GEOLOGY OF CAPITOL REEF NATIONAL PARK

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Introduction

The name of Capitol Reef National Park can be related to the local geology. Resistant, monolithic domes of the Navajo Sandstone reminded early settlers of of the rotundas of capitol buildings and hogbacks of resistant Wingate and Navajo Sandstone formed a barrier to early travelers much as coral reefs form a barrier to sailors. The most prominent geologic feature of Capitol Reef National Park is the Waterpocket Fold, a linear northwest trending monocline (figure 2). From the scenic overlooks you will get nice views of the monocline and the Henry Mountains. Along the Hickman Bridge Trail we will be taking a closer look at one of the stratigraphic units, the Kayenta Formation. Capitol Reef is also an excellent place to observe stream erosion in an arid environment.

Waterpocket Fold

Capitol Reef is located on the eastern margin of the Circle Cliffs Upwarp, a broad asymmetric anticlinal structure with a northwesterly trend that formed during the Laramide orogeny (Stokes, 1986). The western margin of the uplift is characterized by strata that dips gently to the west and the eastern

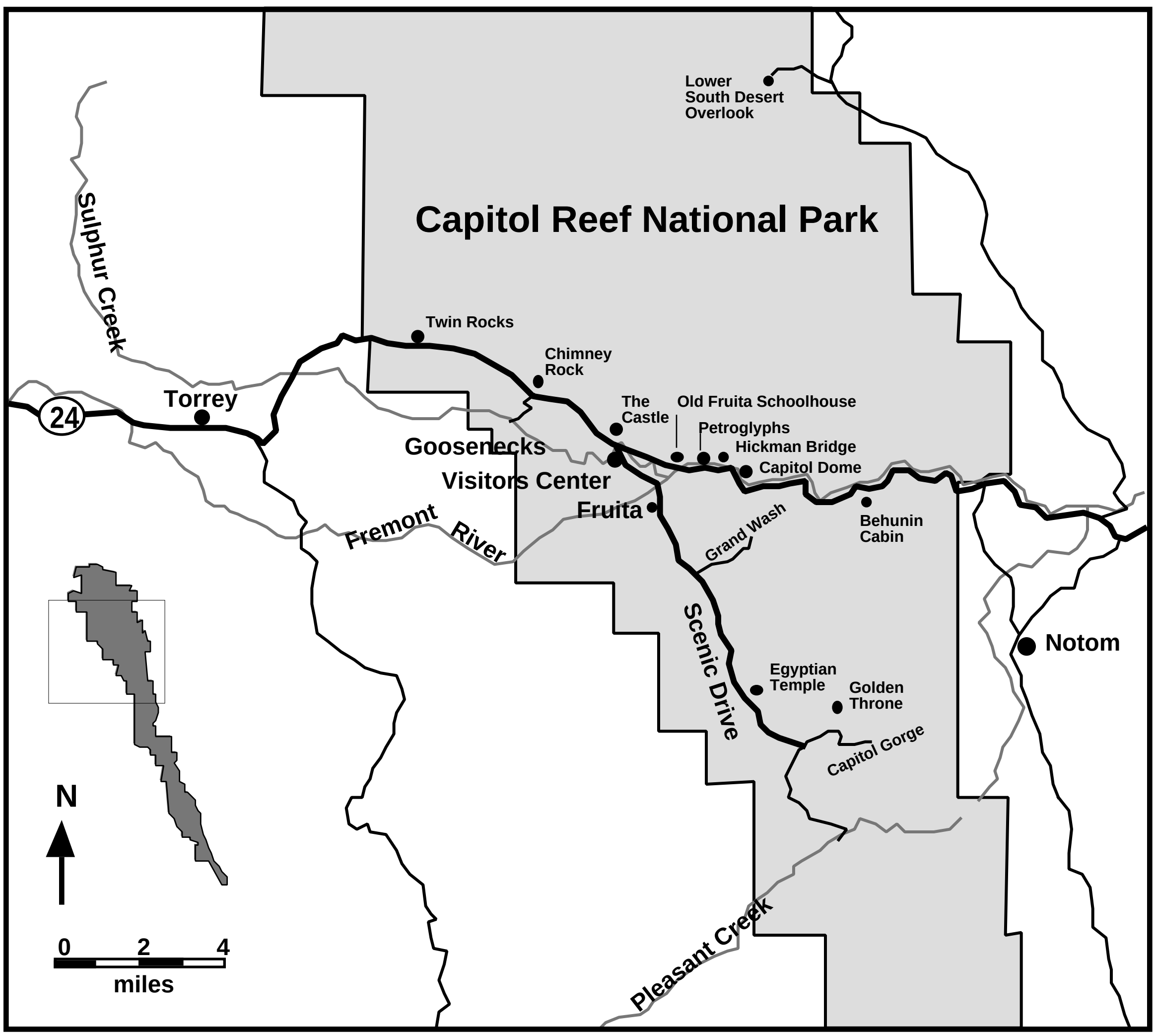

Figure 1. Map of the area around Rt 24 of Capitol Reef National Park (after National Park Service Map).

margin is marked by the Waterpocket Monocline with beds dipping steeply toward the east. The Waterpocket Fold, marked by hogbacks of the Wingate and Navaho Sandstones, is over 100 miles long. Along highway 24 the Fremont River dissects the monocline revealing it's structure. Driving west along highway 24 we pass through progressively older stratigraphic units, because the rocks are tilted, and a complete section of Lower Triassic through Cretaceous is exposed over a short distance (figure 3).

