Revised Field Trip–Doudy Draw

This field trip replaces Field Trip 24 in ***The Geology of Boulder County***. Since the book was published in 2004, Boulder Open Space and Mountain Parks, following the Visitor Master Plan, has completely redone the trails in this area, based on the Eldorado Mountain/Doudy Draw Trail Study Area planning process.

As a result of the EM/DD TSA, the field trip originally published in *The Geology of Boulder County* would take the visitor into closed areas and social trails that are being revegetated, while ignoring new designated trails that visit interesting geology.

This revised trip is therefore being provided on the Web for all interested visitors, and it will also be published in print in my forthcoming *Geology of the Denver Area* (as Field Trip 6).

Please avoid the social trails described in the original printed version of *The Geology of Boulder County*, and follow the designated trails described in this revised guide.

Notes for Readers of *The Geology of Boulder County*

Waypoints listed on this trip follow the same conventions as the book—the GPS datum used is NAD27 to match standard USGS maps. Comparing them with waypoints using a different datum can result in discrepancies of 100 yards. Downloadable routes will be posted at http://www.boulder-geology.com.

Most references to the scientific literature are listed in *The Geology of Boulder County*, but there are a few recent ones that are detailed in my forthcoming *Geology of the Denver Area* (2010). One of these is listed at the end of this field trip.

Note that a few allusions in the text are to the geology of the Denver Basin (such as those to the D1 and D2 sediment packages [Raynolds 2002]). These are discussed at length in the Denver book, but not in the Boulder one. This should not be a source of confusion, since there are no field trip references—this field trip is in the Boulder area, and Denver Basin sediments are not encountered here. They are only mentioned in the geological overview.

Description

The trip is described as a hike, though most of it is open to bicycles, and directions are also given for cyclists.

The hike is on good trails and is a little over 5 ½ miles long with an elevation gain of about 600 feet. Thus, it is moderate, but be sure to take adequate water. It can be hot, especially in summer; it is treeless for the first couple of miles. This hike is at the southern end of Boulder's mountain parks, and it provides some excellent examples of the geology of the Colorado Piedmont at the northwestern rim of the Denver Basin, as discussed in the geology section below. The area is managed by the Boulder City Department of Open Space and Mountain Parks (OSMP), and trail information, regulations, and other useful material can be found at its Website (osmp.org).

The hike goes through grasslands that preserve unique plant communities and ecosystems. The wildflowers can be spectacular, especially in spring, and the field trip is excellent for birding and butterfly-watching, so if you are interested in aspects of natural history other than geology, be sure to bring binoculars and appropriate guidebooks.

This hike offers a superb opportunity to explore the geomorphology of the Boulder area, as well as traveling through a good cross-section of the rocks exposed in the Colorado Piedmont.

Location/Directions

From Boulder: From Table Mesa and Broadway (mile 0) go south on Broadway (State Highway 93). The highway descends into the South Boulder Creek drainage at the south end of town and then begins climbing toward Rocky Flats. At the traffic light at mile 2.6 take SH 170 west (right)—Eldorado Springs Drive. Note that just before the right turn onto SH 170, the buff-colored sandstone outcrop on the right is Fox Hills Formation—remains of the delta and beach sands that formed at the edge of the receding Cretaceous Interior Seaway (see Chapter 9 of either *The Geology of Boulder County* or *The Geology of the Denver Area*). After turning right on Eldorado Springs Drive (SH 170), at mile 2.85, you will see more outcrops of Fox Hills on the left (south) side of the road.

Park at the Doudy Draw Trailhead at mile 4.3 on the left (south) side of the highway (1.45 miles from the intersection).

From Denver: Take the Denver-Boulder Turnpike (U.S. 36) to the Louisville/Marshall/Eldorado Springs exit. Turn left at the top of the ramp (SH 170), cross the overpass (west) and bear right toward Eldorado Springs. Continue for approximately six miles to the traffic light at SH 93. Go straight through the intersection, pass outcrops of Fox Hills Formation on your left, and proceed 1.5 miles to the Doudy Draw Trailhead on the left (south).

By bicycle: From Boulder, ride to Table Mesa and Broadway, then follow the bike path/frontage road on the east side of Broadway south to Marshall. From Marshall turn west (right) up the hill to the light at the intersection with SH 93 (Broadway). Continue west and proceed 1.5 miles to the Doudy Draw trailhead on the left (south).

For direct bicycle access from elsewhere in the Denver metro area, take any route to Superior (e.g., McCaslin Blvd. north from SH 128–120th Ave.) and then follow Marshall Road (SH 170) to the route above. Alternatively, take Simms and then 96th St. north to South Boulder Road at Louisville, turn west to Table Mesa at Broadway, and then follow the directions from Boulder.

From Denver via RTD with your bike, take any Boulder bus (AB, B, etc.) to the Louisville/Marshall/McCaslin exit. Take the overpass west across U.S. 36, turn right on SH 170, go 6 miles to the traffic light and follow the Boulder directions.

Or (also via RTD) from the Cold Spring Park-n-Ride at West 4th Ave. and Union, take the GS bus to the Eldorado Springs Drive stop and follow the Boulder directions.

Geological Maps

The field trip is entirely covered by the USGS 7 1/2-minute Eldorado Springs quadrangle (Wells 1967). It is out-of-print, but is accessible in libraries. A scanned version is available on-line, at ngmdb.usgs.gov/ngm-bin/ILView.pl?sid=q24_21289_us_c.sid&vtype=a. (Display or image conversion software is required for the special format, downloadable from lizardtech.com.)

Transportation

As indicated above, the trailhead for this field trip is usually reached by automobile. It is easily accessed by bike from Boulder, as described above, whether or not one is planning to ride the trails.

