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STATE OF ARKANSAS

ARKANSAS GEOLOGICAL SURVEY
BEKKI WHITE, DIRECTOR AND STATE GEOLOGIST

Geologic Float Guide on Beaver Lake Surrounding Rocky Branch Public Use Area

by
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Little Rock, Arkansas
2018

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Cover photo: sandstone paleokarst near the mouth of Rambo Creek

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2018

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Introduction and Geologic Setting

Welcome to beautiful Beaver Lake in the Ozark Plateaus of northwest Arkansas. This geologic float guide is written to highlight the interesting geology along the shoreline of the lake in a portion of the War Eagle quadrangle (Fig. 1) which was recently mapped as one of the Arkansas Geological Survey's Digital Geologic Map Series.

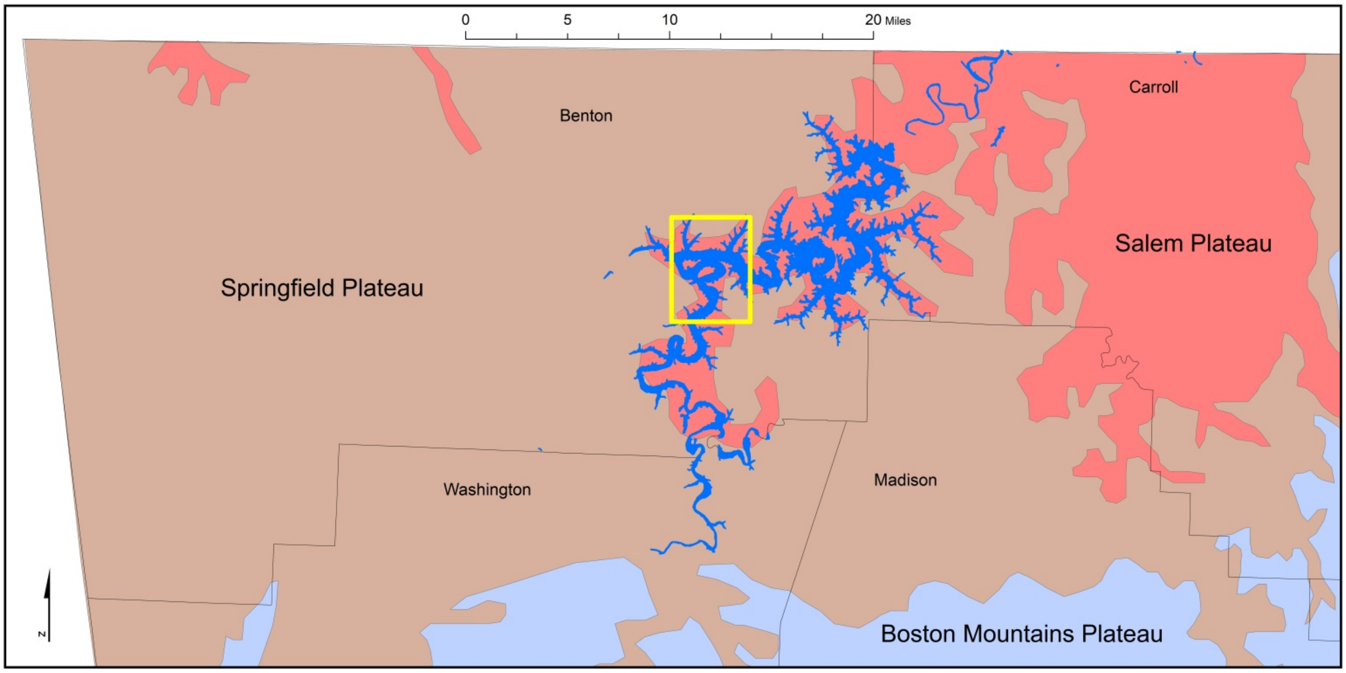


Figure 1. Location of the War Eagle quadrangle (outlined in yellow) within the Ozark Plateaus Province.

The Ozarks are divided into three plateau surfaces (broad, flat-topped areas) that are separated by steep slopes called escarpments:

1) *Salem Plateau – capped by Ordovician-aged rocks, mostly dolostone*

2) *Springfield Plateau – capped by Mississippian-aged rocks, mostly limestone*

3) Boston Mountains Plateau – capped by Pennsylvanian-aged rocks, mostly sandstone

Each plateau is characterized by fairly flat-lying rock strata inclined southward. The plateaus become progressively higher in elevation and expose younger rocks from north to south in the Ozarks of Arkansas. This geologic float is located on the Springfield and Salem Plateaus.

Approximately 200 feet (61 meters) of Lower Ordovician to Upper Mississippian strata crop out around Beaver Lake in this area (Fig. 2). The Lower Ordovician Powell is the oldest geologic unit present in the geologic float area while the Lower Mississippian cherty Boone Formation caps the hill tops, forms steep slopes, and is the youngest geologic unit in the float area. This is one of the best areas to see the Devonian Chattanooga Shale and Clifty Formation which are fairly thick in the geologic float area. The lowest sandstone bed(s) are mapped with the Devonian section but could be Ordovician in age. The St. Joe Limestone, at the base of the Boone, is a small bluff former throughout the area.

