GEOLOGY OF MARSHALL MESA OPEN SPACE
BOULDER, COLORADO

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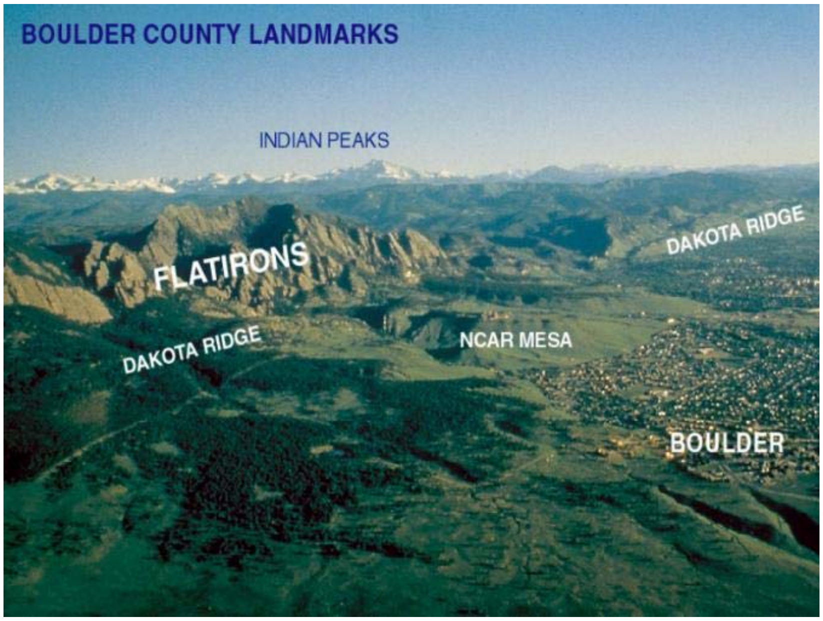


Figure 1. Location of prominent landmarks seen from Marshall Mesa looking west.

Geologic History

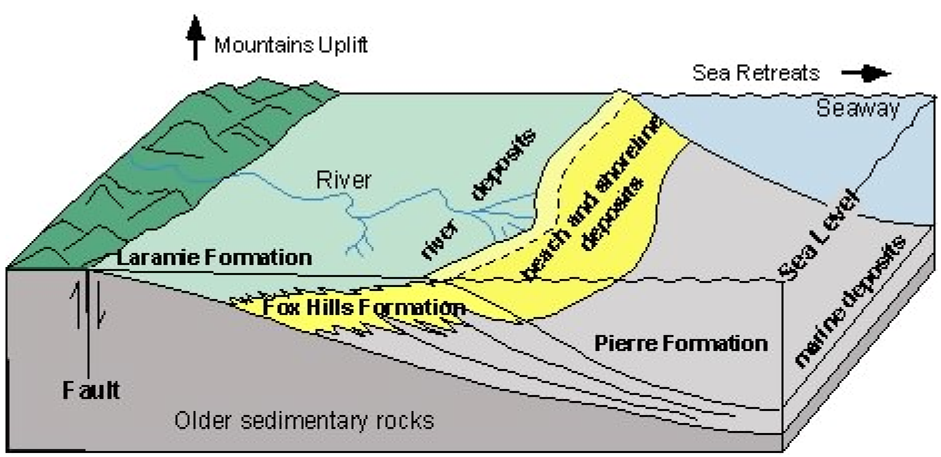
As you look west, you see the high peaks (Indian Peaks) of the Rocky Mountains and the tilted edges of the Flatirons and Dakota Ridge. Prominent flat-topped surfaces (such as NCAR Mesa and Rocky Flats to the south) are found to the east.

Let's journey back in time, and see how the landscape of Boulder Valley and the Front Range of Colorado has changed and how these changing landscapes shaped the history of Marshall Mesa.

