1-2019

A Geological History of Clark County, Arkansas

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The geological history of Clark County is described ranging from 500 million years ago to the present. One-third of present-day Clark County is in the Ouachita Mountains, two thirds is in the Coastal Plain. The formation of the Ouachita Mountains is described, as is the cretaceous formations that led to biological fossils. Historic mining of minerals is also discussed. For the more technically inclined, a detailed description of the geological formations of the county is included near the end.

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Arkansas is divided into six natural divisions[1], as shown in Figure 1.

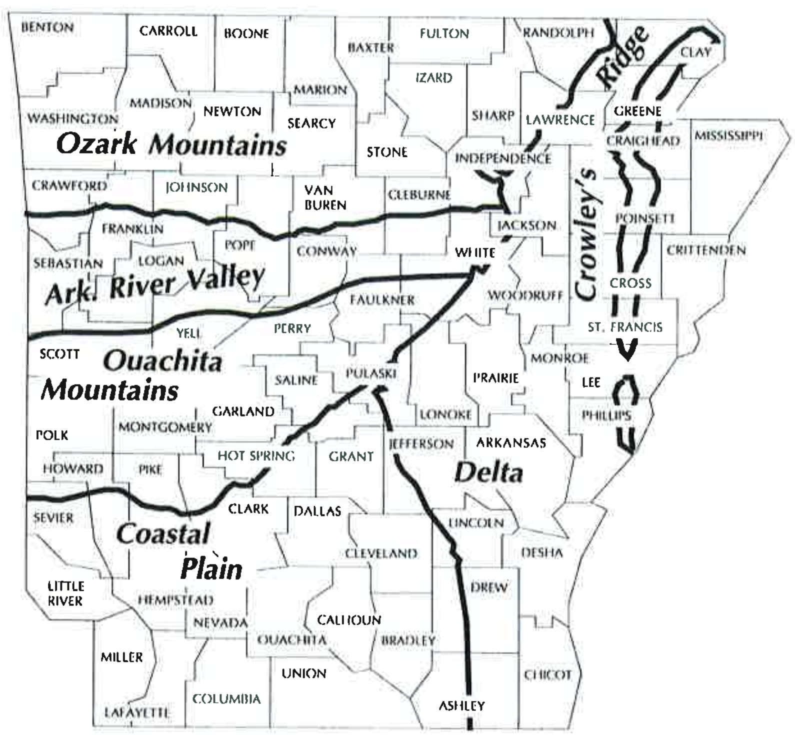

Figure 1: Natural Divisions of Arkansas.
Courtesy of the Arkansas Natural Heritage Commission

[1] "Ecoregions/Natural Divisions of Arkansas," Arkansas Natural Heritage Commission, accessed September 6, 2018, http://www.naturalheritage.com/Education/ecoregions-natural-divisions-of-arkansas.
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Clark County spans two of them: Ouachita Mountains and Coastal Plain. It has not always been this way. To describe the current geology of Clark County, one must look at the geological eras/periods, shown in Table 1.

Era	Period	Years Ago (Millions)
Cenozoic	Quaternary	Present-1.6
	Tertiary	1.6-66
Mesozoic	Cretaceous	66-144
	Jurassic	144-208
	Triassic	208-245
Paleozoic	Permian	245-286
	Pennsylvanian	286-320
	Mississippian	320-360
	Devonian	360-408
	Silurian	408-438
	Ordovician	438-505
	Cambrian	505-570

Table 1: Eras and periods[2] of Clark County.

The Earth's crust is composed of huge plates that float on a material with plastic characteristics called the mantle. These plates are in motion relative to one another with collisions and shearing forces occurring. Also, new material from the mantle oozes up to form new portions of the Earth's crust and some edges of plates get forced back into the mantle. Some plates have continents extending above sea level; others are thinner and totally submerged. The resulting continental drift moves the plates around the globe at a rate of 1-4 inches per year.[3]

The area that is now Arkansas was submerged in a sea off the coast of the North American plate. The Ozark region was in a shallow sea; the Ouachita region was in a very deep sea. Over the Paleozoic era from 550 million years before present (MYBP) to 340 MYBP, sediment from nearby continents eroded and settled into this deep sea. Under the pressure of the water column and increasing layers of sediment, the sediments were compressed into rock. Even older rock underlay these sediments. Starting about 340 MYBP (Mississippian period), a small plate broke off from the plates containing South America and Africa. Some geologists call this plate Llanoria.[4] Others call it Yucatan.[5] As the remnants of

[2] "Putting Time into Proportion," U.S. Geological Survey, accessed September 17, 2018, https://geomaps.wr.usgs.gov/parks/gtime/gtime2.html.
[3] "Australia is Drifting So Fast GPS Can't Keep Up," National Geographic, accessed September 28, 2018, https://news.nationalgeographic.com/2016/09/australia-moves-gps-coordinates-adjusted-continental-drift/.
[4] Hugh D. Miser, "Llanoria, the Paleozoic Land Area in Louisiana and Eastern Texas," *American Journal of Science*, 3, 8 (August 1921): 61-89.

Llanoria were pushed into the North American plate, the lateral compression caused the deep rocks to buckle up, eventually rising above water level to form the east-west ridges of the Ouachita Mountains, as shown in Figure 2.[6] The height above sea level of the Ouachitas at their peak is subject to interpretation. Values higher than 20,000 feet have been reported.[7]

