EWS - 07

STATE OF ARKANSAS

ARKANSAS GEOLOGICAL SURVEY
BEKKI WHITE, DIRECTOR AND STATE GEOLOGIST

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EDUCATIONAL WORKSHOP SERIES 07

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# Arkansas Geology: Karst and Caverns

Angela Chandler

Little Rock, Arkansas
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# Acknowledgments

This laboratory manual is written for Arkansas teachers studying Earth Science. It is also written with the Arkansas Science Curriculum in mind so that students can meet the requirements and goals set for their age groups. Thanks to various staff members at the Arkansas Geological Survey for suggestions and edits to this booklet.

Thanks to all of the science specialists for requesting these fieldtrips. Without you, and teachers, there would be no need for the workshop!

For information related to this manual please contact Angela Chandler: 501-683-0111

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Front cover images: left – Blanchard Spring
right – sandstone pipe at rock shelter

# Arkansas Geology – Karst and Caverns

This is a one day workshop that explores karst features on the Springfield Plateau as we travel to Blanchard Springs Caverns to tour the cave. The following frameworks in Earth and Space Sciences and Environmental Science will be addressed:

ESS.8.3.3 – Identify sedimentary rocks – differentiate between limestone, dolostone, and sandstone

ESS.8.4.1 – Locate the Ozark Plateaus Region and identify each plateau – Salem, Springfield, and Boston Mts.

ESS.9.4.1 – Analyze changes to the Earth's Surface through erosion and weathering of carbonate terrain – identify karst landforms such as sinkholes, springs and caves

ESS.8.8.7 – Use topographic maps to identify surface features of Earth

ESS.9.8.2 – Analyze how rock sequences may be disturbed by the following: erosion and deposition – karst

PD.1.ES.6. – Describe the processes of degradation by weathering and erosion

PD.1.ES.10 – Describe the characteristics of each of the natural divisions of Arkansas: Ozark Plateaus

## Geologic Setting

This workshop examines karst features on the Ozark Plateaus Region of north-central Arkansas at Blanchard Springs Caverns. The Ozark Plateaus Region is located around a broad, asymmetrical dome (or uplift) with its center (oldest rocks; Precambrian basement) in the St. Francois Mountains of southeast Missouri (Fig. 1). The rock formations dip gently away from this area in all directions. The Ozarks of northern Arkansas form the southern flank of this dome.

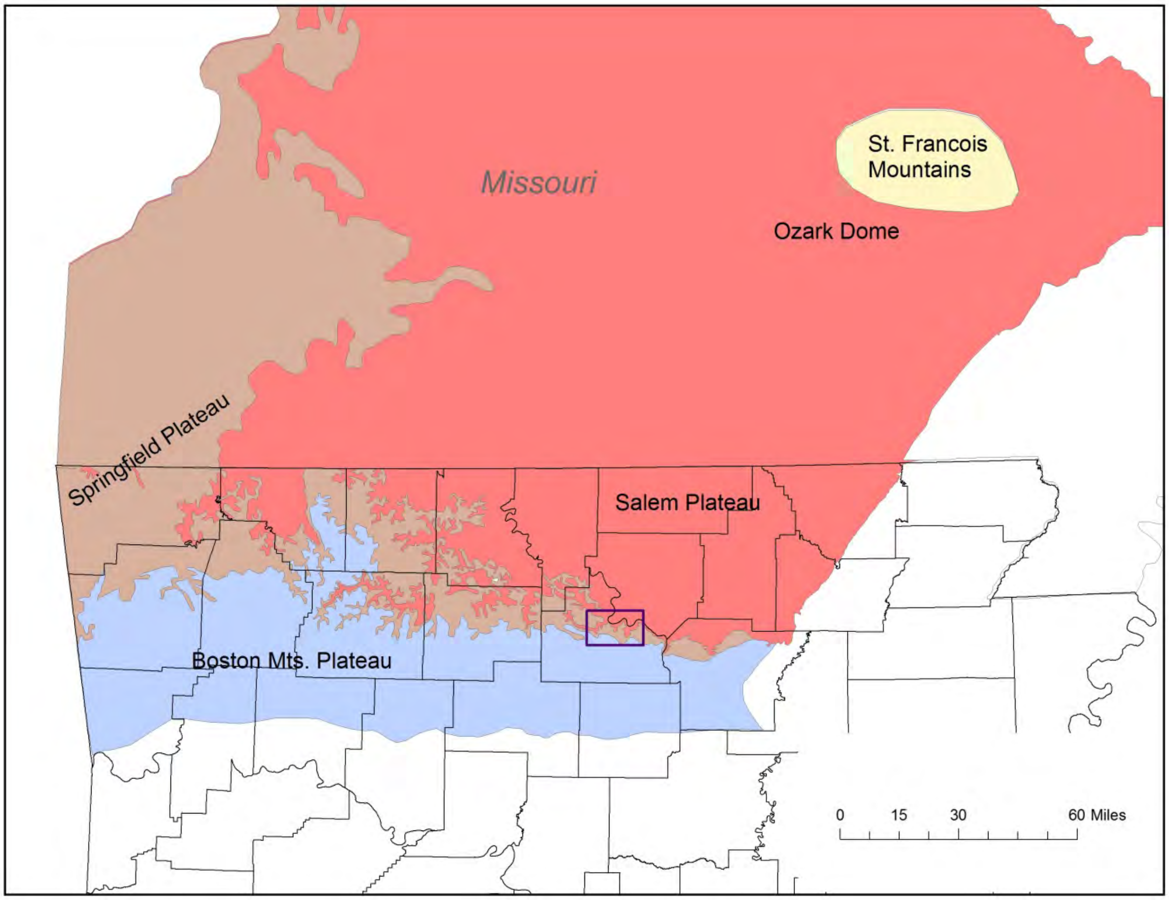


Figure 1. Plateau surfaces in the Ozark Plateaus Region showing location of Ozark Dome and location of workshop outlined in purple.

This part of the state was periodically covered by shallow seas from the Cambrian through Mississippian geologic periods. Primarily carbonate rocks such as limestone and dolostone were deposited at this time. As the sea regressed during the Pennsylvanian period, primarily sandstones and shales were deposited. The rock layers in the Ozarks are only very slightly deformed and generally flat lying. The Ozark plateaus have been deeply dissected by streams, leaving erosional mountains. Streams commonly display a dendritic drainage pattern.

The Ozarks can be divided into **3 plateaus** (broad, flat-topped areas) that are separated from each other by steep slopes called escarpments.

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

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

*3) Boston Mountains Plateau – capped by Pennsylvanian age rocks, mostly sandstone*

The plateaus become progressively higher in elevation and expose younger rocks from north to south in the Ozarks of Arkansas.

Even though this workshop will focus mainly on the Springfield Plateau, the escarpment between the Salem and Springfield Plateaus is present in North Sylamore Creek at Blanchard Springs Caverns. The Springfield Plateau surface is made up of primarily the Mississippian-age Boone Formation (Fig. 2). The Boone Formation consists of interbedded chert and limestone. The base of the Boone Formation is a red crinoidal limestone called the St. Joe Limestone Member. The Salem Plateau, in this area, is capped by Ordovician age rocks called the Plattin, Kimmswick, and Fernvale Limestones (Fig. 2). At various localities in this area, Silurian age rocks are present. The St. Peter Sandstone and the Everton Formation crop out in the deeper drainages.

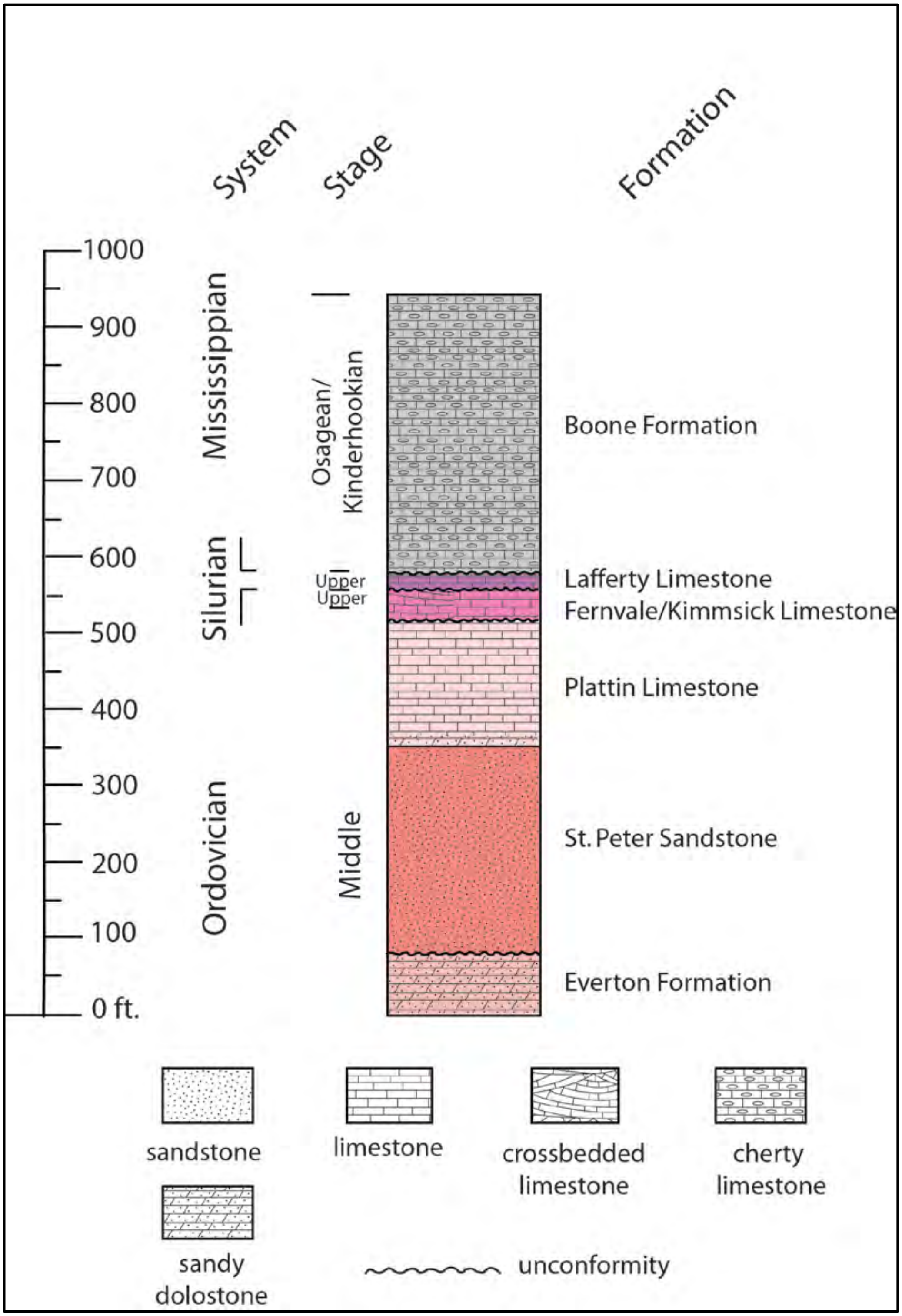


Figure 2. Stratigraphic column for workshop area.