About 300 million years ago (mya) an earlier mountain range, called the Ancestral Rocky Mountains, was uplifted. Sediments eroded from the Ancestral Rockies were deposited by rivers flowing from the mountains. The Flatirons are formed from these ancient deposits. Over a period of nearly 200 million years, the Ancestral Rocky Mountains were worn down, eroded away, and eventually buried under sediments deposited along rivers and in lakes. At this time, Boulder (now over 5000 feet elevation) was near sea level. Between about 100 – 64 mya, ocean water from the Gulf of Mexico flooded this area, eventually covered Colorado, and deposited thousands of feet of mud and sand.

Figure 2. Western Interior Seaway flooded Colorado during the Upper Cretaceous.

Then, beginning around 70 mya, the present (Laramide) Rocky Mountains were uplifted and the sea retreated. As the mountains rose, all the previously deposited sedimentary rocks were tilted up against the rising mountains (creating the Flatirons and the tilted rocks at Marshall Mesa – view geologic cross-section at http://bcn.boulder.co.us/basin/watershed/geology/crosssec.html). See http://ci.boulder.co.us/files/openspace/pdf_education/Boulder_Sediments.pdf for a detailed geologic/stratigraphic column for the rocks of Boulder Valley and Marshall Mesa.



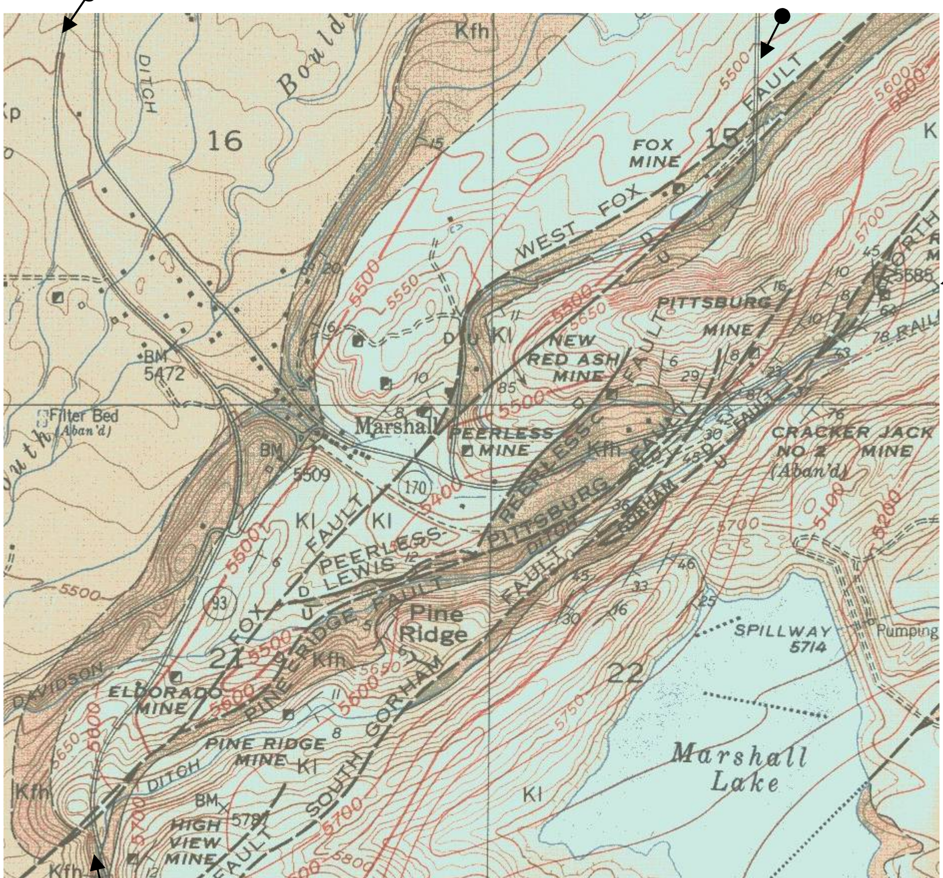
Graphic courtesy of Dr. Robert J. Weimer

Figure 3. Depositional relationship of Upper Cretaceous formations.

