STATE OF ARKANSAS

ARKANSAS GEOLOGICAL SURVEY

Bekki White, State Geologist and Director

STATE PARK SERIES 02

THE GEOLOGIC STORY OF PETIT JEAN STATE PARK

by

Angela Chandler

Little Rock, Arkansas

2007

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THE GEOLOGIC STORY OF PETIT JEAN STATE PARK

by

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Introduction

The majority of Arkansas State Parks are developed around interesting geologic features. Arkansas's first State Park, Petit Jean State Park, was built by the Civilian Conservation Corps (CCC) from 1933 until 1941 and contains some of the best preserved and most scenic geologic features in the state. It is noted in the Nature Center that Petit Jean became the first state park "because of the beauty and drama of the geological features in Seven Hollows".

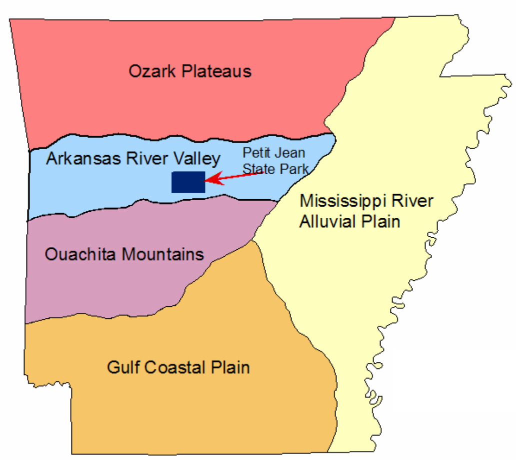

Fig. 1. Physiographic Provinces of Arkansas

Petit Jean Mountain contains many exceptional geological landscapes as a result of weathering and erosion that has taken place during the last 250 million years. Drainage from this bowl-shaped mountain formed scenic Cedar Falls, that carved a steep canyon that is considered the centerpiece of the park. Surrounding the canyon are numerous overlooks and trails containing rock shelters and passageways cut by Cedar Creek long ago. Weathering produced curiosities called "turtle rocks" and "carpet rocks", leaving an unforgettable imprint in the mind. These are just a few of the features preserved as illustrations of the geologic story seen in the rocks at Petit Jean State Park.

Location

Petit Jean State Park is located in the central and southern portion of Petit Jean Mountain. The mountain is located in the Arkansas River Valley Region, a rather narrow and typically low-lying region surrounding the valley of the Arkansas River and its major tributaries. This region is bordered to the north by the Ozark Plateaus and to the south by the Ouachita Mountains. The Arkansas River Valley is characterized by gently tilted sedimentary rocks. In contrast are the flat-lying rocks of the Ozarks, and the steeply tilted and folded rocks of the Ouachita Mountains.

Geologic History

The rocks exposed in Petit Jean State Park formed during the Pennsylvanian Period of geologic time around 315 million years ago. Underneath these sandstones and shales are older rocks, predominantly limestones and dolostones that formed during the Cambrian through Mississippian Periods. The area known as the Arkansas River Valley has been above sea level and eroding since the beginning of the Permian Period. Therefore, no rocks were preserved until the Quaternary Period when the Arkansas River deposited sediment in the form of terraces close to the mountain.

During the Pennsylvanian Period, the area now known as the Arkansas River Valley was a basin sitting between the slightly uplifted Ozarks to the north and the slowly rising Ouachita Mountains to the south. These higher areas from the surrounding regions supplied sand, silt and clay that was carried into the basin by ancient river systems. Periodically, much of the basin was covered by a deepening ocean. Swamplands populated by ferns and trees unlike any today developed around bays and inlets. Sea level fluctuated during this time and as sediment subsided in the basin, sea water spread into the area covering the bays and inlets burying the swamplands. Several cycles of deposition created layers of clay and sand which contained thin layers of plant material. These layers became buried and compressed by overlying deposits to form shales and sandstones with an occasional thin coal bed. These layers of rock are known as the Atoka Formation.

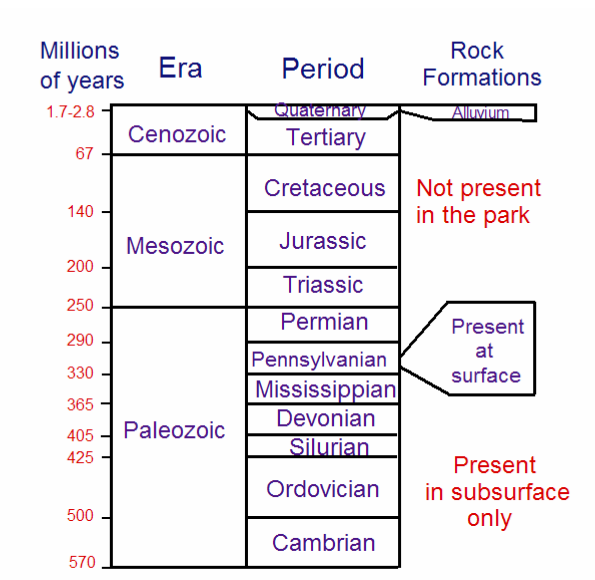

Fig. 2. Geologic time scale showing rocks present at Petit Jean State Park.

Eventually the ocean retreated west and the in-filled basin became exposed. A large river system flowing east to west developed in the low-lying area. Swamplands developed on adjacent flood plain deposits and later became buried when the river meandered and changed its course. This river deposited sandy sediment that became buried and compressed to form sandstone sequences that in some areas contain plant fragments. This is the Hartshorne Sandstone seen today on Petit Jean Mountain.

Continents Collide

The continents as we know them today looked much different in the past. Since Cambrian time they have been shifting and colliding so that around 365 million years ago, North America was attached to the continents now known as Greenland and Europe to form one large landmass called Laurasia situated along the equator. South of the equator a larger continent called Gondwana, made up of the continents now known as South America, Africa, Antarctica and Australia had formed. These two landmasses moved toward each other and finally collided around 340 million years ago. During this collision some of the continental rocks of Gondwana became attached to the southeastern portion of Laurasia in what is now Arkansas.

