COLORADO FRONT RANGE SELF-GUIDED GEOLOGY FIELD TRIPS

By Uwe Richard Kackstaetter, Ph.D.

This little field guide was born out of necessity to accommodate many of my geology students in their desire to see and experience the Front Range geology without the time constraints and conflicts of scheduled field trips. Over time it has grown into the present volume, including many favorite geologic sites and places. While there might be more spectacular examples to visit, the indicated localities in this guide were more or less selected for easy accessibility. I hope that those interested in the geology of the Colorado Front Range will find this guide helpful. Indeed, Colorado is a spectacular place to see and investigate geology and geologic features, almost like living inside a geology textbook. Experiencing geology first hand is much more exciting then reading about it, or as one of my dear geologist colleagues has expressed it: "A bad day in the field is hundred times better than a good day in the office!"

This field guide also includes probing geologic field study questions, which might be used in conjunction with assignments or simply for the perusal of ones own interests. Many of the questions are based on skills of "observation", a quality that should be developed. Learning how to read the blaring obvious and the subtle hints in the rock record compares to crime scene investigation. And solving geologic puzzles can be as exciting as a good murder mystery.

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How to use this field guide:

The guide is subdivided into time segments equivalent to day trips. Localities to be visited are indicated in RED on the maps. Each place to be visited has specific geologic questions assigned or activities to be completed. Collecting samples is possible in many areas, but is prohibited in State and National Parks and Monuments.

You may want to bring a camera for taking pictures of geologic features. Features that might be photographed in order to answer questions or to reinvestigate when back home are indicated by (D) symbol in the text.

A rock hammer, hand lens, and Ziplock® sample bags might also be advantageous. It goes without saying that a raincoat, a hat, sun screen, appropriate clothing and hiking shoes, water and a sack lunch should be a part of your field trip gear.

For those interested in further and other area field-trips, the following resources might be helpful:

Roadside Geology of Colorado by Halka Chronic & Felicie Williams, Mountain Press Publishing Company, Inc.; October 2002, ISBN-13: 9780878424474.

Hiking Colorado's Geology by Ralph Lee Hopkins, The Mountaineers Books, 2000, ISBN-13: 9780898867084.

Roadside Faults, Folds, Fossils, Crystals and Diamond Pipes - Sampling the Geologic Diversity of Northern Colorado by Barbara EchoHawk and Uwe Kackstaetter, 2016, in Keller, S.M., and Morgan, M.L., eds., Unfolding the Geology of the West: Geological Society of America Field Guide 44, p. 247–266, doi:10.1130/2016.0044(11). The Geological Society of America.

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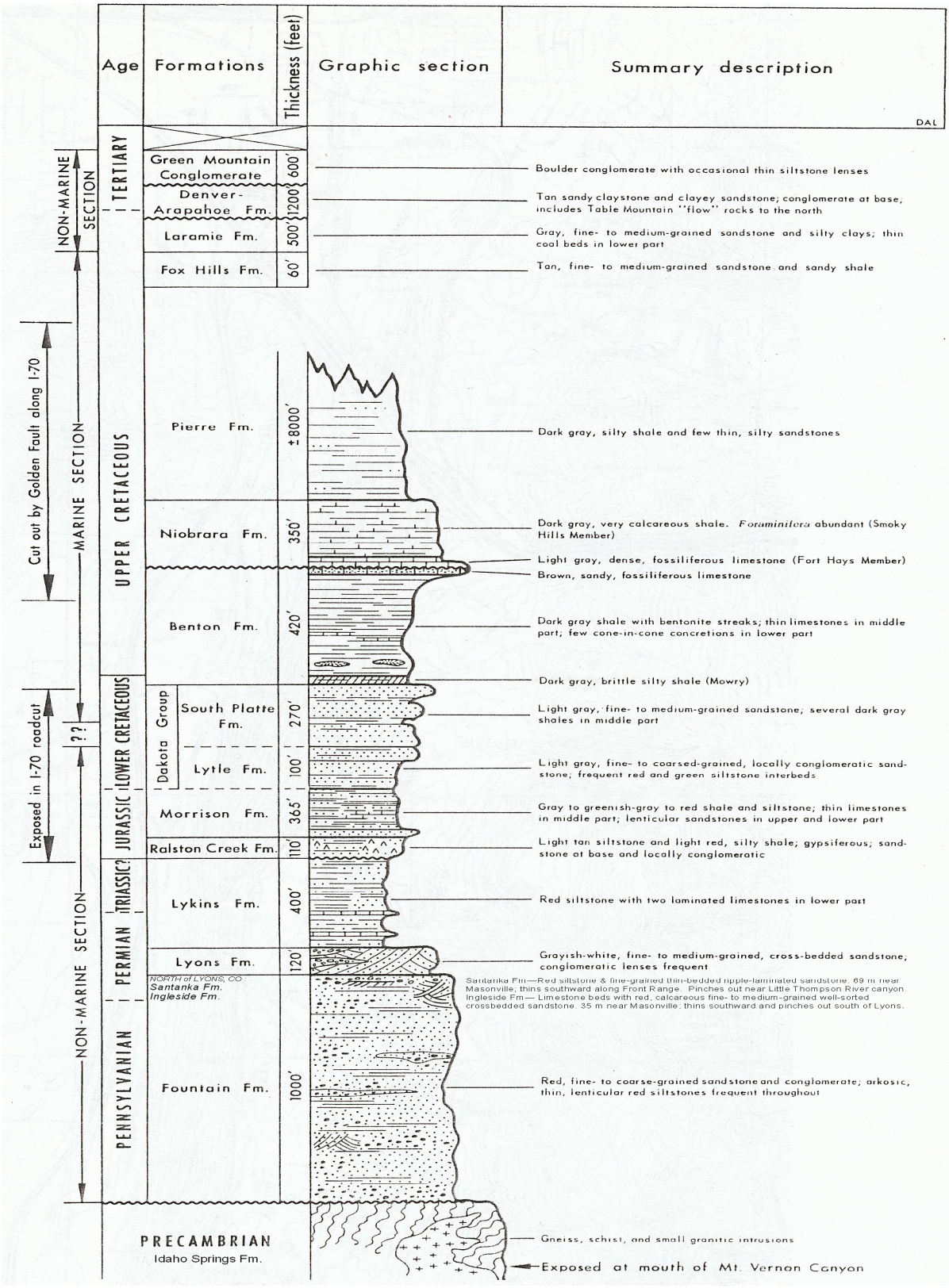
Stratigraphy & Geologic Formation Overview of the Northern Front Range



DAY 1 - Red Rocks, Dinosaur Ridge & Lookout Mountain Field Trip

Start: Red Rocks Park Amphitheater uppermost (highest) Parking Lot.

Geology Questions:

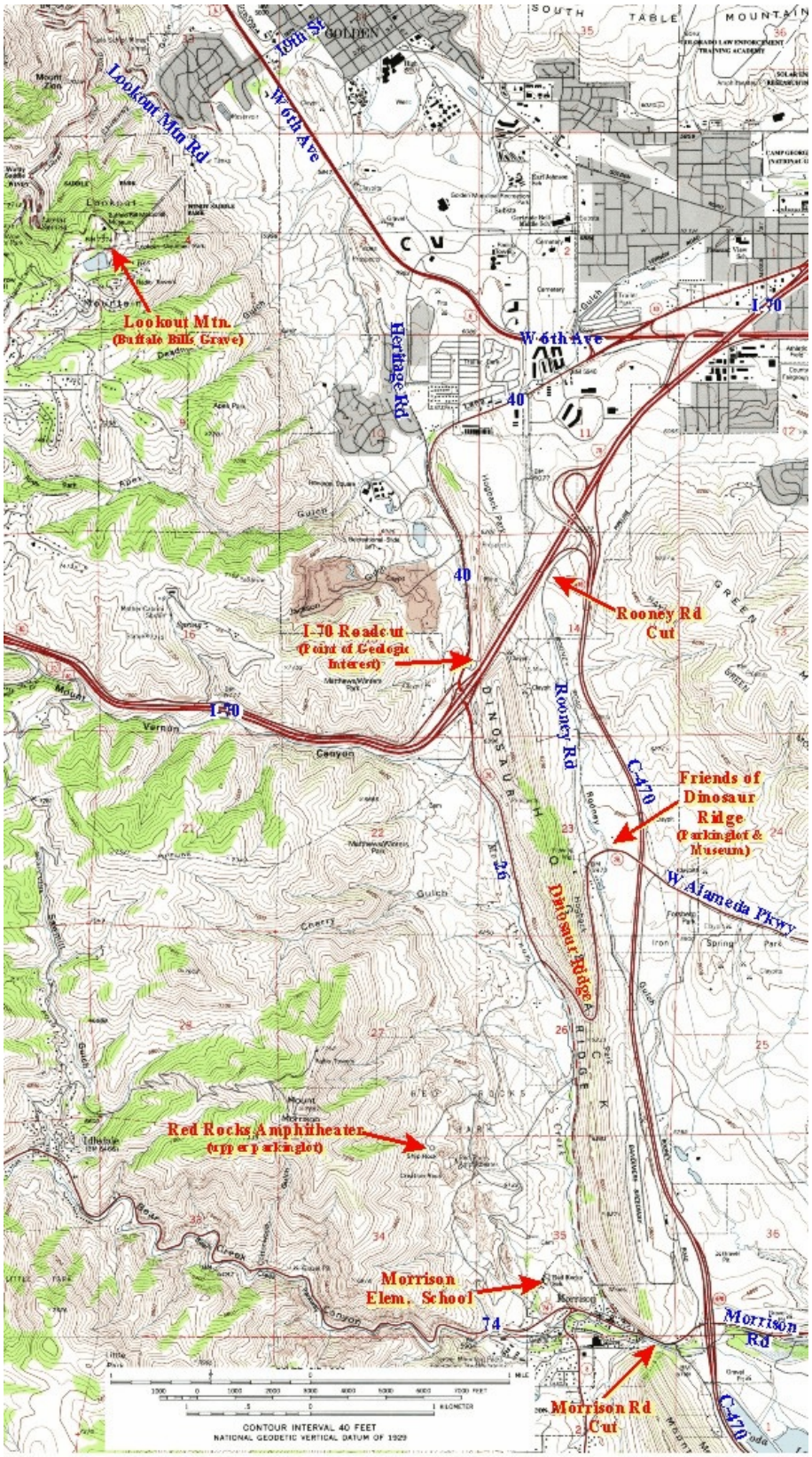
1. *(Take Picture)* What is a slump & how does it form?
2. What type of unconformity is found at Red Rocks park? How can you tell that it is an unconformity *(NO, the answer is not because someone put a sign there!)*
3. Which rocks (Relative ages) are missing at the great unconformity from the previous question?

Next: Drive down the road toward Dinosaur ridge to a sign pointing toward a "Geologic Interest" site. Follow the signs, park the car at the parking lot and hike the short distance to the signs and posters explaining the geology.

Geology Questions:

4. Read the signs. What is the geologic history of the area?

Next: Continue your excursion down the road toward Dinosaur Ridge Road with frequent stops. The tour continues up dinosaur ridge road. The road is closed for vehicles. Drive to the other side of Dinosaur Ridge and park at the "*Friends of the Dinosaur Ridge*" Parking Lot. Walk from there or pay a fee for the tour shuttle bus. For more info visit http://www.dinoridge.org/.



Geology Questions:

5. *(Take Picture)* You can see Dinosaur Bones at one of the stops in the Morrison Formation. How can you distinguish dinosaur bones from the surrounding host rocks?
6. *(Take Picture)* You also find "load casts" in the Morrison Formation: What are they and how are they identified?
7. *(Take Picture)* There are evidences that the Dakota Sandstones was deposited in shallow water! How can you tell from the clues left in the rocks?

8. What evidences are present that would tell you that the climate during the deposition of the Dakota Sandstone was tropical?
9. The Dinosaur footprints at Dinosaur Ridge are famous: (a) What type of Dinosaurs are identified from the footprints? (b) What type of animal behavior could be inferred from the footprints found at Dinosaur Ridge? (c) How can you differentiate between carnivore and herbivore footprints?

Next: Drive southward to the Morrison Elementary school, also called the Red Rocks school. Park in the school parking lot and hike up a small distance toward the Northeast or toward the whitish outcrop. Looking westward you will see a sight similar to the picture. The white outcrop being the Lyons Sandstone, the Maroon hogbacks to the West is the Fountain Fm. and the hills in the distance comprise the Idaho Springs Fm. From there drive the Morrison Road eastward to the Morrison Road cut.

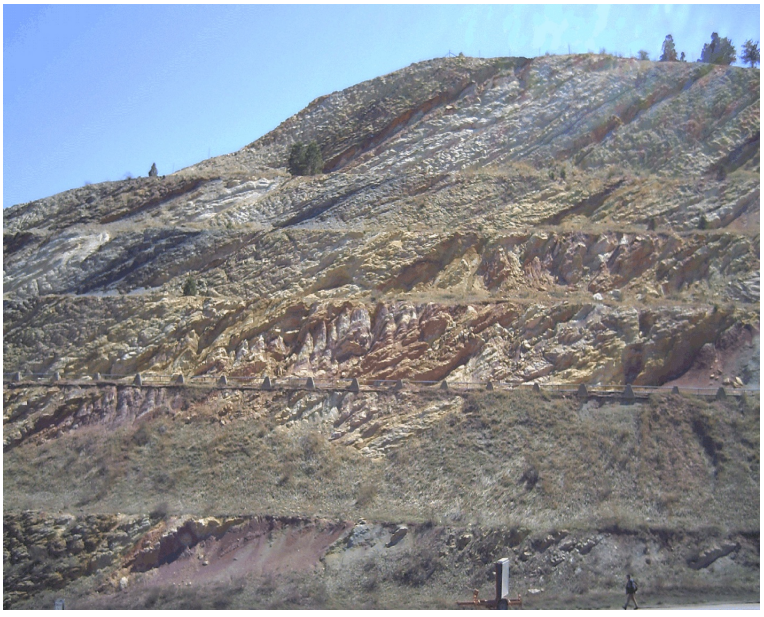
Geology Questions:

10. The whitish outcrop at the Morrison elementary school shows the transition of the Fountain Fm. into the Lyons Sandstone. How are these two sandstones different?
11. Explain how the depositional environment might have changed to reflect the transition observed.
12. *(Take Picture)* At the Morrison Road cut, can you identify the various rock formations?
13. From the Morrison Road cut walk westward toward the Lyons Sandstone. At a parking lot you will come across the brick red Lykins Fm. Why does the Lykins form a valley instead of a hogback?
14. There are two resistant whitish or tan layers in the Lykins Fm. What is there lithology? How did they form?

