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Geology of Nacogdoches, Texas: Texas Academy of Science March 1, 2020

R. LaRell Nielson
Geology Department,Stephen F Austin State University, rnielson@sfasu.edu

Mike Read
Geology Department,Stephen F Austin State University

Mindy Faulkner
Geology Department,Stephen F Austin State University

Hannah C. Chambers
Geology Department,Stephen F Austin State University

Jessica O'Neal
Geology Department,Stephen F Austin State University

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Pruitt Hill, Nacogdoches, Texas1984

Texas Academy of Science
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Trip Leaders
Dr. R. LaRell Nielson
Dr. Mike T. Read
Dr. Mindy Faulkner
Hannah C. Chambers
Jessica O'Neall

Department of Geology
Stephen F. Austin State University
Nacogdoches, Texas

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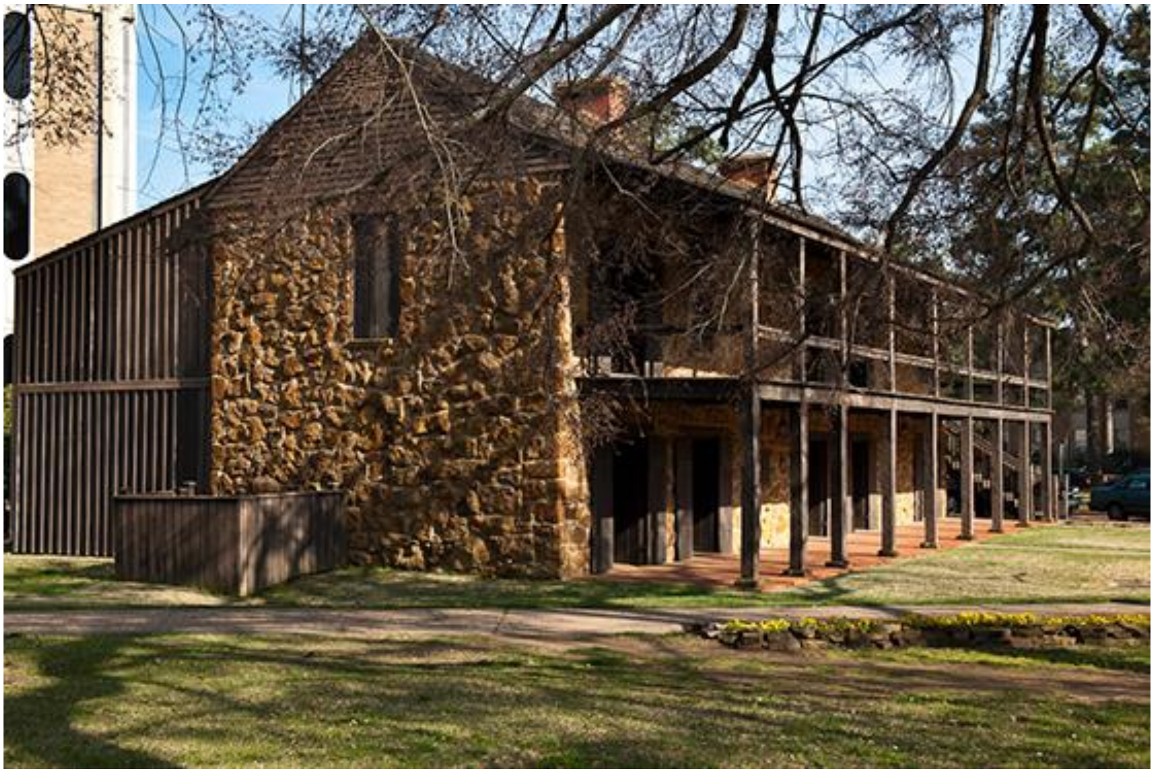
Geology of Nacogdoches, Texas



Old Stone Fort, 2020

Texas Academy of Science
March 1, 2020

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Jessica O’Neall

Geology Department
Stephen F. Austin State University
Nacogdoches, Texas

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Meeting Location for the Texas Academy of Science Field Trip (GPS: 31.619305 N, -94.649086 W)

The 2020 Texas Academy of Science Geology field trip will assemble in front of the Old Stone Fort (southwest corner of the Miller Science Building) at 7:45 AM and leave at 8 AM. The trip will end at approximately 1 PM so participants will have time to return home. The locations of the eight field trip stops are shown on the maps below (Figures 1 and 2).

