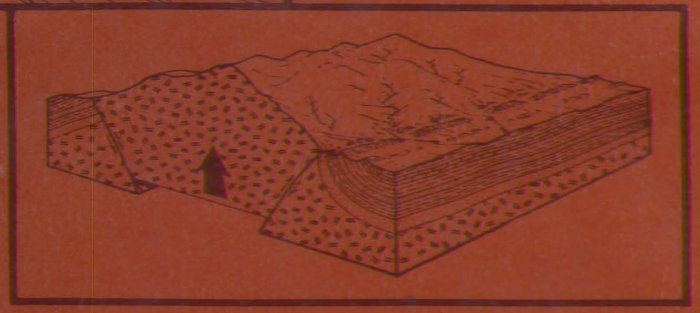
Landforms of Colorado

Richard M. Pearl



Garden of the Gods

Dedicated To

Francis and Muriel Wolle
of Boulder
Teachers, Neighbors, Friends

Earth Science

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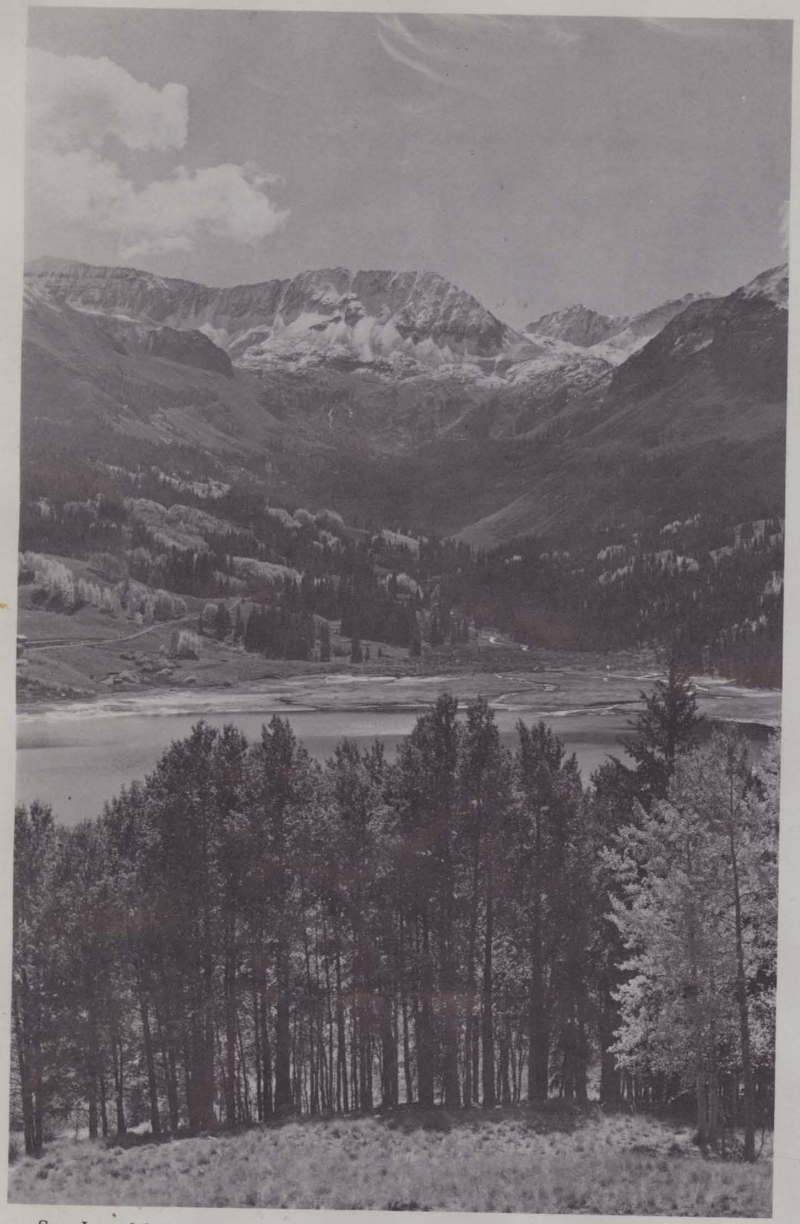


San Juan Mountains

Part I

Preface

This book is intended to describe and intrepret the scenic features of Colorado. It is written for those who, as John Ruskin said, do not want their enjoyment of the landscape to "hang on a curious web of subtle fancy and imperfect knowledge." It tries to tell, simply but correctly, the geologic stories of many of the most worthwhile places of scenic wonder and beauty, so that an understanding of their origin and development may complement an aesthetic appreciation. Here are told, therefore, not only *What* but also *How* and *Why*. This is a supplement and companion to the author's earlier book *Nature as Sculptor*, published by the Denver Museum of Natural History. Another small book in popular language, dealing with the general geology of Colorado, is *Prairie Peak and Plateau*, by John and Halka Chronic, published as Bulletin 32 by the Colorado Geological Survey.

There are those who prefer not to understand scenery but would rather "just enjoy it." Joseph Machlis said about similar persons who feel that way about music: "What they really fear, one suspects, is that knowledge of any kind might interfere with the fantasies they like to interpose between themselves and the sounds. They would rather immerse themselves in a tonal bubble bath, achieving thereby a state of hazy contentment." Hazy — or lazy — contentment? "To understand," said Raphael, "is to equal." "When we completely understand a great work of music," continued Machlis, "we become, if not the equal of the master who created it, at least worthy to sit in his company." Are you worthy to join the Creator of the Universe?

In a recent book (*The Evolution of Scotland's Scenery*), J. B. Sissons has said: "The subject (the study of landforms) depends entirely on simple facts obtained by observation and measurement in the field and in the laboratory, and the amateur, suitably advised, is often just as capable of collecting these facts as the specialist."

This book endeavors to combine geology and geography — as *geomorphology* (grandma called it *physiography*) — in such a way as to explain the origin of the landforms (and hence the basic scenery) of this spectacular part of America. Another purpose is to show how the

past history and present activities of the residents of Colorado have been influenced directly by the nature of the landscape. The history of our people and the state of their economy owe a debt to these landforms that is enormous and only too little appreciated.

Part II discusses the principles of the study of scenery, which is a science as well as an art. It can appeal alike to the systematically inclined and to the aesthetically minded.

Part III presents briefly the major types of landscape features, from volcanoes to glaciers, from mountain ranges to sand dunes. Every effort has been made to use as few technical words as possible, and their meaning is made clear as they are introduced.

Part IV is a guide to places of geologic significance. There has been no attempt either to make the entries of equal length — which would give a false impression of their relative significance — or to suggest their importance by the space devoted to them, which would satisfy nobody. The descriptions and explanations are written solely to inform and to please; the arrangement is alphabetic.

Inquiries were sent to about 100 chambers of commerce and related organizations in Colorado. A number of them suggested "fancifully named rock 'formations'" for inclusion here, and appreciation is expressed for this helpfulness, which is acknowledged on the appropriate pages.

Prelude

Though man may travel the seaways and airways of the world, his habitat is the lands of the earth. He lives in regions flat beyond imagining, where the eye scans the horizon the full circle round and sees only utter levelness. He lives in rugged mountain regions of jumbled slopes, in regions of gently rounded hills, on sloping coastal plains that in their seaward edges mingle with the marshes of great tidal flats. He lives in steep-sided valleys that are, in Kipling's phrase, like "sword-cuts in the hills." These and many other diverse regions are the habitat of man. These are the varied lands that are his home.

The lands of the earth are ever-changing. Even in the brief time of man upon the earth there have been vast alterations in the nature of the lands. Huge glaciers have advanced and retreated across broad regions of the world, each time leaving behind a different landscape. Rain and the water from melting snow have moved great masses of earth materials from higher to lower mountain slopes, from mountain

slopes to piedmont hills, and onward down across the plains to the sea. Wind and sun and other weathers have altered the land. So, too, has the sea whose waves and currents shape and mold the coasts. The impact of ice and weather and the sea upon the land are strikingly visible even in the lifetime of one man, as when a river cuts a new channel during flood or when part of the coast is returned to the stormy sea.

Forces generated in the earth's interior also shape the lands. Over broad regions, lands are raised or lowered. In narrower zones, mountains push upward. Ash and cinder are hurled across the land by erupting volcanoes, and molten rock pours outward from craters or from fissures in the rock. Except for the sudden and spectacular effects wrought by volcanic action or by earthquake, the changes in the lands produced by internal earth forces are less readily observable than those produced by ice or weather or the sea. Yet even in the span of a few generations the upward warping of some coastal zone may lift an ocean beach many feet above the sea.

The varied shapes of the lands, the diversity of their surface materials, and the rock and mineral resources that lie close at hand beneath the surfaces of the land — all these are major elements in the habitats of man. To peoples of different times and places and cultures these things have had different meanings. But always there has been some mode of relationship of man to the land. The physical nature of the lands in all their myriad forms and of the forces that change these forms are vital, major factors in the geography of man upon the solid earth.

— David I. Blumenstock,

Historical Background

Too strong an emphasis on environmental determinism should be avoided if the intellectual balance favored these days is to be sought. Nevertheless, the physical environment deserves more attention than it generally receives; few scholars in the areas of social, historical, and economic studies seem enough interested or qualified in the subject, especially the geologic aspects but also those having to do with physical geography. This dichotomy goes back to ancient times when the literary and humanistic scholars were not interested in technology, and in turn, those persons who were knowledgeable seldom cared about the influence of science and technology on society.

Colorado is most conspicuously divided into three major topographic sections, called by John and Halka Chronic simply "Prairie Peak and Plateau" — the title of their 1972 guide to the geology of Colorado* — these are the Great Plains, the Southern Rocky Mountains, and the Colorado Plateau. Each is described, discussed, and explained below, together with the two smaller regions that are present. The Prairie, unfavorably labeled the Great American Desert, was avoided as undesirable. The Peaks were regarded as a barrier to be passed around, and the Plateaus had little appeal except for special purposes. Consequently, Colorado was settled — except the south-central area, a northward extension of Spanish influence from New Mexico — mainly in the backwash of retreat from gold mining in California.

The cross-country trails over which migration took place toward Santa Fe, California, and Oregon followed the eastward-flowing river systems for several reasons: this was easier than going overland; the streams provided routes through mountains; and, most important, they supplied grass to the beasts of burden, water to men and animals, and wood for fuel. The trails — most of which nevertheless went north of Colorado — proved to be closely related to the major physical features of a vast region. *Seven Keys to the Rocky Mountains*, by Richard M. Pearl, deals further with this subject.

*Colorado Geological Survey Bulletin 32.

Part II
The Message of the Rocks

Chapter 1

The Fundamentals of Scenery

You cannot see things until you know roughly what they are — C. S. Lewis: *Out of the Silent Planet*

Sir Archibald Geike, a distinguished Scottish geologist, wrote:

> The process by which the scenery of a country is produced may be compared to sculpture. In the fashioning of a statue, the block of stone must first be lifted out of its bed in the parent rock, before the sculptor's tools can be used upon it. Apart from the design and workmanship, the aspect of the statue will primarily depend on the nature of the material employed . . . So in the case of the dry land. There first must be an uplifting of the ground above sea-level, and then Nature's tools will slowly carve its surface into the characteristic terrestrial shapes . . . much will (also) depend upon the particular tools which Nature may use, and on the energy with which she wields them. — *The Scenery of Scotland*

This is acceptable scientific doctrine, summarized by William Morris Davis, a physical geographer of renown, as "structure, process, stage": the subjects of the next three chapters.

The message of the rocks depends on who reads it. Some find it a blank page. Some see in it beauty, others utility: the conservationist and the engineer often regard a great, unharnessed waterfall with opposite emotions. The message always has had a broader significance for those who learn a little of its meaning and then go on to expand their outlook as they see more of the face of nature and appreciate more fully the relationship between nature and man. So much has been penned by poets and philosophers and sensitive observers — writing, remember, was one of the beginnings of civilization — that it does not need retelling here. As Henry Fielding said in *A Voyage to*

Lisbon: "In truth, mountains, rivers, heroes, and gods owe great part of their existence to the poets; and Greece and Italy do so plentifully abound in the former, because they furnish so glorious a number of the latter." Some overly sensitive souls have carried this relationship between man and nature to the point of sentimentality. To man, man must be the measure of the worth of a thing. But he needs more to be liberated by enlightenment than by profligacy. The act is reciprocal: "Speak to the earth and it shall teach thee," said Job to his alleged comforters.

The study of the origin of landforms is called *geomorphology*. The older term *physiography* denotes much the same thing, though perhaps more of the descriptive aspects and enlarged to include the ocean and the atmosphere. These sciences are related both to geology — when they emphasize the principles and processes — and to geography, when they describe the distribution of the various forms. To the geologist, landforms represent "a kind of final product, the end of a story," as expressed by Nevin M. Fenneman, a pioneer in regional American geomorphology. Landforms depend on all the physical processes of geology, he said. "To the geographer," however, "they offer a beginning, a point of departure . . . They depend on nothing; almost everything else depends on them in some measure."

Joseph Barrell, a perceptive American geologist, wrote: "The flowing landscape of geologic time may be likened to a kinetoscope panorama. The scenes transform from age to age, as from act to act; seas and plains and mountains follow and replace each other through time, as the traveler sees them replace each other in space."

Scenery has thus existed ever since the primeval ocean beat upon the primeval shore. Modern landscapes often reflect geologic events of ancient days, which have influenced their development, often in detail, even though practically all we see of the land has been shaped during the last few pages of the geologic story of the earth.

The student of the science of landforms contemplates the surface features of the earth in the three dimensions, plus that of time, as well as in color and in the sound supplied by moving air and water, the rustle of trees and shrubs, and the cirrs and voices of animals. The first volume in English to seek natural causes of the earth's landscape was apparently William Bourne's *Booke called the Treasure for Traveilers* (1578).

Natural regions can be based on a number of different factors: geology, physiography or geomorphology, climate and soil and vegetation, animal life. A numerical method for measuring the appeal

of landscapes — a uniqueness ratio — was proposed in 1969 by Luna B. Leopold. Geographic regions can also be described according to the economy, that is, by the occupation — such as industrial activity, agriculture, fisheries — of the people living there.

The geomorphic regions into which areas have been divided by specialists have been based on various considerations. These include geologic structure (the shapes, positions, or attitudes of the rocks), topography, altitude (height above sea level), relief (difference in altitude), stream (drainage) basins, and the totality of landforms and geologic history. Each geologic element has its own highly individualized imprint on the landscape.

The first basis of scenery is rock, for scenery is primarily rock. Vegetation, of course, adds immeasureably to the attractiveness of the scenery, but it grows only from the soil that develops as the rock breaks down and decays under the combined influence of the atmosphere, ground moisture, and organisms. For several billion years, it should be remembered, there was no vegetation on the land. Writes Lester C. King, a South African geologist: "The aspect of those early lands was stark, for the terrains were devoid of life and the transition from one landform to another, from rocky hill to gravel plain or desert dunes, was abrupt without true soils or plant cover to smooth out the contours. Everywhere the aspect of the lands was such as we now find only in the great deserts — the Sahara, the Mohave, or the Namib."

Rocks are the structural materials of the earth's crust. They include bodies of water and ice, as well as unconsolidated sediment. Most rocks, such as granite, consist of two or more *minerals,* but some, such as rock salt, contain only one mineral on a large scale; some rocks, such as coal, are of organic rather than mineral origin; volcanic glass, such as obsidian, is also a rock.

Igneous rocks have formed by the solidification of molten matter called *magma* when beneath the surface and *lava* when at or near the surface. Granite is by far the most common *intrusive* rock, having evolved from magma. Basalt is about equally common among the *extrusive* rocks, hardening from lava. *Sedimentary rocks* have formed by the consolidation of broken matter *(sediment)* from pre-existing rock, and by the precipitation of dissolved mineral matter from solution. Sandstone is a familiar example of a fragmental rock, and shale is the most abundant of them; limestone is the most common rock of chemical origin. *Metamorphic rocks* have been formed by the transformation of igneous or sedimentary rock under the influence of heat, pressure, and fluids. Marble and slate are well-known examples, but gneiss and schist are more widespread.