Next: Drive back North to the Rooney Road cut. Get out of the car and observe the outcrop on the south side of the road, which is the Fox Hill Sandstone. The upper few feet of the road cut outcrop close to the surface show soil formation and soil horizons. Take also a look at the soils exposed on the north side of the road. The mottled soil texture looks a little bit like popcorn and is called "popcorn weathering", indicative of high amounts of bentonite or swelling clay in the soil. Bentonite often forms from the chemical weathering of volcanic ash.

Geology Questions:

15. Take a good look at the sandstone found in the Rooney Road cut. How is this sandstone different from other sandstones observed so far?
16. Put a drop of water on a clean and dry sandstone sample. What do you observe? What does this tell you about the porosity of the Fox Hill Sandstone and the probability of the sandstone as resource material? Resource for what?
17. *(Take Picture)* Look at the soil horizon on the south side of the road cut while walking toward the west. Observe the plants and roots carefully. What you see is indicative of a special type of mass wasting called ...?



Next: Drive to the I-70 road cut and the indicated "Point of Geologic Interest". Park in the PnR parking lot and walk along the road cut.

Geology Questions:

18. The point of geologic interest at the I-70 road cut reveals many colorful, different, and tilted layers. The rock formations are actually labeled. While walking along the trail, try to identify as many different sedimentary rock types as you can.
19. What causes the various colors in the rocks? Especially the greens, reds, and blacks.

Next: Follow W 6th Ave toward Golden. At the 19th Street traffic light take a left (West) and follow Lookout Mountain Rd. all the way up to the top of Lookout Mountain. Look for Pegmatites in road-cuts on the way up (and down)... except the driver, of course! You may also want to stop and take pictures on the way up. Park at the Buffalo Bill Museum and Lodge Parking lot. After visiting the overlook, walk up to Buffalo Bills grave and from there westward through the woods to the parking lot road and back to the parking lot. Look carefully at some of the rocks. Eventually you will find some containing garnets. Unfortunately, these garnets are NOT gem quality.

Geology Questions:

20. Go to the Lookout Mountain overlook and read the geology posters and signs.
21. What type of rock is found on top of Lookout Mountain in Golden and how did it get there?
22. Why do we find Garnets on top of Lookout Mountain?
23. Why is Table Mountain flat?
24. What rock type do you find on top of Table Mountain and how did it get there?
25. *(Take Picture)* What type of fault is the Golden fault and what does it displace?

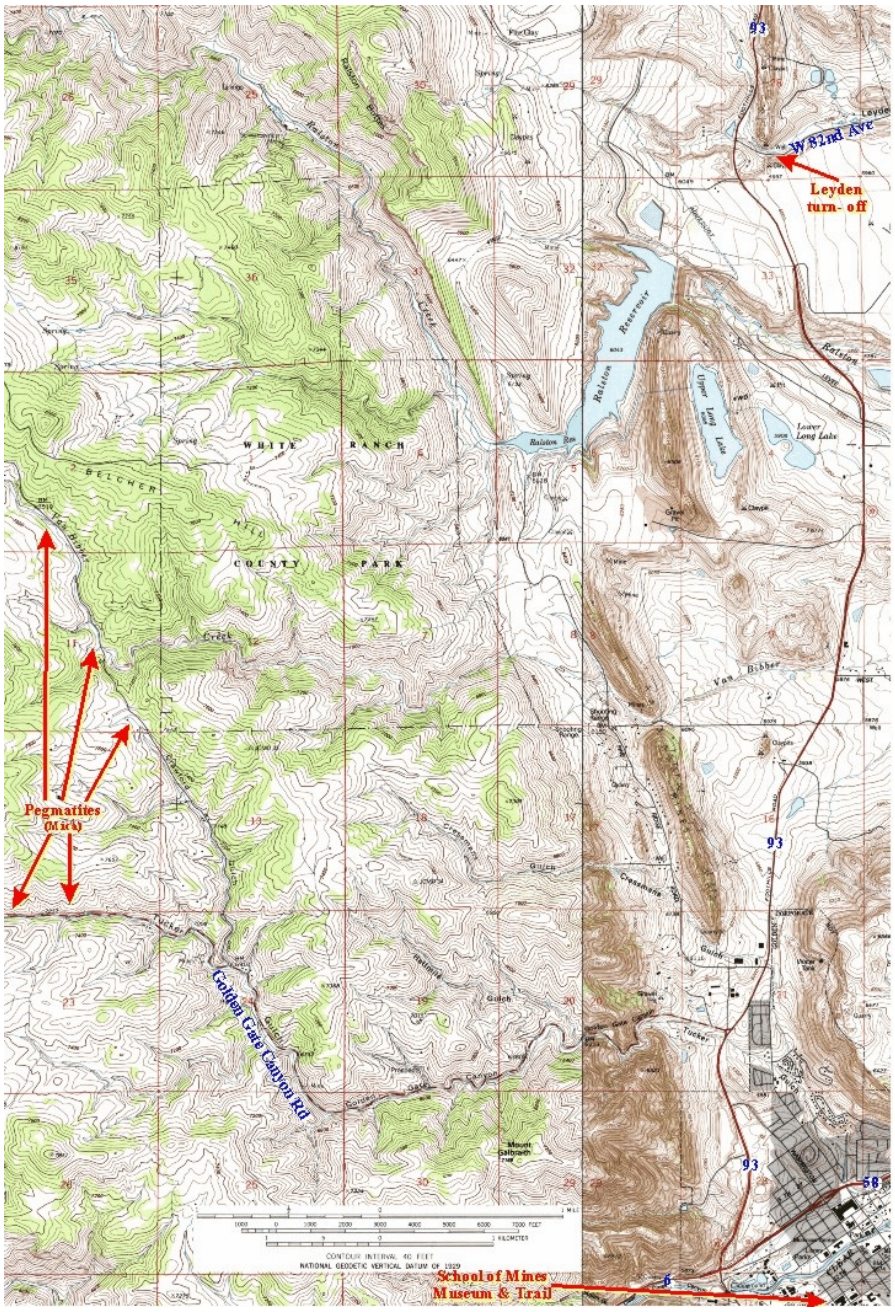
Day 2 - School of Mines Museum & Geology Trail, Golden Gate State Park

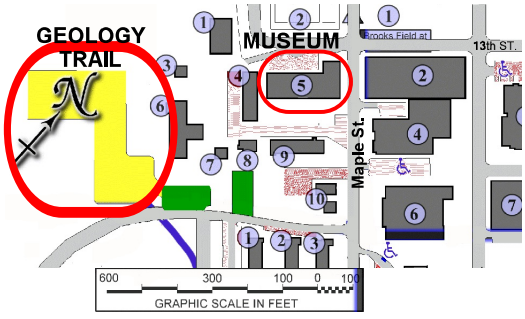
Start: The Colorado School of Mines Geology Museum is located on the corner of 13th and Maple St. in Golden, Colorado. The admission is free and the Museum is open Monday - Saturday: 9am - 4pm & Sunday: 1pm - 4pm. (Closed all CSM Holidays and Sundays during summer). Call for current schedule since it changes frequently.

Geology Questions:

26. The Colorado School of Mines Museum has an exquisite display of Minerals. Survey the great variety of specimens. What is Colorado's State Mineral?
27. What is Colorado's State Gem?
28. From the minerals on display, which ones can be found in the Colorado Front Range corridor?

Next: The Geologic Trail is situated about 600ft uphill just behind the Museum as indicated. A printed trail guide can be obtained free of charge at the Museum or downloaded from: http://inside.mines.edu/UserFiles/File/Geology/geoTrail1.pdf The brochure will answer many of your questions and includes a geologic map of the trail with information for each stop.





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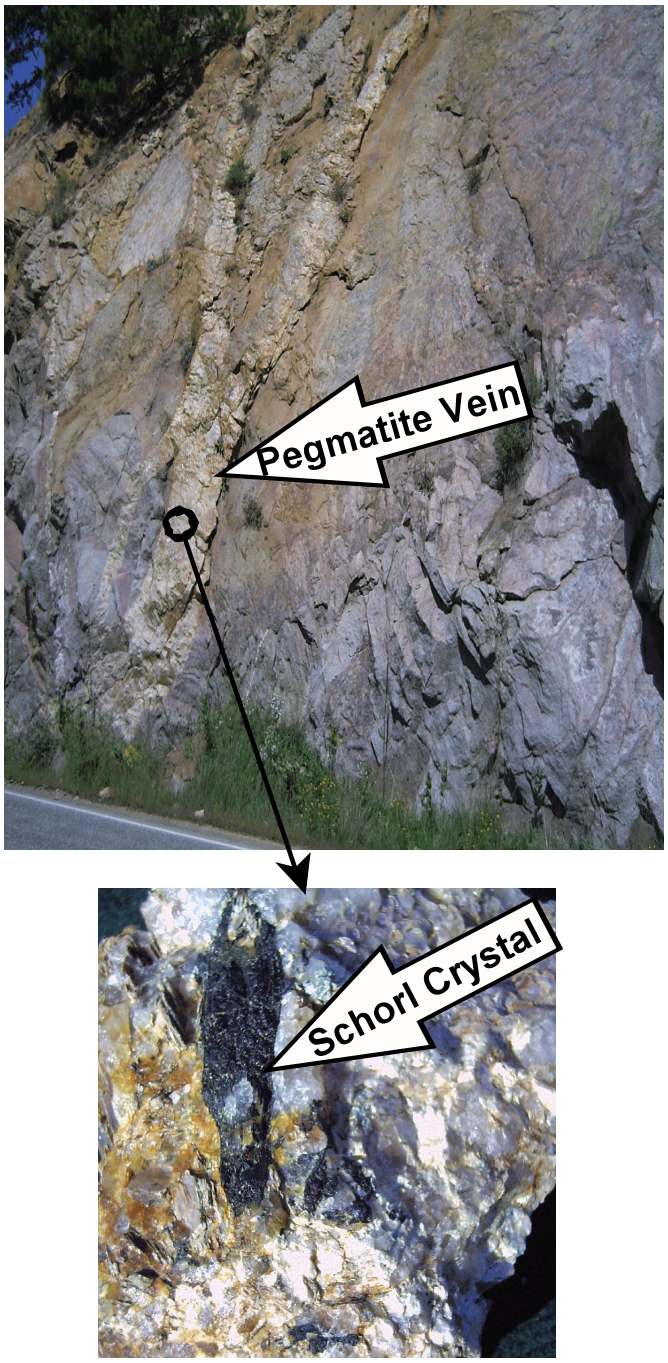
http://www.mines.edu/csm_maps/images/campus-lg.png

Geology Questions:

29. The Front Range of Colorado contains certain Rock Formations of certain geologic ages, which are associated with certain rock types. These rock types in turn reflect the ancient depositional environment or mode of deposition for igneous rocks. Complete the table below for all the Formations exhibited as samples on the geologic trail. As indicated, the youngest formation must be on the top of the table with the oldest on the bottom:

Formation Name	Geologic Age	Major Rock Type(s)	Environment / Mode of Deposition
Precambrian			

30. According to the Colorado School of Mines geologic trail, which igneous rocks are found in Colorado? Where in Colorado do you find them?
31. According to the Colorado School of Mines geologic trail, which metamorphic rocks are found in Colorado? Where in Colorado do you find them?
32. According to the Colorado School of Mines geologic trail, which sedimentary rocks are found in Colorado? Where in Colorado do you find them?
33. *(Take Picture)* What is a geologic fault? Which fault is on display on the geologic trail and what did this particular fault do?



Pegmatitic vein and associated schorl.
(Photos & Graphic: Kackstaetter, 2006)

Next: After the Geologic Trail at the School of Mines drive Northward on 6th Ave straight across Hwy 58 (large intersection) toward Boulder. At the intersection the road turns into Hwy 93. Continue on 93 for about 1 mile to North Golden, where a road will turn westward toward Golden Gate State Park. Follow this road toward the Park for about 4 miles.

Hint: Do not necessarily enter the park, because mineral collecting in State & National Parks is prohibited.

What to look for: After about 4 miles en route to Golden Gate Park look for pegmatite veins in road-cuts. Such veins appear as thick banded intrusion of light material (usually quartz, mica and feldspar) as indicated in the picture, and sparkling muscovite mica is a dead give away. Find a suitable parking spot, walk over to such a vein and investigate. In pegmatitic quartz & feldspar veins you can find black hexagonal crystals of tourmaline, variety "schorl" (see picture).

Hint: You may also try some side roads for better veins and larger crystals

Geology Questions:

34. *(Take Picture)* What is a pegmatite? How does it form?
35. Which minerals are commonly found in the pegmatites of Golden Gate Canyon?
36. What type of Rock is predominantly found in the vicinity of Golden Gate Canyon and how did it get there?
37. How do you use a rock hammer? (This is not a humorous or trick question. It has to do with personal safety)

Next: Return to Highway 93 and drive northward to the Leyden turn off or W 82nd Ave. You will see a rock formation almost standing straight up as shown in the picture. Park the car on the side of the road, get our and investigate.

