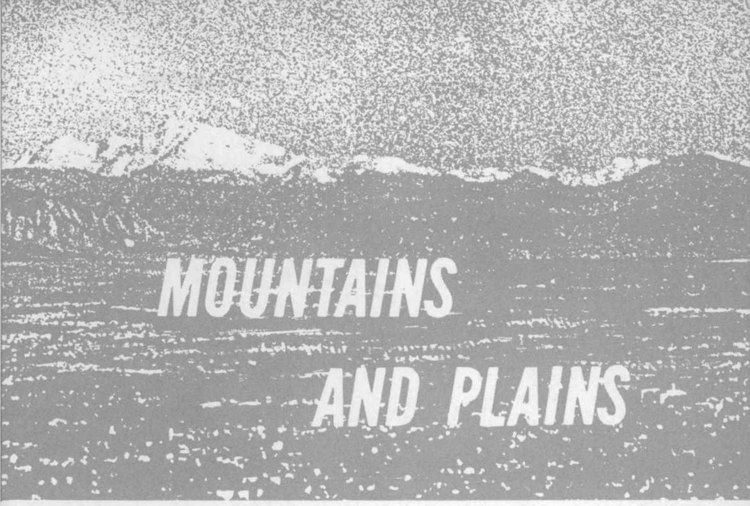
MOUNTAINS AND PLAINS

DENVER'S GEOLOGIC SETTING

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY


HILTON



DENVER'S GEOLOGIC SETTING

A slice of geologic history is exposed to view in the Denver, Colorado area. Denver is situated on the High Plains near the east front of the Rocky Mountains. As one travels westward from Denver toward the mountains, successively older rocks are crossed—from the geologically young rocks of the High Plains and the South Platte River valley to the older rocks of the foothills and the ancient rocks of the mountains. Thus, within a few miles, the journey turns back the pages of time in a life-sized textbook that vividly illustrates the geologic events that shaped the landscape.

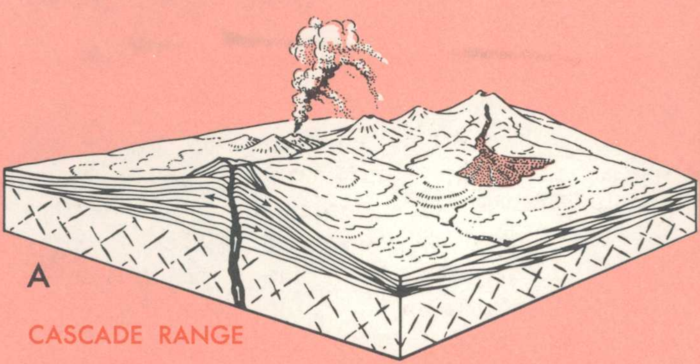
The geologic features are particularly well exposed at Red Rocks Park and along several miles of Alameda Parkway, west of Denver. A road log (see p. 19) describing the features that can be seen at various places along this highway is included as part of this leaflet. The locations of these points of interest, keyed to the road log, are shown on an accompanying map.

The Front Range of the Rocky Mountains in Colorado is an excellent example of one kind of mountain range. Mountains, those great prominences that lend character and beauty to our land, are not all alike in either form or origin. Some, like the Cascade Range in Oregon, are great piles of volcanic rocks. Others, like the Appalachians, are belts of tightly folded rock layers. Still others, like the Teton Range in Wyoming, are great blocks, broken and tilted away from the adjoining rocks. The Front Range, like many of the ranges of the Rocky Mountains, formed as a result of vertical uplift.

Most of the crustal movements in the Front Range during the last half billion years or more have been vertical—both up and down. With each uplift of the land surface, forces of erosion attacked the mountains with renewed vigor, and the eroded material was transported to the flanks of the mountains and redeposited. With each sinking of the land surface that permitted seas to encroach upon the area, sediments were laid like a new carpet on the older rocks of the ocean floor. When the mountains were again uplifted, these newly formed sedimentary layers were worn from the mountain crests, but became buried and preserved in the low areas along the mountain front where we can see them today and interpret their history. Much of the history of uplifted mountains is written in the sedimentary layers along their fronts.

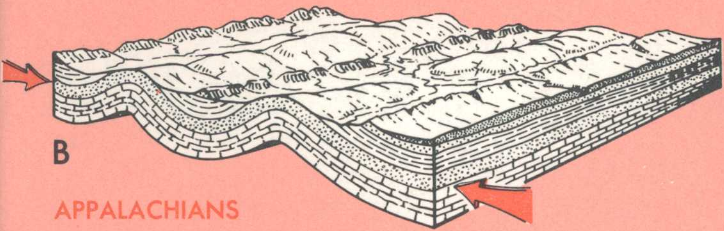
THE VALLEY

Denver lies in the broad, gentle valley of the South Platte River, about 12 miles east of the mountain front. The river has eroded its valley into the rocks of the High Plains, which slope eastward from the foot of the mountains. Gravel-capped terraces along the South Platte River are remnants of previous valley floors, preserved from times when the river was flowing at various higher levels. As the river slowly lowered its bed, parts of its flood plain were left high and dry. The best preserved of these terraces is called the Broadway terrace, named after the main thoroughfare in Denver. Downtown Denver is built on the Broadway terrace,