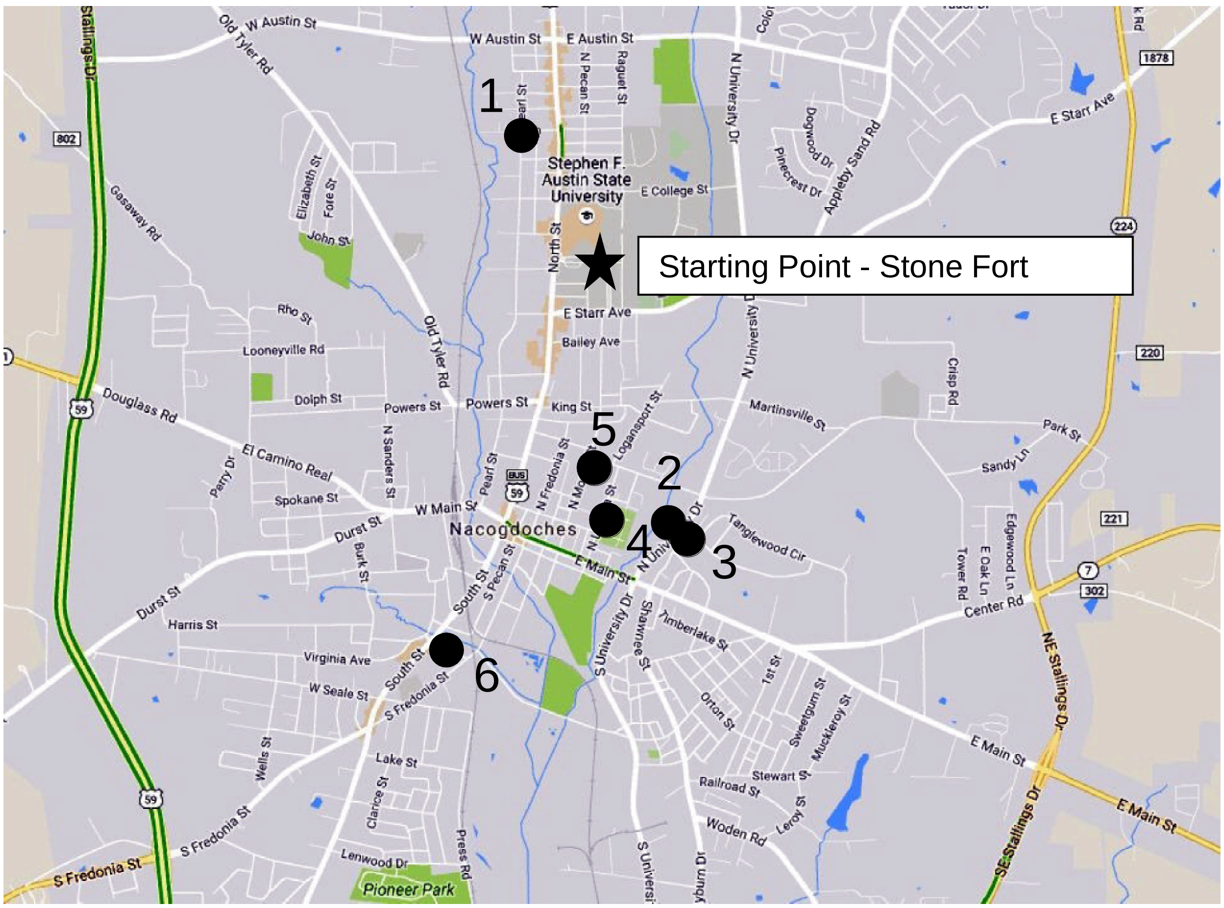

Figure 1: Index map to stops 1 through 6.