The rocks at Marshall Mesa record the beginning of uplift of the Laramide (present) Rocky Mountains. As sediment was eroded from the rising mountains, rivers carried the sediment to the inland sea. Through time, a growing wedge of sediments built outward from the mountain front causing the ocean to retreat eastward. Through time, the Fox Hills Formation migrates eastward over the Pierre and the Laramide Formation migrates eastward over the Fox Hills (where they appear oldest to youngest in the stratigraphic column http://ci.boulder.co.us/files/openspace/pdf_education/Boulder_Sediments.pdf .

In the diagram above, the (gray) Pierre Formation represents the offshore, deeper water mud and sand. Today, approximately 7000 feet of Pierre shale is found west of the Marshall Mesa Trailhead. Pierre Formation underlies the "mesas" such as NCAR Mesa and Rocky Flats. The Fox Hills Formation consists of fine to medium-grained light-colored sandstone representing near-shore and beach deposits (yellow in diagram above). The Laramie Formation is composed of sandstone, shale, and coal beds (light green in diagram). The Laramie is complex and represents a variety of coastal swamps and estuaries near sea level. Coal that formed in these coastal swamps was mined at Marshall Mesa and coal fields to the east. The climate during Laramie deposition was very different from the dry one we find in Colorado today. Plant fossils indicate that this part of Colorado was subtropical with plenty of rainfall. To see what Laramie plants looked like go to http://www.dmns.org/main/minisites/ancientDenvers/cden.html.

The Marshall Mesa area is cut by numerous faults (breaks along which movement occurred) that run in a NE-SW direction. These faults divide Marshall Mesa into a series of uplifted (horsts) and down-dropped blocks (grabens). The faults may have been active during the Laramide mountain building since some of the coal seams are thicker in the grabens (Weimer, 1996).



Geology of Marshall Mesa from Louisville Quadrangle
US Geological Survey Map GQ-151

Figure 4. Geologic Map of Marshall Mesa Open Space.

Before the uplift of the Laramide Rocky Mountain, about 10,000 feet of sedimentary rock had been deposited over the Ancestral Rocky Mountains. As the present Laramide Rocky Mountains were uplifted, these softer sedimentary rocks were rapidly eroded away, leaving harder granite and metamorphic rock forming the "core" of the mountain range and the highest peaks. By about 45-50 mya, erosion had reduced the mountains and rivers carried sediments, worn from the mountains, eastward across the Great Plains spreading over eastern Colorado into Nebraska and Kansas, forming extensive gravel deposits. In the last 5-10 million years, deep steep-walled canyons have been cut into the Front Range. Most recently, near the mountain front, rivers have been eroding these younger deposits. South of Boulder, there is a high, broad, gently-sloping surface called the Rocky Flats Surface. About 1-2 mya, Coal Creek (as it emerged from Coal Canyon) meandered across this surface. In the process, it eroded older Pierre shale and spread coarse gravel over the Rocky Flats surface (terrace). Many of the large boulders and cobbles on Rocky Flats and Marshall Mesa are composed of a blue-gray quartzite and metaconglomerate derived from Coal Creek Canyon (quartzite and metaconglomerate are rocks made of quartz sand and pebbles that were buried to considerable depth where they were subjected to high temperature and pressure). A series of lower surfaces (terraces) are found along South Boulder Creek and its tributaries. These stair-stepped terrace sequences may reflect climate changes during glacial and interglacial periods during the last few hundred thousand years.

Note: GPS tour datum is all WGS84.
N 39° 57.158′,
W 105° 13.881′
Marshall Mesa Open Space Trailhead :
Marshall Mesa is one of the parks in the City of Boulder Open Space and Mountain Parks system. Please remember that collecting plants, animals, or rocks is prohibited. To protect these fragile resources, please stay on the trails.

On this hike we will travel back in time, peeking beneath the now tranquil, grassy hillside to explore Marshall Mesa's coal mining and geologic history. We will be walking over the Upper Cretaceous (about 68-70 million years old) Fox Hills and Laramie Formations.