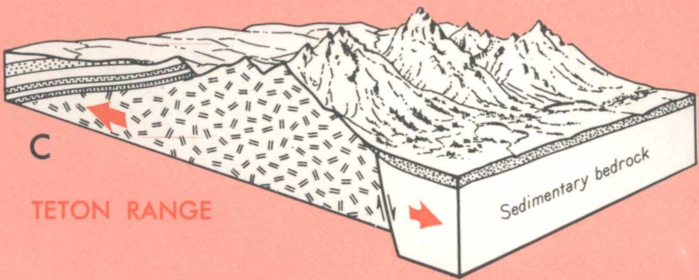
A

CASCADE RANGE



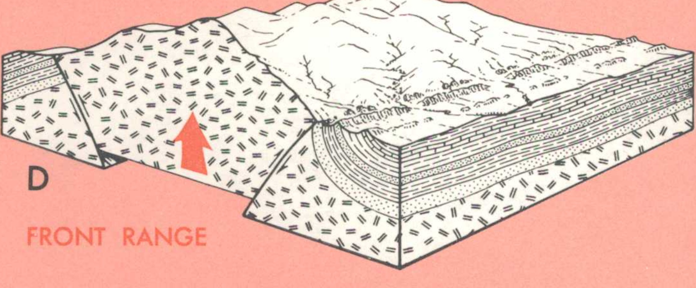
B

APPALACHIANS



C

TETON RANGE



D

FRONT RANGE

Mountains are not alike in form or origin. A, mountains formed by volcanic action; B, mountains resulting from folded layers of rock; C, mountains formed from fault blocks; D, mountains formed as a result of vertical uplift.

and excavations for large buildings have exposed loose sand and gravel deposited long ago by the South Platte River. These buildings are anchored in the bedrock that underlies the gravel. Fossil bones of mammoths and camels, as well as some split- and shaped-bone fragments that probably were tools of ancient man, have been recovered from excavations in the Broadway terrace, and scrapers, arrowheads, and other stone tools of prehistoric man have been found on the surface of the terrace.

West of the South Platte River, several gravel-capped surfaces stand 100 to 450 feet above present stream levels and rise gradually westward toward the mountain front. These surfaces are called pediments. They were formed thousands of years ago by streams that emerged from the mountains, planed off the bedrock, and deposited sand and gravel on the eroded surfaces.

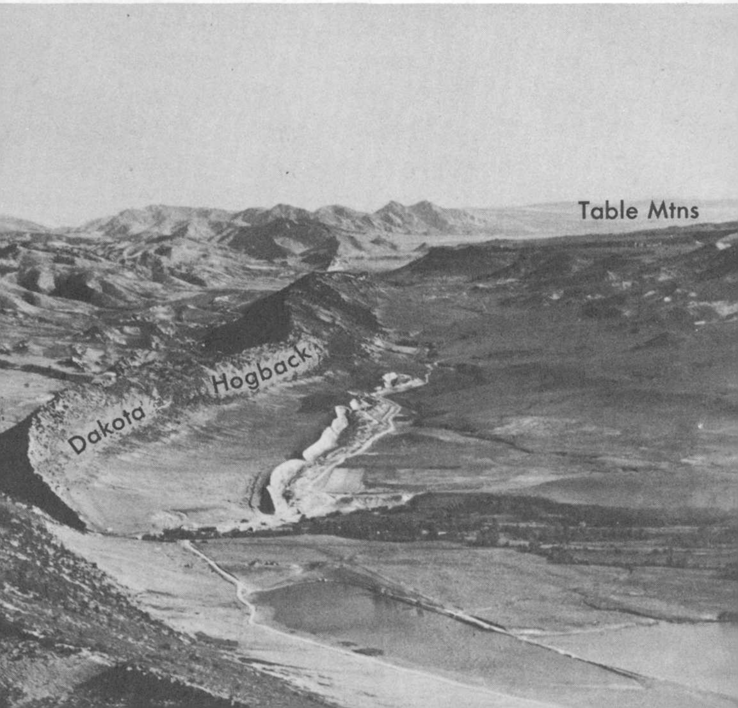
THE FOOTHILLS

As one approaches the mountain front, an array of hills, ridges, and mesas partly hides the high mountains farther west. One of these is Green Mountain, a large rounded hill between Alameda

Parkway and U.S. Highway 6. Conglomerate, or naturally cemented gravel, hundreds of feet thick caps the hulking mass of Green Mountain. The gravel was deposited at a much higher level than the pediments by a still older stream, and is all that remains of a formerly more extensive deposit. The gravel, later cemented to form conglomerate, lies on slightly older volcanic mudflows and stream deposits known as the Denver Formation, the bedrock that underlies most of Denver at shallow depth.

