EWS - 06

STATE OF ARKANSAS

ARKANSAS GEOLOGICAL SURVEY
BEKKI WHITE, DIRECTOR AND STATE GEOLOGIST

EDUCATIONAL WORKSHOP SERIES 06

# Mining, Minerals and More in the Western Ouachita Mountains

Angela Chandler

Little Rock, Arkansas
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2012

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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.

Special thanks to the quarry owners (Meridian and Ouro Mining) who allow access to their quarries and properties.  Thanks also to teachers and Science Specialists at Henderson State University for requesting this workshop.  Without you, there would be no need for the workshop!

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Front cover images: upper left – dipping sandstone at Cossatot Falls
upper right – tuff at Hatton Tuff quarry
lower left – *Lepidodendron* fossil at Bates, AR
lower right – cinnabar on sandstone

## Educational Workshop Series 06 – "Mining, Minerals and More" in the western Ouachita Mountains

This is a three day workshop in the Ouachita Mountains near the town of Mena in western Arkansas. The theme of this workshop is mostly mining and minerals. The "more" includes plant fossil collecting and a visit to Cossatot River State Park. The first day of the workshop we will travel north into the Arkansas River Valley to look for plant fossils in a reclaimed coal mining area at Bates. The second day we will visit a local quarry in the Hatton Tuff Member of the Stanley Formation in the morning, then travel to Cossatot River State Park in the afternoon. The third day we will visit cinnabar workings along the Cinnabar Trail at Lake Greeson.

Since we are staying in the town of Mena, very close to Queen Wilhelmina State Park, there is an added fieldtrip and lesson for landforms in this area.

The following frameworks in Earth and Space Sciences will be addressed:

8.3.1 - Distinguish among Earth's materials

8.4.1 - Locate natural divisions of Arkansas

8.3.7 - Identify common uses of rocks and minerals

8.6.9 - Research local, regional and state landforms created by internal forces in the earth

8.5.7 - Identify characteristics of sedimentary and igneous rocks

9.5.2 - Analyze fossil record evidence about plants and animals that lived long ago

9.5.3 - Infer the nature of ancient environments based on fossil record evidence

9.8.1 - Explain processes that have changed Earth's surface that have resulted from sudden events and gradual changes

9.8.2 - Analyze how rock sequences may be disturbed

## Geologic Setting

The Ouachita Mountains of west-central Arkansas are part of the largest surface exposure of a much larger system of complexly folded and faulted band of Paleozoic strata that was uplifted during the Ouachita Orogeny or mountain building event. This system is approximately 1300 miles long and extends from east-central Mississippi westward and southward into west Texas (Fig. 1). The Ouachita Mountains in Arkansas consist of a series of east-west trending sharp ridges, separated by narrow to broad valleys that extends from Little Rock to the western border of the state and has an average width of 80 miles (Fig. 2).

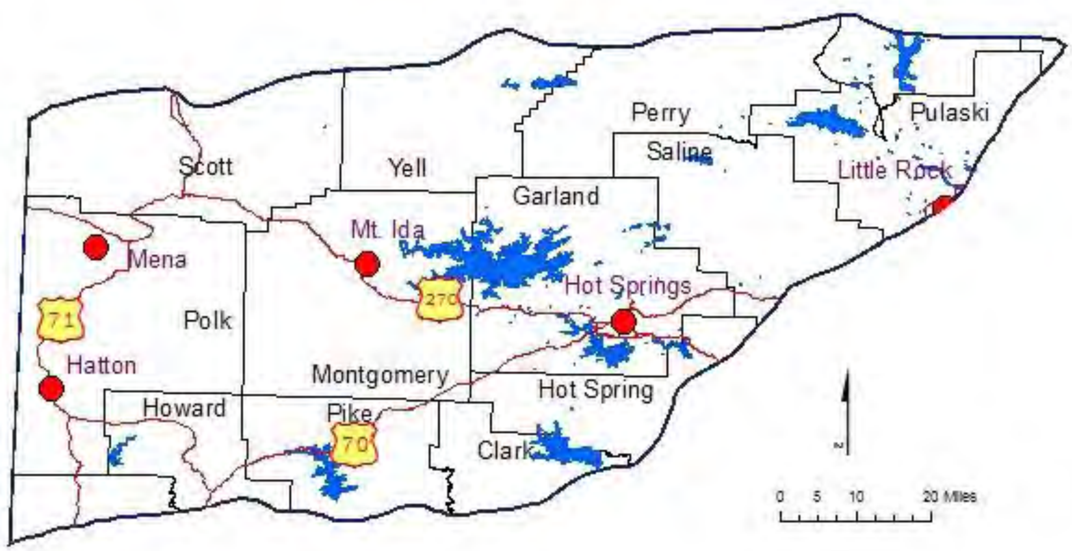



**Figure 1**. Location of Ouachita Mountains region outlined in purple.

The sedimentary rocks of the Ouachita Mountains range in age from Late Cambrian to Middle Pennsylvanian. They can be placed into two sequences based on rock type and rates of deposition (Fig 3). These two sequences were deposited in very different environments. The older sequence consists of rocks of Late Cambrian to Mississippian age and are composed mainly of thin-bedded black to dark gray shale and chert with minor limestone and sandstone. The younger sequence consists of rocks of middle Mississippian to middle Pennsylvanian age and is composed of interbedded black to dark gray shale and sandstone.

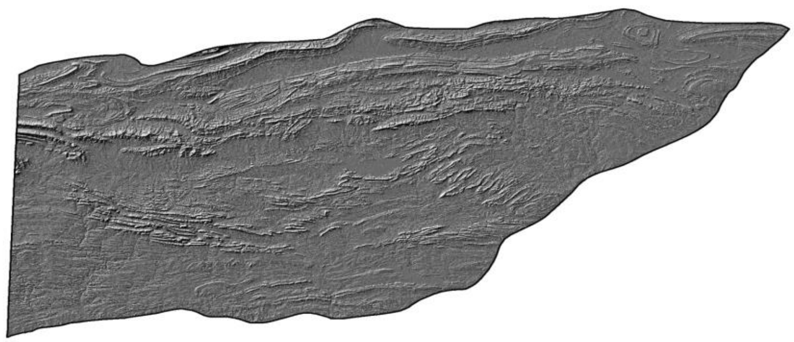


**Figure 2**. Digital ortho-photograph showing development of east-west trending ridges.

**Deposition of older sequence - Cambrian to Early Mississippian (542 – 345 million years ago)**

This sequence of rocks was deposited during a fairly calm time in the geologic history of Arkansas, before the mountain building event that would form the Ouachita Mountains. In the northern part of the state a shallow sea progressively deepened to the south in the basin now known as the Ouachita Mountains. Thick sequences of shales slowly accumulated in the deep water of the basin to form the Collier, Mazarn, and Womble Shales. Small amounts of sediment derived from the north formed thin sandstone units such as the Crystal Mountain, Blakely and Blaylock Sandstones. It is thought that the Arkansas Novaculite and Bigfork Chert formed slowly from the remains of silica-bearing animals living in the deep water.

**Deposition of younger sequence - middle Mississippian to Pennsylvanian (345 – 299 million years ago)**

This sequence of rocks was deposited from the beginning of the Ouachita mountain building event until the end. A shallow platform still existed in the northern part of the state and water depth became progressively deeper to the south in the Ouachita Mountains region. During this time, the continent Llanoria was colliding with what is now Arkansas, causing large amounts of sediment to be brought in from the east, south and north. The sediments rapidly filled the basin and formed sandstone and shale in the Stanley, Jackfork, Johns Valley and Atoka Formations.