Henry Mountains

The Henry Mountains formed by intrusions of igneous rocks that domed and elevated the strata in the immediate vicinity. Figure 4 illustrates the structure of the surrounding sedimentary units. The structure contour lines represent the elevation of the Ferron Member of the Mancos Shale, which increases toward the center of the intrusions. This is the site of the classic study by Gilbert in 1877 where he coined the term laccolith. A laccolith, as described by Gilbert, is a large igneous body that is forcibly injected between sedimentary strata. However, the Henry Mountains actually consist of a series of cylindrical stocks with branching offshoots of radiating laccoliths that penetrate the surrounding strata (Stokes, 1986). The igneous rocks consist of diorite porphyry with scattered dikes and sills of basalt and aplite, that have been dated to be 44 million years old.

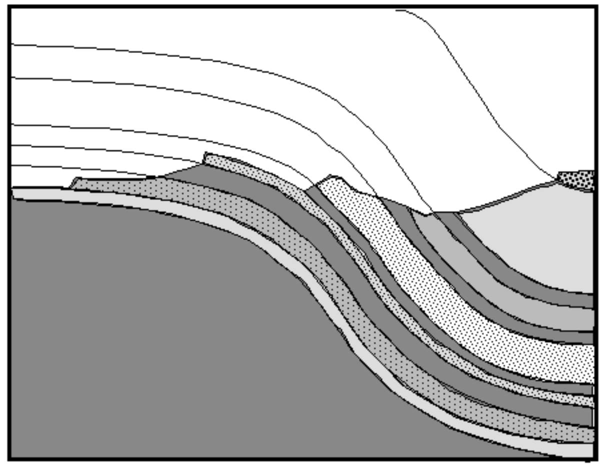

Figure 2. General geologic structure of the Waterpocket Monocline.

Stratigraphy

The rocks at Capitol Reef range in age from Permian through Cretaceous (figure 5), with many of the scenic features carved into the Jurassic, Glen Canyon Group. The Glen Canyon Group consist of the Wingate Sandstone, Kayenta Formation and Navajo Sandstone. Determining the age of the Glen Canyon Group is difficult because of the lack of fossils and controversy still exist as to the stratigraphic position of the Triassic-Jurassic boundary. Initially it was believed that the Wingate and Kayenta Formations were Triassic and the Navajo Sandstone was Jurassic. However, recent studies suggest that the entire Glen Canyon Group is Jurassic in age (Blakey, 1989). The Glen Canyon Group represents two periods of arid eolian deposition (Wingate and Navajo) separated by a period of more humid

