

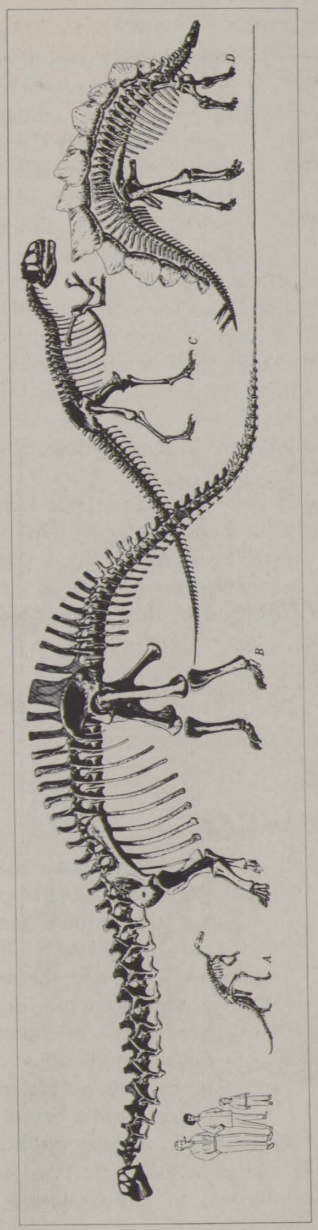
In 1901, Riggs removed all but the forepart of a skeleton of *Apatosaurus* from the southeast side of a large hill of the Morrison Formation just south of the Fruita bridge. Riggs also found remains of *Diplodocus*, *Camarasaurus*, and *Morosaurus*, and, in 1937,

Al Look, prominent writer and amateur paleontologist, and Edwin L. Holt, an instructor in Mesa College at Grand Junction, found the closely associated remains of *Allosaurus*, *Stegosaurus*, and *Brachiosaurus* at the western end of Riggs Hill.

Dinosaurs generally are thought of as huge creatures – many were huge indeed, but they came in various sizes and some were quite small. For example, a full grown *Hoplosuchus*, which was only 7½ inches long, would make a mere speck on the picture appearing on page 31.

Fresh-water clam and snail shells abound in some beds of the Morrison, particularly in limestones, and occur sparingly in other types. A few have been found in the Monument, but they are more abundant in the Redlands, particularly about 1½ miles west of the Fruita bridge. Some of these shells that are filled with agate are sought by rockhounds.

Brass plaque marking the discovery of *Brachiosaurus*.



Skeletons of typical dinosaurs of Morrison Formation. A. *Camptosaurus*, a small dinosaur about 11 feet long *(modified from Gilmore; courtesy, U. S. National Museum)*. **B. *Apatosaurus*, a gigantic dinosaur about 76 feet long** *(modified from Gilmore; courtesy, Carnegie Museum)*. **C. *Allosaurus*, a large carnivorous dinosaur about 30 feet long** *(modified from Mathew; courtesy, American Museum of Natural History)*. **D. *Stegosaurus*, a large armored dinosaur about 24 feet long** *(modified from Romer, after Marsh and Gilmore; courtesy, University of Chicago Press)*.

DINOSAURS ON THE MOVE

THE WET CLIMATE OF LATE JURASSIC TIME was followed by arid or semiarid climate in the Early Cretaceous. Streams continued to deposit gravel, sand, silt, and mud, but at a much slower rate. These deposits eventually hardened into the conglomerate, sandstone, and green shale or siltstone of the Burro Canyon Formation. This formation, together with part of the overlying Dakota Sandstone, caps the highest ridge (7,000 feet) in the Monument about a mile west of the Coke Ovens. Several airway beacons on this high ridge may be seen for many miles. The Burro Canyon is best seen below the Monument along the lower part of No Thoroughfare Canyon, where it is about 60 feet thick.

A few fossil plants and shells have come from this formation, but the seeming absence of dinosaur bones suggests that possibly these reptiles had to move to wetter areas where food was more abundant. Some dinosaurs may have lived in the area at this time, but their bones either were not fossilized or they haven't yet been found.

PEAT BOGS

BY THE BEGINNING OF LATE CRETACEOUS time the Monument was part of a low plain near sea level, and the sea was gradually encroaching from the east or northeast. Gravel and sand carried in by streams during this period form a bed of white conglomerate or sandstone about 40 feet thick, making up the lower part of the Dakota Sandstone. In the photograph on page 33, this bed is visible about two-thirds of the way up the west side of No Thoroughfare Canyon.

Burro Canyon Formation and Dakota Sandstone along west side of No Thoroughfare Canyon, about 2½ miles northeast of Monument's east entrance.

As the land gradually subsided nearer to sea level, swamps which were formed along the coast supported considerable vegetation. As the trees and plants died and were covered by silt and mud, they gradually changed to peat which finally became compacted into lignite coal and brown or black coaly shale containing plant remains. You can dig out some of this low-grade coal and perhaps find some plant remains near the top of the west canyon wall just below the highest sandstone bed shown in the photograph on page 33.

For awhile, the coast alternately sank slightly below and rose slightly above sea level. Beach sand covered the swamp deposits, then more swamp deposits covered the sand. Some of the sand contains seashells such as oysters and clams.

Except at the high hill with the beacons, the Dakota has been entirely eroded from the Monument, but it crops out with the underlying Burro Canyon in a series of low hills south of the Colorado River. The Dakota Sandstone is about 200 feet thick.

THE SEA COVERS THE PLATEAU

STILL LATER IN THE CRETACEOUS Period the whole region sank beneath the sea and stayed there a long time. Silt and mud were piled, layer upon layer, on the sea floor and hardened into the gray and black Mancos Shale. Thin layers of sand were cemented into sandstone, and layers of calcium-carbonate mud became chalk or limestone. Seashells and bones of sharks and sea-going reptiles have been found in the Mancos in many places.

The Mancos and all younger rocks have been stripped off the Monument, but may be seen one after the other as you travel northeastward. Thin remnants of the Mancos cap low hills just south of the Colorado River, and the entire 3,800 feet of the Mancos underlies the Grand Valley and Book Cliffs. The upper part is clearly exposed in the towering, barren Book Cliffs, where the soft shale is protected by a caprock of hard sandstone — the lowermost unit of the overlying Mesaverde Group.