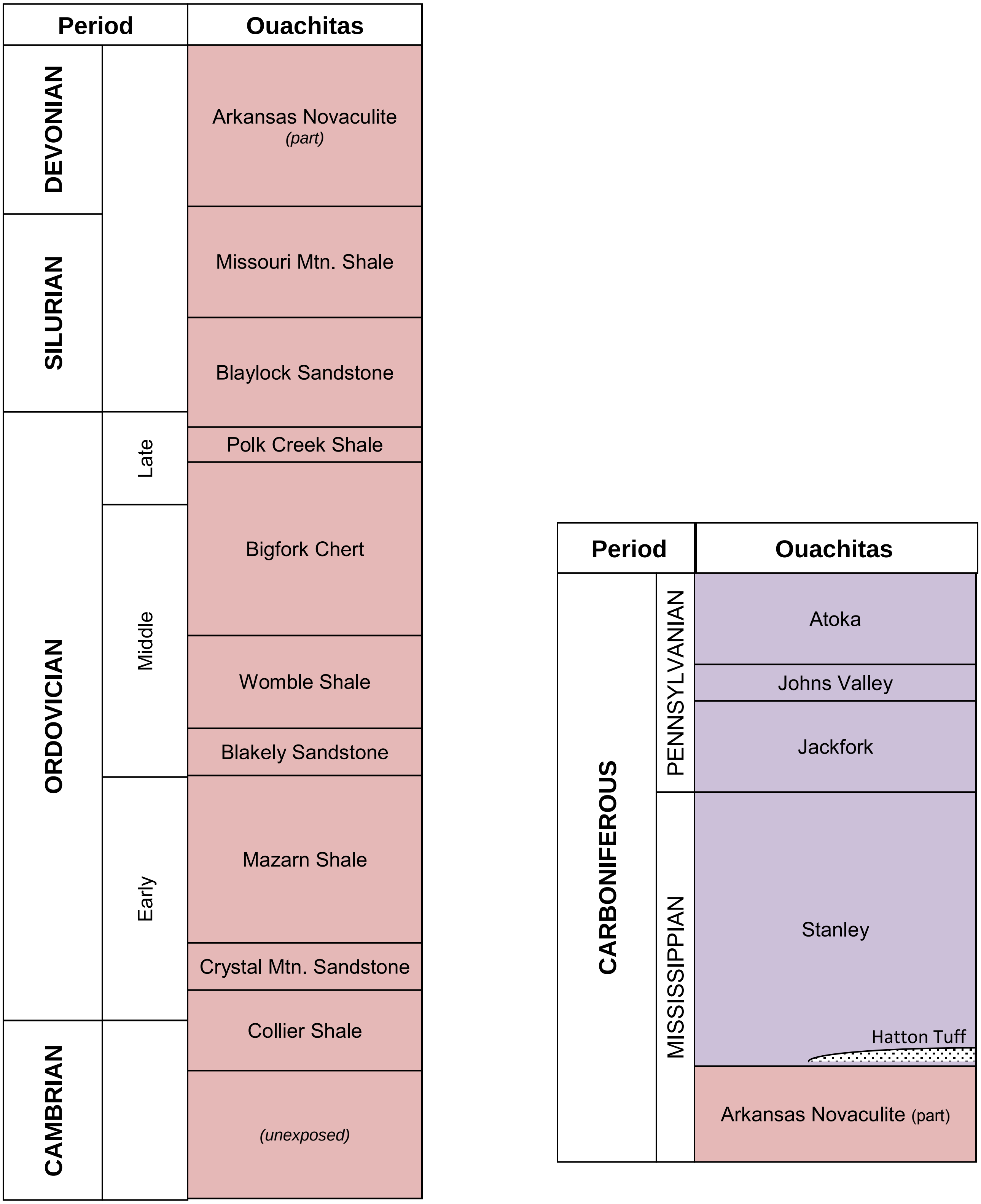



**Figure 3**. Stratigraphic column for the Ouachitas showing older sequence in pink and younger sequence in purple.

This workshop focuses on the Stanley Formation which crops out at the tuff quarry in Hatton, Arkansas, Cossatot Falls Natural Area and the Cinnabar Trail at Lake Greeson. The Stanley Formation was deposited at the beginning of the Ouachita Orogeny.

**Description and deposition of the Stanley Shale**

The Stanley Shale is named for the village of Stanley in Pushmataha County, Oklahoma. The formation consists mainly of shale; however it also contains sandstone and a little tuff and conglomerate. Sandstone is more abundant in the lower and upper parts of the formation. The sandstone is fine-grained and varies in color from bluish gray to greenish. Most of the sandstone is interbedded with shale.

Tuff beds occur in the lower part of the formation. Tuff is a pyroclastic igneous rock made up of volcanic ash and dust that may contain up to 50% sedimentary material. The thickest tuff bed is the Hatton tuff, which is usually around 90 feet thick and named for the town of Hatton (Miser and Purdue, 1929) in western Arkansas (Fig. 4). Tuff beds have been found as far east as Hot Springs, Arkansas (Danilchik and Haley, 1969). The tuff is a hard compact, fine-grained bluish gray rock (Fig 5). The rock is made up of 4 pyroclastic components: crystals of quartz and feldspar, pumice, shards and volcanic ash (Niem, 1971). The largest grains (2mm) in the rock are feldspars that weather white to give the rock a spotted appearance. Locally the tuff contains flattened green lapilli of celadonite (iron-rich muscovite) with large white feldspar fragments. Lapilli is a size term for tephra, which is material that falls out of the air during a volcanic eruption. Lapilli range in size from 2 mm to 64 mm in diameter.