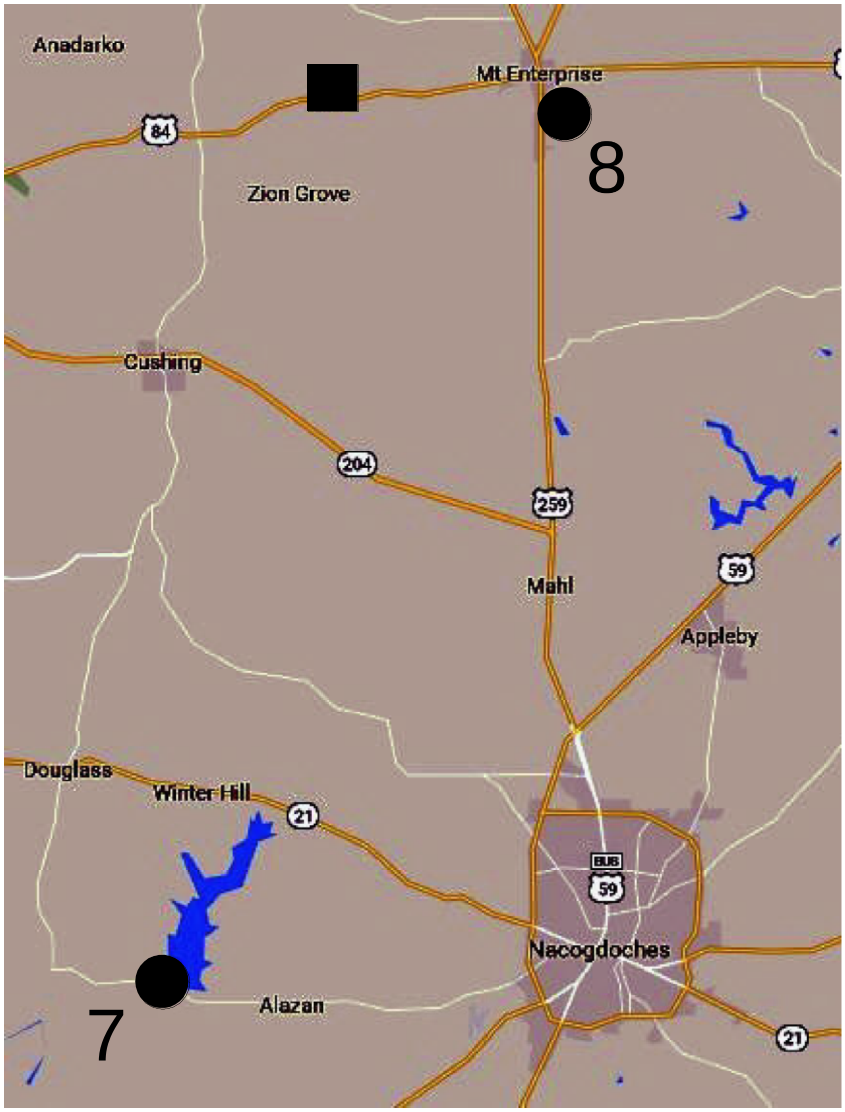

Figure 2: Index map showing the location of stops 7 through 8.