Book Cliffs — Mount Garfield in the middle. *Infrared photo.*

THE SEA'S FINAL RETREAT

SLOW UPLIFT OF THE MONUMENT region caused the gradual retreat of the Mancos sea. Deposition of mud on the sea bottom gave way to deposition of beach sand, coal swamps, and then more beach sand and coal swamps. Finally, in Late Cretaceous time, the sea withdrew entirely, never again to return to the interior of the United States.

Streams deposited sand, silt, and mud on the newly uplifted coastal areas. All these deposits, including some high-grade bituminous coal that was formed in the swamps, we now know as the Mesaverde Group. The thick cliff-forming sandstones of this unit are displayed in DeBeque Canyon of the Colorado River between Palisade and DeBeque. You will see several coal mines in the Mesaverde between Palisade and Cameo and outcrops of coal on the east side of the road just south of Cameo.

The remains of dinosaurs have been located in rocks of this age elsewhere, but near the Monument only their tracks have been found. Some of these, in coal mines along the Book Cliffs and near Cedaredge, are 38 inches across and their placement indicates the incredible stride of 16¼ feet! Had there been highways in Mesaverde time, this bipedal giant could have crossed them in two strides.

END OF THE DINOSAURS

THE END OF THE CRETACEOUS PERIOD was also the end of the dinosaurs. Exactly why the "terrible lizards" died out after dominating the world for more than 150 million years is not known for sure, but many guesses have been made.

One likely idea is that widespread uplift and mountain building that began late in Cretaceous time, accompanied by changes in climate, may have greatly reduced the supply of soft edible plants. If so, it is easy to imagine how huge dinosaurs, accustomed to a ton or more of lush plant food each day, would soon starve to death.

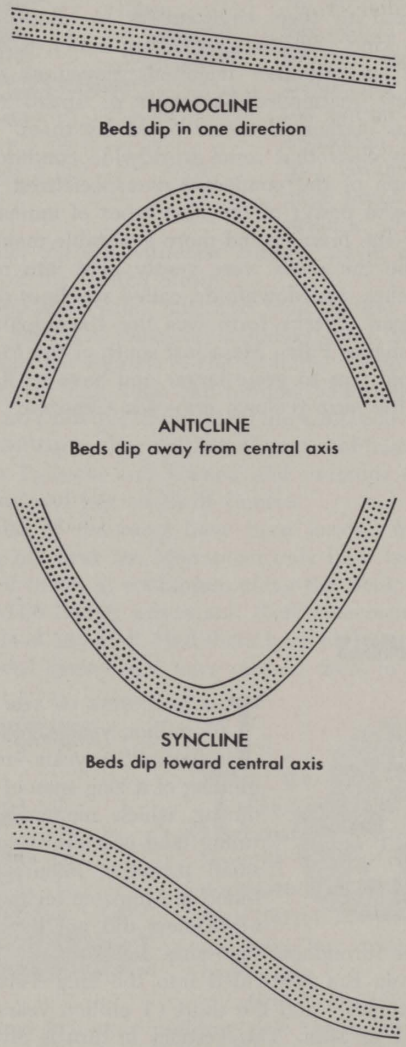
Many dinosaurs were vegetarians. As they died out, the flesh-eaters, such as *Tyrannosaurus*, soon ran short of food also, and probably began to eat each other. The dinosaurs had become too highly specialized to their environment to adapt themselves to changes of this kind. Another fascinating notion is that the growing population of primitive mammals devoured dinosaur eggs (which were left unattended like those of turtles and alligators) nearly as fast as mamma dinosaur could lay them. But whatever the reason, it is clear that some worldwide condition caused the gradual extinction of the ponderous overspecialized dinosaurs and allowed the rise to power of the next types of animals destined to rule the earth – the brainier and more adaptable mammals.

At this time the rocks were gently bent into upfolds, called anticlines or arches, and downfolds, called synclines or basins. One upfold that began to take form was the Uncompahgre arch, the crest of which shapes Piñon Mesa just south of the Monument. But this gentle upfold was to grow larger and have its flanks wrinkled and broken in the next geologic era – the Cenozoic.

THE AGE OF MAMMALS

THE BEGINNING OF THE CENOZOIC ERA 65 million years ago – give or take a few million years – marked the beginning of a long span of geologic time during which mammals became the ruling land animals. Remains of some small primitive mammals have been found in Mesozoic rocks, but these tiny newcomers did not have a chance to flourish until the formidable dinosaurs died out.

The Cenozoic Era is divided into the long Tertiary Period – the Age of Mammals – and the short (1 million years) Quaternary Period – the Age of Man. The Tertiary in turn is divided into five epochs – the Paleocene, Eocene, Oligocene, Miocene, and Pliocene. The events of the Tertiary have an important bearing upon the Monument even though no rocks of this period now occur in or near the area.



HOMOCLINE
Beds dip in one direction

ANTICLINE
Beds dip away from central axis

SYNCLINE
Beds dip toward central axis

MONOCLINE
Dip changes in amount but not in direction

MAIN KINDS OF ROCK FOLDS

The broad inland basins that were formed late in the Cretaceous received sand, silt, and mud brought in by streams from the uplifted or upfolded areas. These materials became compacted into the Wasatch Formation – the red or pink rock from which Bryce Canyon National Park was sculptured. One such basin lay just northeast of the Monument, which was probably covered by some of these stream deposits after the main basin was partly filled.

The mammals that roamed the area during the Paleocene were primitive, but more advanced forms appeared later, in Eocene time. Some of their fossil remains have been found in the Wasatch Formation in Plateau Creek Valley and near Rifle. The entire 5,000 feet of the Wasatch may be seen along the highway between DeBeque and Grand Valley.

LAKE UINTA

IN EARLY TERTIARY TIME the northern part of the Colorado Plateau sagged downward and gradually filled with water until it became a huge lake. The arm of the lake nearest the Monument has been called Lake Uinta. The waters in it teemed with plants and animals, particularly micro-organisms, such as algae, whose remains, coated with calcium carbonate, settled to the bottom along with the sand, silt, and mud washed into the lake by streams. These sediments compacted into the remarkable Green River Formation which contains, among many rock types, large deposits of rich oil shale.