Marshall Mesa is situated at the western end of the Boulder-Weld coalfield. Coal mining began at Marshall in 1863. This is one of the oldest coal mining areas in the Western United States. Coal was mined from the lower part of the Laramie Formation where coal seams were 5-8 feet thick and only 30-40 feet below the ground surface. Early mines were dug into seams exposed at the surface. Later, tunnels were dug underground. The coal was not of particularly high grade. However, it was in demand since it was close to the growing cities of the Front Range. To read about the mining history read Joanna Sampson's "Walking Through History on Marshall Mesa" at http://www.colorado.edu/physics/phys3070/phys3070_sp07/Reading/history_marshall_mesa.pdf .

As you walk the trails, you may find specific identification of the Fox Hills and Laramie sandstones difficult to distinguish. Generally, the sandstones that are well-exposed at the surface are Laramie sandstones. The Fox Hills sandstones are less resistant and form slopes covered with vegetation. Two exceptions are excellent exposures of Fox Hills sandstone at the base of the "knob" on Pine Ridge and along Community Ditch at Highway 93. Making identification more complex, extensive faulting has disrupted the original depositional relationships moving one formation higher or lower, as we will see at the stops below.

DIRECTIONS TO STOPS AND LOCATIONS OF INTEREST ARE GIVEN IN ITALICS. . This field guide follows the Marshall Valley Trail east (to the left), then takes the Marshall Mesa Trail southwest up Pine Ridge connecting to the west end of Community Ditch Trail and returns via the lower part of the Coal Seam Trail (Loop "A"). These trails form a loop approximately 2 miles long. An additional loop about a mile long branches from the Community Ditch Trail to the Greenbelt Plateau Trail to add a second loop ("B") of about a mile. A trail map can be obtained at:
http://www.bouldercolorado.gov/index.php?option=com_content&task=view&id=3073&Itemid=1922

From the Trailhead, walk down the trail to the light-colored rock outcrop paving the trail.

N 39° 57.132′
W 105° 13.862′
Stop 1. Laramie Formation sandstone: Here is a good exposure of the Laramie sandstone. Run your fingers over the rock at your feet. If you have a hand lens, look closely and you will see that the rock is composed of grains of quartz sand cemented together. The Laramie sandstone and beds of shale and coal were deposited in swamps and along rivers flowing across a coastal plain near the ocean. Within the sandstone (here and at other exposures along the Marshall Valley Trail) you can find dark brown, iron-stained concretions. These are very hard, rounded or irregular in shape, and very resistant to weathering and erosion. The concretions were formed after the sandstone was deposited as groundwater, containing the iron, moved through the sandstone. The iron was then deposited and concentrated in the concretions and along fractures in the rock.

Figure 5. Ironstone concretion (right of center).

N 39° 57.116′
W 105° 13.869′
Signpost and trail junction: Follow the trail to the signpost where the Marshall Valley Trail meets the Coal Seam Trail. Follow the **Marshall Valley Trail** to the left (east). Walk to the first 'trench" (long depression) crossing the trail.

N 39° 57.090′
W 105° 13.845′
Stop 2. Coal Mining and collapse features: Notice the long trench-like depressions that cross this area. Most of these "trenches" and depressions throughout Marshall Mesa

Open Space are the result of subsidence into the maze of coal-mine tunnels and passages. Although 51 mines are officially recorded in the Colorado coal mining records, there were probably more mines and tunnels here since declared mines were taxed. Coal was mined underground forming a "room", leaving a "pillar" to support the roof. The tunnels and "rooms" were not far beneath the ground surface (some less than 50 feet). The rock forming the roof of the tunnel has collapsed into the area mined, creating the depression or "trench" seen at the surface.

