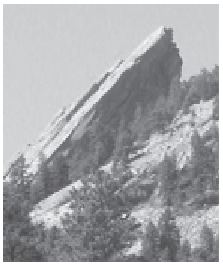


Chapter 1: A Guidebook in the Sky — the Boulder Backdrop

From many places in the City of Boulder and from other locations in Boulder County, one catches breathtaking scenic views that include spectacular rock formations and patterns in the landscape that provoke one's curiosity as well as one's aesthetic sensibilities. What forces were responsible for the soaring faces of the Flatirons? What is the history of the peaks of the Front Range? Why are the rocks that make up the two so different?

One of the fascinating aspects of the Boulder landscape is that much of its history and geology are fairly easy to understand, based on a few simple facts about the way the landscape was formed. While there are plenty of problems remaining for serious scholars, a lot of Boulder's most prominent features present clear evidence of their origins, once you have begun to understand their organization. Boulder is thus a fine beginning geology textbook, written on a grand scale. In only a few places of comparable size in the Untied States can one find such a variety of rock types and landscapes in an area the size of Boulder County.

The Western Landscape

For residents of the eastern United States, trying to gain a basic understanding of local geology can be a frustrating exercise. The geology itself is often quite complex, and a lot of study is required to gain even an elementary command of the explanations of the features by geologists. Learning to recognize the origins of features in an area that one has not studied is more difficult still, except for a few patterns like evidence of ice age glaciation.

This is true both because of the complex geological history of the eastern edge of the North American continent and because of the vegetation and soil cover that obscure the geological structures from view. In huge expanses of the western United States, beginning at the Rocky Mountains and extending most of the way to the Pacific Ocean, much more of the history of the last few hundred million years is widely exposed, and the arid climate of the western interior has left a great deal of the geology manifest. Elevations are higher, so the forces of erosion are more active. Vegetation is sparser, soil cover is thinner, and relatively recent geological activity has either thrust up evidence of the past, or rivers have cut into the landscape to reveal its story.

Zooming in on Boulder

As one of the gateways to the Rockies, Boulder presents the curious observer with a fine example of these characteristics. The evidence of two separate mountain-building events is quite clear (other older ones are more obscure), and with a little more detailed observation the evidence of ancient seas is also writ large.

The Flatirons themselves, which are the most prominent feature of the Boulder landscape from most perspectives, are formed from a durable layer of rock pushed up by the rise of the modern Rockies, a geological event known as the **Laramide orogeny**. This mountain-building event began about 70 million years ago and tipped up layers that were originally laid down as sediment by the uplift of another much older mountain range, usually known as the Ancestral Rockies.

Other prominent ridges and outcrops present evidence of wind-formed dunes (Lyons Sandstone) and fossil-bearing sediments from the beginning of the last period during which the dinosaurs lived (Dakota Group). Less obvious and dominating features show clearly in some places. The Fox Hills and Laramie Sandstones near Marshall and at White Rocks were deposited at the edge of a receding seaway at the end of the age of the dinosaurs. The Morrison Formation, which crops out in a number of places in the county, is one of the most wide-ranging and recognizable formations in the Western Interior of North America, as well as one of the best-known sources of dinosaur fossils in other parts of Colorado and the Western Interior. Some features like the Valmont Butte are evidence of relatively recent intrusions of molten material near the surface of the earth.

The significance of Boulder County for geologists is reflected in some of the names of rock units that are taken from locations in the area. The oldest granite **pluton** in Colorado is the Boulder Creek Granodiorite, named after our own Boulder Creek. One of the widespread and famous sandstones in Colorado is the Lyons Formation, named for the town of Lyons in the northern part of the county. The building stone that dominates the campus of the University of Colorado is Lyons Sandstone, and it is also the material of many buildings and historic sidewalks in Denver. Other less famous rocks are also named for features in the county. (Softer layers like these are easily weathered, so they don't form prominent outcrops.) The Lykins Formation is named for Lykins Gulch, and the Hygiene Member of the Pierre Formation is named after the town of Hygiene. A geological rock unit is traditionally named for the location where it was first described in a scientific paper.