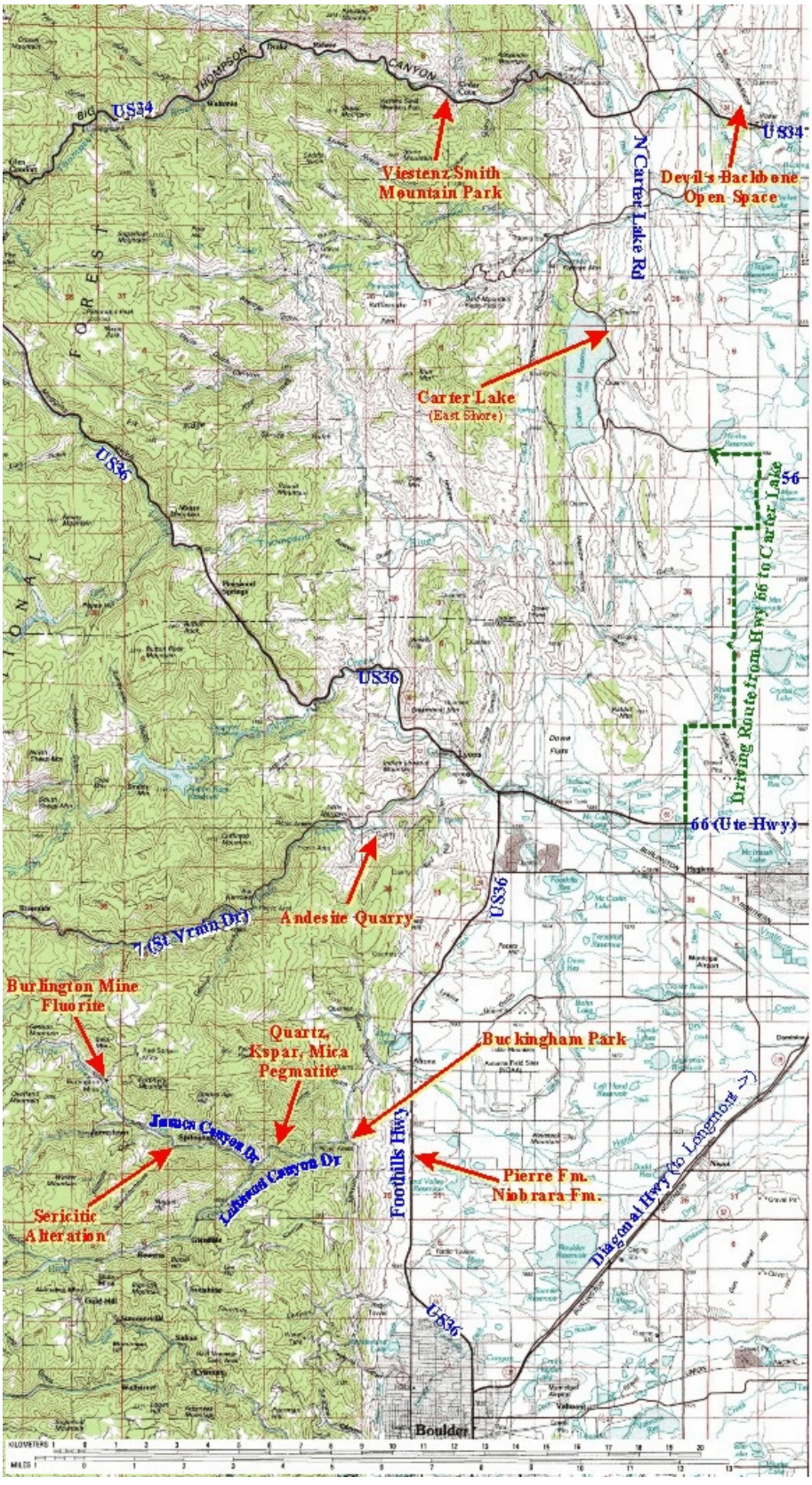
Geology Questions:

38. Which stratigraphic formation is present at this locality?
39. Which two economic rocks / minerals were mined in the locality of the Leyden turn-off?

Day 3 - Jamestown. Lyons, Carter Lake, Devil's Backbone

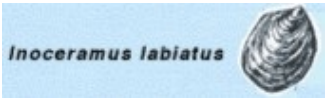
Start: Follow US36 from Boulder northward toward Lyons. About 2.5 miles north of Boulder take the Neva Rd turn-off to the right (East). After 100 yards the paved road turns sharp right with a dirt road going straight. Take the dirt road and stop uphill just before the stop sign. You are at the Pierre Fm and Niobrara Fm stop. Get out of the car and investigate.

Neva Road and U.S. 36, North of Boulder, Colorado (N40°06.34752', W105°16.84206')



Geology Questions:

40. Walk southward down the dirt road to some black shale outcrop. This is the Pierre shale. Brake off a fresh piece of black shale and smell it. What do you smell?
41. What causes the black color of the shale?
42. *(Take Picture)* What is the Pierre Shale, how & where was it deposited, and how thick is it here in Colorado?
43. If you observe the black outcropping closely you will find some inch thick tan or yellow layers parallel to the shale bedding. What are those?
44. Walk back north to the stop sign and cross US36 (BE CAREFUL... This is a high traffic road!). Go about 100ft north to a white outcrop. What rocktype do you observe?
45. If you look carefully at the rock you might be able to find some large Inoceramus clam fossils. What does the size and shell thickness of those fossils tell you about the ancient depositional environment?



Next: Return to the car and continue northwards on US36 to the Jamestown turn off to the west into Lefthand Canyon Rd at the famous Greenbrier Inn Restaurant. Mark your odometer at this point and add 4.5 miles. There will be a significant

stop at that point, but first continue on Lefthand Canyon road to Buckingham Park; make a short-stop there (Vault restroom facilities available). At Buckingham Park walk northward on Lefthand Canyon Rd for about 200 yards to a stand of Cottonwood trees. Cross the road going east and climb about 50 yards up the slope.

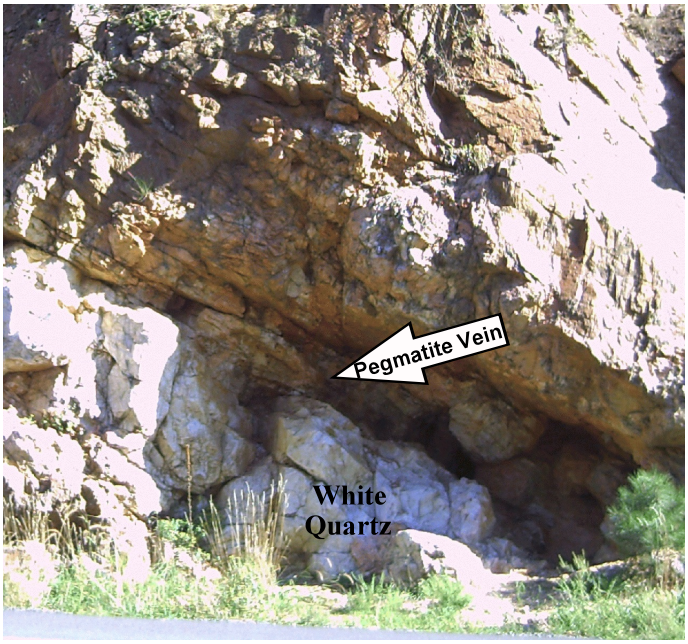
Geology Questions:

46. What rock types do you observe? Which Formation can you identify? What do those rocks tell you about the depositional environment?

Next: Remember your odometer point??? Continue driving Lefthand Canyon Rd westward to this odometer point. You should now be at a large pegmatitic bright white vein appearing in the road-cut to your right. (see picture above). Park at a safe place and investigate.
Granitic Pegmatite–Lefthand Canyon Drive (N40°06.50202', W105°20.02146')

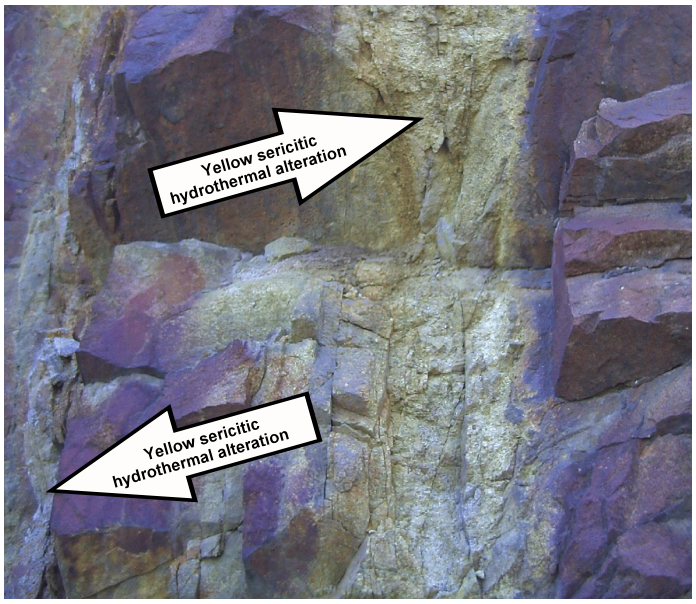
Geology Questions:

47. *(Take Picture)* You may want to take some pictures of this large, attractive pegmatite and it's huge mineral crystals. Identify the minerals present. Sketch freehand or mark on your photograph the distribution of those minerals Then explain what might have caused this dispersion. *(Note: Bowen's Reaction Series might be helpful)*



Pegmatitic vein at side of road on the way to Jamestown
(Photo & Graphic: Kackstaetter, 2006)

Next: Continue on toward Jamestown. Within a mile or two before you enter the town, sericitic alteration of the rocks becomes evident. Mineral laden hydrothermal fluids percolated through cracks & crevasses in the rock, often leaving their valuable mineral load behind. In the process, the host rock was decomposed into yellow or orange, very lose material (see previous picture). Old miners were always on the look-out for these discolorations and used them as a guide to place their mining shafts. Stop at a safe place at one of those altered, lemon colored rocks and investigate.
Hydrothermal Mineralization—James Canyon Drive/Mills Street (N40°06.50910', W105°22.34442')



Prominent yellow colored hydrothermal alterations near Jamestown
(Photo & Graphic: Kackstaetter, 2006)

Geology Questions:

48. What minerals do you observe in the areas of alteration? *(Note: You may want to use a hand lense)*

49. Take a rock hammer and strike some of the rocks. Then smell them. What do they smell like and what does this particular smell tell you?

Next: Continue on through Jamestown on James Canyon Dr. about a mile West of town. You will encounter the old mines and mine tailings of the Burlington Mine. The material is usually whitish tan to yellow. Park at CR87 or Ballard Rd. which turns to the right or northward. (This is about 9.5 miles after the Greenbrier.)

Burlington Fluorite Mine—James Canyon Drive/Overland Road and CR87 (N40°07.71534', W105°24.03828')

- WARNING: Mines are private property. Do NOT walk into a mine or on mine property without permission. Permission can be obtained. Inquire in Jamestown. -

The sides of the main roads are public and sufficient for investigation and collecting. Walk back along the North side of the road to Jamestown (among the trees to the side of the road.) If you look closely at some of the mine tailing rocks along roads you can find purplish fluorite and even some golden pyrite. These are easiest to obtain when cracking some of the larger rocks with a rock hammer. You may also investigate the rubble between the trees on the south side of the road.

Geology Questions:

50. The fluorite in Jamestown was actually mined. What was it used for?
51. The presence of pyrite in mining areas presents a problem. Even though the mineral is worthless, it creates one of Colorado's environmental problems when mixed into the tailings or exposed to air. What is that problem and how is it created?
52. *(Take Picture)* The creeks and rivers around Jamestown are used for amateur gold panning adventures. If you have a pan, you may try your luck. How does gold panning work? Which specific attributes does the river material need to display in order to be panned successfully and most likely yield the desired treasure?
53. How does the gold get into the river?
54. After investigating some of the hydrothermal alterations near Jamestown, which mineral(s) did you find in them? How did those minerals get there?

Next: We are down in Jamestown. Follow the road back to US36 and head toward city of Lyons where a lot of mining activity takes place (There are several quarries in the area). Find out what is being mined and the uses of the mined material. Afterwards follow Hwy66 westward through Lyons and turn southward on Hwy 7 or the St Vrain Dr toward Allenspark. After about 3.5 miles beyond the downtown T-intersection you will see a mining / quarrying operation to the South. Interestingly enough, andesite is mined here, a very unusual rock type for the Colorado Rockies.
Dacite Columnar Jointing—Hwy. 7/S St. Vrain Drive (N40°12.06798', W105°18.26886')

Geology Questions:

55. *(Take Picture)* What is being mined in and around Lyons (other than the andesite / dacite) and what is it used for?
56. What is the geologic time period for this reddish material mined in Lyons and what was the depositional environment? How can you tell?
57. Leaving Lyons on Hwy 7 you will encounter the andesite mines. Unfortunately these quarries are actively mined and are across the St Vrain River on the other side of the road. Binoculars or a telephoto lens would be advantageous at this point. How did we get andesite get to this part of Colorado?
58. *(Take Picture)* With a telephoto lens or some binoculars find columnar jointing in the andesite! Interpret how columnar joints form!

Next: Continue your trip back through Lyons to the Carter Lake recreational area as indicated on the map in green (For just driving through you will probably not need a day use permit. Ask at the entry station). Go to the North shore of the lake as indicated by the arrow on the map, make a short stop and investigate.
Carter Lake Syncline Waypoint—S. County Road 31 (N 40°20.78783', W 105°12.52667')

Geology Questions:

59. So far all sedimentary rock units you have observed were dipping toward the East. Why?
60. Here at carter Lake on the North shore these units dip toward the West. Looking across carter Lake to the West you will see the rock units dipping to the East again. What is the geologic structure you are parked on?

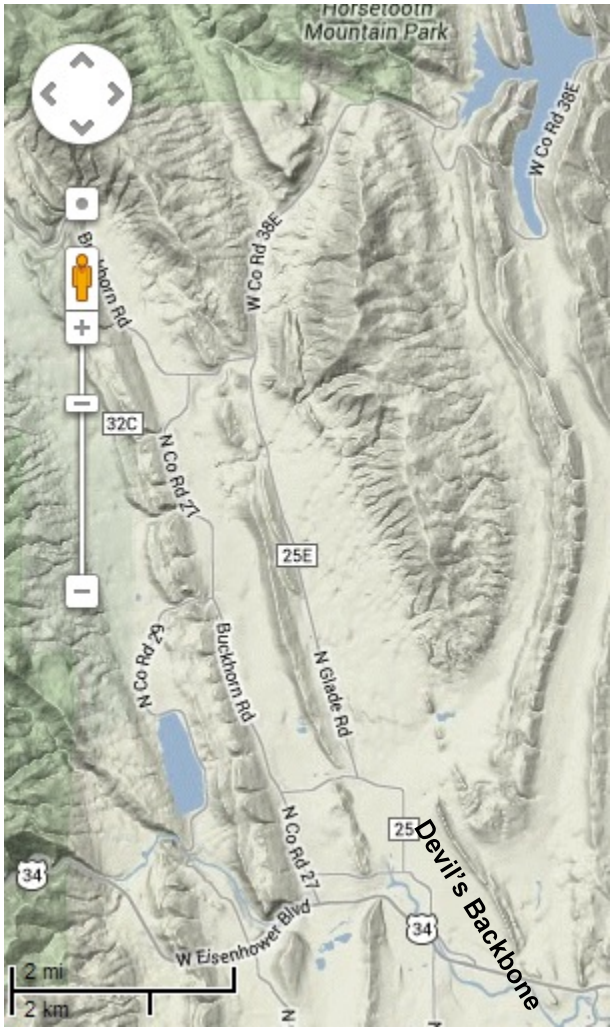
Next: Continue Northward from Carter Lake as indicated until you reach US34. Here you take a right and go eastward toward Loveland. You will also drive past an area known as "devils backbone", where a rugged rock formation is literally sticking straight up out of the ground. "Devils Backbone State Park" is on Hwy 34, about 1 mile West from the Loveland City Limits. The turn-off comes without much warning and the signs are rather small, so pay close attention. Park at the parking lot (Vault toilets and water available). Follow the 1 mile RT geologic hiking trail.
Devil's Backbone Open Space (N 40°24.69817', W 105°09.14100')

Geology Questions:

61. Take a close look at the rocks comprising "Devil's Backbone". What is their lithology? Which Formation?
62. What is the "devil's backbone" and how did it from?
63. *(Take Picture)* "Devil's Backbone" is a geologic puzzle. Looking eastward from the Western most point of the geologic trail you will see a ridge on the horizon. This ridge, which tilts eastward is the same rock formation as "Devil's Backbone". If you look westward you will see a valley and after the valley another hogback tilting again eastward. This hogback is again the exact same rock formation as the lithologies of "Devil's Backbone". As you can observe, "Devil's Backbone" is not very thick were you are standing. How then are these three separate rock outcroppings connected? Try to solve this famous geologic puzzle.