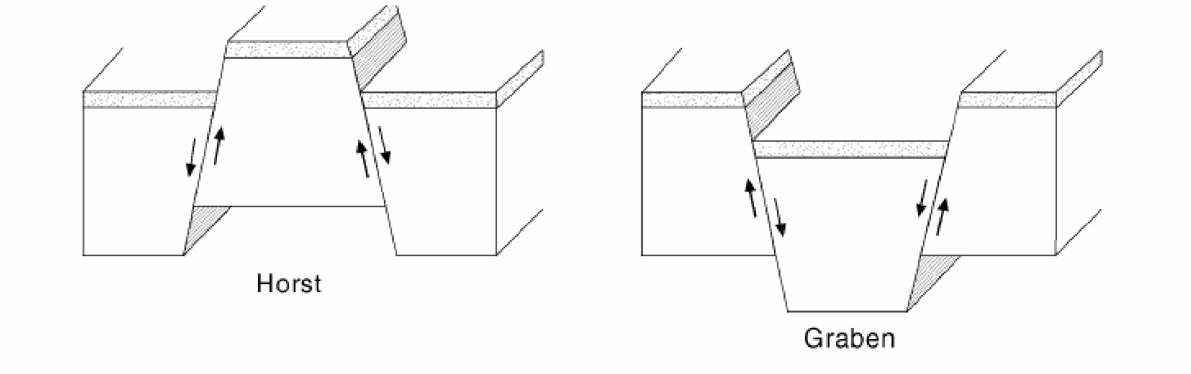
Continue along the trail to a place where you can get a clear view of the western portion (end) of Pine Ridge, the hill on your right. This can clearly be seen from several places along the trail

Stop 3. Along the trail, view of Fox Hills/Laramie interface on "knob" face of Pine Ridge:

View the "knob" to the southwest of the trail. Notice the differences in the colors of the rocks making up the "knob" (Figure 6). Here you see the contact between the lighter Fox Hills Formation below and the browner Laramie Formation above. Since the Fox Hills Formation lies stratigraphically (in order of deposition) below the Laramie Formation, and you have been walking across Laramie Formation on the trail from the trailhead, the Fox Hills must have been uplifted along a fault (see Figures 4 and 5).

Figure 6. Light Fox Hills Formation below and Laramie Formation above.

Where a block has been uplifted, it is called a horst; a down-dropped block is called a graben (Figure 7). Pine Ridge is a horst uplifted along the Pine Ridge Fault that runs parallel to and along the north side the ridge, between the ridge and Marshall Valley Trail. Additional faults cut Pine Ridge into narrow horsts and grabens (South and North Gorham, High View Fault).



(from Colorado Geological Survey, 2000)

Figure 7. Examples of faulting at Marshall Mesa.

N 39° 57.090′
W 105° 13.689′

Stop 4. Sandstone along Marshall Valley Trail: Where the trail crosses the light-colored sandstone, look closely and see if you can find the elongate curved tubes or burrows (Figure 3). These are trace fossils that record the activity of an organism as it moved through the sand. It is not certain what kind of animal left these burrows. Generally burrows like these indicate a marine or brackish water environment.

Figure 8. Trace fossils – burrows by a marine or brackish water organism.

The sandstone, here and farther along the trail, exhibits an interesting polygonal (many-sided) weathering pattern. Where the rock has been cut by fractures, weathering is deeper creating rounding of the blocks.

Figure 9. Polygonal weathering in sandstone.

Notice the ironstone concretions weathering out of the sandstone (as seen at Stop 1). In places, the iron in concretions and thicker deposits was deemed ore quality. In 1864, a foundry and blast furnace was built by Joseph Marshall on South Boulder Creek. It operated for two years before it was shut down.

Continue along the trail toward the Davidson Ditch Bridge. Stop at the fenced "sinkhole".

N 39° 57.207′
W 105° 13.218′
Stop 5. "Sinkhole": This "sinkhole" is probably a collapse into an old mine tunnel or "room" beneath us. Several coal seams were mined north of Pine Ridge. Imagine what it was like to work underground in these mines.

Continue east to the Davidson Ditch Bridge.

N 39° 57.258′
W 105° 13.061′
Stop 6. Views from the Bridge over Davidson Ditch: Look north (toward Marshall Road and the electrical control boxes) for the elevated, flat surface running east-west. This is the old railroad bed of the Colorado and Southern (C&S) Railroad. With the development of coal mining, railroad connections to the coal mines were essential. The first railroad into Marshall was the Golden, Boulder, and Caribou Railway built in 1878. In 1890, the Colorado and Southern built a railroad through Marshall that ran from Denver to Boulder. In 1932, the Marshall Branch was abandoned from the Crown Mine east of Marshall to Canyon Street in Boulder and the tracks were removed.