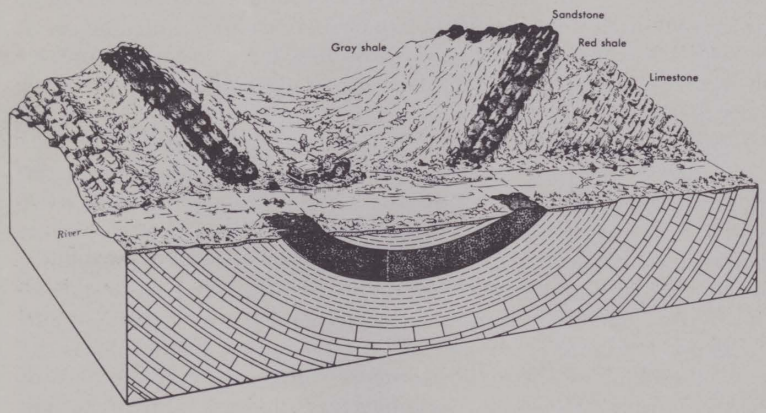
Chapter 2

Structure: The Architecture of the Crust

Our souls, whose faculties can comprehend
The wondrous architecture of the world.
Christopher Marlowe: *Tamburlaine*

The arrangement presented by rocks indicates to the trained eye their previous history. Not only the kinds of rocks but their physical and chemical characteristics and their relative positions are dealt with here.

Igneous rocks occur mostly as *batholiths,* which are irregular, rather shallow bodies of large size; above them are, or were before erosion, volcanic rocks of their own making. The Pikes Peak batholith, composed of the Pikes Peak Granite, is a prominent example. *Stocks* are similar and may be merely the upper knobs on batholiths, but they are limited to exposures of less than 40 square miles. The Spanish Peaks have been classified as typical stocks, containing intrusive as well as extrusive rock, but they are volcanic, the roots of eroded



This cross-sectional view shows how the bending of the rocks forms a trough.

volcanoes. *Dikes* are tabular-shaped bodies that cut across older rock; hundreds of them radiate vigorously from the Spanish Peaks. *Sills* are similar to dikes but are parallel to the surrounding structures, whether now horizontal (as a window sill) or standing at any angle. *Laccoliths* are sills having arched centers, over which the sedimentary or lava layers fold. Crested Butte, in the Elk Mountains, is an example, as is Hahns Peak, on the west edge of the Park Range. *Volcanic necks* are the exposed conduits of former volcanoes, such as, for instance, the Spanish Peaks. *Volcanoes* are vents in the crust from which issue molten or hot rock and vapor, especially steam. The San Juan Mountains are the largest volcanic area in Colorado; Specimen Mountain, in Rocky Mountain National Park, is a superb volcano — but Pikes Peak, in spite of such local names as the Crater, is not a volcano, never was, and never will be. *Lava flows* are the surface extrusions of solidified molten rock. There are hundreds of lava flows in all parts of Colorado, capping mesas in the west, building up mountain ranges in the southwest, and spreading widely in the southeast.

Sedimentary rocks are, like lava flows, stratified: deposited in layers (*strata, beds*) separated by *bedding planes*. Although most of Colorado's high peaks are igneous and metamorphic — the sedimentary cover having been stripped away — the crest of the Sangre de Cristo Range remains sedimentary. *Unconformities* indicate a lapse in time between the deposition of adjacent beds. The rock unit used in mapping is a *formation,* of which many, such as the Morrison Formation and the Pierre Shale, have been named in Colorado.

Metamorphic rocks are characterized by a tendency toward a parallel alignment of minerals *(lineation)* and a wavy banding *(foliation)*. The scenery of the Colorado mountains displays fine examples of metamorphic rocks, such as the canyon of the Big Thompson River out of Estes Park.

Rock structures of deformation include *warping,* which is broad tilting or uplift, and *folding,* which is bending. Folds are classified simply as *anticlines,* which are upfolds; *synclines,* which are downfolds; *domes;* and *basins*. The 50 or more mountain ranges that have been named in Colorado are mostly elongated domes, properly called faulted (broken) anticlines.

Rock structures of displacement include *fractures,* which are cracks; *fissures,* or extensive fractures; *joints,* or groups of fractures; and *faults,* which represent slippage along breaks. A *fault scarp,* such as the abrupt front of Cheyenne Mountain, at Colorado Springs, is a cliff made at the surface as a result of faulting.

Chapter 3

Process: The Geologic Agents

the cosmic process works and shall work forever —
Frederic William Henry Myers: *Human Personality*

Process deals with the geologic agents at work. These agents include gravity, which brings the "high places low"; *streams,* which carry the drainage; *ground water,* the subsurface, or underground, fluid; *currents and waves; glaciers,* or bodies of moving ice; and *wind,* which is air in motion.

The geologic processes include *vulcanism,* which is concerned with the origin, movement, and solidification (and perhaps crystallization) of molten rock — it need not come from a cone-and-crater volcano but will solidify as igneous rock. Other geologic processes are *diastrophism,* or *tectonism,* which is the movement of solid or plastic rock; *earthquakes; weathering,* or the breakdown of rock on exposure; *erosion,* the removal of rock by various geologic agents; *transportation,* the carrying of rock or dissolved matter; and *deposition,* the settling out of this material as sediment, which may become sedimentary rock. *Metamorphism* changes either igneous or sedimentary rock to metamorphic rock.

Chapter 4

Stage: The Evolution Of Landscape

tall turrets do fall
and rocks do crumble
Lucretius: *De Rerum Natura*

The concept of the *geomorphic cycle* was the contribution of William Morris Davis. Stage represents the point in the cycle through which these agents progress from "infancy" to "youth" to "maturity" to "old age" — provided that the land is not disturbed by uplift or subsidence before the cycle is completed. Thus, a youthful landscape that has been produced by glaciers in high mountains has certain distinctive features not found under other circumstances; and these can be recognized, described, and explained by those who have learned to read the record in the rocks.

This concept has its objectors as well as its defenders, but it is a useful one, especially for streams. It should be regarded only as relative: no definite time in years is implied, nor are the stages of equal duration. Some aspects of a scenic feature may be (and are likely to be) in a different stage from other aspects of the same feature. Even the different segments of a stream can be expected to show evidence of having reached different stages in the cycle of stream erosion.

A partial cycle is much more apt to occur than a completed one. Uplift of a landmass, for example, begins a new cycle, and this is called *rejuvenation.* Subsidence of a landmass, on the contrary, hastens the cycle toward its end.

By means of the geomorphic cycle, descriptions of scenery are simplified, and emphasis is placed on the mode of origin. Science is thus applied to scenery.

Chapter 5

Time, Sequence, Fossils

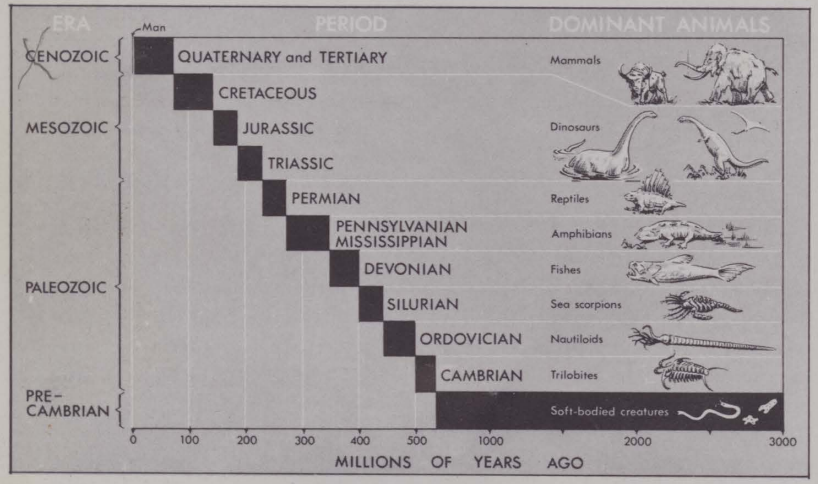
How many years must a mountain exist
Before it is washed to the sea?
Folk song *Blowin' in the Wind* album

"In the beginning, the earth was without form and void." Born of solar origin 4.5 to 5 billion years ago, it shows no known record of its early composition or structure. Geologic time began when the first rocks existed that were similar to those of today. This time is subdivided into eras, periods, and epochs. A generally accepted time scale for geology is printed on page 16. The intervals of time are given (and are best learned) in their normal order: the first, or oldest, at the bottom; the last, or youngest, at the top — just as though a slice were cut into the crust of the earth through all the sedimentary rocks that have been laid upon one another during geologic history. In no one place, however, is such a complete record found, as Charles Darwin was the first to point out.

The relative ages of sedimentary rocks are identified chiefly by the fossils in them. This is possible because of the principle of organic evolution promulgated by Jean Baptiste Lamarck, Alfred Russel Wallace, and Charles Darwin, whereby living things change with the passage of time. Igneous rocks may be dated (in years) by their radioac-

tive constituents: by the ratio of lead to uranium, argon to potassium, and other ratios and transmutations. Igneous, sedimentary, and metamorphic rocks alike are dated by their structural relationships.

G. H. Ashley and William D. Thornbury, American geologists, have particularly emphasized the youthfulness of practically all the world's topography: its landscapes and its scenery. Most of them have been carved, in Colorado as elsewhere, since the Miocene Epoch. The rocks and their structures may be older, much older, but the surface expression is of late origin, mainly Pleistocene. The significance of the Ice Age in terms of climate and the effects of glaciation and changing sea level can scarcely be exaggerated.



Geologic Time Scale

Part III
Features of the Landscape

Chapter 6

Fire In The Earth

Where, piercing Earth's integuments,
The flux of molten matter spills
Through fissures and red-throated vents
Of domed volcanic hills.
F. B. Young: *The Island*

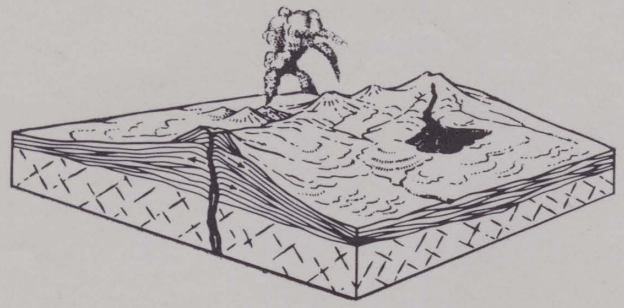
Although he was said to dwell in far-off Mount Etna, on the island of Sicily, Vulcanus — the Roman god of the fiery element — has been busy at many times in many places in Colorado. He has repeatedly declared war on us and has impressed his flaming brand upon the landscape. His trademark is to be seen widely across a broad expanse of rugged mountains, high plateaus, and fertile plains.

Some of the works of Vulcanus date back to when the earth was young. The most conspicuous signs of volcanic activity, however, are connected with events that happened in the Cenozoic Era, the same portion of geologic time to which we ourselves belong. This is because not enough time has yet elapsed for the relentless agents of erosion to bury them in oblivion.

The familiar cone-and-crater volcano, though spectacular as at Specimen Mountain, in Rocky Mountain National Park, and formerly at Cripple Creek, is not the principal source of volcanic material. Having been active throughout geologic history and having changed their site of industry from place to place with the passing epochs, the forges of Vulcan have produced a relatively small amount of rock. This is far less in quantity than the lava-rock that has arisen from fissures in the crust and spread across the countryside.

These two kinds of volcanism — *central eruptions* and *fissure eruptions* — are different aspects of the same geologic process. Through the fiery conduits of volcanoes, molten rock and solid rock discharges, propelled by gas escaping from confinement. Volcanoes give us an oc-

casional awesome glimpse into the world that lies concealed beneath our feet. From otherwise inconspicuous openings in the ground, unaccompanied by the drama that characterizes the functioning of a true volcano, lava has come in quantities to build up thicknesses of basalt such as now constitutes Mesa de Maya in southeastern Colorado. Flat-topped mountains are the subject of Chapter 9.



Like other landforms, volcanoes pass through a cycle of erosion from youth to old age, after their period of growth has ceased. Because volcanoes develop more rapidly than most other features of the landscape, erosion does not usually (except at sea) attack them while they are forming. Then, because their normal growth may be abruptly interfered with at any time, the cycle of volcanic erosion may be more rapidly renewed — restored to the youthful state — than is true of other geomorphic forms.

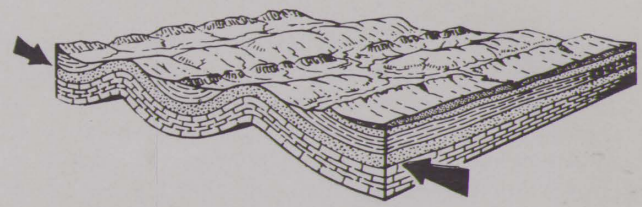
Chapter 7

Wrinkles In The Crust

better able to find out the natural bent
Plato: *The Republic*

The crust of the earth has been folded many times and in many places. The ultimate cause is unknown. It may be the result of the shrinking of the earth by cooling, of the expulsion of volcanic matter from the mantle, or by nuclear reactions that change the silicate rocks of the mantle into denser material. It may, instead, result from expansion, perhaps by the radioactive generation of heat. Folding has also been ascribed to convection currents in the earth's mantle; their drag

would produce continuous or intermittent displacement of parts of the crust. Other possible causes include the sliding of crustal blocks from high to low places; the drifting of continents against a resistant substratum; the wandering of the poles, shortening the crust in some places while lengthening it in others; or a different rate of rotation of



the earth in different latitudes. The recently proposed concept of plate tectonics takes into account a number of related factors, which still await a more complete resolution.

The forms that result from mountain building have been mentioned in Chapter 2: anticlines and domes, synclines and basins. Many variations of these are possible, for the three-dimensional patterns of structures in the earth are enormously complex. When the diversities of erosion are added, no two landforms in regions of folded mountains ought seemingly to be alike. Yet the underlying generalizations make it possible for us to interpret their origin: this is what Part III of this book is designed to do.

Chapter 8

The Sliding Crust

Let the world slide — John Heywood: *Be Merry Friends*

The volcanic mountains described in Chapter 6 and the folded mountains discussed in Chapter 7 are not the only kind in Colorado. When the crust of the earth breaks, fault-block mountains are created.

The upper part of the earth's crust is brittle. At somewhat greater depth, the crust generally yields to pressure by folding, but even there, it can support only a certain amount of compression or shear, and then it fractures and faults.

Chapter 9

Flat-Topped Mountains

There you hev it plain an' flat — James Russell Lowell: *The Biglow Papers*

A fourth type of mountain is the kind that has been built up by lava flows (introduced in Chapter 6) or eroded to form flat surfaces. These may be plateaus of lava, or mesas and buttes that are protected by a cap of lava or other durable rock. They stand, however, above the adjacent landscape, and have appropriately been referred to as mountains of erosion. Sometimes, they rise higher than the nearby volcanic, folded, or faulted mountains. This is true, for instance, in the Colorado Plateau, where such erosion remnants may have higher altitudes than many peaks of the true Rocky Mountains.

A Spanish word meaning table, *mesa* is a local name in the American Southwest and Mexico for a tableland: a plateau, flat-topped mountain, or other elevation having a steep cliff on at least one side. A similar topographic feature in the northwestern United States was called by the French word *butte* because the French were the explorers of that part of the continent, as the Spanish were in the other. Colorado has both, if there is any difference. In general, a mesa was regarded as larger than a butte, chiefly because surfaces of this kind are larger in the more arid south. Inasmuch as steep-sided volcanic necks are also called buttes, the term *mesa-butte* was coined to indicate those produced by erosion, especially the turretlike forms common in the badlands.

Either of these forms becomes a *cuesta* where the layers of rock tilt somewhat, so that one side is steeper and higher than the other. A cuesta grades into a *hogback* as the tilted layers appear more uniform on both sides. The Grand Hogback of western Colorado deserves its name.

An extensive erosion surface, cutting across any kind of rock and any kind of structure, is called a *peneplain*. This is supposed to be the final stage of erosion in an old-age landscape, but the idea is a controversial one. If peneplains exist anywhere, Colorado has a major representative cutting across the mountains and broken (faulted) with these mountains. An erosion remnant called a *monadnock*, such as Pikes Peak, may remain standing above a peneplain.

Chapter 10

The Weeping Earth

the water under the earth — Exodus 20:4

"The water under the earth" circulates in wondrous ways beneath the surface as *ground* (or *underground* or *subsurface*) *water*. It comes from above as rain and snow (and their variants known as sleet and hail); it rises from below from cooling bodies of molten rock; and it occupies and moves through pores and cracks in soil and bedrock.

This precious supply of water makes life possible away from lakes and streams. The hydrologic cycle traces the history of drops of water from their appearance in rain clouds, through precipitation, runoff (in a pattern of channels, or streams), percolation (into the ground, where it may dissolve solid rock or combine chemically with mineral matter), transpiration (by plants), and evaporation into the atmosphere again. Ultimately, the water reaches the oceans and is taken up as vapor, to accumulate once more as rain clouds. Some ground water originates from molten rock below or upon the surface of the earth. Other water, usually salty (saline), had its source in the sediment with which it was deposited, perhaps a very long time ago.