This collision first affected the sequence of rocks in what is now known as the Ouachita Mountains. These once flat-lying rocks were compressed into tight folds, downwarps and upwarps, called synclines and anticlines. Eventually deformation spread to the flat-lying shales and sandstones of what is now called the Arkansas River Valley. These rocks were compressed into more gentle folds that extended far above the current land surface. During the last 250 million years these rocks have eroded to form the present landscapes within the Arkansas River Valley and Petit Jean State Park.

The area now known as Petit Jean Mountain was compressed into a downwarp or syncline. The limbs and younger rocks that would have existed on top of the mountain have been eroded. The lowest portion of the syncline has been preserved as a mountain today.

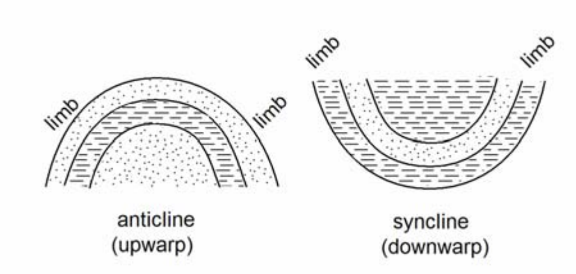

Fig. 3. Diagrams showing folded geologic structures.

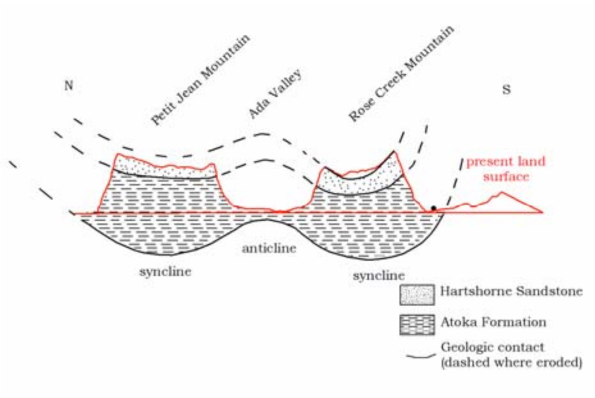

Fig. 4. Generalized cross-section from Petit Jean Mountain to Adona.

Geologic formations present within the park.

Petit Jean Mountain is underlain by shales and sandstones in the Atoka Formation and the Hartshorne Sandstone. The Atoka Formation is divided into upper, middle and lower members based on regionally mappable shale or sandstone intervals. Only the upper member is exposed in the park. In some areas fossiliferous beds containing mostly gastropods and bivalves are present. The upper member of the Atoka Formation can be seen when beginning the climb to the top of the mountain from either direction on Highway 154. The best exposures are found along the highway on the east side of the mountain beneath Stouts Point. At this location dark gray to black shales are interbedded with thin layers of tan to gray sandstone. Thicker sandstones appear along the road at the top of the mountain. These sandstones are part of a different rock formation called the Hartshorne Sandstone.

Fig. 5 The Atoka Formation along Highway 154 beneath Stouts Point.

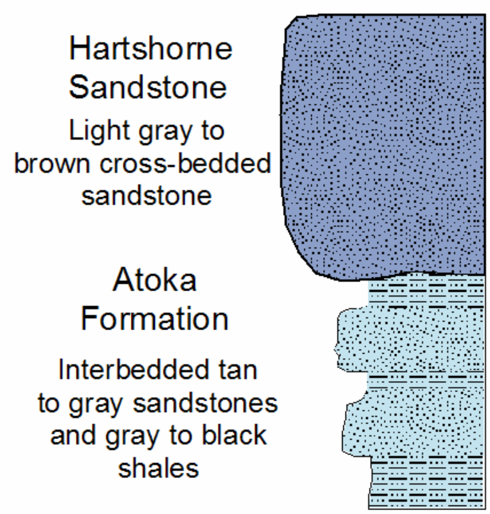

Fig. 6. Columnar section showing sequence of Rock formations at Petit Jean State Park.

The Hartshorne Sandstone caps Petit Jean Mountain and forms the near vertical ledges and bluffs around the top of the mountain. This rock formation also contains most of the geologic curiosities including Rock House Cave and Bear Cave. The sandstone is brown to light gray, forms thick beds, and is usually cross-bedded (cross-bedding is discussed on page 8). Scenic exposures of this sandstone are found behind Mather Lodge and many of the cabins. This formation is easily viewed at any of the overlooks for Cedar Falls and the canyon formed by Cedar Creek.

Surrounding Petit Jean Mountain on the north side are alluvium and terrace deposits of the Arkansas River and Petit Jean River. They consist of low to high level terraces and alluvial deposits of sand, clay and gravel. Mussel shells from a terrace approximately 30 feet above the present river level have yielded a Carbon-14 dating of 38,000 years in age (Stone, 1975).

Fig. 7. Hartshorne Sandstone capping the Mtn..

Overlooks

MA Richter and CCC Overlooks

These overlooks, located on the west side of the mountain along Red Bluff Drive, offer a great view west into the surrounding Arkansas River Valley. The same rock formations that make up Petit Jean extend west and northwest to the Oklahoma border. The sandstones and shales in this region erode at different rates. More resistant sandstones form ridges and mountains while less resistant shales form valleys.

Several mountains in the distance are made up of sandstones and shales characteristic of this region. Mt. Nebo and Crow Mountain are both capped by the Hartshorne Sandstone and underlain by shales of the Atoka Formation similar to Petit Jean Mountain. Flood Mountain and Danville Mountain consist of shales and sandstones of the Atoka Formation only. Magazine Mountain is underlain by shales and sandstones from both the Atoka and Hartshorne Formation, but is capped by shales and sandstones from even younger rock formations.

Stouts Point

Stouts Point is located on the eastern end of Petit Jean Mountain. Here, the bluff forms an enclosure resembling a nose and extends westward creating an elongate mountain. The structure creating this "nose" is called the Pontoon Syncline.