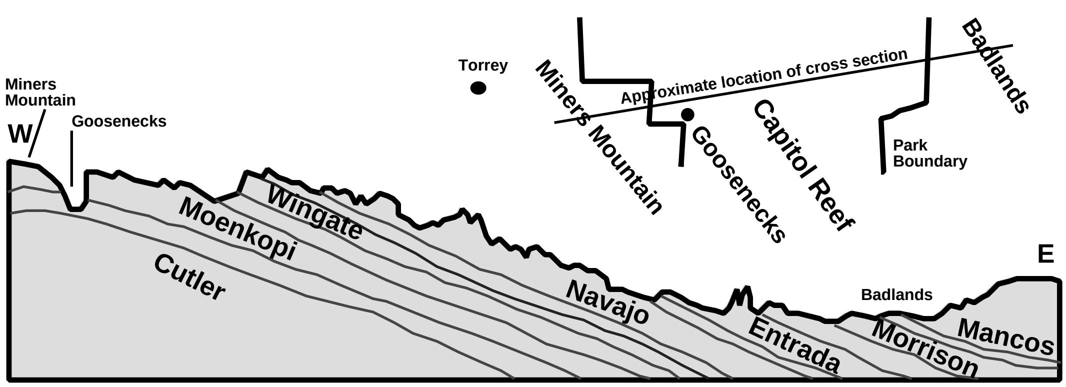

Figure 3. Generalized geologic cross-section along Rt 24 across Capitol Reef National Park. (after National Park Service, 1994)

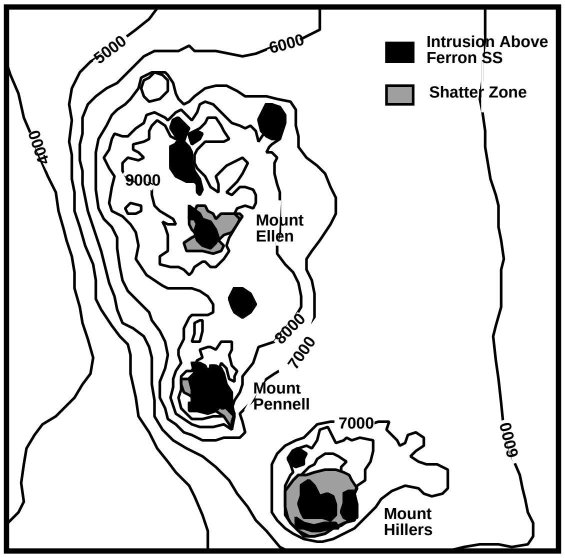

Figure 4. Structure contour map of the Henry Mountains. Contours drawn at the base of the Ferron Sandstone Member of the Mancos Shale. (After Hunt, Averitt and Miller, 1953)

fluvial deposition (Kayenta).

During Wingate and Navajo time the western United States was covered by a large sand sea known as an erg. The term erg is used in the Sahara for a vast region covered deeply with pure sand and occupied by dunes. The Wingate and Navajo Sandstones are classic examples of eolian deposits or wind blown sand dunes. The most characteristic feature of eolian dunes is their enormous cross-beds. Cross-beds form as the dunes migrate. Sand is transported up the gentle stoss slope of the dune and cascades down the steeper lee slope forming foreset cross-beds (figure 6). Cross-beds can form both subaerially by migrating sand dunes or underwater as migrating sand bars or sand waves. Different types of cross-beds form, depending on factors such as, the energy of the system, morphology of the sand dune and the agent of deposition (wind or water). Eolian cross-beds are typically very large with cross-bed sets up to 35 meters. The dip of the foreset beds is steep, between 20° and 30° (Prothero, 1990). The sand itself also contains clues as to its eolian deposition, it tends to be fine sized, very well sorted, well rounded and under the microscope appears frosted or pitted. Associated with the cross-bedded sandstones are interdune deposits of thin mudstones with mudcracks and freshwater limestones deposited in ephemeral lakes. Fossils are rare, but vertebrate footprints, root cast and insect burrows have been observed.