NOTE: If you take Dr.K's GEL1010-Physical Geology Class at Metro State, pay special attention to the Geology at Devil's Backbone. This Geologic Puzzle will be ON THE LAST EXAM. It will be imperative that you complete LAB Exercise 15 - Dipping Geologic Structures, p.110-113 in your Laboratory e-Manual in conjunction with your observation at Devil's Backbone.

Hint: There is an information plaque on the geologic trail explaining the "puzzle"



Next: Drive US34 west from "Devil's Backbone State Park" past the mouth of Big Thompson Canyon to Viestenz-Smith Mountain Park (about 4 miles after the "Dam Store" at the Canyon mouth). The Park contains remnants and memorial plaques detailing the story of the greatest natural catastrophe in Colorado's history, the "1976 Big Thompson Flood". Park at the recreational area, investigate the flood story. If you have time, take the 1 mile hike from the park to the Overlook.

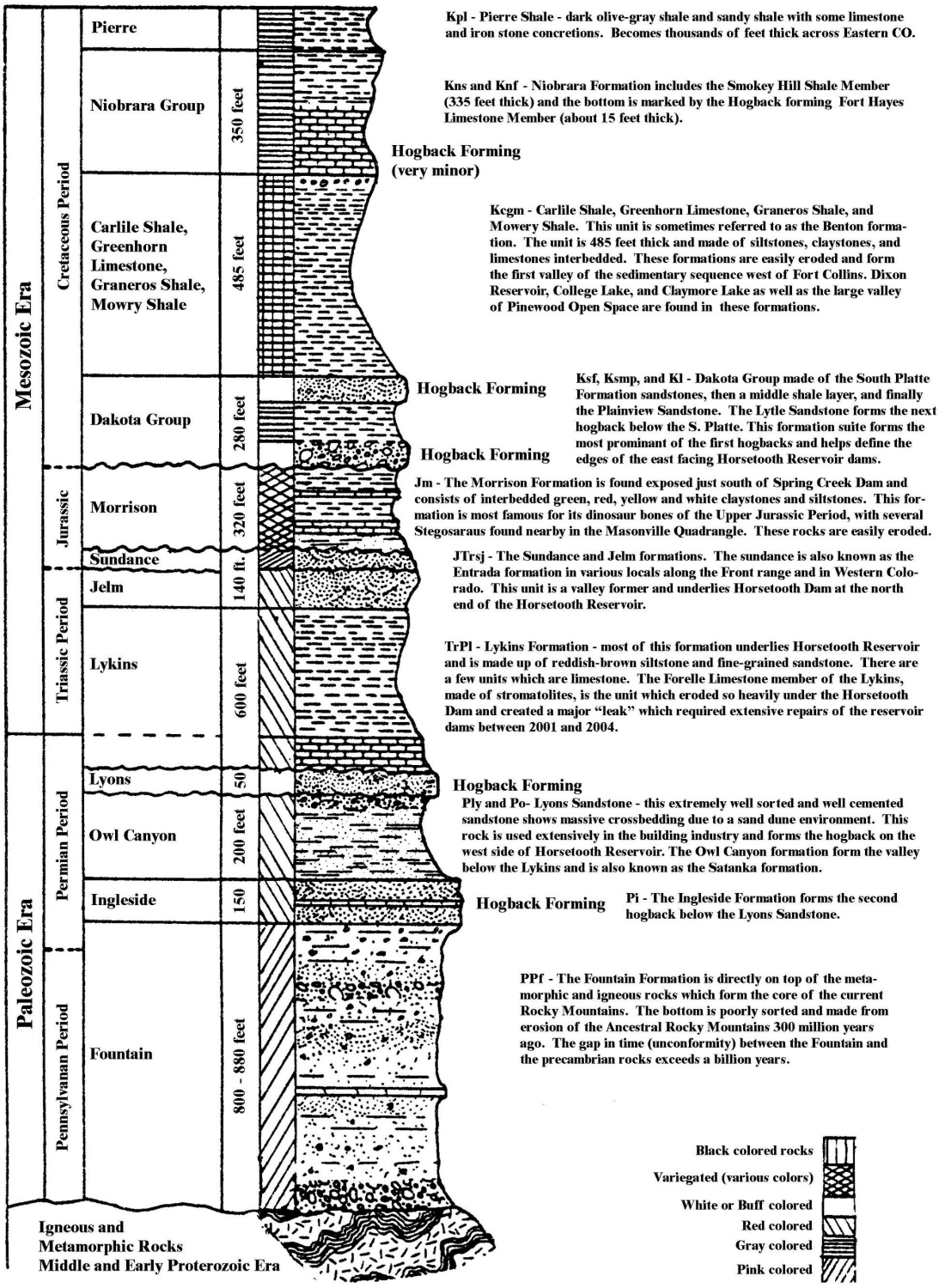
Geology Questions:

64. What caused the historic 1976 flood and why was it so devastating?
65. What safety measures are in place to avoid as many human casualties as possible, should such a flood reoccur?
66. What rocktypes and formation(s) are you encountering on the Overlook hike?

Day 4 - Ft. Collins and Horsetooth Reservoir

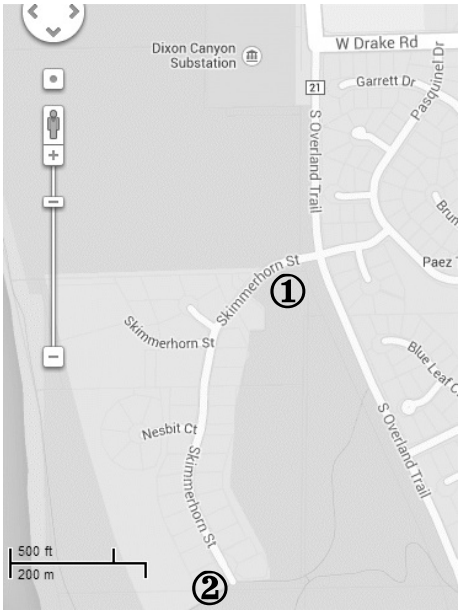
Overview: The stratigraphy changes somewhat in Northern Colorado as can be seen in the stratigraphic section below.

Generalized Sratigraphic Column
Horsetooth Reservoir Quadrangle, Larimer County, Colorado
(graphic by Department of Earth Resources, Colorado State University, 1978; after Wolfe, John A., Geology of Masonville Mining District, Larimer Co. , CO)



Compiled by Dave Swartz, Rocky Mountain High School Science Department, 1300 W. Swallow Rd. Fort Collins, Co 80526

Start: This day will be an exercise in identifying rock formations in the field around Horsetooth Reservoir in Ft. Collins. Fill in the name of all the rock formations in the blank labels on the provided geologic maps.
Start by taking Drake Road in Ft. Collins all the way West until you come to a T-intersection with South Overland Trail Road. Turn South (left) unto South Overland Trail Road for about 800ft and turn right (West) unto Skimmerhorn Street.
Stop1 - corner of S. Overland Trail and Skimmerhorn St., 1/4 mile south of the intersection of S. Overland Trail and W. Drake Road. Turn west on Skimmerhorn, drive 50 yards and park at the base of the incline.

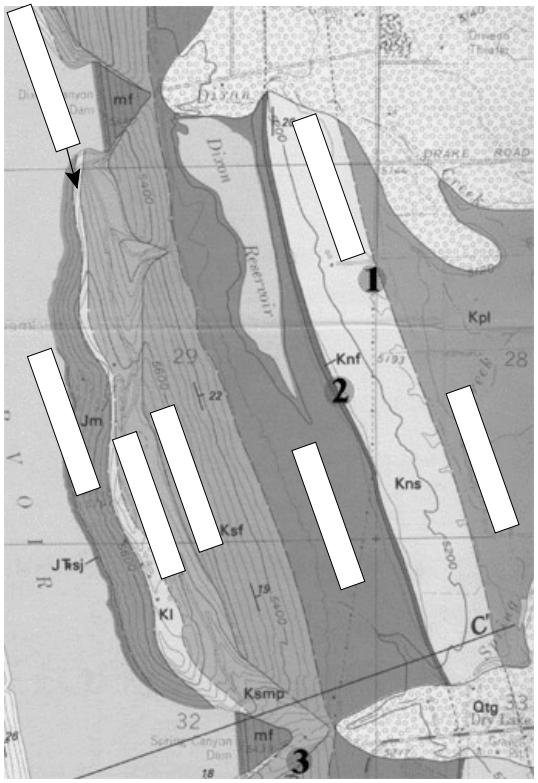


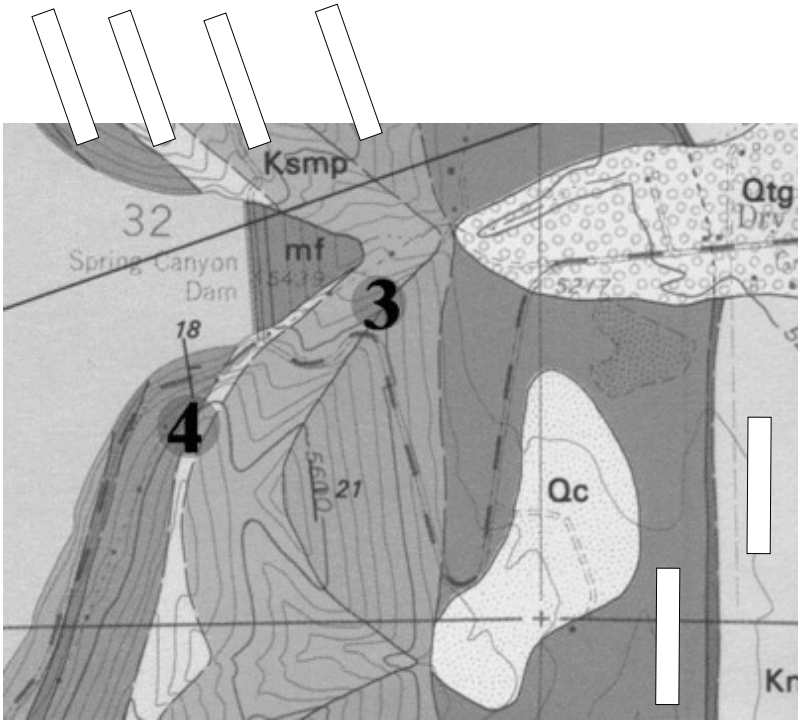
Geology Questions:

67. Which rock formation is exposed at Stop 1?

68. Stop2 - Drive to end of Skimmerhorn Street (2900 block) and directly south of the cul-de- sac is an access trail to the City of Fort Collins Pineridge Natural Area. Be sure to pay attention to parking restrictions and also trail closures in this area. Take trail a short distance (200 yards) up the hill towards the southwest, you will reach the ridge of the first hogback. What rock formation is exposed at Stop 2? Can you find any fossils? What are these fossils telling you?

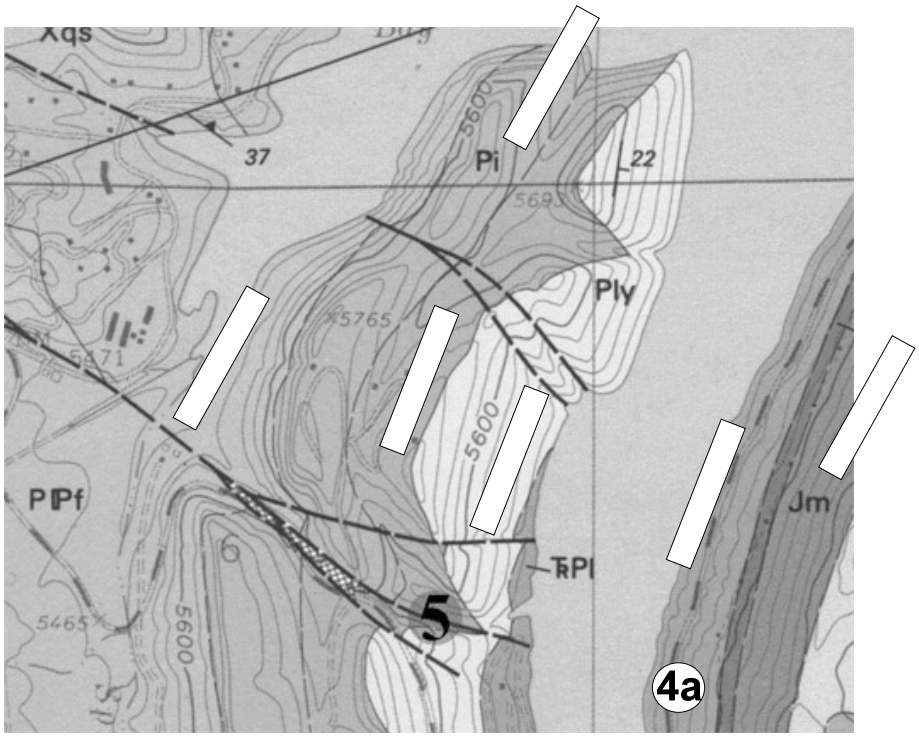
69. Stop3 - Go north on S. Overland Trail from Skimmerhorn Street (Stop 1) 1/4 mile to W. Drake Road. Turn right (east) onto W.Drake Road and go one mile to S. Taft Hill Road. Turn right (south) onto S. Taft Hill Road and drive 1 1/2 miles to the intersection of S. Taft Hill and W.Harmony/W. County Rd 38E. Turn right (west) onto W. County Rd 38E and drive approximately 1 3/4 miles to Stop 3 at the top of the switchback and the exposed road cut. The parking area is directly in front of you as you climb the hill. Be careful pulling off into this small parking area - you can bottom out low suspension vehicles! There are many features to be observed here. Can you see a discoloration on the South side of the roadcut? What caused this discoloration? How is the rock outcrop to the North cemented?





70. Stop4 - Walk to Stop 4. The road cut here is particulary dangerous, as the road shoulders are narrow and you may need to cross at a blind corner for both directions of traffic. The rock is interbedded green, red, yellow, white, and even purple weathered claystone and siltstone which is poorly cemented. The rock crumbles easily and is difficult to sample. What rock formation is exposed at Stop 4?