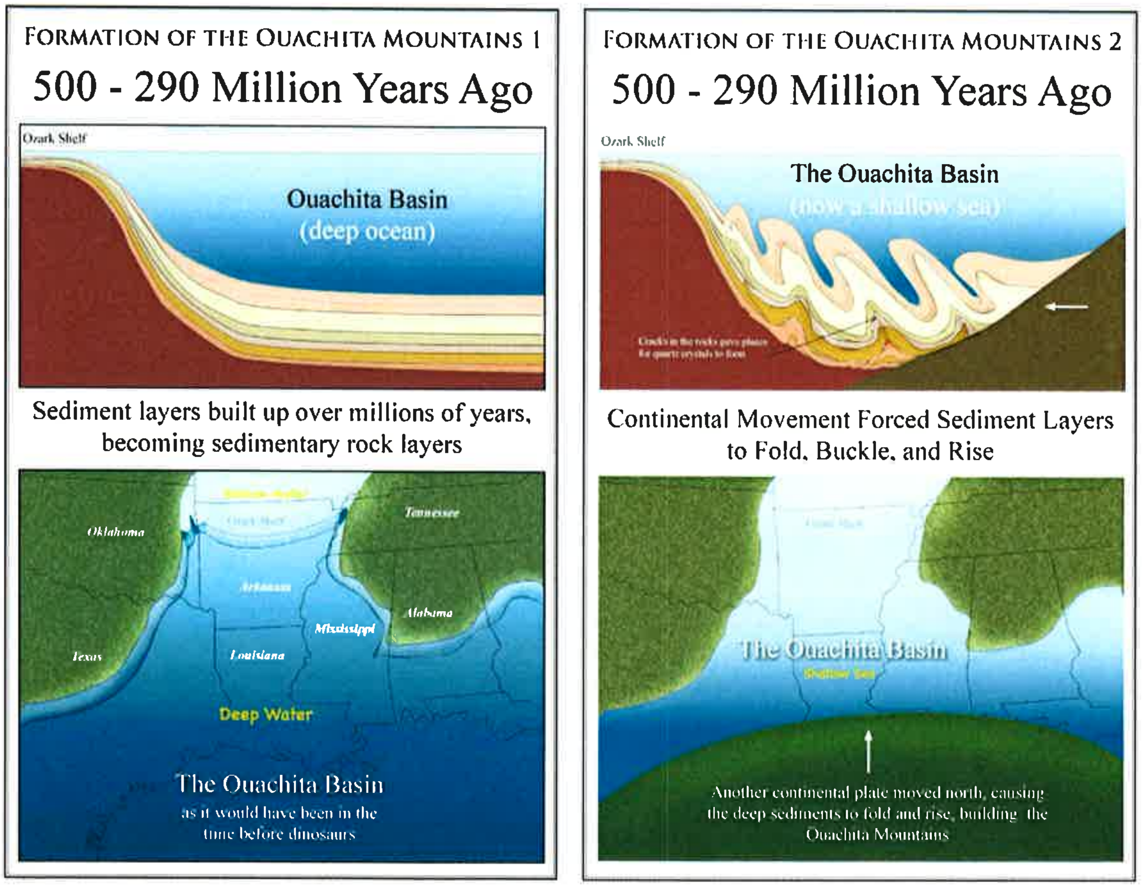

Figure 2: Formation of the Ouachita Mountains: 1, sediments in deep ocean; 2, lateral pressure causing folding and buckling.
Courtesy of Rockhounding Arkansas

5 Doug Hanson, "Geological History of Clark County Region," Clark County Bicentennial Lecture, Arkadelphia, AR, September 20, 2018.
6 "Formation of the Ouachita Mountains," Rockhounding Arkansas, accessed August 2018, http://rockhoundingar.com/ouamtns.php.
7 Thomas Foti, *The Natural Divisions of Arkansas: A Classroom Guide* (Little Rock: Arkansas Ecology Center, 1978), 15.

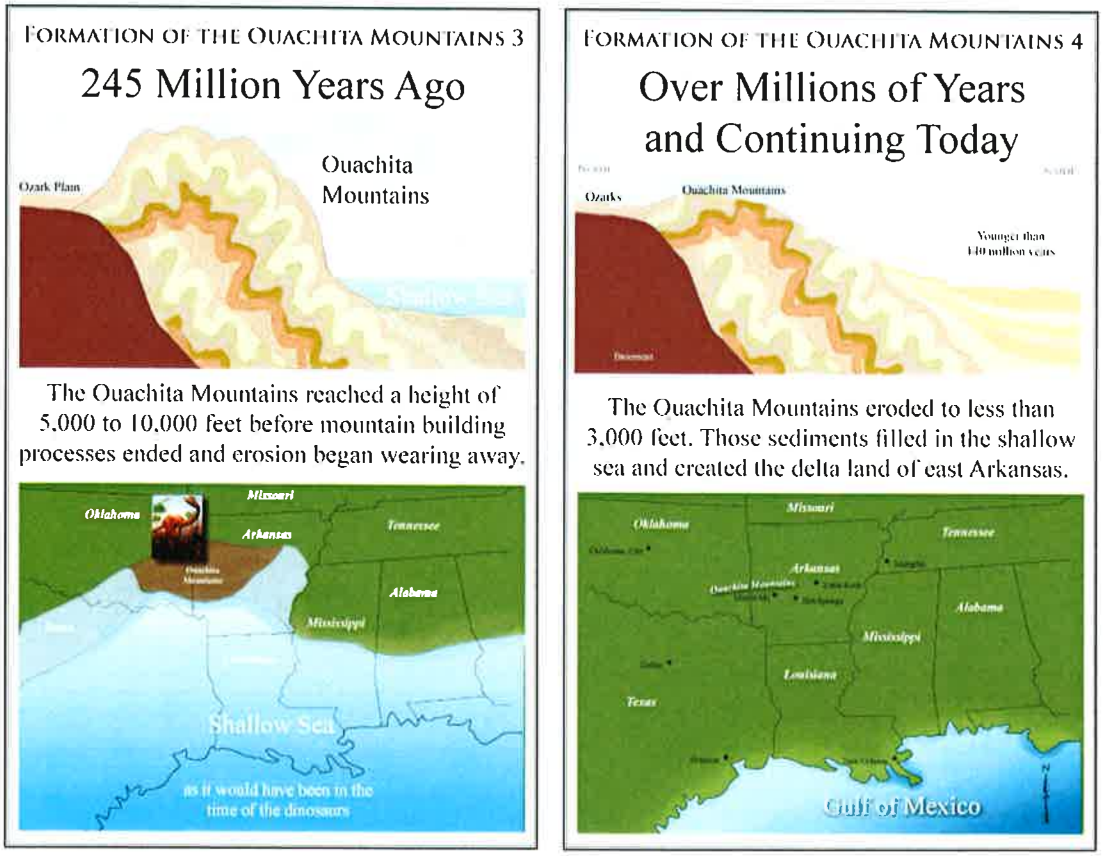

Figure 2 continued: Formation of the Ouachita Mountains: 3, Ouachita Mountains at peak height; 4, Ouachita mountains today.
Courtesy of Rockhounding Arkansas

These plate collisions probably caused mountain building events from the Appalachian Mountains to the Marathon Mountains in Texas.[8] Gradually the continental plates came together to form the supercontinent Pangaea[9], as shown in Figure 3. Continued continental drift over the past 250 million years led to the present continent arrangement.

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[8] "Ouachita Mountains, Oklahoma," NASA, accessed September 5, 2018, https://earthobservatory.nasa.gov/images/46485/ouachita-mountains-oklahoma.
[9] "Historical Perspective," US Geological Survey, accessed September 6, 2018, https://pubs.usgs.gov/gip/dynamic/historical.html.