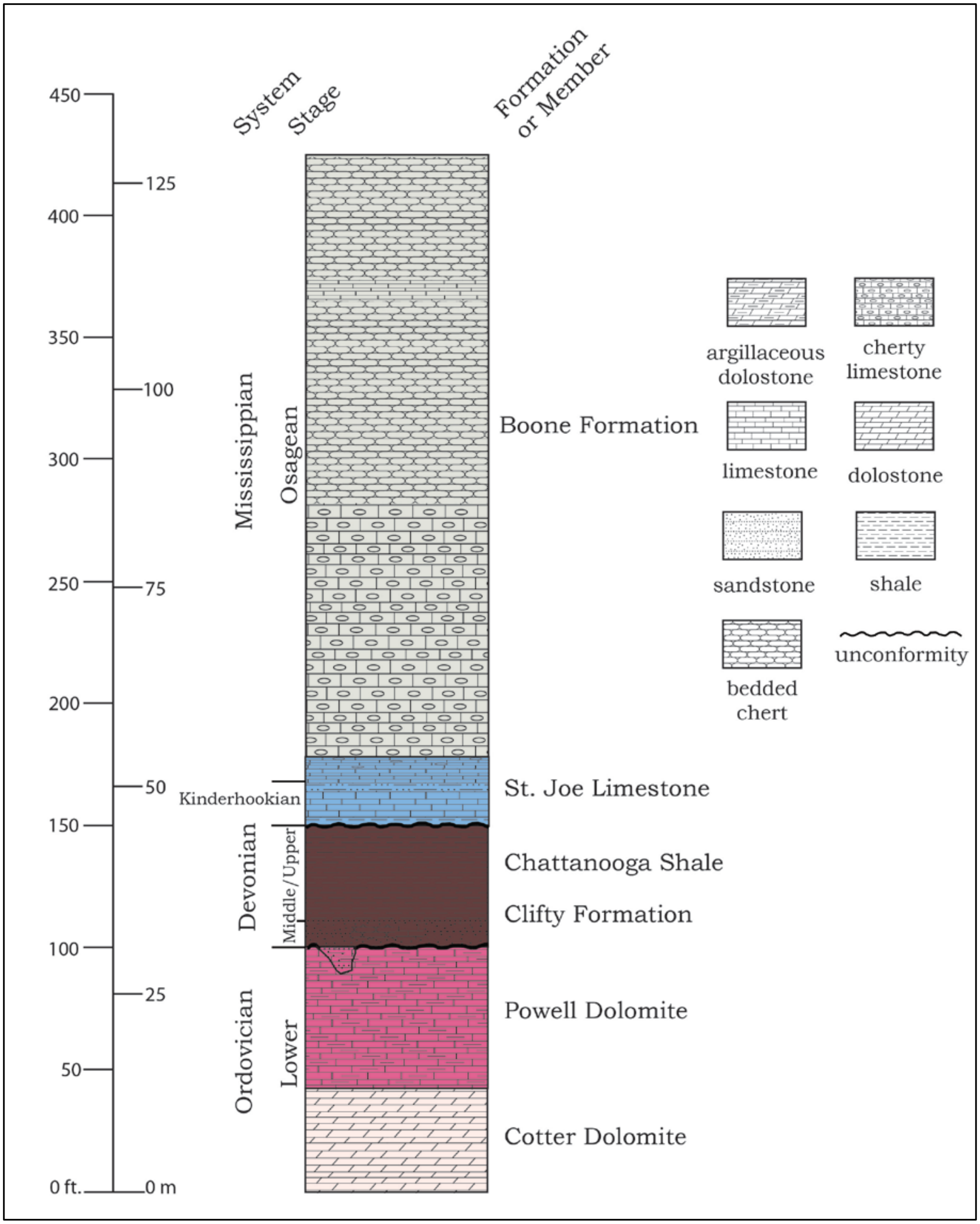


Figure 2. Stratigraphic column of rock formations present around Beaver Lake.

Deposition of rock formations – Lower to Upper Ordovician (485-444 million years ago)

The Ordovician Period is probably best known as a time when sea level was higher than in any other period of geologic time. In fact, this time is known as the Great American Carbonate Bank because of the large extent of shallow seas and the amount of carbonate rocks (limestone and dolostone) that were deposited. The carbonate bank extended from Tennessee to Nevada and from Texas to Minnesota (Derby et al., 2012). The depth of water increased southward and became notably deeper in south Arkansas. Sea level fluctuated within the Ordovician as can be seen by unconformable surfaces in the rock record. An unconformity is a rock surface that represents a gap in the geologic record. This is due either to no deposition or erosion after deposition. There may be Middle Ordovician rocks in the thicker sequence of sandstone in the geologic float area around Beaver Lake, but there are no Upper Ordovician rocks in the area. The Upper Ordovician rocks were likely never deposited in northwest Arkansas.

As previously mentioned, carbonate deposits such as limestone and dolostone accumulated in shallow seas and on tidal flats over large areas in what is now the United States. Dolostone in the Powell was deposited on a very low angle slope in a shallow sea that covered northern Arkansas. The tidal flat consisted of a broad area of lime mud several feet above high tide. Eventually, sea level lowered and deposition ceased for a period of approximately 20 to 80 million years. It was during this time that sinkholes developed on the Powell and were eventually filled with sandstone. (see Sandstone Paleokarst section).

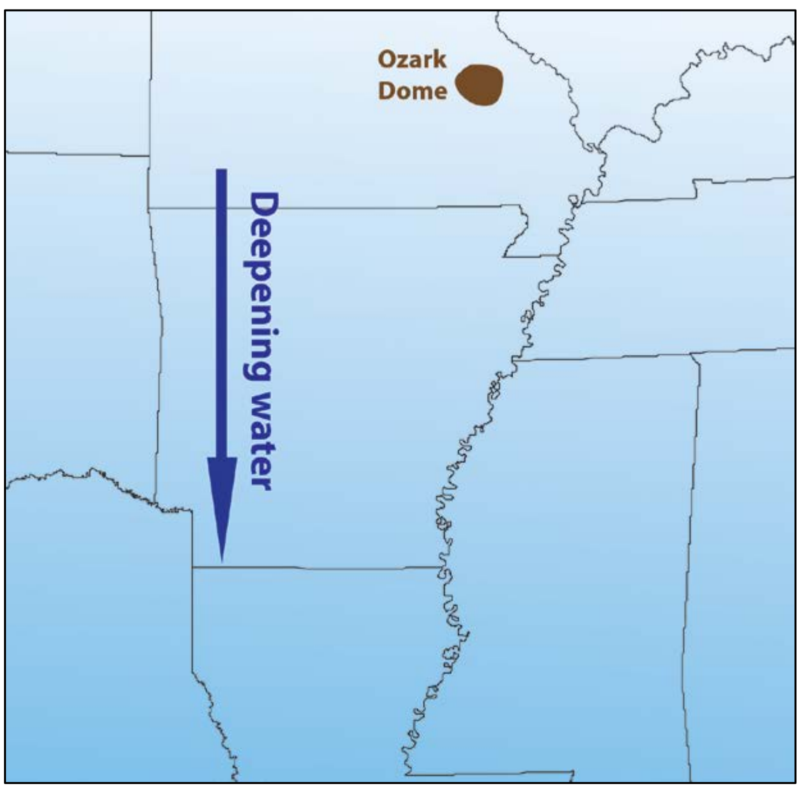


Figure 3. Paleo-geographic map illustrating the covering of Arkansas by the Early Ordovician sea.