Just east of the town of Golden are North and South Table Mountains, two flat-topped mesas capped by lava flows. The lava appears to have poured out from great fissures adjacent to the Ralston reservoir north of Golden. These fissures now contain tabular masses of chilled lava called dikes, a name first applied to similar features in Scotland because of a fancied resemblance to the dikes of Holland. The lava flows were once continuous between North and South Table Mountains. Clear Creek once flowed in a higher channel across the lava, and in time cut its present lower channel between North and South Table Mountains.

Foothills between Morrison and Golden, looking north.



Ripplemarks on the Dakota Sandstone.

Between Green Mountain and the Table Mountains, the rock layers are nearly horizontal. Just to the west, however, they bend abruptly upward, like the tip of a ski, so that successively older rocks are exposed westward toward the mountain front. The harder layers of rock form sharp ridges called hogbacks; the softer more easily eroded layers form the intervening valleys. The most prominent hogback is formed of the Dakota Sandstone, a beach deposit of an ancient sea. Abundant ripplemarks, still preserved, formed in the shallow water. The footprints of dinosaurs that walked the sandy beaches can still be seen on the sandstone layers. Older than the Dakota Sandstone and farther to the west, upturned against the ancient rocks of the mountains, are the colorful red sandstone monuments of the Fountain Formation, which frame Red Rocks Amphitheater and for which the amphitheater is named.

THE MOUNTAINS AND THE ANCIENT ROCKS

The rocks of the foothills and the plains are mostly of sedimentary origin. The rocks of the mountains, in contrast, are mostly of igneous and metamorphic origin; they formed more than a billion years ago in Precambrian time, and some of them are more than a billion and a half years old. Their age has been determined by measuring the amount of decay of radioactive minerals, a process that takes place at a constant and determinable rate. Most of the Precambrian rocks have been so drastically changed by pressure and heat deep within the earth that their original character is now obscure. Banded crystalline rocks called *gneiss* (pronounced nice) and micaceous rocks called *schist*, originally were mostly sedimentary rocks much like those along the foothills, but vastly older.

Aerial view of the foothills and mountains near the South Platte River. Roxborough Park at lower left.

Conspicuous light-colored ribbons of very coarsely crystalline igneous rock called *pegmatite* are seen in the canyon walls of the Front Range. They were injected as molten rock into cracks in the gneiss and schist. Some pegmatites contain gemstones, such as topaz, garnet, amethyst, and amazonstone, particularly in the Pikes Peak region. Others have been mined for feldspar and mica.

Great masses of granite intrude the metamorphic rocks of the Front Range from Pikes Peak northward to Wyoming. All these granites exceed a billion years in age. Most typical are the light-gray Silver Plume Granite west of Denver, the gray Boulder Creek Granite west of Boulder and near Mt. Evans, the red Pikes Peak Granite west of Colorado Springs, and the red Sherman Granite farther north astride the Colorado-Wyoming border.

Similar but much younger granite bodies—less than 70 millions of years old—are the source of the famous gold-bearing veins discovered at Central City and Idaho Springs in 1859. This discovery caused very rapid settlement of the territory that was to become Colorado. In 1858 Colorado contained less than 200 persons who were not Indians. Two years later there were 35,000 people in the mining camps of Colorado. Uranium minerals from Central City were part of a shipment sent to Madame Curie in 1898—uranium minerals from which she extracted the first radium.

HOW THE ROCKS WERE FORMED

Although the earth is estimated to be about four and a half billion years old, the "recorded" history of the Denver area began less than two billion years ago when intense heat and pressure, generated by the forces of mountain building, contorted and recrystallized the rocks of the earth's crust. Great masses of molten granite intruded the upper part of the crust and contributed to the deformation.

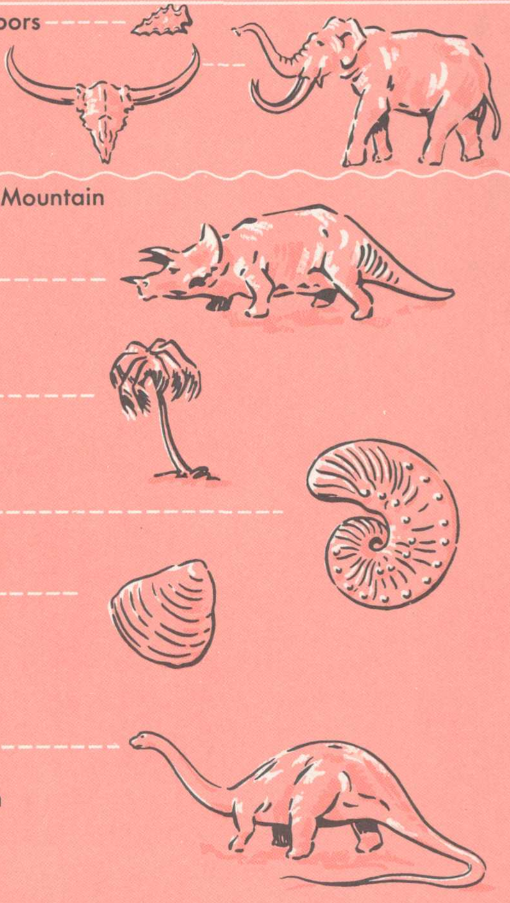
While uplift was still in progress, the mountains were being eroded. Ultimately the mountains were reduced to a flat featureless plain, which was submerged at the beginning of the Paleozoic Era, some 600 million years ago, when a broad seaway en-