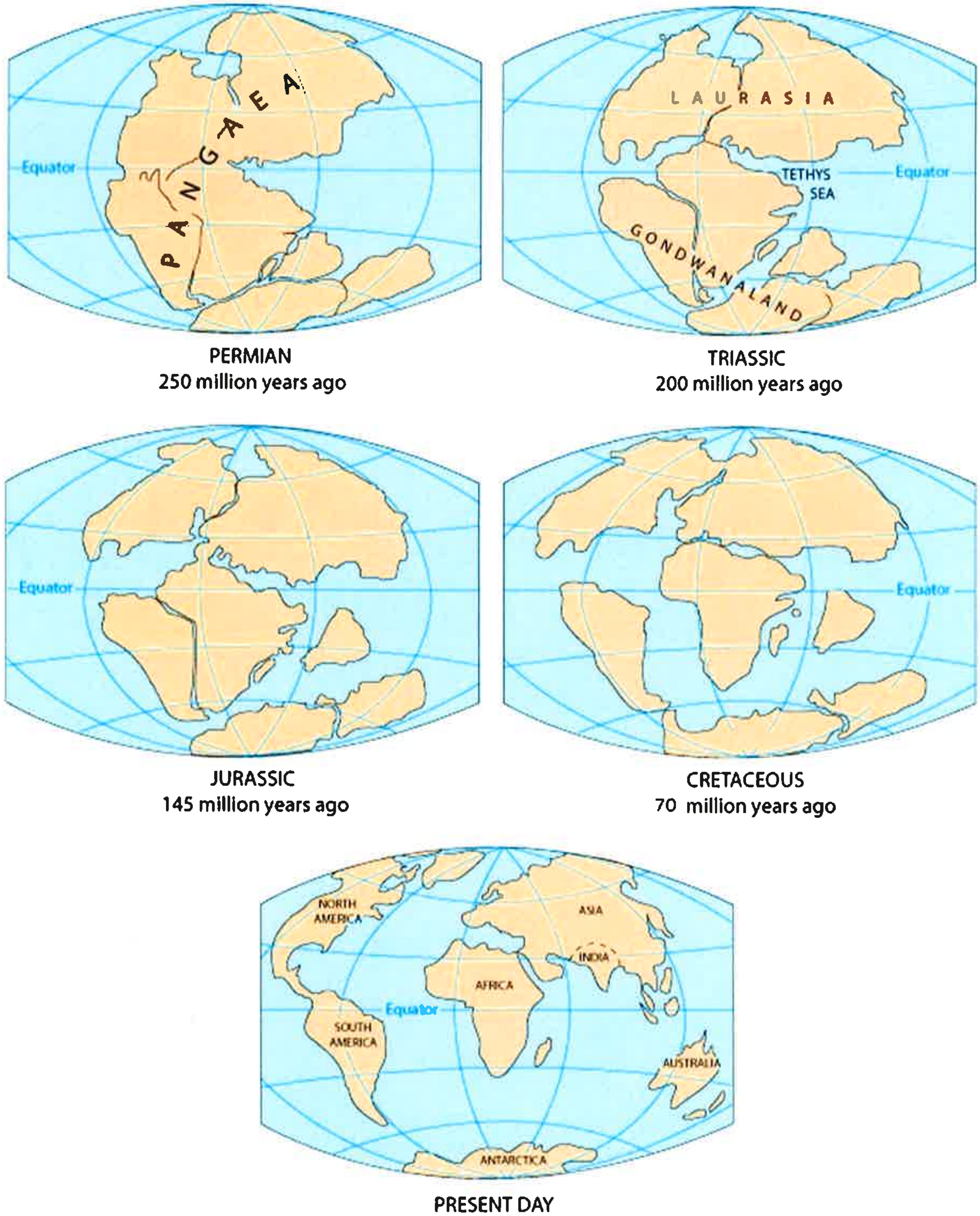

Figure 3: The Breakup of Pangaea.
Courtesy of the U.S. Geological Survey

The lateral buckling pressure that formed the Ouachitas is evident today where rock strata are exposed, as in the DeGray Lake spillway shown in Figure 4. Because the Ouachitas were formed from such a deep sea, there was not much sea life and fossilized sea creatures are not abundant.

Figure 4: Folded strata typical of Ouachita Mountains.
Courtesy of the Arkansas Geological Survey

In contrast, the Ozark Mountains were uplifted from a shallow sea that was very productive for sea life, so numerous fossils and much limestone, containing a high proportion of crushed sea shells, is found in the Ozarks. The Ozark Plateau was lifted up from pressures underneath, so its strata were not buckled.[10] The upland plateaus eroded to form valleys because limestone is a soft rock. Sediments from harder rocks ate into the limestone as sediment-laden water coursed over it. As a result, outcrops reveal more horizontal bedding plains, as shown in Figure 5.

Figure 5: Horizontal strata typical of the Ozark Mountains.
Courtesy of Joe Nix

[10] Foti, *Natural Divisions*, 15.

With Pangaea's break up, waters came back into the lower Ouachitas, producing a shallow sea. Erosion from the mountains filled in lower folds of the Ouachitas and provided much of the sediment of the Coastal Plain.

While the coastline ebbed and flowed during the time after the Ouachita uplift, it is marked by where the Coastal Plain begins. This was the sea shore. During periods when gulf waters lapped the edge of the Ouachitas, the sea was shallow and more biologically productive. Because of drifting plates, the region was nearer the equator than it is now.[11]

Where does Clark County fit into this pattern? The northwestern third of the county is in the Ouachitas; the southeastern two-thirds is in the Coastal Plain[12], as shown in Figure 6. Essentially, area B1 has Cretaceous formations; B2 has Tertiary and Quaternary deposits. The boundaries shown here are general. Pockets of one subdivision may appear in the general area of another. More detail is shown later in Figures 13 and 14.

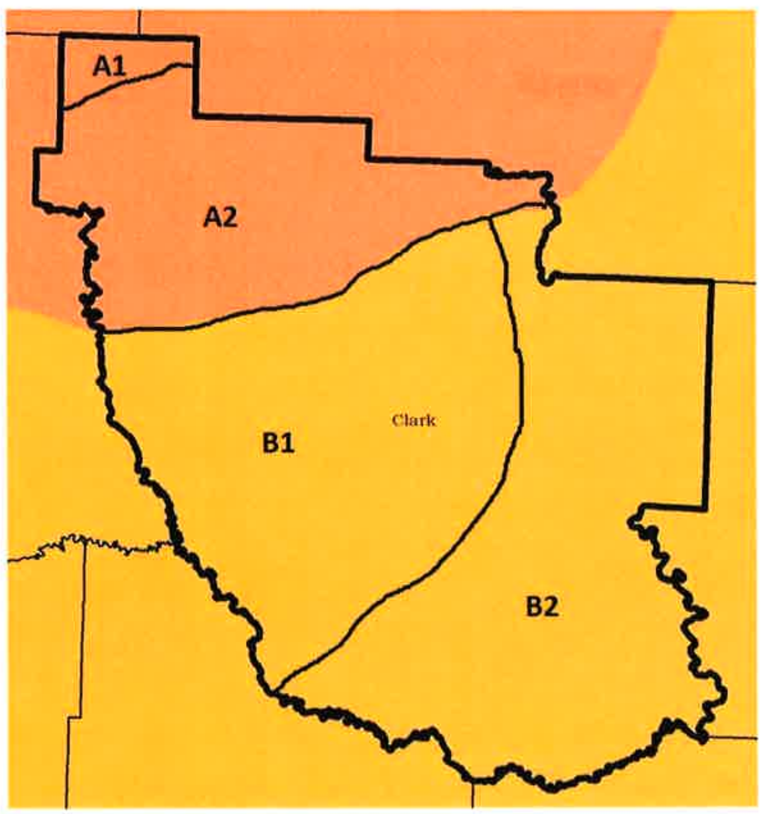

Figure 6: Ouachita Mountains, A1 (Central Ouachita Mountains), A2 (Athens Plateau); West Gulf Coastal Plain, B1 (Southwestern Arkansas), B2 (South Central Arkansas).

[11] Hanson lecture, 2018.
[12] Bill Pell, "The Natural Divisions of Arkansas: A Revised Classification and Description," *Natural Areas Journal* 3, 2 (1983): 12-23.