This light-colored formation, which is about 3,800 feet thick, may be seen in the upper part of the towering Roan Cliffs on the northwest side of the Colorado River between DeBeque and Rifle. It also underlies the volcanic caprock of Grand and Battlement Mesas. Geologists have estimated that the oil shale in the Piceance Creek Basin, northwest of the Colorado River alone, contains more than one trillion barrels of oil. The Monument was at or near the south shore of this lake, and may once have been covered with a veneer of the Green River Formation.

THE MOUNTAINS RISE AGAIN

LAKES, LIKE MOUNTAINS, ARE TEMPORARY things. Even as they are forming, sediment begins to fill them until ultimately they are obliterated. So it was with Lake Uinta. Sometime after this lake dried up, the earth's crust again became restless. The gentle folds that were formed late in the Cretaceous were lifted higher and bent more sharply, and the flanks of some folds were wrinkled and broken. The sharply bent, broken rocks along the northeastern border of the Monument are thought to have been deformed mainly at this time, but in part both earlier and later.

At the north entrance to Fruita Canyon the layers of rock are bent sharply downward to the northeast. Closer inspection shows that they are not just bent but have been broken; such a break is called a fault. If you look to the southeast from the easternmost loop of the road, you will see that the rocks there are bent but not broken. This kind of fold is called a monocline and is common throughout the Colorado Plateau (see the chart showing the main kinds of rock folds). These features are well defined on the vertical and oblique aerial photographs of the northwestern part of the Monument, which appear on pages 4 and 5.

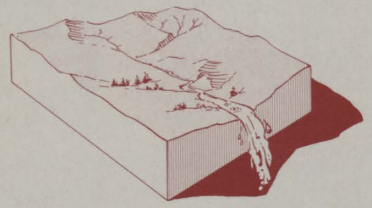
Bent and broken rocks in Fruita Canyon.

Redlands fault, indicated by white arrows.

If you travel along South Broadway through the Redlands, you will note the high dark bluff along the northeastern boundary of the Monument. About midway up the bluff is the Redlands fault along which the rocks were sharply broken. Just below the fault may be seen patches of the Wingate Sandstone that were dragged upward along the fault. The rocks southwest of the fault plainly moved upward in relation to those to the northeast, for the Wingate Sandstone to the southwest stands high above the bluff whereas northeast of the fault it is near the foot.

At the No Thoroughfare Canyon entrance to the Monument, the Redlands fault has died out, but it may be seen for several miles toward the northwest. As you climb the road in No Thoroughfare Canyon, you will see that the rocks are bent sharply downward to the northeast. The old Serpents Trail climbs these steeply tilting rocks. When this road was in use, water in the radiators of most cars boiled before the top was reached, so barrels of water were kept at the top of the hill near Cold Shivers Point.

A MIGHTY RIVER IS BORN



SOON AFTER THE BENDING and breaking of the rocks, the Colorado River probably began flowing in about its present course, with one notable exception which will be discussed later. Since then this river has carried thousands of cubic miles of sediment to the Gulf of California, including a lot of rock that once covered the Monument. The river is still actively at work on this immense earth-moving project.

If the ancestral Colorado River carried sediment at about the same rate as the present river since the building of Hoover Dam, it may have carried about 3 cubic miles of sediment each century. Now most of the rock debris is being dumped into Lake Powell — the new reservoir behind Glen Canyon Dam. When this, Lake Mead, and other reservoirs ultimately become filled with sediment, the Gulf of California will again be the burial ground.

The river did not always have an easy time maintaining this course. Soon after it was born, volcanoes a few miles east of the Monument spewed out molten lava toward the west and northwest. For a while this moving wall probably pushed the river to the west and northwest, but when the smoke cleared and the lava solidified,

the river cut through the mass and carried most of it to the sea along with remains of other rocks. Large remnants of this once molten rock, known as basalt, still cap Grand and Battlement Mesas. The Monument, too, probably was once covered by this lava.

Rivers, like people, do not always choose their courses wisely. After a few million years of downcutting through the soft sedimentary rocks, the Colorado River reached the dark Precambrian rock which had been pushed and bent upward beneath the Uncompahgre arch. This hard rock proved to be a serious obstacle and greatly slowed the rate of downcutting. But the river was not to be denied, and slowly but relentlessly it cut a gorge several thousand feet deep. This gorge, only a few miles southeast of the Monument, is now known as Unaweep Canyon.

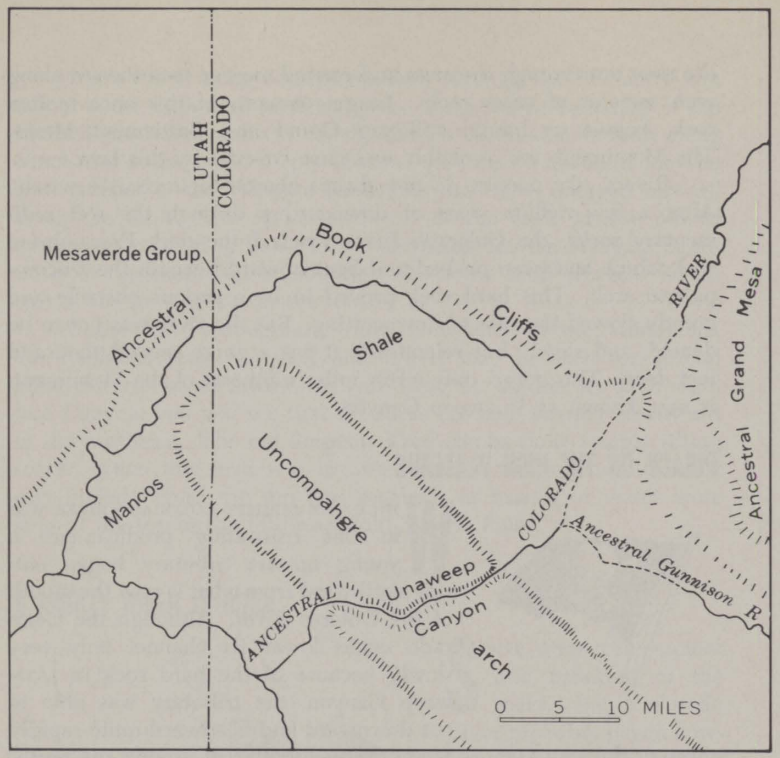
PIRACY ON THE HIGH PLATEAUS

WHILE THE MIGHTY COLORADO RIVER was in this frustrating predicament, a young upstart tributary began cutting northward from what is now the mouth of the Dolores River. Although the Colorado could lower its channel only very slowly because of the hard rock in Unaweep Canyon, the tributary was able to cut downward and headward quite rapidly through the soft Mancos Shale. It eventually cut around the northwestern end of the Uncompahgre arch and headed southeastward toward the Colorado River near the present site of Palisade.