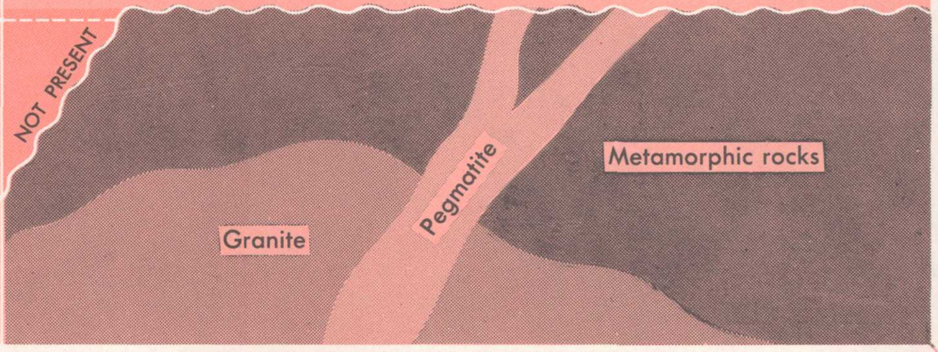
Pegmatite dike in Precambrian gneiss in Bear Creek Canyon.

gulfed the Denver area. Sediments that became limestone, sandstone, and shale accumulated on the floor of this sea, only to be uplifted and eroded. After most of these marine Paleozoic rocks had been removed during this second wearing-down process (perhaps about 300 million years ago) sand and gravel, eroded mainly from the Precambrian core rocks of the planed-off ancient mountains, were deposited by streams. These sediments, now hardened, are called the Fountain Formation.

Two major advances and withdrawals of the sea marked the next 200 million years. As the sea re-advanced across the region, during the Permian Period, onshore dunes and beach sands were deposited. These now make up the Lyons Sandstone. As the waters deepened, muds and limy sediments accumulated on the sea floor, and these became the shale and limestone of the lower part of the Lykins Formation.

GEOLOGIC AGE			AGE IN MILLIONS OF YEARS	NAME OF FORMATION
CENOZOIC ERA	Quaternary	Recent	(5,000 yrs.)	Alluvium of the valley floors Terrace deposits
		Pleistocene	3	Pediment deposits
	Tertiary	Pliocene	12	NOT PRESENT Conglomerate of Green Mountain
		Miocene	25	
		Oligocene	40	
		Eocene	60	Denver Formation
		Paleocene	70	Arapahoe Formation
MESOZOIC ERA	Cretaceous		135	Laramie Formation Fox Hills Sandstone Pierre Shale Niobrara Formation Benton Shale Dakota Sandstone
	Jurassic		180	Morrison Formation Ralston Creek Formation
	Triassic		225	Lykins Formation
PALEOZOIC ERA	Permian		270	Lyons Sandstone
	Pennsylvanian		300	Fountain Formation
	Mississippian		350	NOT PRESENT
	Devonian		400	
	Silurian		440	
	Ordovician		500	
	Cambrian		600	
	Precambrian			Granite, Pegmatite, Metamorphic rocks





GEOLOGIC TIME CHART AND DENVER'S ROCKS

Rolling upland surface, cut by glacial cirque, on the crest of the Front Range northwest of Berthoud Pass (in foreground).

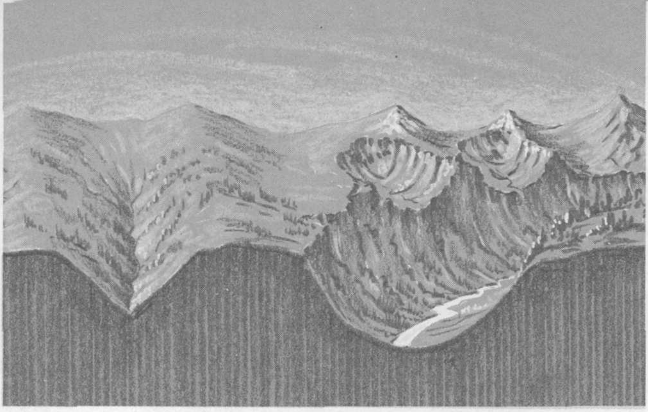
In the later part of the Paleozoic Era the sea withdrew to the east, leaving a lake-dotted coastal plain drained by sluggish streams. In Triassic time the area probably was a dry land on which silt and sand of the upper part of the Lykins Formation were deposited by wind and intermittent streams. No deposits of Early Jurassic age are preserved, but in Late Jurassic time the area became a swampy lowland where sediments were deposited that became the Ralston Creek and Morrison Formations. Dinosaurs fluorished in Morrison time, and their fossilized bones are found in the Morrison Formation throughout the Rocky Mountain region.