The principal large-scale geologic effect of ground water is the dissolving of caverns and their later, partial refilling. These are explained in Chapter 11.

Ground water feeds streams (discussed in Chapter 12) and in turn is fed by them. A few waterfalls (see Chapter 13) are born fullgrown from a single source of ground water. Some ground water comes from the melting of glaciers, explained in Chapters 15 and 16. Some of it enters and flows out of lakes, the subject of Chapter 18. Where, however, ground water emerges at the surface as springs, it is considered in this chapter. Numerous springs — far too many to be more than hinted at — occur in Colorado. They have a wide range of origins.

Cool water is more or less mineralized, the mineral content varying according to the locality. Springs have been classified in numerous ways, but with a decline in the therapeutic use of mineral waters — especially in the United States, where spas have given way to swimming pools — the emphasis is less on the medical aspects. A simple chemical classification of alkaline, alkaline-saline, saline, and acid

serves most purposes, with subdivisions, such as iron springs or lithium springs, to bring out certain dominant compositions. Comparing the chemical analysis of mineral waters with the famous springs of Europe or elsewhere is old fashioned.

Heated (thermal) water rises to become a hot spring; such a spring is always mineralized, and its deposits may build up extensive terraces of sinter (if silica) or travertine (if calcium carbonate), being colored by the mineral content or by algae. A smaller amount of water present results in a mudpot, the mud being formed by the decay of rock acted on by carbon dioxide and sulfuric acid. Besides the temperature and composition, springs may be compared as to radioactivity, rate of flow, and geologic origin, including the kind and age of rock.

Springs of Colorado, by Richard M. Pearl, describes the most important ones in the state.

Chapter 11

Beneath The Land

caverns measureless to man — Samuel Taylor Coleridge: *Kubla Khan*

Just as earthquakes prove the terra firma to be somewhat less than firm, so does the widespread presence of caves and caverns show the solid earth to be other than solid. Ground water, made slightly acid by taking up a small amount of carbon dioxide from the atmosphere and vegetation through which it has passed, becomes carbonic acid and dissolves carbonate rocks slowly but effectively by long contact with them.

Limestone is the chief carbonate rock, both in quantity and in the ease with which it tends to dissolve. Rock salt is, of course, soluble even in neutral water, but it is less abundant. Except ordinary marble, which has the same composition and reaction rate as limestone, dolomite and other carbonate rocks react more slowly, but they are much less common. Gypsum contains caverns in some places. Sea caves and the caves in tubes of cooled lava do not fall into this category, for they have not been produced by the solution of rock. Neither have those relatively few Colorado caves that have formed artificially in sandstone, talus (landslide debris), even granite. Caves that open at ground level — like those in which the early Americans

lived at Mesa Verde — are sometimes of solution origin and sometimes not.

The downward percolation of ground water along openings in rock enlarges them, forming a funnel-shaped hole called a *sink* (or *sinkhole* or *swallow hole*). The roof may collapse when weakened. Continued solution underground opens caverns. Extensive solution at the surface and below removes more rock, until a rough and barren landscape, called *karst topography* after the Karst region now in Yugoslavia, is the ultimate result.

As the water level lowers with further erosion, the caverns drain into the deepening streams. Into the open caverns, abandoned by their subsurface flow, the ground water that drips into them may deposit carbonate and other mineral matter. This becomes *dripstone,* which goes under a variety of different names: *stalactites* (like icicles), *stalagmites* (built up from the floor), *columns* or *pillars* (joined at top and bottom), and other forms that resemble all sorts of familiar objects. The Cave of the Winds, at Manitou Springs, is known to geologists everywhere. Fairy Cave, Fulford Cave, Hubbards Cave, Ice Caverns, Porcupine Cave, and Spanish Cave are also described in this book.

Chapter 12

Flowing Water

I hurry amain to reach the plain
Run at the rapid and leap the fall,
Split at the rock and together again
Sidney Lanier: *Song of the Chattahoochee*

Streams are at the heart of physical geology. Aided by gravity movements, they have been the chief agents in the sculpturing of the landscape, even in arid regions. They are the most effective agent for the moving of rock material from one place to another. It was the recognition that streams were the chief means of erosion and transportation and deposition — as a normal process taking place at ordinary rates of activity — that led to the founding of geology as a science.

Most precipitation takes place between 10,000 and 12,500 feet in altitude. Because Colorado has by far the largest percentage of land in the United States at this altitude, it is the source of many great rivers, which begin in the Rocky Mountains and flow into both oceans. The

northern part of the state east of the Continental Divide is drained into the Mississippi River by tributaries of the Missouri. The southern part east of the Divide is drained by the Arkansas River and its tributaries into the Mississippi, and by the Rio Grande directly into the Gulf of Mexico. West of the Divide, the Colorado River gathers all the streams to itself and empties them into the Gulf of California.

These rivers traverse 19 states, bringing them water for agriculture and domestic use, and furnishing power and recreation. On the way, they go through diverse geologic terrains, show various geographic patterns (deep canyons, steep gorges, looping meanders), pass large cities and small settlements, and stay awhile behind dams.

The Continental Divide — "the backbone of the nation" — is not everywhere the sharp edge popularly conceived. Most of the highest peaks of Colorado that belong to the Sawatch Range are not on the Continental Divide; and at Poudre Lake, the Divide is crossed at the bottom of a valley. Elsewhere, of course, the streams that go their opposite ways to the Atlantic or Pacific separate along a conspicuous ridge.

Chapter 13

Smoke That Thunders

stand secure amidst a falling world — Joseph Addison: *Horace*

Water in motion exerts at times an almost hypnotic fascination. The joyful gurgling of a mountain brook as it tumbles capriciously between overhanging trees adds pleasant music to the wilderness hush that enriches so much of the scenic beauty of western America. The tone deepens and becomes more impelling as the stream is funneled through the narrow rapids of a canyon or gorge. The excitement reaches its climax where the river descends in torrents over a waterfall.

No form of moving water, not the restless swell of the open sea or the white froth of breakers on the shore, has a more universal appeal than a waterfall. Its vigorous plunge contrasts with the delicate, misty spray that tries to conceal it. The sudden sound reverberating through the countryside has the power of a giant drumbeat to stir the pulses. Earth tremors, which may be sufficient to be recorded instrumentally, are set up.

Colorado has at least its share of fine waterfalls, of which Box Canyon Falls, at Ouray, is surely one of the most dramatic on the entire continent. Boulder Falls, near Boulder, and Seven Falls, at Colorado Springs, are among the waterfalls having somewhat special geologic origins described in this book.

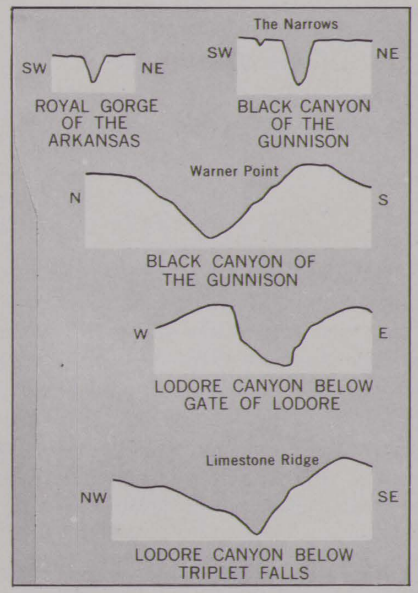
Waterfalls: An Appreciation and an Explanation, by Richard M. Pearl, deals with this subject.

Chapter 14

Mountains Upside Down

down the valleys wild — William Blake: *Songs of Innocence*

Streams in Western America have indeed stamped the mark of their genius upon the landscape of the continent. Into the rocks formed during long ages past, they have patiently but inexorably cleaved their



Canyon Profiles

way, sculpturing an immensity of space, some of it enclosed within gentle valleys, some of it confined within the limits of abrupt canyons and precipitous gorges.

The canyon-and-gorge land of the West is a region of high plateaus and mountains overlooking the magnificant canyons so aptly referred to by Roderick Peattie as "inverted mountains." There are hundreds of them, many being scenic wonders in the flush of their youthful grandeur. The dryness of most of this part of the continent and the levelness of many of the rocks give rise to steep cliffs, which are slowly retreating before the forces of destruction. Erosion produces somewhat frayed and tattered edges to these cliffs, and they wear away more quickly than the surface of the plateau.

Three factors have operated to produce the tangible results. One is the height and expanse of the land. Another is the uplift that has brought the terrain to its present, lofty altitude and has given the streams the opportunity to do their downward work of erosion with renewed vigor. A third is the recent glaciation of the Ice Age, which accumulated enormous amounts of frozen water, later to be released with canyon-cutting violence when the climate grew warmer.

Chapter 15

Rivers Of Ice

The glaciers cold and restless mass
Moves onward day by day — Lord Byron: *Manfred*

Before the Ice Age closed in on Colorado, most of the mountains were as high as they are now, but if any tourists had been here at that time, they would have been much less impressed by the scenery than present-day visitors are. Instead of the clusters of jagged peaks that call forth exclamations of awe at every turn, and the distinct ranges of ample dimensions that rise and fall like the disturbed bosom of the sea, the prehistoric traveler would have seen only an elevated land of considerable monotony. It was the glaciers that have transformed the gentle slopes and rounded contours of yesterday into a succession of thrilling scenes.

Like the maid who spends her time "rearranging the dust," America's glaciers were active in rearranging an enormous amount of rock, removing it from one place and leaving it somewhere else. In so

doing, they created a large share of the present, spectacular scenery of Colorado, as well as many features less startling but equally enjoyable.

Sharply rising mountains, spacious natural amphitheaters, and many, many lakes are among the results of the great bodies of moving ice that sojourned in our midst.

Fortunately, the ice has not entirely disappeared, although it seems to have done so prior to the so-called Little Ice Age that started about 800 years ago, only to reappear since as it had done about 3,000 years before. In addition to numerous snow and ice banks in the higher altitudes, helping to air condition the summer climate, there are still true glaciers that advance down the mountain valleys, until they finally melt and drop their burden of loose rock brought from above. Included here are Andrews, Arapaho, Mildred, Roberts, Rowe, St. Marys, St. Vrain, Sprague, Taylor, and Tyndall Glaciers, but some of these may be only stagnant bodies of ice rather than true glaciers.

The evidences for the existence of the glaciers that have vanished are strikingly apparent to even the casual visitor, once he knows what to look for. The great hollows in which they started, the ridges against which they pressed, the valleys through which they moved, the rock heaps they deposited, and the lake basins they left behind them all can be seen in beauty and profusion.

As snow accumulates in a protected pocket on a high mountain, it changes to a granular substance called *firn,* or *nêvé,* and then to hard, crystalline ice. When it starts to move under the weight of the overlying layers, it becomes a glacier and plucks away pieces of rock loosened by water that had frozen in the cracks. In this way, a huge arena called a *cirque* and shaped like a bowl of a spoon or the shell of a clam is scooped out at the head of the glacier. Horseshoe Mountain, near Fairplay, is just one of many scenic features produced by glaciers in this fashion. Lone Eagle Peak, on the Continental Divide south of Rocky Mountain National Park, is a typical *horn,* or matterhorn, left standing by a ring of encircling glaciers.

The glacier advances through a valley that has already been prepared for it by a stream, deepening it and (especially) widening it until it typically acquires a U-shaped profile. Marks of abrasion are left everywhere.

Deposition at the front of a melting or retreating glacier takes on a diversity of topographic forms. These are often given special names.

Originating as individual *mountain, valley,* or *alpine glaciers,* the moving bodies of ice merged with one another on the lowlands of northern

Colorado as *piedmont glaciers*. This took place especially in the vicinity of Estes Park.

The effects of the Ice Age can scarcely be exaggerated, for we live in what remains of this time. Man himself is chiefly a creature of the Pleistocene — the Ice Age — during the last part of which he arrived in that part of the New World to which this book is devoted. The pattern of our lives is, in a profound way, the result of the coming of the glaciers.

This period of refrigeration began perhaps 3,000,000 years ago, a round number seemingly as reliable as any other. Four principal glacial stages are recognized, separated by three longer, interglacial stages. The present, postglacial time be merely the early part of a fourth interglacial stage, but it will not be known for a long while whether this is so.

Scouring the surface, removing soil and loosening solid rock, transporting it long distances, and dropping it far from its source, the glaciers produced scenic features of many kinds.

Chapter 16

Boiling Fountains

born to fly upward,
wherefore at a little wind
dost thou so fall
Dante: *Divine Comedy*

Ground water — the subject of Chapters 10 and 11 — may penetrate far enough below the surface of the ground so that it becomes heated by the higher temperatures that exist at depth. If it chances to enter the complex system of underground plumbing that characterizes a geyser, the water will erupt at intervals. Bursting forth as steam, superheated by the pressure that kept it confined above its normal boiling-point within the earth, a geyser is a scenic phenomenon well worth traveling long distances to see. But there are no geysers in Colorado, even though neighboring Wyoming is one of the world's three classic localities.

Chapter 17

Hollows In The Surface

where the blue lake
brims her cup
Wendell Phillips Stafford: *Vermont: A Song*

Lakes are always temporary features of landscapes. They are either drained within a relatively short time or are filled with sediment or overgrown by vegetation.

Much the largest proportion of the lakes of North America owe their origin to Pleistocene glaciation (see Chapter 15 and 16). Unequal erosion or deposition by the ice has left basins deeper than the surrounding area: lakes held in by cirques, moraines, and in other ways.

Many lakes represent wide parts of streams. Volcanic activity and warping of the earth's crust produce some lakes. Other lakes are dammed by landslides, as is Lake San Cristobal. Still others — called *sagponds* — occupy depressions that are due to uneven settling of ground; and some have been built by animals, such as beavers. Northeastern Colorado has a number of these types.

Chapter 18

Stone Arches

the bridge of time — Sir Richard Francis Burton:
The Kasidah of Hajo Abdu El-Yazdi

The great bridges of stone that arch across flowing streams, above the dry beds of vanished streams, and over other landscapes are features of especial interest. Some are indeed colorful enough to be referred to as rainbows in stone.

These natural bridges originate in several ways. The largest ones have been produced by stream erosion. The most numerous owe their existence to underground solution of limestone. Our neighboring state of Utah is famous for its stone arches.

Chapter 19

Shifting Hills Of Sand

the sand against the wind,
And the wind blows it back again.
William Blake: *Untitled Poem*

The fickle nature of wind causes it to shift constantly and drop its burden of sand or dust unpredictably. It moves with equal irregularity sand that had previously been dropped. Thus do sand dunes develop, and thus do they shift from place to place. Great Sand Dunes National Monument has some of the best places.

The removal by wind of fine rock material is termed *deflation*. Sand grains jump by a leaping motion called *saltation*. Most dunes consist almost entirely of quartz, because this abundant mineral is hard and chemically resistant. Other dunes are composed of less likely materials, such as gypsum. A highly characteristic feature of dunes is *cross-bedding*, which is caused by an overlapping structure as material is laid down at changing angles when the wind veers.

The mineral and rock grains of sand dunes blow up to the crest of the dune and roll down the steep, lee side. Dunes are of several shapes and have been classified accordingly: *barchans* are crescent shaped; *seifs* are long and have the outline of a scimeter. Other names are used, depending on the relationship of the dune to the direction of the wind, whether it is fixed or changing.

Chapter 20

Relics Of The Past

The earth that hides things old — John Masefield:
The Everlasting Mercy

The birth, growth, and death of trees that later turn to stone provide a curious kind of scenery, one that seldom fails to impress the viewer. Other fossil deposits are rarely attractive, but some of the larger ones have much to offer as elements of the scenery.

The process of *petrifaction* is one of filling and replacement. The pores of wood, bone, or other organic matter are first filled by mineral-laden solutions that penetrate them. The organic substance can actually be substituted for by atoms of the new material, until they have, as Shakespeare said, "turn'd to stone," heavier than before and perhaps more brightly colored. Petrified wood is common in Colorado, and Florissant Fossil Beds National Monument owes much of its importance to it.

Chapter 21

Plant Life-Zones

acquaint ourselves with every zone — Sir John Davies:
The Vanity of Human Learning

In general, the vegetation of the continent corresponds to the climate, particularly the rainfall. In the Temperate Zone, there are four different types of plants, but adjacent provinces overlap. Within a single region, the differences can be explained by differences in the soil — a geologic factor dependent on the kind of rock — or by the particular history of the vegetation. Where the dominant forms of vegetation are the same in contiguous regions, the transition is apt to be gradual. Abrupt changes are most noticeable where there is sharp change in elevation, resulting in a decrease in temperature and a usual increase in precipitation.