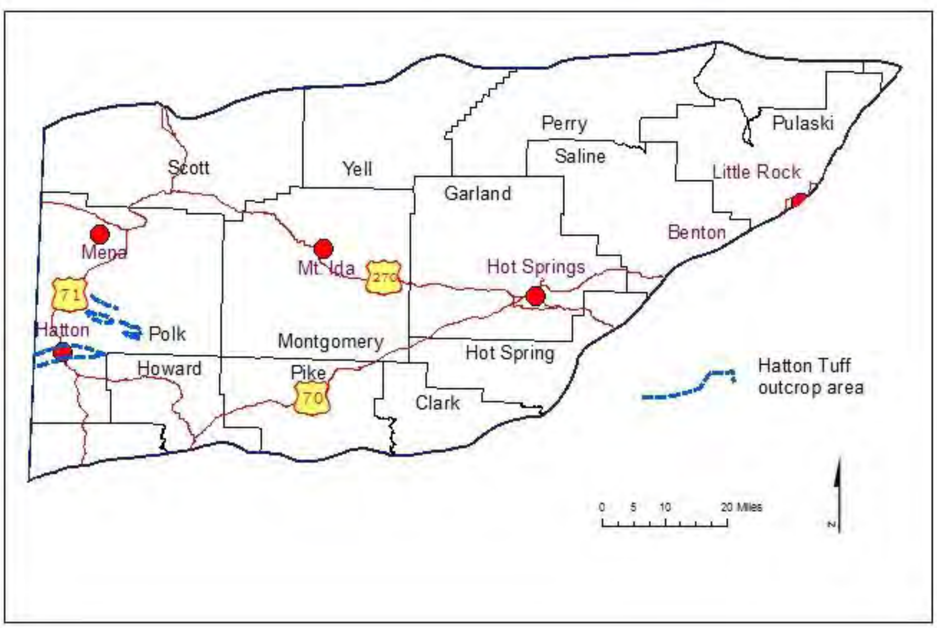



**Figure 4**. Location map showing outcrop area of Hatton Tuff.

**Figure 5.** Tuff containing shale clasts (left) and fine-grained tuff containing white feldspar fragments (right).

In middle Mississippian time mountain building began as a result of subduction of an oceanic plate beneath the North American continental plate near what is now southern Arkansas (Fig. 9). An island arc system (Fig. 6) probably resulted. It is likely that a vent or fissure in the system produced an extremely violent eruption of magma creating an ash flow and overriding ash cloud (Niem, 1977). The ash interacted with sea water and generated a steam-inflated turbulent slurry of pyroclastic debris (Fig. 7). The slurry was denser than sea water and flowed downslope as a density current. The flowing mass scoured the muddy sea floor bringing pieces of shale into the tuff (Fig. 7). Continued eruptions brought more material in surges downslope into the basin. The pyroclastic flows were deposited within minutes to hours, while fine ash and buoyant pumice that floated on the sea surface eventually sank to the bottom over a much longer period of time.

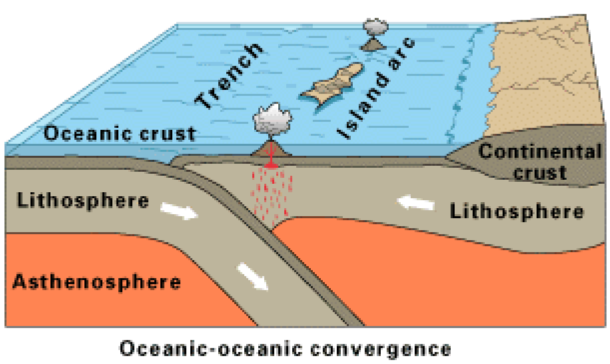



**Figure 6.** Diagram showing possible scenario that occurred during the Ouachita Orogeny in Arkansas to form the Hatton Tuff (from U.S. Geological Survey).

Studies of paleocurrent, grain size distribution and geometry of the Hatton Tuff suggest a volcanic source to the south or southeast (Niem, 1977) (Fig. 9). Analyses of recent ash falls show that grain size increases and the deposits thicken toward the source. This is the case with the Hatton Tuff as well.

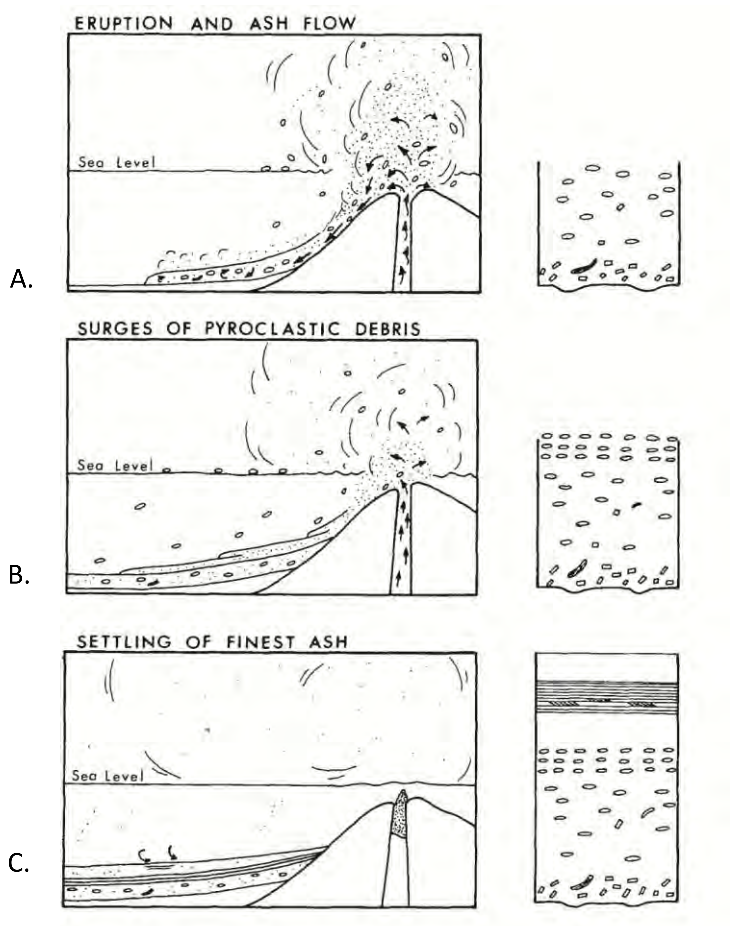



**Figure 7.** A. Early in a volcanic eruption, a large volume of pyroclastics produced a pyroclastic flow that deposited thick unstratified tuff. B. Numerous thin slurries followed the main flow and deposited thin-bedded tuff. C. Toward the end of the volcanic eruptions, settling of fine ash produced fine-grained tuff (from Niem, 1977).

**Ouachita Orogeny (Middle Mississippian-Pennsylvanian, 345-299 million years ago)**

The rocks exposed in the Ouachita Mountains region are no longer flat-lying as they were originally deposited. They are steeply inclined and have been folded into anticlines and synclines. Compare the attitude of the rocks in the Ouachita Mountains region with those in the Arkansas River Valley and the Ozark Plateaus Regions.

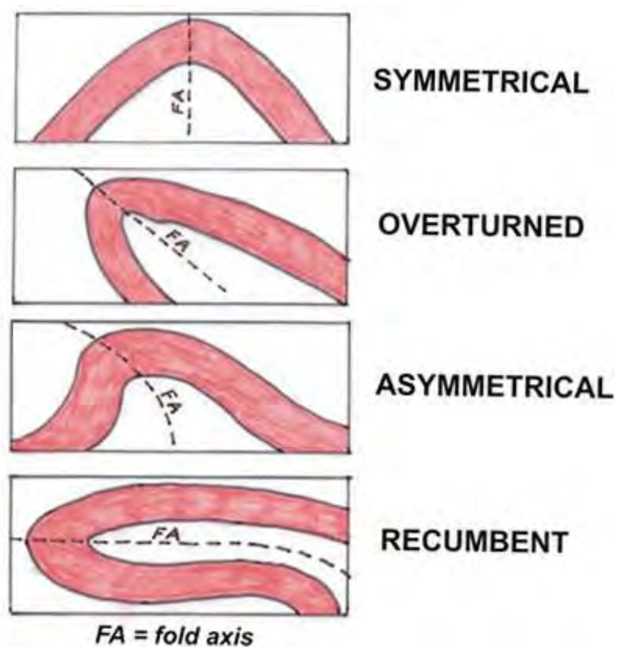



**Figure 8.** This figure displays an anticline that has been distorted due to folding. Look for these types of folds at each fieldtrip stop.

To understand why the rocks are no longer flat-lying we need to look back in geologic time. By the Middle Pennsylvanian Period, geologists believe that there was approximately 50,000 feet of sediment that had been deposited in a deep ocean basin in the area of the present day Ouachita Mountains (Stone and Haley, 1982). At that time, around 345 million years ago, plate tectonics began to shape what is now Arkansas (Fig.5). The continents of Laurasia and Llanoria began to collide, pushing together this large mass of material. Over time, this collision caused the rocks to be folded, faulted and uplifted into the Ouachita Mountains that we see today. Deformation of the rocks increases as one travels from south to north, with more complex folds, thrust faults and sizeable quartz veins in the northern region.