During the Cretaceous Period, beginning about 135 million years ago, the sea again moved westward across the area, and the ripplemarked sands of the Dakota Sandstone accumulated near the advancing shore. Dinosaurs which trod these intertidal beaches were driven westward by the advancing waters. With the shoreline far to the west, water covered the Denver area, and thousands of feet of muds and limy muds accumulated on the ocean floor. These are the Benton Shale, the Niobrara

Formation, and the Pierre Shale. They contain abundant remains of marine life such as the shells of mollusks and the skeletons and teeth of great fish and marine reptiles.

Late in the Cretaceous Period the entire region began to rise slowly, forcing the sea to withdraw for the last time. As the shoreline retreated eastward across the area, beach sands of the Fox Hills Sandstone were deposited. Streams then deposited muds and sands on the newly emerged coastal plain, which supported a lush growth of vegetation that was buried and became coal. These are the rocks of the Laramie Formation. As the mountains rose, vigorous streams stripped away the soft sedimentary rocks and, for the first time since the Fountain Formation was deposited, cut into the hard Precambrian rocks. The eroded material was carried eastward beyond the mountain front, where some of it is preserved in the younger formations of the plains, such as the Arapahoe Formation.

After a slow start, the rate of uplift increased during early Tertiary time, and about 70 million years ago the sedimentary layers adjacent to the mountains were bent sharply upward. Molten lava found its way to the surface through great fractures



V-shaped stream valley, left; U-shaped glaciated valley, right.

along the flanks of the mountains. Volcanoes, probably somewhere to the west, contributed to the stream-laid volcanic debris as well as to layers of volcanic ash and mud deposits of the Denver Formation. Fossilized leaves and twigs of trees that grew in the fertile volcanic soil are preserved in the rocks of the Denver Formation. Lavas that poured across what was then the land surface now form the caprock on the Table Mountains.

Molten granite from deep within the earth also was intruded along fractures in the ancient Precambrian core of the range. Hot solutions and gases from these melts spread into fractures deep within the rocks, and deposited the rich gold, silver, and lead ore in the veins of Colorado's mining districts.

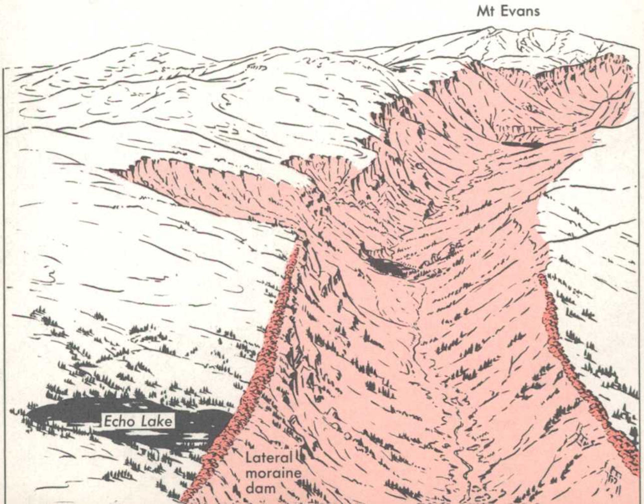
The shape of the Front Range as we see it today is the result of processes of erosion acting over tens of millions of years. In most places the mountains are dissected into peaks, ridges, and canyons. Remnants of a gently rolling upland surface, however, are preserved locally in the highest part of the Front Range. This upland surface is a remnant of a former widespread erosional plain. Travelers in Rocky Mountain National Park are especially impressed by the rolling uplands preserved above timberline along Trail Ridge Road.