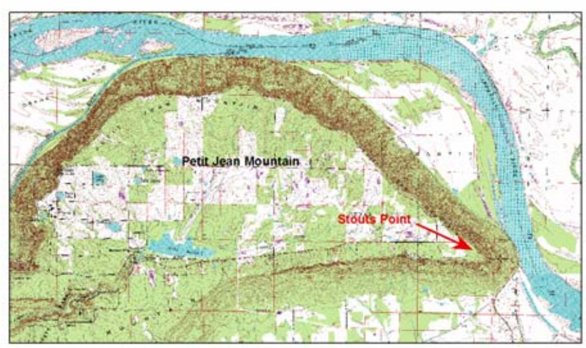

Fig. 8. Topographic map showing the "nose" at Stouts Point.

Mostly seen from this point is the meandering Arkansas River and its modern floodplain. Terrace levels that were deposited over the past 1.5 million years are present southeast of this overlook. The terraces and floodplain are made up of gravel, sand and clay.

Fig. 9. The Arkansas River and its flood plain as seen from Stouts Point.

One interesting feature that formed from weathering of the Hartshorne Sandstone is abundant at this overlook. Some of the best examples of color banding, also referred to as liesegang banding, occur in the rocks used to build the abandoned CCC structure at this overlook. Liesegang banding is a result of rhythmic precipitation of iron hydroxide within a fluid-saturated rock.

Fig. 10. Liesegang banding in rocks used to build the CCC structure at Stouts Point.

Cedar Creek

Cedar Creek developed due to the geologic structure of Petit Jean Mountain. Petit Jean Mountain is a syncline or downwarp of the rock formations creating the mountain. The top of the mountain forms an elongate bowl and the rock formations are slightly tilted toward the center from all sides. As a result, water collects in Lake Bailey then drains from the mountain by Cedar Creek.

In the past, Cedar Creek flowed in basically the same channel it occupies today but was 50 to 400 feet higher than at present. During that time, the rock layers forming the ledges and cliffs were continuous across the canyon. The down cutting action of Cedar Creek dissolved portions of the cement holding the sand grains together and eroded passageways through the sandstone in the Bear Cave area and left rock shelters like Rock House Cave, and even a natural bridge on the north side of the canyon.

Fig. 11. Rock House Cave rock shelter.

Cedar Falls formed downstream on the west side of the mountain where Cedar Creek now widens into the Petit Jean River bottom. Here, the falls would have flowed over the thicker and more resistant sandstone layers that formed the caprock of the mountain onto the thinner sands and shales that formed the slope and valley. The shale layers were more easily excavated by the scouring of sand and gravel in the falls. As shale eroded from the base of the falls, overlying sandstone was left unsupported. The sandstone then became more susceptible to erosion from the pounding action of water from the falls and eventually fell to the stream bottom below. Continuing migration of the falls upstream to its current position and dissolution of the sandstone caprock eroded the canyon that now forms the centerpiece of the park.

Today, Cedar Falls cascades over a thick sequence of resistant sandstone of the Hartshorne Sandstone onto less resistant shales of the Atoka Formation. The contact between the two formations is approximately 20 feet above the base of the waterfall. Steep walls dominate the canyon just downstream from the falls. Farther west, Cedar Creek has eroded a wider canyon with more gently sloping sides. Finally, Cedar Creek reaches the lower elevations of the mountain and flows into the Petit Jean River.

Fig. 12. Cedar Falls. Notice contact between Hartshorne and Atoka Formations.

Often seen along the gentler slopes of Cedar Creek canyon are large accumulations of sandstone boulders called talus. Water from rain and snow collects in cracks, also called joints, and pores of the sandstone caprock. When the water freezes it expands, pushing already existing cracks farther apart and creating new ones within the rock. After many periods of freezing and thawing pieces of the rock split apart and moved down the slope to collect in a pile often called talus or colluvium.

Fig. 13. Talus or rock fall slope near Cedar Falls Trail.

Interesting features within the park

Carpet Rocks

Box-shaped and triangular patterns are abundant in the sandstones on top of Petit Jean Mountain. These patterns form when iron present in the rock is oxidized. Iron exists as the minerals siderite, magnetite, hematite and some clay minerals that are present in the Hartshorne Sandstone. At some point in geologic history water fills the pore spaces of the rock formation and comes into contact with minerals made up of iron. This causes the iron to go into solution. If the rock becomes exposed to air then oxygen is added to the solution and will cause the iron to oxidize and precipitate out along exposed joints in the rock formation. Sometimes color bands result from the different oxidation states of iron. These bands are also referred to as Liesegang banding or box-work by the scientific community. Often the joints form interesting triangles referred to as “carpet rock” by the park community.

Fig. 14. "Carpet rocks" along Cedar Creek Trail.

Turtle Rocks

Some of the most unique features seen around the park are those called "turtle rocks". Mounded polygonal structures resembling a turtle shell were carved in thick sandstones of the Hartshorne Sandstone. These features are unique to this sandstone but not to the mountain itself. More turtle rocks can be found throughout the Arkansas River Valley where the Hartshorne Sandstone is exposed. Turtle rocks also exist on Pleasant View Mountain and London Mountain near Russellville and Cove Mountain south of Petit Jean State Park.

The exact processes that create "turtle rocks" are poorly understood. One explanation involves spheroidal weathering. This process occurs when water percolating through cracks and between individual grains in the rock loosens and separates layers of the rock. The weathering acts more rapidly on the corners and edges of the rock producing a rounded shape. Another theory concerns the amount of calcite present in the matrix of the rock holding the grains together along with the size of the grains that allow for this type of weathering. Either way the weathering of the rocks is strongly influenced by the polygonal joint pattern seen in all "turtle rocks".

Fig. 15. "Turtle rocks" above Seven Hollows Trail.

Ancient river features

Some features preserved in the sandstones on top of Petit Jean Mountain provide evidence of a river system from the Pennsylvanian Period of geologic time approximately 300 million years ago.

←------- current direction

Fig. 16. Ripple marks in rock at the CCC Overlook.