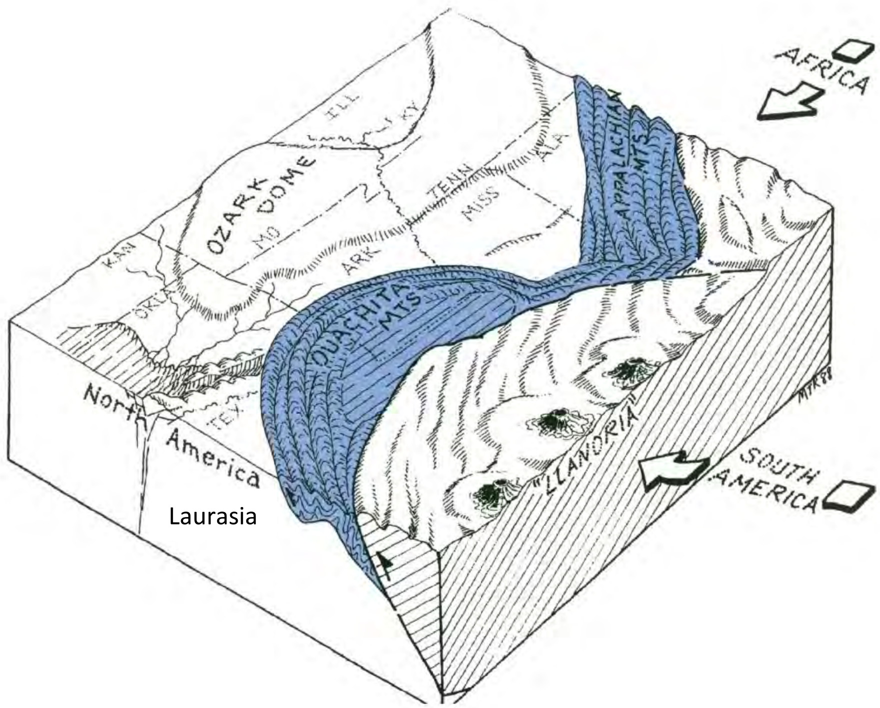



**Figure 9.** Late Mississippian to mid Pennsylvanian paleogeography of Arkansas showing the collision of Laurasia and Llanoria, location of volcanics and formation of the Ouachita Mountains. *From Guccione, 1993*.

**Landforms in the Ouachita Mountains Region**

The Ouachita Mountains Region contains thick sequences of sedimentary rocks deposited in a deep ocean basin that have been uplifted and compressed northward into east-west trending complex folds (anticlines and synclines) and thrust faults due to a major orogenic (mountain building) process called the Ouachita Orogeny.

The rocks in the Ouachita Mountains Region have been exposed to weathering and erosion since approximately 290 million years ago. This process has resulted in a series of sharp ridges, mostly east-west trending and often buckled and distorted, separated by narrow to broad valleys. Streams display a trellis drainage pattern due to the geologic structure in this region. (Fig. 11)

*Landforms in this region*

The Ouachita Mountain Region contains mountains, canyons, valleys, ridges and pinnacles. Some islands are present in Lake Ouachita. Refer to the following quadrangles for these landforms: Crystal Springs, Fountain Lake, Hamilton and Pinnacle Mountain.

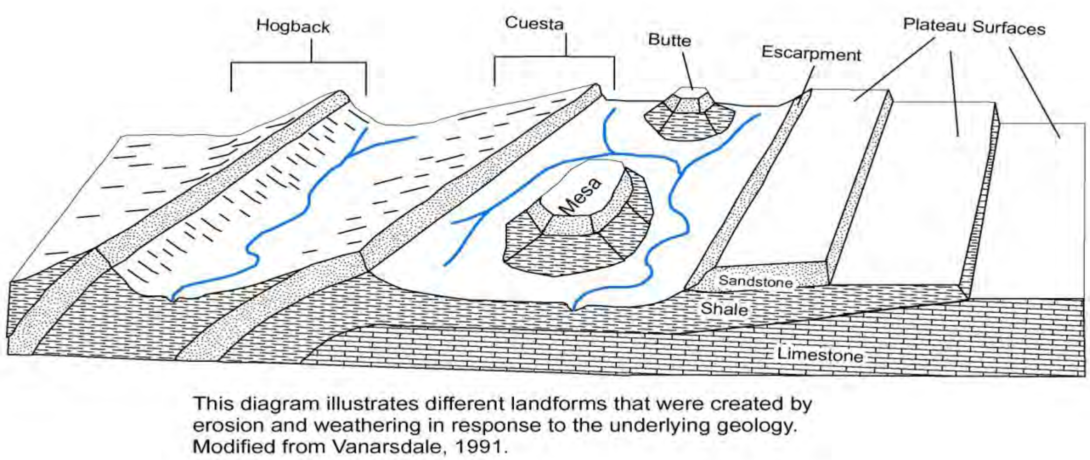



**Figure 10.** Diagram showing different landforms from the Ozark plateau surfaces to the hogbacks in the Ouachita Mountains region.

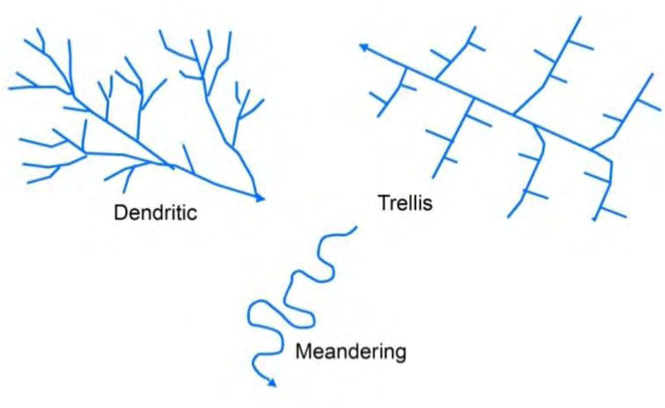



**Figure 11.** The three major drainage patterns in Arkansas.

Varying stream patterns develop according to the underlying geology of an area. By familiarizing oneself with the different patterns a quick look at streams on a map will allow for an interpretation of the evolution of a landscape. Figure 11 shows the common stream drainage patterns observed in map view. The most common drainage pattern is dendritic, resembling the branches of a tree or a root system. This drainage pattern is typical of streams that develop in regions underlain by relatively flat-lying or uniformly eroded sedimentary rock. A trellis pattern results where rocks have been folded and bent into long folds and eroded into resistant ridges and valleys. A meandering stream develops in areas of relatively low relief.

**Mercury District of Southwest Arkansas**

The following excerpt from *Information Circular 23* by Clardy and Bush, published by the Arkansas Geological Commission in 1976.

Cinnabar was discovered in southwestern Arkansas in 1930. Mining began in 1931 and mercury was produced each year through 1944. Production through this period was approximately 12,500 76-pound flasks. Mining has been negligible since 1944.