**Deposition of rock formations:** ***Middle Ordovician to Late Ordovician (472-444 million years ago)***

The Ordovician period is probably best known as a time of high sea level, although there were periods of relatively low sea level as indicated by unconformable surfaces in the rock record. Carbonate deposits accumulated in shallow seas and on tidal flats over large areas of what is now the United States. There were areas west and north of Arkansas called the Canadian Shield and Transcontinental Arch (Fig. 3) where the continent was exposed and eroded. Deposition of the Everton through Fernvale Limestone occurred on very low angle slopes in a shallow sea that was periodically exposed, forming barrier islands, lagoons, and intertidal to supratidal flats (Fig 4). The tidal flats consisted of broad areas of lime mud and sand several feet above mean high tide. Quartz sand was brought into the sea by rivers from the Canadian Shield to the north (Fig. 3). It was distributed by long-shore currents which built barrier islands much like the present-day Gulf Coast barrier islands.

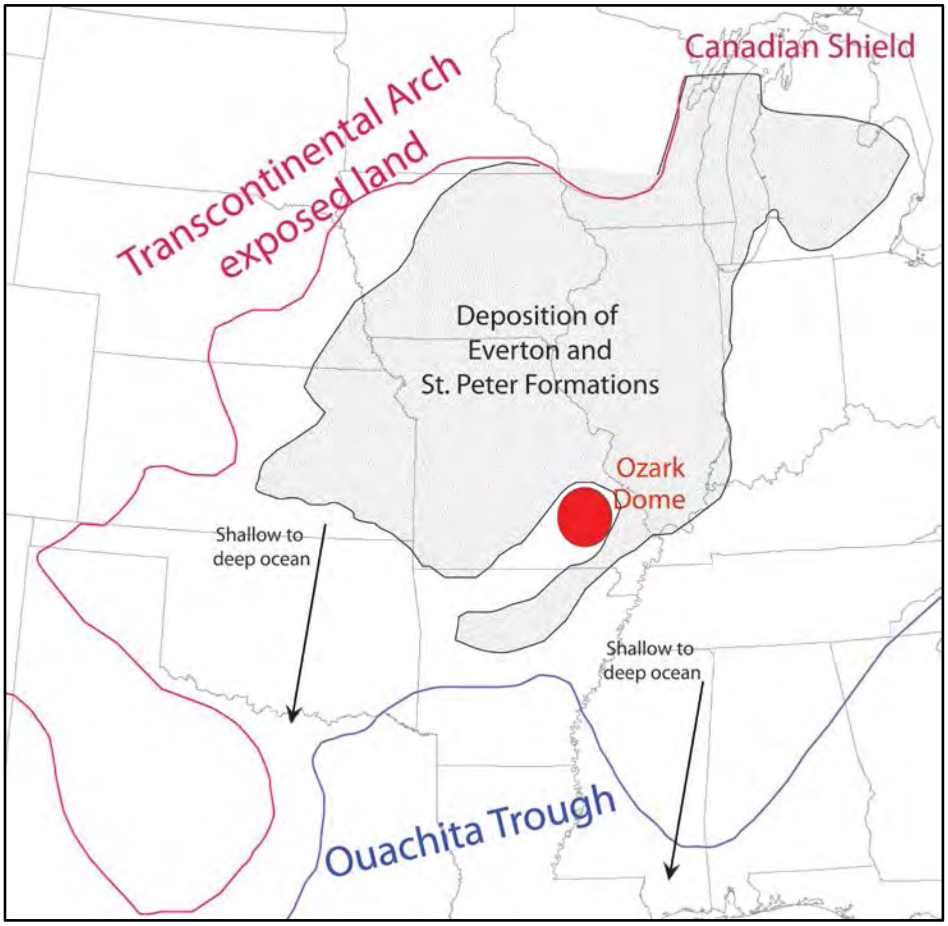


Figure 3. Depositional environment of the Everton and St. Peter Formations. *Modified from Suhm, 1977*.

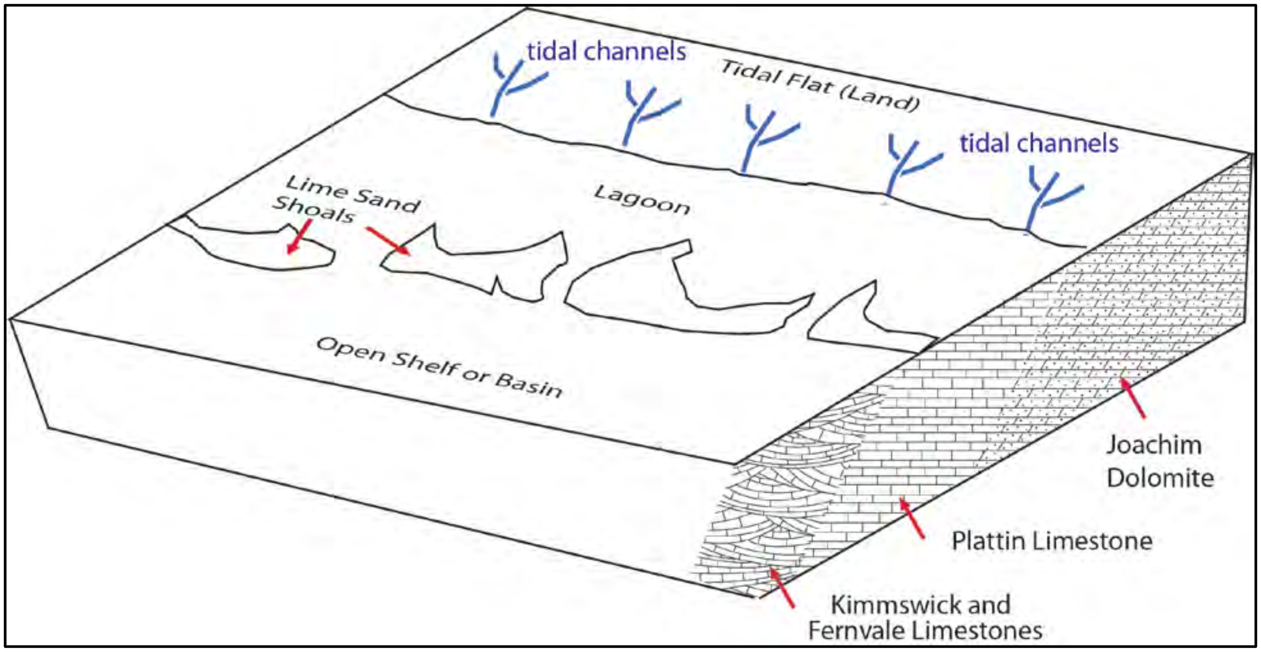


Figure 4. Depositional environment of the Joachim through Fernvale Formations.

*Description of rock formations*

*Fernvale Limestone* – This limestone is named for the town of Fernvale in western Tennessee. It is a medium to coarse grained crinoidal limestone that is white to light gray with a pink to reddish tint or mottles on fresh surfaces. It contains nautiloids and barrel-shaped crinoid fragments that are accentuated on weathered surfaces. On a weathered slope, the Fernvale occurs as rounded masses that are usually friable. The contact with the underlying Kimmswick is usually a stylolitic bedding plane contact (sometimes solutionally enlarged) that is probably unconformable.

*Kimmswick Limestone* – This limestone is named for exposures at Kimmswick in Jefferson County, Missouri. It is a medium crystalline limestone. It also tends to weather to rounded masses much like the Fernvale; however, it is very hard and not friable. Its rounded appearance easily distinguishes it from the blocky Plattin Limestone on a weathered slope. The contact with the underlying Plattin Limestone is usually stylolitic and probably unconformable.

*Plattin Limestone* – This limestone is named for exposures near Plattin Creek, Jefferson County, Missouri (Keroher et al., 1966). It is a thin- to thick-bedded micritic (fine-grained) limestone. The Plattin Limestone is conformable with the underlying Joachim Dolomite in this area.

*Joachim Dolomite* – This dolostone is named for exposures along Joachim Creek, Jefferson County, Missouri. It is a fine-grained dolostone that contains sand in the lower portion near the contact with the St. Peter Sandstone. Calcite-filled voids (1/10 inch to 1/4 inch) are abundant. It also contains mud cracks, lamellae, and rip-up clasts. This dolostone is conformable with the St. Peter Sandstone.