Geology of Nacogdoches, TX
Introduction

East Texas and Nacogdoches in particular is a geological interesting place to have the Texas Academy of Science meeting in 2020. We are located on the Sabine Uplift with a major oil-producing province to the northwest known as the East Texas (Salt Dome) Basin (Figures 3 and 4). The first producing oil well in Texas was drilled near Woden (approximately 12 miles southeast of Nacogdoches) and produces from the Sparta and Queen City sandstones. Three principal depositional systems have been recognized in the Sparta Sandstone of Texas. They are: a constructive delta system in east Texas; strand plain-barrier bar system in central Texas; and a destructive, wave-dominated delta system in south Texas. This shoreline complex was deposited 42-49 Ma (55-50 Ma have also been used). The Weches Formation ("Weches Shale") was deposited on a shallow marine shelf and consists of fine-grained sedimentary rocks that contain fossils and fecal pellets and outcrops in the valleys and low areas around Nacogdoches. Most of the hills in Nacogdoches are capped with the Sparta Sandstone that does not contain fossils. The Sparta Sandstone was deposited as beach sands in association with a wave-dominated delta. In our area, we have the Mt. Enterprise fault system that in recent years has had a number of earthquakes associated with it of a magnitudes as high as 4.8 on the Richter scale (Frohlich, et al., 2014), (Figures 3, 4, 5, 6 and 7).).

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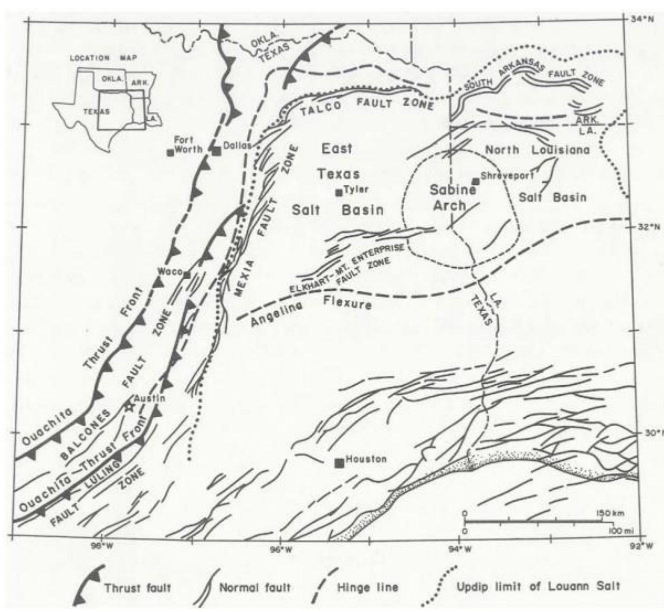

Figure 3: Map of the major faults and structural features in East Texas (Wood 1981).