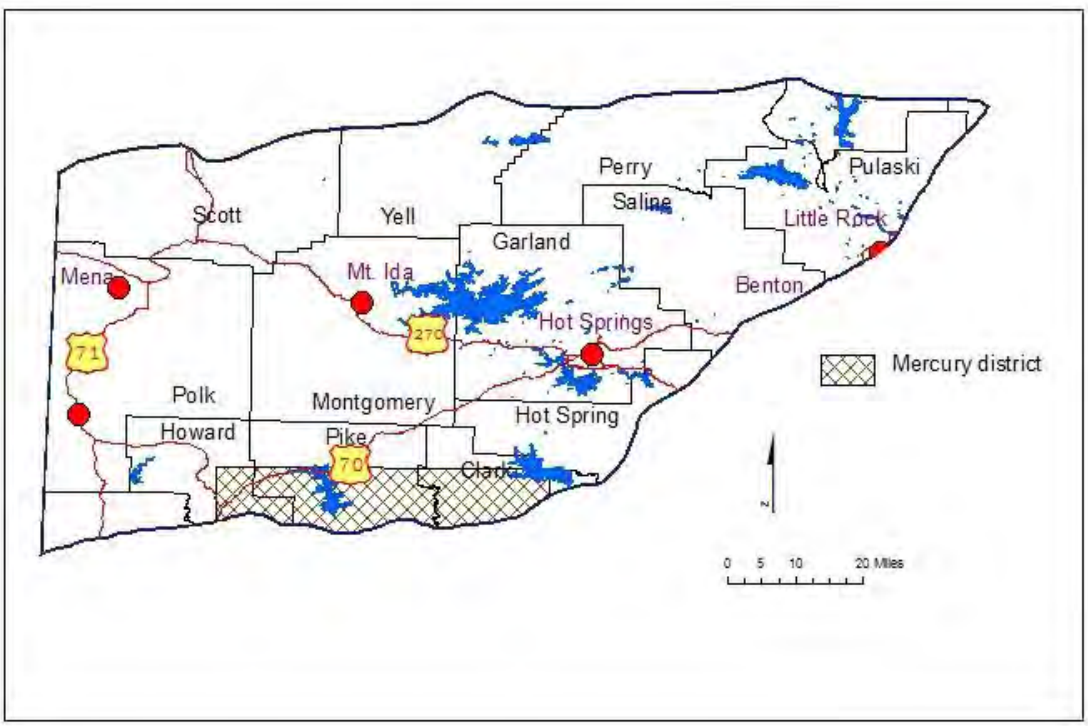



**Figure 12.** Location map showing Mercury district (stippled pattern).

The mercury district occurs in a belt 12 miles wide and 50 miles long extending from eastern Howard County through Pike County and into western Clark County (Fig. 12). The two areas of greatest concentration of mining were just west of the Antoine River and on both sides of the Little Missouri River.

At our fieldtrip location, the mercury ore occurs in sandstone units near the top of the Stanley Shale. The sandstone is gray and made up of a fine to medium grained mosaic of rounded to sub-angular grains of quartz with minor amounts of shale, white angular feldspar grains and flakes of mica. Locally, the sandstone may contain quartz and chert pebbles.

Cinnabar is the only primary ore mineral in the district. Freshly exposed cinnabar is translucent and bright vermillion red. The cinnabar occurs as fine to medium crystalline coatings on fracture surfaces and as coarsely crystalline material filling larger fractures and open spaces. Dickite and quartz also crystallized with the cinnabar and are associated with it in the fracture fillings. Dickite is a soft white to light brown clay mineral. It is often powdery or has a fine-grained appearance. Dickite is present at all of the mines and prospects in the district. Quartz occurs as small clear crystals and as massive milky quartz in fractures and open spaces.

Cinnabar and other primary minerals were deposited from aqueous solutions rising through fractures and porous rock. These mercury bearing solutions were probably the result of epithermal discharges of fluids from metamorphic rocks at depth west of the present mineralized area (Howard, 1979). It is thought that the solutions traveled northward up fault planes and into fractured sandstones and fault breccias where cinnabar was precipitated in open spaces. Ore bodies occur as pipe-like bodies in association with minor folds and faults and as tabular bodies generally restricted to an individual sandstone bed or a small group of beds.

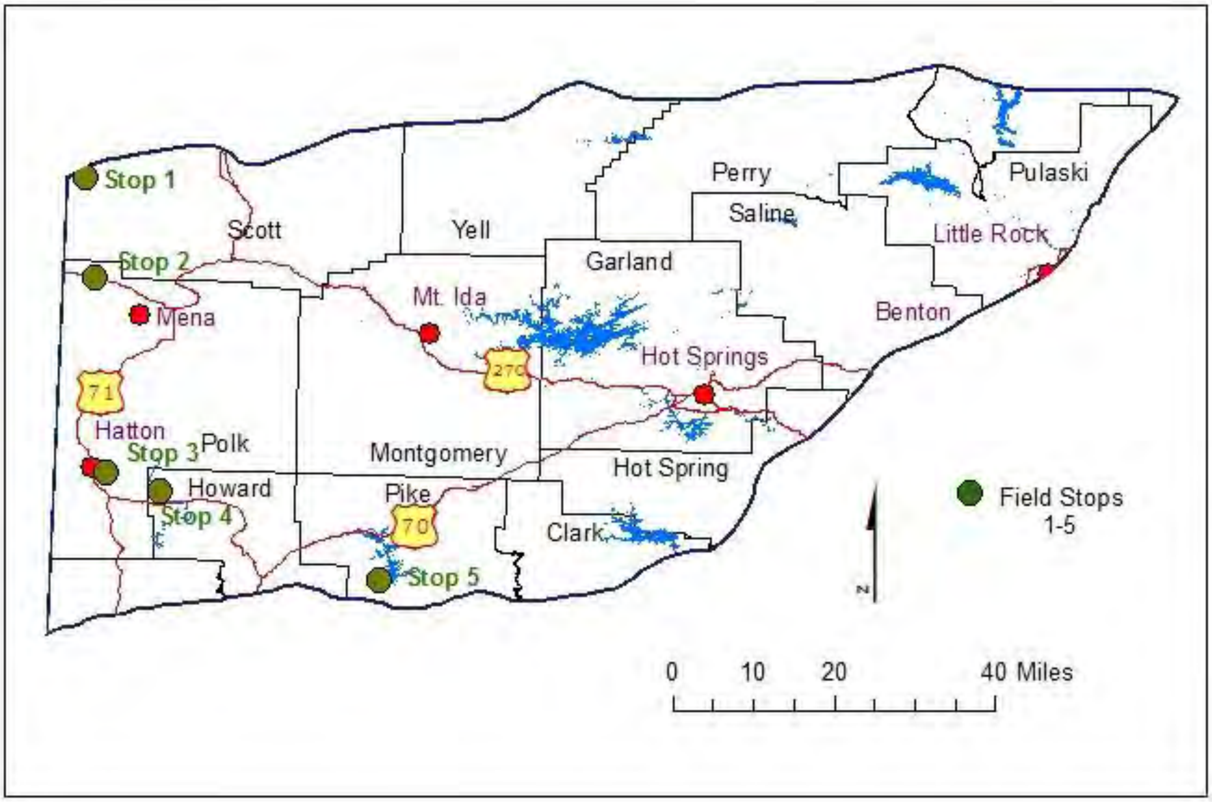



**Figure 13.** Map showing location of fieldtrip stops.

**Day 1**

**Stop 1 – Ouro Mining – Plant Fossil Locality – Bates, Arkansas**

Coal seams occur in various places in the Arkansas River Valley, ranging from two inches to six feet thick. Major coal beds occur in the McAlester Formation and the Savanna Formation (Fig. 14). Coal production in Arkansas started in the late 1800's mostly from underground mines. In the 1950's surface mining began and became the dominant form of mining well into the 1970's (Haley, 1978). The only coal mined in Arkansas at this time is from the Lower Hartshorne Coal in the McAlester Formation. There are two active mines in Sebastian County. The major use of this coal is in steel-making.