To describe the current geology of Clark County, one must look at the three major types of rock – sedimentary, igneous, and metamorphic. The most common in the Ouachitas are sedimentary rocks, e.g. sandstone, shale, chert, novaculite, and a small amount of limestone.[13] Arkansas novaculite is considered microcrystalline sedimentary rock and probably formed due to warm waters expelled during the Ouachita mountain building process altering the original chert into novaculite. The intense folding of the Ouachitas allowed fissures to develop, so, in a few places, deep material intruded to form igneous rock.[14] Very little igneous rock is found in the Ouachitas. Hydrothermal deposition of hot waters laden with minerals seeped up in the cracks leading to veins of ores containing mercury, lead, antimony, and copper.

The Central Ouachitas contain Ordovician sandstone and shale (438-505 MYBP) and novaculite.[15] Novaculite, formed in the Devonian and early Mississippian periods (408-320 MYBP), is found primarily in the Ouachitas. Caddo Indians used it for tools and weapons, e.g. arrow heads. Later settlers used it as whetstones, an industry that still exists.[16] The Athens plateau contains the same rock types, but periodic coastal variations resulted in more recent additions of sediments. All of these areas have much older rocks underlying them, but those rocks are not found at the surface.

The West Gulf Coastal Plain during the Cretaceous period was a biologically productive, shallow sea. Small amounts of limestone and sea creature fossils are not uncommon, as shown in Figure 7. Oyster fossils (Exogyra ponderosa) can be found lying out in the pastures a few miles west of Arkadelphia. Other fossil finds are abundant. Ammonites were marine mollusc animals of the Cretaceous period. The fossils in Figure 8 were found near Hollywood.

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[13] "Rocks: Igneous, Metamorphic and Sedimentary," Geology.com, accessed September 13, 2018, https://geology.com/rocks/.
[14] "What Are Igneous Rocks?" US Geological Survey, accessed October 1, 2018, https://www.usgs.gov/faqs/what-are-igneous-rocks?qt-news_science_products=0#qt-news_science_products.
[15] Charles G. Stone and William V. Bush, *General Geology and Mineral Resources of the Caddo River Watershed* (Little Rock, AR: Arkansas Geological Commission, 1984), 1.
[16] "Arkansas Novaculite," Arkansas Archeological Survey, accessed September 28, 2018, http://archeology.uark.edu/novaculite/index.html.

Figure 7: Fossils from Arkadelphia Marl.
Courtesy of the U.S. Geological Survey[17]

Figure 8: Ammonite fossils. The left specimen is 15X18"; the right 10X12".
Courtesy of Meeks Etchieson

[17] Joseph A. Cushman, *The Foraminiferal Fauna of the Upper Cretaceous Arkadelphia Marl of Arkansas* (Washington, D.C., U. S. Department of the Interior, 1949), plate 1.

The Mesozoic Era was the time of the dinosaurs. Dinosaur fossil footprints have been found in Howard County. While no dinosaur fossils have been found in Clark County, mosasaur fossils have been found. Mosasaurs were the apex predator of the seas during the Cretaceous period, ranging in size up to 60 feet in length.[18] Like the dinosaurs, they became extinct at the end of the Cretaceous period. The example shown in Figure 9 is in the Perot Museum of Nature and Science in Dallas, Texas. The fossils in Figure 10 were found in Arkansas.

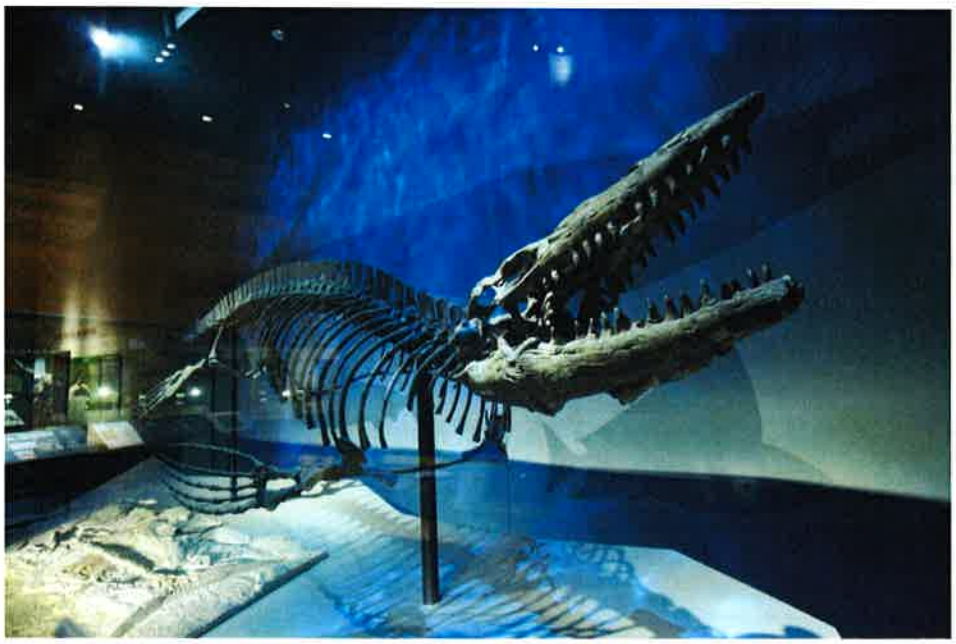


Figure 9: Mosasaur skeleton.
Courtesy of the Perot Museum of Nature and Science

Figure 10: Mosasaur vertebrae and tooth,
Courtesy of the Arkansas Geological Survey

[18] "Paleoaerie: Arkansas Educational Resource Initiative for Evolution and Arkansas Paleontology," accessed September 27, 2018, https://paleoaerie.org/.

Minerals, namely mercury as cinnabar (mercury sulfide), antimony, and lead were mined in Clark County.[19] Gravel was/is also mined. The quicksilver (mercury) district extended from Howard County through Pike County into Clark County.[20] From its discovery in 1931 until 1946, cinnabar was mined at seven locations in Clark County, all a few miles south of Amity and west of Alpine (Figure 11).[21] Mercury is widely distributed in the Ouachitas. A 1995 study with more than 700 samples found mercury amounts ranging from 3 to 6100 parts per billion (ppb), with a mean of 88 ppb.[22] Small amounts of zinc, copper, and silver are also found in the Ouachitas.