The field trip itself is accessible by bicycle, except for WP3 and the section from WP14-WP20. Up to this latter section, the route is moderate single-track, easily ridden with a mountain bike or a fat-tire touring bike. Bikes are prohibited on the Fowler Trail beyond the Dakota road cut, so you'll need to carry a lock to secure your bike while you visit this section (WP14-20).

Cycling or pedestrian access via RTD: To get to the beginning of the field trip by bike, you need to ride from Boulder or Denver, as described above, or bring your bike from Denver via RTD. Take one of the Denver-Boulder buses to the downtown Boulder terminal or to the Marshall Road stop on the Turnpike. Alternatively, take the GS bus from the Federal Center or the Cold Spring Park-n-Ride and get off at Eldorado Springs Drive (SH 170). The GS bus runs almost exclusively during commuting hours—morning and afternoon—between Boulder and Golden. You can use it reasonably to get to the field trip in the morning and return at the end of the day, but there is little flexibility in schedule, either for cycling or on foot.

From Boulder, you can take the GS (during commuting hours) and get off at Eldorado Springs Drive. You then need to walk 1.7 miles west to the trailhead. Return the same way. For a day trip, this is reasonable, but you need to be back to the bus stop to fit the commuting schedule. (Current schedules can be found at rtd-denver.com). From the south, the GS leaves from either the Federal Center or from Cold Springs Park-n-Ride.

Overview of the Geology

This field trip provides an excellent view of the geomorphology of the Boulder area. Since Boulder is situated at the northwest edge of the Denver Basin (see Figure DD-1—where sediments were eroded into the basin and pre-basin bedrock was preserved—this is an important location.

Specifically, in the Boulder area, geomorphology is preserved that is absent or complicated south of Rocky Flats, where the Denver Basin directly abuts the mountain front. In Boulder, debris from the Laramide uplift and volcanic eruptions washed by and was carried into the Denver Basin to the southeast. The sediments represented by the Denver Formation or the D1 and D2 sediment packages don't exist on this field trip, as they do at Green Mountain (near Morrison) and elsewhere.

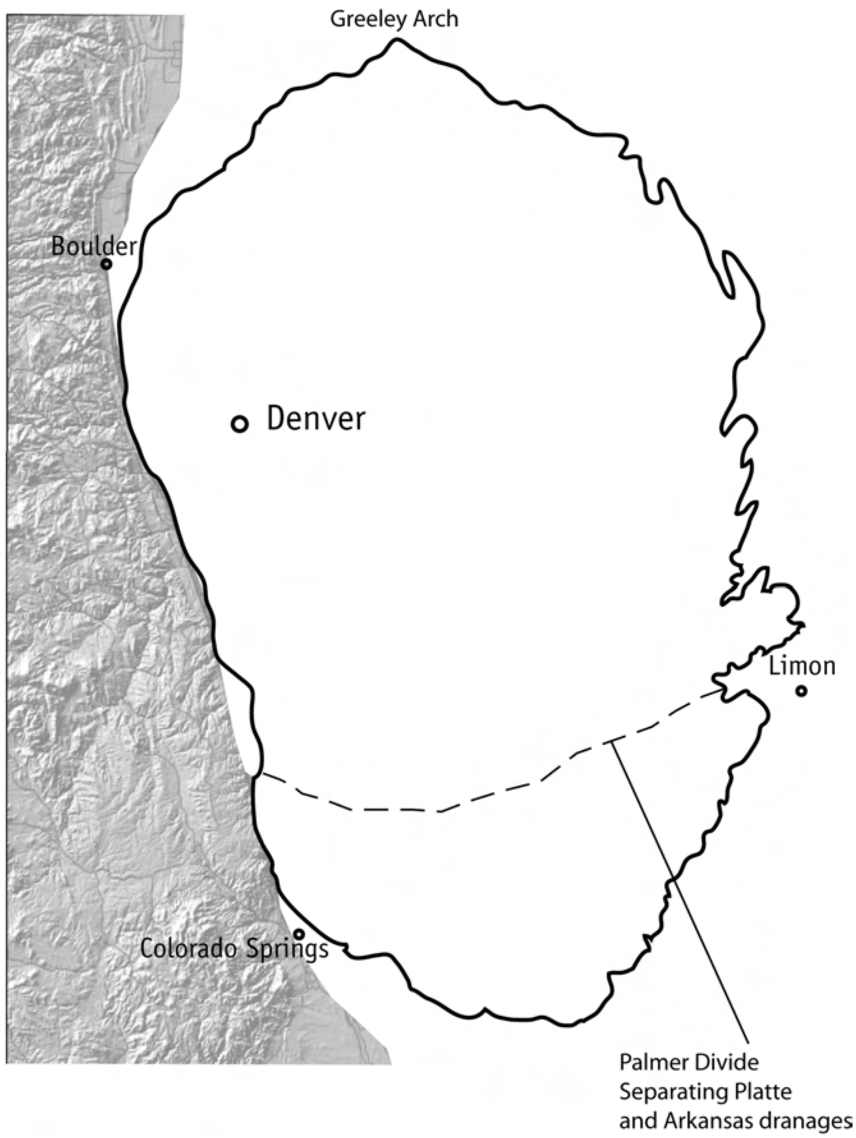

Figure DD-1—The Denver Basin

Instead, the pattern at Boulder, exemplified on this field trip, is that many of the Cretaceous sedimentary rocks continue to form the primary bedrock. Quaternary sediments lie directly on the Cretaceous bedrock with no intervening Tertiary synorogenic[*] deposits, like those that occur in the Denver Basin, where they were deposited as the modern Front Range was uplifted.