To rise 1,000 feet higher in the mountains is equal, in the change in climate and environment — the so-called life zones — to traveling about 200 miles closer to the North Pole. From the bottom of the Royal Gorge to the summit of Pikes Peak — both visible from the same spot in central Colorado — is a difference in elevation of 9,000 feet. This is the equivalent of going from Virginia to Labrador, or from Mexico City to beyond Chicago.

Life zones tell us which plants and animals find congenial habitation within each zone. Recognizing the natural community of plants in any place tells us a good deal about the temperature and the moisture (both precipitation and humidity), and possibly the wind velocity, of the locality and indicates the altitude. Many of the animals, in turn, live on a diet suited to their tastes; and so each kind of mammal, bird, and reptile is more or less restricted to a certain range in altitude associated with particular vegetation.

Physiographic Provinces of Colorado

Part IV

Field Guide to Colorado Scenery

The State of Colorado

Exceeded in the diversity of its scenery only by Alaska, a much larger state, Colorado has long been divided into five natural regions, called physiographic provinces. The accompanying map shows where they are. The large eastern zone is the Great Plains, rising from 3,350 feet to an altitude of 6,500 feet at the foothills of the mountains. The central zone is the Southern Rocky Mountains, which surrounds and includes many valleys and a few flat areas known as parks. The western zone is the Colorado Plateau, 5,000 to 11,000 feet high. Each of these major provinces is described later.

Much smaller are the other two provinces. The Middle Rocky Mountains — running east-west as the Uinta Mountains — and the Wyoming Basin — a rolling prairie broken by streams and separate mountains — occupy the northwest corner of the state.

Basic geographic facts about Colorado are given below:

Area: 103,948 square miles
Dimensions: 387 miles east-west, 276 miles north-south
Average altitude: 6,800 feet

The following places of interest are given alphabetically for convenience, smaller associated features being noted at the same time. Otherwise, there is no attempt at classification and subdivision, for the obvious reason that several quite nearby places may be within more than one physiographic (or other) section — such as, for instance, features close to Colorado Springs, which may yet be on the plains, in the foothills, or in the mountains. A certain degree of grouping has already been done in Part II, where similar kinds of landforms (such as volcanoes and caves) have at least been mentioned. The natural phenomena described are to be regarded as samples only, the author's apologies being offered for the omission of your favorite spot.

Virtually every square inch of every good map of the U. S. Geological Survey or U. S. Forest Service names one or more places with an intriguing name probably deserving attention in this book. There are thousands more; many of Colorado's mountains, and lesser features as well, bear names that describe their appearance. Space forbids, and so does the author's knowledge. Two other books by Richard M. Pearl cover in detail special aspects: *Colorado Gem Trails and Mineral Guide* and *Exploring Rocks, Minerals, Fossils in Colorado.*

Andrews Glacier

First alphabetically among Colorado's most obvious souvenirs of the Ice Age, here is a typical glacier, moving between steep walls at an altitude of about 12,500 feet in Rocky Mountain National Park and adding its meltwater through Loch Vale into Glacier Creek. The origin of Andrews is like that of the others, whatever that may prove to have been: certainly a decline in temperature and an increase in winter precipitation. Andrews was formerly a feeder for the now vanished Bartholf Glacier.

Angel of Shavano

Of geologic origin in its occupancy of a frost-sprung crevice — very like the Holy Cross on the mountain of that name — the Angel appears at favorable times on the side of 14,229 foot Shavano Peak, in the Sawatch Range, Chaffee County.

Arapaho Glacier

This body of snow and moving ice stretches from 13,300 down to 12,075 feet in a cirque on the east side of Arapaho Peak (13,506 feet), melting conveniently to help supply pure water to the city of Boulder. The largest and best glacier in Colorado, probably the most southernly active (true) one in the Rocky Mountains, Arapaho is shrinking like the rest of them.

Battlement Mesa

Similar to lava-capped Grand Mesa, from which it is separated by the Plateau Creek Valley, this huge, flat land, especially on its north face, resembles the walls of an ancient castle. The volcanic rock is of Tertiary age.

Beecher Island

Colorado does not have many islands. Most are temporary spots in braided streams, waiting to be washed away by the next overflow of water, which can be expected to create new passageways for itself as it silts up previous ones. Beecher Island, situated in Yuma County 17 miles from Wray, was the site of a major, week-long battle in 1868 between the U. S. Army and Cheyenne, Arapaho, and Ogallala Sioux. The course of Black Wolf Creek has since changed, carrying the island away, and the flood of 1934 removed the monuments that marked the place.

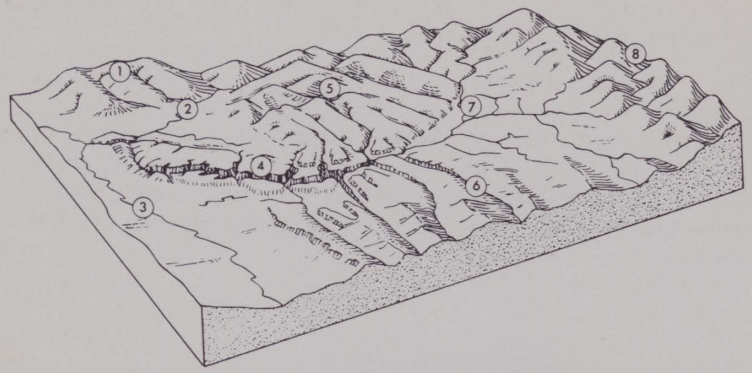
Big and Little Narrows

These openings along the route of U. S. 34 west of Fort Collins, in Larimer County, just into Roosevelt National Forest, owe their existence to ordinary stream erosion, which provided later access to animals, Indians, roads, and even a now abandoned railroad. Red granite forms the enclosing cliffs, impressive in heights and shapes.

THE NARROWS is a stream-made defile on the Williams Canyon road from the Cave of the Winds, near Manitou Springs. The narrowness is due to the presence of a resistant layer of pink dolomite at the base of the Manitou Limestone.

Black Canyon of the Gunnison National Monument

Bright in sunlight, frighteningly dark otherwise, Black Canyon is a gorge of a kind hardly surpassed on the continent. Far below, the Gunnison River roars through this canyon in Montrose County, as much as 2,800 feet beneath the rim. Formerly crossing a plain of sandstone and black Tertiary lava, the stream was let down by superposition onto the hard, ancient (Precambrian) granite and metamorphic rock that lay hidden underneath. This erosion was put into effect about 2 million years ago by a flood of lava, which diverted the river (by stream piracy) to its present course. The lower reaches of the Gunnison was favorably situated on softer rock, and the rapid downcutting enabled the upper stretch to be steepened and hence to erode more successfully.



Present stage. — Gunnison River has entrenched itself into Precambrian core of exhumed Gunnison uplift, and in so doing has carved Black Canyon. (1) Shoulder of Grand Mesa, (2) North Fork, (3) Uncompahgre River at Montrose, (4) Black Canyon, (5) West Elk Mountains, (6) Lake Fork, (7) Gunnison River at Gunnison, (8) Monarch Pass.

Book Cliffs

Resembling volumes standing on end, these sedimentary rocks, like books on geology, reveal the story of Earth's development and change. The strata are of Cenozoic age, less elevated than the Uncompahgre Plateau, across Grand Valley.

Boulder Falls

Dropping 75 feet into Middle Boulder Creek, North Boulder Creek occupies a hanging valley (in Boulder County) that resulted from an unequal uplift of the land within the rising mountains. They are still rising, and the inequality will be accentuated, for the main stream has more water and sediment with which to erode.

Box Canyon Falls

This most impressive waterfall, in a municipal park at Ouray, Ouray County, is closely confined as it twists, turns, roars, and sprays in a fashion unequalled elsewhere in Colorado. Its geology complexly

involves rising mountains, glacial water and sediment, rock jointing, and even more. But the scenery it makes in the Leadville-Ouray Limestone is worth the effort.

Bridge of Heaven

A narrow but very high hogback, rising almost 2,000 feet from the floor of the Uncompahgre Valley, is found in the San Juan Mountains near Ouray, Ouray County. Sedimentary rock layers, originally horizontal or nearly so, become tilted by a general rising of the land and are then separated from weaker beds on both sides until they resemble the arched back of a hog.

Canyon Lands Section

This natural subdivision of the Colorado Plateau has its southern part in Colorado. It consists of young to mature canyons within high plateaus, obviously a place of strong topographic relief.

Caron Mountain

This moving mountain of notoriety has much troubled highway engineers, for it has slipped from time to time since 1932, blocking traffic and threatening U. S. 160 3 miles east of Durango, La Plata County. From an altitude of 7,834 feet, Caron tends to slide as an easily water-soaked layer of Fruitland Shale upon a more solid bed of Pictured Cliffs Sandstone, which slants (dips) in the wrong direction. Engineering techniques have been tried to stop this slippage. Burning coal beds here do not help matters.

Castle Rock

Unlike the black mesas farther south and east in Colorado, this conspicuous eminence is capped with coarse volcanic rock, the Castle Rock Conglomerate, of probable Oligocene age, this in Douglas County being the type locality. Most such mesas or buttes are capped by basalt, another igneous rock (lava) that rose from the crust as molten material and cooled to become solidified (though full of holes) and partly crystallized. Here, the underlying rock is the Dawson Formation (arkose: coarse, feldspar-rich sedimentary rock).

There are more than enough Castle Rocks in Colorado to go around, including some — as at Golden, in Jefferson County — that are part of larger bodies of rock.

Cathedral Bluffs

Running north from the Roan Plateau are these castellated cliffs within the Colorado Plateau. Sedimentary rock of Cenozoic age borders Mesozoic rock of similar kind.

Cathedral Rock

"Fantastic weathering" produced this bit of volcanic scenery in the San Juan Mountains. Towers and minarets succeed one another throughout.

Cave of the Winds

Colorado's only commercial cave, near Manitou Springs, in El Paso County, inhabits the Madison Limestone of Mississippian age. Like many other of the world's tourist caves in its "specialties of the house," the Cave of the Winds is a bit different in having deposits of aragonite, rather than just calcite, and in its abundant display of helictites: the cave icicles that curl upward against the pull of gravity. Allegedly mysterious affairs, these really are readily explained by the gentle flow of air that gives the cave its name and causes the dripping moisture to evaporate in a restricted direction.

The road down from the cave goes through The Narrows, described in this book with Big and Little Narrows. Huccacove Cave and Pedro's (or Broken Rock) Cave are on the same property.

Chalk Cliffs

Looking like chalk in their glistening whiteness, these cliffs along Chalk Creek, out of Nathrop on Colorado 162, in Chaffee County, consist actually of quartz monzonite, an igneous rock related to granite.

CHALK MOUNTAIN, at Climax, is not chalk either but a volcanic rock, which is rhyolite of Tertiary age.

Cheyenne Mountain

Upthrust along a giant surface of slippage — a fault — that marks its abrupt eastern face, resulting in its standing apart from the Front Range of which it is a part, Cheyenne Mountain, near Colorado Springs, is otherwise a piece of the Pikes Peak Granite. The Ute Pass

Fault defines the remarkably conspicuous front, below which is the slope of the Pierre Shale.

Chimney Canyons

Off the main route of Colorado 34 between Iliff and Sterling, in Logan County, are Chimney Canyons, once a source of wood and now places to camp and picnic. Here is an area of differential erosion, quite normally typical in origin.

Chimney Rock

Appropriately rising on Chimney Rock Mesa west of Pagosa Springs, Archuleta County, this place is more significant as an archaeologic site now being excavated and studied than as a bit of curious scenery of erosional origin. Mesaverde Sandstone stands on Mancos Shale and is crumbling to form the pinnacles called chimneys.

Lesser Chimney Rocks exist at Rabbit Ears Pass (along with Grannys Nightcap and other cheerful spots), and additional locations. Weathering and erosion are the dominant geologic agencies responsible.

Cold Spring Mountain

An elongated, flattop mesa, this area in the extreme northwest corner of Colorado is nevertheless called a mountain. However, Diamond Peak rises well above it on the north and Diamond Mountain on the south.

Colorado National Monument

A striking array of water- and wind-sculptured cliffs constitute this 17,669-acre scenic preserve in western Colorado. Mostly red sandstone layers of the Wingate and Entrada Sandstone have been fashioned into huge monoliths, steep box canyons, lofty pillars and domes, balanced and mushroom rocks — there seems an infinite variety without end. The Chinlee Shale constitutes the steep, red slopes beneath. As elsewhere, the fanciful names suggest the appearance: Miracle Rock (balanced), the Pipe Organ, Cleopatra's Couch, the Coke Ovens, Ot's Shoe, Liberty Cap, the Keyhole, Squaw Fingers, and Cold Shivers Point. They may need description, but they scarcely require profound explanation.

The story of Colorado's National Monument began with the layers of sediment deposited here on a floor of even more ancient (Precambrian) rock during the Mesozoic Era — the Age of Dinosaurs, some giants of which lived in the region and have been excavated in fossil form. Some of the sediment was marine, some of stream origin, some consisting of huge sand-dunes. Compacted by pressure, and cemented by percolating mineral-laden water, the sediment became strata of solid rock. S. W. Lohman had likened them to a vast layer cake, one end of which looks as though it "had been carelessly placed over the edge of a table and had sagged." Uplifted with the rising land and isolated by steam erosion, the mesa has been reduced by the gradual decay and disintegration of the sandstone and the removal of the mineral grains by water and wind.

Colorado Piedmont

Between the High Plains and the mountains is a rough region that is the result of extensive erosion by streams coming from the Rockies. The slope is steeper than in the High Plains, and the climate is drier, so the soil is thinner. Directly along the mountain front, in fact, erosion by the stronger streams here has cut a shallow trench in which cities such as Denver and Colorado Springs are situated. Removal of some of the previously deposited sediment has left mesas, buttes, and other landforms above an irregular surface.

Colorado Plateau

The westernmost of Colorado's three main topographic sections is constructed largely of flat layers of sedimentary and volcanic rocks, cut by deep gorges: certain of the "mountains upside down" of Chapter 14. The volcanic rock is basalt of Tertiary age; the sedimentary strata are Paleozoic, Mesozoic, or Cenozoic. The Uinta Mountains thrust up sedimentary Precambrian rock along the northwest corner.

Continental Divide

As previously mentioned, this "backbone of the nation" — and of Canada and Mexico as well — does not everywhere correspond to the highest crest along the mountains. It crosses from one range to another and is known to make its way across the bottom of at least one valley (at Poudre Lake). In general, however, the watershed between Atlantic (Gulf of Mexico) drainage and Pacific (Gulf of California) drainage is striking enough to suit the fancy of almost any armchair geographer.

Crested Butte

Just outside the town of the same name, in Gunnison County, is this conspicuous conical, serrated mountain of gray color. Geologically, it is a laccolith, having forced its way into layered rock above and pushed the strata upward.

The Maroon Bells (described in this book) are not far northward, also in the Elk Mountains, but in Pitkin County.

Curecanti Needle

At the confluence of Blue Creek and the Gunnison River, in Gunnison County, rises this abrupt remnant of erosion, the pinnacle of Curecanti Needle. Nearly 800 feet high, within walls that exceed 1,000 feet, it is an upward tapering pyramid of quartz monzonite.

Devils Backbone

Another of Colorado's fine hogbacks — upturned sedimentary rock between parallel trenches on both sides — is conveniently situated 4-5 miles west of Loveland, Boulder County, along U. S. 34. This Cretaceous rock contains fossil sea-turtles of considerable size. It is the steeply dipping western limb of an anticline. Eric J. Redding, representing the Loveland Chamber of Commerce, supplied this information.

Devils Causeway

Five and one-half miles from scenic Trappers Lake, in Garfield County, stands a high, narrow ridge of basalt described by this name. Normal erosion has left it above the surrounding, less resistant country.

Devils Wings

Debris composed of sliderock is known as the Devils Wings, 3 miles northeast of Grand Junction, in Mesa County. The large masses have come detached from the rocky walls and are spread along the roadside where the highway climbs before dropping into a shallow valley.

The Devil has been credited with ownership of numerous rock "formations" in Colorado. He is also the proprietor of a complete moun-

tain, Devils Head, which stands at 9,748 feet conspicuously above the countryside between Denver and Colorado Springs, west of I-25, in Douglas County; it is an important mineral-collecting locality in the Pikes Peak granite. The Virgins Bath — but without virgins — is nearby. Devil Mountain (9,957 feet) is west of Pagosa Springs, Archuleta County.