*St. Peter Sandstone* – This sandstone is named for exposures on the St. Peter River, now called Minnesota River, in southern Minnesota (Keroher et al., 1966). It is mostly a fine- to medium-grained clean sandstone with rounded quartz grains. It is thin- to medium-bedded and is commonly friable. The sandstone contains vertical trace fossils called *Scolithos* (Adams et al. 1904) that weather to resemble icicles in cross-sectional view. The St. Peter Sandstone forms a prominent bluff-line in the area and is unconformable with the underlying Everton Formation.

*Everton Formation* – The Everton Formation is named for exposures near the town of Everton in Boone County, Arkansas. This formation consists of interbedded sandy dolostone, sandstone, and limestone. A stromatolitic, very thin-bedded fine-grained limestone is present at the top of the formation throughout the fieldtrip area. Springs are abundant in this unit.

### ***Deposition of rock formations: Early Mississippian (359-345 million years ago)***

During the beginning of the Mississippian Period, northern Arkansas and most of Missouri and Kansas was covered by shallow marine seas on a southward gently sloping shelf or ramp called the Burlington Shelf (Fig. 5). Abundant crinoids and bryozoans were living on the northern-most shallow portion of the shelf. After the animals died, their remains were disarticulated and began to decay. Most of this material was transported down the southerly dipping ramp and deposited in northern Arkansas along the shelf margin and on the deeper outer shelf. There is an abundance of quartz in the rocks deposited during this time period. The source of the quartz is thought to be from the remains of siliceous radiolarians and sponges or from volcanic ash falls.

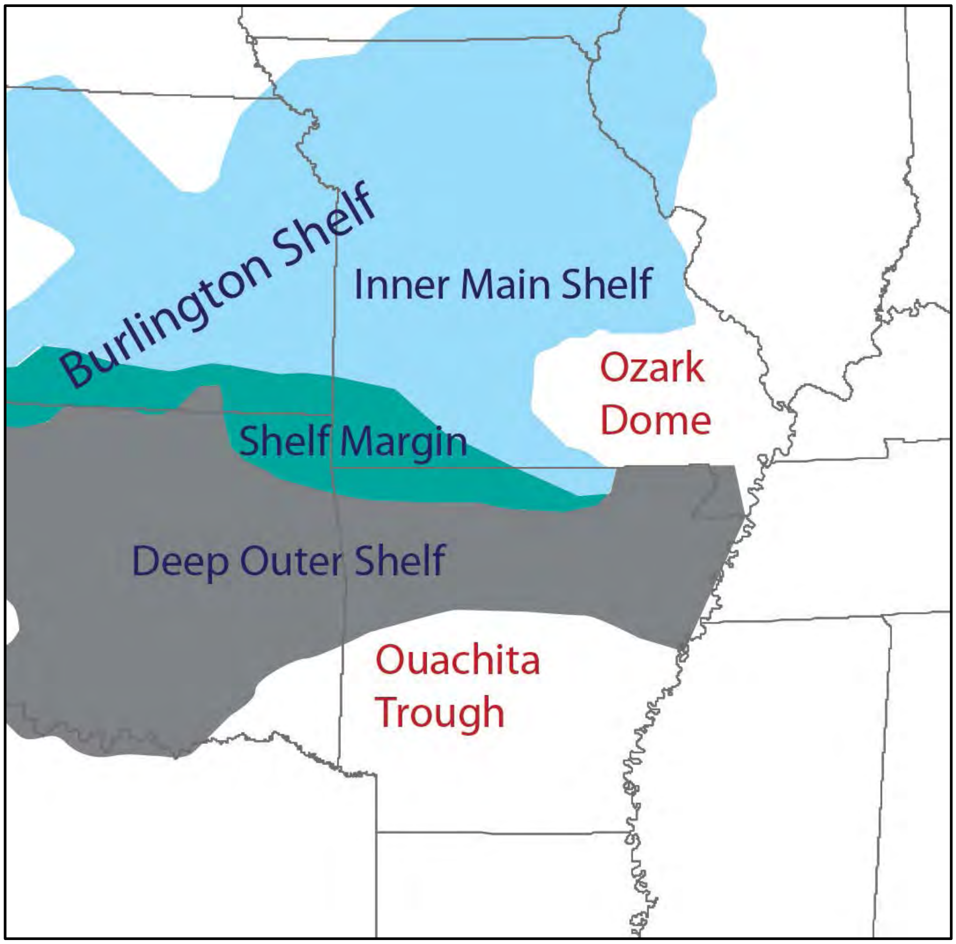


Figure 5. The Burlington Shelf on which the Boone Formation was deposited in the Mississippian Period. *Modified from Robert Handford, 2013.*

*Description of rock formations – Springfield Plateau*

*Boone Formation* – The Boone Limestone was named by J.C. Branner for Boone County, Arkansas where cherts and cherty limestones form the dominant rock types in the region (Penrose, 1891). The Boone Limestone consists of coarse-grained fossiliferous and fine-grained gray limestone interbedded with anastomosing and bedded chert. 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 brachiopods, corals, and crinoids. The Boone Formation is the surface rock of the Springfield Plateau and forms the ceiling in Blanchard Springs Caverns. It is present over many of the hills in the area.

*St. Joe Limestone Member* - The St. Joe Limestone was named for the town of St. Joe, Arkansas by J.C. Branner (Hopkins, 1893). It consists of medium to coarsely-crystalline and fine-grained, thin-bedded limestone. The limestone is usually reddish gray in color and contains abundant crinoid columnals. This limestone varies from 2-15 feet thick in the area.

### *Formation of karst – present day*

Karst Topography

Karst topography refers to natural features produced on a land surface due to the chemical weathering or slow dissolving of limestone, dolostone, marble or evaporite deposits such as halite and gypsum. The chemical weathering agent is slightly acidic groundwater that begins as rainwater. Rainwater becomes acidic by absorbing carbon dioxide to create carbonic acid as it falls through the atmosphere. It then passes through the soil horizon and becomes even more acidic. As it moves down through fractures (cracks) and open spaces within the rock below, the carbonic acid in groundwater dissolves minerals such as calcite, a process called solution or dissolution. Calcite is the principal mineral in limestone and marble. Dolostone, which is composed of dolomite, is chemically similar to calcite.

The Ozark Plateaus region contains the majority of karst features in Arkansas. Features of karst landscapes include caves, springs, disappearing streams, dry valleys and sinkholes (Fig. 6). Large subterranean openings and connected passages are created as acidic groundwater moves through fractures and spaces within the rock.

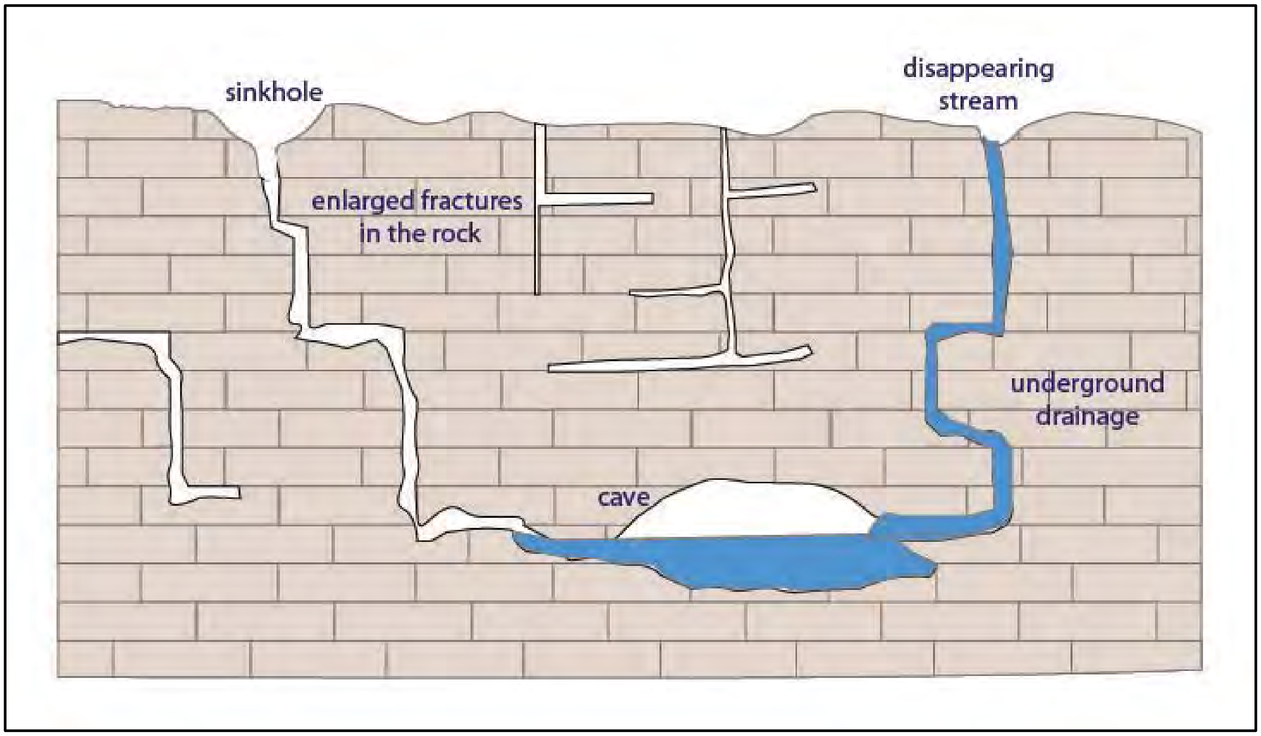


Figure 6. Features created by underground drainage.