The general pattern is that when the era of the most recent ice age began, a little over 2 million years ago (the most recent ice age intensification, or glacial

[*] Sediments that are shed from a rising mountain range.

maximum, occurred about 20,000 years ago), the regional flood plain of the South Platte extended throughout the Denver Basin and the Boulder area. The surface that was established by that flood plain—all the alluvial deposits—is now known as the Rocky Flats Alluvium. The remnants of that flood plain throughout the region are contemporaneous in age. Where it is preserved, the Rocky Flats Alluvium, because it was deposited on the South Platte flood plain at the time, marks a particular date range, which is correlated with a phase in the continent-wide glacial maximum. During the ice age, continental glaciers never reached Colorado, but with each expansion of continental glaciers, Colorado experienced glaciers that built up at high altitudes and extended down the valleys to approximately the level of Georgetown in the I-70 corridor and the Peak-to-Peak Highway in the Boulder area.

The area around Boulder, well exposed on this field trip, is particularly important to our modern understanding of the glacial-interglacial cycles because it is located at the edge of the Denver Basin. Boulder has no synorogenic sediments that are the products of the rise of the Front Range. As the mountains rose, the sediments produced by the initial mountain uplift were carried beyond Boulder into the basin.

What remains at Boulder is the bedrock from Cretaceous time that was left at the rim of the Denver Basin as it subsided. Boulder sits on Pierre Shale and other Cretaceous sediments. Because they are weak rocks, they usually erode away easily. To the southeast, in the Denver Basin, these Cretaceous rocks are buried under layers eroded from the rising mountains (the synorogenic sediments).

Here and there, where canyons exit the mountains, floods in the last two million years have transported massive alluvial fans and debris flows out onto the flood plain. The gravel of these deposits, which includes pebbles, cobbles, and huge boulders, tends to protect the weak Cretaceous bedrock pediments below. Gravel is more resistant to erosion than the underlying bedrock.

As a result, in the Boulder area, we find a series of mesas or tablelands at nearly every canyon mouth, where the gravel has capped the underlying Cretaceous shale and protected it from erosion. The mesas are arrayed along the mountain front from the edge of the Denver Basin north. The first such mesa is at Rocky Flats at the mouth of Coal Creek. Then, proceeding north, there is a set of mesas produced by South Boulder Creek, including the ones we visit on this field trip. Still farther north are Shanahan Ridge and then Table Mesa, on which the National Center for Atmospheric Research (NCAR) is constructed. The mesas continue to the north, most obviously at Table Mountain, the Federal property between Boulder and Lyons. From a geomorphological point of view, these mesas are all capped by the Rocky Flats Alluvium, roughly 2 Ma in age. The composition of the gravel on each mesa consists of source rocks carried from the mountains immediately upstream at the time of deposition. Lower mesas are capped with younger gravels, the Verdos Alluvium, for example, which is 0.64-0.68 Ma in age. In the Denver Basin farther south—to the east of Roxborough Park, for example—Rocky Flats Alluvium can rest atop the D1 or D2 sediment packages, instead of the Cretaceous formations found here. And the Rocky Flats Alluvium always represents a specific age and a flood plain surface. Nonetheless, the actual composition of the gravel will vary at every location, depending on the foothills source area to the west. Some Rocky Flats Alluvium locations have a lot of Fountain Formation debris, some have Boulder Creek Granodiorite, some Colorado Metamorphic Complex, and some Silver Plume Granite—whatever is upstream to the west.

The beginning of this trip explores the recent (Pleistocene and Holocene) geomorphology of the area, with one detour to look at an exposure of Pierre Shale. The interaction of the geomorphology of the area and the plant ecology is of particular interest, and we will consider it along the way (Buckner 2010). From an ecological point of view, this trip traverses very important examples of stable grassland communities that have persisted in the Rocky Flats Alluvium for well over a million years (ibid.).

On the continuation of this trip, we encounter one of the best cross-sections of the Dakota Group in the entire region. This begins with exposures of ripple rock (WP12) stripped bare by clay mining, followed by the railroad cut through the lower Dakota (WP14-16), which exposes the lower Dakota shales and sandstones.

After traversing the Dakota Group, including the Lytle Formation, the trip passes through good exposures of the Morrison and Lykins Formations with views of the Fountain Formation, which was formed from detritus eroded from the Ancestral Rockies 300 million years ago.

Road/Trail Log

Waypoint	Latitude	Longitude	UTM Zone	UTM Easting	UTM Northing
WP01	39.93822	-105.256	13S	478153.2	4420722

WP1 — The Doudy Draw parking lot. Note the overall landscape around you. Consider the slope to the east; it consists of a thin cover of colluvium over the bedrock of Pierre Shale, sloping up at the angle of repose. The level area at the top of the slope has been protected by a cap of gravel known to geologists as the Verdos Alluvium (the Verdos constitutes the terrace just below, and a little younger than, Rocky Flats Alluvium), which was deposited 640,000-680,000 years ago (Birkeland et al. 1996; Chadwick, Hall, and Phillips 1997). This capping layer of gravel resists erosion, except at the edge of the slope. When it is undercut, gravel at the edge slides down the incline and forms the colluvium on the slope itself and at the base, where you are standing.

In nearly every direction there are other gravel-capped mesas, which represent river terraces formed during the glacial cycles of the last two million years. The highest ones, like the one to the southwest, which our route will climb, are capped by the Rocky Flats Alluvium, dated between 1.35 and 2 Ma (Birkeland et al. 2003, Knepper 2005).[1] Where the gravel alluvial surfaces capping the mesas

[1] The Rocky Flats Alluvium has not been dated precisely, but the age of the main surface has been established as having been deposited between 1.5 and 2 MA, with some reworked portions thought to date to 1.35 Ma.

are close enough to the foothills to receive additional moisture, they often support Ponderosa pine-Douglas fir forest (*Pinus ponderosa* and *Pseudotsuga menziesii*), because the gravel caps are thick enough to hold a significant amount of moisture over the impermeable shale pediment, whereas the slopes below do not, except in catchment areas. Thus, from a distance, the beginning of the gravel cap is often easily visible where the trees begin. You can look across the drainages and see the geological formation boundaries delineated by the vegetation.