Sand deposited as a bed in the bottom of a stream usually forms ripple marks due to current action. The shape of a ripple mark shows the direction the stream is flowing. By looking at the diagram of ripple marks you can see the inclined slope provides a ramp for sand to be transported over the steep face. Eddies occur in front of the steep slope eroding a trough and the process continues downstream as sediment is transported over the next ripple deposit. Ripple marks can be seen in some of the rocks used as steps at many of the overlooks and facilities in the park. Ripple marks are preserved in both the Hartshorne Sandstone and the Atoka Formation.

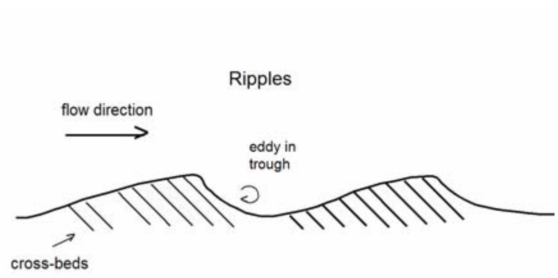

Fig. 17. Diagram of ripple marks

What appear to be diagonal lines within sandstones on top of Petit Jean Mountain is called cross-bedding. They represent the downstream movement of large ripples and indicate the direction the river once flowed. Cross-beds are very abundant in the thick sandstones of the Hartshorne Sandstone and are best seen along Cedar Creek and Seven Hollows Trail.

Fig 18. Cross-bedding in Hartshorne Sandstone

Fossils

Most of the plant fossils found on Petit Jean Mountain belong to a group of plants called lycopods, tree-like forms that grew up to 150 feet tall. They are preserved mostly as molds or impressions but are relatively scarce in the park. More commonly found are the root system of these trees. They are recognized by the round nodes on the surface where rootlets were once attached. One large mold is on display at the visitor center.

Marine invertebrate fossils are rarely found at Petit Jean State Park; however a fossil bed exists on the east side of Petit Jean Mountain below Stouts Point. At this location a one foot thick interval in the Atoka Formation contains mostly fossil snails and clams called Gastropods and Pelecypods.

Trace fossils are also found below Stouts Point in the Atoka Formation. Trace fossils are the fossilized tracks, trails and burrows left by animals as they moved, fed or rested in soft sediment. Some of the most abundant trace fossils found in this area are the burrows of sea anemones. Once the animal left the burrow, the empty space became filled with sediment and formed a mold.

Fig. 19. Lycopod fossils

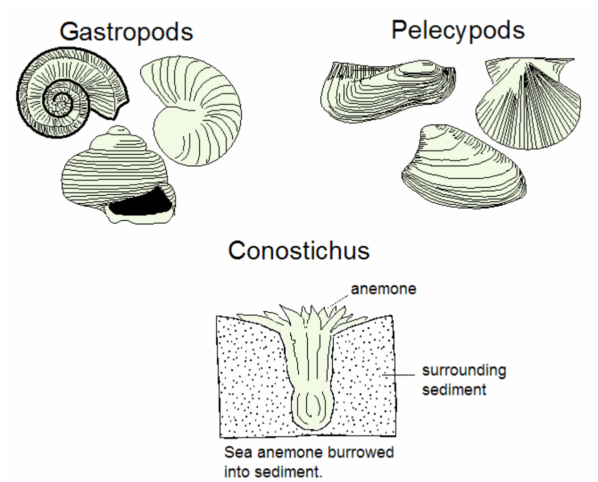

Fig 20. Fossil snails, clams and sea anemone

Trails

The trails on Petit Jean Mountain offer a variety of geologic features to be observed. The state park contains two natural bridges, one major rock shelter (Rock House Cave) and a host of other curiosities like leaning rock and other large boulders. Look closely at the rock formations along trails to see cross-bedding, turtle rocks, carpet rocks and other shapes due to weathering and liesegang bands. To aid in the search, four trail maps are located in the back of this publication. On these maps are locations with pictures showing some wonderful examples of all of these features. Next time you visit Petit Jean State Park, look at it in a whole new way, with a geologist's eye!

References:

Stone, Charles G., 1975, Geologic Summary of the Petit Jean Mountain Area, Arkansas Geological Commission, Open-file report.

For more information contact:

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agc@arkansas.gov
501-296-1877

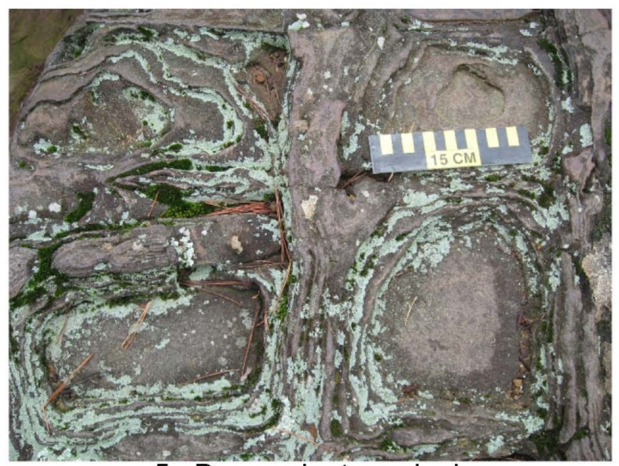
NOTES:

Geologic Map of Rock House Cave and a portion of the Boy Scout Trail

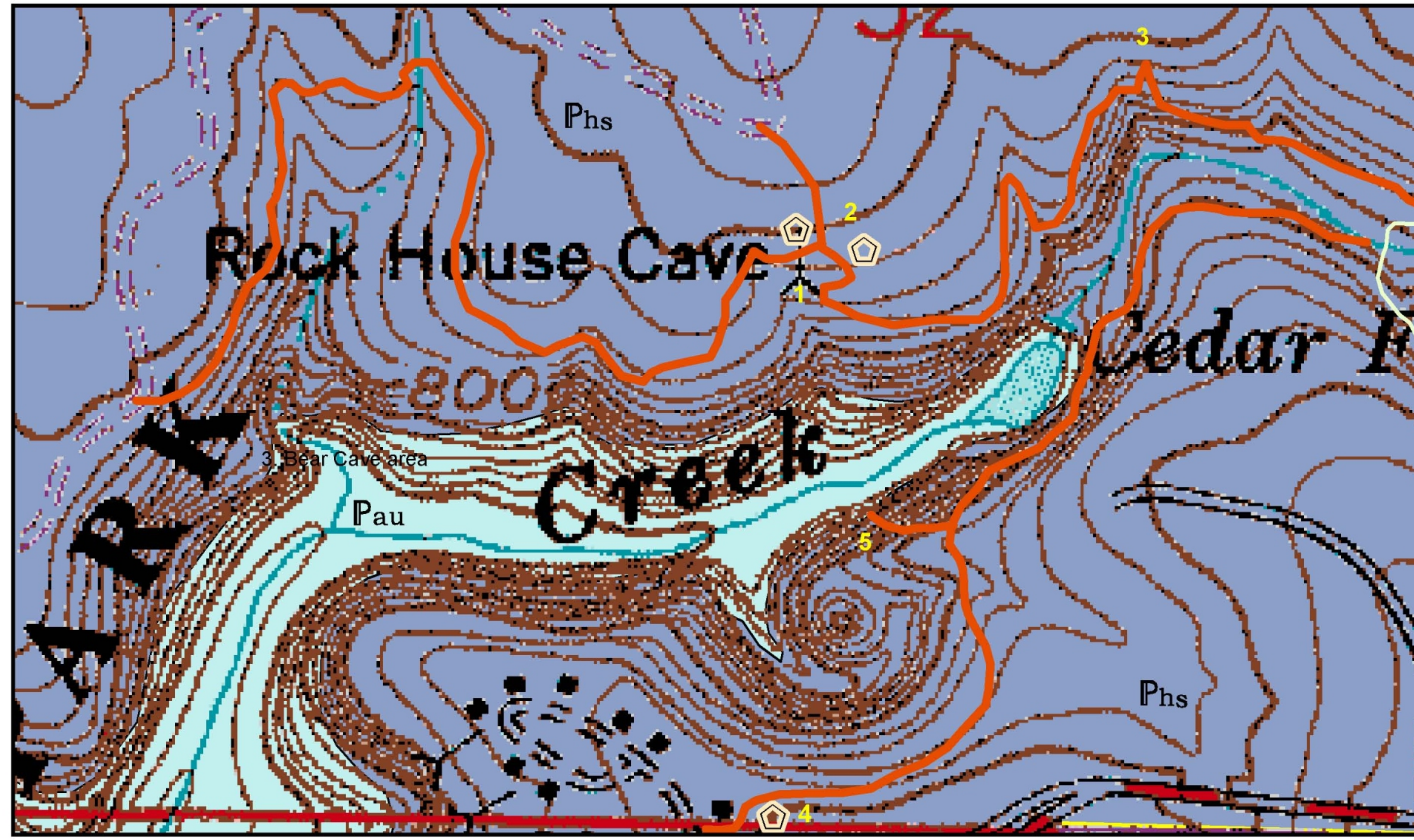
1. Rock House Cave

2. Tube formed by liesegang banding

4. "Turtle rocks" with cross-beds in relief.



5. Box-work at overlook



Scale 0 0.1 0.2 0.4 Miles

3. Natural bridge above trail

Description

The first description begins where the Boy Scout Trail starts near Mather Lodge beside the first cabin. The trail starts behind the cabin along the bluff line and beside the great "turtle rock" outcrop area. The trail then veers from along the roadside and meanders through the woods to an overlook area. Travel to the end of the overlook area to see an abundance of box-work, carpet rock and cross-bedding. Don't forget to look into the canyon as well! Now walk back up to the new walkway and overlook. Walk underneath the stairs and continue along the trail following above Cedar Creek. There are grand views of the canyon from this trail. At one point on the trail you can walk down into the creek above the falls and view ripple-marks on the bedrock in the creek. There are also boulders with liesegang bands along the trail in this area. Shortly the trail drops down to creek level once again to join with the Cedar Creek Trail.

Next, start at the Rock House Cave Trail and walk down to a excellent exposure of "turtle rocks". This is a good area to examine the joints around each "turtle back". Follow the trail off of the outcrop and down to the rock shelter. See what Cedar Creek carved out long ago! Continue along the Boy Scout Trail east to walk along the edge of outcrops of Hartshorne Sandstone containing cross-beds and ripple-marks. Enjoy the view below if you are not afraid of heights! At least continue along this trail until you get to the natural bridge. You will have to take a small side trail above the main trail so don't miss it! Either continue along until the trail meets up with the Cedar Creek Trail or backtrack to the turtle rock area and head west along the Boy Scout Trail for some wonderful views of Cedar Creek Canyon.

Phs Hartshorne Sandstone

Pau Atoka Formation

Symbols

1-4 Pictures

Boy Scout Trail

Cedar Creek Trail

Turtle rocks

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Geologic Map of Cedar Creek Trail