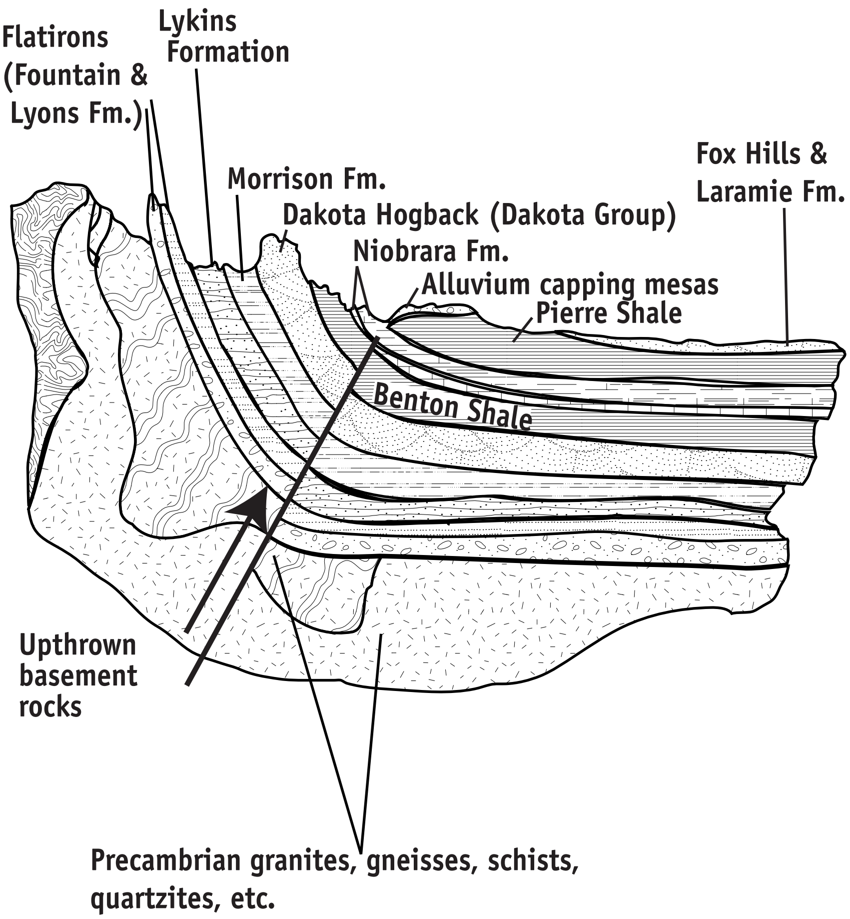
Boulder is notable for a wide range of geological features. The southernmost ice glacier in the Rockies, Arapaho Glacier, has long been a major source of the city's water supply. Boulder County is at the northeast end of the Colorado Mineral Belt, one of the most important sources of precious metals in the world. The Flatirons are, of course, widely renowned.

Boulder County is located across important geological transition zones. To the east is the High Plains geological province. The western boundary of the county is the continental divide. Stream runoff from the county moves toward the Atlantic Ocean, via the South Platte and Mississippi Rivers and the Gulf of Mexico, but just to the west, the runoff follows the Colorado River toward the Gulf of California and the Pacific. (Water diversions and dams ensure that water from Colorado snowmelt is unlikely to ever reach the Pacific.) The western third of Boulder County is in the Front Range of the Southern Rocky Mountains. The mountain front is marked by the uplifted edges of sedimentary rocks ranging widely in age. The area between the mountain front and the High Plains, is the geological province known as the Colorado Piedmont.

