GEL3530 Field Geology: Advanced Geology of the Colorado Plateau (Summer, 2022)

Geology is very much an observational science. You are expected to keep field notes, ideally using a field notebook, and systematically record your observations. Dr. Kackstaetter has extra field notebooks available in his office. We'll be driving three State 7-passenger minivans, Jess Davey's small SUV, and our travel trailer. We'll be leaving from my house hopefully no later than 8:30 a.m. on Tuesday, May 17. Be absolutely sure that you bring an extra blanket because the nights can get very cold, in the past down to freezing.

The *Ancient Landscapes of the Colorado Plateau* provides an excellent source for the paleogeography of the plateau through time. We believe that you'll thoroughly appreciate the other publications for years to come. **Don't forget your camera.**

ALWAYS KEEP THE STRATIGRAPHIC SEQUENCE IN MIND TO HELP YOU IDENTIFY THE VARIOUS FORMATIONS.

Each one of you will have a talking point to be researched prior to the trip. You will become the "expert" on that subject during the trip, mostly related to different formations that we'll study during the trip. You will be graded on your oral presentation given during the trip. Take this assignment seriously. After the trip is over, the student will write a report on their talking point, incorporating additional knowledge and figures obtained during the trip. The report **MUST BE TYPED** (double-spaced with proper margins) and should consist of 5 to 10 pages of text. Make them as interesting as possible by including **properly referenced photographs and figures**; these are encouraged because they enhance student learning and the quality of their reports. The grade on the final exam plus the report and oral presentation will be used to determine the final grade in the course.

Quiet time starts at 10:00 every night. No alcohol of any kind will be permitted on the trip. Every morning we'll get up at 6:00, so take an alarm clock.

Directions to Dr. Cronoble's House:

In general, our house is located near the intersection of Jewell and Garrison at

1768 S. Flower Street
Lakewood, Colorado 80232-6406

303-988-1077 (Home), 303-587-7406 (Cell), and 720-338-1237 (Linda's Cell)

From 6th Avenue, go south on Garrison through lights at 1st Street, Alameda, Mississippi, and Florida (T's with Garrison from west).
From Florida/Garrison light, drive 3 blocks south to intersection of Mexico and Garrison. Turn left (east) on Mexico and then immediately turn right (south) on Flower Street. My house is the 6th house down on Flower on the left (east) side of the street.

If you are coming from Hampden and Wadsworth, drive 2 miles north on Wadsworth to Jewell, and then turn left and go 1 mile west to Garrison. Then from the intersection of Jewell and Garrison, go north a long block and turn right (east) on Mexico and proceed as above.

If coming from I-470, turn north and drive all the way to Jewell (estimate 10 miles) and then follow directions above.

Our white, travel trailer will probably already be hooked up to "Clifford" (Linda's Red Truck) in front of our house.

DO NOT park in front of the house directly across from me. Anywhere else along the street will be fine. But, it will be best if you have someone drop you off because there is limited parking on our street

MAY 17 (Tuesday) – We'll be leaving from Dr. C's house hopefully no later than 8:30. We'll make a gas/restroom stop at Vail at Exit 173. We may get lunch here or later or you may want to make your lunch before leaving Denver.

As we drive west on I-70, see if you can pick out the different formations exposed along the Front Range, i.e., try to pick out the formations exposed west of Denver as well as observing new formations, e.g., the Middle Pennsylvanian-aged, marine/nonmarine Minturn and the Late Pennsylvanian- and Permian-aged, nonmarine Maroon formations that are partly equivalent to our Front Range's Fountain Arkose. The Minturn Formation, well exposed at Vail, is marine and gray at its base and becomes more nonmarine and red toward its top (See Taylor's Stratigraphic Correlation Chart). Also look for the Morrison, Dakota, Niobrara, and Pierre formations. Watch for the contorted bedding in the Pennsylvanian-aged Eagle Valley Evaporites between Eagle and Dotsero, which are well exposed between mile-markers 147 and 133. We will stop at the Gypsum exit (Mile Marker 140) to look at these evaporites. These evaporites are equivalent to the Paradox Formation salts, but they were deposited in the Central Colorado Trough rather than the Paradox Basin in southeastern Utah. The contortions are related to the evaporites themselves. Why?

We'll make a short stop at Dotsero (Mile Marker 133) to look at the Recent (4,150 year-old) cinder cone. What's the composition of the Dotsero volcanics? What was the probable source of the magma?

Glenwood Canyon is fabulous. When we get to Glenwood Canyon, we'll exit at the Grizzley Creek Exit (Exit 121) and look at the geology, especially at the "Great Unconformity," a nonconformity (where sedimentary beds are resting on eroded igneous and/or metamorphic rocks) that separates the Late Cambrian Sawatch Sandstone (about 505 myo) from the Precambrian (about 1.7 byo). What conclusions can you draw from the fact that this nonconformity exists?

Referring to the Glenwood Springs-Rifle area stratigraphic section, the formations overlying the Late Cambrian Sawatch Sandstone include the Late Cambrian Dotsero (Peerless Formation exposed west of Colorado Springs), the Early Ordovician Manitou Limestone

(about 490-480 myo), the Late Devonian Chaffee Group (the Harding Sandstone and Dyer Limestone and about 370-360 myo), and the Early to Middle Mississippian Leadville Limestone (about 360-330 myo). What kind of unconformity (100 million-year plus) separates the Early Ordovician Manitou Limestone from the Late Devonian Chaffee Group? What does this unconformity tell us about the stability of this portion of the North American Continent during this missing time? Recalling your historical geology class, what stratigraphic sequences are represented by these formations? Which sequence is missing?