The Kayenta Formation, which occurs between the Wingate and Navajo, was deposited in a broad alluvial plain, and represents a period when the climate became more humid. Distinct facies within the Kayenta represent braided streams, flood plains and lake environments. Because of this wide range in depositional subenvironments the Kayenta is more variable consisting of interbedded sandstones, siltstones and mudstones with a range of colors including red, brown, and gray. The sandstones within this unit occur as lenses and are cross-bedded. Compared to the Navajo Sandstone the cross-bedding within the Kayenta is smaller scale and the dip of the foreset beds is lower, reflecting its deposition by water rather than wind. Other sedimentary structures common within the Kayenta include ripple marks, mudcracks and dinosaur foot prints. The transition between the alluvial plain (Kayenta) and sand seas (Navajo) known as the

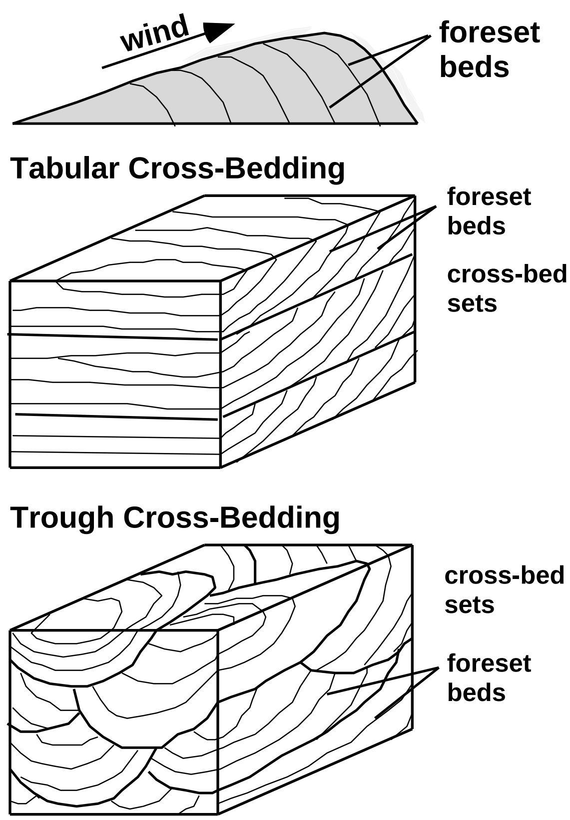

Figure 6. Two major types of cross-bedding.