The Landforms Reflect the Geology

The shape of the land anywhere reflects the underlying geology, but this is especially true in a place like Boulder, where there is a lot of relief — itself reflecting recent large-scale geological activity. Because the mountains of the Front Range rose just to the west of Boulder, all the layers of rock near the junction of the mountains and plains were tipped upward, and they were then subject to erosion by the forces of streams and glaciers pouring off the mountains. Valleys formed by the glaciers and streams were then cut progressively deeper, landslides cascaded down steep slopes, and all these forces of erosion tended to wash away weaker layers of rock more quickly than stronger layers.

That is why along the eastern flank of the mountains, we tend to see a series of parallel ridges — **hogbacks** — just in front of the foothills. The crest of each ridge represents a layer of durable rock, while the low areas between and the slopes in front of and behind the crests represent weaker intervening layers of rock. Thus, the main ridges all along the east side of the Front Range are generally made up of the same strong layers of sedimentary rock, from the Wyoming border to Colorado Springs. The Fountain Formation constitutes the body of the Flatirons in Boulder and the Red Rocks Amphitheater between Golden and Morrison. The Lyons Formation forms the cliffs near Lyons, many formations above Boulder, and spires in the Garden of the Gods in Colorado Springs. The Dakota Hogback is prominent west of Boulder, at Dinosaur Ridge near Golden, and at many other locations along the mountain front. See Figures FT7-WP10 (page 210) and FT9-WP14



(page 225) for examples of the hogbacks and intervening valleys.

Just east of the hogbacks we find many mesas capped by **alluvial** deposits — sheets of debris washed down by rushing water — and intervening canyons and valleys where more recent streams have cut channels through these deposits. Driving along the north-south thoroughfares in Boulder, or the north-south highways between cities — Highways 36 north of Boulder and 93 to the south — we alternately drop into the valleys and climb up onto the mesas. If we hike or drive up to a higher point, these patterns are clearly visible spreading out below, like tables extending out from the wall of the mountain front. In both the canyons and the alluvial deposits, we frequently see huge boulders that have been dislodged from the Fountain Formation and other durable layers now sitting in the creeks or on the mesas. A little farther east, beyond the distance travelled by the large boulders, the rocks are smaller and more rounded by obvious stream wear during their trip down from the mountains. Often these stream-rounded rocks, on close inspection, reveal their sources in the granites and other ancient rocks west of the foothills.

Still farther east are plains capping thousands of feet of debris that have washed off the rising mountains. Here much of the geology is buried and more difficult to see. We will have more to say about what lies below in subsequent chapters. Clues on the surface are farther apart, revealed here and there by stream erosion or by road cuts that expose a few tens or a few hundreds of feet of rock for us to inspect and interpret.

With all the rows of rock sentinels we pass travelling any east-west corridor, there is a fairly uniform pattern. The mountains pushed up the sedimentary rocks that originally covered them, bending the sediments into a large dome, the top of which has been eroded off. The side of that dome is still visible in the form of upturned edges of rock, the stronger ones still exposed to form ridges, and the weaker ones worn and washed away to form valleys. Since the original layers of rock were generally very similar for long distances, we see the same ones again and again. Moreover, they stand in order of age. Younger sedimentary rocks are deposited on top of older ones. Therefore here along the eastern flank of the Front Range, the ridges to the east are formed by rocks that are younger than the ones to the west. The Fountain Formation and the Flatirons are older that the Dakota Hogback. Despite interesting complications here and there, this sequence reflects one of the fundamental principles of geology — newer sedimentary rocks are always deposited on top of older rocks, and their positional relationship is maintained, even when extreme distortion and folding moves them around. You can see that all the layers were pushed upward by the mountain uplift; a geologist might say that as you drive up one of the canyons, you are moving 'down-section.' That is, even though the road is climbing, it is travelling through progressively older rocks.