The Lower Hartshorne Coal was strip-mined at this locality from 2004-2006. Older workings were encountered during the mining which hindered operations. This site has since been reclaimed and sold to Ouro Mining to undertake an underground mining effort.

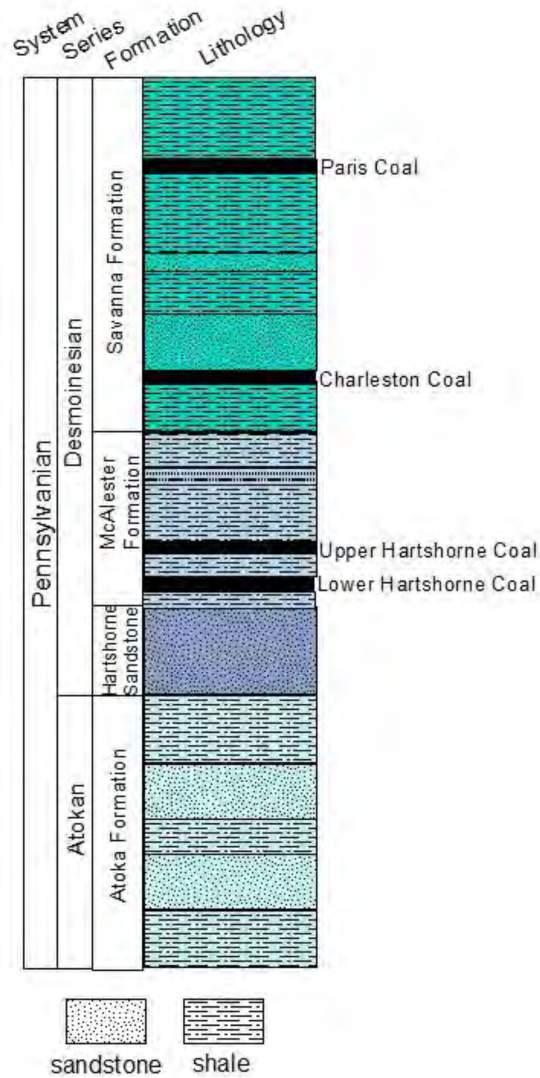



**Figure 14.** Generalized stratigraphic column showing named coal beds.

This area is rich in plant fossils.  Fragments of a lycopod known as *Lepidodendron* (Fig. 15) are abundant as well as its root system (*Stigmaria*) (Fig. 16).  Leaves and other woody fragments are also present.

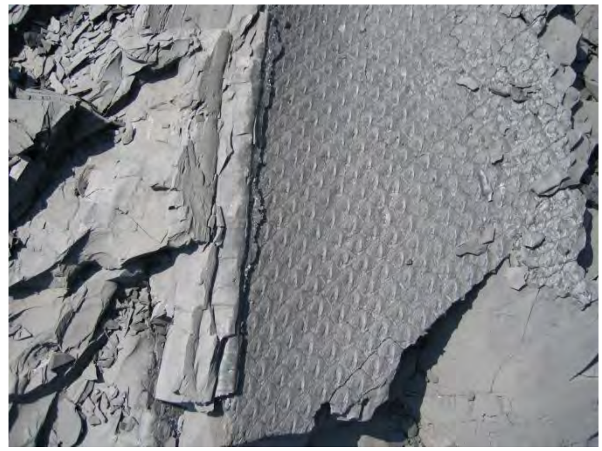



**Figure 15.** Reclaimed strip mining at Bates (left) and *Lepidodendron* fragment (right).


**Figure 16.** *Crossopteris* leaves (left) and *Stigmaria* fragment (right) from Bates, Arkansas.

*Crossing from Arkansas River Valley Region to Ouachita Mountains Region*

As we drive back to Mena we will cross back into the Ouachita Mountains Region.  Look for the small community of Boles about four miles before the town of Y City.  As we cross Ross Creek we will be crossing the Ross Creek Fault which is the northernmost thrust fault of the Ouachita Mountains Region.  Do you notice any change in landforms?

**Stop 2 - Ouachita landforms drive up Highway 88 – Rich Mountain**

We will take Highway 88 north of Mena on top of Rich Mountain which is a ridge classified as a hogback (Fig.10). There are several spots to pull over and view the scenery along the way, but we will stop at the Rich Mountain Lookout Tower to get a good view of the landforms and structure to the north and south of the ridge (Fig 17).

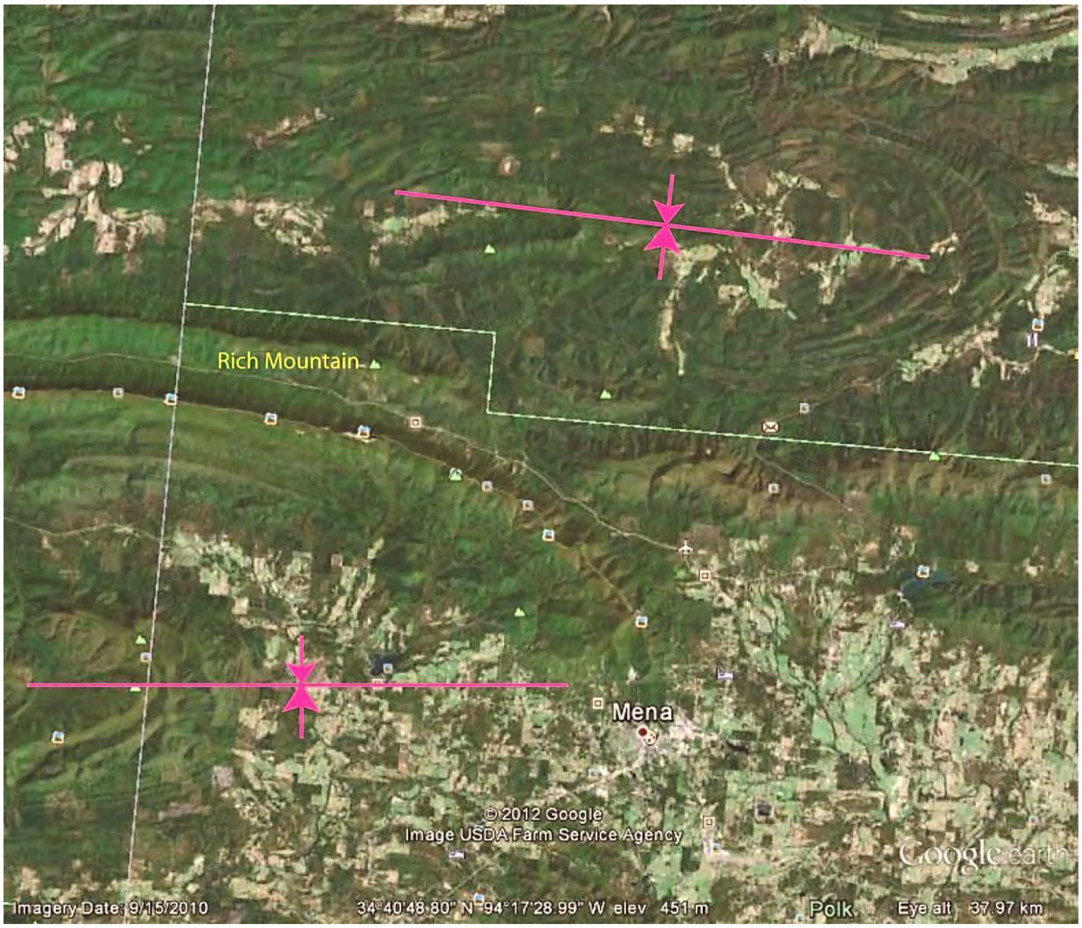



**Figure 17.** Google map showing geologic structures north and south of Rich Mountain.

**Day 2 – Morning**

**Stop 3 - Meridian Tuff Quarry – Hatton, Arkansas**

The mining at this locality has opened up an area where the Hatton Tuff can be studied in great detail. We will visit the working quarry after watching a video that provides details on the company, mining and uses of the rock. Since we are looking at rock in the Ouachitas, be prepared for steeply dipping rock.