Description of rock formations – Lower Ordovician – Salem Plateau

Powell Dolomite – This sequence of dolostone is named for Powell Station, once a Missouri-Pacific railroad station, located about 2 miles down Crooked Creek from the community of Pyatt in Marion County. It is composed of very fine- to fine-grained thin- to medium-bedded argillaceous (containing clay) and mottled dolostone that is usually white or light gray (Fig. 4). The dolostone contains calcite vugs, gastropods, and stromatolites. Very thin bedded gray-green shale is interbedded with the dolostone at a few localities. The basal contact is placed at the appearance of banded chert nodules and/or chert breccia in the upper portion of the Cotter Dolomite. Only the upper portion of the Powell Dolomite is seen on this geologic float.

Figure 4. Dolostone in the Powell Dolomite along Beaver Lake.

Sandstone Paleokarst

There are many large sandstone masses protruding out of the lake or near the edge of the lake. Some stand tall like towers while others appear to be irregular to rounded masses (Fig. 5). These masses are paleokarst features. Paleokarst consists of karst features that formed in the geologic past and were preserved in the rock record. Karst features include sinkholes, springs, and caves. These features form when acidic rain water and groundwater dissolve carbonate rocks. Carbonate rocks are those that contain calcium carbonate or calcite and calcium magnesium carbonate or dolomite.

The majority of sandstone masses are surrounded by dolostone, a carbonate rock made up of dolomite, in the Powell Formation. The Powell is Lower Ordovician in age, meaning it formed around 470 million years ago (mya). After deposition, it is likely that this formation was exposed to weathering during a time of lowered sea level. Depressions of various size, called sinkholes, developed on the exposed land surface. Later, the depressions were filled with sand which lithified into the sandstone masses we see today. The age of the sandstone masses ranges from Middle Ordovician (approx. 450 mya) to Middle Devonian (approx. 390 mya). Therefore, there is a gap in the rock sequence called an unconformity, between dolostone in the Powell and the sandstone masses that represents approximately 20 to 80 million years.

Why is paleokarst important? Paleokarst provides clues to former geologic conditions and changes in climate and sea level (Palmer and Palmer, 2011). We know that sea level was high in the Lower Ordovician when shallow seas covered all of northern Arkansas. But, in the Middle Ordovician, we can hypothesize that sea level lowered and the sandstone paleokarst features provide evidence supporting this change.

Figure 5. Sandstone mass (paleokarst) in Beaver Lake.

Deposition of rock formations – Middle to Late Devonian *(393-359 million years ago)*

During the Middle Devonian, sea level once again rose and covered the karsted Powell land surface (Fig. 6). Sand was transported from the north and northeast and filled the depressions on the surface to eventually create the sandstone paleokarst. We know the sand accumulated under shallow water because there are many tracks and burrows of marine organisms preserved in the rock. Locally, there was a pause in sand deposition and lime mud was deposited in a shallow sea. In the Upper Devonian, organic-rich clay accumulated in deeper conditions and pyrite precipitated in the sediment due to low amounts of oxygen. The clay eventually lithified into shale.

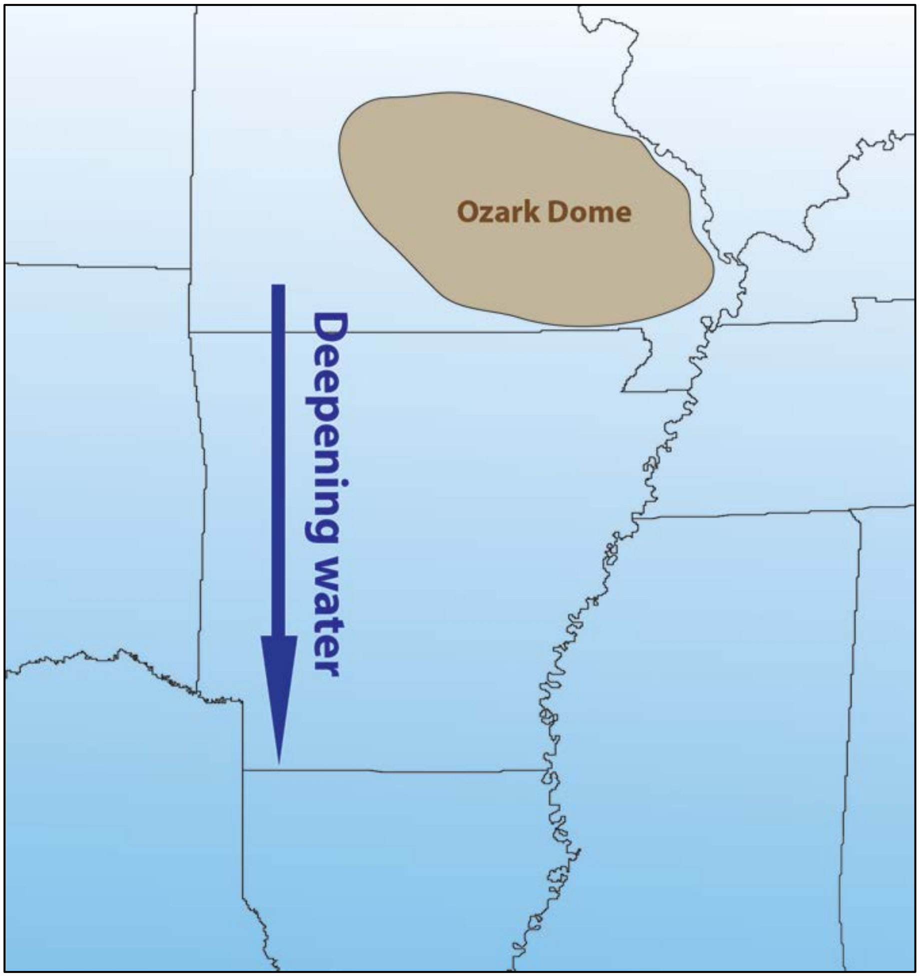


Figure 6. Paleo-geographic map illustrating shallow sea coverage during the Devonian Period.

Description of rock formations – Middle to Upper Devonian

Chattanooga Shale – This shale is named for Chattanooga, Tennessee (Hayes, 1891) where it is well developed. The shale is mostly clay rich and is black on fresh and weathered surfaces. It contains pyrite concretions that vary in size from one inch to three inches (25 to 76 millimeters) in diameter (Fig. 7). Thickness of this unit ranges from 10 to 40 feet (3 to 12 meters) thick.