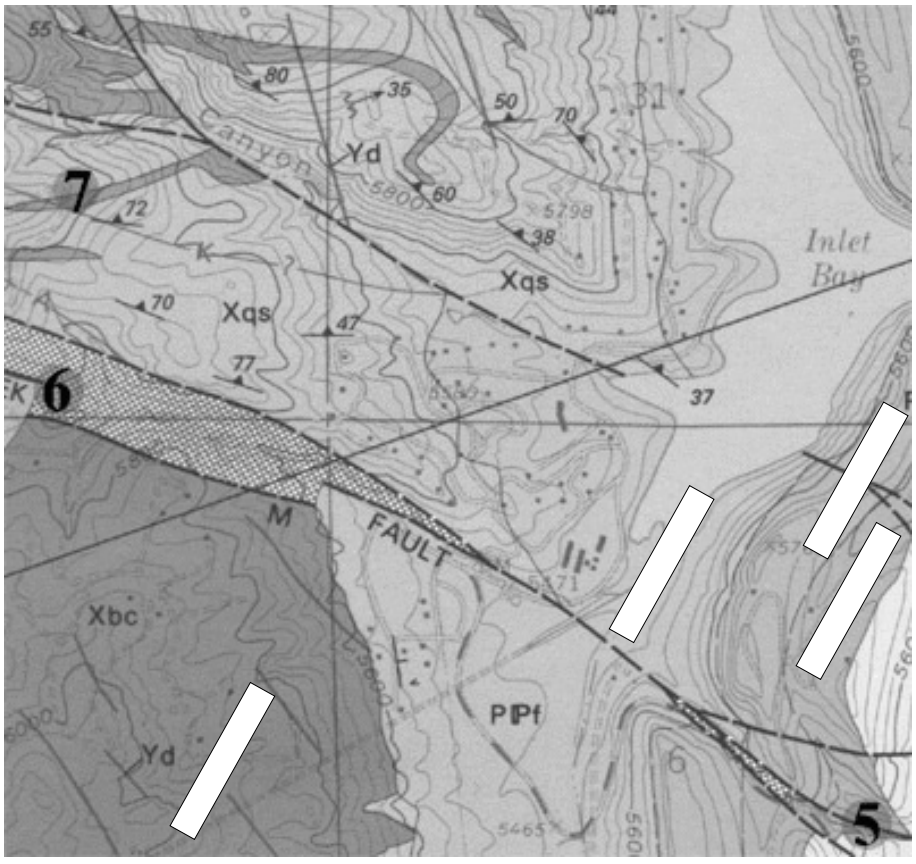
71. Stop4a - Following W. County Rd 38E south for approx 1 mile, stop on the turnout on the east side of the reservoir. Looking toward the east investigate some bright red outcroppings. Careful when crossing the road.



72. Stop5 -Continue through the former town of Stout, CO. (An alternative Stop is the South Bay area which has restrooms, but there is a user fee for this area. Continue up the west side of Horsetooth to the top of the hill and pull off at "The Perch" parking area. Walk around and investigate! Can you detect faults within the rock formations? How?

73. Stop6 - As you proceed to Stop 6, you will go down a fairly steep hill. Pull off in the parking area for Horsetooth Mtn Park. There is a daily use fee of $6 / vehicle if you plan to hike to Stop 7 and Horsetooth Mtn beyond. Your altitude is roughly 5800 feet. It is a 1400 foot verticle climb to the top of Horsetooth Mtn. There are two trails you can take - one follows a road and is suggested for bicycles and horses. This trail initially travels west. The second trail is for hikers and starts off by the upper pavillion and heads east, but soon swings back west as it switches back up a small valley. What can you tell about the rock types in this area?

74. Stop7 - Where the trail splits to Horsetooth Falls or the Soderberg Road, follow the Sodderberg Road to the left and climb to an altitude of almost 6200 feet, where the trail meets the bicycle/horse road. At the junction is a very large pegmatite dike (1.6bya) w/ crystals. Further up the road is another parallel pegmatite dike which includes xenoliths of metamorphic rock. Can you tell by the “law of inclusions” which is older, the metamorphic rocks or the pegmatite dike?



Day 5 - US 287 Morrison Fm road-cut and Owl Canyon

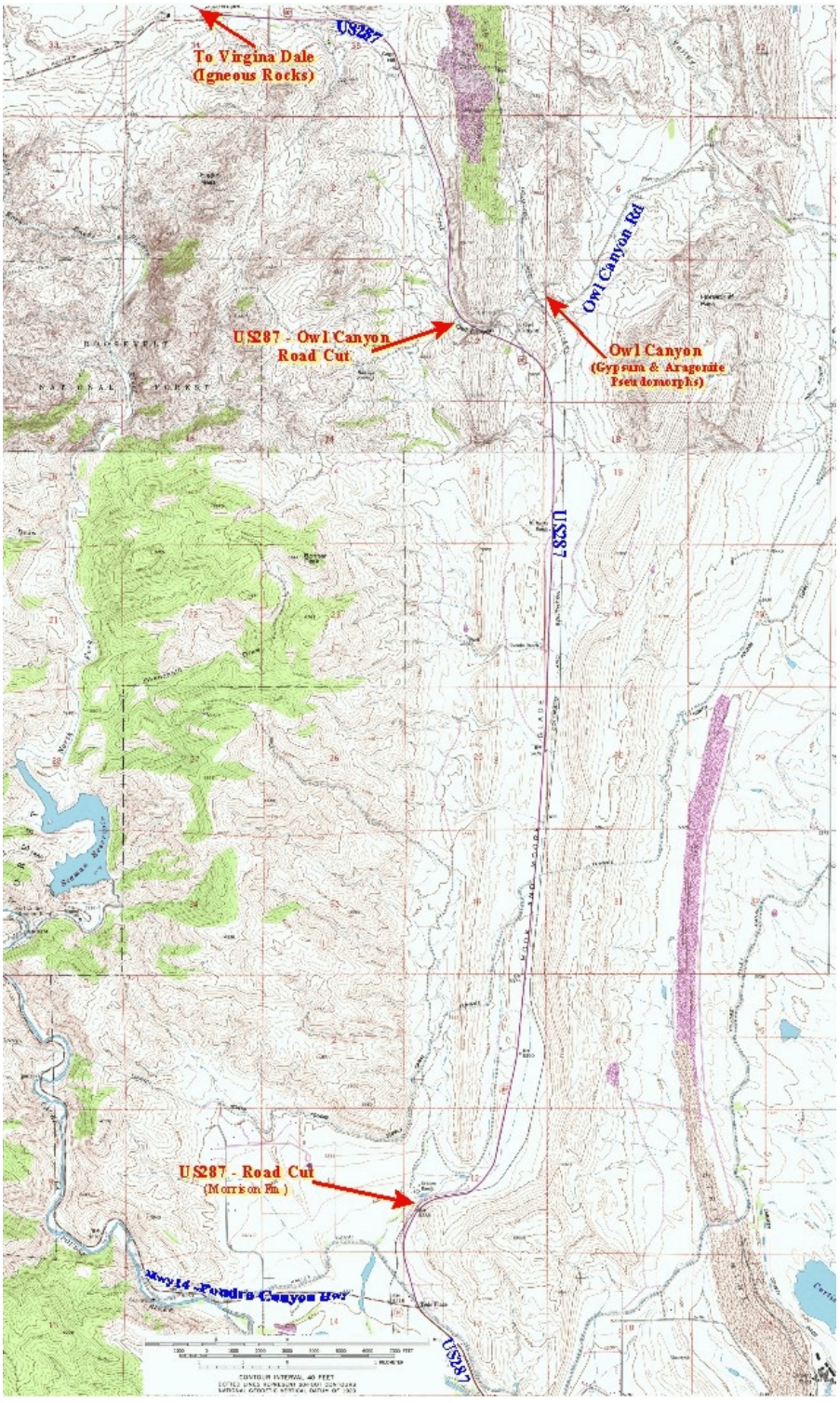
Start: From Ft. Collins take US287 northward as indicated on the map. North of LaPorte, the highway will go through an elongated bend right after the Highway 14 (Poudre Canyon Hwy) turn off at Ted's Place. You will see the massive road cut exposed to the east consisting of the Dinosaur fossil bearing Morrison Formation. Stop at the end of the bend and hike up this road cut (coming from the North) as indicated on the map.

Dinosaur Bones, Morrison Formation—U.S. 287 Roadcut, N. Fort Collins, Colorado (N 40°40.38050', W 105°11.35533')

Geology Questions:

75. *(Take Picture)* At the Morrison Formation you will find sandstone lenses. These sandstone lenses are sandbars in ancient river channels where dinosaur carcasses were often washed together. Within these sandstones, one often finds fragments of dinosaur remains or bones. Go look for such bone pieces (You may have to search a little... bone fragments are present, but are not too common). When you think you have identified a dinosaur bone, take a picture, indicate the bone on it! Explain how you can distinguish such a dinosaur relic from the surrounding rock.

- Warning: It is illegal in Colorado to remove dinosaur artifacts. Keep to taking pictures. -



Next: Continue northward on US287 for about 6 miles. The road will be absolutely straight and follow a North - South trending Valley between two massive hogbacks, the Dakota Group on your right and the Ingleside Formation on your left. At the Owl Canyon turn off, US287 will jog west right through an impressive road cut (as indicated on the map). Park right after the cut and investigate the exposed Ingleside Limestone. You will find cavities brimming with calcite crystals. These crystals weather out of the rock and often litter the roadside of 287.

Owl Canyon Roadcut, Ingleside Formation—U.S. 287 and Owl Canyon Road (N 40°45.77900', W 105°10.87100')

Geology Questions:

76. What was the depositional environment of the Ingleside formation?

77. How do the calcite crystals in the Ingleside Fm form?

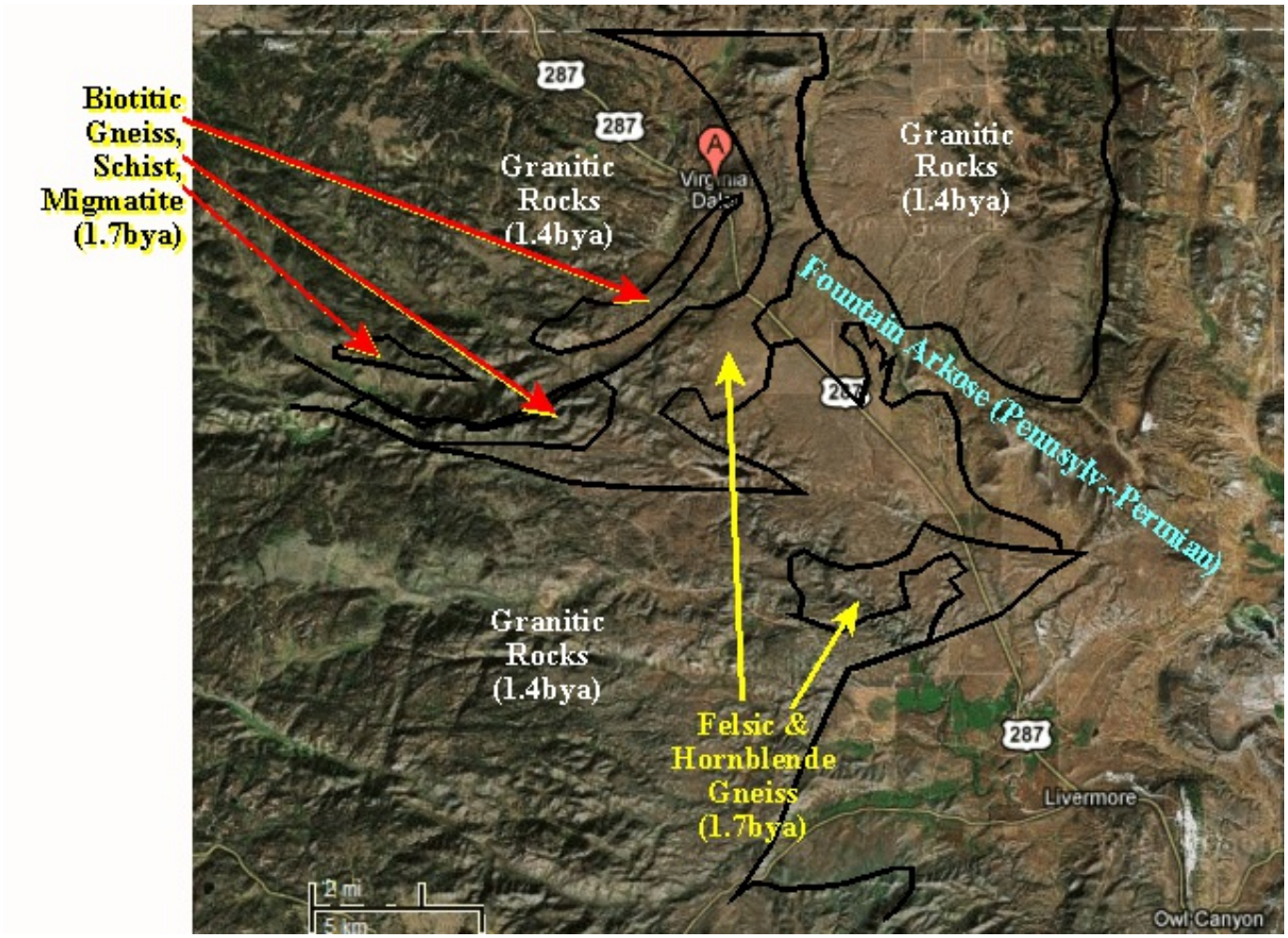
Next: Go back on US287 for about ½ mile and turn left into the Owl Canyon Rd. In the weathered valleys of the brick red Lykins Fm many gypsum varieties can be founds, from alabaster to satin spar to selenite. The area is completely under private ownership and access is severely limited. Permission to collect must be obtained. However, on the sides of the roads within the DOT property and easements, some small chunks are occasionally found. A neat discovery are calcite pseudomorphs after aragonite, which are hexagonal in shape and can be the size of a silver dollar.

Geology Questions:

78. How did those gypsum deposits form? What do they tell about the environment of deposition and possible prehistoric climates?

Next: If time permits, follow US287 northward toward the Wyoming-Colorado border to the small community of Virginia Dale. You are entering the Virgina Dale ring-dike complex, about 9 miles or so across, straddling the State boundary. On the southern end diorite and quartz monzonite can be found. The outermost area consists of biotite and hornblende containing granite. At the side of US287 igneous rocks of granitic and monzogranitic composition can be found. The area is often referenced as the Virgina Dale Ring Dike complex.