Phs Hartshorne Sandstone

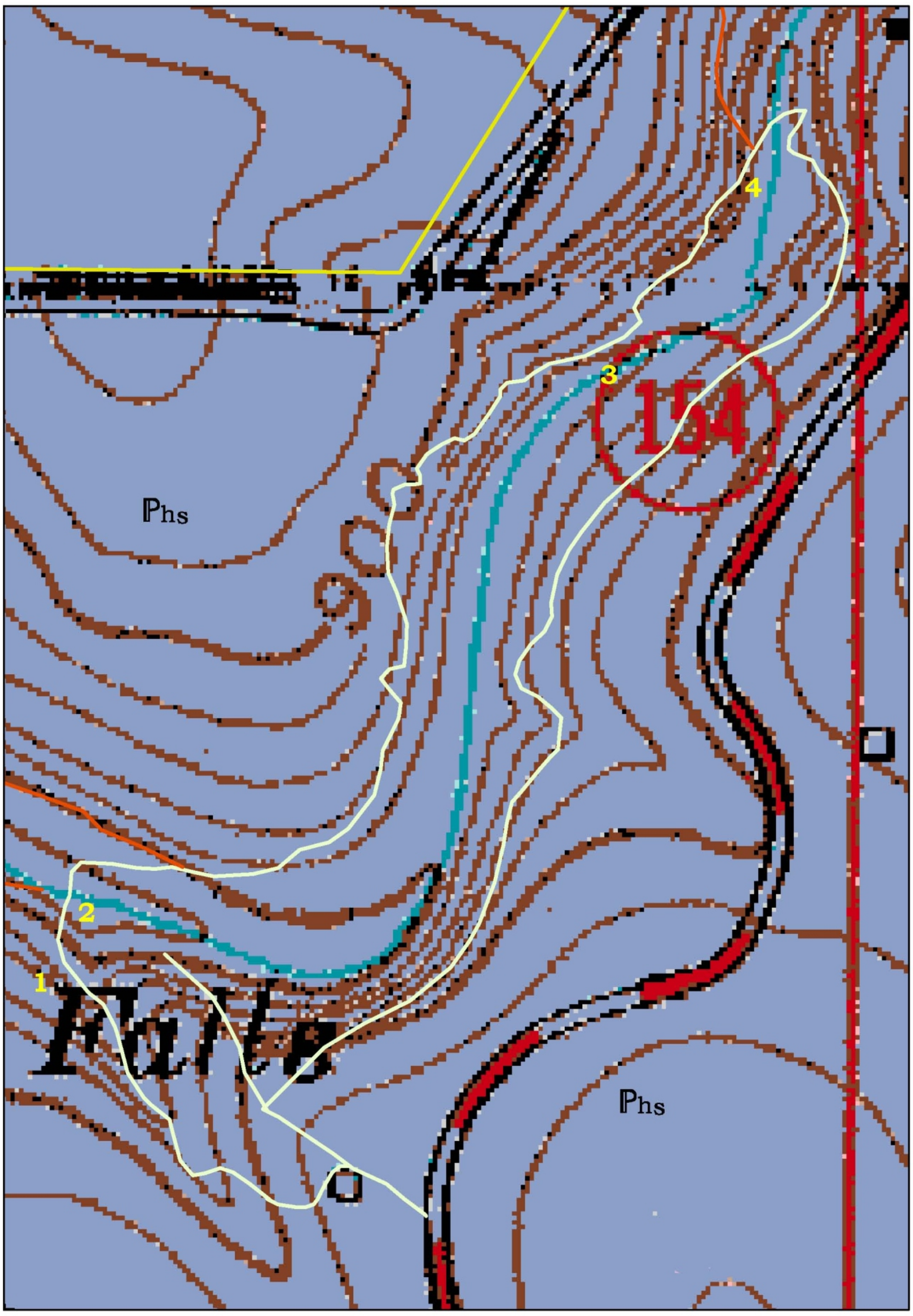
Description

This trail follows a small tributary to Cedar Creek then meanders above the creek for some spectacular views of the Hartshorne Sandstone along the drainage. While following the tributary notice the Hartshorne Sandstone blocks in the drainage and forming the bedrock for the stream. The running water accentuates the cross-bedding and ripple-marks in the rock. At Park Station 3 be sure to notice the “carpet rock” and great cross-beds in the rock creating the small bluff. Walk upstream upon the sandstone in the creek bed to Park Station 4 and examine the orange stripes on the sandstone. Here are two small springs or seeps of iron-rich water flowing out of the outcrop. The orange color is due to the iron being leached out of the rock. After crossing the bridge and continuing on the trail you will walk uphill and stay above the creek for awhile. There are large boulders of sandstone along the trail that contain impressive cross-bed sets. After a while you will step back down into Cedar Creek and be surrounded by the Hartshorne Sandstone. Notice how the water has carved and smoothed the sandstone forming the creek bottom. At Park Station 8 there is a large boulder that has fallen into the creek but is supported by a small ledge creating the ‘leaning rock’. When crossing the bridge look upstream and see all of the boulders in the creek bed. You are near an old landslide area that has caused much of the rock to slide down the hillside and into the creek.

Continue along on the opposite side of the creek. There isn’t much rock exposed along this section, however do not miss the scenic overlook at Park Station 10. This stop provides a great exposure of Hartshorne Sandstone that contains good cross-beds.

Symbols

- 1-4 pictures
- Cedar Creek Trail
- Boy Scout Trail
- Park boundary (approximate)



Scale 0 0.025 0.05 0.1 Miles

2. Chalybeate or iron-rich springs

1. Cross-bedding in Hartshorne Sandstone

1. Carpet Rock

3. Hartshorne Sandstone forming bottom and sides of creek bed.

4. Leaning rock

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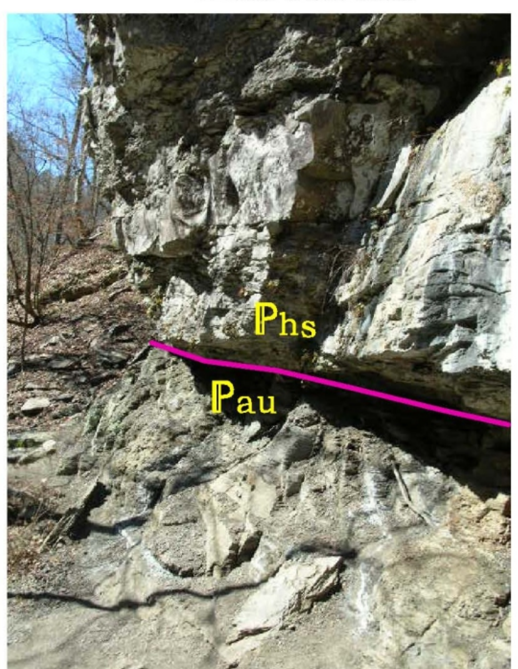
Geologic Map of Cedar Falls Trail, Bear Cave Trail and a portion of the Boy Scout Trail