Figure 7. Black shale containing pyrite concretions in the Chattanooga Shale along the shoreline of Beaver Lake.

The Sylamore Sandstone which is the basal member of the Chattanooga Shale may be present in this area. One to several beds of sandstone are present beneath the Chattanooga. It has not been determined if these beds belong to the Sylamore, Clifty, or Middle Ordovician Everton Formations. Therefore, they are grouped together and called Clifty.

Clifty Formation – This formation is named for Little Clifty Creek in the War Eagle quadrangle where it is limited in outcrop (Purdue and Miser, 1916). Little Clifty Creek has been re-named Rambo Creek since the creation of Beaver Lake. The Clifty is a fine-grained thin- to thick-bedded sandstone (Fig. 8). Locally, a fine-grained limestone and sandy limestone are interbedded within the sandstone sequence. The sandstone contains vertical and horizontal trace fossils (Fig. 9). The Clifty is unconformable and locally sits upon an angular unconformity with the underlying Powell or Cotter Dolomites. The sandstone paleokarst features are composed of this sandstone. Thickness of this unit ranges from 2 to 12 feet (0.5 to 3.6 meters) thick.

Figure 8. Sandstone in the Clifty Formation along Beaver Lake.

Figure 9. Trace fossils in the Clifty Formation along Beaver Lake.

Chert – Locally, a massive-bedded chert breccia is present between sandstone beds. The chert contains sponge spicules, calcite- and quartz-filled vugs, and sandstone tubes filled with sandstone that is similar to that in the overlying sandstone beds. The chert is tan, white, or gray and contains wavy fractures filled with white chalcedony, giving it a very distinctive appearance (Fig. 10). This unit is approximately 5 feet (1.5 meters) thick.

Figure 10. Chert in the Clifty Formation along Beaver Lake.

Deposition of rock formations: Kinderhookian to Osagean (359-331 million years ago)

During the beginning of the Mississippian Period, northern Arkansas and most of Missouri and Kansas was covered by shallow seas on a gentle southward-sloping continental shelf or ramp called the Burlington Shelf (Lane, 1978) (Fig. 11). Abundant crinoids and bryozoans were living on the northernmost shallow portion of the shelf. After the animals died, their bodies were disarticulated or broken up and began to decay. This material was transported down the shelf and deposited as a fossil hash (pieces and parts of different animals) in northern Arkansas. This material eventually lithified into a fossiliferous limestone known as the St. Joe Limestone.

As sea level rose, the Boone Formation was deposited in deeper water. Carbonate sediment including fossil material continued to move down the shelf, southward, eventually forming limestone. However, siliceous (quartz-rich) material was also deposited as chert. The Boone contains an abundance of chert. In the lower portion of the Boone, dark-gray chert is present as nodules that formed during deposition. In the upper part of the Boone, white chert replaced individual beds of limestone after deposition. The siliceous material is thought to be ash from a volcanic source south of the Ouachita Basin (Philbrick et al., 2016). The volcanoes formed in front of the advancing tectonic plate that eventually created the Ouachita Mountains (Fig. 11).

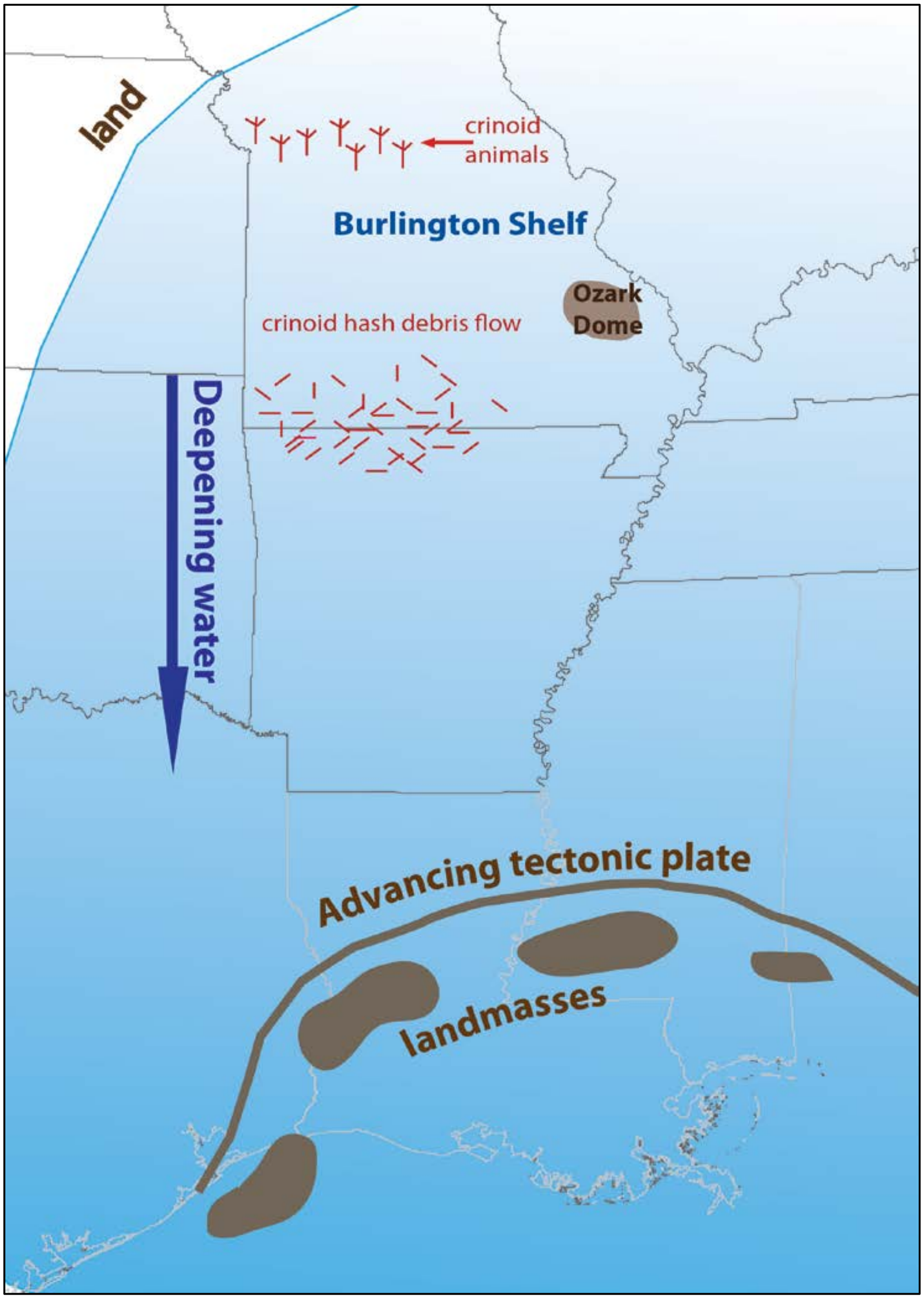


Figure 11 . Diagram illustrating deposition of the St. Joe Limestone on the Burlington Shelf.