Age	Thick. (ft)		Description
Quaternary		**Q**	Unconsolidated alluvium (**Qal**), rock glacier deposits (**Qmr**), dune sand (**Qed**), landslide deposits (**Qms**), terrace gravel deposits (**Qat**), glacial till (**Qgt**), pediment deposits (**Qap**), and boulder deposits (**Qnb**)
Tertiary		**Tv**	Extrusive volcanics
		Tdp	Diorite porphyry
		Ti	Intrusive volcanics
	Unconformity		
Tertiary	**> 500**	**Tf**	**Flagstaff Limestone** White fossiliferous limestone, tuffaceous sediment and conglomerate. Forms slopes and ledges.
	Unconformity		
Cretaceous	**300-400**	**Kmv**	**Mesa Verde Formation** Light brown, thick-bedded sandstone and thin bedded dark shale. Forms a cliff.
Cretaceous		**Km**	**Mancos Shale** Consist of the following five members:
	650-750	**Kmm**	**Masuk Member** Yellowish-gray mudstone and minor bluish gray to black mudstone with interbedded light gray sandstone. Forms slopes and ledges.
	300-400	**Kme**	**Emery Sandstone Member** Light gray to yellow, medium-bedded sandstone containing interbedded carbonaceous shale and coal beds in the upper part. Forms a cliff.
	1200-1500	**Kmb**	**Blue Gate Shale Member** Laminated blue-gray and black shale with interbedded light yellow sandstone and limestone lenses. Forms a slope.
	205-385	**Kmf**	**Ferron Sandstone Member** Fine grained laminated brown sandstone and white cross-bedded sandstone containing interbedded carbonaceous gray shale and impure coal in the upper part. Forms a cliff and ledges.
	540-720	**Kmt**	**Tununk Shale Member** Bluish gray and black shale, locally fossiliferous. Forms a slope.
	Unconformity		
Cretaceous	**0-150**	**Kd**	**Dakota Sandstone** Yellowish-brown to gray sandstone and conglomerate with interbedded carbonaceous shale and thin coal beds, locally fossiliferous. Forms ledges and slopes.
	Unconformity		
Cretaceous	**0-166**	**Kcm**	**Cedar Mountain Formation** Variegated mudstone and sandstone with conglomerate at the base.
	Unconformity		
Jurassic	**400-700**	**Jm**	**Morrison Formation** Varicolored shales and fine-grained sandstones, massive sandstones, conglomeratic sandstone, and conglomerate. Brushy Basin Shale Member (**Jmb**) forms a slope, Salt Wash Sandstone Member (**Jms**) forms ledges and cliffs
	Unconformity		
Jurassic	**50-250**	**Js**	**Summerville Formation** Thin beds of reddish-brown siltstone and mudstones. Forms a slope.
Jurassic	**0-175**	**Jcu**	**Curtis Formation** Thin- to thick-bedded, white, fine-grained calcareous sandstone and sandy limestone. Forms a cliff.

Figure 5. Description of Stratigraphic Units at Capitol Reef National Park (modified from Billingsley, Huntoon, and Breed, 1987)

Jurassic	**400-900**	**Je**	**Entrada Sandstone** Thin- to thick-bedded reddish-brown sandstone and siltstone. Slope to cliff forming.
Jurassic	**200-1000**	**Jc**	**Carmel Formation** Very fine-grained, thin-bedded, orange-red sandstone and siltstone, calcareous mudstone, pink gypsiferous siltstone and gray limestone. Forms ledges and slopes.
	Unconformity		
Jurassic	**950-1400**	**JTrn**	**Navajo Sandstone** White, yellow and light reddish-brown, fine- grained, large-scale cross-bedded, sandstone. Forms cliffs and hummocky knobs.
Triassic	**350**	**Trk**	**Kayenta Formation** Grayish-purple to reddish-brown, irregularly- to thin-bedded, fine-grained sandstone and siltstone. Forms ledges and cliffs.
	Unconformity		
Triassic	**350**	**Trw**	**Wingate Sandstone** Reddish-brown, thin to thick bedded, massive and cross-bedded, fine-grained, well-sorted sandstone. Forms a prominent cliff.
Triassic	**500-700**	**Trc**	**Chinle Formation** Variegated red, brown, green and gray, bentonitic sandstone, siltstone, mudstone and limestone. Generally forms a slope. Shinarump Conglomerate Member of medium- to coarse-grained cross-bedded sandstone and conglomerate forms a ledge at the base.
	Unconformity		
Triassic	**800-1000**	**Trm**	**Moenkopi Formation** Light gray to reddish-brown, evenly-bedded, ripple-marked, cross-laminated, mudstones, siltstones and fine-grained sandstones. May be dolomitic or contain veinlets of gypsum. Forms slopes, ledges and cliffs.
	Unconformity		
Permian	**200**	**Pk**	**Kaibab Limestone** Thin bedded, fine-grained, white calcareous siltstone and porous oolitic dolomite containing chert layers near the top. Forms a cliff.
Permian	**800**	**Pc**	**Cutler Group** Light yellow to white, very fine-grained cross-bedded sandstone, dolomitic near the top. Forms a cliff.

Figure 5 (cont.). Description of Stratigraphic Units at Capitol Reef National Park (modified from Billingsley, Huntoon, and Breed, 1987)

erg margin occurs in the area to the west, near Zion, where tongues of eolian sand deposits occur within the Kayenta.