Caves are naturally open spaces underground, generally with a connection to the surface, and large enough for a person to enter. Underground passages allow groundwater to travel long distances and re-appear as springs. Springs occur where groundwater flows naturally from bedrock or soil onto the land surface or into a body of surface water. Surface streams can disappear into the subsurface through fractures and passageways and travel underground for some distance before re-appearing downstream or discharging as a spring elsewhere. These streams are called disappearing streams (Fig. 7A). In areas where the stream is mostly dry year round, the valley is called a dry valley (Fig. 7B). Dry valleys are common in areas underlain by carbonate rock with underground drainage.


(A) (B)

Figure 7. (A) A stream disappearing into a sinkhole. (B) A disappearing stream in the Everton Formation creating a dry valley.

Sinkholes are commonly bowl or funnel-shaped depressions and are usually the surface expression of underground drainage. Sinkholes form by solution, and collapse. Solution sinkholes form as water infiltrates fractures in bedrock at the surface, dissolving and enlarging them (Fig. 8). A depression forms through a gradual settling or lowering of the surface (Fig. 9). Carbonate rock can also undergo solution under the surface of the earth causing the overlying material to subside or collapse. When the rock is overlain by clay or sand or other insoluble materials, the surface of the ground will subside into the underlying void but still cover the void. Collapse sinkholes form when the rock or other material overlying a cave chamber or other void collapse into the chamber leaving a void at the surface (Fig. 10).

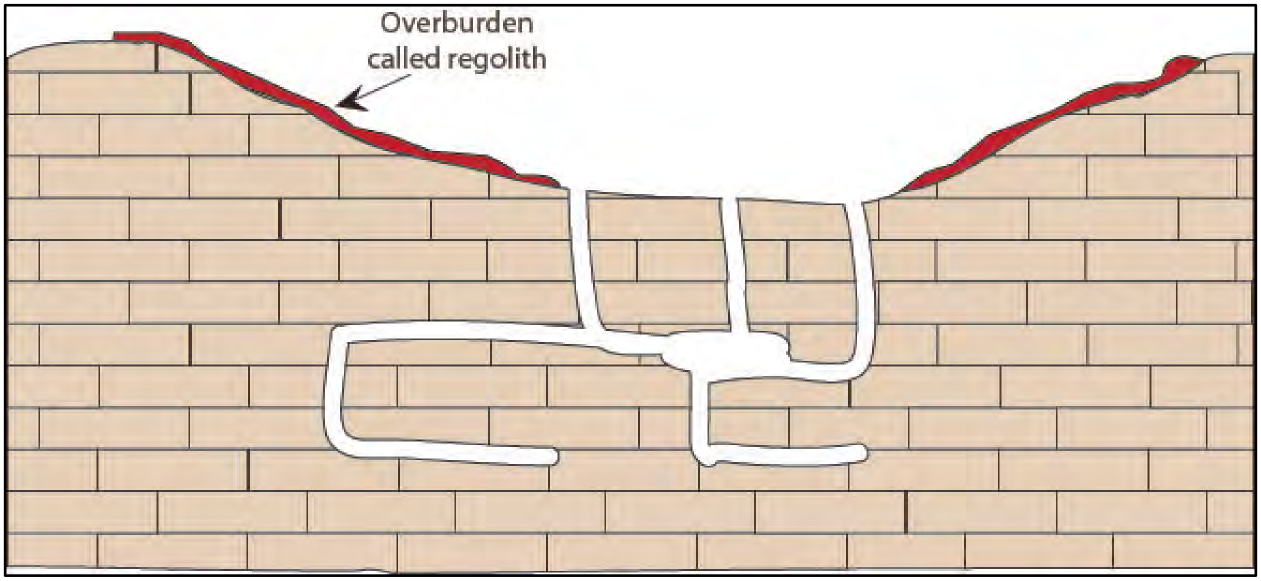


Figure 8. Diagram showing a solution sinkhole. Regolith consisting of clay and chert fragments is present in varying thicknesses. When regolith is absent, water acts directly on the limestone exposed at the surface.


(A) (B)

Figure 9. (A) Solution sinkhole in the Boone Formation. (B) Sinkhole created when insoluble regolith in the Boone Formation collapses into the underlying void.

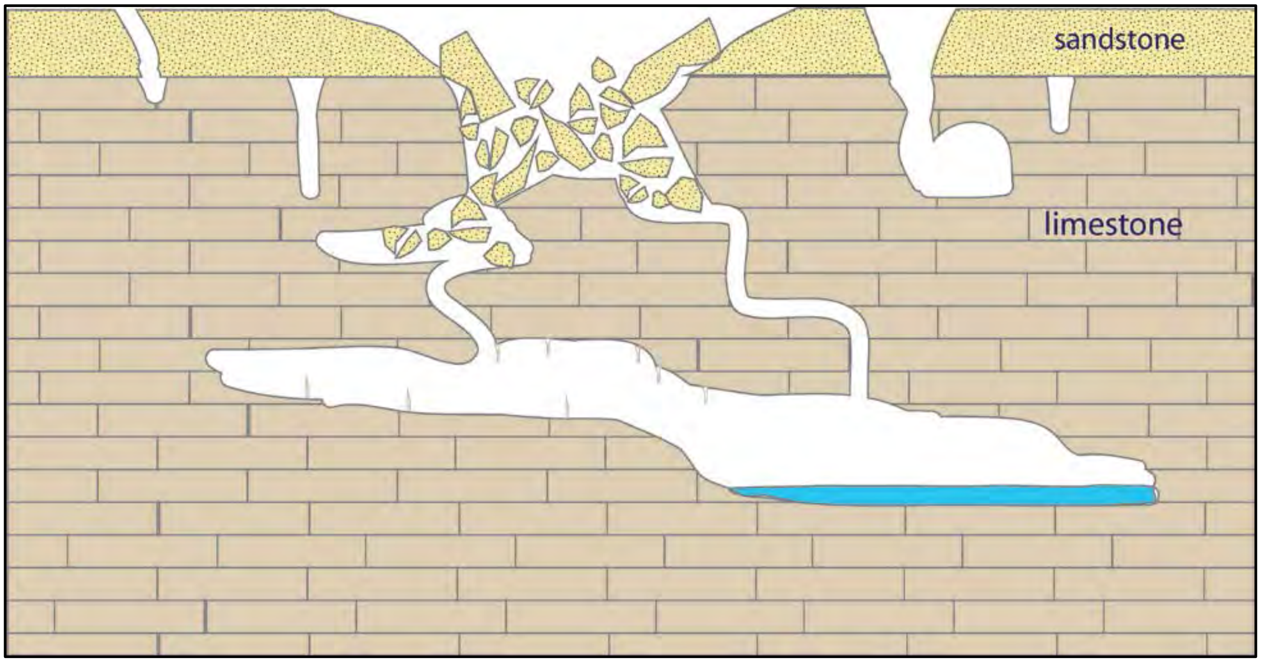


Figure 10. Diagram showing a collapse sinkhole.

The majority of surface rocks in the Ozark Plateaus Region of northern Arkansas are limestone and dolostone, and the region contains all of the features typical of a karst landscape. Thousands of caves and hundreds of springs are present in this region. Disappearing streams and dry valleys are common in the Salem and Springfield Plateau Regions.

The Salem Plateau surface is primarily underlain by dolostone in the Everton, Powell, and Cotter Formations. Mammoth Spring, the largest spring in Arkansas, is located in this region and discharges an average of 150,000 gallons of water per minute. Solution sinkholes occur in dolostones on this plateau surface. Solution subsidence and collapse sinkholes are present where a thin veneer of the St. Peter Sandstone overlies the Everton Formation. Approximately twenty percent of the caves in Arkansas are located in this region.

The Springfield Plateau surface is underlain by limestone in the Boone Formation. The Boone Formation contains the majority of karst features throughout the Ozark Plateaus Region and contains more than fifty percent of all caves in the state. Solution and collapse sinkholes are abundant in the Boone Formation. Solution subsidence and collapse sinkholes are also present where a thin covering of Batesville Sandstone overlies the Boone Formation. The Joachim Dolomite and Plattin, Kimmswick, and Fernvale Limestones are present along the escarpment between the Springfield and the Salem Plateau surfaces. Approximately five percent of the caves in Arkansas are developed in these formations combined.

The Boston Mountains Plateau surface consists of mostly sandstone and shale in the Atoka Formation which is not susceptible to karst development. Approximately ten percent of the caves in the state occur in the Brentwood Limestone and the Prairie Grove Member of the Hale

Formation in this region. In deep drainages and along the escarpment of the plateau, the Pitkin Limestone is present and contains hundreds of caves and springs.

### How do caves form?

After falling as rain, acidic groundwater moves through fractures and spaces within the rock slowly dissolving and enlarging spaces to create larger openings and connected passages. Every rock that you see in nature has natural fractures or cracks (Fig. 11A-B). These fractures allow groundwater to travel downward (vertically) below the ground surface due to gravity. The water travels downward until it reaches the water table. Once water reaches the water table, it travels horizontally. This is very important to remember when you think about how passages in caves form.

(A) (B)

Figure 11. (A) Fractures or cracks in limestone. (B) An enlarged fracture large enough for a person to enter.

The water table (Fig. 12) is highly irregular and discontinuous in a karst region, yet it is always possible to tell from passage morphology whether a particular passage formed under vadose or phreatic conditions (Palmer, 1991). The vadose zone is the area between the surface of the earth downward to the water table, or the unsaturated zone. Passages form in vadose conditions from gravitational flow and trend downward along the steepest pathway available. Water that descends vertically along a fracture may form a shaft with nearly vertical walls (Fig. 13A). The phreatic zone is the area below the water table, where all the pores and fractures are filled with water, or the saturated zone. Phreatic passages form along routes of greatest efficiency. They are usually rounded or lenticular and horizontal or have a low gradient (Fig. 13B).