When we reach the Rifle area, we'll see Tertiary-aged rocks, including the Eocene Wasatch and Green River formations. At first glance, how would you differentiate between them? Do you know what economic product is locked up in the Eocene-aged Green River Formation? As we approach Grand Junction, observe the Late Cretaceous Mancos Shale and Mesaverde Sandstone. Which of these formations is made of more resistive rocks, forming the "Book Cliffs?" The Mancos Shale is, in part, equivalent to the lower Pierre Shale in eastern Colorado.

The Fruita exit is at Mile Marker 19. We'll buy gas for the vehicles, and then we'll drive south toward the Colorado National Monument. As we drive south, what formation are we driving on in the valley as we approach the monument? **Always keep the stratigraphic sequence in mind to help you identify the various formations.** You will be able to see the Wingate Sandstone cliffs with the Kayenta Formation on top and then the Entrada Sandstone. Are there any formations in this portion of the stratigraphic section that are missing? Are the rocks of the cliff flat lying? How about the rocks immediately north of the cliffs...are they flat lying?

After setting up camp (for two nights) at the Saddlehorn Campground, we'll spend the rest of the day discussing the geology and geomorphic features of the monument, including the different formations, their ages, their rock types, and their depositional environments. It is imperative that you know the stratigraphic section of the Colorado National Monument by the time you get to the campsite. You will be tested on it about 8:00 after dinner **(PART OF YOUR FINAL GRADE)**.
Students will discuss the Triassic-aged Moenkopi and Chinle formations, the Wingate Sandstone and Kayenta formations, and the Entrada and Morrison formations while we're here. For your information, the **Early Jurassic Glen Canyon Group** consists of the Wingate Ss, Kayenta Fm, and Navajo Ss. The **Middle Jurassic San Rafael Group** consists of the Page Ss, Carmel Fm (formerly called the Dewey Bridge member of the Entrada), Entrada Ss, Curtis Fm, and Summerville Fm. **The Morrison Formation is Late Jurassic in age.** After dinner, someone will discuss orogenic processes, orogeny versus epeirogeny. Which one of these has resulted in the Colorado Plateau? What are the hypotheses/mechanisms associated with epeirogenic uplift? Some one will also discuss the weathering processes in the plateau region.

MAY 18 (Wednesday) – I plan to travel through the monument and then drive through the Unaweep Canyon to Gateway. If we do, when we leave the monument, we'll drive to the turnoff to Whitewater (at the intersection of Highways 141 and 50). We'll then drive south-southwest on Highway 141 about 9 miles to Cactus Park Road and make a stop to look at the Gunnison River Gravels (See reference article). What formations can you identify in the

distance? Then, from Cactus Park Road we'll drive about 5.3 miles to Divide Road.

Along Divide Road we'll get an excellent view of another major nonconformity, but this one separates the Late Triassic Chinle (about 210 myo) from the Precambrian (about 1.7 byo). Is this the same nonconformity that we saw in Glenwood Canyon? Why are the Lower Paleozoic rocks that were present in Glenwood Canyon absent here? Hint: Go to your handouts and find the packet with the "Western U.S., Figure 57" as its first page and then find "Figure 2. Stratigraphic column, Paradox Basin and Uncompahgre highland." We'll also get a great view of Unaweep Canyon, which crosses the Uncompahgre Plateau. Do you think that West and East Creeks carved Unaweep Canyon? How do you think Unaweep Canyon was formed (See Unaweep Canyon reference material)? Is the answer to this question related to the Gunnison River Gravels? Someone will discuss the origin of Unaweep Canyon at this stop.

Immediately after we get through Unaweep Canyon we'll make a stop at the north end of Gateway (Turnoff on 6^{3} Road) to look at rocks of the Late Pennsylvanian to Middle Permian-aged (about 310-270 myo) Cutler Group Undivided for the first time. What conclusions can you draw regarding proximity of these rocks to the Cutler's source area and what geomorphic feature was the source area for the Cutler Group? Are these deposits grain-supported or mud-supported? Based on your answer to this question, what might you conclude regarding the depositional environment of the Cutler at this location? Then, we'll return to the monument.

May 19 (Thursday) – After breakfast, we'll leave the Colorado National Monument and drive west on I-70 to US-191 (Crescent Junction), turning south toward Moab. We'll make a quick stop a few miles south of the intersection where you'll be able to look down the axis of the Salt Anticline of Arches National Park, and then we'll drive to Ken's Lake Campground in Moab where we will camp for 2 nights.

Unfortunately, because of a new reservation system, we won't be able to go into Arches National Park. So, after setting up camp, we'll drive north on US-191, turning west onto State Hwy 313 (the turnoff to Dead Horse Point State Park and Northern Canyonlands National Park). We'll make a stop at one of the first viewpoints. What formations can you identify? Someone will discuss the Navajo Sandstone at this stop, including what happens to its thickness from Zion National Park to Arches National Park to the Colorado National Monument. Our next stop will be to look at the effect of hydrocarbon migration through the Entrada Sandstone at Dubinky Wash (refer to the article related to the reduction of iron oxides by migrating hydrocarbons) as well as several very large water-escape pipes/structures in the Carmel Formation. We will access Dubinky Wash by turning west on a dirt road near Mile Marker 14; we'll veer right after about 1.5 miles and then drive about 5 miles to a junction where we'll veer left for about another 2 miles.