Dinosaur National Monument

Dinosaur National Monument

The present scenery, of truly spectacular quality, of this 206,663-acre federal preserve bears little resemblance to the landscape that existed when the dinosaurs inhabited this northwestern corner of Colorado. Then, it was a flat-lying Jurassic swamp, a warm and humid graveyard in which the bones of the great reptiles accumulated after most of the animals had died elsewhere and presumably floated

downstream, until they became stranded on a shallow sandbar. Now, it is a primitive wilderness of majestic gorges surpassed by few older canyons anywhere in the world.

These mighty slices made by two of nature's waterpowered saws — the Green and Yampa Rivers — were cut long after the day of the dinosaur. They are still being deepened today, as the precipitous Canyon of Lodore (in places more than 3,000 feet deep) and Yampa Canyon continue to be lowered between the oddly etched and delicately colored walls upon which the sun shines but rarely. Pats Hole, of interesting historical association, is a flat area enclosed by impressive cliffs at the union of the rivers, where imposing Steamboat Rock stands amidst an immense loop in the Green.

Eagle Park

A former lake bed, this open space lies along U. S. 24 and the Eagle River between Leadville, in Lake County, and Pando, in Eagle County. The water has drained away.

Elephant Rock

Eroded from red sandstone of the Lyons Formation, this enormous structure in El Paso County is historically important as a resting place of the Long Expedition in 1820.

Different from most of the Elephant Rocks in the state is the one situated in the Narrows of South St. Vrain Canyon between Lyons (in Boulder County) and Estes Park Village. It is a huge boulder in the midst of the stream. Although the Indians associated it with the abode of the unpleasant Underwater People, simple erosion by the force of the moving water is enough to explain it. It is situated below the Barking Dog. Kerstin Adams, representing the Longmont Chamber of Commerce, supplied information and listed numerous other "fancifully named" rocks in that area.

There are also the Elephant Rocks, on the airport road north of Del Norte, Rio Grande County; Sleeping Elephant Mountain, in Rocky Mountain National Park; Elephant Butte, near Evergreen, Jefferson County; Elephant Head Rock, at the southeast corner of San Juan National Forest; and probably many other similarly named places. Most of them have been carved into this particular pachyderm profile, a rather easy shape for nature to sculpture. Red Elephant Mountain, in northwestern Colorado, seems a more formidable project.

Elk Mountains — West Elk Mountains

Layers of sedimentary beds were pushed westward over one another to make these mountain groups. Changes to metamorphic rocks are conspicuous in places, as where the Yule Marble appears. Some rock was forced into arched strata to form laccoliths, as at Crested Butte.

Fairy Cave

This is the best known cave in the White River Plateau, so much so, in fact, that the older part has been badly damaged by amateur exploring parties, and so Fairy Cave is barred. It is situated northeast of Glenwood Springs, in Garfield County, and occupies cavities in limestone of Paleozoic age. Cave of the Chimes and Cave of the Clouds, both nearby, have also been meanly treated.

Finger Rock

Little different from other shafts of volcanic rock, but perhaps higher than many, this gray spire rises conspicuously 300 feet above the valley floor between Toponas and Yampa, in Routt County. Finger Rock is evidently composed of more resistant rock than its surroundings.

Fishers Peak

A mountain only in its lofty altitude of 9,627 feet, this noted landmark at Trinidad is a former extension of Raton Mesa (which see). It is likewise composed of lava flows of dark-gray basalt erupted during the Ice Age, at least eight different sheets of lava. Erosion has separated it from Raton Mesa, also in Las Animas County.

Flatirons

Triangular slabs of red rock — the Fountain Formation of Pennsylvanian age — lean against the much older (Precambrian) granite of Bear Mountain like huge flatirons south of Boulder, in Boulder County. Pushed up as the mountains rose, they rest against weathered igneous and metamorphic rock.

Flattop Mountain

Giving its name to a once well-established geologic feature, the Flattop peneplain, this 12,118-foot mountain — second highest spot in the Park Range — perhaps deserves special attention in a book such as this. The peneplain was considered the higher of two such extensive erosion surfaces in the Colorado Front Range, resulting from stationary intervals during the uplift of the mountains after the creation of the present generation of the Rockies. The shoulders of Pikes Peak, for instance, represent an extension to the south of the same level. This explanation seems to be obsolete, but at least the original name persists, for Flattop Mountain indeed does have a flat top!

So presumably does Flattop Mountain along the southwestern boundary of Routt National Forest and probably many more with such a name. The Flat Tops Primitive Area, in western Colorado, embraces much flat land in the White River Plateau, including Flat Tops itself. Both of these names suggest lava flows and therefore built-up features rather than erosional ones such as peneplains.

Case Flats, near Walden, is a more specific indication of an erosional area, likely suitable for an airstrip. Such a name elsewhere could, of course be one of numerous indications in Colorado of mesa, or butte constructions, typically though not always capped by lava.

Squaretop Mountain (11,777 feet) and Nipple Mountain, though neighbors east of Pagosa Springs, are without doubt the products of unlike erosion in dissimilar rocks — but this geologic knowledge comes at second hand.

Flirtation Point

At the western edge of Wray, in Yuma County, stands a lone limestone relic of erosion. A legend places in the eastern wall of the cliffs an Indian temple where demons were worshipped.

Florissant Fossil Beds National Monument

More than half of all known fossil butterflies of the world have come from the thin-bedded volcanic strata near Florissant, Teller County. Here also are known the largest stumps of petrified wood ever discovered — sequoia like the California coast redwood up to 55 feet around and 140 tons in weight. Other fossils, including fish, birds, mollusks, mammals, more insects and plants, occur and are now protected in this 5,992-acre public preserve. An ancient volcano erupted repeatedly during the Tertiary Period, raining ash onto and into former Lake Florissant, creating this "insect Pompeii."

Front Range

A long, uparched row of mountains, the first one reached from the plains, the Front Range exposes a core of ancient (Precambrian) rock, across which younger sedimentary strata (Paleozoic and Mesozoic) once extended. These are now seen in such places as the Garden of the Gods. When the same anticline structure crosses into Wyoming, it separates into the Laramie Range and the Medicine Bow Mountains.

Fulford Cave

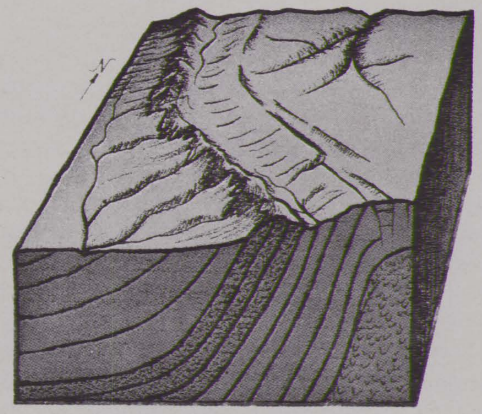
South of Eagle 17 miles, in the Sawatch Range, Eagle County, is this cavern in the Leadville Limestone of Mississippian age. The rock outcrops widely and has been much eaten into. The Register Room is in the interior. Two entrances exist at different levels, and a third level lies in between. A small stream becomes a spring outside. This cave and some others of the numerous ones in this area, near Woods Lake — Sinking River Cave, expecially — are probably not safe for others than qualified cavers, called spelunkers.

Garden of the Gods

An 824-acre municipal park of Colorado Springs, El Paso County, here are as many named features ("formations") as one could wish for. Others previously known have been eroded away or lost track of. The origin of them all is about the same. Red sandstone, white sandstone, white gypsum, and black or gray shale were deposited during the Paleozoic Era by streams and in shallow seas and lagoons. Pushed up, broken off, and the weaker layers eroded into valleys and hollows (while the more resistant strata held up) during and after the rise of the Rocky Mountains in two different geologic events, the rocks have become what they are today. Chance has made them into such notables as the Balanced Rock and its neighbor, Steamboat Rock, the Kissing Camels and the Gateway supporting them, the Washerwoman, the Bear and Seal, and the appropriate features of Mushroom Park. As has been said, though, "to distinguish most of them requires a guide."

Grand Hogback

No other resistant ridge of rock in Colorado equals in magnitude the Grand Hogback, which extends 135 miles in west-central Colorado. It is properly a monocline, representing upturned sedimentary layers of Cretaceous and Tertiary rocks. The more durable of them remain as ridges of Mesaverde Sandstone, whereas the weaker ones (shale and coal) have worn down to form valleys. The Grand Hogback constitutes the west and south sides of the White River Plateau.



Structure of Grand Hogback

Grand Lake

Deep, beautiful, and at times turbulent, this is Colorado's largest natural lake, confined in Grand County — as are so many of the world's lakes — by the glacial deposits called a moraine.

Grand Mesa

In certain ways much like the other, but smaller, high tablelands of the Colorado Plateau — the result of long-continued vertical rise of the earth's crust — Grand Mesa possesses unique features of its own. This so-called Roof Garden of the World has also a thick capping of Tertiary basalt, but it is fringed with more than 200 fine lakes. One type of lake was scoured out of the rock by former glaciers. The other kind has resulted from the slumping of the underlying shale along the 60-mile rim of the mesa.

Though larger than the other capped rocks in Colorado, Grand Mesa is rather similar in its protecting layer to countless other mesas and bluffs. Castle Rock (described in this book) has a different top. Cap Rock, west of Virginia Dale, in Larimer County; Table Mountain, east of Virginia Dale; Round Butte, still farther east; and Twin Butte, much closer, are pretty well recognized by their names, and their geology cannot be greatly dissimilar.

Great Plains

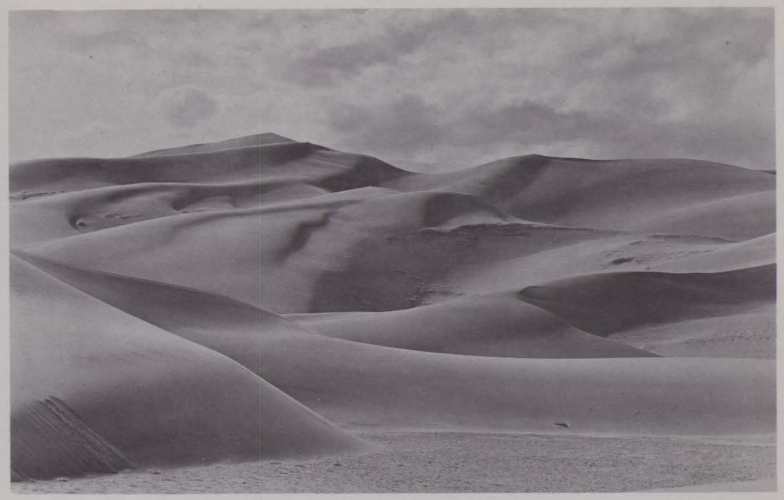
Occupying the eastern two-fifths of Colorado, this region has an appeal of its own, though far less dramatic than most of the rest of the state. Even so, the southern section amazes the unsuspecting traveler with a certain number of deep and steep canyons.

Once covered by inland seas, before the present generation of Rocky Mountains arose, and since then invaded in places by vast floods of lava, the Great Plains were formerly part of what was so wrongly named the Great American Desert, feared and avoided when possible. In their fine book *Prairie Peak and Plateau*,* John and Halka Chronic call these also the Prairies. Three divisions of the Great Plains are known: the High Plains, the Colorado Piedmont, and the Raton section. Each is outlined on the accompanying map.

Great Sand Dunes National Monument

The largest and highest sand hills in America are banked against the Sangre de Cristo Mountains, along the eastern edge of the San Luis Valley where this lofty and narrow range swings in a great curve to become the Culebra Range. Disappearing streams, colored sand, and strange animal life characterize this mysterious country. The sand came from the mountains on both sides — mostly from the San Juans on the west, some from the Sangre de Cristos on the east, and much from the south, and accumulated in the recently formed San Luis Valley. When the lake that dammed the Rio Grande was finally drained, the loose sand was blown from deposits along the Rio Grande and piled against the mountain barrier.

*Colorado Geological Survey Bulletin 32, 1972.



Denver Convention and Visitors Bureau

Great Sand Dunes National Monument

Grottoes

Just off the Independence Pass road to Aspen, Pitkin County, can be seen a rather good series of potholes where the Roaring Fork used to have its bed before it decided on a new channel closer to the highway. The grottoes are large enough to bear witness to powerful forces of stream erosion.

Hahns Peak

Rhyolite porphyry invaded sedimentary rock as young as Cretaceous age to form a laccolith. This structure was eroded to become Hahns Peak, a most prominent though not exceptionally high mountain on the west flank of the Park Range.

Hanging Lake

Reached by a hike above I-70, Garfield County, this charming feature of Colorado's scenery is the product of a mineral spring that emerges from a 500-foot-wide underground channel into a natural cup held in the face of a cliff. This cup is the bright-blue lake itself, a strongly petrifying agent.

High Plains

Fringing eastern and northern Colorado and penetrating the interior somewhat, this outer division of the Great Plains features only a few widely separated stream valleys. It is quite flat, covered with gravel, sand, and silt carried down from the mountains that lie to the west. Some of the ground is remarkably free of stones, an aspect that makes farming easier and also aids the search for the very foreign rocks we call meteorites. (*Meteorites of Colorado,* by Richard M. Pearl, deals with this subject.)

Hovenweep National Monument

Extending into Utah, the 505 acres of this government property offer geology and archaeology rather like Mesa Verde. The occupancy of these four groups of prehistoric dwellings was made possible by the distinctive setting of rock and water.

Hubbards Cave

Near Glenwood Springs, Garfield County, is this gypsum cave, which shows the curious geologic features of gypsum flowers, gypsum blisters, and cave "coral" of the same mineral. To some Coloradans, according to William R. Halliday, the term "ice cave" means a cave in gypsum.

Huerfano Butte

Historically famed as a landmark on the long journey westward, this is a finely shaped pinnacle of black basalt, which rose from within the earth's crust in association with the Tertiary volcanic eruptions of the Spanish Peaks area not far away, in Huerfano County. *Huerfano* means orphan, and the so-called butte is truly an isolated entity close to U. S. 85, near which erosion has reduced the surrounding landscape.

Ice Caverns

Hardly unexpected at the terminous of a body of glacier ice, these hollows nevertheless are particularly beautiful. The ice is that of St. Marys Glacier (described in this book) on Kingston Peak.

Isabelle Glacier

Navaho, Apache, and Kiowa Peaks share this striking relic of the rivers of ice that once filled the high valleys of Colorado. Isabelle is west of Ward, Boulder County, on the Continental Divide along the Front Range. The lesser Fair Glacier is nearby, to the west.

Italians Cave

Rumored the spot where robbers buried treasure from Old Julesburg, Sedgwick County, this cave mainly represents the enlargement of a natural fissure in the rock. A Cripple Creek miner named Uberto Gabello took away material for building purposes and later operated a tourist attraction. Of all Colorado's geologic wonders, this is perhaps the least geologic.

Lake San Cristobal

When volcanic rock, badly decomposed by sulfurous vapors, rushed for a distance of 6 miles as the Slumgullion mud flow and dammed Lake Fork of the Gunnison, Lake San Cristobal was created in the San Juan Mountains near Lake City, Hinsdale County. This curious lake will eventually be annihilated either by its receding waterfall or its growing delta. One will drain it; the other, fill it up.

Little Book Cliffs

Another of the large mesas of western Colorado, this one is also capped by hard rock, which has preserved its form and existence.

Lizard Head

Described as "the most conspicuous isolated spire in the San Juan region," this formidable pinnacle rises nearly 500 feet from the summit of the mountain on which it stands. High-country erosion in volcanic rock is responsible for this appropriately named profile.

Lone Eagle Peak

As characteristic a horn, or matterhorn, as any mountain in Colorado, this one in Rocky Mountain National Park was named indirectly for Charles A. Lindbergh. Glacial erosion of the most spectacular sort has left this striking finger of granite pointing skyward.

Lowry Pueblo Ruins
National Historic Landmark

The settled Indians and their predecessors built and lived where nature supplied the first necessities for shelter, protection from enemies, water, and land for farming. The three-story pueblo here was based on nature's providence. Lowry is rather remote, being reached from U. S. 666 at Pleasant View, in Montezuma County.

Maid of the Mountain

Resembling the figure of a woman carved out of the side of a mountain west of Georgetown, in Clear Creek County, and most clearly seen from Strousse Park, this product of ordinary rock erosion has been described with horrendous exaggeration properly analyzed by the *Clear Creek Courant* as "a lot of malarkey." If you fall trying to climb it, it's your own fault. Dee Barrom, representing the Georgetown Chamber of Commerce, sent information.