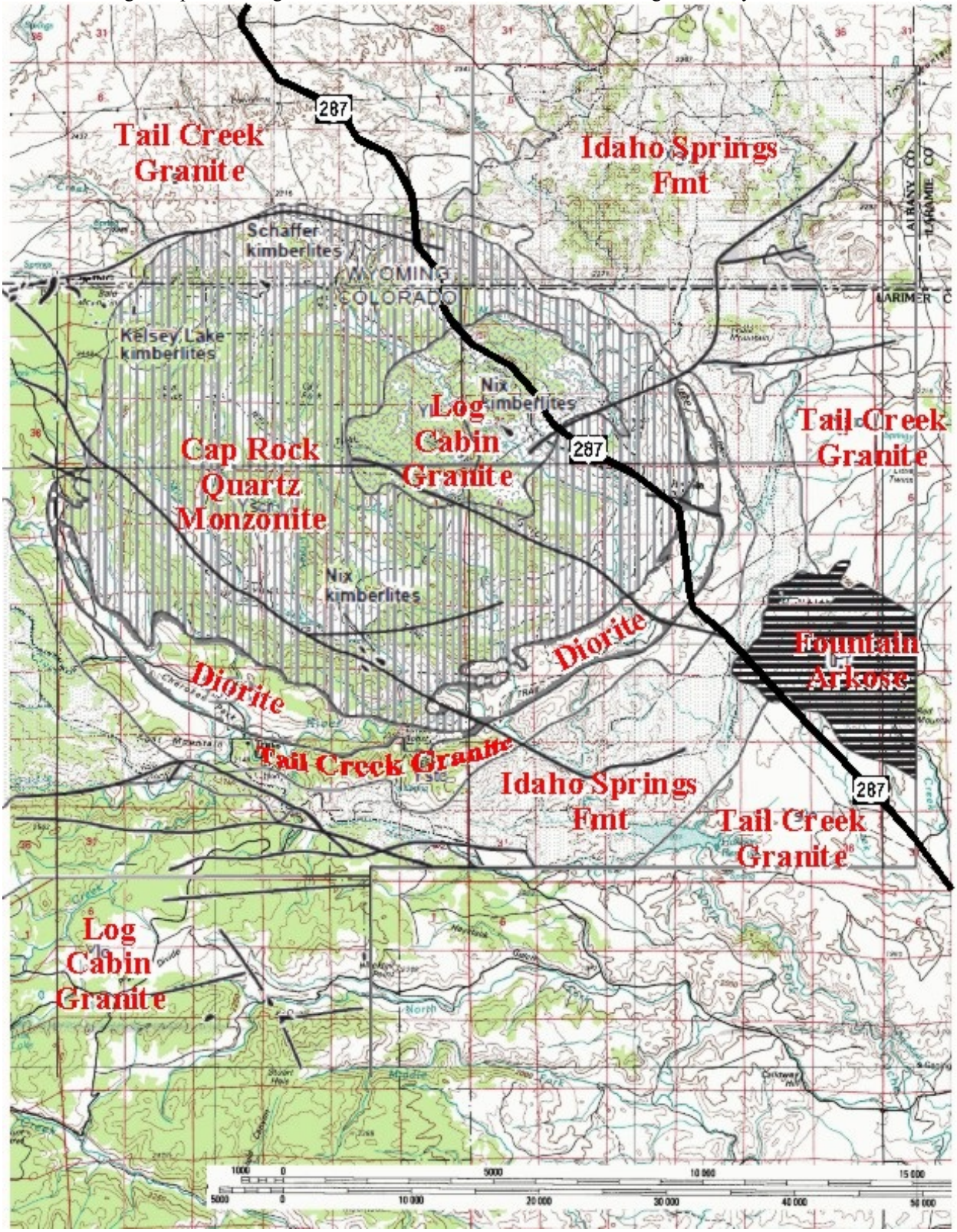
Ring-Dike Complex—U.S. 287, Virginia Dale, Colorado (N 40°56.748', W 105°20.596')

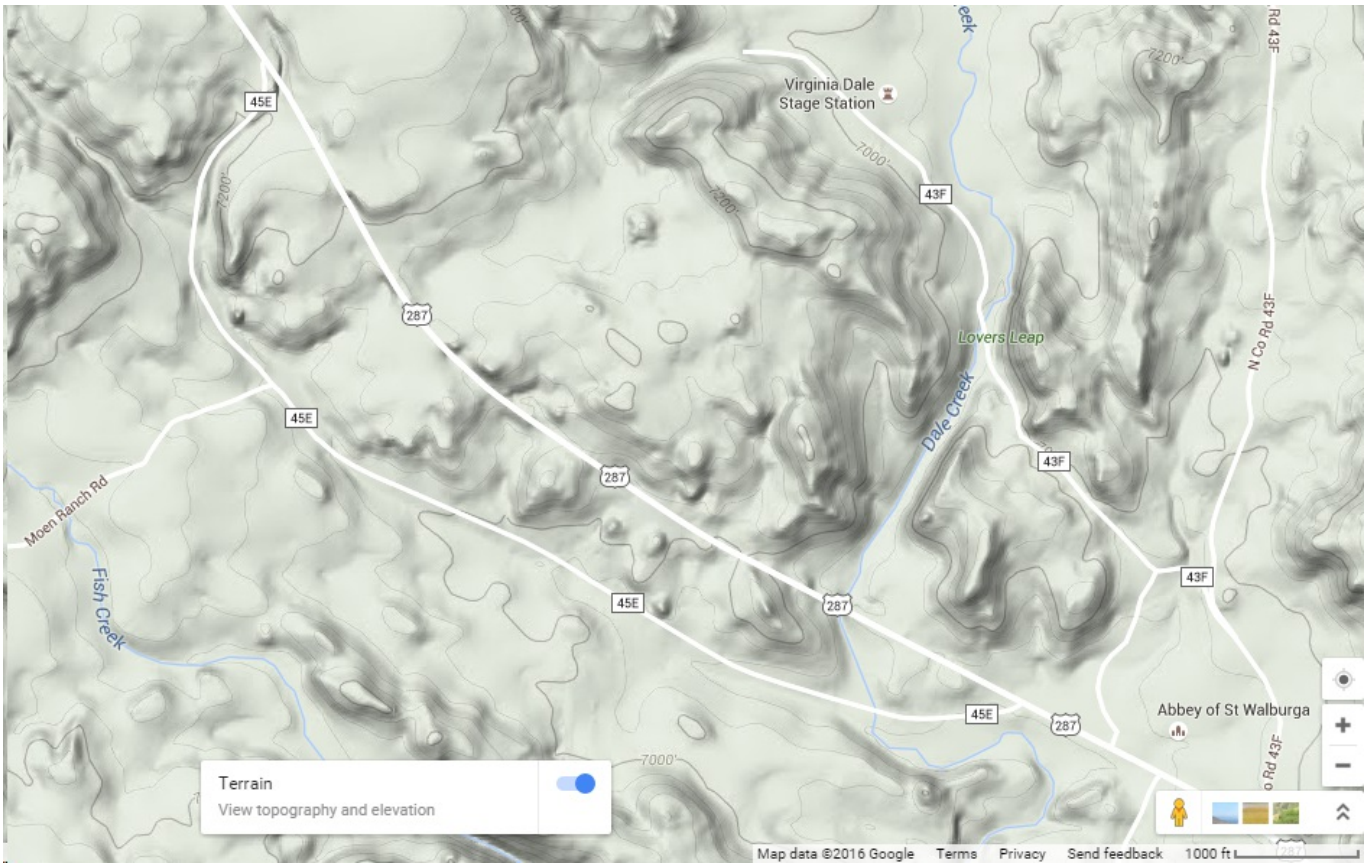


Geology Question:

79. What is the difference between the igneous rocks mentioned?

Detailed Geologic Map of the Virginia Dale Area modified from Colorado Geological Survey ROCKTALK Vol. 2, No. 3.





80. For a special treat continue North on US287 in Virgina Dale to Road 45E. Take the Southern entrance to 45E and follow that road. Somewhere along 45E is a small Kimberlite which was discovered recently by Dr. Kackstaetter and his undergraduate research student S. Gallegos from Metropolitan State University of Denver. Kimberlites are ore rocks for diamonds and many have been discovered within the Colorado-Wyoming border area. Almost all are gated and are inaccessible for rock hounds and students. However this small, deeply weathered kimberlite is right in a 45E road cut within the CDOT easement. Your job will be to find that kimberlite along 45E.
Hint: It is close to the Moen Ranch Road turn off.
Kimberlite—CR 45E and Moen Ranch Road, Virginia Dale, Colorado (N 40°58.03600', W 105°23.06033')

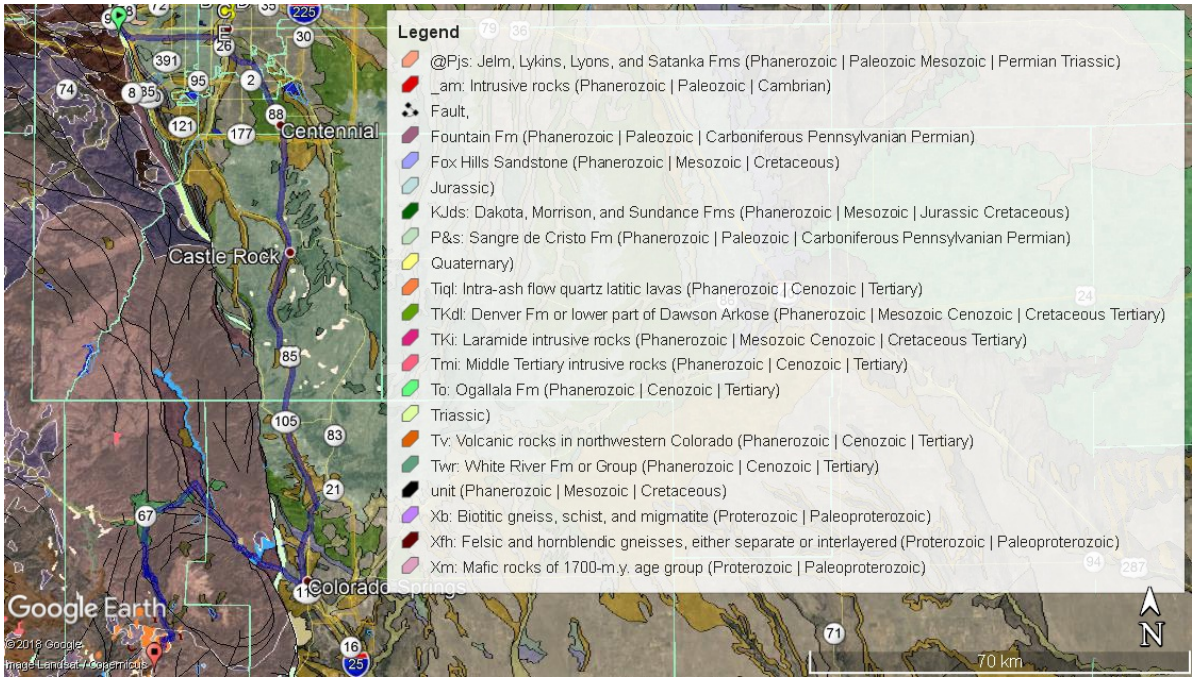
Kimberlites are very elusive rock types because they weather rapidly and are often not really noticeable on the surface, even for seasoned geologists. Good luck on your hunt. Hint: What mineral would be massively produced when a kimberlite weathers? This clue may help you discover the location of this small kimberlite.

Day 6 - Geologic Overview between Golden and Cripple Creek

written Barbara EchoHawk and Uwe Kackstaetter as part of Colorado School of Mines 2019 Field Trip

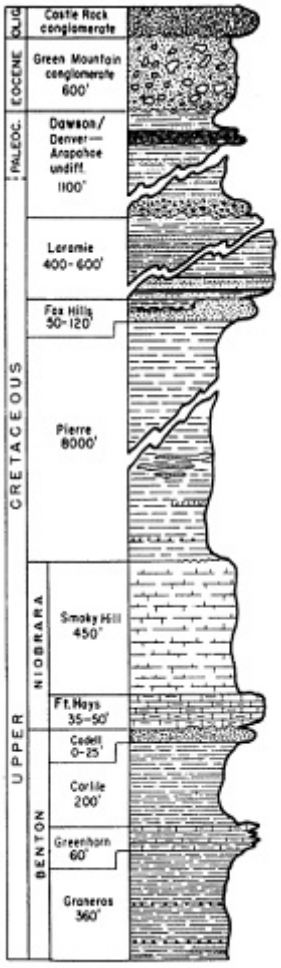
Travel and Stop Overview with approximate Travel times

	Travel	Points of Interest	Drive Time min	Distance Miles	Stop Time min	From	To
CSM	CSM	Denver Basin Overview	0	0	15	08:30 AM	08:45 AM
Stop1	Greenland Exit - Rattelsnake Butte	Short Stop: Overview of Wall Mntn Tuff Eruption	60	58	15	09:45 AM	10:00 AM
Stop2	Garden of the Gods North Entrance	Garden Gods Geology & Walk	30	26	30	10:30 AM	11:00 AM
Stop3	Manitou Springs	Manitou Springs Mineral Water Hydrogeology	20	7	30	11:20 AM	11:50 AM
Stop4	Mueller State Park en route to CC	LUNCH: Pikes Peak Batholith	35	25	20	12:25 PM	12:45 PM
END	Victor Gold Mine	Victor Gold Mine Geology Overview	35	20	15	01:20 PM	01:35 PM



Trip Route and Geology (Google Earth Pro, 2019)

Denver to Colorado Springs (~ 70 mi)



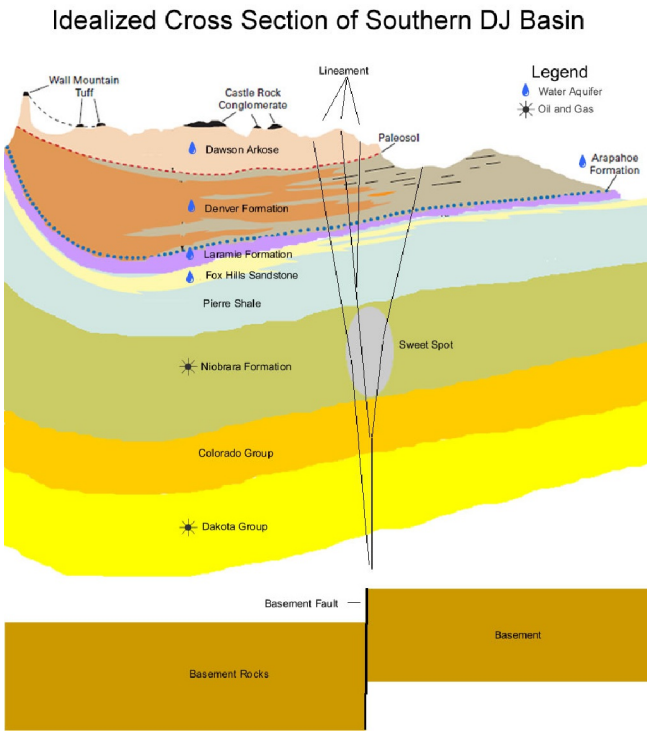
Stratigraphic section of the greater Denver Basin area (from Noe, 1997)

The Denver Basin (aka Julesburg Basin)

The Denver Basin extends from the Front Range eastward to Colorado's eastern border, northward into Wyoming and Nebraska and southward about 50 miles past Colorado Springs. The deepest part is in the Denver area where it is roughly 4,000 m (13,000 ft) in depth.