Once back on Highway 313, we'll then go to Dead Horse Point State Park (we don't have an entrance-fee waiver). Up to this point you'll be wondering if we can show you anything more beautiful than what you've already seen. Be prepared. The view from Dead Horse Point is breathtaking. **What formations can you identify?** What are the blue lakes to the east of Dead Horse Point? Do you think these lakes pose any kind of environmental hazard? The mountains you can see to the west are the Henry Mtns, to the south are the Abajo Mtns, and to

the east are the Las Sal Mtns. Someone will discuss these laccolithic mountains, including when and how they formed as well as the rock types. Do they have any relationship to the origin of the Colorado Plateau? What are entrenched meanders? How and when were they formed? Needless to say, we'll spend time talking about the geology. Depending on the time, we'll drive south through Northern Canyonlands and go to Upheaval Dome. What process or processes do you think formed the dome?

MAY 20 (Friday) – We need to leave early and drive south on US-191 about 40 miles to State Hwy 211 and turn west toward Southern Canyonlands National Park. Being able to identify the Carmel Formation (formerly called the Dewey Bridge member of the Entrada) helps you determine where you are in the stratigraphic section. In this area, the Carmel separates the Navajo Sandstone (below) from the Entrada Sandstone (on top).

We will proceed to Southern Canyonlands National Park, making a brief stop at Newspaper Rock, then to Big Spring Canyon, and eventually to the Elephant Canyon Trailhead for the death march (11 miles) into the Needles District of Southern Canyonlands. In parts of Northern and Southern Canyonlands, the Permian-age Cutler Group can be subdivided into the basal Lower Cutler, the Cedar Mesa Sandstone, The Organ Rock Shale, and the uppermost White Rim Sandstone (well exposed from Dead Horse Point). Most of the rocks exposed in the Needles District as well as on the BLM land to the east of Southern Canyonlands belong to the Cedar Mesa Sandstone. Hopefully, we'll have time to go for a dip in a pothole associated with Indian Creek on BLM land located about 4 miles outside of the entrance to Southern Canyonlands along Lockhart Basin Road. So, bring your swimming suits. This area also contains a number of Anasazi ruins. Perhaps we will skip the death march, concentrating our time on Big Spring Canyon and the BLM land. If we decide to skip the death march, you should plan to return in the future and do the hike into the Needles District, spending several hours in the Joint Trail. Regardless, we'll return to our Moab campsite after leaving Southern Canyonlands.

May 21 (Saturday) – We will leave Moab and drive northeast on State Hwy 128 about 30 miles to the Dewey Bridge Group Campsite where we'll camp for two nights. As we drive northeast on Hwy 128, determine which formations we're driving through. When we reach the campground, what formations can you identify? After setting up camp, we'll drive back to Fisher Towers. What formations can you identify from this viewpoint? Can you find the contact between the Moenkopi and Cutler Group? **Note: As the crow flies, Fisher Towers are only about 16 miles west of Gateway.** Is the Cutler Group still undivided? Has the depositional environment of the Cutler Group changed? Try to visualize what the region looked like millions of years ago, i.e., the **paleogeography**. For example, during Permian time (about 286 to 245 million years ago) during the deposition of the Cutler Group, how did the depositional environment of the Cutler change from near its source area, the Ancestral Uncompahgre Mountains, southwestward to where the Paradox Basin was? What would you look for in the Cutler rock types to help you answer this question? Can you see an angular unconformity to the north? What are the ages of the Moenkopi and Chinle formations? Do you think the unconformity is related to salt movement associated with the Pennsylvanian Lower Hermosa Group (the Paradox Formation)? Why? If so, can you conclude anything about when salt movement occurred?

On the final exam you'll be asked to discuss the lateral changes, called facies changes, within the Cutler Group, during Cedar Mesa time, from its source area southwestward toward the Paradox Basin. BE ABLE TO DISCUSS THE RELATIONSHIPS SEEN AT GATEWAY, FISHER TOWERS, AND SOUTHERN CANYONLANDS, INCLUDING THE NEEDLES DISTRICT/BLM LAND AND BIG SPRING CREEK.

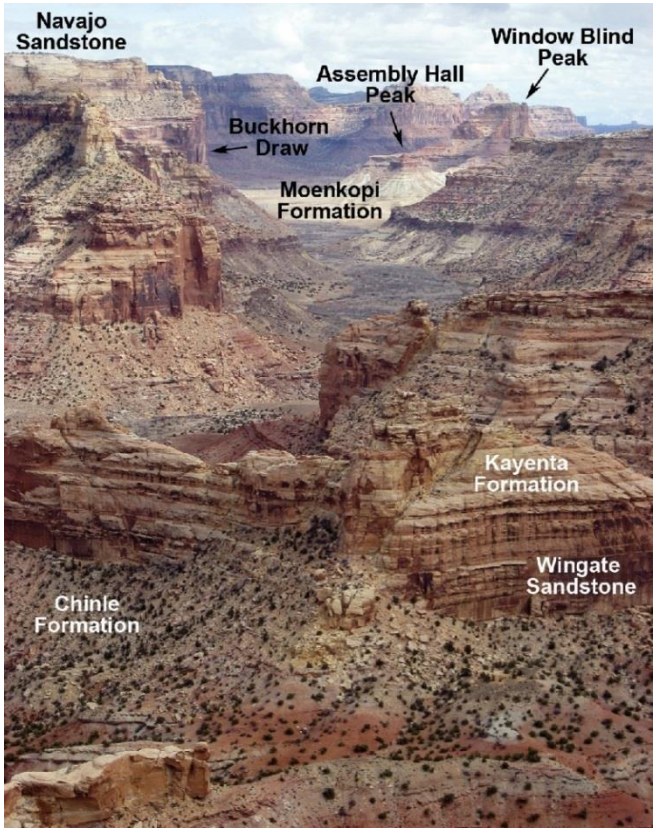
May 22 (Sunday) – We'll drive southeast on Highway 128 and to the turnoff to Onion Creek. What formations are exposed along Onion Creek? For fun, how many times do we cross Onion Creek? Why do you think it is called Onion Creek? What formations do we drive through during our trip up Onion Creek? What formation is exposed when we reach the "top" of Onion Creek? What is the predominant rock type of the formation? Have you seen anything similar to it earlier in the trip?