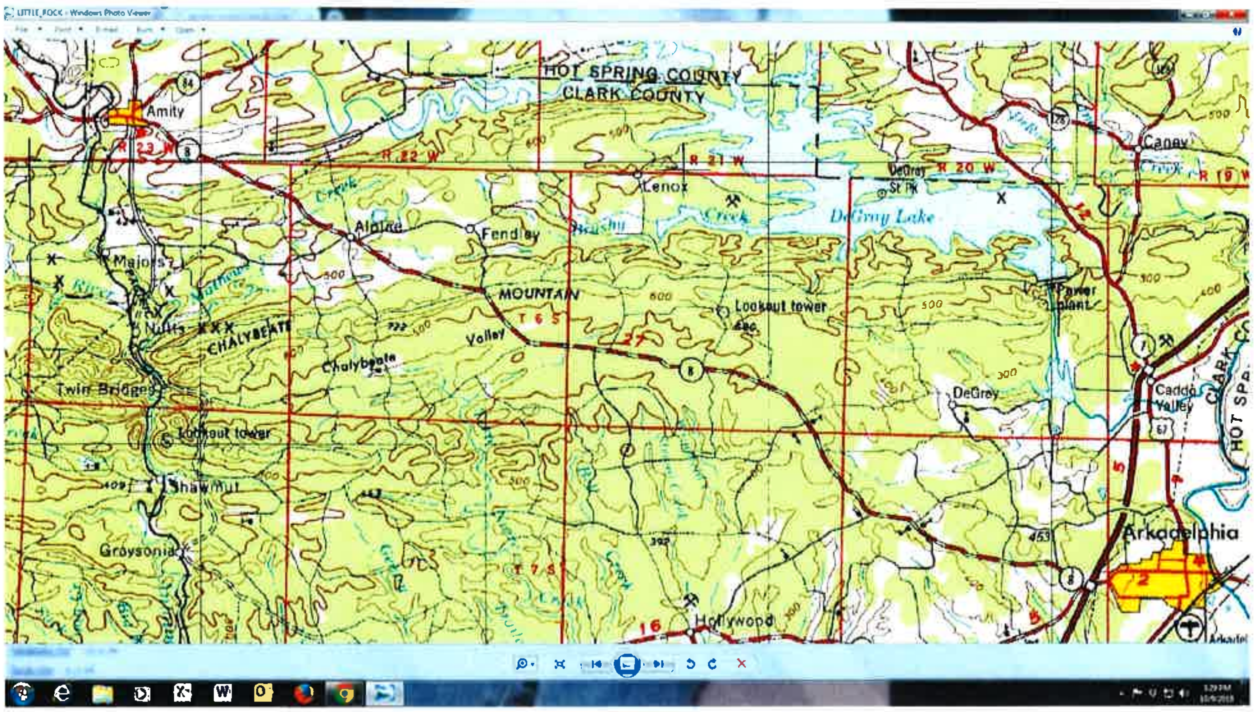


Figure 11: Mineral map of Clark County. Seven Xs south of Amity and west of Alpine mark seven cinnabar mines; X at DeGray Lake marks antimony mine before DeGray Lake was formed.

The Paleozoic rocks of the Ouachitas are present in the Coastal Plain, but are buried under late Cretaceous rock (66-100 MYBP) and even Tertiary and Quaternary deposits of clay, sand, gravel, and cobbles.[23] Chalk beds extend southwestward from Arkadelphia. During the late Cretaceous and Tertiary periods (66-1.6 MYBP), the sea shore was off and on where the Ouachita River is now at

19 Charles Leming, "Geological History of Clark County," *Clark County Historical Journal* (1981), 45.
20 John C. Reed and Francis G. Wells, "Geology and Ore Deposits of the Southwestern Arkansas Quicksilver District," *Clark County Historical Journal* (1992): 54.
21 "Mineral Commodity Search," Arkansas Geological Survey, accessed August 13, 2018, https://www.geology.arkansas.gov/maps-and-data/mining-map.html.
22 Ibid.
23 Stone and Bush, *General Geology*, 1984.

Arkadelphia. Swampy areas developed in the Coastal Plain. Alluvial deposits from river flooding added more soil to the plain. Lignite beds, early stage coal, developed near Manchester. Some areas of the Coastal Plain in Clark County had sand and coarse gravel overlying beds of clay. These areas were not suitable for agriculture. Areas where alluvial deposits occurred did become rich agricultural regions.[24] The clay was suitable for pottery. Caddo Indian pottery dates to the Woodland Period, perhaps as early as 500 B.C. Examples are shown in Figure 12.

Figure 12: Caddo Indian pottery.
Courtesy of the Arkansas Archeological Survey,
Henderson State University Research Station

As the sea retreated in the Quaternary period, salt water was trapped below the surface. Salt wells and springs remain today. Salt was Clark County's first industry by settler John Hemphill in the early 1800s. Waters from the salt springs just east of Arkadelphia were evaporated to collect the salt.[25] The Caddo Indians, however, had mined salt since ca. A. D. 1200.[26]

A detailed look at the geology of Clark County is shown in Figures 13 and 14. Figure 13 provides a map of the geological formations that follow. These descriptions are direct quotes from the Arkansas Geological Survey website, expurgated for conciseness.[27] For example, Stanley Shale is designated Ms;

[24] Norma S. Arnold, "The Manchester Region of Eastern Clark and Western Dallas Counties, Part I: General History," *Clark County Historical Journal* (1979-1980): 2-3.
[25] Trey Berry, "Colonization and Settlement in Clark County and southwest Arkansas," Bicentennial Lecture, Arkadelphia, AR, September 27, 2018.
[26] Mary Beth Trubitt, "Pre-History of Clark County Region," Bicentennial Lecture, Arkadelphia, AR, September 27, 2018.
[27] "Stratigraphic Summary of the Arkansas River Valley and Ouachita Mountains," and "Stratigraphic Summary of the Mississippi Embayment and Gulf Coastal Plain," Arkansas

Arkadelphia Marl (lime-rich mudstone) is designated by Kad. The descriptions are technical. Figure 14 is a modification of that map to show the Cretaceous formations in black. Most of the formations to the north and west of the Cretaceous group are in the Central Ouachitas and the Athens Plateau. Those to the east and south are from the Tertiary and Quaternary periods. The incursions from the southeast follow stream beds. The surface geological formations vary in age from the Devonian period (360-408 MYPB) to the present.