Take the trail to the south. The rocks bordering the trail at the beginning were brought in from elsewhere and tell us nothing about the surrounding geology. A little farther up the trail, this changes, and the trailside rocks have an interesting story to tell, as we will see.

Except for the segments where exceptions are noted, the entire trip described is open to bicycles. You can check for changes in access rules at the OSMP Web site mentioned above. Most cyclists would want mountain bikes; the route consists of nontechnical single-track. I've ridden it on my touring bike equipped with relatively fat tires. As mentioned above, bring a bike lock, since there are two segments we will visit that are closed to bicycles.

WP02	39.93326	-105.255	13S	478181.4	4420171

WP2 — A little under half a mile from the trailhead, you'll come to a picnic area and trail junction. Continue along the Doudy Draw Trail.

WP03	39.93194	-105.256	13S	478106.3	4420025

WP3 — Two hundred yards farther along you'll reach a bridge across Community Ditch[1], dug in 1885. Before the bridge turn right on the social trail leading along the north bank of the ditch (no bikes allowed; lock them at the bridge).

As you walk west, paralleling the ditch, note that the walls of the ditch are made up of incompetent Pierre Shale. This shale is weak, and it degrades rapidly to dirt, but because the ditch is a relatively fresh excavation, the layers of shale are visible at places in the walls, and they are tilted at the same angle as the Flatirons to the west—in the vicinity of 50 degrees.

WP04	39.9319	-105.259	13S	477891.9	4420021

WP4 — Approximately 300 yards along the trail, you can see and hear a dam in the ditch. Walk over to the edge where you can inspect it (Figure DD-WP4). Here a stronger sandstone layer in the Pierre Shale resists erosion by the running water far more than does the enclosing shale, so it has formed a dam. It also clearly demonstrates the angle at which the shale is uplifted—just the same angle as the Flatirons and the Dakota ridge a little farther west—a little over 50 degrees.

This dam is formed by the Hygiene Sandstone member of the Pierre, which forms a small ridge at a number of locations to the northeast in Boulder County, particularly near the town of Hygiene, after which it is named. The origins of

[1] The ditches of the Colorado Piedmont are enormously important in the history of European settlement of the region, but they also have completely changed the geomorphology and the riparian ecosystems from what prevailed when Native Americans were the principal human inhabitants of the area. Flood plains have been transformed, and grasslands are now dotted with stock ponds.

these sandstone bodies in the Pierre are discussed in both *The Geology of Boulder County* and *The Geology of the Denver Area*.

Return to the trail by the bridge. As you walk back east, note the outcrops visible in the distance where SH 93 climbs south toward Rocky Flats. These outcrops are sandstone of the Fox Hills and Laramie Formations, dating from the final retreat of the Cretaceous Seaway.

Proceed across the bridge and up the main trail for another quarter mile, where the trail makes a sharp turn around an inholding of private property and a ranch house.

Figure DD-WP4—Dam formed in Community Ditch by the Hygiene Sandstone member of the Pierre Shale. Because the sandstone layer is more durable than the shale above and below, it resists erosion by the water, and has formed a dam.

WP05	39.92839	-105.256	13S	478106	4419630

WP5 — Go through a gate in the fence. As always in rangeland, close the gate after you pass. After another half mile you'll reach a trail junction.

Beyond this point nearly all the rocks in and around the trail are from the natural colluvium, so all the cobbles and boulders you see at the sides of the trail came from the gravel that caps the mesa, all originally part of the Rocky Flats or the Verdos Alluvium. They impart interesting information. They are mostly at least partly rounded from their journey downstream. Some are from the Fountain

Formation. There are also some that are granodiorite from the Boulder Creek Batholith and some that are gneissic or schistose metamorphic rocks. Most striking, however, is the large number of clasts of Coal Creek Quartzite, which is frequently very distinctive. Since the only bodies of potential source material are in Coal Creek {*Geology of the Denver Area,* FT7, WP3-4; *Geology of Boulder County*, FT26, WP6}, which now exits the mountains at Rocky Flats, this means that the main flow at the time of alluvial deposition must have been from the current mouth of Coal Creek, and the direction of flow beyond the mouth of the canyon was then trending north, unlike the present easterly flow. This implies that a million and a half years ago, floods carried boulders and cobbles north to this area from the mouth of Coal Creek.

Most of the clasts of Coal Creek Quartzite along the trail are a fine-textured gunmetal or blue-gray, but some are a gray to pink conglomeratic quartzite that is easily mistaken for sandstone conglomerate unless you examine it carefully with a hand lens. On close inspection, you can see that there are no individual sand-sized clasts. Everything in these cobbles and boulders is metamorphosed, recrystallized, and fused together. In some instances, large pebbles have been clearly flattened by the pressure that produced metamorphosis. These are examples of *conglomeratic quartzite.*

When we reach the gravel cap of the mesa, we'll continue to see a lot of quartzite clasts of various sizes. The quartzite in the alluvium cap is the source of the clasts we see along the trail—cobbles are eroded from the mesa top and roll down the slopes as colluvium.

WP06	39.92404	-105.259	13S	477857.9	4419148

WP6 — The junction with the Spring Brook Trail. Turn west and continue another couple of hundred yards to the next trail junction. Note that when you look up the slope, the gravel on the mesa tops is clearly marked by transition to Ponderosa pine stands.