1. Rock fall area above trail.

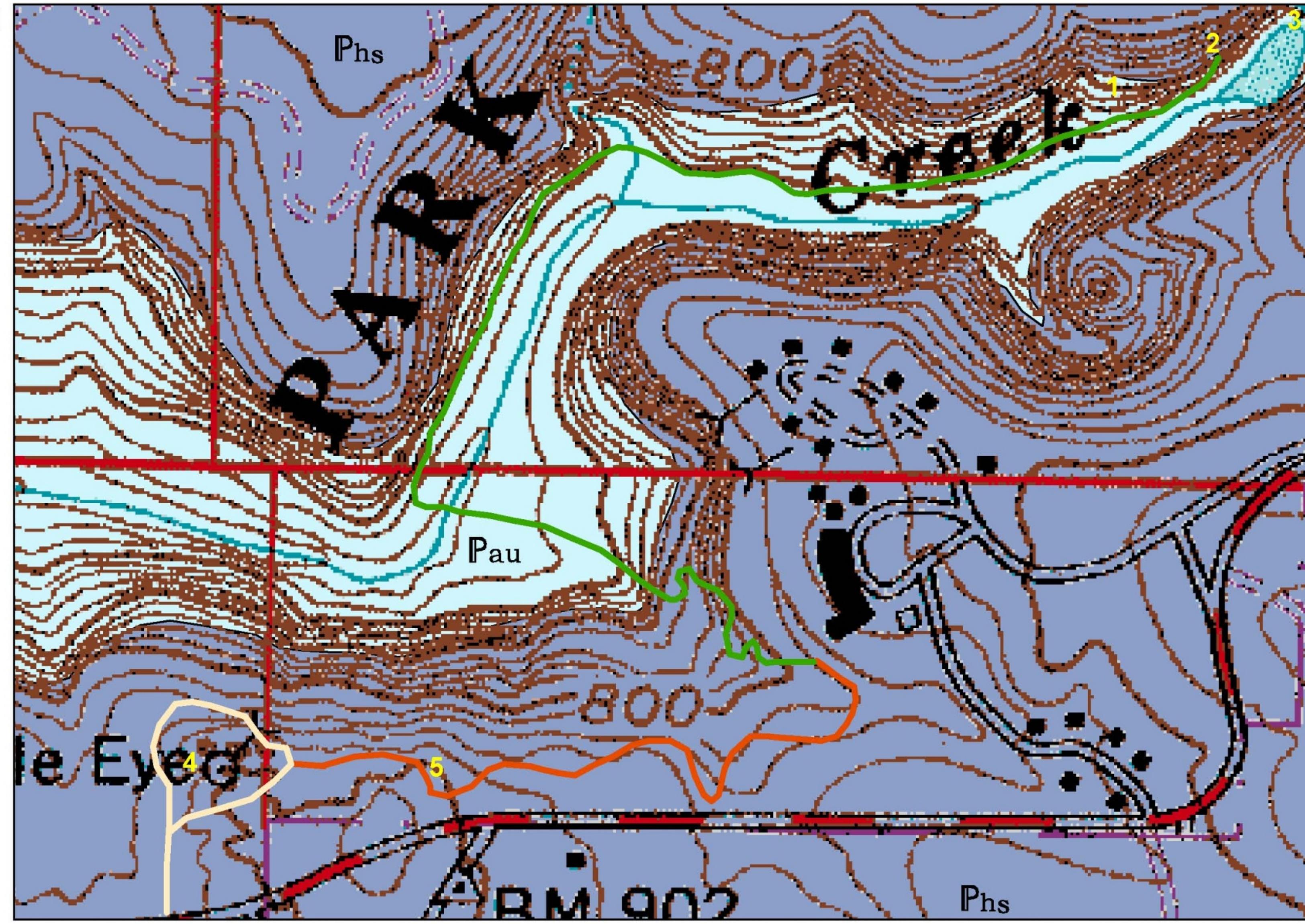
2. Cedar Falls and contact between Hartshorne Sandstone and upper member of the Atoka Formation.

4. Bear Cave area.

5. Balancing rock along trail.



3. Contact between Hartshorne Sandstone and upper member of the Atoka Formation.



0 0.1 0.2 0.4 Miles

Scale

ℙhs Hartshorne Sandstone

ℙau Atoka Formation

Symbols

Boy Scout Trail

Bear Cave Trail

Cedar Falls Trail

1-5 Pictures

Description

Cedar Falls Trail starts in a series of switchbacks following a side tributary to Cedar Creek. Mostly seen in this quick descent are Hartshorne Sandstone boulders sliding down the steep slope. Although the contact between the Hartshorne Sandstone and the Atoka Formation is covered by boulders and vegetation you will have crossed it once the slope changes from steep to a gentle grade. Continue until you reach the floodplain of Cedar Creek, cross over the bridge and start the walk up the creek to the falls. This portion of the trail allows you to see a bluff of Hartshorne Sandstone outcropping along both sides of the trail. There are several rock fall areas as well. Once at the falls try to find the contact between the Hartshorne Sandstone and the Atoka Formation and contrast the different rock types. Observe the characteristics of Cedar Creek below the falls and compare to the creek above the falls. Think about the geology of the area and there is the answer!

The Bear Cave Area is a great place to see a variety of geologic features along a very short trail. Walk along and through large fractures in the Hartshorne Sandstone. Weathered in relief are sizeable cross-beds and reddish-brown patterns formed by liesegang bands. The tops of the large boulders are weathered similar to "turtle rocks". A portion of the Boy Scout Trail continues from the Bear Cave Area to Cedar Falls Trail. At number 5 along this trail is a balanced boulder and good outcrops of the Hartshorne Sandstone. Notice the impressive cross-bedding! This is probably the last outcrop along this trail since it mostly meanders around in the woods along the highway from here to Mather Lodge.