The active portion of the quarry is located in the fine-grained gray tuff (Fig. 18). Look for mineralization (pyrite, calcite or quartz) along bedding planes as well as sedimentary structures. Notice the thickness of the beds and fine-grained character of the rock.

The mine manager has collected samples of tuff that have the large green lapilli (Fig. 18). Compare the two rocks. Look for shale rip-up fragments.

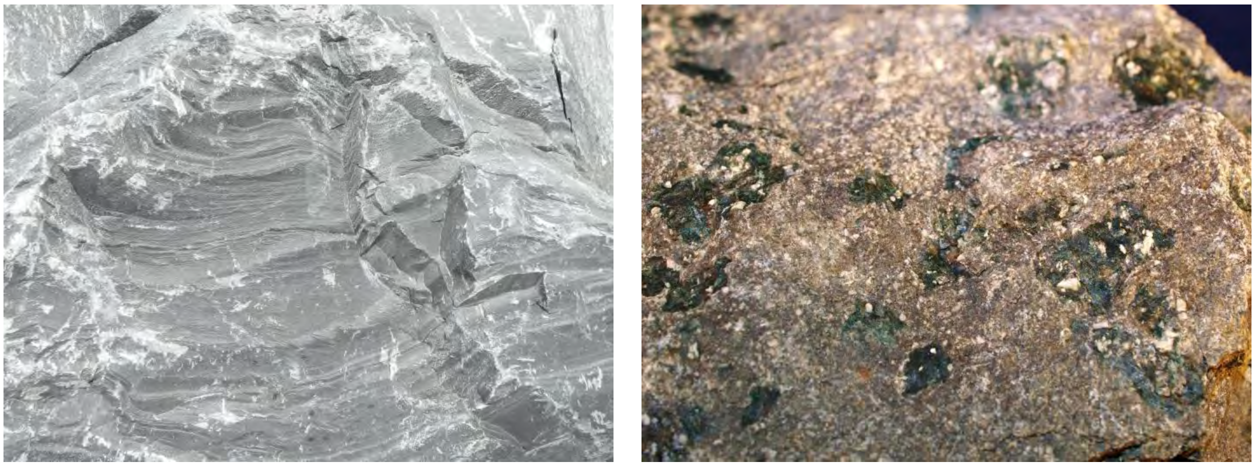


**Figure 18.** Fine-grained gray tuff displaying small scale cross-bedding (left). Large (1-2cm) green lapilli in a fine-grained matrix (right).

We will also look at the northern section of the quarry where the Arkansas Novaculite is present. At various times the novaculite has been mined as well. Look for manganese dendrites (Fig. 19). Notice the red chert nodules in the novaculite. What other rock types can you find?

**Figure 19.** Manganese dendrites on novaculite (left). Red chert nodules in novaculite (right).

**Day 2 – Afternoon**

**Stop 4 - Cossatot River Visitor Center and Cossatot Falls**

After a visit to the new Cossatot River Visitor Center we will walk along the trail past the shale pit and glade to Baker Creek (Fig. 20). This is a good opportunity to look at shale and sandstone in the Stanley Formation.

**Figure 20.** Shale glade near the Visitor's Center (left) and sandstone along Baker Creek (right).

Next we will travel to Cossatot Falls Natural Area. This area is a rugged and rocky canyon that has ledges of sandstone in the Stanley Shale over which the river drops 33 feet in elevation in 1/3 of a mile (Fig. 21). Notice the inclination of the sandstone beds. At this location we will take a strike and dip reading.

1. Which direction are the beds dipping?_______________________________________
2. How many degrees from horizontal are the ledges inclined? ___________________________________
3. List sedimentary features that are here______________________________________
4. Find load features in the sandstone (Fig. 21). Which surface is the top of the bed? ______________
5. Why are the beds inclined?_________________________________________________

**Figure 21.** Load features on sandstone bed at the falls (left). Inclined (dipping) beds of sandstone at the falls (right).

This is also a good area to do a gravel bar experiment.

**Day 3**

**Stop 5 – Cinnabar Trail – Lake Greeson**

This trail offers a short walk to good examples of abandoned cinnabar prospects in sandstone of the Stanley Formation. This particular area is called the Gap Ridge Prospect. The Southwestern Quicksilver Corporation operated the mine in 1934 and Arkansas Quicksilver Mines, Inc. operated it in 1940 (Clardy and Bush, 1978). The main prospect is 25 feet wide by 75 feet long and filled with water (Fig. 22). It is reported to have been 230 feet deep with 5,980 tons of rock removed. Several hundred flasks of mercury were produced from the mine. Other smaller trenches and digs are located west on the ridge.

The cinnabar occurs as fracture fillings and as disseminated grains in the sandstone. Associated minerals are dickite, quartz, limonite, siderite and barite. There are several faults at this location. Slickensides on sandstone fragments show evidence of movement within of the beds of sandstone (Fig 23). Slickensides are polished and smoothly striated surfaces that result from friction along a fault plane. Look around for cinnabar and slickensides on the tailings.

**Figure 22.** Cinnabar on sandstone (right) and Gap Ridge Prospect (left).

**Figure 23.** Slickensides on sandstone (left). Mine tailings from Gap Ridge prospect (right).

**References:**

Clardy, B.F., and Bush, W.V., 1976, Mercury district of southwest Arkansas: Arkansas Geological Commission Information Circular 23, 52 p.

Danilchik, W. and Haley, B.R., 1964, Geology of the Paleozoic area in the Malvern quadrangle, Garland and Hot Spring Counties, Arkansas: U.S. Geological Survey Miscellaneous Investigations Map I-405.

Guccione, M.J., 1993, Geologic history of Arkansas through time and space: National Science Foundation Grant No. ESI-8855588.

Haley, Boyd R., 1978, Resources of low-volatile bituminous coal and semianthracite in west-central Arkansas, 1978: U.S. Geological Survey Bulletin 1632.

Howard, J.M., 1979, Antimony district of southwest Arkansas: Arkansas Geological Commission Information Circular 24, 29 p.

Miser, H.D. and Purdue, A.H., 1929, Geology of the DeQueen and Caddo Gap quadrangles, Arkansas: U.S. Geological Survey Bulletin 808, 195 p.

Niem, A.R., 1971, Stratigraphy and origin of tuffs in the Stanley Group (Mississippian), Ouachita Mountains, Oklahoma and Arkansas: University of Wisconsin M.S. Thesis, 151 p.