Then occurred an act of piracy that put to shame the mightiest exploits of Blackbeard and Captain Kidd. During some unusually large flood, probably in Pliocene time, the Colorado River overflowed its banks and spilled into the headwaters of the tributary. With this enormously increased supply of water, the tributary cut down rapidly through the soft shale, captured the waters of the Colorado River, and left the Gunnison River "high and dry" in Unaweep Canyon. Stream capture of this type is appropriately called "piracy."

But the piracy had not ended. The rapidly downcutting new river sent out several tributaries, one of which headed for and soon captured the Gunnison River. This second act of piracy left Unaweep Canyon really dry except for small streams that carried off what little water the canyon received from local rain and snow.

While these piracies were going on, the Book Cliffs and the edge of Grand Mesa gradually retreated away from the valley because of erosion, and more of the Uncompahgre arch was uncovered.



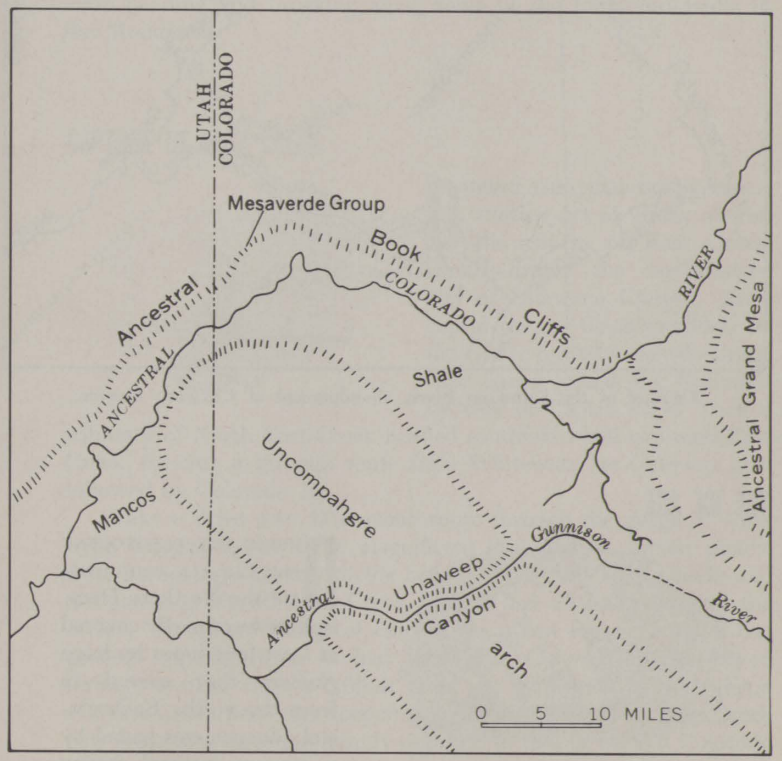
Old course of Colorado River through Unaweep Canyon.

The Age of Man

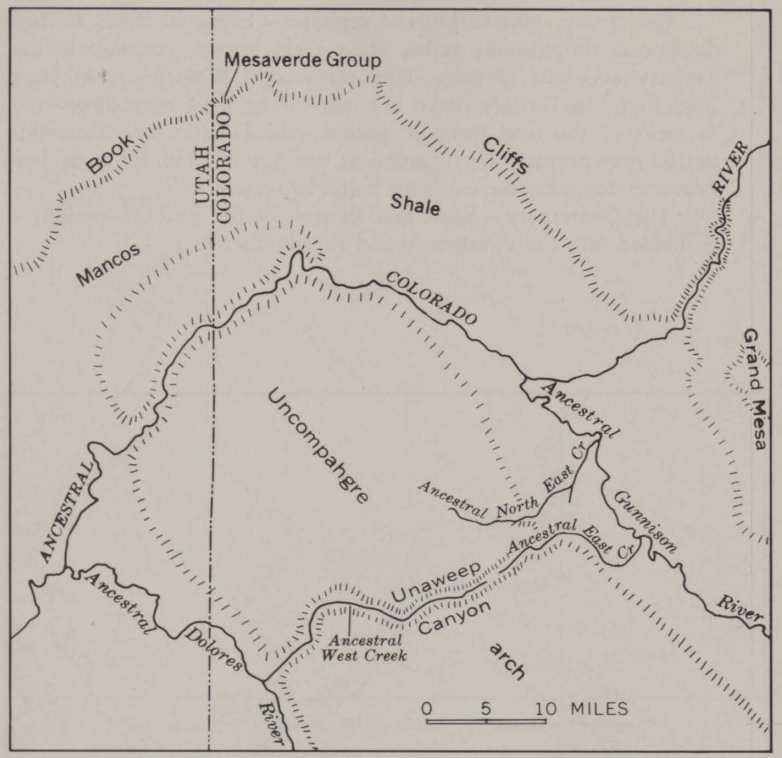
LIKE THE DINOSAURS BEFORE THEM, a few of the Tertiary mammals were so long on brawn and short on brains that they evolved into grotesque monsters and overspecialized themselves into early extinction. Fortunately, however, most of the mammals evolved more slowly and moderately into the forms we find today.

One group – the anthropoid primates – began to think, so they developed their brains rather than their brawn, particularly the Tertiary ancestors of man. Few remains of these ancestors have been found in Tertiary rocks, but many more have been discovered in rocks of the next geologic period – the Quaternary. Thus this period may properly be regarded as the Age of Man, for man then began to dominate the earth for better or for worse.