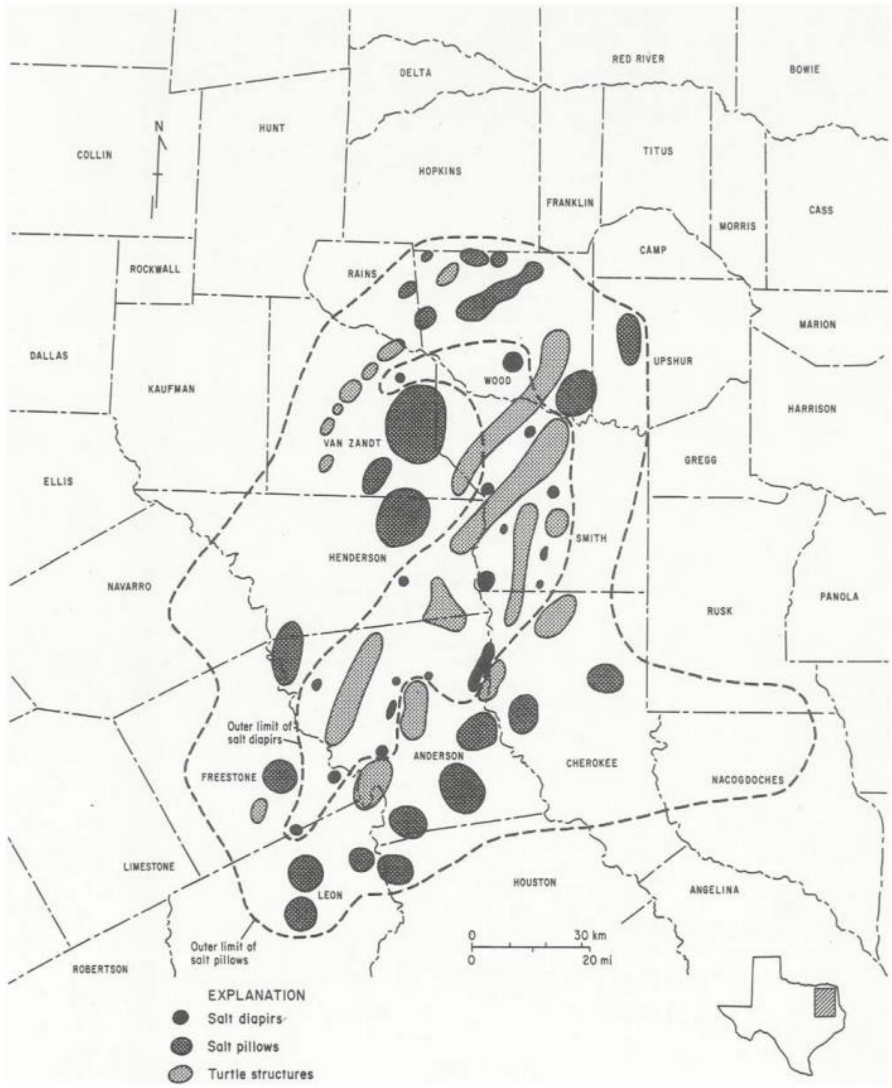

Figure 4. Map of the East Texas salt-diapir and salt-pillow provinces based on borehole and gravity data. Bulge to the southwest in Nacogdoches and Rusk Counties contains numerous small pillows not shown on map. Adapted from Wood (1981).

Figure 4: Map showing the location of the salt domes in the East Texas (Salt Dome) Basin (Wood 1981).