There are several types of caves, however only the branchwork type is discussed here. Branchwork caves form as water concentrates in and beneath depressions and penetrates the aquifer below at various locations. Large rooms form only at passage intersections and they commonly have a spring as an outlet for the cave. Branchwork caves are the most common type in Arkansas (McFarland, 2007) and around the world (Fig. 14A) (Palmer 1991).

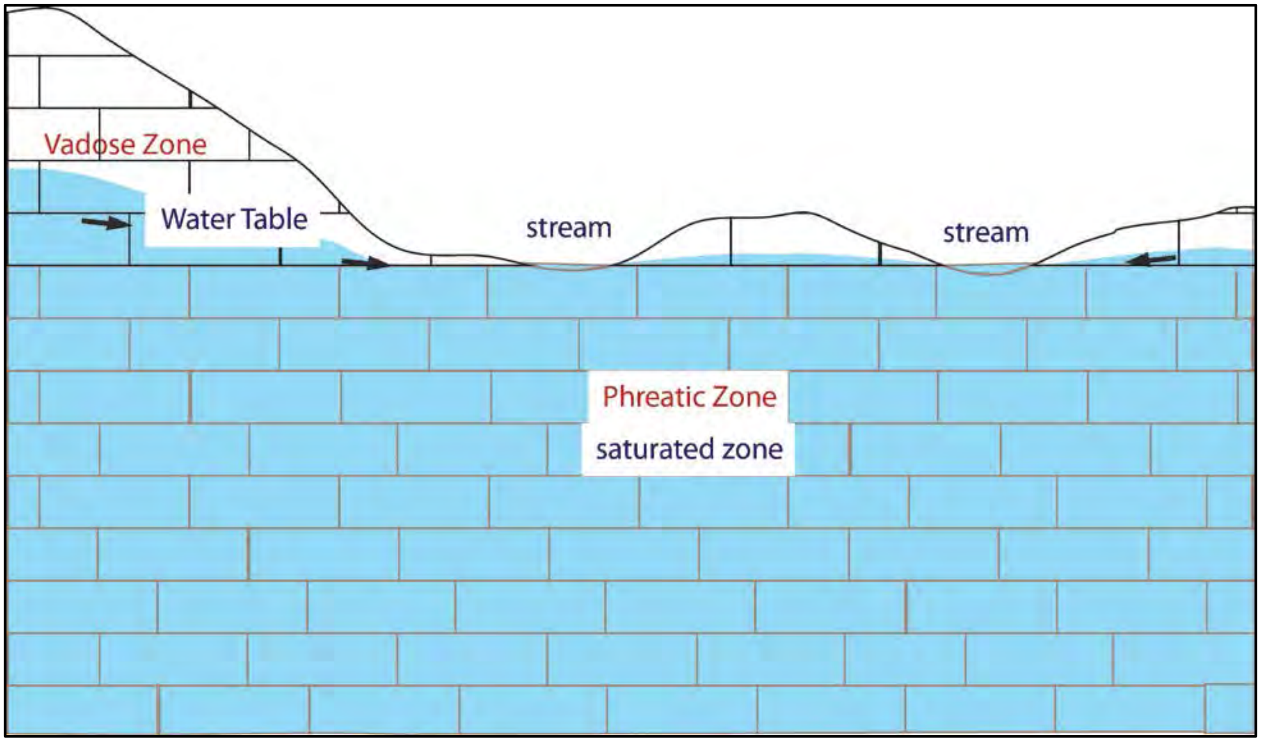
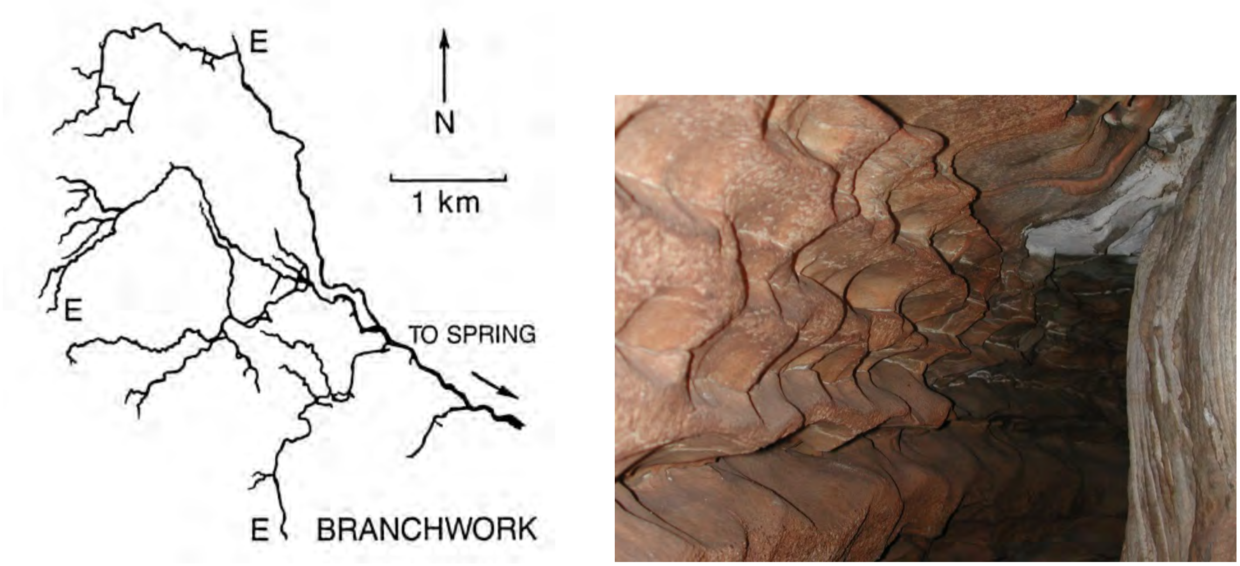


Figure 12. Water table showing vadose and phreatic zones. Water moves very slowly except in a thin horizontal layer directly below the water table.

Caves contain speleothems and other features such as scallops that indicate water levels and how fast the water was moving through the cavern. Most speleothems form in a passage after all of the water has flowed to a lower level. As a drop of water enters the cave, the carbon dioxide dissolved in the water is given off as a gas, causing the water to become less acidic and over saturated in calcium carbonate. This results in deposition of the mineral calcite in the form of stalactites, stalagmites, flowstone, etc. Scalloped bed rock (Fig. 14B) in passages forms when the passage is water-filled or under phreatic conditions. The size of the scallops reflects the speed of water flow: small scallops indicate fast flow, large scallops indicate slow flow.

(A) (B)

Figure 13. (A) Vertical shaft created under vadose conditions. (B) Passageway created under phreatic conditions. Photograph by John David McFarland.



(A) (B)

Figure 14. (A) Diagram of a branchwork cave system (from Palmer, 1991). (B) Scallops along a passageway. Photograph by John David McFarland.

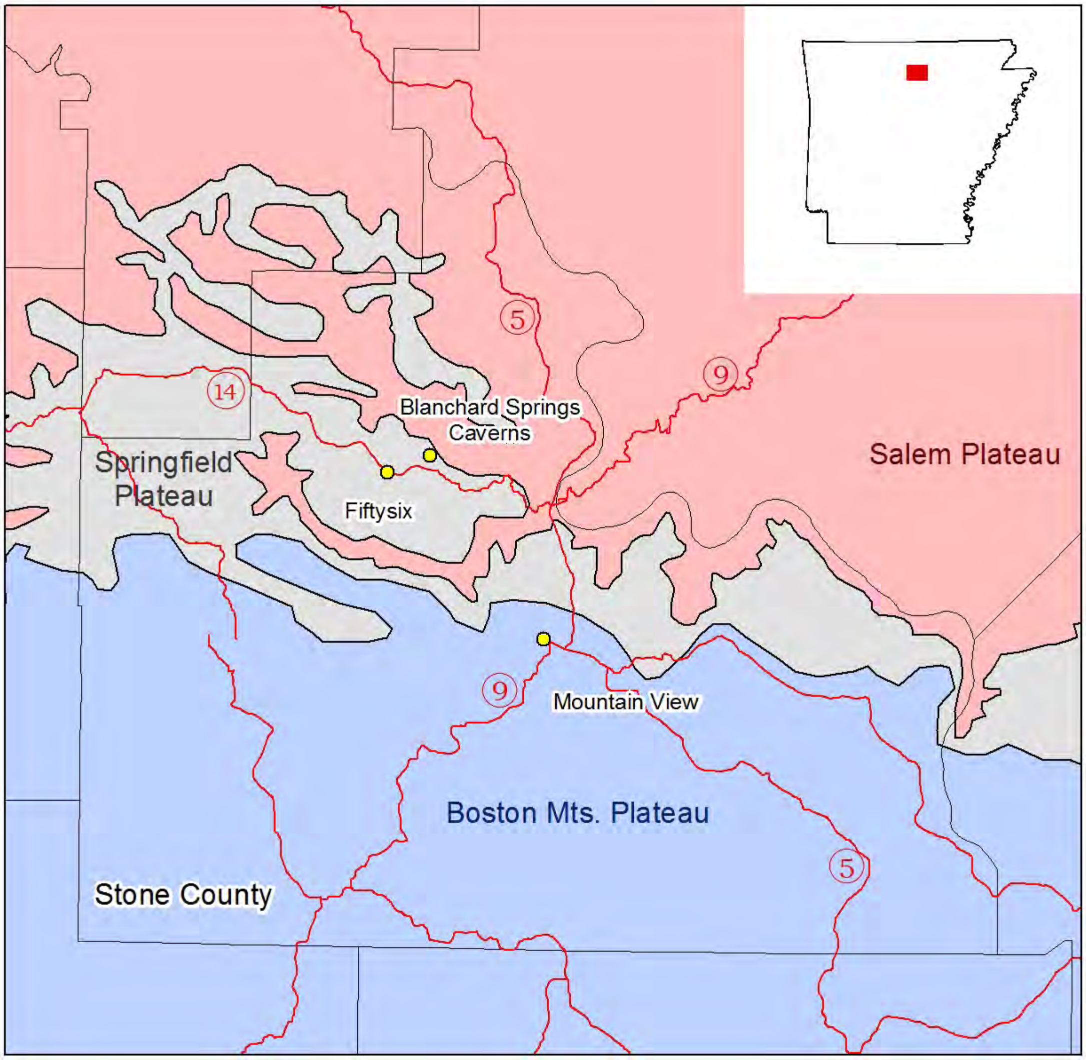


Figure 15. Map showing location of workshop on Ozark Plateaus. Note highway numbers and county boundaries.