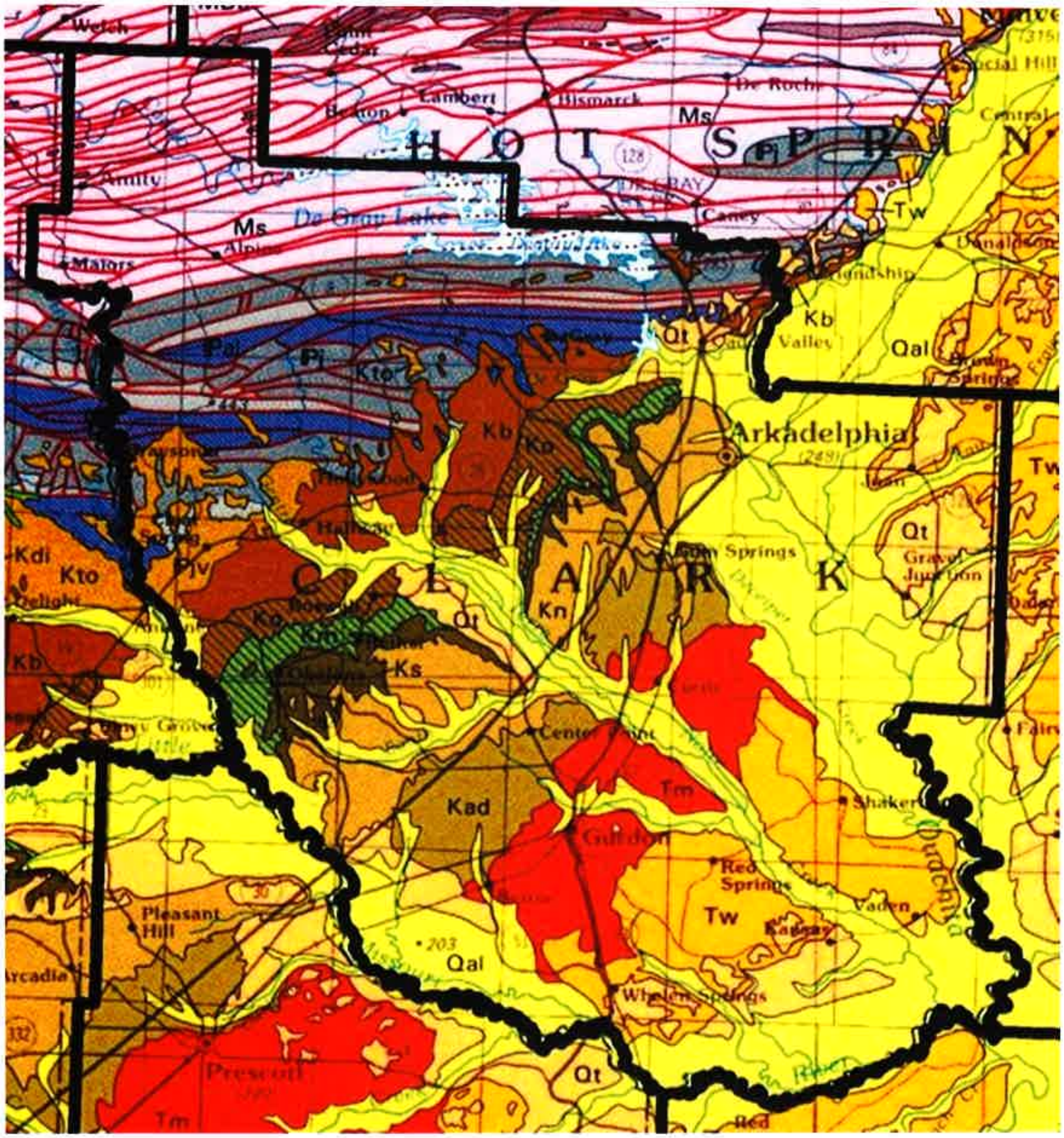


Figure 13: Geological formation map of Clark County.
Courtesy of the Arkansas Geological Survey

Geological Survey, accessed September 23, 2018, https://www.geology.arkansas.gov/geology/stratigraphy.html.

Figure 14: Clark County geological formation map with Cretaceous formations shown in black.

CENTRAL OUACHITA MOUNTAINS/ATHENS PLATEAU[28]

Arkansas Novaculite *(MDA, not marked on map)*

Age: Devonian and Early Mississippian Periods

Three Divisions of the Arkansas Novaculite Formation are recognized (except in the northern exposures). The Lower Division is a white, massive-bedded novaculite with some interbedded gray shales near its base. The Middle Division consists of greenish to dark gray shales interbedded with many thin beds of dark novaculite. The Upper Division is a white, thick-bedded, often calcareous novaculite. Conodonts and other microfossils are sometimes common in the Arkansas Novaculite.

Stanley Shale *(Ms)*

Age: Mississippian Period

Composed of dark-gray shale interbedded with fine-grained sandstone. A thick sandstone member, the Hot Springs Sandstone, is found near the base of the sequence and an equivalent thin conglomerate/breccia occurs at the base of the unit in many other places. Stratigraphically minor amounts of tuff, chert, bedded

[28] "Ibid.

and vein barite, and conglomerate have also been noted in various parts of the sequence. Silty sandstones outside the Hot Springs Sandstone Member are normally found in thin to massive beds separated by thick intervals of shale. The tuffs (Hatton Tuff Lentil and others) seem to be restricted to the lower part of the Stanley Shale. Cherts are sometimes present in the middle and upper parts of the formation. Both plant and invertebrate fossils occur in the Stanley Shale, but the preservation is usually poor.

***Jackfork Sandstone** (IPj)*
Age: Pennsylvanian Period
Thin- to massive-bedded, fine- to coarse-grained, brown, tan, or bluish-gray quartzitic sandstones with subordinate brown, silty sandstones and gray-black shales. Toward the north of its outcrop area the shale units of the lower and middle Jackfork Sandstone take up more of the section and the sandstones are more lenticular, often occurring as chaotic masses in the shale. Minor conglomerates composed of quartz, chert, and metaquartzite occur notably in the southern exposures of the formation. A few poorly preserved invertebrate and plant fossils have been recovered from the Jackfork Formation.

***Johns Valley Shale** (IPjv)*
Age: Pennsylvanian Period
Generally a gray-black clay shale with numerous intervals of silty, thin to massive, brownish-gray sandstone. Small amounts of gray-black siliceous shale and chert have also been noted.

***Atoka Formation** (Pa1)*
Age: Pennsylvanian Period
Sequence of marine, mostly tan to gray silty sandstones and grayish-black shales. Some rare calcareous beds and siliceous shales are known.

COASTAL PLAIN[29]
***Brownstown Marl** (Kb)*
Age: Late Cretaceous Period
Composed of clay marls, thin (sometimes sandy) limestones, sandy marls, and some fine-grained sands. Glauconite and some phosphatic material may be associated with the various lithologies. Color is quite variable, depending on the degree of weathering, iron content, and other factors, yielding tan, brown, blue, green, red, yellow, gray, or any color combination and hue. Near the base of the unit, beds of thin hard limestone exist that contain poorly preserved fossils. The marls in the formation are often highly fossiliferous. The most common fossils

[29] Ibid.

are oysters and other bivalves, some cephalopods, and occasional echinoderms, fish material, and annelids.

***Tokio Formation** (Kto)*
Age: Late Cretaceous Period
Composed of a basal gravel overlain by coarse sand that is interbedded with light- to dark-colored clays. Some beds of calcareous or ferruginous sandstone are present. This gravel may be cemented by iron oxides in places to form a conglomerate. The sands are brown to gray and generally cross-bedded. The dark-gray clay is pyritic and contains plant imprints. Fossils from the Tokio Formation include bivalves, gastropods, plant material, and a few vertebrate remains.

***Ozan Formation** (Ko)*
Age: Late Cretaceous Period
Consists of tan, sandy, micaceous marl with a basal lentil of sandy marl and marly sand. The basal lentil, known as the Buckrange Sand, is highly glauconitic and contains shark teeth and phosphatic nodules. Another glauconitic interval is sometimes present about 55 feet above the base of the Ozan. Near the top of the formation, the marls become more chalky. An occasional bed of hard limestone occurs in some outcrops near the top of the unit. Some of the Ozan Formation marls are highly fossiliferous, commonly containing bivalves (mostly oysters), cephalopods, gastropods, echinoderms, corals, crustaceans, fish material, and annelids.

***Marlbrook Marl** (Km)*
Age: Late Cretaceous Period
Uniform, chalky marl that is blue-gray when freshly exposed, and white to light-brown when weathered. This unit is moderately fossiliferous in its upper part, in contrast to the lower part where fossils are few. Common fossils include Exogyra, Gryphaea, and Ostrea oyster species and reptile remains.