WP07	39.92385	-105.262	13S	477586.3	4419128

WP7 — Junction of Spring Brook south and north branches. Turn right on the north branch. The trail now climbs towards the mesa top and is cut primarily into the Pierre Shale bedrock. If you examine the slope ahead of and behind you, you'll see examples of past slumps here and there on the slope. (The shelf just below the trail is an old railroad grade, not a geomorphological feature.) Examine the trail cut as you climb up this section. You'll see places where the Pierre Shale is quite visible, with small (¼- to ½-inch), platelike fragments visible in the cut. When wet, the shale turns to a slippery, gooey, sticky mass. (It has a high clay content.) Hopefully, during such times, OSMP will close the trail to minimize deterioration.

The geomorphology of the slumps is that when heavy precipitation or melting snow saturates the slope, the weight of the saturated material causes it to slide, and material moves downslope. This undercuts the material above, which can slide in its turn. Ultimately, the edge of the gravel cap is undercut, and that material rolls down the slope, forming the thin layer of colluvium at the slope surface. Evidence of many past slumps is everywhere on these slopes, which are all at the steepest angle that the bedrock will support (the *angle of repose*). They are basically falling downhill over time.

The implication of all this is that the trail cut into this slope is not very sustainable. It will suffer from slumps, and their timing will be determined by precipitation patterns. The vegetative cover on the slopes can shed moderate amounts of rain, but the only plants that can grow on the slopes have shallow root systems. They can't effectively stabilize the slope, because it is formed by weak and impermeable Pierre Shale. Under conditions when the slope becomes saturated with water it will slump, and sections of the trail will fall down the hill.

As you come up towards the top of the climb, note that you can see the gravel that caps the terrace. The ponderosa pines mark the surface just above you. The precipitation is greater here than it is farther east, because of the proximity to the mountain front, and there is enough moisture to support the Ponderosa-Douglas forest ecosystem. At the top of the mesa, the gravel is thick enough to store sufficient water above the relatively impermeable shale, and tree roots can penetrate the gravel enough to get moisture and nutrients and to anchor the tree mechanically. On the slopes below, the trees can't take root, except in isolated locations where debris has accumulated in watercourses. On extensions of the terrace where the alluvium is relatively thin, like the one we first encounter, the gravel is not thick enough to support trees, though it does support very deep-rooted grasses, like big bluestem (*Andropogon gerardii*).

WP08	39.92656	-105.265	13S	477352.2	4419430

WP8 — The top of the terrace. Note that we've now reached the 1.5-2 Ma surface that is at the same elevation (ca. 6,100 feet) as the NCAR hill, other Rocky Flats surfaces to the north, and Rocky Flats itself to the south. The most important geomorphic characteristic to notice and understand is that this surface is at a common elevation, because it represents the floodplain of the entire (South Platte) river system at the time of deposition, approximately 2 million years ago. Here, the Rocky Flats Alluvium rests directly on Cretaceous Pierre Shale. Farther south along the mountain front, as, for example, to the east of Roxborough Park, the Rocky Flats Alluvium rests atop synorogenic sediments like the Denver Formation. But in all instances, the Rocky Flats Alluvium has a uniform age.

In addition to providing a good view of the geomorphic features, this is an excellent vantage point for seeing other geologic features. Most prominently, looking northwest, you look straight up Shadow Canyon (Figure DD-WP8), which follows the trace of the Hoosier Fault.

Figure DD-WP8 – Shadow Canyon viewed from the Spring Brook Trail-North. The canyon follows the path of the NNW-trending Hoosier Fault. Like most of the major faults near Boulder, the Hoosier Fault results from the eastern block being raised over the western one, duplicating the strata at the surface. Hence, two arrays of Fountain Formation (Flatirons) are visible. The Maiden and Devil's Thumb are on the right ridge and the Matron is on the left ridge. A diagram of the fault is shown below. Remarkably, the grasses in the foreground have formed a stable ecosystem for hundreds of millennia.

To the southeast Rocky Flats is visible, at the same elevation we are standing. To the east, just past the road cut of SH 93, you can see outcrops of Fox Hills and Laramie Sandstones, remnants of the last shoreline of the receding Cretaceous Interior Seaway. To the west, the Fountain-Lyons outcrops dominate the landscape, and below them, the Dakota Sandstone is prominent, partly because a line of rock exposed by quarrying of clay makes a visible band. (We'll see this segment of the Dakota close up farther along on this trip.)

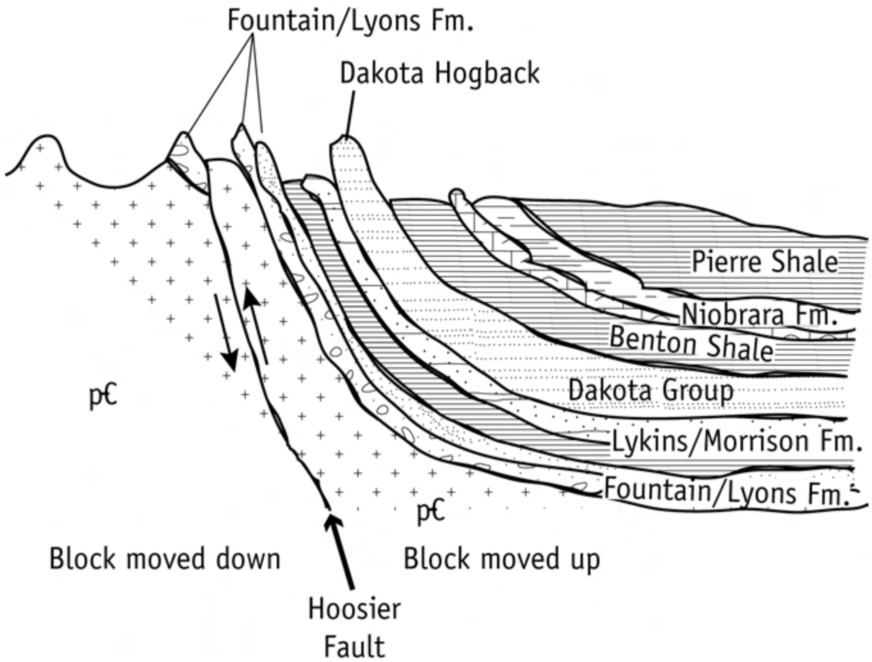

Figure DD-WP8a—Schematic Diagram of the Hoosier Fault, one of the many north-northwest trending faults near Boulder, where a reverse fault causes uplifted strata to be repeated along the mountain front. The Hoosier fault, just north of Eldorado Canyon, results in two rows of flatirons, one behind the other (see the preceding photograph). The dip angle of the fault is unknown, and the illustrated angle is chosen for artistic convenience.