Maroon Bells

More resembling peaks in the Canadian Rockies than most of Colorado, the Maroon Bells consist of colorful, metamorphosed sedimentary rocks — now quartzite and slate — of the Maroon Formation, of Pennsylvanian and Permian age. These are more than 4,000 feet thick and were deposited by swiftly moving streams that transported coarse gravel. North Maroon Peak (14,014 feet) and South Maroon Peak (14,156 feet) are the Bells. These rocks were bulged upward during the making of the present generation of Rocky Mountains and stand over 4,500 feet above Maroon Lake, which lies below Crater Lake. Kay Winblood, representing the Aspen Chamber of Commerce, supplied information.

Capitol Peak, Snowmass Mountain, and Pyramid Peak are adjacent to Maroon Bells and are likewise named for their shape and appearance. Red and White Mountain, some little distance away, suggests the layered nature of the Maroon Bells.

Mesa de Maya

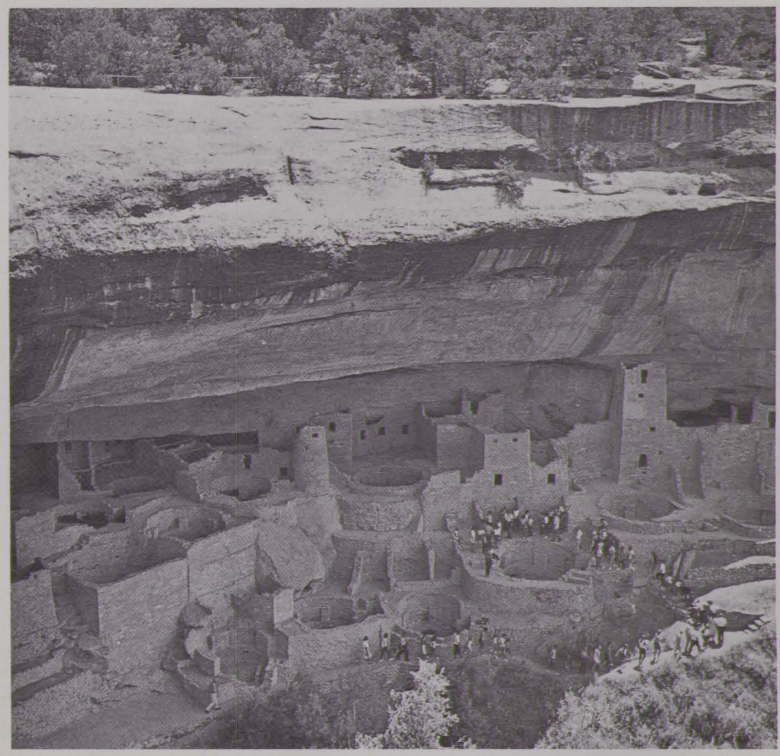
This, the "armored mesa," is one of the two largest such isolated masses of high rock in the Raton section of the Great Plains. It lies east of Raton Mesa, in Las Animas County, close to the border of New Mexico. Capped with successive flows of basalt lava, it has resisted the erosion that has lowered the surrounding country.

Mesa Verde National Park

Notable for the finest cliff dwellings in the country, occupied by prehistoric Indians until almost the year A. D. 1300, Mesa Verde originally owed its distinctive position among the wonders of the world to its geology, which made possible its archaeologic significance.

Overhanging cliffs of Mesaverde Sandstone covered caves in the sides and near the top of steep canyons. Protection from hostile tribes was provided by this natural arrangement. Springs in the sandstone decided the location of the individual dwellings, which were built upward from the floor of the caves, the rock being bonded together with the underlying clay.

Mesa Verde ("green table") occupies 15 by 8 miles in Montezuma County; the park itself has about 80 square miles of area.



Cliff Palace, Mesa Verde

Middle Park

The middle of the three broad, high-altitude so-called "valleys" in central Colorado — the fourth, to the south, is named the San Luis Valley — this park is, like the others, marked off by strong faults and heavily loaded with sedimentary rock obtained from the surrounding mountains during the Tertiary Period. Middle Park is bounded on the north and east by the Rabbit Ears Range and Front Range, on the south by the Williams Fork Mountains, on the west by the Park Range. These had their modern debut during the Cretaceous-Tertiary transition.

Middle Rocky Mountains

The Uinta Mountains constitute the Middle Rockies. This largest east-west range in America outside Alaska is believed to represent an aulacogen, a Russian invention supposed to be one of the arms of sedimentary accumulations. The rocks are mainly little altered Precambrian sedimentary.

Through the Uinta Mountains flow the Green and Yampa Rivers. The Green cuts through Lodore Canyon, in places more than 3,000 feet deep, then joins Yampa. It is now believed that as a result of superposition, the Yampa River flowed easily across sedimentary rock until it had cut its channel into harder rock below, explaining its otherwise illogical position. Meanwhile, the Green River, which flowed eastward parallel to, but north of, the mountains until it was diverted by one of its tributaries, had its course changed to the present one.

Mildred Glacier

Fascinating as a curiosity of the Ice Age in Colorado but of no special significance individually, Mildred Glacier keeps company with Roberts Glacier in the area of Raymonds, Boulder County, in the Front Range.

Monkey Face

Just south of Larkspur, on I-25, in Douglas County, is this cliff eroded by water and perhaps modified by wind into the south-facing profile of your friend the snub-nosed simian.

Mount of the Holy Cross

For some years a national monument in Eagle County, and one of the best known though little visited, the Mount of the Holy Cross (14,005 feet) has, like Wheeler Geologic Area, returned to a more humble status as a part of Colorado's national forests. Remeasuring has pushed its altitude above the magic 14,000 level — a neat 14,005 feet. The outline of the cross — 1,500 feet in each direction — is produced by deep snow drifts in natural crevices cut out by frost action.

Supplicating Virgin

Situated on the Mount of the Holy Cross and formed by the same association of snow and rock crevices in different outline, this is a somewhat familiar scenic feature, though relatively seldom seen by visitors. The Bowl of Tears is a meltwater basin beneath it, a glacial tarn.

Musgrove Corral

"Three-finger" Musgrove, a 19th-Century bandit in these parts, occupied this bowl-shape enclosure on the North Fork of the Cache la Poudre in the vicinity of Redfeather Lakes, in Larimer County.

Natural Arch

La Ventana is a natural window in rock a few miles north of Del Norte, in Rio Grande County. Wheeler Geologic Area is not far away to the northwest. B. J. Shuler, representing the Monte Vista Chamber of Commerce, furnished information.

Natural Fort

One and one-half miles east of I-25 and U. S. 87, on the Warren Ranch, in Larimer County, between Wellington and the Wyoming state line, can be seen a large outcrop of gray sandstone that has been eroded into a natural corral measuring 80 by 30 feet. What remains was the site of an 1831 battle between the Crow and the Blackfeet, as well as of other Indian fights, bandit hideouts, and other 19th-Century events reported to have been of much excitement.

North Park

The northernmost of the four parks — which include the San Luis Valley — in central Colorado is, like the others, occupied by Tertiary sedimentary rock derived from the adjacent mountains and separated from them by large faults. North Park is enclosed in Colorado by the Park Range on the west, the Medicine Bow Range on the east, and the Rabbit Ears Range on the south — all products of the Laramide orogeny of Cretaceous-Tertiary ages and Tertiary volcanic activity.

Old Mans Face

Most of the distinctively named rocks created by erosion are, for obvious reasons, concentrated in the places where tourists congregate. This rocky profile of an elderly man, situated unpretentiously along Colorado 14 in the general area of Chambers Lake, between Glen Echo and Home, is seen in a little traveled setting in Larimer County. It is possibly better looking than Monkey Face (described in this book) but not necessarily so.

Paint Mines

A miniature Bryce Canyon and similarly caused by the normal agents of erosion, these are grotesque features — hoodoos — in white sandstone and brightly colored shale and clay of many hues, especially purple, yellow, green. Sandstone caps of the Tertiary-age Dawson Formation protect painted pillars of Dawson Clay in one of several such gullies 3 miles southeast of Calhan, in El Paso County. Indians and others are said to have acquired colored clay here, hence the name.

Paradox Valley

Crossed by its stream the wrong way — this is Paradox Valley. Trending northwest-southeast from near the Utah border, it contains a Dolores River that flows in a northeasterly direction, leaving by way of a large gap in the colorful cliffs at the north end. This paradox is explained by the presence of a 40-mile-long uparched fold of rocks, an anticline. This was eroded and reversed into a trough. Salt and gypsum of Late Paleozoic age were squeezed upward through overlying (and hence younger) beds of sand, shale, and limestone. Being rather soluble, the salt and gypsum were carried away. Sinbad Valley and Gypsum Valley are of similar origin.

Park of the Red Rocks

Strata of red arkosic (feldspar-rich) sandstone of Pennsylvanian age, the Fountain Formation, come down steeply from the mountains west of Denver to backdrop this magnificent municipal park of unexcelled acoustics. The most familiar spot here is the Amphitheater, with its rugged beauty and remarkable sound qualities. The red beds, which are like those of the Garden of the Gods, have been tilted, broken, and eroded into shapes that bear names that appeal to the tourist. The Titanic and the Iceberg, Picnic Rock, Ship Rock, Rock of the Nine Parts (different strata), Park Cave Rock, Frog Rock, Rock of the Seven Ladders, Creation Rock (a natural auditorium) — they are more alike than different, the names crediting the fertile imagination of a tour driver or an early hiker but having little significance otherwise.

Park Range — Gore Range

Another elongated upfold (anticline) of old (Precambrian) rock, the Park Range is united with the Front Range by the largely volcanic material of the Rabbit Ears Range.

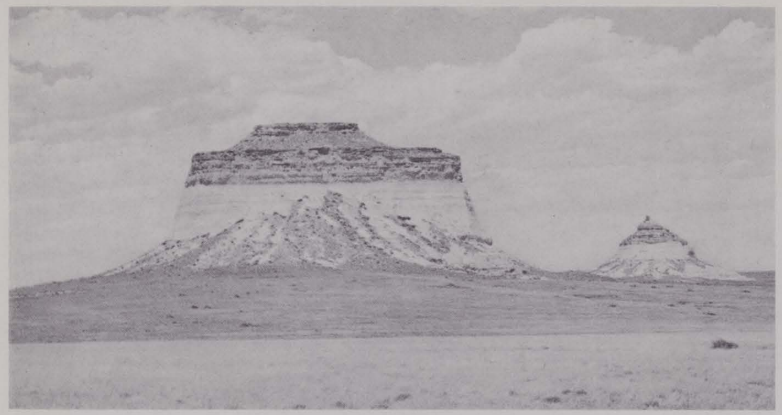
The Gore Range is a similar uplift having a granite and metamorphic core of Precambrian age flanked by Paleozoic or Mesozoic sedimentary strata. Southward are the Tenmile Range and the Mosquito Range of somewhat related origin, but the latter is really the east side of a dome of which the Sawatch Range is the other part.

Pats Hole

A flat area surrounded by mighty cliffs, this place of exciting historical associations lies at the confluence of the Green and Yampa Rivers in Dinosaur National Monument in the Uinta Mountains of the Middle Rockies.

Steamboat Rock

A sheer cliff of sandstone having this name stands where the Green River joins the Yampa River at Pats Hole.



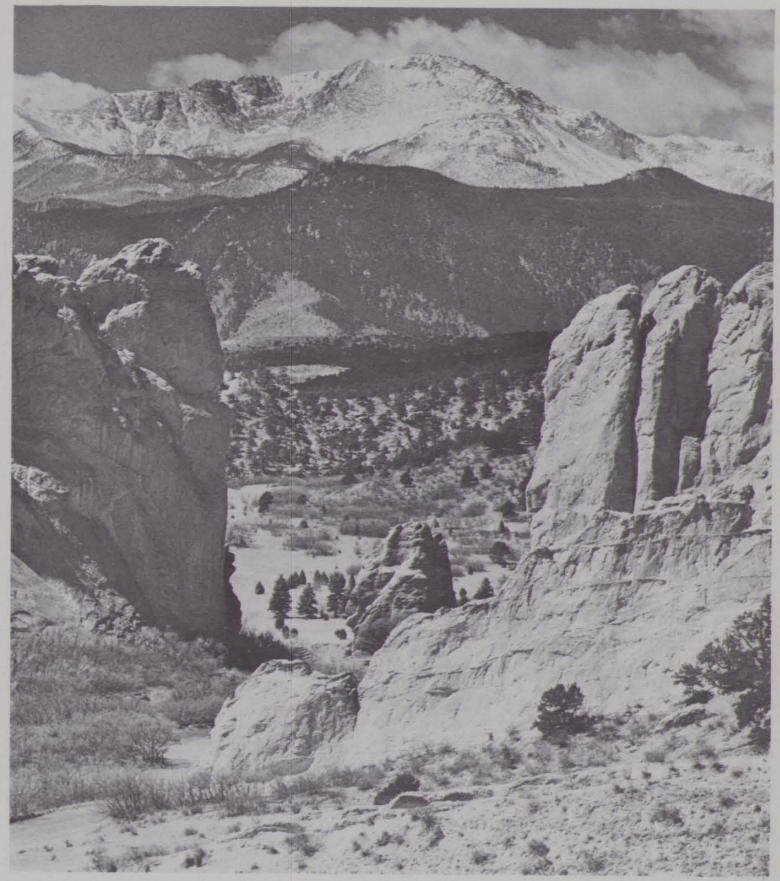
Pawnee Buttes

Pawnee Buttes

Although perhaps not too much bolder than other mesas and buttes in Colorado, these twin bodies rise like fortresses above the plains of northeastern Weld County. East and West Pawnee Buttes are prime examples of the badlands that are better known in South Dakota and possibly other states.

More important than the flat beds of sedimentary rock themselves are the fossil treasures they contain. The bones of Tertiary-age vertebrate animals, some weird indeed, occur here in abundance. Meet some of these characters: three-toed horses, titanotheres ("thunder beasts"), enteledonts ("full teeth"), rhinoceroses. More familiar are the primitive horses and camels, whose ancestry has been traced through their remains at Pawnee Butte.

The retreat of the Cretaceous sea, as the Rocky Mountains came into being 60-70 million years, enabled this part of the South Platte Valley to be covered with stream-laid deposits of sedimentary rock: the Brule Formation (mainly clay) below and the Arikaree Formation (sandstone from sand and conglomerate from gravel) above. Meandering streams wandered between numerous lakes, burying the animal bones in mud and silt. Wind-blown sand also covered them. Then, the land rose in a broad uplift, causing the resistant rock to wear away by wind and running water. The deeply gullied badlands, the terraces, and the buttes are the result.



Colorado Springs Chamber of Commerce

Pikes Peak through Gateway to Garden of the Gods

Pikes Peak National Historical Monument

Not a volcano — either past, present, or future — but a solid granite remnant of erosion, Pikes Peak is America's most famous mountain. It cooled as a gigantic mass of molten rock deep within the crust of the earth almost exactly 1 billion years ago. As the older rock above it was worn away, the Pikes Peak granite slowly reached the surface, becoming the kind of erosion remnant known as a monadnock, rising above an extensive level of erosion termed a peneplain.

This mountain owes its abrupt sides, sharp ridges, and generally magnificent sculpturing — especially on the east and north — to the local glaciers of the Ice Age. The rosy hue of Pikes Peak sunrises is due largely to the pink color of feldspar, the most abundant mineral of the granite.

The Bottomless Pit is a tremendous glacial cirque 1,700 feet deep, on Pikes Peak. The Crater is also a cirque. Lake Moraine and Seven Lakes are due to the glaciers.

America's Mountain: Pikes Peak and the Pikes Peak Region, by Richard M. Pearl, describes this area.

Porcupine Cave

Known to some Coloradans as an ice cave because it contains gypsum (but not ice), this cave 6 miles south of Bassam Ranger Station, in Fremont County, described by Don Black, is noteworthy for its sparkling crystals of gypsum. It occurs principally in limestone.

Rabbit Ears

The Precambrian granite bunny that gave its name to this prominent rock structure also helped name Rabbit Ears Pass on U. S. 40 below. This is perfectly normal erosion of rough volcanic rock in high country. Chimney Rock (described in this book) stands nearby, along with dikes, lava flows, and numerous other volcanic features of Tertiary age. The Rabbit Ears Range separates Middle and North Parks.