Description of rock formations – Kinderhookian to Osagean – Springfield Plateau

Boone Formation – The Boone is named for Boone County, Arkansas where chert and cherty limestone are the dominant rock types in the region. The Boone Limestone consists of coarse-grained fossiliferous and fine-grained gray limestone interbedded with chert (Fig. 12). The chert varies in color from white to light gray in the upper portion to dark gray or blue gray in the lower portion. Fairly chert-free sections are petroliferous and contain brachiopod, coral, and crinoid fossils. The Boone Formation, excluding the basal St. Joe Limestone Member, is approximately 340 feet (103 meters) thick in this area.

Figure 12. Chert nodules (dark gray) interbedded with limestone (tan) in the lower part of the Boone Formation.

St. Joe Limestone Member – The St. Joe Limestone is named for the community of St. Joe, Arkansas. It is the basal member of the Boone Formation and consists of medium- to coarsely-crystalline and fine-grained, thin-bedded limestone. The limestone is usually gray to reddish gray in color and contains abundant crinoid columnals (Fig. 13). This limestone varies from 40 to 60 feet (12 to 18 meters) thick in this area. Four distinct divisions can be recognized here. These units from oldest to youngest are as follows: Bachelor, Compton, Northview, and Pierson.

Pierson – This is a fine to coarse-grained, thin to thick, planar-bedded crinoidal limestone. It is gray to white on weathered surfaces and gray to reddish gray on fresh surfaces. This unit forms the upper 10 to 15 feet (3 to 5 meters) of the St. Joe bluff above the Northview re-entrant.

Northview – This is a fine-grained argillaceous limestone that is red to gray-green on fresh and weathered surfaces. It forms a 2 to 3 foot (1 meter) re-entrant between the Compton and Pierson Limestones.

Compton – This is a fine-to medium-grained crinoidal limestone that is thin bedded with wavy or nodular bedding. It is gray to reddish gray on fresh surfaces but weathers light gray to white and contains brown to reddish chert with white crinoid fragments and horizontal trace fossils. It ranges from 12 to 15 feet (3 to 5 meters) thick.

Bachelor – This is a gray-green clay shale. The contact with the underlying Chattanooga Shale is sharp and unconformable. It ranges from 0 to 1 foot (0 to .3 meters) thick.

Figure 13. Crinoidal fragments in the St. Joe Limestone along Beaver Lake.

Beaver Lake Geologic Float Stops – Red Bluff to Van Hollow

All of the stops are located on the War Eagle 7.5-minute quadrangle, Benton County, Arkansas. See the Geologic Map in the back pocket for locations.

Stop 1 - Rocky Branch Public Use Area Paleokarst

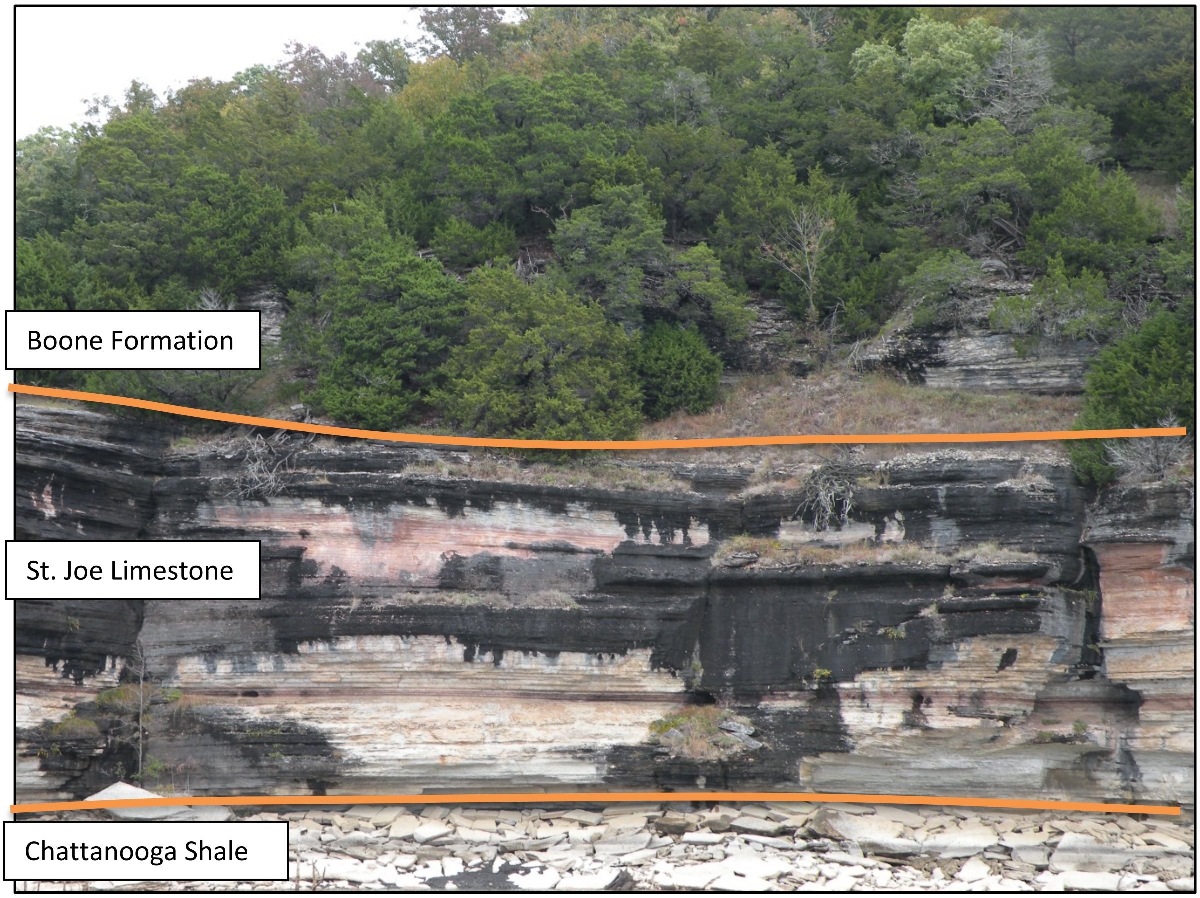
Location – Rocky Branch Public Use Area is located 11 miles east of Rogers on State Highway 12, then 4.5 miles northeast on State Highway 303. Continue on Park Road and follow the signs to the U.S. Army Corps of Engineers Park. The sandstone paleokarst is located just off the tip of the Public Use Area. Lat: 36°20’36.899”, Long: 93°55’47.75”.