Pleistocene Deposits

The Colorado Plateau is located beyond the margins of Pleistocene continental ice sheets, however this area was still effected by the the ice ages. During the Pleistocene, the climate on the Colorado Plateau was cooler and more humid with much faster rates of erosion. Isolated mountain glaciers occurred at higher elevations such as the Henry Mountains to the west and Aquarius Plateau to the east of Capitol Reef (Hintze, 1973). At this time the Fremont River carved a broad floodplain where outwash streams deposited boulder sized sediment transported from distant source areas. Since that time the Fremont river has eroded downward leaving the flood plain behind as an elevated terrace. Rounded, black, boulders of volcanic rock are concentrated on the terraces, their most likely source being Boulder and Thousand Lake Mountains of the volcanic capped Aquarius Plateau. Some of the boulders are coated with desert varnish, a coating of manganese oxides, or caliche, an accumulation of calcium carbonate. Because these coatings accumulate very slowly some workers use their thickness to estimate the age of geomorphic surfaces. Their presence here suggest that since the boulders were deposited they have remained stable for a long time.

Weathering and Erosion

On a hot August day it may be difficult to imagine that in this arid environment, water and streams are responsible for the majority of the landforms observed. Capitol Reef receives 7 inches of precipitation a year with nearly half falling as snow in the winter months. Compare that to the 40 inches of precipitation that Ohio receives. The infrequent rainfalls and thunderstorms of late summer and early fall can result in flash floods. Water rushing down canyons can sound like an approaching jet with a wall of water up to 15 feet deep. Then within a few hours the water recedes. The bare rock exposures and lack of soil, prevent rainfall from soaking into the ground, resulting in immediate runoff. Water draining from vast areas, funnels into washes, building volume and speed. Sand and clay gets suspended in these waters giving it a brown color, with the consistency of chocolate milk. The erosive power of this water is enhanced by this high sediment load. Erosion in this region is characterized by long periods when nothing occurs, punctuated by intense episodes of erosion that last only a few short hours.

Hickman Bridge, carved out of the Kayenta Formation, is an excellent example of a natural bridge. It has a 133 foot span and stands 125 high. Natural bridges differ from arches in that they span a watercourse and are formed by stream erosion.

Waterpocket Fold derives its name from depressions in the sandstone which hold water after a rainfall known as waterpockets, tanks, potholes or tinajas. Some of these waterpockets are deep enough to be permanent sources of drinking water. These depressions form by a variety of methods. Some are true potholes formed by running water and sand abrasion. The plunging and pooling effects of running water can create localized eddies which abrade and carve out circular depressions. In other areas the waterpockets form by solution. Slight depressions in the bare rock accumulate moisture which enhances chemical and physical weathering processes, eventually enlarging the depressions. The water in these depressions attract a community of microscopic plants and animals that secrete acids which further enlarges the potholes.

The Fremont River is one of the few rivers in this area that flows year round. It is an example of a superimposed stream that flows across the strike of the beds. It is believed that after the Laramide Orogeny the structures, including the Waterpocket Fold were completely buried with sediments. The Fremont River established it’s course on a level plain of flat lying sediment. Later uplift of the Colorado Plateau caused it to erode downward through the structure while maintaining it’s original course.