The Quaternary – latest and shortest of the geologic periods – is divided into the Pleistocene and Recent Epochs.

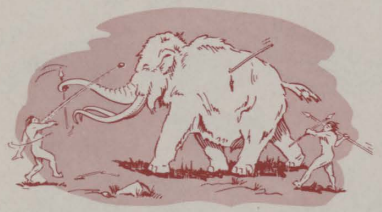


Capture of the Colorado River.



Capture of the Gunnison River, abandonment of Unaweep Canyon.

THE ICE AGE



DURING THE PLEISTOCENE EPOCH, ALL continents of the Northern Hemisphere were partly covered at least four times by huge glaciers that moved in from the north. Each glacial advance was ended by a warmer interval during which the glaciers melted and retreated northward and vegetation and soil had time to become re-established. Thus the Pleistocene has been called the ice age.

None of the continental glaciers reached the Monument, but small alpine glaciers grew in high mountains and plateaus, including Grand Mesa, sculpturing scenic sharp-crested peaks and ridges and forming beautiful valleys and lakes.

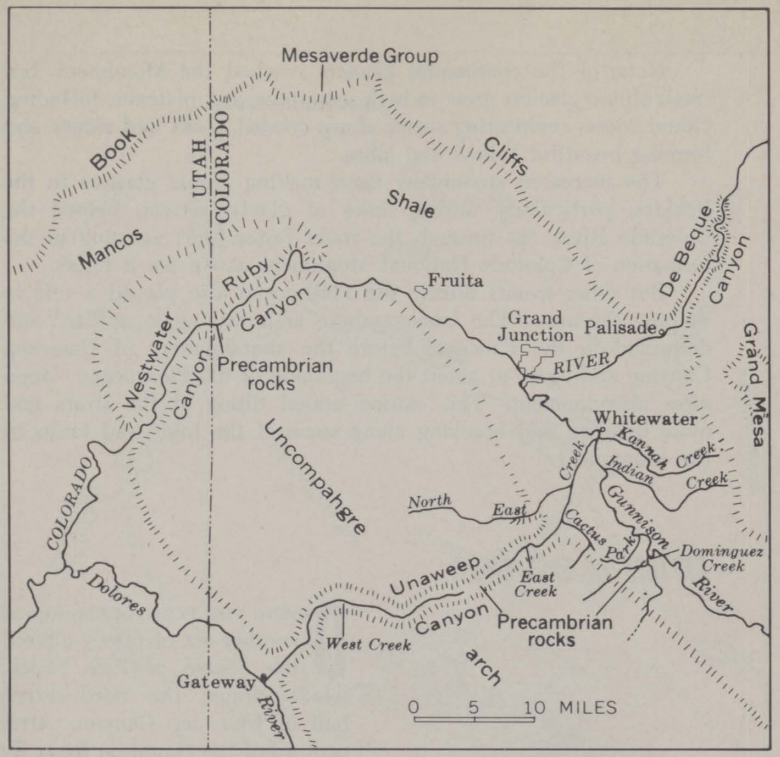
The increased streamflow from melting alpine glaciers in the Rockies, particularly during times of glacial retreat, helped the Colorado River cut through the rocks faster, thus assisting in the formation of Colorado National Monument as we see it today.

But other events during the Pleistocene also played a role in shaping the area. The Uncompahgre arch was again uplifted and deformed in the Pliocene, before the abandonment of Unaweep Canyon, and again at about the beginning of the Pleistocene – soon after abandonment. This caused added tilting of the strata and more bending and breaking along some of the folds and faults in the Monument.

CAPTURE OF EAST CREEK

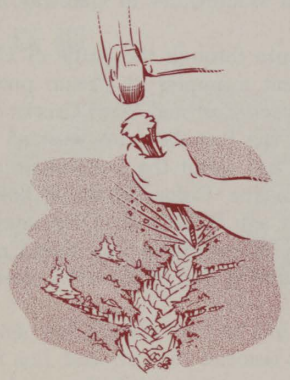
DURING THE PLEISTOCENE EPOCH another act of piracy altered the course of East Creek, which drains the northeastern half of Unaweep Canyon. After capture of the Gunnison River by the newly routed Colorado River, East Creek joined the Gunnison by way of Cactus Park. Then a tributary of North East Creek headed southward and captured East Creek, forming a through route from Whitewater to Gateway now followed by Colorado 141.

Take a drive over this scenic route through the gorge of Unaweep Canyon to see these magnificent examples of stream piracy. Note particularly the low divide between East and West Creeks and the gentle grade of West Creek for the first 2½ miles west of the divide. This short stretch of canyon has about the same slope and general appearance as it had when the Colorado River flowed through it more than a million years ago. The rest of the canyon of West Creek has been deepened by later erosion, and East Creek now flows in a direction exactly opposite to that of the old Colorado River.



Unaweep Canyon today, after capture of East Creek by North East Creek.

CANYON CUTTING



When the Colorado River was diverted into its new course through the Grand Valley past the Monument, the stream channel was only about 600 to 800 feet higher than it is today, but the present divide in Unaweep Canyon is now about 2,500 feet higher than the channel is now. The difference of 1,700 to 1,900 feet was caused by the additional uplift of the Uncompahgre arch during the Pleistocene.

Thus the Grand Valley and its tributary canyons, such as those of Colorado National Monument, were

Unaweep Canyon, looking up East Creek. *Photo by John R. Stacy.*

cut since the abandonment of Unaweep Canyon, probably mainly during the Quaternary Period. This suggests that the cutting of the Monument's canyons began only about a million years ago, but that much of the canyon cutting occurred only a few hundred thousand years ago. Indeed, the canyons are still slowly being deepened, lengthened, and widened.

As you stand on any of the lookout points and gaze down into the canyons of the Monument, you may well wonder how such immense chasms could have been cut by such puny streams that are dry most of the time. The streams flow only for short periods after heavy thundershowers or after rapid melting of snow. If you are lucky enough to see them flow, you will notice that the water is red or brown because of the suspended mud, silt, and sand. If the flow is large, you may see or hear pebbles and cobbles rolling along the bed. Thus the streams and their cutting tools are slowly deepening the channels. But, you may ask, how does this account for such wide, broad-bottomed, cliff-walled canyons? Such streams act mainly as storm sewers to carry off the rock debris formed by other types of erosion.