## Day 1

### Stop 1 – Blanchard Springs Caverns

Blanchard Springs Caverns is located near the town of Fiftysix, Arkansas, approximately ten miles northwest of Mountain View, Arkansas (Fig. 15). The cave is located in the Springfield Plateau which consists of the Mississippian Boone Limestone. North and South Sylamore Creeks eroded into the plateau surface and exposed Ordovician limestone and sandstone.

Rock types in this area consist of mostly of Mississippian limestone and sandstone with minor amounts of chert, dolostone, and shale, however streams eroded into the plateau surface have exposed Ordovician limestone and sandstone. In the upper level of the cave system (Dripstone Trail), the roof of the Cathedral Room is capped by the Boone Limestone (Fig. 16A). Notice the chert layers in the ceiling. The lower level of the cave (Discovery Trail) is developed in the Plattin Limestone (Fig. 16B, 17A and 17B). In this portion of the cave, you will also see an underground stream.

(A) (B)

Figure 16. (A) Chert nodules in the Boone Limestone. (B) Blanchard Spring issuing from the Plattin Limestone.

(A) (B)

Figure 17. (A) Vertical shaft formed in Blanchard Springs Caverns under vadose conditions. (B) Speleothem (column) in Blanchard Springs Caverns. Notice the Plattin Limestone.

## Stop 2 - Blanchard Spring

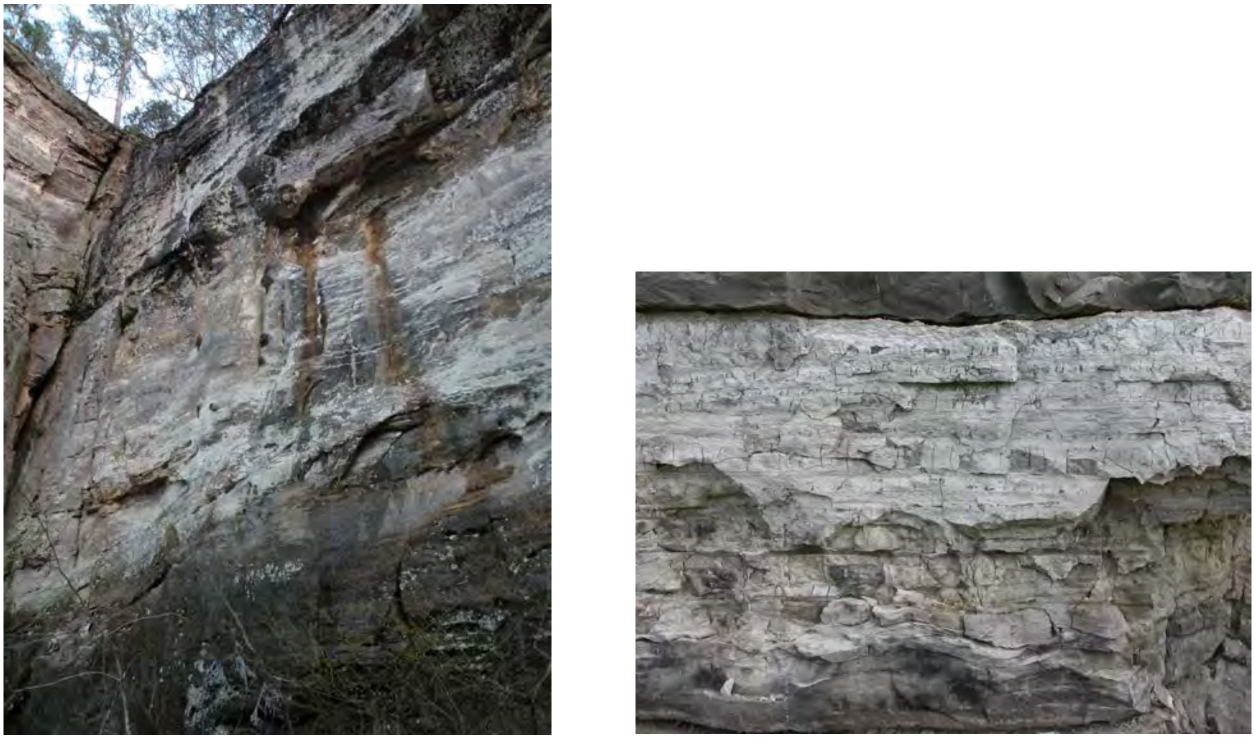
After the tour of the cave, we will travel to Blanchard Spring (Fig. 16B). The spring flows from the Plattin Limestone. Flow can vary from 1,000 to 103,000 gallons per minute depending on local rainfall. The excerpt below is taken from the National Forest website:

*Here in 1971, scuba divers entered to explore the mysterious watercourse all the way to the natural entrance.*

*In 4,000 feet of unexplored, mostly water-filled passageways, the scuba divers mapped five inaccessible air filled rooms and corridors. They returned with photographs of remarkable cave formations, waterfalls and cave life. They also brought back valuable data on the rate of water flow through this portion of the cave. They determined that it takes eighteen and a half hours for water to flow through 1,000 feet of cave passages full of water and five hours to flow through 3,000 feet of stream in the air-filled rooms. A cave journey of less than a mile takes almost 24 hours.*

## Rock formations

Next we will walk up an old paved road from the spring. This road was the original access to the park. Back in the parking lot, we saw the St. Peter Sandstone (Fig. 18A). Here we will walk stratigraphically up-section to see younger rock. At this location you will see the Joachim Dolomite (Fig. 18B) and the Plattin, Kimmswick and Fernvale Limestones (Fig. 19A-B). These formations were solutioned to form Blanchard Springs Caverns, so they are the “cave makers” in this area.



(A) (B)

Figure 18. (A) St. Peter Sandstone at Blanchard Springs Caverns. (B) Dolostone in the Joachim Formation at Allison, Arkansas.

(A) (B)

Figure 19. (A) Kimmswick and Plattin Limestones at Allison, Arkansas. (B) Fernvale Limestone near Fiftysix, Arkansas.

## Stop 3 - Blanchard Rock Shelter

A rock shelter in the St. Peter Sandstone (Fig. 20A) is located near the group camp area and amphitheater. Here, an unconformable contact between the St. Peter Sandstone and the Everton Formation is easily seen. Look closely at the rock. Notice the round sandstone features (Fig. 20B). These are called sandstone pipes. They are columns of the same material as the surrounding rock – sandstone. Walk around the outcrop until you get behind the amphitheater. Look for a sandstone pipe at the base of the bluff. Now look at the top of the bluff. Imagine how tall this sandstone pipe would be had it not weathered out of the rock!

(A) (B)

Figure 20. (A) Rock shelter at Blanchard Springs Caverns. (B) Sandstone pipe in St. Peter Sandstone at rock shelter.

These vertical cylindrical features were observed in Ordovician-aged sandstone in Arkansas as early as 1916 (Purdue and Miser). Research by Hawley and Hart in 1934 showed that these pipes formed in sand that was slightly deformed by a column of water rising through it from a lower horizon and feeding a spring at the surface. This sand then lithified into the rock we see today which includes the sandstone pipe. A modern-day example of sandstone columns forming in springs is present in the Dismal River in the Nebraska Sand Hills. At this location, boiling (motion, not temperature) sand springs fed by groundwater moving upward along cylindrical conduits have developed.

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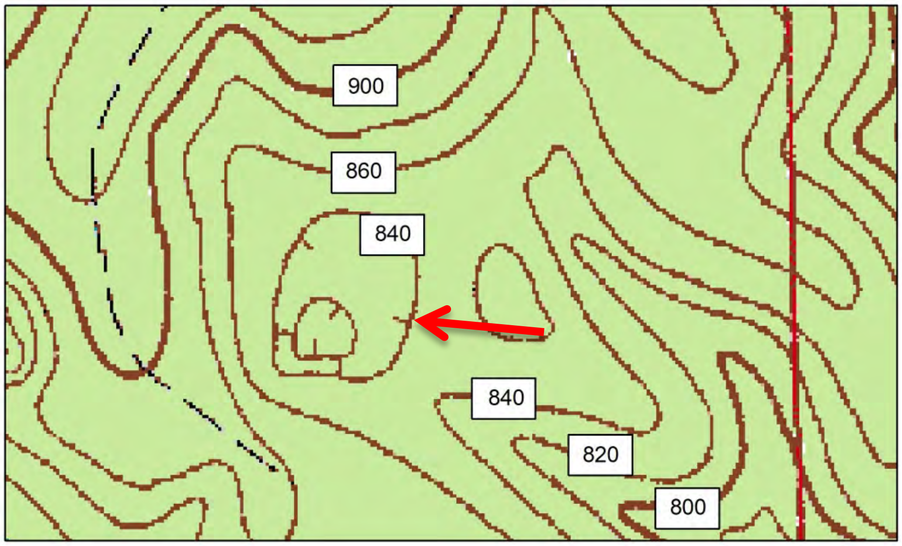
## Topographic Map Reading

Topographic maps illustrate landforms by equal lines of elevation also called contour lines. There are several rules of contours that should be followed when reading topographic maps. Always know the contour interval of your map.