We'll then drive to the La Sal Loop Road. We'll make a brief stop and observe a white sandstone to the west. This may be some White Rim Sandstone, the uppermost formation of the Cutler Group. Then, we'll complete the La Sal Loop Road, stopping several times. The Road ends at US 191 south of Moab. We'll stop at Moab's City Market for supplies, and on our way back to our campsite on Hwy 128, we'll stop at Mile Marker 10 where we will look at a prograding Gilbert-type delta in the Chinle. Can you see where the topset beds interfinger with the foreset beds? We will also discuss the Chinle's crawfish burrows.

May 23 (Monday) – We'll leave our campsite and drive to US 191, turning north to I-70. We'll drive west on I-70 through a spectacular road-cut as we climb into the San Rafael Swell Be aware of the formations we are driving through and note the change in dip angle of the various formations as we approach the top of our climb. Continuing on I-70 about 15 miles from the San Rafael Swell overlook, our exit will be UT I-70 EXIT 131, where we will turn around, and after a short stop, go back east. Just before we climb down out of the Swell, we will stop at a spectacular view area, overlooking the monocline from the west.

The San Rafael Swell is a large kidney shaped asymmetrical anticline about 75 by 40 miles (121 by 64 km) in size. We will drive right through the middle of this spectacular feature, entering the steepest anticlinal limb from the East. The Swell was pushed up during the Paleocene Laramide Orogeny, about 60-40 million years ago.

The following is based on a description from the Utah Geological Survey: "The upwarp resulted from compressional forces in the Earth's crust about 40–70 million years ago. This mountain-building episode uplifted other areas as well, such as the Rocky Mountains to the east and the Uinta Mountains to the north.



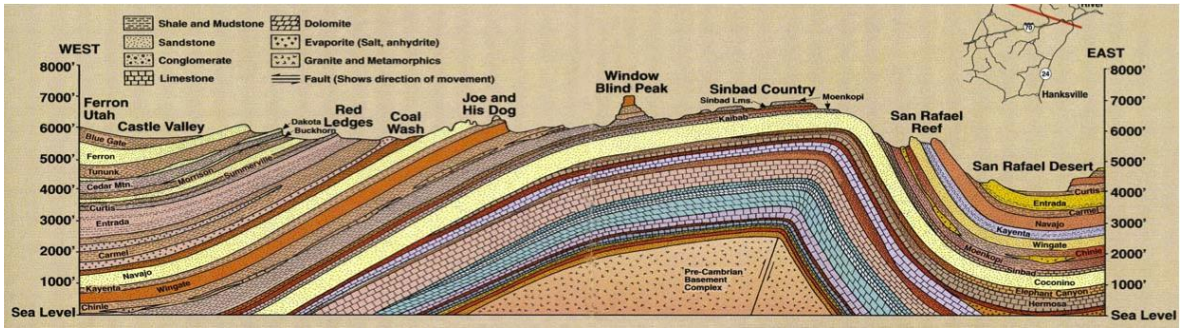
Millions of years later, erosion began in force, eventually removing thousands of feet of rock from the Swell's crest, exposing older rocks (about 300 million years old) in the middle region of the Swell surrounded by a ring of younger rocks (ranging in age from 100 to 230 million years old).

Numerous canyons were eroded into and through the Swell by rivers and streams. The San Rafael River, the largest river in the north part of the Swell, slices across the Swell, cutting deepest along the 3-mile stretch of the Little Grand Canyon.

As you enter the Swell from the northwest, you follow geologic history back in time. From youngest to oldest, the strata include mostly sandstones of the Carmel Formation, Navajo Sandstone, Kayenta Formation, Wingate Sandstone, Chinle Formation, and Moenkopi Formation, which were formed in a variety of depositional environments (rivers, deserts, and shallow seas).

Driving on Wedge Road to the Overlook you cross the Carmel Formation, which is composed of alternating beds of light-grayish limestone and light-brown fine-grained sandstone. The rock formation exposed at the edge of the Overlook is the Navajo Sandstone, which is probably the most famous rock formation in Utah. It is composed of mostly light-brown to white sandstone, and is sometimes seen as sloped domes or rounded knobs reminiscent of the ancient sand dunes from which it formed.

The Navajo Sandstone is also present as you first turn onto Buckhorn Draw Road, where you can see a three-toed dinosaur footprint on a ledge 10 feet up on the left side of the road. The underlying Kayenta Formation consists of reddish-brown sandstone and siltstone that forms slopes and benches.