Good exposures of the Laramie Formation are found on the south side of Davidson Ditch. Note the alternating sandstones and shale beds dipping (tilted) to the southeast. The dip of these beds is at right angles to the bridge. The upper edge of the sandstone runs east-west. Geologists describe this as the strike of the bed. Regionally, rock units along the Front Range, like the Flatirons, dip steeply eastward and strike north-south, parallel to the mountains. The difference in dip and strike here is the result of localized folding of these rocks between faults.

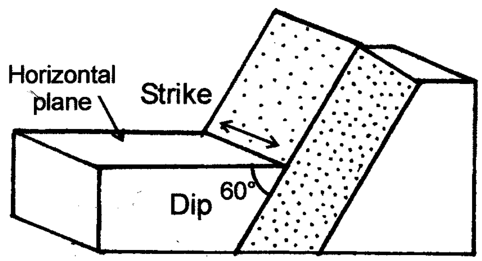


Figure 10. Diagram illustrating strike and dip.

After you cross the bridge, walk east (to your left) a short distance along the trail. Notice how the sandstone ends abruptly. It has been cut off by the Gorham Fault.

Continue up the stairs and along the trail to an excellent exposure of the Laramie Formation sandstone (to the south (uphill side) and across the trail.

N 39° 57.105′
W 102° 13.228′
Stop 7. Laramie Formation sandstone: At the "Geology of a Coal Field" sign is an exposure of Laramie sandstone (Figure 8). Rain and snow-melt run down the face of the sandstone deeply eroding the lower surface since it is not as well-cemented as the upper part. Unfortunately, this makes it easier for people to leave graffiti carved into the surface.


Figure 11. Laramie Formation sandstone.

Along the trail past the sign look for a large quartzite (metamorphosed sandstone) boulder, more than 3 feet long and two feet across. This boulder is sitting on the Laramie sandstone and did not form here. It has been moved from uphill to this location. Where it came from will be discussed at Stop 12.

Continue along the Marshall Mesa Trail to the "Underground Fires" Sign.

N 39° 57.027′
W 102° 13.413 ′
Stop 8. "Underground Fires" sign: Coal mine fires can start by natural or human actions and may burn for many years. As the fire consumes coal seams underground, areas above may subside or collapse. This is a problem throughout the Boulder-Weld coal field and has affected land-use planning and development in Boulder, Lafayette and Louisville.

Continue along the Marshall Valley Trail to the intersection with the Community Ditch Trail. Continue west on the Community Ditch Trail.

A sliver of Fox Hills Formation (not visible under the hill slope vegetation) is uplifted along the South Gorham Fault where the Marshall Mesa Trail branches from the Community Ditch Trail.

The Bridge across Community Ditch - N 39° 56.884′, W 105° 13.798′ leads uphill to the Greenbelt Plateau Trail. This will take you around a second trail loop ("B") for excellent views of Boulder Valley and the mountains to the west.

N 39° 56.891′
W 105° 13.810′
Just past the bridge across Community Ditch to the north and down the slope are several "benches" of Laramie sandstone. This was the location of a large coal mine. Look back from the Trailhead for a better view.

Hiking west along Community Ditch, look at the alternating sandstone and finer shale beds exposed across the ditch. In places, there are excellent examples of ripple marks in the sandstone. More ripple marks can be seen on an elongate slab of sandstone at:
N 39° 56.934′
W 102° 13.707′

Continue west along the Community Ditch Trail.

N 39° 56.769′
W 105° 14.177′
Signpost for **Community Ditch Trail and Coal Seam Trail .**

Walk toward Highway 93 to observe the sandstone forming the banks of Community Ditch. This is Fox Hills sandstone. It is fine-grained, cream-colored with iron staining. Across the ditch and uphill are the remains of the High View Mine.

*At this point, you can take the lower part of the Coal Seam Trail (north) to return to the Trailhead (Loop "A") or connect with the upper part of the Coal Seam Trail that parallels Highway 93 to cross the ditch and then goes uphill and east to connect with the Greenbelt Plateau Trail. A short connecting trail takes you back to the bridge and the Community Ditch Trail (*N 39° 56.884′, W 105° 13.798′) *you already hiked.*

COAL SEAM TRAIL (to return to Trailhead)
As you walk down the trail, you will get views of the remains of the El Dorado Mine between the trail and Highway 93.