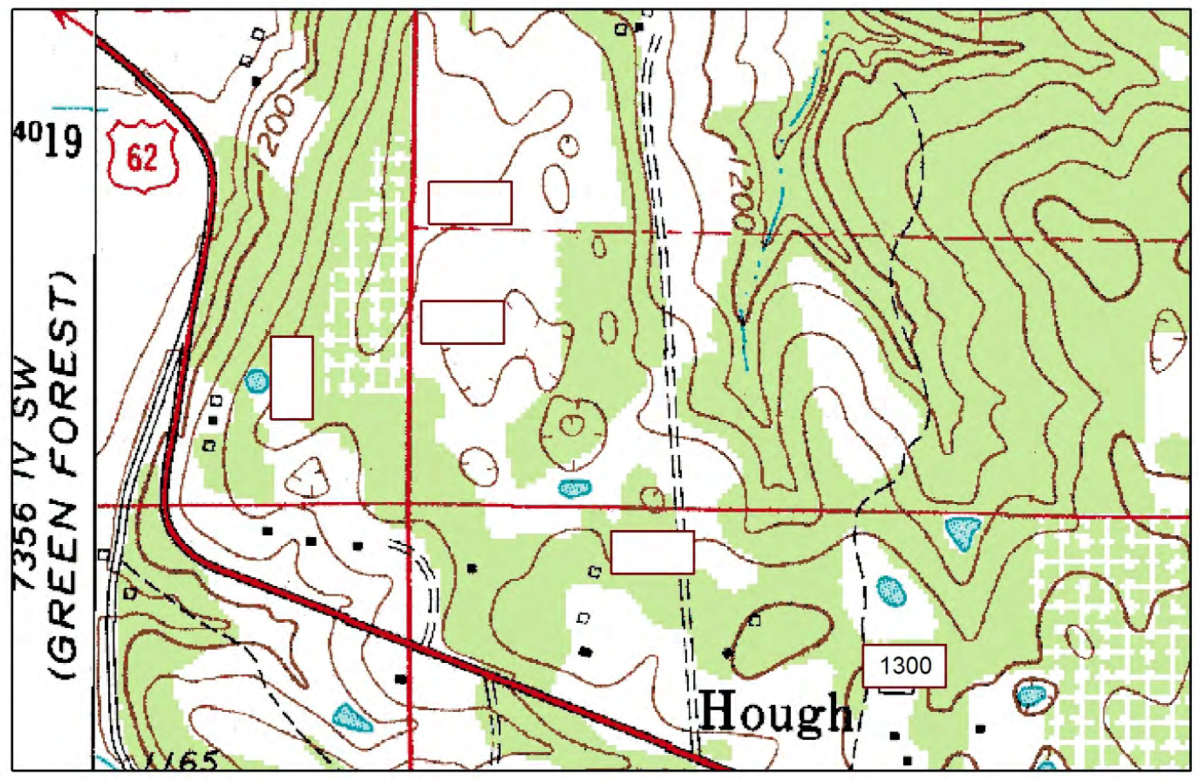
1) The closer the contour lines, the steeper the slope.
2) Contour lines are farther apart on more gentle slopes.
3) Contour lines will never cross one another but will merge where an overhanging cliff is present.
4) Contour lines will merge to form a single contour line where there is a vertical bluff.
5) A concentric series of closed contours represents a hill.

6) Depressions are represented by hatchure marks on the downhill side.
   The outermost depression contour line has the same value as the next lower normal contour line.



## Exercise 1

The map below contains contour lines that represent depressions or sink holes. A couple of elevations are shown at 1200 and 1300 feet. Use a contour interval of 20 feet to fill in the correct elevations for the contour lines.



**Exercise 2**

## Topographic Map Reading – Fiftysix Quadrangle

Locate Blanchard Springs Recreation Area

1. What is the symbol for a cave? ________________________________________
2. How many cave symbols are on the map?_______________________________
3. What is the name of another cave in the area?___________________________
4. What is the symbol for a spring?_______________________________________

Locate a sinkhole on the map

1. How deep is the sinkhole?_____________________________________________

   Use the contour interval and the rules for depressions

2. Locate other sinkholes. How many are on the map?______________________

Download the Fiftysix geologic map from the Arkansas Geological Survey's website at [http://www.geology.ar.gov/geologic_maps/dgm24k.htm](http://www.geology.ar.gov/geologic_maps/dgm24k.htm) for the following questions.

1. Locate the sinkholes on the geologic map. In which geologic formation are the sinkholes formed?____________________________________________
2. In which formation is Blanchard Spring?_______________________________
3. In which formation is the entrance to Rowland Cave?___________________
4. Which formation contains the entrances to Blanchard Caverns?___________
5. What rock types are all of the above formations?________________________

# “Eons and Eons of Ozarks Long Ago”

Modified from exercises by Mary Ann Mutrux, Willow Springs Middle School, Missouri

**Directions:** The table below describes various events in Arkansas’ geologic past that have lead to today’s geologic conditions.

1) Your team will read the table that your teacher assigns.

2) Your team will then discuss the table and examine the sequence of events in the table. Afterwards your teacher will take the table away from you and provide you with the table in cut up sections. Then, your team will try to reconstruct the geological past by reconstructing the table as best as you can.

3) Once your team has completed the table reconstruction, ask the teacher for a key to check your work.

4) After checking your table reconstruction, discuss where any “mistakes” have occurred. In a few cases, the order may not affect the processes, and therefore may not be a “mistake”, but remember that the order is the most relevant and important part of the exercise.
Your teacher may instruct you to read and reconstruct other tables as time allows.

| **Fossils Form in Warm Shallow Seas** |
|---|
| During most of north Arkansas’ geological past, the state was covered by warm shallow seas.<br>*[North America was located at a lower latitude and had not moved to its present temperate location.]* |
| These warm shallow seas were teeming with diverse marine organisms. |
| Many of these marine organisms had shells made of the mineral calcite (consisting of the elements calcium, carbon, and oxygen). |
| After the shelled organisms died, gravity pulled them down to the bottom of the sea. Many of them became dissolved into calcite particles. Some organisms remained all or partly intact. |
| These layers of sediment formed in horizontal layers. Geologists call this the principle of original horizontality. |
| Many shelled organisms fell into soft sediments and made an impression in the seafloor. |
| Over time, the soft tissue of the organism decayed leaving the “hard parts” or shells to make a “mold” of the organism. |
| Some of these molds became filled with dissolved minerals in the water and in time became “casts” of the organism. These hard parts were buried in the layers of sediment. Shelled organisms continued to die and fall to the sea floor. |
| In time the sediment was cemented together by calcite and hardened into the sedimentary rock limestone containing marine fossils. |
| Today, these rock layers can be seen in bluffs along Arkansas streams and along road cuts on highways. These are good places to hunt for fossils. |
| Geologists infer that if these sedimentary rocks layers are not disturbed (folded or faulted); the oldest rocks are on the bottom, and the youngest are on top. This is called relative age dating. |

| **Formation of Karst Features** |
|---|
| Long after the shallow seas were gone and limestone covered the Ozarks, the water cycle powered by the sun provided rain water that soaked into the ground. |
| The rainwater picked up carbon dioxide from decaying plant matter as it soaked into the ground. |
| The groundwater became a weak carbonic acid and soaked into fractures or cracks in the limestone and dolostone. |
| Slowly over time, this weak carbonic acid dissolved the rocks along the fractures. |
| The fractures became larger and larger, creating the cave systems we see today. |
| As groundwater levels dropped, these cavities drained. Some caves were then filled with air. In those caves, “decorations” developed. These are features that form from calcite, which precipitates out of the groundwater that drips into the caves from above. |
| A sinkhole forms when a cave roof collapses. Sinkholes allow surface water to quickly enter the groundwater system. |
| Some streams in the Ozarks won’t hold water and are called losing streams. They form when the ground underneath the stream has many openings, or fissures in the rocks below. These openings allow surface water to go directly down into the groundwater system. |
| Groundwater sometimes finds an opening on a hillside or valley. Then it comes out onto the surface to form a spring. There are many big springs in the Ozarks. |
| Dissolved calcium from the limestone can be found in Ozark groundwater. Many area residents depend on it for drinking water. |

# “Karst Rock Detective: Identifying Ozark Rocks” Lesson Plan

**Modified from Mary Ann Mutrux, Willow Springs Middle School, Missouri**

## Lesson Summary:

For this lesson, students will be asked to bring an Ozark rock from home or nearby. They will conduct common tests to identify the rocks. A simple rock lab chart will be used to identify four common Ozark rocks: limestone, dolostone, chert, and sandstone. Students will most likely bring in chert. The limestone and dolostone are water soluble and therefore, are more easily dissolved. The insoluble chert will not dissolve or become solutioned . Students will graph the lab results and most likely realize that the limestone and dolomite rocks at the surface have been solutioned because they are water soluble, and the water-resistant chert is not subject to solution.

This curriculum was written to accompany the educational video “*Karst in the Ozarks*.” Students should watch the video before beginning the lesson. It is available online at http://www.watersheds.org .

Note: This lesson is recommended only for schools located in the Ozarks.

## Arkansas Standards:

***Science Contents Standards – Strand 5 Earth Systems:***

ESS.8.5.7 - Identify characteristics of sedimentary rocks.

ESS.9.3.1 - Analyze the effect of water on earth's surface.

ESS.9.4.1 - Analyze changes to Earth's surface: Erosion and Weathering.

PD.1.ES.6 - Describe the processes of degradation by weathering and erosion.