Stop 1. Sandstone paleokarst near Rocky Branch Public Use Area.

Here is an example of one of the many sandstone paleokarst features in and around the lake. It is common to see only the top portion of the sandstone mass above the lake level (Stop 1 Photo). The sandstone is an unexpected rock type at this elevation since the rock that is exposed at the edge of the lake in this area is dolostone in the Powell Formation. Also note that the rocks along the shoreline are horizontally bedded. The outcrop here is a vertical irregular mass. Refer to the Sandstone Paleokarst section in this guidebook for a description of how these features form.

Stop 2 - Red Bluff

Location – This is Location Marker 7 on a Beaver Lake map. Travel north from Rocky Branch Public Use Area following the White River. Lat: 36°21'33.742", Long: 93°54'29.866".



Stop 2. Rock formations exposed at Red Bluff.

Red Bluff takes its name from the red color of the rock outcrop. The red color is due to iron, probably hematite, in the rock matrix. Also notice the black coating on the bluff (Stop 2 Photo). Water seeps out over the top of the bluff, giving it a wet look. Manganese, present in some of the overlying rock layers, dissolves in the water and precipitates on the rock face once it is exposed to oxygen in the air.

The formations exposed at this stop are Mississippian in age, the youngest on this geologic float. The main portion of the bluff face is the St. Joe Limestone. The contact with the Boone Formation starts at the top of the bluff face (Stop 2 Photo) where there is an inclined surface and tree growth. The Boone can be distinguished from the St. Joe by its abundance of chert. The contact with the underlying Chattanooga Shale is only visible during low lake level. Notice the limestone layers that have eroded from the base of the formation onto the black shale below. The black shale is the Chattanooga Shale which is Devonian age.

Look at the natural fractures in the rock that are perpendicular to bedding planes. When they are present at regular intervals and develop cross-cutting sets, we call them joints or a joint set. Joints allow rain water to enter into the rock where it either dissolves it, if it is carbonate rock, or dissolves the carbonate cement holding the grains of rock together. As the rock is dissolved, the joints become wider, allowing larger passageways for water to travel. Joints are well developed in the St. Joe Limestone. In fact, keep an eye out for joints in just about every outcrop around the lake.

Stop 3 - Fayetteville Fault at Glade

Location – Travel northwest from Red Bluff toward the community of Glade.
Lat: 36°21’54.518”, Long: 93°54’49.536”.

Stop 3. Limestone boulders within the Fayetteville Fault zone along Beaver Lake. The red line indicates the location of the Fayetteville Fault.

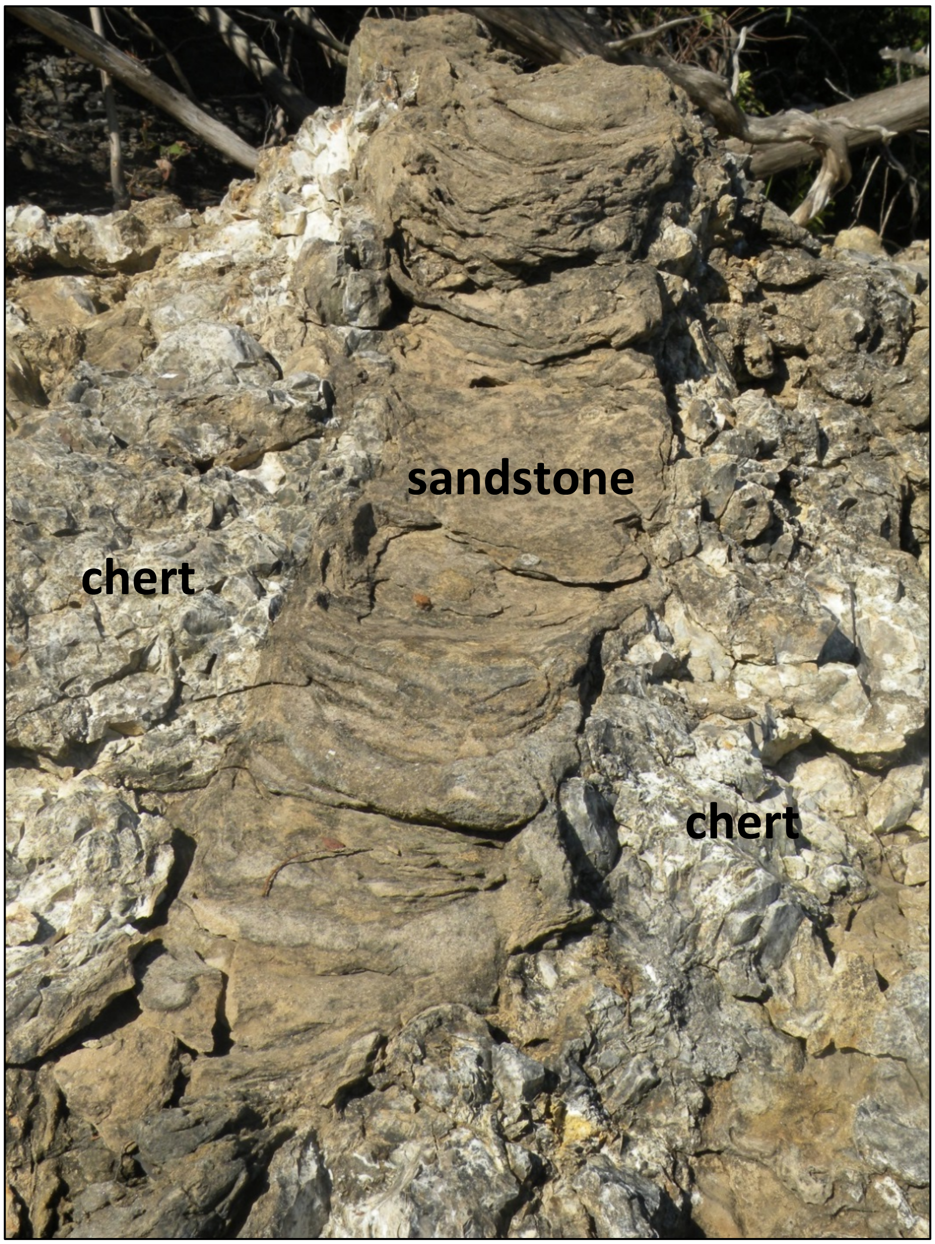
The Fayetteville Fault is exposed at this location along the shoreline (Stop 3 Photo). The actual fault plane is not exposed, therefore, other evidence is used to locate the fault here. The rock formations present on each side of the fault are different. On the southeast side of the fault, the St. Joe Limestone is present. On the northwest side of the fault, the Powell Dolomite is present. If there was no fault, the Ordovician Powell Dolomite would be continuously exposed along this shoreline. The amount of offset along the Fayetteville Fault at this location is approximately 80 feet (24 meters).