As you continue driving southeast on Buckhorn Draw Road, you see the red and pale orange vertical cliffs of the Wingate Sandstone which are home to the well-known Buckhorn Draw rock art panel. The Chinle Formation is composed of green-gray sandstone, red-brown sandstone, gray-brown limestone conglomerate, and maroon shale.

As you exit Buckhorn Draw and cross over the San Rafael River, you can see Assembly Hall and Window Blind Peaks towering overhead. The formation exposed at the bottom of these peaks is the Moenkopi Formation, which is composed of red-brown fine-grained sandstone and siltstone.

We will return east on I-70 to the Hwy 24 exit, turning south for about 25 miles to the turnoff to Goblin Valley State Park where we'll camp. As we drive south on Highway 24, you will be able to see the eastward-dipping San Rafael Swell. You'll be able to see almost vertical Triassic and Jurassic beds. Repeating myself, the **Glen Canyon Group** consists of the Early Jurassic Wingate, Kayenta, and Navajo formations, and in this area the **San Rafael Group** consists of the Middle Jurassic Carmel, Entrada, Curtis, and Summerville formations. The Morrison Formation is Late Jurassic in age.

As we drive southward toward Goblin Valley, what formations can you identify? Can you find the Morrison Formation? Have you noticed that the nature of the Entrada Sandstone has significantly changed? Is this related to a facies change (time-equivalent units) in the Entrada Sandstone? How has it changed? Before hiking Goblin Valley, someone will discuss the Curtis and Summerville formations.

We'll leave Goblin Valley and drive south about 20 miles to Hanksville and continue west on Highway 24 (about 35 miles) to Capitol Reef. We'll cross the Waterpocket Fold. What is the Waterpocket fold? What formation creates the "capitol domes?" As usual, **always keep the stratigraphic sequence in mind to help you identify the various formations.** As we drive through Capital Reef, what formations can you identify? Note: there is a basal member of the Late Triassic Chinle and above the Early Jurassic Moenkopi, called the **Shinarump** member of the Chinle.

We'll drive through Capitol Reef National Park on our way to the Doctor Creek Campsite (at the north end of Fish Lake) where we will camp for three nights. We will drive through Capital Reef, eventually turning north on Hwy 72 at Loa and then through Fremont, turning left onto Hwy 61 for about 10 miles to our campsite.

May 24 (Tuesday) – We'll return to Capitol Reef, making several stops, including the Goosenecks Overlook, Chimney Rock, the Narrows (a man-induced, eroding slot canyon), soft-sediment deformation in the Navajo Sandstone and an excellent example of an angular unconformity. Then, we'll drive to the Notom exit, turning south and driving a short distance to an outcrop of the Entrada Sandstone. Why is the sandstone white? Has the nature of the Entrada changed from what you saw near Goblin Valley? Are we looking at a facies change? Then, we'll return to our campground.

May 25 (Wednesday) – After breakfast we'll drive back through Capitol Reef to the turnoff at Mile Marker 91. This 4-wheel drive trip takes us to the Bentonite Hills and Cathedral

Valley, including stops at the Gypsum Sinkhole, Glass Mountain, and igneous intrusions. Be sure to bring your camera for we will see some of the most spectacular geology of the park. This trip will take most of the day.

GEOLOGY: Note: Stratigraphic Sections for many of the places visited in Utah's West Desert can be downloaded at:
http://www.utahgeology.com/stratigraphymap.htm

May 26 (Thursday) – After breakfast and packing up camp we will continue westward on Hwy 24 crossing some Pliocene Basalt and after the road turns northward mostly Miocene Volcanic Rocks until we reach Burrville, UT. Continuing north on Hwy 24, more volcanics will appear toward the west of the road, namely the Late Eocene to Oligocene Isom Fm (tuff) and Needles Range Fm (29 my, ash-flow tuff) and the Bullion Canyon Volcanics, until we turn westward onto Hwy 119 toward Richfield. UT. Right after the turn we will drive approximately for 2 miles through a small sliver of the middle Jurassic Arapien Shale (Summerville Formation, Entrada Sandstone and Carmel Formation).

You will notice that we have left the familiarity of the Colorado Plateau behind, and we are now entering the geology of the Basin and Range. This system is one of the largest Horst and Graben structures in the world, spanning from the edge of the Colorado Plateau in Utah all the way through Nevada to the eastern part of California, roughly 400 miles. This extensive system consists of alternating mountain ranges and valleys with a more or less S-N strike direction. All these mountain ranges are bound by repeated normal faults, many with present or historic geothermal activities and thus their own unique set of mineralization. Many mining districts of Nevada and some in Utah owe their riches to these fault systems.

In Richfield, UT it is time to have lunch (or go out to lunch), go shopping (stock up) and gas up.

We will then continue southward on Hwy 118 for approx.. 7 miles to the small community of Monroe, UT. Here we will turn East on E 300 N and follow the road to the edge of the village to about N 540 E. There are some vacant lots and side streets where we can park. After this point E 300 N becomes more like a Jeep trail going east, and if nothing has improved, it will not be suitable for all cars, definitely not trailers. We will then hike a short distance of about ½ mile or so east to the Red Hill Hot Springs at 38°38'22.9"N 112°05'58.1"W. The red coloration of the rock altered by the hot springs should be easily visible from our parking spot.