***Saratoga Chalk** (Ks)*
Age: Late Cretaceous Period
Consists of fossiliferous, hard, sandy, somewhat glauconitic chalk with some beds of marly chalk and chalky sand. It weathers white, light gray and light brown, and is blue-gray when freshly exposed. The common fossils found in the unit include sponges, bryozoa, echinodermata, annelids, bivalves, gastropods, cephalopods, crustaceans, and fish teeth.

***Nacatoch Sand** (Kn)*
Age: Late Cretaceous Period

Composed of cross-bedded, yellowish and gray fine quartz sand; hard, fossiliferous sandy limestone; coarse, highly glauconitic sand; fine-grained, argillaceous blue-black sand; bedded light-gray clay and marl. The sands in the Nacatoch are generally unconsolidated. At the base of the unit hard, fossiliferous limestones and marl are present. Near the middle of the unit, a coarse, highly glauconitic lens exists. On outcrop, this lens appears almost black in places. Thin-bedded gray clay is present interbedded with fine sands close to the top of the unit. Fossils in the Nacatoch Sand include corals, echinoderms, bryozoa, annelids, bivalves, gastropods, cephalopods, crab remains, and some shark teeth.

***Arkadelphia Marl** (Kad)*
Age: Late Cretaceous Period
Mostly a dark-gray to black marl or marly clay with some limy, gray sandstone, gray sandy clay, sandy limestone, concretionary limestone, and white to light-brown impure chalk. The sandy marls and limestones are at or near the base of the unit, while the impure chalks are present in the upper part of the formation. The fossil fauna includes corals, bivalves, gastropods, cephalopods, shark teeth, and various microfossils.

***Midway Group** (Tm)*
Age: Tertiary Period, Paleocene Epoch
Sequence exposed in Arkansas represents a marginal marine depositional environment. The lithologies include calcareous shale, arenaceous limestone, calcareous glauconitic sandstone, conglomerate, and light to very dark bluish-gray clay shale. The fossils of the Midway Group include a rich fauna of bivalves, gastropods, foraminifera, and ostracods with bryozoa, brachiopods, echinoids, crabs, fish, and crocodile teeth fossils also present.

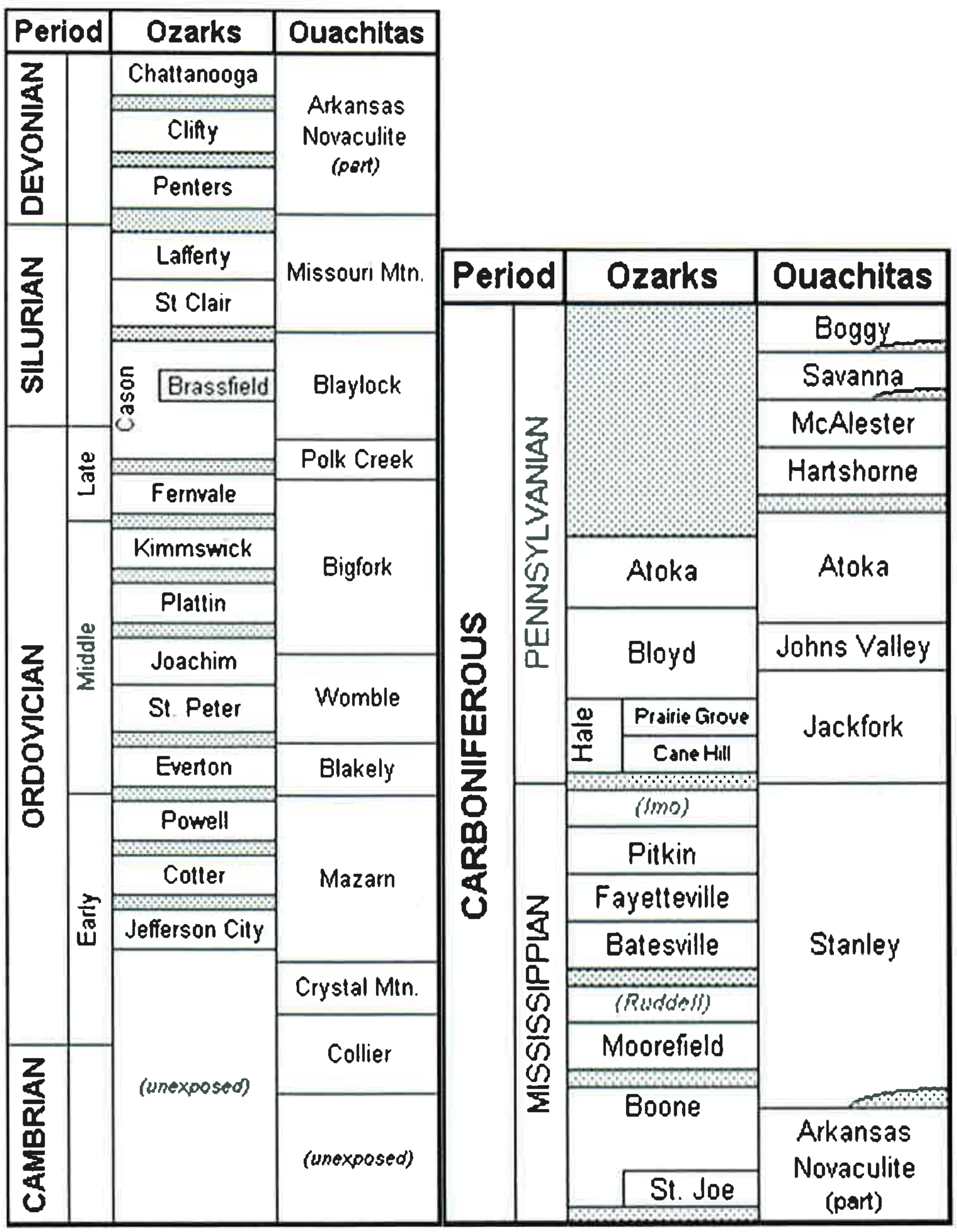
***Wilcox Group** (Tw)*
Age: Tertiary Period, Eocene Epoch
A thick series of non-marine sands, silty sands, clays, and gravels with some thick deposits of lignite. The sands are generally fine- to very fine-grained and light-gray when fresh. The clays are light-gray or brown and often sandy or silty. Frequently, either lithology will be dark brown to black when enough carbonaceous material is included. The lignites occur throughout the sequence, controlled by depositional environment rather than stratigraphic position. Plant remains and trace fossils, associated with the lignites and lignitic clays, are the most common fossils present.

***Terrace Deposits** (Qt)*
Age: Quaternary Period, Pleistocene Epoch
Include a complex sequence of unconsolidated gravels, sandy gravels, sands, silty sands, silts, clayey silts, and clays. The individual deposits are often lenticular

and discontinuous. At least three terrace levels are recognized with the lowest being the youngest. Fossils are rare.

***Alluvium** (Qa1)*
Age: Quaternary Period, Holocene Epoch
Consist of alluvial sediments of present streams and include gravels, sands, silts, clays, and mixtures of any and all of these. Fossils are rare and modern.