Naturalists and ecologists should note the grassland community that covers the surface here. The dominant grass is big bluestem, more characteristic of wetter areas. This is a remarkably stable ecosystem, which has been shown to have successfully resisted invasive species for approximately two million years (Buckner 2010). Whether it will continue to do so is still an unanswered question, since trail construction provides a demonstrated path for invasive species, as well as disturbing the defenses of the established grassland ecosystem against invaders. One reason that the Rocky Flats surface here has been so successful in resisting invasive plants since European settlement of the region is that it is so rocky (hence "Rocky Flats") that the most ambitious settlers have been unsuccessful in trying to plow it. Hence, even though cattle have been brought in to replace buffalo, elk, and other native grazers, the imported grasses that have taken over elsewhere have so far not managed to colonize these surfaces. The plant groups that have remained so stable over millions of years are not particularly diverse, and the characteristics may be unique to this area. Whether a similar pattern applies on the Rocky Flats and Verdos terraces farther south at Arvada, Westminster, and east of Roxborough Park is a question that has not yet received sufficient research to be answered. At those locations, the pediments consist of synorogenic sediments, rather than Cretaceous bedrock, and the Alluvium is made up of different material, generally with smaller clasts, so there are many factors that might create different evolving ecosystems there.

A final note for naturalists is that the grasslands here provide important habitat for breeding birds. Wildflowers and butterflies are spectacular here in spring.

Follow the trail into the ponderosa-Douglas forest, still on the Rocky Flats Alluvium. As you walk through the trees, note that there are many large weathered boulders scattered on either side. Some are from the Fountain Formation just above, but there are also examples of Coal Creek Quartzite. The many large weathered pockets, particularly in the Fountain boulders, are indications that these rocks have been sitting in place and weathering for many tens of thousands of years.

Continue for half a mile through the ponderosa-Douglas forest, where the large weathered boulders are mainly from the Fountain Formation.

WP09	39.91977	-105.268	13S	477077.3	4418676

WP9 — West junction of the south and north branches of the Spring Brook Loop.

Climb a few yards up the embankment to the Denver Water Board access road, which services the canal carrying water from Gross Reservoir and South Boulder Creek to the Denver metropolitan water system. Turn right and go north-northwest along the road and the canal. (The road is closed and posted to the south [left]). Go past the footbridge at the south terminus of Goshawk Ridge Trail. (This trail travels through the Eldorado Mountain Habitat Conservation Area. It connects to the end of the field trip, so it can be used as a return route. Bicycles are *not* permitted on the Goshawk Ridge Trail.)

Take the opportunity to examine the exposed bank on the opposite (west) side of the Water Board Canal. The canal has been excavated in the Rocky Flats Alluvium, and the exposure here provides a rare glimpse at a cross-section of the alluvium itself. It consists of clasts ranging in size from sand to boulders four feet in diameter, or more. Most of the boulders derive from the Fountain Formation. It is clear that the gravel of the Rocky Flats Alluvium here is quite thick. Based on work that has been done at Rocky Flats itself (Knepper 2005), we can infer that before the gravel was deposited, the bedrock was sculpted by streams at the surface, so that it had channels and intervening high points, all of which were filled and covered with gravel during flood events. As a result, the thickness of the gravel may range from 20 to 50 feet, filling the relief of an earlier incised erosion surface.

Continue along the Water Board Road for another 200 yards. The road drops down to Spring Brook where the canal crosses the channel in a concrete flume to the left.

WP10	39.91987	-105.27	13S	476946.6	4418689

WP10 — The flume is above to the west (left), and a branch of the Water Board Road branches up to the left, posted against trespassing. Continue on the main road, following the right branch.

Note the large, weathered Fountain Formation boulders beside the road. Their size is suggestive of the power of the flood events that carried them here, and the extensive weathered pockets on their surfaces indicate that they have stayed in the same positions for at least 100,000 years.

Continue up and along the road a little less that half a mile to the old clay pit in the Dakota Formation on the left.

WP11	39.92472	-105.273	13S	476690.6	4419227

WP11 — The clay pit. Note that looking back (Figure DD-WP11), several layers of rock were stripped away to reach the clay layer in which the miners were interested. In looking at the upper section that was stripped away, note the alternating layers of sandstone and shale (respectively strong and weak). These connote alternating periods of deposition of sand in river deltas and foreshore environments, interspersed with muddy plumes that deposited fine-grained rock layers with far less strength and smaller clast size (sea bottom environments collecting fine silt and clay-size particles, farther from the coastline).

Figure DD-WP11—Looking back south from the first clay pit in the Dakota Group. The miners stripped the upper sandstone and shale layers above the high-quality clay they wished to extract. The tree in the center is about twelve feet high.

Continue for approximately another hundred yards to the sandstone slope that shows marked ripples.