Raton Mesa

Another basalt-protected mesa resulting from Ice-Age lava flows of considerable extent, Raton Mesa is situated east of Trinidad, in Las Animas County, just south of Fishers Peak and north of Bartlett Mesa and Barilla Mesa. It was once connected with the similar Mesa de Maya (described in this book) farther east. Its former extension is Fishers Peak (described also), now an important place name in itself. Raton Mesa reveals as many as 11 separate sheets of dark-gray lava, totaling as much as 500 feet in thickness.

Raton Section

Rugged canyons beneath sharp ridges and high mesas characterize this southern division of Colorado's Great Plains. During the Ice Age, great flows of basalt lava spread over this region. Where cut into by erosion since then, they stand as isolated mesas and buttes. The

Raton section is also noted for its unexpectedly prominent canyons and gorges, rather well hidden until you reach their edges. Purgatoire Canyon is 70 miles long and up to — down to! — 900 feet in depth. Chacuaco Canyon is 30 miles long and 900 feet. Apishapa Canyon is 15 miles long and 300 feet deep. You can drive to the water's edge and across in a very few places; hardly anyone not resident here knows about these splendid canyons.

Red Canyons Park

Similar to the Garden of the Gods (at Colorado Springs) and Park of the Red Rocks (near Denver) in geology and appearance, this municipal park of Canon City is an attractive place little known to the outside world. Red rock, tilted on end, stands as pinnacles and cliffs above the adjacent land in Fremont County.

Roan Cliffs

Hardly distinguishable from Roan Plateau to the north and Book Cliffs on the south, this is a high and flat part of the all-embracing Colorado Plateau of western Colorado. Cenozoic sedimentary rock margins Mesozoic strata.

Roan Plateau

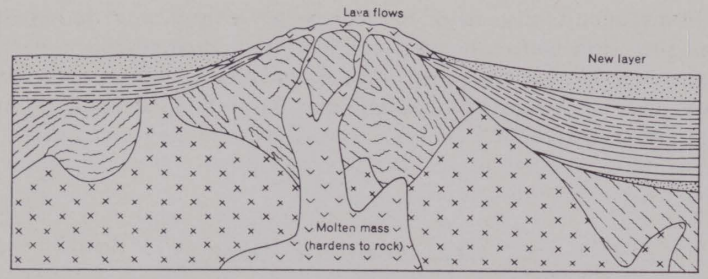
More or less continuous with Roan Cliffs and Book Cliffs, which lie to the south, here is another part of the great flat-topped land of the Colorado Plateau.

Robbers Roost

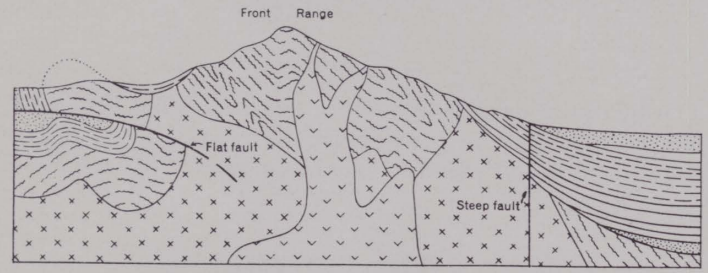
Hollowed out of a hill, this erosional depression was a fortress for outlaws in the old days. Nearby is Lookout Mountain, used for signalling by Indians. Both are close to Virginia Dale, which is on U. S. 287 in Larimer County, close to Wyoming.

Rocky Mountain National Park

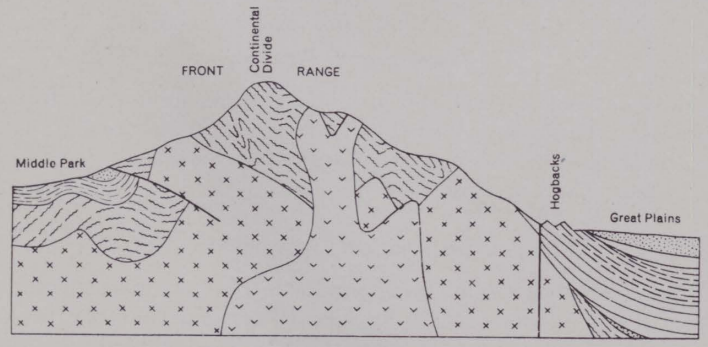
One of America's scenic wonderlands is this 410 square miles in the Front Range of the Southern Rockies. Its extreme ends at Estes Park and Grand Lake are connected by the lofty Trail Ridge Road. Longs Peak at 14,256 feet, dropping off into Chasm Lake, may be thought of as the cornerstone of the park.



A molten mass appears at great depth and sends prongs upward. Shoots from these reach the surface, which becomes mantled with lava flows. The mountains rise higher. The lava flows are gradually worn off the mountains, and the material derived from them is deposited on the lowlands at each side, forming a new layer there.



Continued rise of the core of the mountains tilts the rocks on the flanks at steeper angles and causes them to break along great fractures known as "faults." The rising mountains also bulge outward, crumpling the rocks and forming flat faults at places.



The outward shape of the mountains changes slowly but continuously as a result of successive uplifts and the destructive work of streams and glaciers. Gradually, the configuration that we see today is achieved.

Many agents of geology have been active here, but dominantly glacial erosion, transportation, and deposition. Scarcely a feature that glaciers can produce has been omitted, and even a few bodies of ice remain nearby. Volcanic eruptions also show their effects here, and other processes as well.

Rocky Mountains

Colorado's mountains have been named and grouped variously by different authorities; there is no one standard way to identify them. Most of the mountains are arranged in more or less linear patterns termed ranges, such as the Front Range, which in turn is known as the Laramie Range when it crosses the border into Wyoming. Certain ranges are further subdivided; thus, the Rampart Range is a conspicuous branch of the Front Range. Other mountains have formed as clusters rather than as rows; the San Juan Mountains contain both configurations.

The present list of 14,000-foot peaks in Colorado totals an approximate 53 — up from the figure of 52 that was "official" for several decades. Three more — Ellingwood, Conundrum, and South Elbert — are technically ineligible. Revisions depend solely on new surveys, even though it seems to be a geologic fact that the Rockies are still slowly rising while at the same time undergoing gradual erosion.

Rowe Glacier

Rocky Mountain National Park is the home of this lesser known glacier in Colorado's high country. Its origin presents no problems not present in the geologic story of all the world's bodies of ice. It may not even be a full-fledged glacier, which it was termed when it became known as Hallett Glacier prior to being renamed in 1924. Rowe is situated at about 13,200 feet on the north slope of Hagues Peak and drains into the North Fork of the Thompson River.

Roxboro Park

The Fountain Formation stands vertical here, south of Denver. In places, the red beds even tilt backward, so strong were the earth forces that created this area, at least as varied as the better known Garden of the Gods (at Colorado Springs).

Royal Gorge

The Arkansas River races torrentially through the deepest segment of its Grand Canyon, 1,100 feet below the world's highest suspension

bridge and cable car, west of Canon City, in Fremont County. We should scarcely, it seems, criticize this great stream for cutting so dramatic a gorge through hard rock — Pikes Peak granite and Idaho Springs gneiss, both very ancient and very resistant to erosion. Yet, the Arkansas could have taken easier courses on sedimentary rock not far away.

The explanation lies in the uplift, or renewal, of a low-altitude landscape across which the river used to make its way. Obliged to maintain its path, it found itself working in less favorable rock. Hence, the Royal Gorge is deep even though a youthful feature. The presence of large vertical cracks, called joints, helps to keep the walls straight — in places, they even taper inward at the top.

Roberts Glacier

Somewhere near Raymonds, in Boulder County, is this one of Colorado's few glaciers still extant from the Ice Age. Its origin holds no puzzle other than the great, general one: what caused it in the first place? More moisture, cooler climate, yes — but what caused these?

St. Marys Glacier

Reached by a drive to the end of Fall River Road and then a 2-mile hike, this most accessible glacier in Colorado lies at the northern limits of Clear Creek County. Occupying a south cirque on Kingston Peak, it shares the history of Colorado's other true glaciers. The Ice Caverns (described in this book) were hollowed out of the glacial debris by a stream of meltwater.

St. Vrain Glaciers

There are two patches of ice at the head of Middle St. Vrain Canyon. Situated in the general region of Raymond, Boulder County, in Colorado's Front Range, these are among the relatively few moving bodies of ice remaining in the state from the Great Ice Age.

Sangre de Cristo Range — Culebra Range

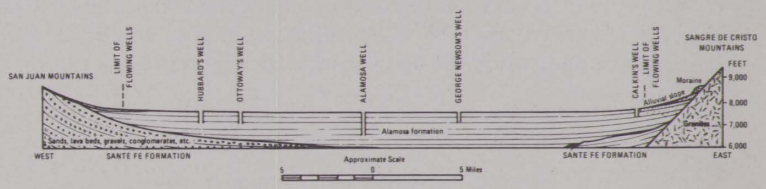
From Colorado to New Mexico, this high and narrow range exposes rocks of various ages — more altered (metamorphosed) toward the north end. Parallel to it, on the east, are the Wet Mountains, rather similar to the Front Range, with which they connect, though more broken up by faults. Where the Sangre de Cristos swing eastward in a huge loop at Sierra Blanca, the Culebra Range, of hard rock, begins and proceeds straight southward until the Rocky Mountains themselves terminate in New Mexico.

San Juan Mountains

Isolated from the rest of Colorado's Rockies is this group of mountains (and a couple of outlying ranges). It is geologically diversified, mostly volcanic rock of Tertiary age, representing the output of a cluster of volcanoes. The load of rock perhaps weighed down an earlier bulge, or dome, until they depressed it under their great weight. This is scenically the most spectacular part of Colorado.

San Luis Valley

The southernmost of Colorado's large parks was lowered along great faults as the adjacent Sangre de Cristo Mountains were rising on the east. The San Juan Mountains serve as the eastern boundary. The floor was covered with sediments of the Santa Fe Formation and



sheets of lava. The southern end was blocked by a lava dam (now the San Luis Hills) while the center was warped downward, and a freshwater lake occupied the Valley. Beds of sand of the Alamosa Formation carry artesian water from the surrounding mountains; confined within layers of clay, the water moves under pressure until it arrives at a natural outlet or else a well, up which it comes to the surface. There are more than 7,000 flowing artesian wells, some of which freeze into fountains of ice during the winter, being especially visible between Saguache and Monte Vista.

Sawatch Range

Including the highest peaks of the Rockies, this "ridgepole of the continent," as Will Rogers called it, is an upfold (an anticline) broken by faults. It constitutes the western part of a large dome of which the other half is the Mosquito Range.

Seven Falls

The seven major steps over which this waterfall descends near Colorado Springs represent shrinkage cracks in the Pikes Peak granite as the molten rock cooled. Seven Falls is presently situated at its point of retreat into the mountain mass, which has risen (as mountains do!) against the eroding force of the stream responsible for the well-known cascade.

Skyline Drive

Treading high above the Colorado State Penitentiary, at Canon City, in Fremont County, the one-way automobile road that bears this name offers an outstanding view of the surrounding area from an altitude of 5,958 feet. It follows the upturned crest of the Dakota Formation, which was thrown into folds and eroded to a hogback. Smaller "piggybacks" of adjacent Cretaceous formations stretch along the base, and Jurassic to Cretaceous rocks lie below the Dakota. As usual with this sort of geology, the more resistant strata remain as the hogbacks and ridges while the less substantial ones represent the valley between them.

Sleeping Ute Mountain

Surely one of the largest Colorado profile rocks, this stone relic of the great Indians who used to live in this region is situated in Montezuma County above Cortez. Marjorie Lengenburgh, representing the Cortez Chamber of Commerce, supplied information.

Southern Rocky Mountains

Stretching in single and parallel ranges, grouped in circular array, situated pretty much at random — the mountains of the Southern Rockies defy an orderly classification. A reasonably successful attempt has been made by Robert Ormes in his *Guide to the Colorado Mountains*.* Amidst the ranges are large, level areas known as parks; in fact, John Wesley Powell, the conqueror of the Grand Canyon, called this the Park Province.

More than 50 peaks rise above 14,000 feet, the highest being Mount Elbert, 14,433 feet in altitude.

*The Swallow Press, Chicago, 6th edition, 1970.

Inasmuch as the origin of mountains remains one of the great speculative problems in geology, the cause of the formation of the Southern Rockies is no better settled than any other. Were they crumpled like a squeezed rug as the earth's crust shrank? Did they fold together as it expanded, perhaps by radioactively generated heat? Had they been lifted up and then slid back down under the influence of gravity by a rising and sinking crust? Or is there a better explanation? Vertical uplift seems to account for the present Front Range, at least, and many others too.

We do know that our Rocky Mountains are merely the latest of a number of successive mountain-forming events termed orogenies: uplift accompanied by erosion, then subsidence and encroaching seas. In between were long intervals of quiet during which erosion was dominant, the sediment being carried to the mountain flanks, now the mountain front. The ocean came and went; in it was deposited thicknesses of marine sediments, in which there were uncounted multitudes of the shells and bones of marine plants. This is the last half-billion years or more of Colorado's geologic history, which has been described as being like the life of a soldier: long periods of boredom interrupted by short intervals of terror. The mountains are still rising, perhaps as rapidly as in the past.

South Park

Held between great mountains but parted from them by the presence of big faults, this basin contains Tertiary sedimentary rock that was eroded from the highlands.

The Front Range on the east, and the Mosquito Range on the northwest and north are its mountain boundaries, formed during the Laramide orogeny of Cretaceous-Tertiary times.

Spanish Cave

Perhaps the highest limestone cave in the United States, the Caverna Del Oro — the Cave of Gold — is a reef of Pennsylvanian age. Invaded at depth by molten rock, dissolved above into complicated passageways by the action of ground water, partly occupied by flowstone, this cave is cooled by moving air that changes direction several times daily. Marble Mountain Cave is another name for this difficult, dangerous, and romantically historic cavern, situated 15 miles southwest of Westcliff, near White Marble Halls and five smaller caves.

Spanish Peaks

"The great isolated double mountain situated at the northernmost limits of the Empire" — this is the Spanish Peaks, in Huerfano County. West Peak is 13,623 feet high; East Peak reaches 12,683 feet. Scenic as they are, the Spanish Peaks are most remarkable for their 500 or so rock walls — dikes — that are associated with both of them (especially West Peak), evidently in a coincidental manner. These molten bodies were injected in seven separate phases after the main stocks had risen into the crust of the earth during the Tertiary Period. Penetrating the enclosing strata of sandstone and shale, baking them and splitting into splinters, they cooled as a rich diversity of igneous rock types as much as 14 miles in length. The Devil's Stairway was separated into two sections that resemble the steps of a giant staircase.

Teresa Bertolino, representing the Aguilar Booster Club, sent information.

Profile Rock

One of the many dikes radiating from the twin Spanish Peaks has been eroded to resemble a human face. There must be a million others in Colorado.

Devils Stairsteps, or Staircase

This names and describes the way the dikes of the Spanish Peaks have split along the natural shrinkage cracks called joints.

Sawtooth Rock

The same applies here.

Spanish Peaks Dikes

Spiral Hill

Otherwise like so many rather similar hills in Colorado, this one is rather more symmetric than most and is more conveniently situated, being close to Salida, in Chaffee County. Spiral Hill is a volcanic mound of Tertiary age. A road spirals to the top.

Sprague Glacier

Another ice body in Rocky Mountain National Park, Sprague Glacier is, like the rest, a remnant product of the Pleistocene Epoch, or Great Ice Age: a quite recent time of greater moisture and cooler climate. It curves off into a lake at its base and then drains through Spruce Canyon into the Thompson River. Sprague used to be a feeder for Thompson Glacier, now gone from the scene and scenery.