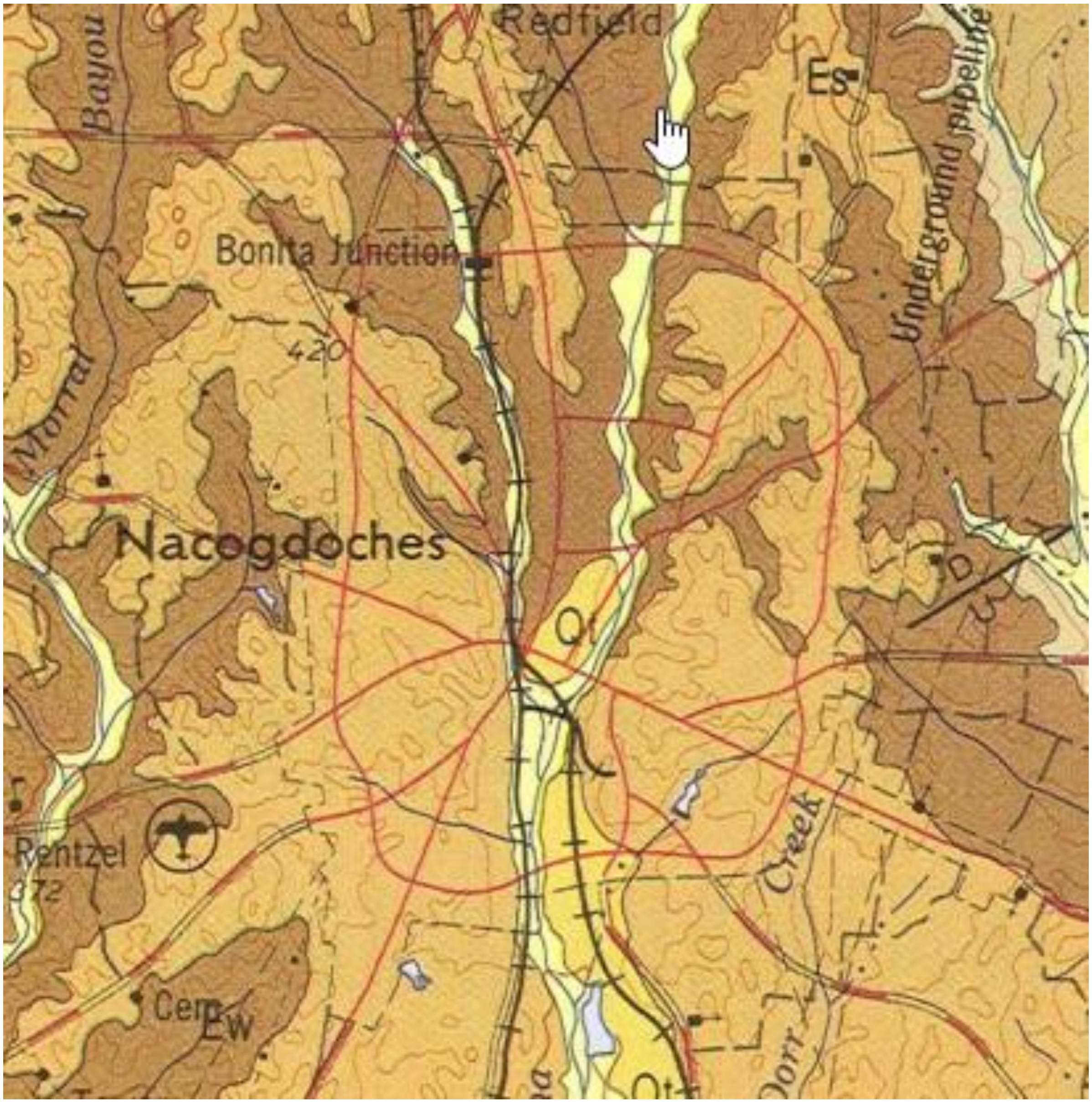

Figure 5: Geologic map of the Nacogdoches, Texas area taken from the Palestine Sheet of the Geologic Atlas of Texas (1993). Stratigraphic units are: Weches Formation – Ew, Sparta Sandstone - Es and Quaternary Alluvium - Qt (www.twdb.texas.gov/groundwater/aquifer/GAT).