A Tale Told by the Missing

Travelling west towards the mountains the first important story that we encounter is that of the spectacular Flatirons, but what is far less obvious, is what is ***not*** there. Going up any of the canyons leading into the mountains we travel west through progressively older rocks. At first the layers are relatively close to one another in time — rocks deposited by the great Cretaceous inland sea that prevailed in Boulder 80 million years ago, then the rocks representing the age of the dinosaurs, then those from the age of the great ancient continent Pangaea, and then the Fountain Formation, which was laid down by erosion of the Ancestral Rockies, around three hundred million years ago.

But then we suddenly pass from the latter rocks originally deposited 300 million years ago (**Ma**)[6] to much, much older rocks — either 1.1 or 1.4 billion years older, depending on which canyon we are going up. Geologists recognized this time gap long before the ages of the rocks had been nailed down to the level of precision that we know today. They knew from comparisons with rocks in many different places, matching of fossils and other techniques, that the Fountain Formation was of Pennsylvanian age,[7] and the rocks just to the west were Precambrian. In between these periods are the Cambrian, the Ordovician, the Silurian, the Devonian, and the Mississippian, which cover hundreds of millions of years. (See Figure 2-1.)

This great gap of over a billion years, known in geology as an **unconformity**, is missing from the history written in the rocks in the Boulder area. What the rocks tell us is that sediments were not being deposited here during that time, or that they were deposited and were subsequently eroded away, or some combination of the two. We have some information from other nearby areas about what was probably going on then, but the geological book of Boulder only tells us that the chapters covering this period have been torn out, or that they were never written at all, or that some of the chapters were written and then discarded. What we can infer from evidence elsewhere is summarized in Chapter 5 (pages 55-61).

The Mountain Core

Head up any of the canyons to the west of Boulder, and you will soon pass the unconformity and see obviously different rocks! Typically, reddish sandstone changes suddenly to gray crystalline rocks. Even to the unpracticed eye, these rocks of the mountain core usually seem obviously older and more durable.

The core of the Front Range, which forms the Continental Divide a few miles west of Boulder, is made up of ancient rocks well over a billion years old that were subsequently pushed up in a great mountain-building event beginning about 70 million years ago. These ancient rocks have their own

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[6] Many abbreviations have been used to designate geological chronology. MYA, m.y.a., MYBP, and m.y.b.p. have been used for **m**illion **y**ears **a**go and **m**illion **y**ears **b**efore the **p**resent. Current usage is generally *Ma* for million years ago and *My* or *m.y.* for an interval of a million years. Thus, one might say that the Pennsylvanian Period began 325 Ma and lasted for 39 My. For billions of years, one similarly finds BYA in many places, but current practice is to use the standard scientific magnitude abbreviations, in which G stands for 1,000,000,000 or 10^9. Thus Ga designates billions of years ago, and Gy an interval of billions of years.

[7] The first geologist to describe the Fountain, C.W. Cross in 1894, placed it in the Carboniferous, now divided into the Mississippian and the Pennsylvanian in the U.S. Geologic periods are discussed in the next chapter.

stories to tell, and we will spend some time exploring them. Like many older stories, however, they are written in a more arcane language that is harder to read than the more recent tales of the Flatirons, so we will have to be satisfied with a few representative passages.

The Colorado Front Range is the main geological and geographic uplift forming the high peaks rising above the Great Plains from approximately the Wyoming border to the Arkansas River south of Colorado Springs.

One other tale that we will explore in these older rocks is one that has had major influences on the history of Boulder and the surrounding towns — particularly those sprinkled through the mountain canyons. There are veins of younger origin snaking through the older crystalline rocks that form the mountain core. These veins were deposited relatively recently by hot, mineral-rich fluids seeping through old cracks in the Precambrian rocks. The minerals left behind were exploited by hordes of prospectors and miners seeking fortunes in the hills, as well as the wives, merchants, preachers, hucksters, and whores that followed them to the area. Had it not been for these deposits, the Utes who lived here before our arrival would have been left in peace far longer than they were.