Continue north along Coal Seam Trail until you come to a hole with a small tree growing out of it.

N 39° 56.918′
W 105° 14.016′
Stop 9. "Sinkhole" (west of the trail): Here is another example of collapse into underground tunnels or rooms.

Continue on the Coal Seam Trail to the bridge across Davidson Ditch.

N 39° 57.023′
W 105° 13.945′
Stop 10. Bridge across Davidson Ditch: From the west side of the bridge, if the channel of Davidson Ditch is dry, look for excellent examples of potholes (formed by small rocks grinding into the sandstone as water flowed over it) and scour marks in the polished sandstone. Stems of fossil plants can be found in the large boulders (used to keep the bank from eroding) on the south side of the bridge.

Walk across the bridge north to the fence. Look across Davidson Ditch to get a clear view of the stratification in the wall of the ditch.

A dark seam of coal is visible about two-thirds of the way down to the bottom on the ditch on the south side. Sandstone forms the bottom of the channel.

Figure 12. Coal seam exposed in wall of Davidson Ditch.

LOOP "B" UPPER COMMUNITY DITCH TRAIL TO GREENBELT PLATEAU TRAIL

From the junction of the Community Ditch Trail and Coal Seam Trail, walk toward Highway 93, through the gate, and close to the edge of the Highway to access the upper part of the Coal Seam Trail (that runs east and up the hill).

N 39° 56.705′
W 105° 14.157′
Stop 11. Seasonal closure sign: You are walking along an exposure of (?) Fox Hills sandstone that has numerous fractures highlighted by the more resistant iron oxide in the cracks. This sandstone is between the Fox Hills Fault and the High View Fault, and has been broken by movement along these faults.

Figure 13. Iron oxide filling fractures in sandstone.

Good views of the Rosser Mine location and dump uphill and south of the trail.

As you walk uphill, look north across Marshall Road and the intersection with Cherryvale Road. Northeast of this intersection, note the linear (straight) features on slope. These are excellent examples of room and pillar construction of underground mines where the roof collapsed into the “rooms” below leaving the long depressions. Collapse has also resulted from underground coal fires burning here.

Walk past the sign for Community Ditch and Greenbelt Plateau Trail to the top of the hill.

N 39° 56.701′
W 105° 13.819′
Stop 12. Rocky Flats Surface. You are now on the Rocky Flats alluvial surface, a prominent upland surface. This gently sloping surface extends from the mountain front to the south and east. The flat mesas to the northwest, including NCAR Mesa, were once continuous with this surface. Look for rounded and polished boulders and cobbles by the trail. Most of these are metamorphic quartzite (often blue-gray) and metaconglomerates (with pebbles of quartz) that were carried here by floods from Coal Creek 1-2 million years ago. Over time, as Marshall Mesa was eroded, these boulders were left scattered across the area. Some boulders are huge, more than 3 feet across, like the one seen at Stop 7.

Figure 14. Metaconglomerate: blue-gray quartzite surrounding quartz pebbles.

N 39° 56.736′
W 105° 13.857′
Sign for Community Ditch and Greenbelt Plateau Trail: Look at the boulders scattered down the slope below the sign.

From here there are excellent views of the Front Range, Longs Peak, the Flatirons, the “mesas” and Boulder Valley as illustrated in Figure 1.

Follow the trail back to Community Ditch and return to the trailhead via the (lower) Coal Seam trail.

References:

Bridge, Raymond, 2004, The Geology of Boulder County, Lone Eagle Publications, Boulder, Colorado, 468 p.

Spencer, Frank D., 1961, Bedrock Geology of the Louisville Quadrangle, Colorado; USGS Geologic Quadrangle Map CQ-151.

Weimer, Robert J. 1996, Guide to the Petroleum Geology and Laramide Orogeny, Denver Basin and Front Range, Colorado; Colorado Geological Survey, Denver, CO, 127 p.