Stop 4 - Bland Peninsula

Location – Travel south from Glade. This peninsula is southeast of Rocky Branch Public Use Area and before the confluence of Rambo Creek. Lat: 36°19’55.315”, Long: 93°54’56.567”.

Stop 4A. Rock units exposed along Bland Peninsula.

This is one of the most geologically interesting locations along the lake. The bluffs to the south are composed of the St. Joe Limestone as seen at Red Bluff, however, at this location we get to see rock layers underneath the St. Joe Limestone. The rocks below the St. Joe are older – they are Devonian in age. At this location, black Chattanooga Shale is exposed in the neck of the peninsula. If the lake level is low, a cherty unit can be seen beneath the shale (Stop 4A Photo). The chert is light brown to gray, banded, and contains quartz- and calcite-filled vugs. This cherty unit varies in thickness and is not present at all locations around the lake. Look closely within the chert on the northwest side of the peninsula. Here, you see sandstone that was deposited into fractures within the chert (Stop 4B Photo). The source of this sand appears to be the same that formed a 2 to 3 inch bed of sandstone underneath the Chattanooga Shale and above the cherty zone. Sandstone is also present beneath the cherty zone. The chert and sandstone units are considered the Clifty Formation in this area.



Stop 4B. Sandstone filling a fracture within the cherty zone.

Stop 5 - Sandstone paleokarst in Powell Dolomite

Location – Continue south from Bland Peninsula into Van Hollow. Turn right into the second inlet and travel to the end of the finger. Lat: 36°19'33.969", Long: 93°55'6.001".

Stop 5A. Sandstone paleokarst (rounded feature) surrounded by dolostone along the shoreline of Beaver Lake.

It is rare to see the contact between a paleokarst feature and the surrounding rock, so this is an excellent opportunity to examine one of these structures (Stop 5A Photo). First, note the rounded shape of the feature and that it is composed of sandstone. Next, look at the rock surrounding the sandstone. The rock layers on either side of the sandstone are composed of dolostone in the Powell Dolomite. During deposition, sand filled a depression within the Powell. From this we can deduce that the sandstone we see today was deposited after the Powell, and is therefore younger. It is difficult to know whether the sand was deposited during the Late Ordovician or the Devonian Period since we cannot see a direct connection between the sandstone paleokarst and the overlying sandstone units at this location.

There are several interesting features in the sandstone. One feature is a slickenside (Stop 5B Photo). A slickenside is a striated surface showing grooves that are aligned parallel to the movement that has occurred along a fracture or a fault. They are common along faults and indicate the trend of relative movement of one block to the other. Look on the west side of the sandstone paleokarst near the top to see the grooved surface. Notice the mineral calcite (orange/white) on the surface. Rub your hand along the surface. The smoother direction indicates the direction of movement. In this case, the surface is smoother in a downward direction. This slickenside formed as the sand was moving downward into the depression.

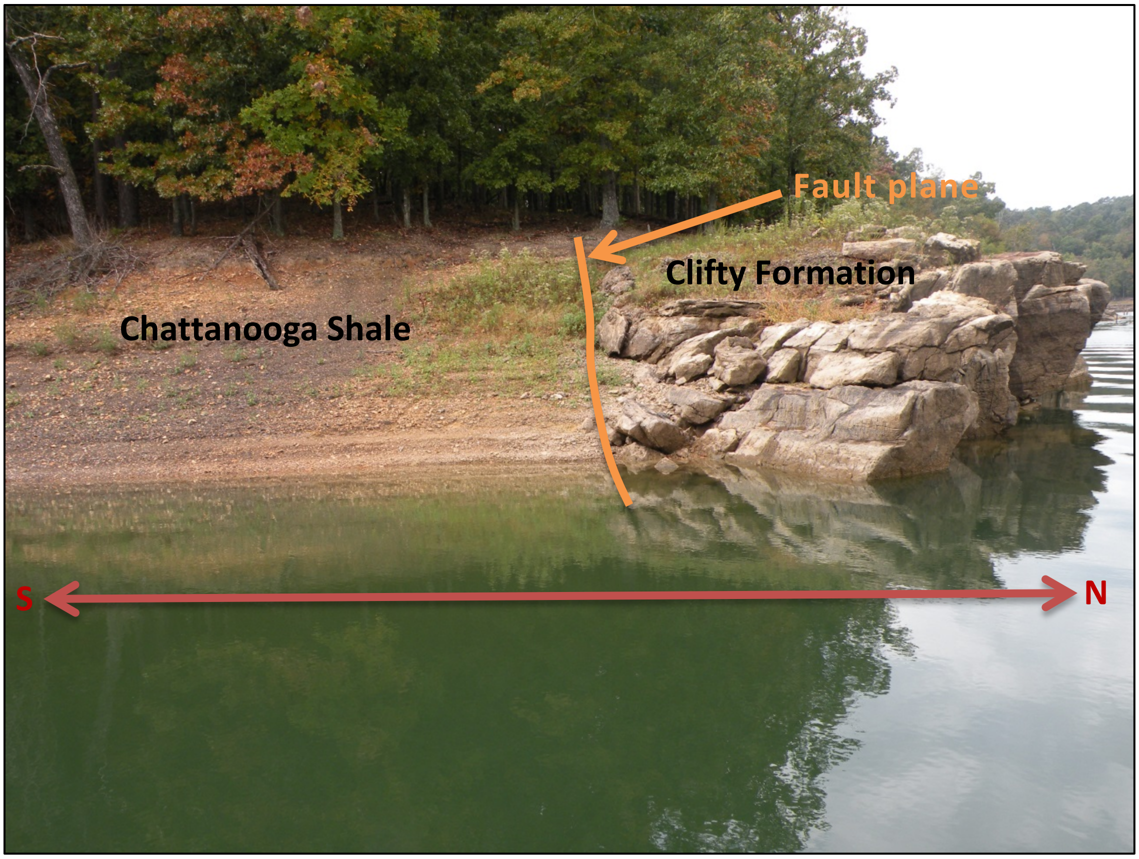
Stop 5B. Striations or slickensides in the sandstone paleokarst showing relative movement of the sandstone against the surrounding material that has since eroded.