When cutting first began, the Monument's canyons probably were narrow, steep, and V-shaped. When the top of the hard, dark Precambrian rocks was reached, however, downcutting slowed just as it had earlier in Unaweep Canyon. While the streams were thus hung up, other erosional processes caused the cliff walls to recede away from the streams, forming broad, flat-bottomed, U-shaped canyons.

Recession of the cliffs away from the middle of the canyons probably was caused partly by undercutting of the soft Chinle Formation by wind and in places by streams. This allowed slabs of the overlying Wingate Sandstone and younger rocks to break off and fall into the canyons – eventually to break up and be carted off as sand and mud by the streams.

But other processes are probably the ones chiefly responsible for the present shape and width of the canyons. The summer sun heats the cliff faces until they are hot to the touch, but in the desert climate of the Monument the rocks cool rapidly after sundown. Oftentimes the hot cliff faces are chilled rapidly by summer thundershowers. Repeated heating, cooling, wetting, and drying causes expansion and contraction of the rocks so that thin layers break off and fall. This process goes on more slowly in winter on sun-facing cliffs, but does not occur on the cliffs that face away from the winter sun.

Even more important, perhaps, is the alternate freezing at night and thawing by day on sun-facing cliffs during the winter. Water in cracks near the cliff faces alternately freezes and melts, gradually prying off slabs of rock. Canyon walls that are shaded from the winter sun, however, stay cold or frozen much of the winter, hence are not subject to repeated heating and cooling or freezing and thawing. Thus you will notice that many such canyon walls are sloping rather than vertical.

PREHISTORIC PEOPLE IN THE MONUMENT

JOHN OTTO, EARLY EXPLORERS, AND EVEN the Ute Indians who once hunted in the area were by no means the first people to view the Monument, in fact they were "Johnnies-come-lately." Considerable evidence indicates that prehistoric people inhabited the area thousands of years ago.

In No Thoroughfare Canyon, upstream from the Monument entrance, is a fallen slab of Wingate Sandstone containing drawings of animals, people, and other objects or patterns that were chiseled into the rock by prehistoric people. These petroglyphs, or rock drawings, are the principal evidence of early man in the Monument, but additional indications of prehistoric habitations have been found nearby.

Al Look discovered and excavated two caves in No Thoroughfare Canyon, about 5 miles southwest of the entrance station to the Monument. He found stone projectile points, knives, awls, and milling stones, parts of a sandal and coiled basket, reed matting, corn, corncobs, acorns, and animal bones, but no pottery. Similar artifacts were excavated at two places in Unaweep Canyon just west of Cactus Park, and at several places in the western part of Glade Park. Here again no pottery was found, indicating that the people had not progressed beyond basket-making. Archeologists have named this old culture the Uncompahgre Complex, and date it back to a few thousand years before the time of Christ.

Petroglyphs in No Thoroughfare Canyon. *National Park Service photo.*

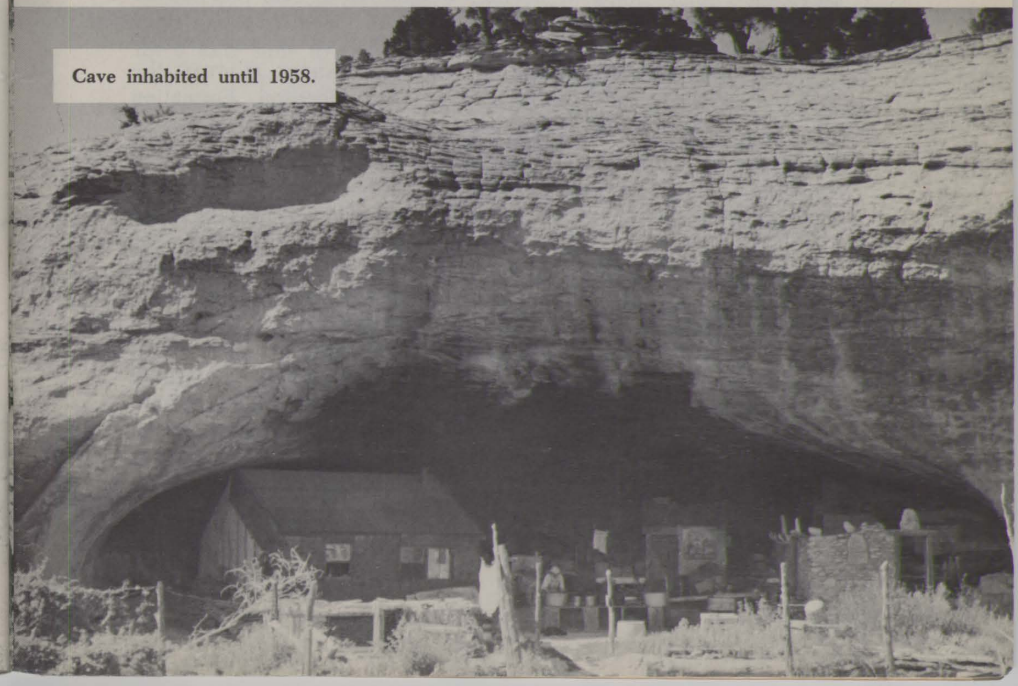
MRS. MILLER'S CAVES

MENTION WAS MADE EARLIER OF three caves about 3 miles west of the Glade Park Post Office. One of these caves was the home of Mrs. Laura Hazel Miller until 1958, when she moved to Grand Junction to live with her daughter. She lived alone in the cave for about 40 years, greatly preferring it to the hustle and confusion of city life.

ARTESIAN WELLS

IT MAY SURPRISE YOU TO LEARN that the Wingate and Entrada sandstones, which form the colorful cliffs and rock features of the Monument, supply artesian water to flowing wells in the Redlands, Orchard Mesa, and the southwestern side of the Grand Valley. These rocks look bone dry, so you may wonder how this can be.