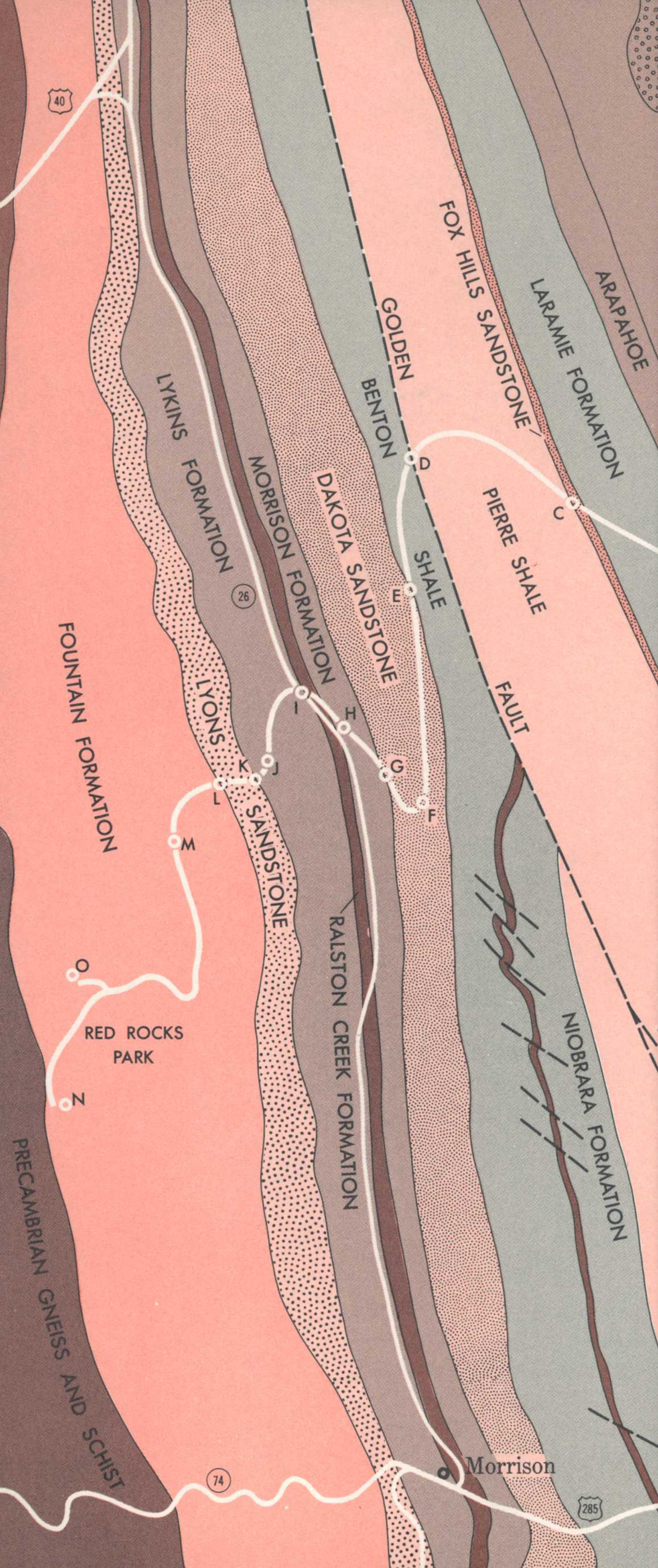
During the Pleistocene Epoch—popularly called the Great Ice Age—which continued throughout most of the past million years or more, great masses of snow and ice accumulated along the crestline of the mountains and moved down the valleys as glaciers. These glaciated valleys head in great semi-circular amphitheaters called "cirques"—spectacular and precipitous features of the high country scenery such as is seen near Mount Evans. As the glaciers moved down the valleys they acted as giant rasps, gouging and scraping the irregularities from the rocks, and rounding and smoothing the canyon walls to produce broad U-shaped valleys like that of Clear Creek, near Georgetown. This U-shaped valley profile near Georgetown contrasts sharply with the V-shaped profile farther downstream between Idaho Springs and Golden, where the stream valley was untouched by the glacier.

Heaps of debris strewn along the edges of the ice and left after melting of the glacier are called lateral moraines. The farthest advance of a glacier commonly is marked by a ridge of rock debris known as a terminal moraine. Many moraines effectively dam the streams and impound lakes. Echo, Brainard, Bear, and many other lakes in the mountains owe their presence to such natural dams.

After retreat of the valley glaciers, some 6,500 years ago, the streams continued their work of downcutting in the mountains and foothills, and transporting and depositing sand and gravel throughout the plains. Thus, over the past billion and a half years the combined forces of mountain-building, volcanism, and erosion and deposition by streams and oceans, winds, frost, and glaciers have sculptured our present-day landscape. The results are here for all to see, to admire, and to ponder.

Echo Lake, dammed by lateral moraine along the rim of the glaciated valley of Chicago Creek.