Niem, A.R., 1977, Mississippian pyroclastic flow and ash-fall deposits in the deep-marine Ouachita flysch basin, Oklahoma and Arkansas: Geological Society of America Bulletin vol. 88, no.1, pp. 49-61.

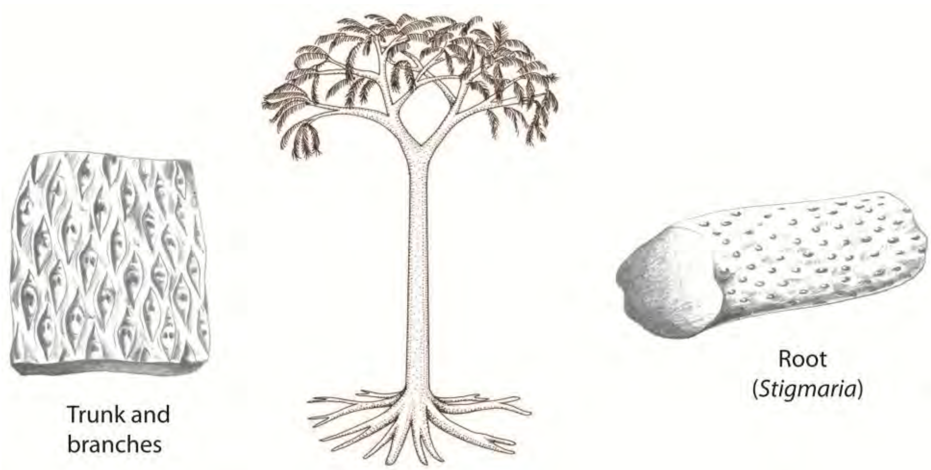
Stone, C.G. and Haley, B.R., 1984, A guidebook to the geology of the central and southern Ouachita Mountains, Arkansas: Arkansas Geological Commission Guidebook 84-2, 131 p.

Vanarsdale, R., 1991, Geologic interpretation of remote sensor imagery and topographic maps: *in* Methods and Practices of Physical Geology, third edition, by Konig and Zachry Jr.: University of Arkansas Physical Geology Lab book.

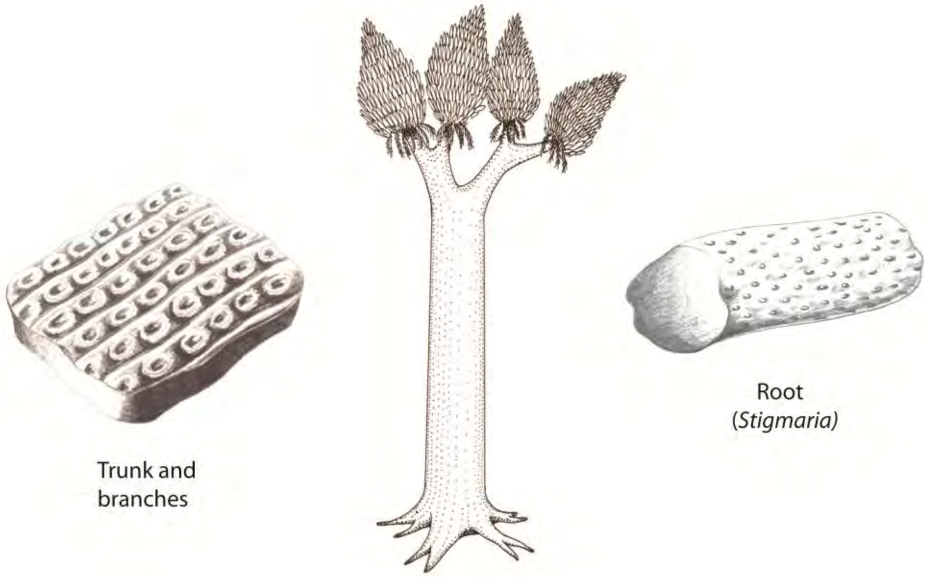
## Appendix 1 – Plant Fossils

### Lycopods

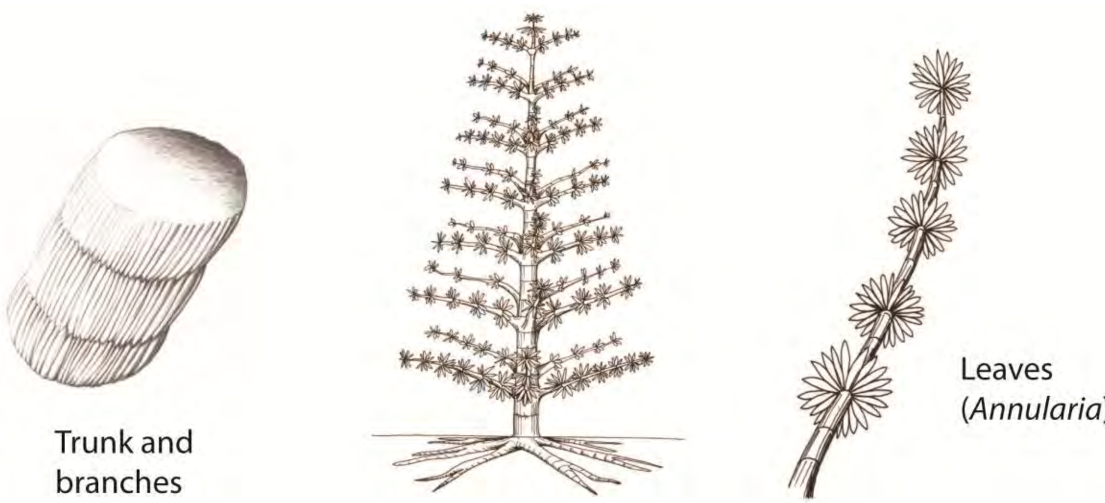
Throughout geologic time the seas have undergone transgressions (high sea level) and regressions (low sea level). During regression there is more land exposed and in the Mississippian and Pennsylvanian Periods there was abundant plant life thriving in subtropical conditions throughout the world. Most of the plants grew in swampy areas, where they eventually accumulated in large numbers to ultimately form coal. This led to the name Carboniferous Period or Coal Measures, for rocks deposited during this time. The dominant trees of this period were the lycopods *Lepidodendron* and *Sigillaria*. Other plants that were more common on higher ground and floodplains were the horsetails called *Calamites.* These were tree-sized plants reaching a height of approximately 20 meters or 65 feet. In Arkansas, the best preserved of these fossils are found in Pennsylvanian-age rocks from the Arkansas River Valley Region. Fragments of plant fossils can also be found in Pennsylvanian age rocks in the Ozark Plateaus Region.




*Lepidodendron*, an extinct coal-age tree. Illustrations by Sherrie Shepherd.




*Sigillaria*, an extinct coal-age tree. Illustrations by Sherrie Shepherd.




*Calamites*, an extinct horsetail. Illustrations by Sherrie Shepherd.

## Landform Exercises

**Exercise 1 (Refer to landforms diagram and Rich Mountain Quadrangle)**

Examine Rich Mountain. Follow Highway 88 (Skyline Drive) and notice the steepness on both sides of the ridge.

Which landform name can be applied to this ridge?________________________

In which physiographic region is the feature located? _____________________
________________________

**Exercise 2 (Refer to landforms diagram and Ferndale Quadrangle)**

Examine the ridge created by Brush Mountain in the southern portion of the quadrangle. Notice the steepness of both sides of the ridge.

Which landform name can be applied to this ridge?________________________

What can you infer from these features and the stream pattern?______________