The basin started forming about 300 mya during the formation of the Ancestral Rockies. This ancestral basin filled with rocks of the Pennsylvanian-Permian Fountain Arkose conglomerate and subsequent formations and later culminated in the interior Cretaceous seaway when about 2,500 m (8,000 ft) of the marine Pierre Shale was deposited.

During the Paleogene Laramide orogeny (65 - 45 mya) and the uplift of our modern Rockies, the Denver basin widened and deepened. The erosional material from these new mountains started to form the coarser alluvial fan deposits of the Arapahoe, Denver and Dawson formations and eventually the Green Mountain conglomerate (see figures).



Idealized cross section of the Denver - Julesburg Basin showing principle formations and important water, oil and gas resource strata (from Scrat2, 2011)

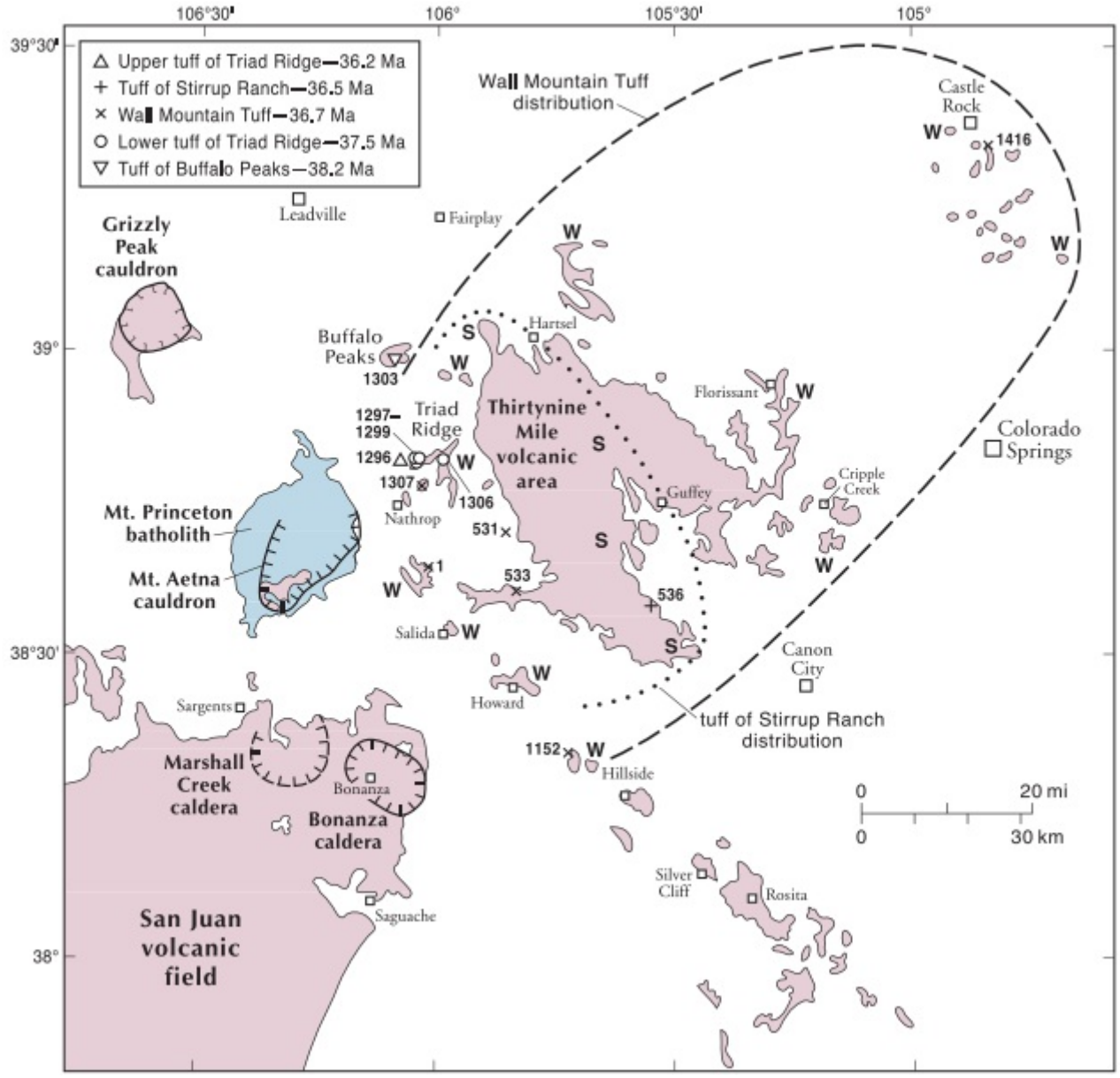
The Denver Basin is an important groundwater and energy resource area, especially oil and gas.

As we drive through Denver southward along the I 25 corridor, we are predominantly traversing the Arapahoe, Denver and Dawson formations.

Dawson Fm	Early Paleocene; > 300 m (1,000 ft+); alluvial fan and fluvial deposits; arkosic sandstone with some mudstone (Scott, 1962)
Denver Fm	Late Cretaceous - Early Paleogene; 480 m (1,580 ft); alluvial fan, fluvial and marsh deposits; claystone, siltstone, sandstone with some conglomerate (Machette, 1977)
Arapahoe Fm	Late Cretaceous; 90 m (300 ft) thick; alluvial fans; conglomerates, claystone and quartz sandstone (Van Horn, 1957)

Evidence of a Volcanic Catastrophe

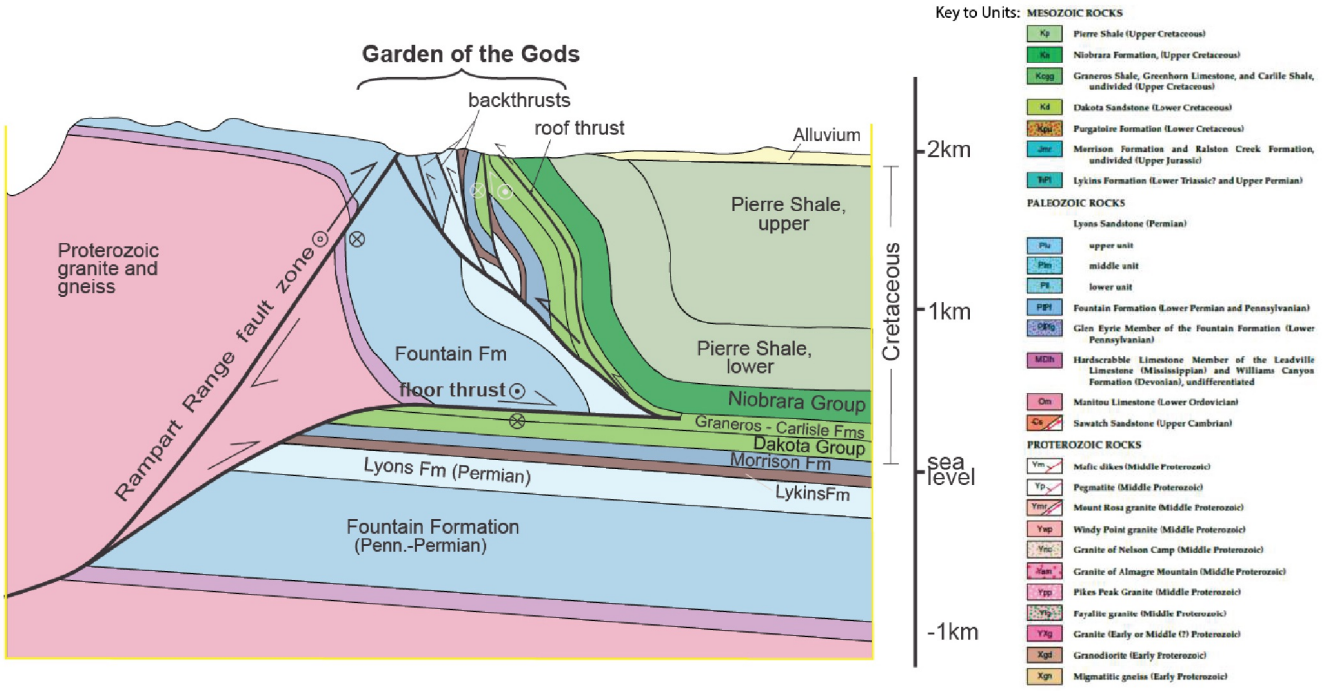
As we approach Castle Rock on our way to Colorado Springs, a new formation prominently caps the underlying strata, making resilient buttes reminiscent of castles. The Castle Rock Conglomerate, the youngest unit within the Denver Basin, contains fragments and pieces from older sedimentary rocks as well as the crystalline igneous and metamorphic lithologies. Added in the mix is the so-called Wall Mountain Tuff, a 36.7 my old rhyolitic ignimbrite, formed by the cataclysmic eruption of the 140 km (90 mi) distant Mt. Princeton volcano. The generated pyroclastic flows inundated the area and are also responsibly for the extinction event at the Florissant Fossil beds near Colorado Springs. Here at Castle Rock was the outer edge of the pyroclastic event, and the resulting tuff was fragmentally imbedded within the castle rock conglomerate (Evanoff, 2007).



Extent of the Wall Mountain Tuff (pink) originating from the Mt. Princeton – Mt Aetna volcanic complex (blue). (from McIntosh and Chapin, 2004)

Garden of the Gods (*A FREE park with NO entrance fees*) - if you have never been there, it is really worth your visit

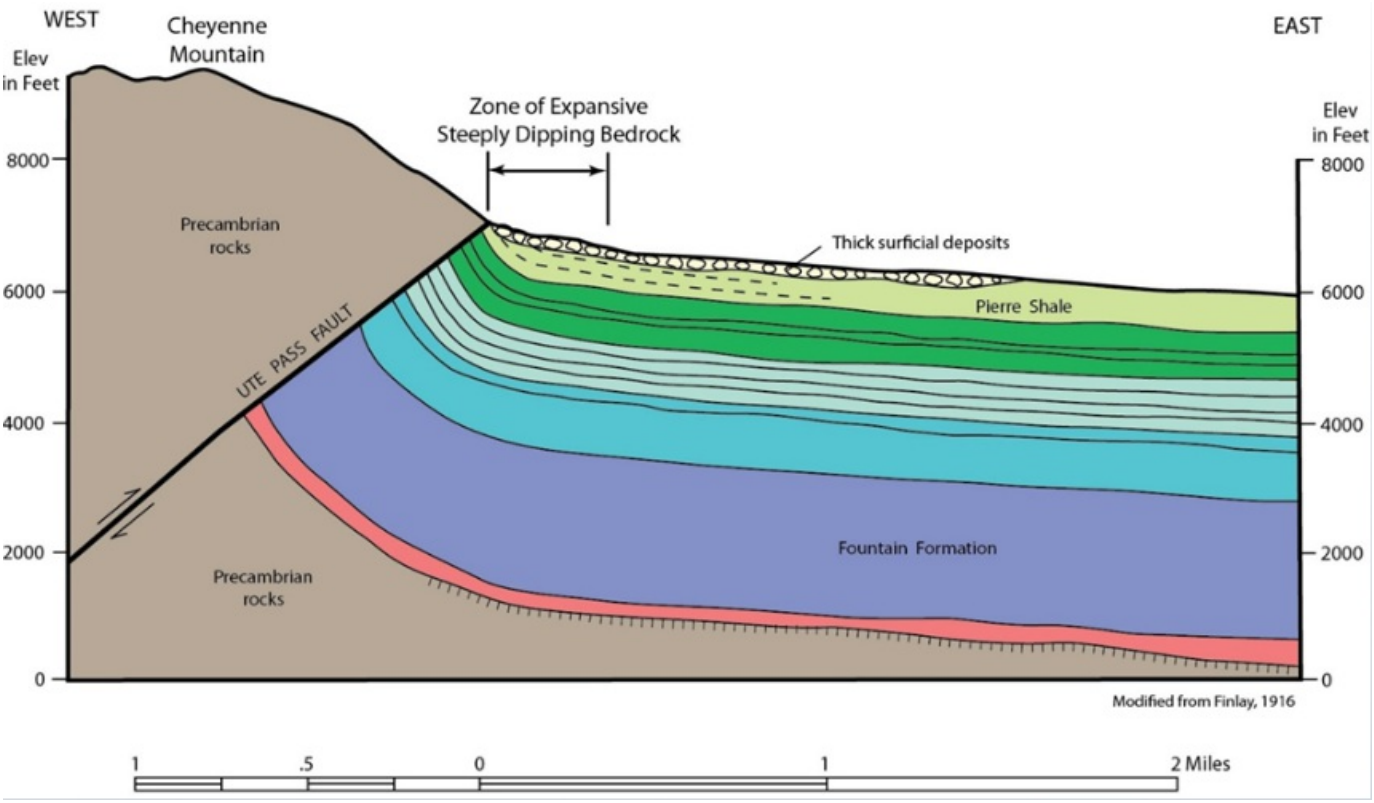
As we continue toward Colorado Springs we basically follow the Rampart Range with its nearly horizontal strata. Near the famous Air Force Academy campus to the west we can see Pleistocene pediments forming terraces (Chronic, 1980). Approaching the city of Colorado Springs, we will enter the beautiful Garden of the Gods geologic area, with its orange red, almost vertically protruding hogbacks. Here, faulting has caused an incredible thrust fault system to develop (figure below). Next to obvious surface faulting, a prominent floor thrust in the subsurface causes near horizontal layers to laminate upward in an incredible display of force (Siddoway and others, 2013), causing the enchanting features that make Garden of the Gods famous.