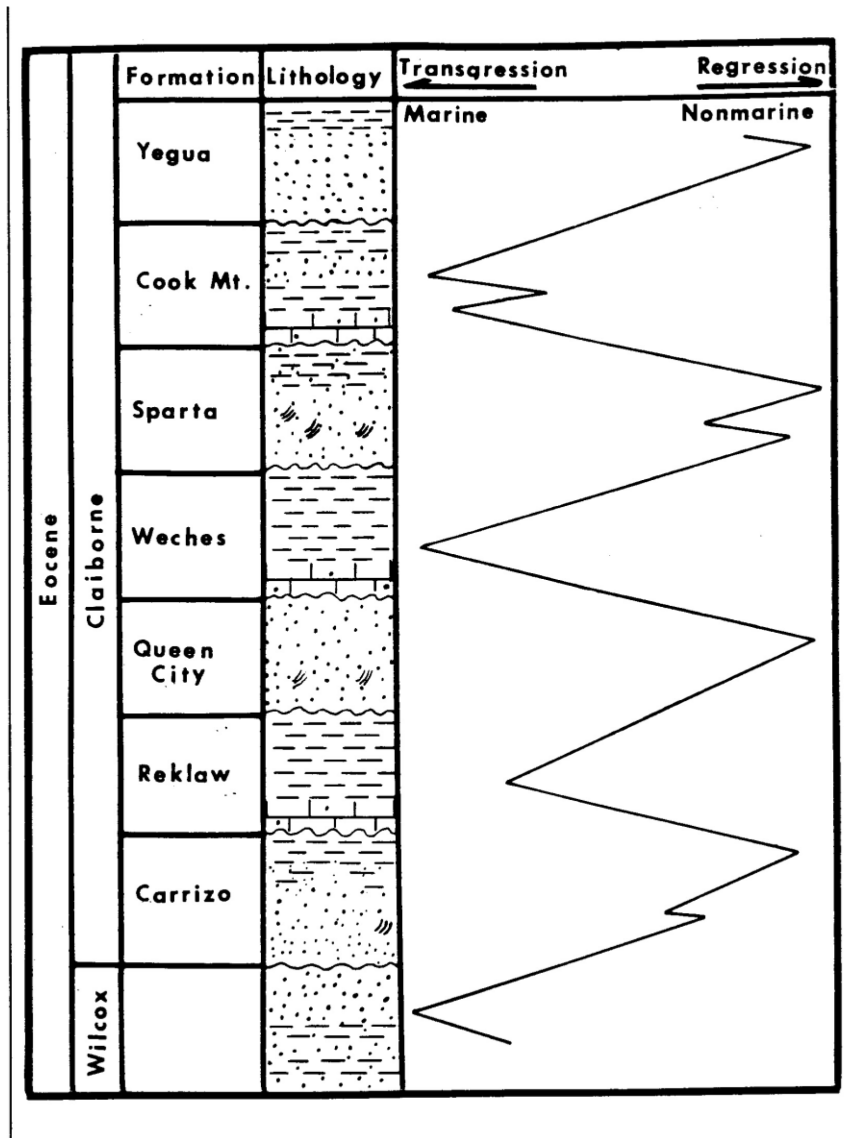

Figure 6: Generalize stratigraphic column for East Texas from Sartin and Brooks (1977). Note where in the stratigraphic section the Weches Formation and Sparta Sandstone are located. They are the principle formations that outcrop in the Nacogdoches area.