PD.1.ES.10 - Describe the characteristic of of the natural divisions of Arkansas
Ozark Plateaus

## Essential Vocabulary:

| | |
|---|---|
| Sedimentary rock | Chemical change |
| Sediments | Limestone |
| Minerals | Dolostone |
| Calcite | Sandstone |
| Acid | Chert / Nodules |
| Weathering | Silicate |

-

Template for bar graphs]

**Required Materials:**

**Lab:**

- Assorted Ozark rocks collected by students (this lesson is limited to schools located in the Ozarks)
- Weak acid in drop bottle (5% hydrochloric acid – see high school chemistry teacher for solution) or vinegar - *Ozark Rock Chart* copies (one per student)
- Hand lens (one per student)
- Goggles (one pair per student, if students are allowed to do the acid test)
- Iron Nails (one per student)
- Access to water / Paper Towels
- Thick Glass Plates (for mineral hardness test, see a geology supply catalog)

**Visuals:**

- Overhead transparency of the sedimentary rock formation or projected Internet image
- Missouri maps (see related web links above)

**Optional Materials:**

- Rock Samples: Limestone / Dolostone / Sandstone / Chert
- Rock hammer:( Utilize to break rock open to observe fresh face of rock instead of weathered exterior). - Copies of the MDNR Fact Sheet: Chert and / or Missouri Ozarks

### Safety Considerations:

- Depending on student ages, general level of lab experience, and the availability of goggles, the teacher needs to decide who will apply the weak acid drops on the rock samples (teacher or students).
- If possible (not necessary), break the rock open with a rock hammer to expose a fresh face. Observations and tests are easier to conduct on an exposed interior of the rock. For middle school children, the teacher should break the rocks and anyone in the area must be wearing goggles. **This must be done outdoors so tile or flooring is not damaged.**
- Goggles should be worn when placing a drop of weak acid on the rock samples.
- Students should not touch the rocks where acid has been applied.
- All rocks that have had acid placed on them need to be washed immediately by the teacher.
- If students touch the acid, they need to wash their hands immediately.
- If glass plates are used for a hardness test, then they will need to be kept flat on the table surface when performing the test.
- All rock samples should be rinsed with water thoroughly after the lab.

### Time Requirements:

*Preparation Time:*

- Preparation time will vary according to the availability of the lab supplies.
- Students will have to be given direction and the opportunity to gather a rock from their home, park, or area in the Ozarks before conducting the activity.

nearby

*Activity Time:*

- Activity time will depend on the number of samples being tested. Instruct students to get a rock sample from the sides of Ozark hills, rocky outcrops along roads (with adult supervision) or along creeks and streams.

### Lesson Warm Up:

- Have students get out their rocks and examine them. Then have them look at each other's and make general comparisons. Ask them to determine if they think any of them are the same kind. Ask for students to support their reasoning.
- Tell students that they are going to use several tests and a rock lab chart to determine what type of rock they may have. Explain they will be testing both a physical property (hardness ) and chemical property (acid test).

- Explain that the limestone and dolostone (only when powdered) will bubble or effervesce in the weak acid. This is how karst features such as caves and sinkholes form. Rainwater becomes a weak acid when it picks up carbon dioxide from decaying vegetation on its way into the ground. The rainwater, like the acid, dissolves surrounding soluble material.

- Explain that they are like detectives and are using tests to find clues about the unknown rock. Explain that if their rock cannot be identified with the key, then it may not be one of those rocks.

- Have students predict which of the four rock types will make up most of the samples collected by the class.

**Karst Rock Detective Activity:**

- Pass out the *Ozark Rock Lab* chart and step sheet. Go through the handout and explain how to conduct each test (see safety considerations above). *Note: the chart is required, but the step sheet is optional.*
- Take a rock (one that you have previously identified as one on the flow chart) and demonstrate the process of identifying the rock using the flow chart and tests. If possible, do this for each of the four rocks on the chart.
- Tell students that they will be doing the same thing. Have students work in small groups and verify each others observations. Assist each group.
- Emphasize that a chemical change is taking place when the acid test produces bubbles and that a physical change is taking place if the rock is scratched.
- Have the students group the rocks according to type and discuss other differences or similarities that they may observe.

- Students can read the handout about chert after they conduct the activity and are waiting for others to finish.

**Lesson Wrap Up:**

- Have students construct a bar graph for the number of Ozark rocks identified. Make a bar for the unknown rocks that could not be identified by the chart. For bar graph construction see the performance event template for immediate science at the DESE website (stated above).
- Explain that when the limestone bubbled on contact and the dolostone bubbled when in powder form, the rock was dissolving. Rainwater that soaks through the ground acts like a weak acid and dissolves these two rocks. As a result, cavities such as caves and sinkholes form. This is a chemical change taking place.
- Remind students that the rocks under their feet in the Ozarks are mainly layers of limestone and dolostone that dissolve by rain water, creating karst features over millions of years. The chert and sandstone are other rocks that formed along with them, but they are not soluble in water. (In the pilot for this lesson 76% of the rocks students brought in were chert. Students realized that the insoluble chert will not be solutioned. The rocks which are soluble in water have “disappeared” as they have dissolved in water**.**

**Modifications:**

*The lesson difficulty could be decreased by making the following adaptations:*

- Provide students with rock samples that were previously identified.
- Take students to a location to collect rocks (quarry, outcrop).

*The lesson difficulty could be increased by making the following additions:*

- Provide students with the chemical formula for the weak acid reaction.
- Have other rock and mineral identification guides available for students to use with rock specimens that are not on the flow chart.

**Assessments:**

To assess the student's learning, have them complete one or both of the following activities.

- Construct a table of four common sedimentary rocks of the Ozarks. Include their name, grain or crystal composition, and identification tests.
- Write a paragraph explaining how limestone and dolostone can be identified.

# Karst Rock Detective: Ozark Rock Lab

**Directions:** Identify your Ozark rock using the provided supplies and teacher instructions; then follow the key below to determine its type. **Note** the teacher will provide all acid drops and will collect and wash all rocks after acid use. This chart is useful only to identify limestone, dolomite, sandstone, and chert. If the rock does not fit any of the descriptions below, it may be another rock type.

**Step 1:** Examine the rock to determine if you can or cannot see the grains. If you cannot observe grains go, to Step 2. If you can see grains go to Step 3. If neither or uncertain, then go to Step 4.

**Step 2:** (If you cannot find grains) Examine the rock carefully. See if a nail can scratch it. If the rock cannot be scratched by a nail, go to Step 5. If the rock can be scratched by a nail, go to Step 6.

**Step 3:** (If you found grains) Examine the grains carefully. Using a nail, try to pick off some of the grains. Examine the grains using a hand lens. Use a water dropper to dribble water onto the rock. Do the water droplets roll off or are they absorbed into the rock? If grains you observe are sand and if some of the water droplets are absorbed into the rock, you have **sandstone.** Look to see if your rock has any layers of color. If so, those are different minerals that "cemented" your sandstone rock. It is possible that your sandstone may have a cement of calcite. Ask your teacher to find out by placing a drop of HCL five percent (weak) acid solution on your sandstone. If it fizzes, the rock has calcite cement. Your teacher will need to wash your rock if you test for calcite cement.

**Step 4:** (If you are uncertain) Examine your rock carefully. Feel the rock, and see if it is smooth. Using a glass plate provided by your teacher, see if the rock can scratch a piece of glass. Be sure that the glass stays flat on the table, and hold the glass down carefully and firmly. If the rock scratches glass and is smooth, it is **chert**. Look to see if it has any lines of different colors. It may be well rounded. The rock might have small pockets of quartz crystals as well.

**Step 5:** (If it cannot be scratched by a nail) Using a glass plate provided by your teacher, see if the rock can scratch a piece of glass. Be careful. If the rock scratches glass, it is **chert**. Most chert is smooth, but some has very small grains. See Step 4 to learn more about chert.

**Step 6:** (If your rock can be scratched by a nail) Have your teacher place a small drop of HCL five percent (weak) acid solution carefully on your rock. Examine carefully with a hand lens to see if bubbling occurs. If the rock bubbles, you have **limestone.** Let your teacher take the rock for washing. Afterwards, see if the rock has any fossils-it might! If the rock does not fizz in acid, proceed to step 7 after the teacher cleans off your rock.

**Step 7:** (If your rock did not fizz in acid) Take a nail and scrape the rock until you accumulate some powder on the surface of the rock. Once you have an area about the size of a penny covered with powder, then ask the teacher to place a drop of HCL five percent (weak) acid solution on the powder. Examine it for bubbles with the hand lens. If the powder bubbles, you have **dolostone**. Let the teacher take your rock for washing. Afterwards, examine your rock for fossils.

# Karst Rock Detective: Ozark Rock Lab Chart

**Directions:** Identify your Ozark rock using the provided supplies, teacher instructions, and the chart below. **Note** the teacher will provide all acid drops and will collect and wash all rocks after acid use. This key is only useful to identify limestone, dolostone, sandstone, and chert. If the rock does not fit any of the descriptions below, it may be another rock type.

| **Ozark Rock Type** | **Crystal / Grain Composition** | **Hardness** | **Other Observations** | **Acid Reaction** |
|---|---|---|---|---|
| **Limestone** | Composed of small crystals | Limestone cannot scratch glass.<br>A nail can scratch limestone. | Gray color<br>Solutioning of surface.<br>May contain fossils. | Fizzes on contact |
| **Dolostone** | Composed of small crystals | Dolostone cannot scratch glass.<br>A nail can scratch dolostone. | Gray color<br>May contain fossils. | Fizzes on contact with powder of rock |
| **Sandstone** | Composed of sand grains that can be picked off with a nail | Harder varieties may scratch glass. | Sand grains can be identified.<br>Some water droplets are absorbed. | If the sandstone cement is composed of calcite, it will fizz. |
| **Chert** | Composed of:<br>Crystals too small to see, or<br>Crystals that can be seen | Chert can scratch glass. | Smooth or sharp edges. May contain fossil molds.<br>May be a nodule and/or banded | No fizz |