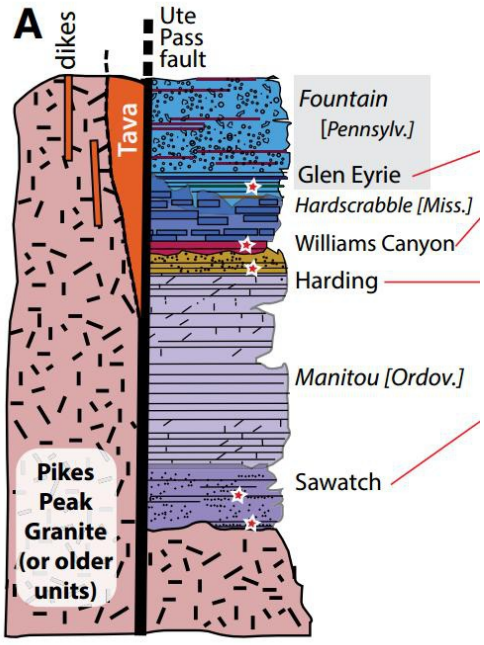
Vertical rock fins at Garden of the Gods Park

Cheyenne Mountain

At the south end of Colorado Springs majestic Pikes Peak, composed of 1 bya old granite, is clearly visible to the west. The Colorado Springs area exhibits Paleozoic sedimentary units not present in the Denver area. However, to the south of Pikes Peak near the famous Cheyenne Mountain military complex, the major Ute Pass thrust fault causes the Cretaceous Pierre Shale to be in direct contact with the Precambrian bedrock (see figure). The official Colorado Front Range geographic area ends south of Cheyenne Mountain.



Cross section of the Cheyenne Mountain complex showing the Ute Pass thrust (from White, 2017)

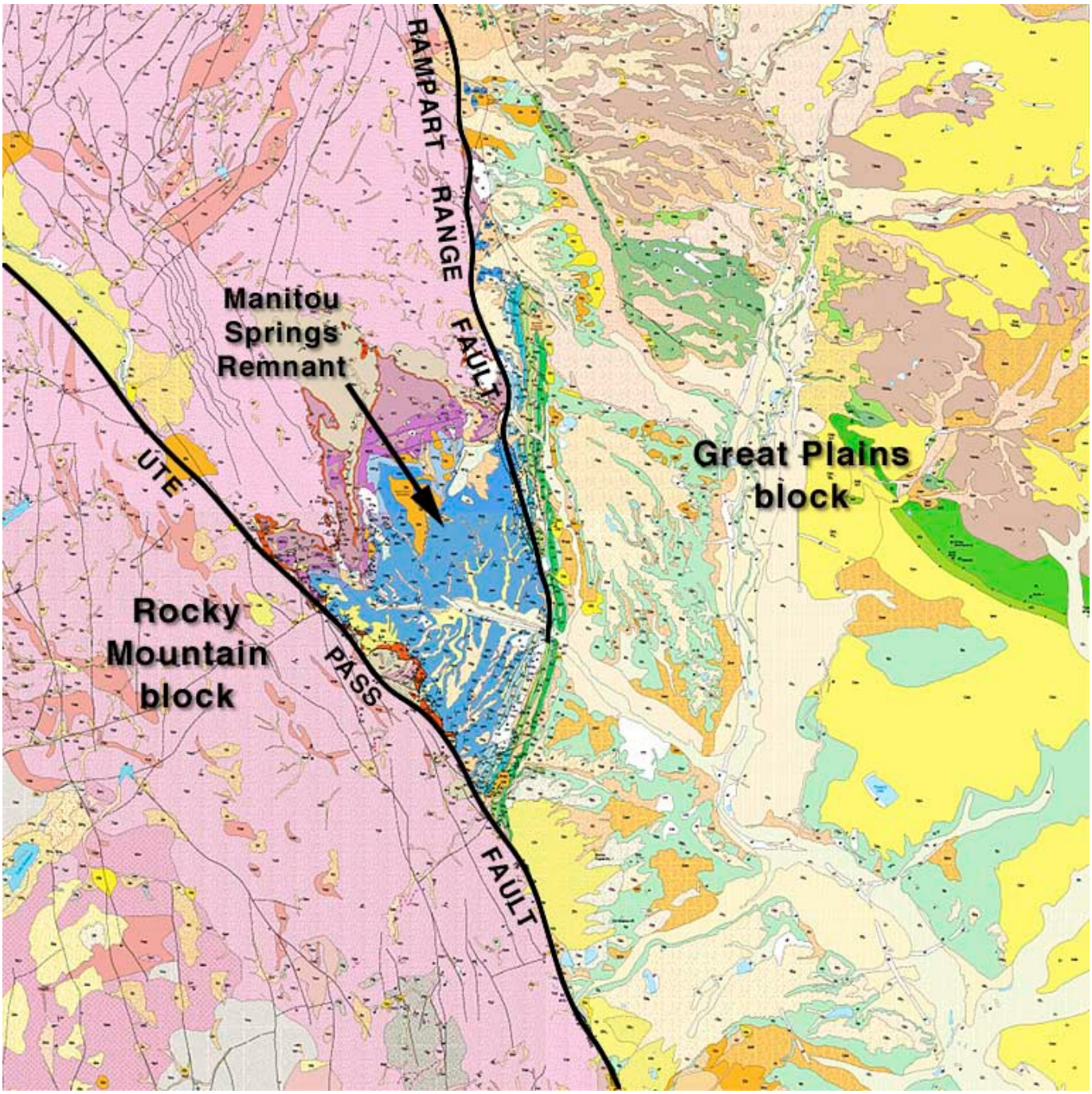


A Geologic Enigma - The Tava Formation

An interesting discovery in the area by Christine Siddoway and George Gehrels in 2014 is a very unusual soft sediment deformation. Sandstone dikes penetrate the Precambrian Pikes Peak granite and have been named the Tava Formation. While the process of the sandstone injection is still unclear, it is surmised that large earthquakes in the form of natural fracking events are likely instigators. Zircon studies revealed an approximate geochronology of emplacement around 750 million years ago in the Cryogenian Period (Siddoway and Gehrels, 2014).

Manitou Springs - Geology you can literally "drink"

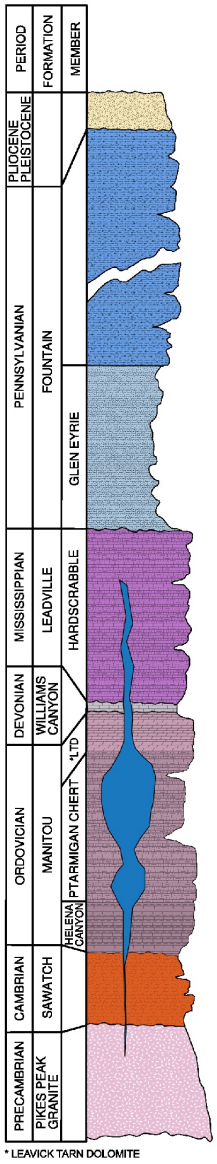
The vicinity around Manitou Springs in Colorado is known for its mineral waters, which are naturally carbonated. These springs occur only in a small segment which is bound by the Ute Pass and the Rampart Range thrusts as indicated in the figure.



Geologic Overview Map (from Mineral Springs Foundation, Manitou Springs, Colorado | Geology, 2015)

The chemistry of each of the seven springs distributed throughout the city is slightly different. Ongoing hydrochemical research at Metropolitan State University of Denver indicates a possible smaller fault block controlled system explaining the compositional differences.

The Manitou Springs aquifer system appears to be concentrated in the following Paleozoic formations as indicated in the stratigraphic column below:



The bulk of the aquifer system sits within the Ordovician Manitou limestone sequence. The effervescent characteristic of these natural occurring mineral waters has been attributed to the liberation of carbon dioxide in the calcareous rock formations comprising the aquifer. However, as in Europe, where natural CO_2 waters are very common, helium isotope studies suggest an upper mantel derived carbon dioxide source, where the gas migrates upward into the aquifer through the Ute Pass and Rampart Range faults. (Mineral Springs Foundation, Manitou Springs, Colorado | Geology, 2015)

Mineral		7 Minute	Shoshone	Wheeler	Navajo	Cheyenne	Stratton	Twin	Iron Geyser
Alkalinity (bicarbonate)	HCO_3	1,310 mg/L	2,561 mg/L	2,439 mg/L	2,317 mg/L	2,439 mg/L	1,951 mg/L	1,585 mg/L	1,463 mg/L
Calcium	Ca	303 mg/L	470 mg/L	440 mg/L	420 mg/L	440 mg/L	370 mg/L	310 mg/L	170 mg/L
Chloride	Cl	96.4 mg/L	270 mg/L	240 mg/L	230 mg/L	240 mg/L	180 mg/L	86 mg/L	190 mg/L
Copper	Cu	-	0.12 mg/L	0.17 mg/L	0.07 mg/L	0.08 mg/L	0.05 mg/L	-	-
Fluoride	F	0.64 mg/L	3.90 mg/L	3.30 mg/L	3.10 mg/L	3.50 mg/L	3.20 mg/L	2.10 mg/L	5.10 mg/L
Iron	Fe	0.54 mg/L	-	0.11 mg/L	-	-	-	-	14 mg/L
Lithium	Li	.277 mg/L	.866 mg/L	.726 mg/L	.705 mg/L	.743 mg/L	.568 mg/L	.233 mg/L	.787 mg/L
Magnesium	Mg	82.6 mg/L	73 mg/L	66 mg/L	82 mg/L	90 mg/L	68 mg/L	90 mg/L	26 mg/L
Manganese	Mn	-	3.00 mg/L	1.60 mg/L	0.78 mg/L	1.50 mg/L	0.42 mg/L	0.0023 mg/L	0.75 mg/L
Potassium	K	19.5 mg/L	72 mg/L	55 mg/L	70 mg/L	79 mg/L	50 mg/L	21 mg/L	74 mg/L
Silica	SIO	22 mg/L	45 mg/L	41 mg/L	41 mg/L	40 mg/L	34 mg/L	17 mg/L	75 mg/L
Sodium	Na	159 mg/L	510 mg/L	460 mg/L	430 mg/L	460 mg/L	360 mg/L	160 mg/L	500 mg/L
Sulfate	S04	96.7 mg/L	220 mg/L	200 mg/L	190 mg/L	190 mg/L	160 mg/L	76 mg/L	210 mg/L
Zinc	Zn	.34 mg/L	.105 mg/L	.097 mg/L	.094 mg/L	.102 mg/L	.072 mg/L	.086 mg/L	.051 mg/L
Total Dissolved Solids	TDS	1,560 mg/L	2,980 mg/L	2,790 mg/L	2,690 mg/L	2,760 mg/L	2,280 mg/L	1,580 mg/L	2,100 mg/L

Hydrochemical composition of the mineral springs analyzed in 2015 (Mineral Springs Foundation, Manitou Springs, Colorado | Geology, 2015)

For fun, do a taste test at each of the springs and see if you can taste the difference in the mineral water composition. Which one do you like best?

Bibliography for Day 6 trip segment

Chronic, H., 1980, Roadside Geology of Colorado: MOUNTAIN PRESS PUBLISHING CO., Missoula, Montana.

Evanoff, E., 2007, The Castle Rock Conglomerate, *in* 2007 GSA Denver Annual Meeting.:

Google Earth Pro, 2019, 2019 CSM Trip Map with Geology.

Machette, M.N., 1977, Geologic map of the Lafayette quadrangle, Adams, Boulder, and Jefferson Counties, Colorado: Geologic Quadrangle 1392, accessed September 6, 2016, at http://pubs.er.usgs.gov/publication/gq1392.

McIntosh, W.C., and Chapin, C.E., 2004, Geochronology of the central Colorado volcanic field: New Mexico Bureau of Geology & Mineral Resources, v. 160, p. 34.

Mineral Springs Foundation, Manitou Springs, Colorado | Geology, 2015, accessed May 12, 2019, at Mineral Springs Foundation at http://manitoumineralsprings.org/geology.html#.

Scott, G.R., 1962, Geology of the Littleton quadrangle, Jefferson, Douglas, and Arapahoe counties, Colorado: U.S. Govt. Print. Off., Bulletin 1121–L, accessed September 6, 2016, at http://pubs.er.usgs.gov/publication/b1121L.

Scrat2, 2011, Stratigraphic Cross Section of the Southern Denver Basin, accessed September 5, 2016, at The Niobrara News at http://www.niobraranews.net/geology/attachment/djcrosssection/.

Siddoway, C.S., and Gehrels, G.E., 2014, Basement-hosted sandstone injectites of Colorado: A vestige of the Neoproterozoic revealed through detrital zircon provenance analysis: Lithosphere, v. 6, no. 6, p. 403–408.

Siddoway, C., Myrow, P., and Fitz-Díaz, E., 2013, Strata, structures, and enduring enigmas: A 125th Anniversary appraisal of Colorado Springs geology, *in* Classic Concepts and New Directions: Exploring 125 Years of GSA Discoveries in the Rocky Mountain Region: Geological Society of America, p. 331–356.

Van Horn, R., 1957, Bedrock geology of the Golden quadrangle, Colorado: Geologic Quadrangle 103, accessed September 6, 2016, at http://pubs.er.usgs.gov/publication/gq103.

White, J.L., 2017, Landslide Susceptibility in the Colorado Springs Area – Geology and History: 60th Annual Meeting of the Association of Environmental & Engineering Geologists (AEG), Colorado Springs.

Public Transportation Field Trip Possibilities within the Denver - Boulder Vicinity

Dinosaur Ridge and Red Rocks Amphitheater, West Alameda Pkwy

Take RTD Bus #21 to Stop Number: 20802 Bear Creek Blvd & W Jewell Ave {1304} or Stop Number: 20786 W Alameda Pkwy & W Jewell Ave {1304}, depending which direction you are going.

Walk west on West Alameda Pkwy for 1.8 miles (36 min) to the Dinosaur Ridge Main Visitor Center. Start your field trip from there.

Follow West Alameda Pkwy across Dinosaur Ridge to the Red Rocks Amphitheater Entrance 1, about 1.4 miles (30 minutes).

From there walk to the Red Rocks Park Geologic Marker & Picnic Shelter and from there to the upper parking lot of the Amphitheater, another 1.5 miles (33 minutes)

Conclude by walking back to the bus stop (around 5 miles, 1 hr 40 min)

Colorado School of Mines Museum and Geologic Trail in Golden

In Golden, take RTD Bus #16 or 16L to Stop Number: 24413 Washington Ave & 13th St {1109}

From there walk up 14th St for four blocks to the Museum

Flatirons Near NCAR in Boulder

In Boulder, take the RTD SKIP Bus to Stop Number: 16688 Table Mesa Dr & Colby Dr

From there walk about ½ mile west along Table Mesa Drive and then turn ½ mile SW on a hiking trail to the NCAR building. From there, many hiking trails will lead into the Flatirons park.