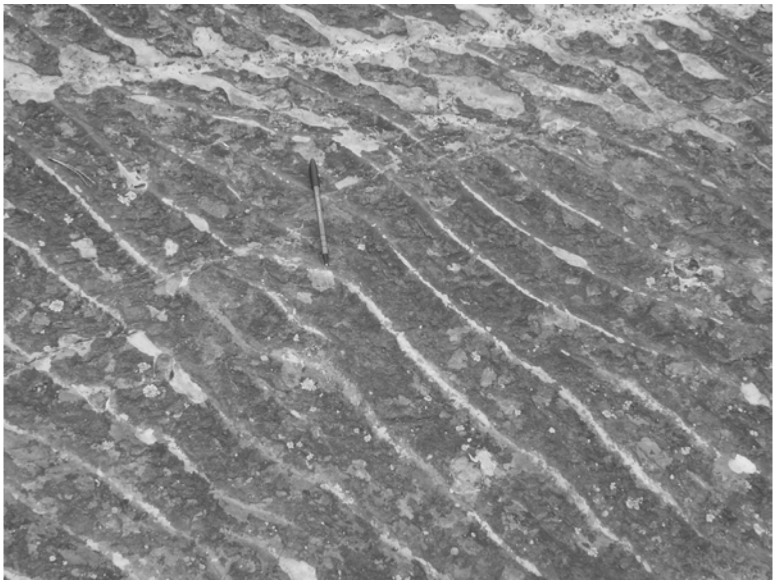

Figure DD-WP12—Ripple rock in the South Platte Formation of the Dakota Group. The ripples were exposed by miners quarrying the clay that had covered this sandstone layer. The ripples are symmetric, indicating that they were formed below waves that were bidirectional, perhaps in shallow water below a surface subject to wind that caused surface waves. A current in one direction would have produced ripple marks that are steeper on the downwind/downcurrent/downstream side.

WP12	39.92559	-105.273	13S	476672.9	4419324

WP12 — Some of the best examples of 'ripple rock' are exposed on the left, where the clay that once filled in and preserved the ripples has been stripped away for use in brick making. Note that the ripples are symmetrical—of equal reach and angle on each side, so they were not formed in a current like a stream or an offshore current, which produce asymmetrical ripple shapes—steeper on one side. The ripples here could have been formed in shallow tidal flats or in a shallow area behind a front line of dunes. In these environments the wind blowing over the water generates small waves on the surface and ripple marks are mirrored on the bottom, like those in relatively shallow water offshore in the Bahamas today, where such ripple-marked sandy bottoms extend for many miles.

Good examples of the ripple marks continue along the outcrop for another couple of hundred yards.

WP13	39.92872	-105.273	13S	476650.3	4419672

WP13 — Approximately ¼ mile from the beginning of the ripple rock, the road drops down into the Spring Brook drainage.

Above and to your left, the Denver Water Board canal is carried over the drainage in a concrete flume. The creek passes below. Wildlife also passes below the flume, though some animals also cross the channel of the ditch, either by walking or swimming, depending on the water flow in the canal. Both behaviors have been observed, but no detailed study has been done of wildlife crossing patterns.

Continue on the main road and follow the signs for the Fowler Trail. Don't take the left branch, posted against trespassing by Denver Water, nor the road down to the right.

Before reaching the old railroad grade cut through the Dakota Hogback, you'll encounter signs prohibiting bicycles. Cyclists need to lock their bikes here.

WP14	39.93097	-105.274	13S	476576.4	4419922

WP14 — Start of the cut through the Dakota Hogback along the old railroad grade. The cut was originally excavated and blasted by the Denver Utah & Pacific Railroad, one of David Moffat's attempts to build a railroad line to the west. Tracks were never laid on this route (Hilton 1990, 357-59), but the grade provides a very important geological cross-section of the Dakota, and the old railroad grade continues up the south side of Eldorado Canyon.

Just before entering the railroad cut, take a look at the view up Shadow Canyon (Figure DD-WP8), which traces the path of the Hoosier Fault. The rows of Flatirons (Fountain Formation) on either side of the fault are clear. These have been separated by the fault, and they are now separated by Precambrian granite in the saddle at the top of the canyon (see Figure DD-WP8a for a diagram of the fault). The Hoosier Fault is a prime example of the family of faults near Boulder that trend north-northwest from the mountain front, most of which are characterized by east blocks uplifting over the west, unlike the dominant pattern in the Denver region of western blocks thrusting over the east, like the Golden Fault, or the Boulder Fault, just to the north.

Traveling from the south, the first of the north-northwest trending faults one encounters is the Livingston Fault in the vicinity of Coal Creek Canyon, and there are a half-dozen others around Boulder, with the last one beginning near Lee Hill Road. These north-northwest trending faults are discussed in Chapter 10 of *The Geology of Boulder County*, and in a regional context in Chapter 11 of *The Geology of the Denver Area*.

The road cut itself (Figure DD-WP14) curves through the Dakota ridge, so interpreting the strata is a bit tricky for those who want to pick out particular layers. A further complication is that the members of the Dakota vary widely along the mountain front, as one would expect for an ancient coastline interrupted by many river deltas. (The Dakota east of Morrison is very different from this location. [See *Geology of the Denver Area*, FT7, WP41-42]) In general, this cross-section exposes a number of durable sandstone layers that were deposited as river deltas, beaches, and foreshore deposits. These are interspersed with shale deposited as mud that was carried out from rivers in plumes. Darker shale layers are carboniferous, resulting from organic material in the mud that was buried in low-oxygen environments, so that some of the carbon is preserved. There are some layers of shale and sandstone visible in the road cut that have the remnants of burrows from marine invertebrates that lived in the mud and sand of the shallow foreshore zone; these strata are generically referred to as showing *bioturbation*.

The specific members of the Dakota Group exposed at this location are the lower ones, generally corresponding in age to the strata exposed at the Alameda road cut at Dinosaur Ridge {*Geology of the Denver Area,* FT18}. You have already passed the ripple rock layer that has been exposed by clay quarrying. This is the same layer exposed on the east side of Dinosaur Ridge, near the dinosaur tracks.

The railroad cut here travels through the Dakota stratigraphically below the ripple rock and the dinosaur tracks at Dinosaur Ridge. It ends in the Lytle Formation, as you will see.