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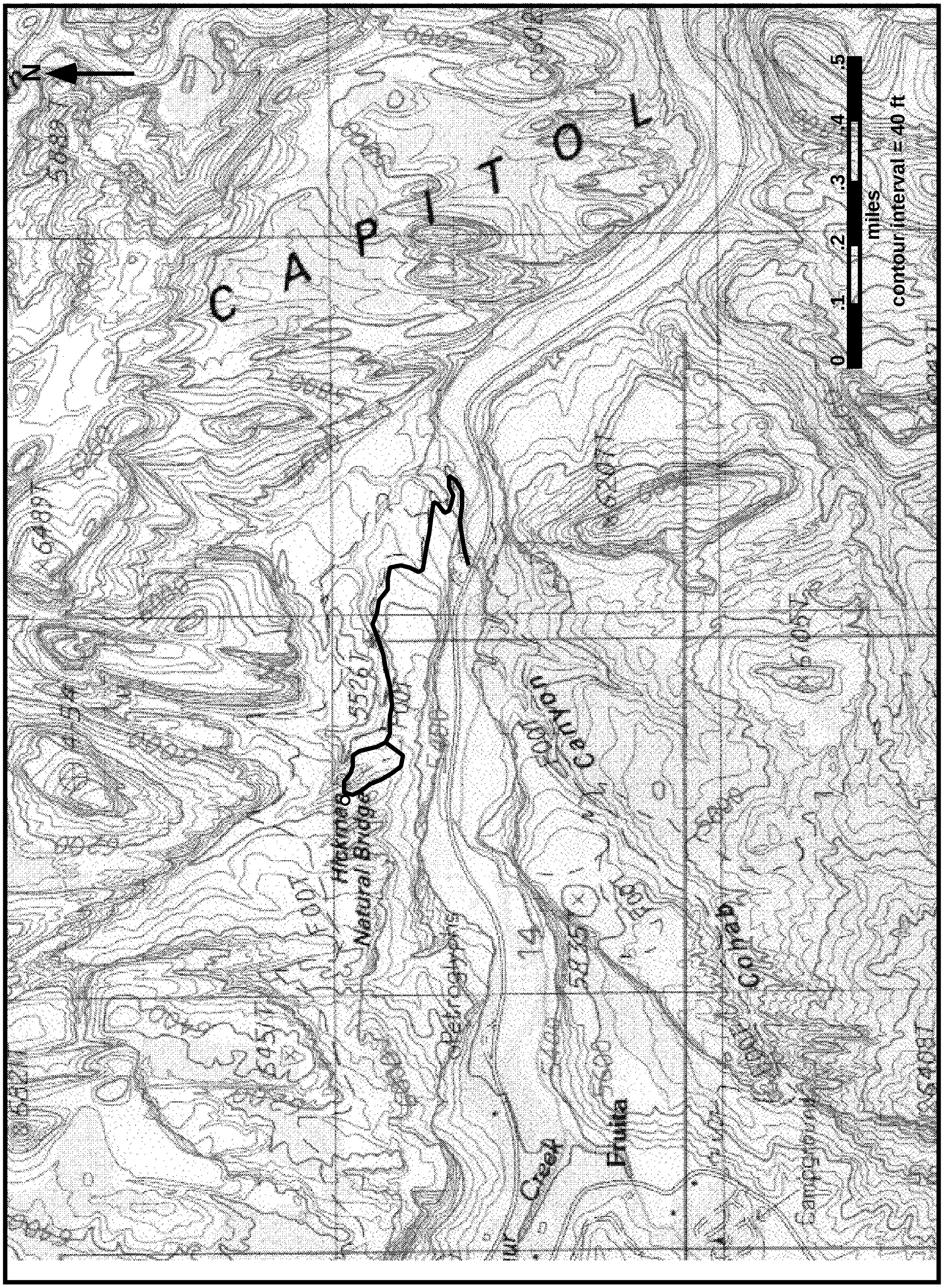
Exercises

Hickman Bridge Trail

1) After hiking up onto the Pleistocene terrace, locate two prominent features such as Capitol Dome and Fern's Nipple and label them on your topographic map. Take a compass bearing on these features and use them to plot your exact location on the map.

2) Sketch in the distribution of black boulders on the topographic map.

3) List and describe the features you observe that that would suggest the canyon you are hiking up was eroded by a stream.



Topographic map of the Hickman Bridge Trail

4) Describe the Kayenta Formation at this locality. Include characteristics such as color, lithology, grain size, bedding, sedimentary structures, trace fossils and fossils.

5) Define the following terms and give examples of each feature.

Caliche

Desert varnish

Incised meander

Laccolith

Monocline

Monolith

Natural bridge

Pothole

Superimposed stream

Waterpocket