Even though the Red Hill Hot Springs are privately owned, the owner turned the location into a public park to be enjoyed by everyone. Please respect the posted rules and regulations to keep it this way. Do NOT confuse the Red Hills Hot Springs with the nearby Mystic Hot Springs Resort which looks similar but is a pay-for-use outdoor spa facility. The Mystic resort is about ½ mile southwest of the Red Hill Springs site at the end of E 100 N street.

The Red Hill Hot Springs are located within the Miocene Volcanic Rocks previously encountered during our drive toward Richfield. Thick deposits of travertine material are creating visible terraces and coatings on rocks. Red Hill Hot Springs are part of three hot spring areas that extend about 6 miles (10 km) at the southern end of the Sevier Valley. The springs -- Monroe, Red Hill, and Joseph – were originally included in the Monroe-Joseph Known Geothermal Resource Area (KGRA). The springs are associated with Quaternary normal faults which offset widespread mid-Tertiary, intermediate volcanic rocks erupted from the Monroe Peak and Mount Belknap calderas, and other sources farther westward (Mabey and Budding, 1994).

The Monroe and Red Hill Hot Springs issue at about 170°F (77°C) near the surface trace of the Sevier fault, adjacent to the Sevier Plateau. The Sevier fault is a 300-mile (480-km) long zone of rupture extending from the Grand Canyon northward into central Utah. Chemical geothermometers suggest maximum resource temperatures of about 230°F (110°C). Maximum measured temperature is 171°F (77°C) at Red Hill Hot Springs and 169°F (76°C) at Monroe Hot Springs. Combined flows for the Monroe-Red Hill system have been estimated at about 320 gpm (20 L/s).

The water geochemistry of the Red Hills Hot Springs is classified as a sulfate-chloride (-bicarbonate) water with the following composition:

T	pH	Li	Na	K	Ca	Mg	Cl	F	SO_4	HCO_3	B	SiO_2
°C		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
76.5	6.3	0.72	590	60	290	34	660	2.8	890	416	2.8	58

After our visit to the hot springs, we will make our way back to I-70 North, and then to Hwy 50 N for an approx. one-hour drive to our campsite at Maple Grove Group Campsite: Scipio, UT +14357435721 Reservation: 0484822301 Group Site A, GPS: 39.021434713708544, -112.0894703891504. Dr. K will join us this evening. After camp set up and dinner you may want to hike ~1,000ft due West to the Late Cretaceous Price River Fm outcrops and investigate.

May 27 (Friday) – This will be a busy day and we should break camp as early as possible, leaving no later than 8am. We will travel to our next campsite at the Oak Creek Campsite and very quickly set up camp. Since May 27 is the first day this campground opens for the season, there should be no one occupying our space. The 66-mile drive is about 1 ¼ hours long following US 50 W northward to Scipio, taking I-15 south to Holden and the continuing on US 50 W to McCormick where we will follow Hwy 125 through Oak City to our Oak Creek Group Campsite Delta, UT +14358969233 Reservation: 0456856683 Group Site 4, GPS: 39.46538770099254, -112.27586464716319.

Please set up camp quickly and don't doddle. The goal is to reshuffle ourselves into the various cars and vans for today's full day of adventure, led by Dr.K. We should pull outy of camp no later than 10am. Don't forget to grab a sack lunch, water and possibly some toilet paper. There will be NO facilities available during our excursions this day.

Our first stop will be in Delta, UT where we will gas up. It is also the last chance to use the facilities. From there we will go north on Hwy 6 for about 5 miles to Rd 174 (or Brush Wellman Rd). Note this road is a paved highway straight into Utah's West Desert area with hardly any traffic. It is part of the Brush Wellman Beryllium mining operation and was required by the State of Utah to shuttle trucks with beryllium ore from the mine to the processing plant. We will drive past the processing plant on the paved road directly to the mine. We will pass a coal fired power plant in the middle of this deserted desert road. As we pass the power plant, look to the north. You will see a small, but beautiful extinct shield volcano called Fumarole Butte.

Fumarole Butte: (39.616°N 112.803°W) Shield volcano; 207 meters (679 ft) high with a diameter of 12 kilometers (7 mi). It last erupted roughly 900,000 years ago during the Pleistocene. The lava at Fumarole Butte has been identified primarily as an "aphyric basaltic andesite" in which tiny crystalline structures are visible. In certain places hot steam vents from cracks and crevasses hence the name Fumarole Butte.

Baker Hot Springs (also called Abraham or Crater Hot Springs in older literature): (39°36'44.24"N 112°43'1.78"W) From the Brush Wellman Highway we will turn onto Hot Springs Road going North and the following Baker Hot Springs Road to the NE to Baker Hot Springs which are right at the foot of Fumarole Butte.

The Baker Hot Springs are somewhat unusual since no fault system has been identified that feeds the springs. The springs themselves are within the Lake Bonneville valley fill deposits. The temperature of the springs is quite high and at 84°C (183°F) it is one of the hottest natural geothermal springs in Utah. Take precaution as you go exploring, especially the drainage creeks from the hot springs, which, despite their distance, do not look hot but still carry scalding water.

The water geochemistry of the Baker Hot Springs is a sodium calcium-chloride type and has the following bulk composition:

T	pH	Li	Na	K	Ca	Mg	Cl	F	SO_4	HCO_3	B	SiO_2
°C		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
84	6.5	1.00	830	57	340	52	1500	2.5	1500	156	0.9	69

Manganese and some small amounts of uranium have been found in the water of Baker Hot Springs.