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FOX HILLS SANDSTONE
LARAMIE FORMATION
ARAPAHOE
GOLDEN
BENTON
D
C
PIERRE SHALE
SHALE
E
LYKINS FORMATION
MORRISON FORMATION
DAKOTA SANDSTONE
26
FOUNTAIN FORMATION
LYONS
SANDSTONE
I
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J
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L
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FAULT
RALSTON CREEK FORMATION
NIOBRARA FORMATION
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RED ROCKS PARK
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PRECAMBRIAN GNEISS AND SCHIST
74
Morrison
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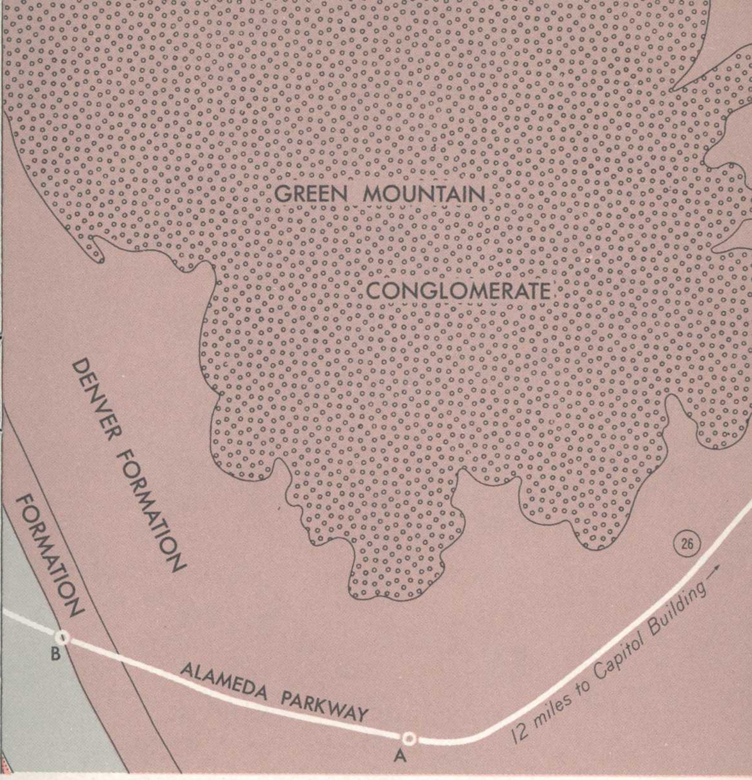


Geologic map showing route of the road log.

ROAD LOG DESCRIBING GEOLOGIC FEATURES WEST OF DENVER AND AT RED ROCKS PARK

(letters are keyed to accompanying map)

Miles—Start from the southeast corner of the Denver Federal Center, intersection of Alameda Parkway and Kipling Street. Drive west on Alameda Parkway.

3.0 A to 4.5 — Road cuts show nearly flat-lying Denver Formation overlain by pediment gravel. The Denver Formation contains pebbles of volcanic rock (andesite). The first remains of the three-horned dinosaur *Triceratops* were found in the Denver Formation near here in 1887.

B 4.9 — Contact between the Laramie Formation below and conglomerate of the Arapahoe Formation above. This conglomerate bed, unlike the Denver Formation, contains no pebbles of volcanic rocks. The Arapahoe Formation, which is tilted steeply here, underlies downtown Denver at a depth of 500 feet and is an important source of ground water. Other ground-water sources beneath Denver are sandstone beds of the Laramie and Fox Hills Formations. Water enters these beds in the foothills area and slowly seeps down dip toward Denver.

Fossil footprint on the Dakota Sandstone and sketch of the dinosaur that made the print. Print is 18 inches long.

C 5.2 Exposed here from west to east is the Pierre Shale, the Fox Hills Sandstone, and the Laramie Formation—the sandstone at the extreme east end of the cut. The Pierre Shale was deposited in a sea, and contains fossil marine shellfish. The Fox Hills is a transitional beach deposit between the marine Pierre Shale and the nonmarine Laramie Formation which was deposited on land and contains fossil leaves and wood. The Laramie also contains the coal beds that are mined near Denver, and is a major source of brick clay.

D 5.7 The Golden fault, although not visible here, brings the Benton Shale in contact with the upper part of the Pierre Shale, and the intervening strata are missing.

E 5.9 Contact between the Benton Shale on the east and the underlying Dakota Sandstone on the west. The marine Benton Shale contains abundant fossil fish scales and rare mollusks.

F 6.5 Parking area on top of Dakota Sandstone hogback. On the east side of the hogback the sandstone beds, which dip about 45 degrees to the east, are ripplemarked, and some surfaces have dinosaur tracks. At the east base of the hogback are the black shales of the Benton. Below and to the south is an abandoned limestone quarry in the Niobrara Formation. This limestone contains oyster shells. The limestone, displaced by the Golden fault between the quarry and Alameda Parkway, does not appear at the surface northward to Golden.

G 6.6 Contact between the Morrison Formation and the Dakota Sandstone.