The stratigraphic columns in Figure 15 show the time and duration of the various formations.[30]



30 Hanson, Geology lecture, 2018.

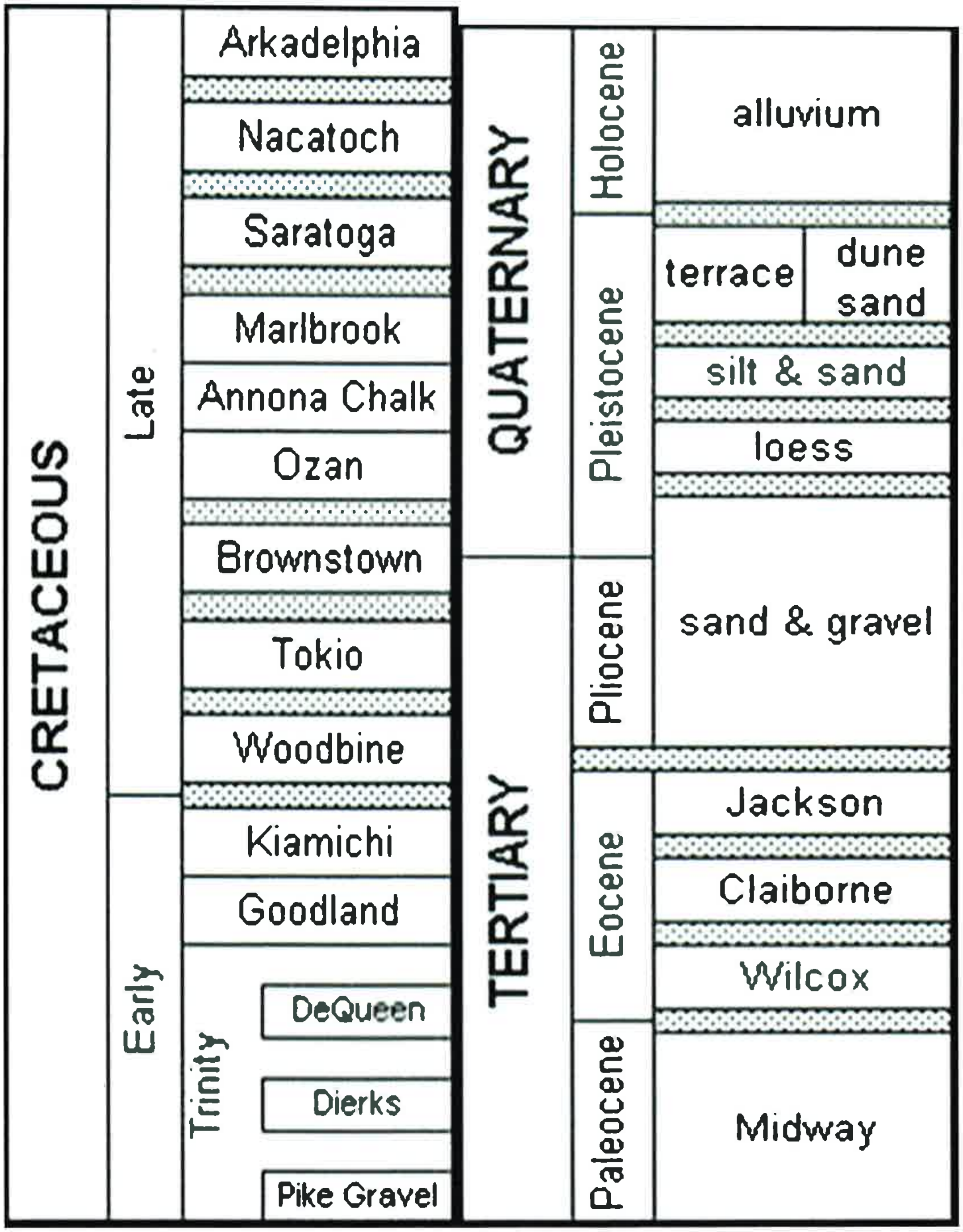


Figure 15: Arkansas Stratigraphic Columns.
Courtesy of the Arkansas Geological Survey

What would it take to return the Gulf Coast shore to Clark County, as it was in the Cretaceous Period? (Figure 16) If all of the polar ice were to melt, sea level is projected to rise 215-230 feet.[31] That rise would bring the waters back to the

[31] "What the World Would Look Like if All the Ice Melted," National Geographic Magazine, accessed September 18, 2018, https://www.nationalgeographic.com/magazine/2013/09/rising-seas-ice-melt-new-shoreline-maps/.

Coastal Plain level of the Cretaceous Period. Arkadelphia would once again be at the coast.[32] Gurdon would be an Arkansas Venice. Stay tuned.

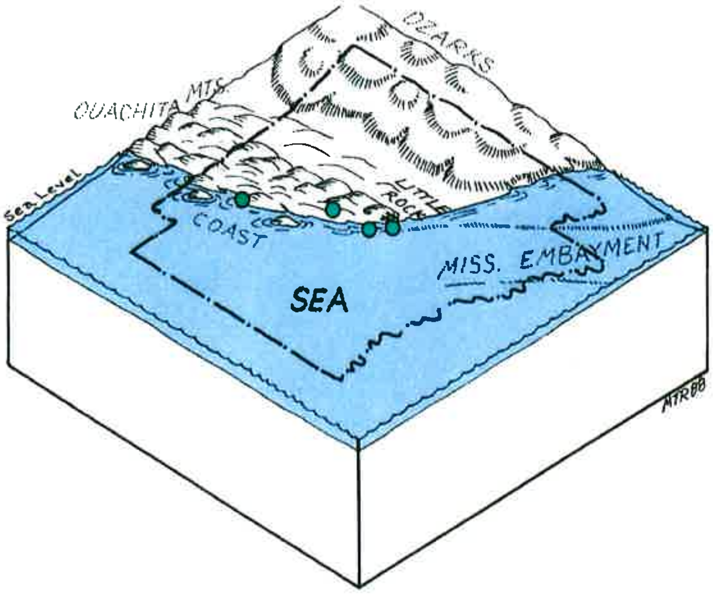
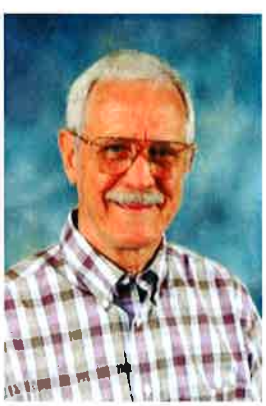


Figure 16: Sea coast in Arkansas during the Cretaceous Period.
Courtesy of the Arkansas Geological Survey

Acknowledgement
The author wishes to thank Mr. Doug Hanson, Arkansas Geological Survey, and Dr. Joe Nix, Emeritus Professor of Chemistry, Ouachita Baptist University, for expert advice. The onus for any errors is on the author.



Joe Jeffers, professor emeritus of chemistry at Ouachita Baptist University, holds a Ph.D. in biochemistry and molecular biology from Purdue University. He retired from his role as Ouachita's Charles S. and Elma Grey Goodwin Holt Professor of Chemistry and Pre-Medical Studies in spring 2017. He taught at Ouachita since 1972. He was thrice named Professor of the Year by the Central Arkansas Section of the American Chemical Society.

[32] "Elevation of Clark County, AR, USA," Worldwide Elevation Map Finder, accessed September 18, 2018, https://www.nationalgeographic.com/magazine/2013/09/rising-seas-ice-melt-new-shoreline-maps/.