Figure DD-WP14 – The road cut through the lower Dakota Group following the old railroad grade on the side of the canyon wall above Eldorado Springs. The strata dip to the east, but the road cut angles through the strata heading first northwest and then trending southwest, so that the angles of the sandstone and shale layers are intercepted at different angles as you go through.

The sandstone layers at the beginning of the cut are mainly parts of the (informally named) Bear Creek and Eldorado members of the Dakota Group (MacKenzie 1971), local deltas and channel fills that have been documented mainly here and at Bear Creek Canyon, 3 miles to the north.

WP15	39.93091	-105.274	13S	476552.6	4419915

WP15 — The first major layer of shale, which is mostly dark gray. Just below it are a couple of sandstone strata that show significant bioturbation. These layers are probably in the Plainview Sandstone, which includes both shale and quartz sandstone strata in the Boulder area. Farther north, the Plainview Sandstone is a

very durable quartz-rich sandstone that forms a distinctive ridge in the Dakota Hogback, along with the Lytle Formation.

WP16	39.93035	-105.274	13S	476558.4	4419852

WP16 — Start of the thickest shale layer in the Plainview. At the base of the shale, the light-colored sandstone of the Lytle Formation begins.

WP17	39.93052	-105.275	13S	476508.1	4419872

WP17 — Cross-bedding is visible in the light-colored Lytle Formation.

WP18	39.93029	-105.275	13S	476501	4419846

WP18 — A layer of pebbles can be seen in the Lytle Formation. As you continue, examples of the pebble layers can be seen in a number of outcrops (Figure DD-WP18).

Figure DD-WP18 – Pebble layer in the Lytle Formation along the old railroad grade. The pebbles are chert and have been determined to have been transported from what is now Utah, by rivers meandering on a vast alluvial plain.

This pebble layer can be found in many outcrops of the Lytle along the mountain front, but not in all, a pattern one would expect in alluvial deposits, since rivers deposit heavier clasts below point bars and other places where the current slows.

The pebble layers are discussed in Chapter 9 in both *The Geology of Boulder County* and *The Geology of the Denver Area*.

WP19	39.92974	-105.275	13S	476504.6	4419785

WP19 — The varicolored mudstones of the Jurassic Morrison Formation can be seen in the slope. The characteristic gray-green and maroon layers, visible in many locations throughout the western U.S., result from oxidation of volcanic ash that was blown from volcanoes to the northwest during the Jurassic. The Morrison was formed mainly by large, meandering rivers draining from the west, similar to the Early Cretaceous Lytle Formation just above it.

Below you as you continue along the roadbed is the old resort of Eldorado Springs, now the center of Eldorado Springs State Park, a world-famous climbing mecca. To the southwest you can see (and sometimes hear) the railroad (now an Amtrak route) that climbs up South Boulder Creek and travels under the Continental Divide through the Moffat Tunnel to Winter Park. Also in the same direction is the partly reclaimed excavation of the Conda Mine, where aggregate was briefly mined for construction projects, until the operation was stopped through the efforts of outraged citizens (People for Eldorado Mountain). High above is the aptly named Mickey Mouse Spire, a famous climbing location. (From many vantage points, the “ears” of Mickey Mouse are prominent.)

WP20	39.92598	-105.276	13S	476399.1	4419368

WP20 — Continue another 600 yards along the road to a large red outcrop above the road to the left. This is the mudstone/fine sandstone of the Permian-Triassic Lykins Formation Its deep, brick-red color is distinctive.

Return – You can return along the original route. For a little variety, take a right at the trail junction at WP9, and follow the south branch of the Spring Brook Loop, which will take you back to the parking lot.

The most interesting and scenic route, which adds a mile and a few hundred feet of climbing (no bicycles permitted) is to continue along your current route, past a right-hand branch on the Fowler Trail, to the Goshawk Ridge Trail, which travels through the Eldorado Mountain Habitat Conservation Area to cross the Denver Water canal just above WP9 and the Spring Brook Loop.

Finally, if you want the most direct route back, follow the road bed back through the Dakota cut, continue to WP13, and take the road down the hill. This reaches a gate on County Road 67, which intersects Eldorado Springs Drive ¾ miles west of the parking lot.

Waypoint	Latitude	Longitude	UTM Zone	UTM Easting	UTM Northing
WP01	39.93822	-105.256	13S	478153.2	4420722
WP02	39.93326	-105.255	13S	478181.4	4420171
WP03	39.93194	-105.256	13S	478106.3	4420025
WP04	39.9319	-105.259	13S	477891.9	4420021
WP05	39.92839	-105.256	13S	478106	4419630
WP06	39.92404	-105.259	13S	477857.9	4419148

WP07	39.92385	-105.262	13S	477586.3	4419128
WP08	39.92656	-105.265	13S	477352.2	4419430
WP09	39.91977	-105.268	13S	477077.3	4418676
WP10	39.91987	-105.27	13S	476946.6	4418689
WP11	39.92472	-105.273	13S	476690.6	4419227
WP12	39.92559	-105.273	13S	476672.9	4419324
WP13	39.92872	-105.273	13S	476650.3	4419672
WP14	39.93097	-105.274	13S	476576.4	4419922
WP15	39.93091	-105.274	13S	476552.6	4419915
WP16	39.93035	-105.274	13S	476558.4	4419852
WP17	39.93052	-105.275	13S	476508.1	4419872
WP18	39.93029	-105.275	13S	476501	4419846
WP19	39.92974	-105.275	13S	476504.6	4419785
WP20	39.92598	-105.276	13S	476399.1	4419368

Reference

Buckner, David L., 2010, *Variation in Plant Community, Species Richness and Invasibility in a 2-Million Year Chronosequence along the East Slope of the Front Range of Colorado,* in press.