Another feature in the sandstone appears to be a jumble of material (Stop 5C Photo). Look on the east side of the sandstone paleokarst for these features. The parallel lines in the pieces of sandstone could be cross-bedded sandstone fragments that have broken and fallen into the mass of sand. Another explanation could be that the sand was deformed during settling while it was still soft and before it lithified into sandstone.

Stop 5C. East side of sandstone paleokarst showing either deformation of sand or inclusion of semi-consolidated sandstone fragments during deposition.

Stop 6 - Blackburn Creek Fault

Location – Continue southwest through Van Hollow from Stop 5. Turn left into the second small inlet and look for the fault on the south side of the finger. Lat: 36°18’45.524”, Long: 93°55’12.929”.



Stop 6A. Blackburn Creek Fault, Van Hollow.

Here we can see a fault or break in the rocks where they have moved relative to each other (Refer to Appendix 1 for more information about faults). Notice that the sandstone is not continuous around the shoreline in the left half of the photo (Stop 6A Photo). Sandstone in the Clifty Formation (N) is against Chattanooga Shale (S). Normally, the sandstone outcrop would be continuous but a fault has displaced it here causing it to drop below lake level on the south side. If one were to scuba dive below the Chattanooga Shale on the south side of the fault, the Clifty Formation would be present approximately 20-40 feet (6-12 meters) below the surface. This fault is named after Blackburn Creek in the western part of the War Eagle quadrangle.

Other features in the rock also provide evidence of a fault at this location. Look closely at the edge of the sandstone closest to the fault. A breccia containing chert fragments is present along the fault (Stop 6B Photo). This material is referred to as fault breccia because it formed by the crushing and displacement of the sandstone and chert during movement along the fault.

Stop 6B. Fault breccia along Blackburn Creek Fault, Van Hollow.

Also, look for white lines in the sandstone (Stop 6C Photo). These lines are called deformation bands. Deformation bands are small linear zones where grains of quartz are crushed and aligned due to movement with the rock. These bands appear as raised white ridges which are approximately one millimeter thick. The abundance and size of the bands depends upon the amount of displacement along a fault.

Stop 6C. Deformation bands along the Blackburn Creek Fault, Van Hollow.

Finally, look across the lake toward the northeast. You can see the fault on the other side with the same characteristics seen here. The Clifty Formation is present on the north side and the Chattanooga Shale is present on the south side. This fault also extends eastward through Rambo Creek.

Stop 7 - Boy Scout Cave

Location – Continue southwest through Van Hollow from Stop 6. Turn left into the second inlet and look for the cave on the east side of the finger. Lat: 36°18'22.55", Long: 93°55'39.012".

Stop 7. Boy Scout Cave that has developed at the base of the St. Joe Limestone.

Hobbs State Park is known for its karst features. Karst refers to the natural features or landforms created due to the solutioning or dissolving of the bedrock. These features include caves, springs, sinkholes, and disappearing streams. All of these features are present at Hobbs State Park.

Notice the two different rock types in Stop 7 photo. The St. Joe Limestone is present above the Chattanooga Shale. Water traveled downward from the surface through joints in the St. Joe Limestone until it reached the Chattanooga Shale. The shale acts as a barrier to the water moving downward since it is made up of tiny particles of clay. Groundwater flowed along this boundary between the two rock types and started slowly dissolving the limestone creating a cave. Eventually, as the land surface was cut through by the White River and its tributaries, the cave was exposed. Now the cave is exposed along the edge of Beaver Lake due to the development of Beaver Dam.

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Appendix 1

Normal Fault

A fault is a break or fracture in the rock along which there has been displacement of one side relative to the other. It is difficult to determine whether one side or both sides have moved. However, after faulting has occurred, it can be said that one side has moved with respect to the other. In order to determine the fault movement we must first look at the *fault plane*, label the *hanging wall* in relation to the *foot wall*, then determine the *upthrown* and *downthrown sides*. Refer to the definitions below:

Fault plane – the break along which the slipping or movement occurs.

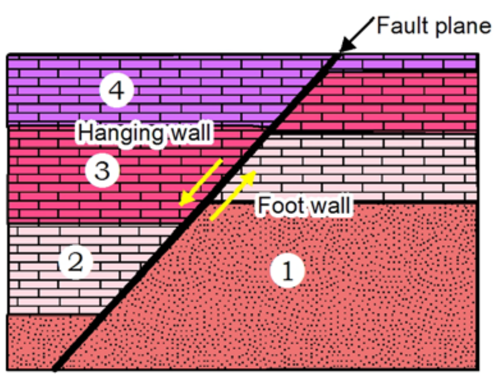
Hanging wall – the rock which overhangs or rests on the fault plane.

Foot wall – the rock which supports the hanging wall and faces obliquely upward.

The *upthrown side* is the side which moves upward relative to the other side.

The *downthrown side* is the side that moves downward relative to the other side.

After we determine the relative movement along the fault then we can label the fault as *normal*, *reverse*, *thrust*, or *strike-slip*. Refer to cross-sections below for examples of each type of fault.



This diagram illustrates a normal fault in which the hanging wall has moved down relative to the footwall. The hanging wall is the downthrown side while the foot wall is the upthrown side. The strata are numbered from oldest (1) to youngest (4).