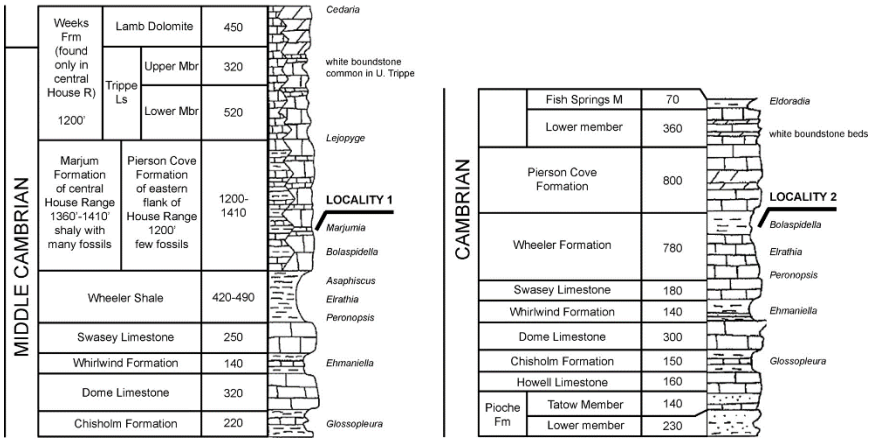
Topaz Mountain: (39°41'12.45"N 113° 5'11.79"W) From Baker Hot Springs we'll visit the infamous Thomas Range by going back to Rd174 and then going west for about 16 miles to Topaz Mountain. What rock type is Topaz Mountain composed of? What does this tell you about its origin? The mountain rightfully carries its name because it is a famous location for gem hunters from all over the nation. As a matter of fact, this place has been set aside by the

State of Utah especially for rockhounds and minerals in any quantity may be freely collected. However, only the use of hand tools is allowed, NO machinery or explosives. After a short lecture on expected mineralization, we will spend 2 - 3 hours or so prospecting for topaz and other unique minerals. Time permitting we may also try for some garnets and the elusive and extremely rare red beryl, only found in three localities around the world. (Clear Red Beryl specimens have sold for $10,000/carat). Students should read:
http://www.minsocam.org/ammin/AM69/AM69_223.pdf

Most of the land is public, but there are some old, grandfathered mining claims in the area. **Note: Please observe all posted mining claims. You are allowed to walk across a claim and investigate. It is, however, illegal to remove any specimens from a claim.**

A couple of additional questions to consider: What is the difference between a rhyodacite, an alkaline rhyolite, and a rhyolite? How come we have rhyolitic rocks and a mafic shield volcano within a short distance of one another?

Cambrian Trilobites: (39.3610611°N 113.2674711°W) We should leave the Topaz Mountain site no later than 3pm toward our fossil collecting site in the Cambrian Wheeler Shale of the House Range.



We will continue on to the House Range Amphitheater (39.3610611°N 113.2674711°W) to collect fossils. Dr. Aaron Adams may have a different collecting locality in mind and we may alter our plans accordingly. As we drive for the next 1½ hours toward the House Range Mountains, take a good look at the stratigraphy. What is meant by the term Basin and Range Province? How did it form? Is the stratigraphy dipping? If yes, in which direction? The House Range of Western Utah is a famous type locality for Cambrian fossils, which can be found here in great abundance. The most common fossils are a great variety of trilobite species. We will spend the better part of the late afternoon collecting fossils and discussing ancient sedimentary environments and stratigraphy. The return trip to our camp will take a good 2+ hours and we will need to plan our departure accordingly. If time permits we will return to Delta for quick shopping, bathroom, and refueling stops. We'll try return to camp around 7:30pm for evening meal and a good night's rest.

MAY 28 (Saturday) – Long haul home, leaving at 9:00. We should be back in Denver around 7:00 p.m.