They are indeed dry in all the cliff exposures, for there the beds dip gently northeastward so that any water in them has long since run out. But, along the northeastern border of the Monument, erosion has exposed the upturned edges of these sandstones so that they can take in water from the many small streams that drain the canyons of the Monument. The water then moves slowly down the dipping rocks and becomes trapped under



Cave inhabited until 1958.

pressure beneath the overlying Summerville and Morrison Formations, which are nearly impermeable to water. Wells several miles to the northeast tap these sandstones at depths of 500 to more than 1,000 feet. When they are reached in drilling, the water flows up the well and out at the surface. Such wells are called flowing artesian wells. Sandstones in the Morrison Formation also supply artesian water to a few wells.

The artesian water is under considerable pressure but the flows are small because the sandstones are partly cemented and therefore have few openings through which water can flow. Moreover, too many wells have been drilled in several small areas, a situation not unlike several children sucking on too many straws in the same ice cream soda. Each flowing well reduced the output of neighboring wells so that it became necessary to install pumps. This threat to the artesian water supply of the region led to the need for a detailed investigation by the U. S. Geological Survey in cooperation with the Colorado Water Conservation Board.

URANIUM

SOUTH OF THE UNCOMPAHGRE PLATEAU the Morrison Formation has yielded considerable uranium and vanadium ore, but seemingly none in commercial amounts has been found in or near the Monument. Coalified wood, which helped precipitate these ores from solution in the ore-producing areas, is lacking in the Morrison Formation on the northeastern side of the Uncompahgre Plateau.

A Look Into the Future

THIS ENDS THE BRIEF STORY OF Colorado National Monument, except for a peek into the future. The temporary nature of lakes, rivers, and even mountains has been discussed – the Monument of today and the new course of the Colorado River are no exceptions.

The Colorado River didn't solve its problems by abandoning its hard-rock course in Unaweep Canyon in favor of a soft-rock course through Ruby and Westwater Canyons – it just postponed them. The river has again cut down into its old nemesis – the hard Precambrian rock – at two places in Ruby Canyon just within the Colorado border and also in Westwater Canyon in Utah. Thus once again hard rock is slowing down old man river, and will slow him down for a long time to come. Someday Westwater and Ruby Canyons will be deep gorges like Unaweep Canyon. Then it seems quite likely that another young tributary may sneak around the Uncompaghre arch some miles northwest of these canyons, and pirate the river into a new soft-rock course.

By this time the Monument will have changed appearance considerably. Some of the canyons will have come together by eating away the ramparts that separated them – just as the north and east entrances of Monument Canyon have already done. But as the lower canyons thus eliminate themselves, the headwaters will bite deeper into Piñon Mesa, so perhaps the Monument will simply creep slowly southwestward. However, renewed uplift, more volcanoes, changes in climate, or other events could change the picture.

Thus, if the geologic clock ran as fast as the ones we use, the picture of the Monument we see today would be on the screen only a small fraction of a split second. But the geologic clock ticks on, slowly but surely, and some day the Recent Epoch in which we live will become just another brief chapter in the long geologic history of the earth.

Additional Reading

IF THIS BRIEF STORY MAKES YOU want to dig deeper into the geology of Colorado National Monument, you may wish to read my report on "The Geology and Artesian Water Supply of the Grand Junction Area, Colorado," which is being published by the U. S. Geological Survey as Professional Paper 451. This report has a geologic map of a large area, including the Monument, and a detailed description of the geology. It may be purchased from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402, or may be borrowed from any of the larger public, university, or institution libraries. The geologic map accompanying this report has been published separately as "Geologic Map of Grand Junction Area, Colorado, Miscellaneous Geologic Investigations Map I-404, 1963," and may be purchased from the Denver Distribution Section, U. S. Geological Survey, Denver Federal Center, Denver, Colo. 80225. Copies of the report and the map are also available at the Monument visitor center.

A fascinating account in popular style of the geology and archaeology of the Monument and nearby areas has been written by Al Look. The first edition, published in 1951 by the University of Denver Press, was titled *In My Back Yard.* A second and somewhat enlarged edition titled *1,000 Million Years on the Colorado Plateau, Land of Uranium* was printed in 1955 by Bell Publications, Denver.

If you wish to learn more about John Otto, read another interesting book by Al Look titled *John Otto: Fantastic Father of Colorado National Monument.* The first edition was published in 1961 by the Denver Westerners, Inc.; the second in 1962 at Grand Junction by the Sandstone Publishing Company.