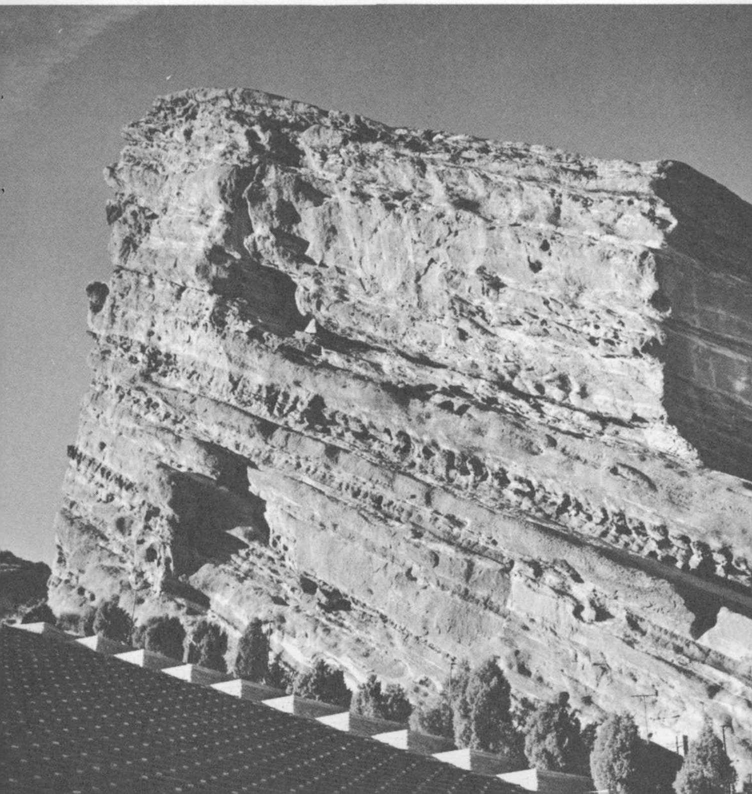
H 6.8 Varicolored rocks of the Morrison Formation were deposited in swamps, lakes, and streams. A brown sandstone bed here contains dinosaur bones, first discovered in 1877.

I 6.9 Road intersection. Cross highway and enter Red Rocks Park. Valley of Mt. Vernon Creek is in varicolored claystones of the Ralston Creek Formation and red mudstone of the Lykins Formation.

J 7.1 "Crinkled" limestone in Lykins Formation.

K 7.2 Contact between the Lykins Formation (red mudstone here) on the east and the Lyons Sandstone on the west. Lyons Sandstone, quarried near the town of Lyons, was used in the construction of the buildings at the University of Colorado in Boulder.

Fountain Formation, Ship Rock at Red Rocks Theater.



L 7.3 Contact between the Lyons Sandstone and the Fountain Formation. The Lyons here is a light tan and gray sandstone. The Fountain to the west is pink.

M 7.5 Fountain Formation. Note conglomerate filling channel in mudstone, which marks the course of an ancient stream carrying gravel in its bed.

8.0 Road junction. Go straight ahead.

8.2 Tunnel through Fountain Formation.

N 8.4 Highest parking area above amphitheater at Red Rocks Park. In the distance to the south can be seen sloping pediment surfaces cut by streams flowing across the tilted Fountain Formation. Conglomerate and sandstone of the Fountain Formation frame the theater. The Fountain Formation rests on Precambrian metamorphic rock (granite gneiss) of the Front Range at the west side of the parking area. Geologic markers describe the geology to be seen at this locality.

O Another large geologic marker is at a viewpoint 0.4 miles below the parking area and 0.3 miles north of the road. This point provides a superb view of the foothills area, and the plaque reviews much of the geology seen on this trip.

Mountain front south from Red Rocks Theater with pediments in the distance.

SELECTED REFERENCES TO SOME DETAILED REPORTS

U.S. Geological Survey Professional Papers:

No. 223 Geology and ore deposits of the Front Range, Colorado, by T. S. Lovering and E. N. Goddard, 319 pages, 1950. A comprehensive description and discussion of the geology of the Front Range from a regional point of view.

421-A Quaternary geology and geomorphic history of the Kassler quadrangle, Colo., by G. R. Scott, 70 pages, 1963.

421-B Bedrock geology of the Kassler quadrangle, Colo., by G. R. Scott, pages 71 to 125, 1963.

U.S. Geological Survey Bulletin:

No. 996-C Pleistocene and Recent deposits of the Denver area, by C. B. Hunt, pages 91 to 140, 1954.

U.S. Geological Survey Maps:

No. GQ-103 Bedrock geology of the Golden quadrangle, Colo., by Richard Van Horn, 1957.

I-428 Geology of the sedimentary rocks of the Morrison quadrangle, Colo., by J. H. Smith, 1964.

Denver Mountain area map, containing The Story of the Mountains by Ogden Tweto: for sale by the U.S. Geological Survey, Federal Center, Denver, Colo., or Washington, D. C., 50 cents.

THE GEOLOGICAL SURVEY AT DENVER

The Geological Survey, a scientific agency of the United States Department of the Interior with headquarters in Washington, D. C., maintains one of its major field centers at Denver, Colorado. Here earth scientists, technicians, and administrative personnel, working in laboratories, instrument shops, libraries, and offices conduct and support geologic, topographic, and hydrologic research throughout the central and western States.

Main offices are in the Federal Center, located about nine miles west of the downtown Denver area, where all published geologic, topographic, hydrologic, and State base maps covering the States west of the Mississippi River may be purchased over-the-counter or by mail.

A Public Inquiries Office is located in downtown Denver at 15426 Federal Building for the convenience of the public. This office stocks reports and maps for over-the-counter sale and provides information about the work of the Geological Survey.

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As the Nation's principal conservation agency, the Department works to assure that nonrenewable resources are developed and used wisely, that park and recreational resources are conserved for the future, and that renewable resources make their full contribution to the progress, prosperity, and security of the United States—now and in the future.