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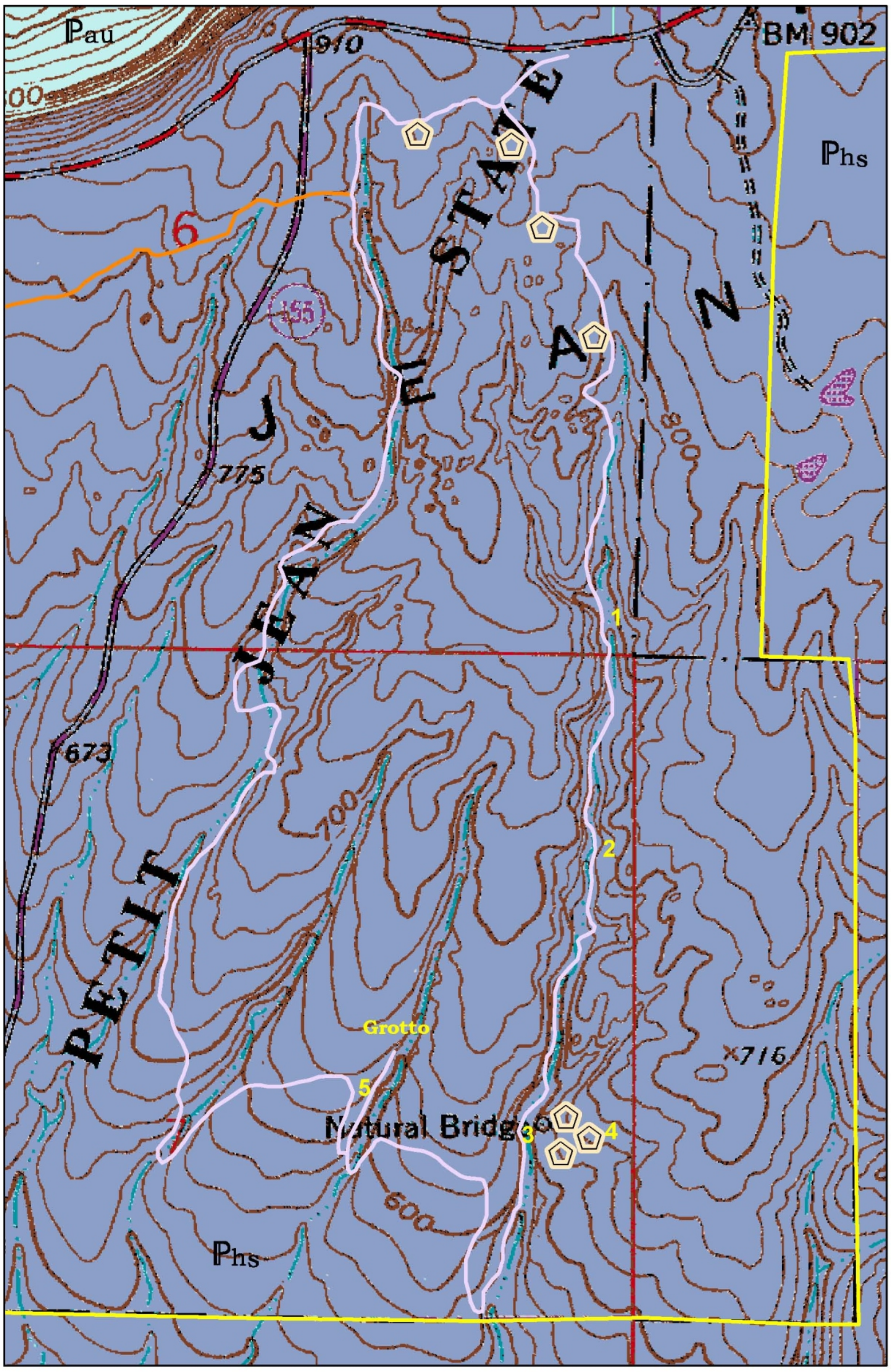

Scale 0 0.1 0.2 0.4 Miles

Geologic Map of Seven Hollows Trail

- **Phs** Hartshorne Sandstone
- **Pau** Atoka Formation (upper part)

Description

The Seven Hollows Trail follows and crosses four of the seven hollows located in this portion of the park. The trail winds around within the Hartshorne Sandstone and contains spectacular outcrops along almost every foot of the trail. This narrative will begin where the trail splits heading toward the natural bridge. Along this portion of the trail a few outcrops of "turtle rocks" (see map) can be seen before the trail weaves along the first hollow encountered on the trail. Once the trail starts following the small side creek, impressive outcrops of the Hartshorne Sandstone can be seen paralleling the drainage. These outcrops contain wonderful examples of liesegang banding (box-work) and cross-bedding. Some of the most outstanding "turtle rocks" along the trail are located above the natural bridge on top of the outcrop (#4 on map). Notice the polygonal joints surrounding each "turtle back". After getting back on the main trail note the large boulders that have broken away from the main outcrop and fallen into the creek at various locations.

Once the trail heads out of the first drainage you will be walking up the outcrop along "bald" areas where there is very little to no vegetation on the sandstone. After you are on the top there are great views of the hollow you just walked along. In the second hollow is a side trail to the Grotto, which is a small waterfall over a sandstone ledge that has "boxed in" this hollow. Here you can observe more cross-beds in the Hartshorne Sandstone with a few "turtle rocks" on top. As soon as you get back to the main trail you will once again walk up the top of the outcrop to another "bald" area. The trail will cross the third hollow near an outcrop with pronounced cross-bedding. When you finally get to the fourth and last hollow you will see the Hartshorne Sandstone paralleling the hollow again. Keep an eye out for a natural bridge trying to form along the trail before you get to mile marker 3. The trail will be right on top of the "bridge" with great joints on either side. Continue along the trail looking at great sandstone outcrops displaying box-work (liesegang banding), cross-bedding and a few isolated mounds of "turtle rocks" near the end of the trail.

Whether you hike the complete trail or just a portion, take a few minutes to walk up to the outcrop and enjoy some of the fascinating geologic features the Hartshorne Sandstone has to offer.

Symbols

- "turtle rock" areas
- 1-5 Pictures
- Seven Hollows Trail
- Boy Scout Trail
- Park boundary (approximate)

1. Box work in outcrop above trail.

2. Liesegang banding in rock along trail.

5 - Trail through boulders to Grotto.

3. Natural bridge

4. "Turtle rocks" above natural bridge.

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