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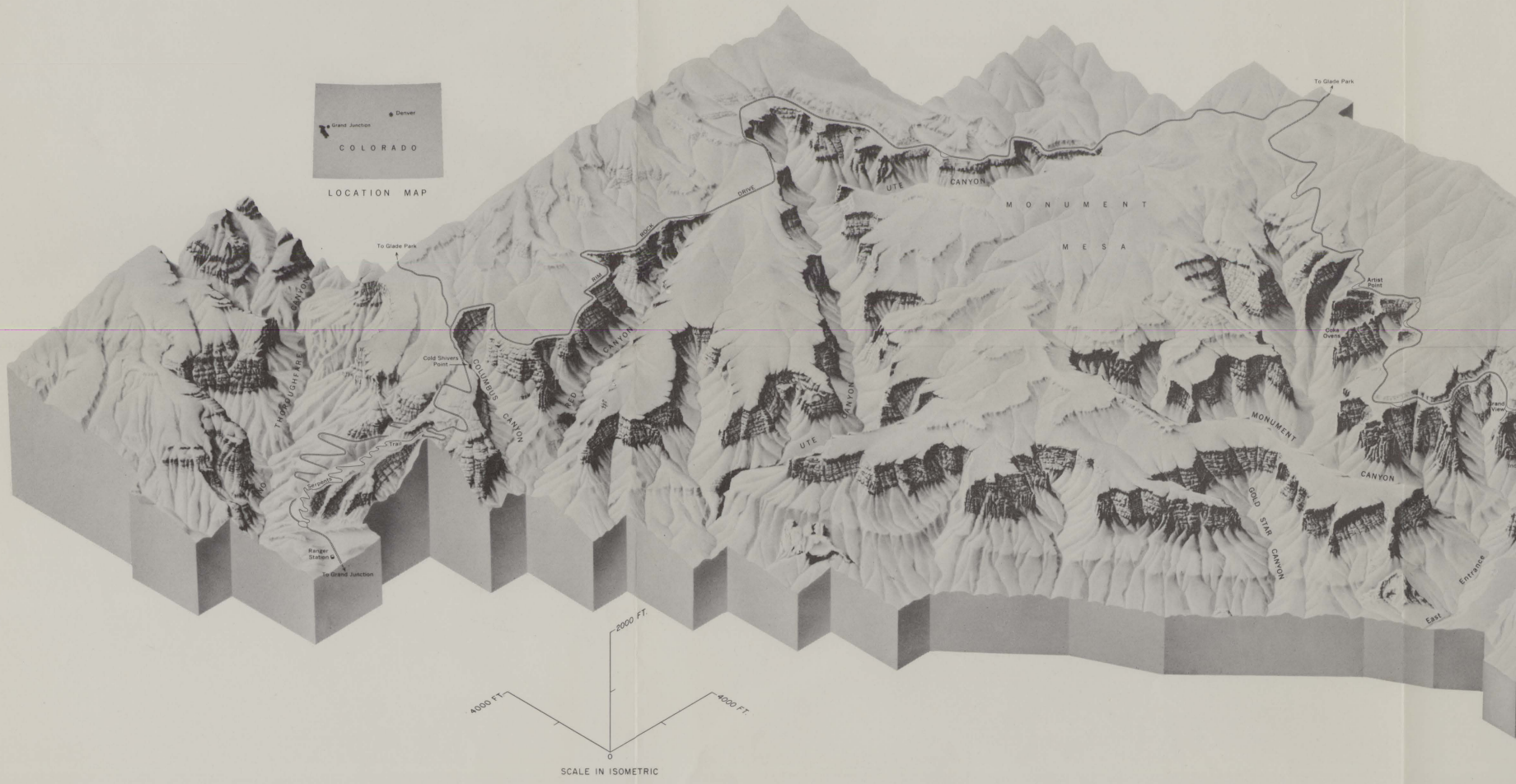
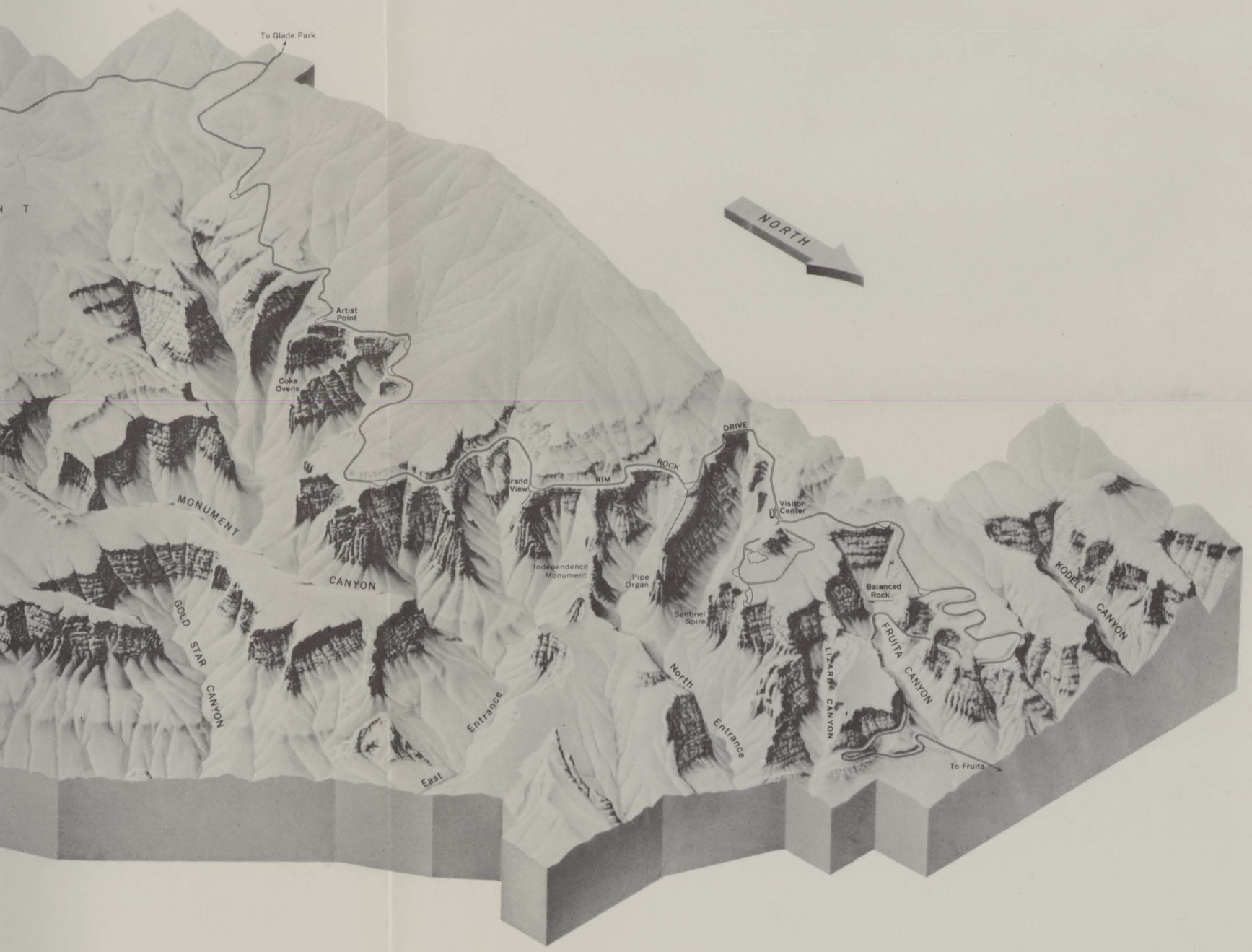


BIRD'S EYE VIEW OF COLORADO NATIONAL MONUMENT



Shaded isometric projection by Fred Hostetler, from U.S. Geological Survey topographic map, scale 1:31,680, Edition of 1948.
Vertical exaggeration approximately 2 times

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