TRIP SUMMARY with Lodging References

Tuesday, May 17, 2022	Denver - Colorado National Monument with field stops Leaving at 8am with 45 minute field stops at Dotsero and Gypsum and 1 hr lunch break -> Grand Junction around 3:30pm. Geology of CoNM in the evening.	260 mi	Drive time: 4:30
Lodging [Camping]: Colorado National Monument - Saddlehorn Campground. +19708583617 Reservation: 0441818756 Loop A: Space 03, 04, 05, 06 GPS: 39.10523808854993, -108.7328482			
Wednesday, May 18, 2022	Site visits around Colorado National Monument Fill in details.	RT 150 mi	Drive time: 2:30
Lodging [Camping]: Colorado National Monument - Saddlehorn Campground. +19708583617 Reservation: 0441818756 Loop A: Space 03, 04, 05, 06 GPS: 39.10523808854993, -108.7328482			
Thursday, May 19, 2022	CoNatMonument - I70 - US191 - Moab - Ken's Lake Fill in Details.	120 mi	Drive time: 2:00
Lodging [Camping]: Ken's Lake Campground - Moab, UT. +14352592100 Reservation: 0421255173 Loop A: Space 01, 03, 07 GPS: 38.47805338839284, -109.42299400260724			
Friday, May 20, 2022	DEATH MARCH - Southern Canyonlands: Needles & The Maze Leaving Campground at 8:00am to Trailhead (38° 10.692'N, 109° 49.019'W) w/ stop at visitor center. RT 12 mi hike, the return to Camp ~7:00pm. Evening Crash and Eat.	RT 150 mi	Drive time: 3:00
Lodging [Camping]: Ken's Lake Campground - Moab, UT. +14352592100 Reservation: 0421255173 Loop A: Space 01, 03, 07 GPS: 38.47805338839284, -109.42299400260724			
Saturday, May 21, 2022	Ken's Lake - La Sal Mountain Loop road - Dewey Bridge Campground Leaving at 8:00am. From Moab west on 128 to HC 64 -> La Sal Mountain Loop Road. Stopping at La Sal Mountains: Lacolith, Contact Metamorphism (38° 21.925'N, 109° 15.002'W); field stops and exercises. Dewey Bridge Group SIte 11:00am. Afternoon: Fisher Towers, Onion Creek, Arches	50 mi via La Salle Loop Rd 60 mi	Drive time: 1:30 Drive time: 1:30
Lodging [Camping]: Dewey Bridge Group Campsite - Moab, UT. +14352592100 Reservation: 0490065032 Group Site A, GPS: 38.81286343986397, -109.30805840204039			
Sunday, May 22, 2022	Moab - Rainbow Rock - Dead Horse Point - Upheaval Dome - Chinle Petrified Wood - Hermit Shale - Moab Leaving at 8:00am toward Rainbow Rock (Stop 1: 38° 41.095'N, 109° 54.958'W; Stop 2: 38° 41.787'N, 109° 54.763'W)!, Afternoon Dead Horse Point (38° 28.247'N, 109° 44.437'W) and Upheaval Dome (38° 25.579'N, 109° 55.561'W). Evening Fossil collecting at Chinle Petrified Wood (38° 39.302'N, 109° 42.308'W) & Hermit Shale (38° 36.822'N, 109° 37.332'W). Back to Moab around 5:00pm. Evening exercises.	RT 150 mi	Drive time: 2:30
Lodging [Camping]: Dewey Bridge Group Campsite - Moab, UT. +14352592100 Reservation: 0490065032 Group Site A, GPS: 38.81286343986397, -109.30805840204039			
Monday, May 23, 2022	Moab - I70 - San Rafael Swell - US72 - Loa - Doctor Creek Leaving at 8:00am. Multiple field stops at San Rafael Swell (Overview 38.92265584861, -110.43190231161; Black Dragon 38.94552288298, -110.48151245225; Salt Wash 38.83810072528, -111.11185302399). Continue on US 72, right after exit around 38.74715286877, -111.39269103728 look for large Selenite Xls in Mancos. Onward to Loa (Shopping?) And campsite.	200 mi	Drive time: 3:00
Lodging [Camping]: Doctor Creek Campsite: Loa, UT Reservation: 0450733617 Site 25, 26, 27, GPS: 38.54785945875886, -111.74649654264925			

Tuesday, May 24, 2022	Goblin Valley - Capitol Reef NP Leaving at 8:00am to Capitol Reef NP. Many field stops w/ geology of Capitol Reef (estimate 4 hrs). Lunch at one of these field stops! - Goblin Valley in the afternoon -> Doctor Creek Campground around 6:00pm.	RT 240 mi	Drive time: 4:30
Lodging [Camping]: Doctor Creek Campsite: Loa, UT Reservation: 0450733617 Site 25, 26, 27, GPS: 38.54785945875886, -111.74649654264925			
Wednesday, May 25, 2022	Capitol Reef NP Day Excursion: Bentonite Hills - Cathedral Valley - Dikes - Gypsum Sinkhole - Crystal Dome Leaving at 8:00am all day excursion with many field stops and exercises. Back at Doctor Creek Campground around 6:30pm.	RT 150 mi	Drive time: 3:30
Lodging [Camping]: Doctor Creek Campsite: Loa, UT Reservation: 0450733617 Site 25, 26, 27, GPS: 38.54785945875886, -111.74649654264925			
Thursday, May 26, 2022	Doctor Creek - Richfield, UT - Monroe, UT Hotsprings - Maple Grove Camp Leaving at 8:00am to Richfield (Shopping ?). Monroe Hot Springs - Red Hill (38.639806866274, -112.0991585312). Continue to Maple Grove Camp. From Camp hike ~1,000ft due West to the Late Cretaceous Price River Fmt and investigate.	100 mi	Drive time: 2:00
Lodging [Camping]: Maple Grove Group Campsite: Scipio, UT +14357435721 Reservation: 0484822301 Group Site A, GPS: 39.021434713708544, -112.0894703891504			
Friday, May 27, 2022	Maple Grove - Baker Hot Springs - Topaz Mountain - Wheeler Shale - Oak Creek Campsite Leave around 8am Gas-up in Delta, UT - Baker Hot Springs & Shield Volcano (39.6128151465, -112.72902390050) - Topaz Mountain Mineral Collecting (39.688847107817, -113.08968436742) - Wheeler Shale Trilobites (39.238522007747, -113.38168036884) - Oak Creek Camp	270 mi	Drive time: 6:00
Lodging [Camping]: Oak Creek Group Campsite: Delta, UT +14358969233 Reservation: 0456856683 Group Site 4, GPS: 39.46538770099254, -112.27586464716319			
Saturday, May 28, 2022	Oak Creek Group Campsite - Denver Long haul home: Leaving at 8:00am. Additional 2 hours for gasing and additional field short stops will get us back to Denver at around 7:00pm or so.	520 mi	Drive time: 8:30
	TOTAL	**2,420 mi**	**Drive time: 45:00**