Steamboat Rock

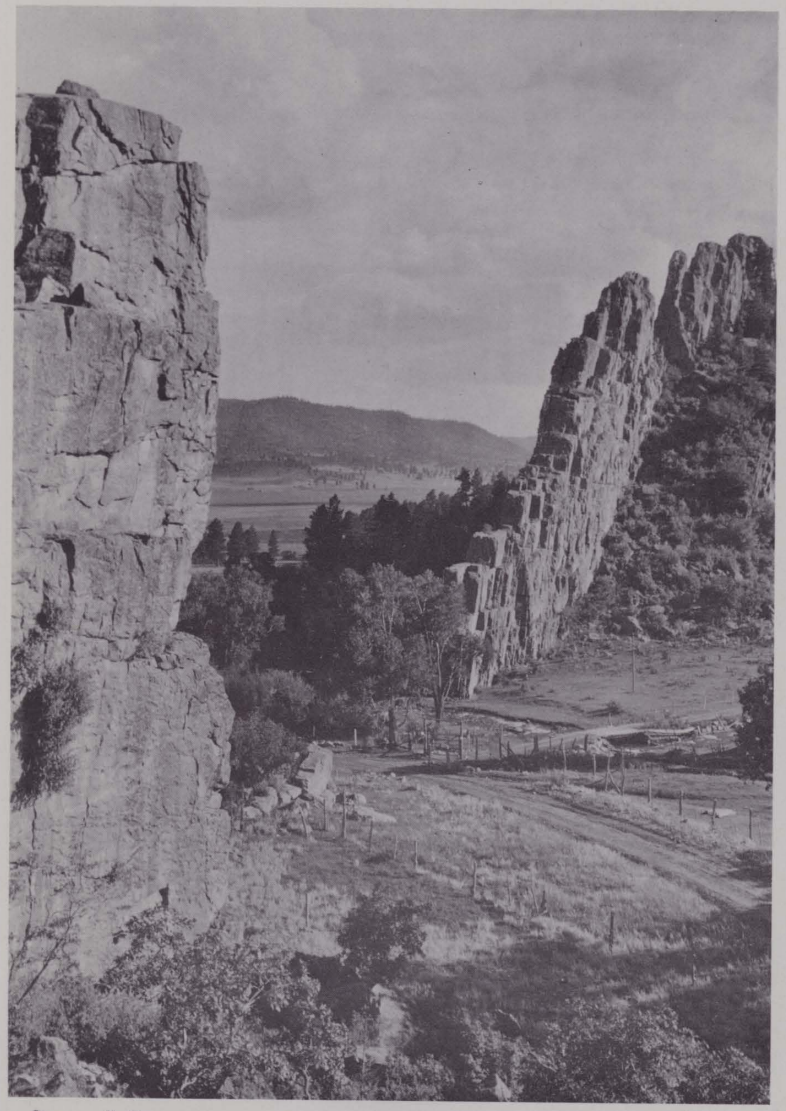
Resembling an old-style steamship with two funnels — which served Indians as a lookout and signal point — this one-time landmark for travelers is situated southeast of Virginia Dale, in Larimer County, near the Wyoming border. Deposition, burial, uplift, erosion — the usual story — explain Steamboat Rock.

The best known Steamboat Rock in Colorado faces Balanced Rock in the Garden of the Gods, at Colorado Springs. The softer red shale of the Fountain Formation has been cut away — as it has at the base of the adjoining Balanced Rock — leaving a wedge-shaped body of harder, coarser rock, which, properly railed in, really looks like a boat.

There is another Steamboat Rock near Lyons, in Boulder County. The one that is a lofty cliff of Late Paleozoic sandstone at Pats Hole, in Dinosaur National Monument, is the most impressive of all. Steamboat Hill is found in southwestern Colorado, and there must be others. There surely is famous Ship Rock at Red Rocks Theater, near Denver, and others of the same name.

Stonewall Gap

A natural opening produced by stream erosion (a water gap) cuts through Stonewall Gap, just outside the resort community of Stonewall, west of Trinidad on Colorado 12, in Las Animas County. The Stonewall is a considerable hogback of upfolded sandstone of the Dakota Formation, of Cretaceous age. The same formation makes up Skyline Drive (described in this book) and many high ridges in Colorado.



Stonewall Gap

Table Mountains

North and South Table Mountains lie astride Clear Creek at Golden, in Jefferson County. They belong to the same flows of lava, separated now by Clear Creek, which once moved in a higher channel across the lava, and they are a famous locality for zeolite minerals. The lava poured out of giant fissures near the Ralston Reservoir; Ralston Buttes lies beyond. Charles S. Morris, representing the Golden Chamber of Commerce, supplied information.

Table Mountains and Table Rocks are numerous in Colorado.

Taylor Glacier

Much like the few other glaciers of Rocky Mountain National Park, Taylor is a cliff glacier located at about 12,700 feet at the head of Loch Vale Gorge, not far from Taylor Peak. Taylor was once one of the starting places for the former Bartholf Glacier.

Turquoise Lake

Very profoundly of glacial origin, this noted body of water near Leadville, Lake County, occupies a rock basin scoured out by a river of ice of the Pleistocene Epoch and confined by deposits of rock that were left by the same glacier when it departed.

Twin Owls

Few figures resulting from out-and-out erosion are more realistic than the Twin Owls, north of Estes Park, in Rocky Mountain National Park. They overlook a wide panorama and can be seen from afar.

Tyndall Glacier

Ice of uncertain depth constitutes this glacier, which begins at about 12,300 feet below the summit of 12,725-foot Hallett Peak, in Rocky Mountain National Park, draining into Glacier Creek by way of Emerald and Dream Lakes. At this altitude, the slopes and mountain walls have been badly shattered by frost action. The crevasse, or bergschrund, at the head, is impressive.

Uinta Basin

Situated south of the Uinta Mountains is the Uinta Basin. The southern part, the Piceance Basin, contains Colorado's vast deposit of oil shale. Although high now, this region had a basinlike structure for millions of years, during which it accumulated thicknesses of eroded sediments.

Uinta Mountains

These are the Middle Rocky Mountains in Colorado, as described in this book. Dinosaur National Monument belongs here.

Unaweep Canyon

The mile-wide, open Unaweep Canyon has a U-shaped profile in Precambrian gneiss, over which appears sedimentary rock of Triassic and Jurassic age. Through this canyon in southwestern Colorado, now drained by two small streams going in opposite directions, once flowed the Gunnison River. The Colorado River may also have occupied it before the Uncompahgre Plateau was uplifted, diverting the drainage.

Uncompahgre Plateau

"A perfect flower garden," said an early explorer of this segment of the Colorado Plateau. Preserved against erosion by its hard caprock of sandstone, it resembles in its geology others of the large mesas in this part of the world, particularly the White River Plateau. Both plateaus stand higher than many other flattops of the general region. Uncompahgre is "remarkably smooth," Horsefly Peak rising above it as a result of its protective cap of glacial debris, and McKenzie Butte as an igneous sill.

Ute Peak

Sharing a high area with Hermano Peak west of Mesa Verde National Park, this is an intrusive stock of igneous rock thrust up into older rock on the Southern Ute Indian Reservation.

Valmont Dike

This conspicuous body of black basalt east of Boulder, in Boulder County, is often visited for its geologic interest. The volcanic rock of which it is composed may not, however, have reached the surface until exposed by erosion.

Vermilion Bluffs

Within the northwest corner of Colorado stands this array of cliffs, named for its impressive color glowing in the strong sunlight. Erosion around the edges has worn back the sedimentary strata of Cenozoic age to the present limits. This is part of the Green River Basin within the Colorado Plateau.

Wagonwheel Gap

The Rio Grande is abruptly restricted by the presence of unusually hard lava south of Creede, to be confined within the narrows of Wagonwheel Gap. Some distance elapses before the valley begins to broaden again.

Wet Mountain Valley

Really a Colorado park instead of a valley because it is a structural feature rather than one caused by stream erosion — as every well-behaved valley should be — this open space stretches between the Wet Mountains on the east and the Sangre de Cristos on the west. Whatever combination of uplift and compression produced the adjacent mountains was likewise responsible for the making of the Wet Mountain Valley.

Wheeler Geologic Area

Formerly Wheeler National Monument — the first in the country — this curious area of 300 acres in the San Juan Mountains consists of grotesquely carved masses of colorful volcanic rock, called volcanic tuff, of Tertiary age. You will see turrets and spires, pinnacles and pedestals, balanced rocks and caves, winding canyons all but concealed from the sky. Weird though the shapes are, there is nothing mysterious in their origin. Weathering and erosion by water and wind have slowly done their job, here as elsewhere, producing these hoodoos, as Westerners term them.

White River Plateau

Nearly horizontal sedimentary rock of Paleozoic age folds downward along the south and west edges of the White River Plateau, as marked by the Grand Hogback. The White River structure is similar to that of the Uncompahgre Plateau, and has an 11,000-foot average altitude, uplifted by faulting and folding.

Wyoming Basin

This northward-facing natural province in northwestern Colorado consists of elevated plains and low mountains. The plains exist in various stages of erosion. The mountains are isolated highlands. Both can be dated to the great mountain-making event known in geologic history as the Laramide orogeny, of Cretaceous-Tertiary age. Here is the Green River Basin.

Yampa Plateau

Bordering Dinosaur National Monument on the south, this part of the Colorado Plateau is protected by a resistant caprock, which has slowed the forces of erosion to their present extent.

Yucca House National Monument

Occupying 10 acres on the slope of Sleeping Ute Mountain west of Mesa Verde National Park, this inaccessible preserve in Montezuma County protects scenery, geologic structure, and archaeology very similar to those of the nearby national park (described in this book). Constructed of limestone from the cliffs of Mesa Verde are some of the buildings used here by prehistoric Indians.

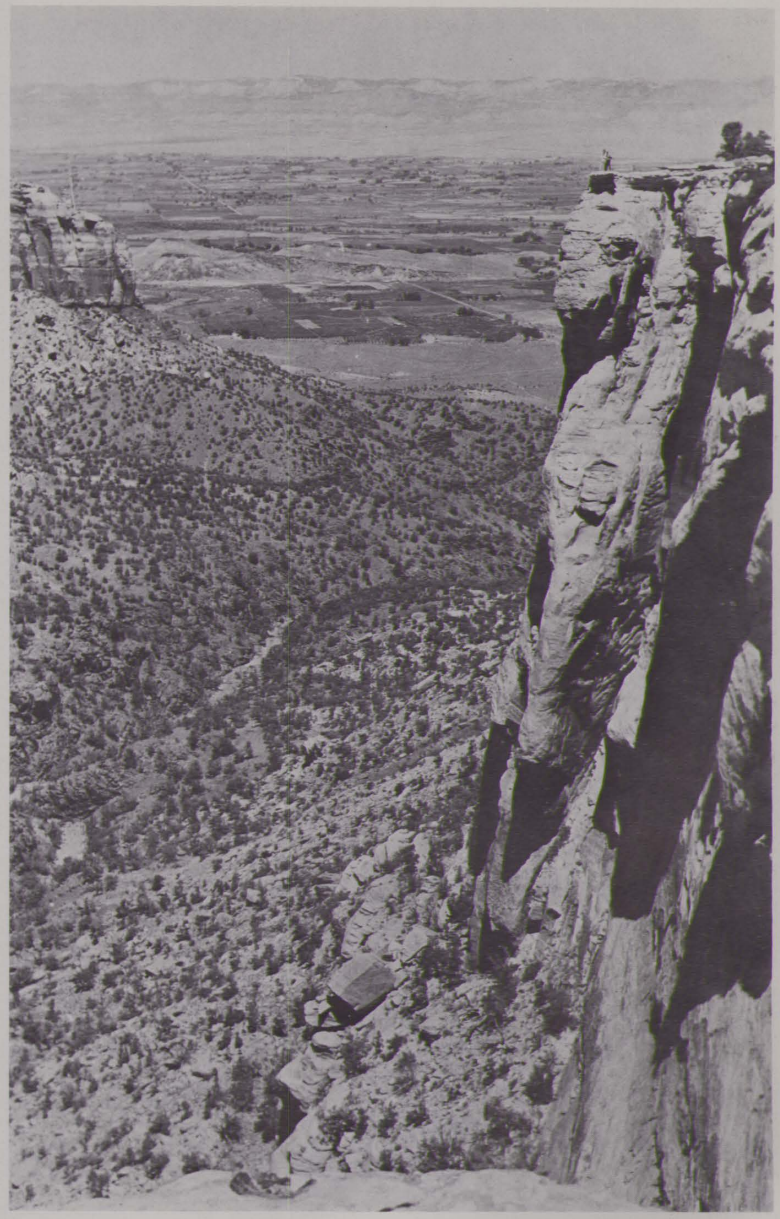
Upper Boon Falls

Books by Richard M. Pearl

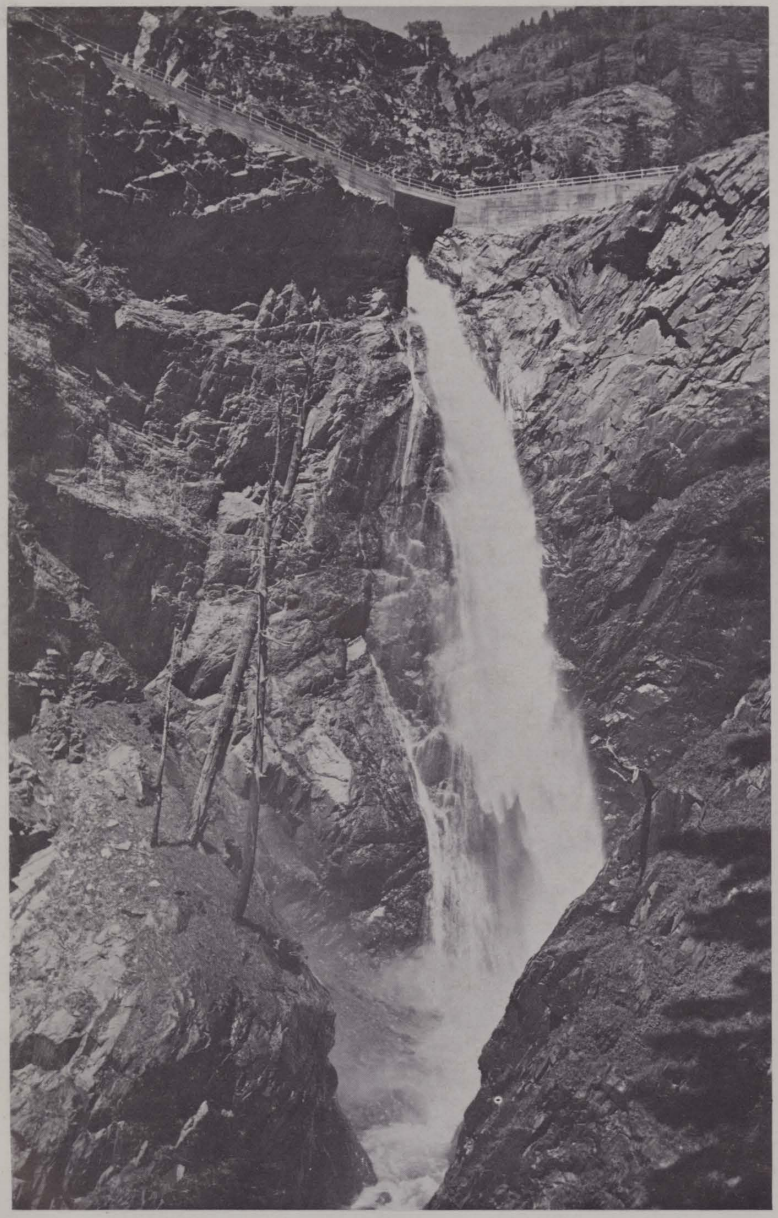
Cleaning and Preserving Minerals
Handbook for Prospectors
How to Know the Minerals and Rocks
Rocks and Minerals
Agates
Turquoise
Fallen From Heaven: Meteorites and Man
Garnet: Gem and Mineral
1001 Questions Answered About the Mineral Kingdom
Wonders of Rocks and Minerals
Successful Mineral Collecting and Prospecting
Wonders of Gems
The Wonder World of Metals
1001 Questions Answered About Earth Science
Geology: An Introduction to Principles of Physical and Historical Geology
Geology Simplified
Colorado Gem Trails and Mineral Guide
Exploring Rocks, Minerals, Fossils in Colorado
Seven Keys to the Rocky Mountains
America's Mountain: Pikes Peak and the Pikes Peak Region
Historical Atlas of Colorado
Richard Pearl's Field Book of Minerals
Atlas of Crystal Stereograms
Blowpipe and Chemical Testing of Minerals
The World of Rocks
Waterfalls: Appreciation and Explanation
Dinosaurs: Their Life and Times
The Boundary Book
Meteorites of Colorado
Springs of Colorado
Nature's Names for Colorado Communities
Landforms of Colorado
Popular Gemology
American Gem Trails
Gem Identification Simplified
Nature As Sculptor: A Geologic Interpretation of Colorado Scenery
Gems, Minerals, Crystals, and Ores: The Collector's Encyclopedia
Guide to Geologic Literature
Mineral Collectors Handbook
Colorado Gem Trails
The Art of Gem Cutting (With Dr. H. C. Dake)

Royal Gorge

Unaweep Canyon



Cold Shivers Point,
Colorado National Monument



Bear Creek Falls, near Ouray

Foothills Scenery