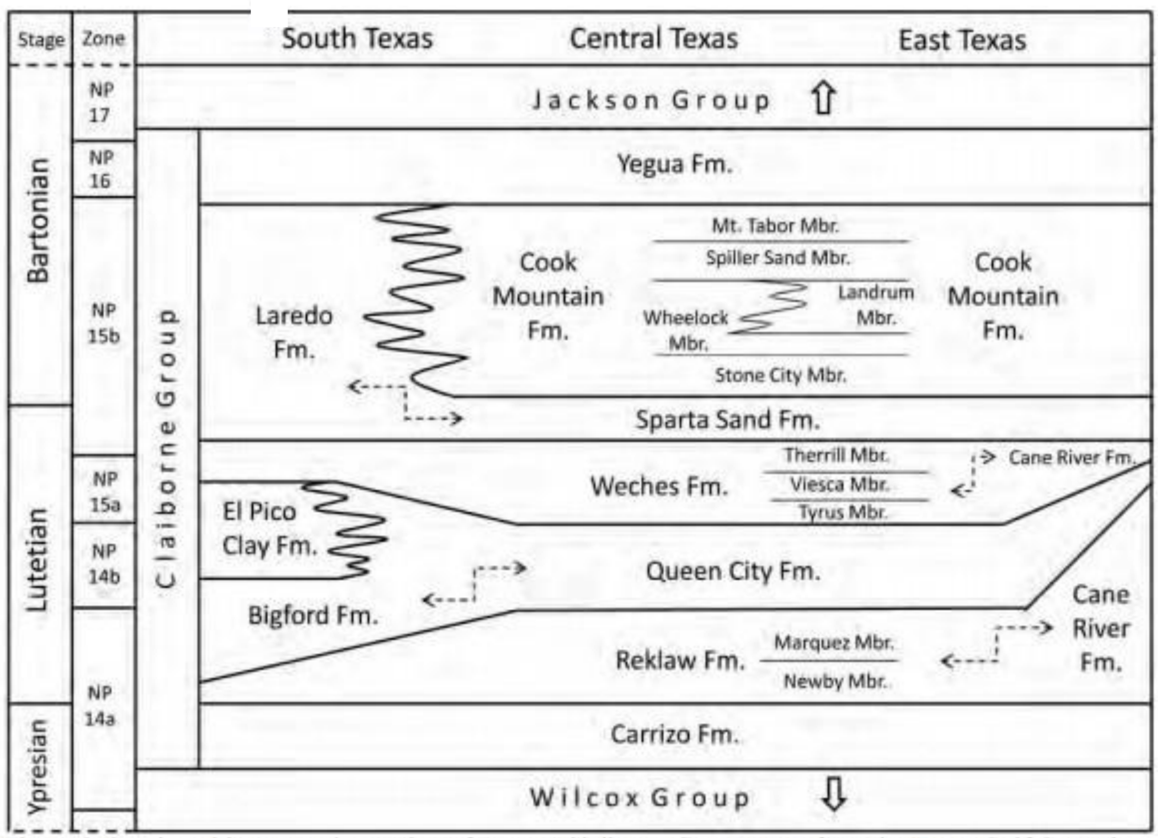

Figure 8. Stratigraphic composite section of Eocene Claiborne Group strata from the Texas Gulf Coastal Plain, illustrating European stages, nannoplankton zones, formations, members, and other Eocene Groups. Poorly defined stratigraphic transitional zones are indicated as dotted double arrows (from Garvie, 2013).

Figure 7: Idealized stratigraphic cross-section across East Texas (Garvie 2013).

Nacogdoches Oil Field (Location: 31.4724061°N, -94.4677056°W)

Although a lesser-known oil field, the rich history of the Nacogdoches Oil Field spans more than a century. The first oil discovery in this field was likely made by the local Native Americans who found oil in pools near present-day Oil Springs, Texas. There were various uses for the oil including medicinal applications and water proofing of canoes. Later, Spanish settlers with Antonio Gil Y'Barbo in 1779 used the oil found in Nacogdoches County as a lubricant for their wagon wheels and other various purposes (Chamberlain, 1968). The person who discovered the Nacogdoches Oil Field was Lyne T. Barret (1832-1913). Born in Appomattox, Virginia. Barret moved to San Augustine County, Texas along with his family in the early 1840's. Shortly after beginning his career as a partner in the Hardman Brothers and Barret Mercantile Company, Barret became interested in petroleum exploration. In December of 1859 he leased 279 acres of land near the town of Oil Springs, Texas which had become known for its oil seeps. With the onset of the Civil War his efforts came to a halt (Devereaux, 2010).

In the months following end of the Civil War, Barret along with several other partners organized the Melrose Petroleum Company in December of 1865. The following summer, the Melrose Petroleum Company began drilling the No. 1 Isaac C. Skillern well. At the time, cable tool techniques were the preferred drilling methods of Pennsylvanian drillers. Barret instead used an auger measuring eight feet long, and eight inches wide attached to a pipe that was rotated by a wheel driven by cogs from a drive shaft on a steam engine. On September 12, 1866, at a depth of 106 feet the Melrose Petroleum Company completed the first successful oil well in the Nacogdoches Oil Field (First, 2019). Barret most likely drilled into the Queen City Formation (Aniekwensi, 2010). This oil discovery was most significant because it was also the first successful oil well drilled in the state of Texas. Due to the unrest brought about by reconstruction that followed the Civil War, nearly two decades would pass before the Nacogdoches Oil Field would see any substantial development (First, 2019).

By the late 1880's prospectors and small petroleum companies returned to the Nacogdoches Oil Field and began operations. Edgar Farrar and William H. Wilson's Petroleum Prospecting Company of New Orleans, Louisiana began operating in the Oil Springs area. Farrar and Wilson employed Pennsylvanian drillers who used cable tool drilling methods. After they had drilled to 180 feet approximately 250 to 300 barrels of oil flowed out of the well. Between 1887 and 1890, they drilled forty wells with thirty of them bearing oil. In 1890 the Petroleum Prospecting Company's two 1000 barrel iron tanks were filled to capacity (Dumble, 1890). Other operators drilling in the Nacogdoches Oil Field at the time. They included Lubricating Oil Company of New Orleans, the Pennsylvania Oil and Mineral Development Company, and the Southwestern Petroleum and Mineral Developing Company (Warner, 2007).

In 1920, a 150 barrel refinery was completed in Nacogdoches and operated by the Yuba Oil Company. However, it was in operation for only a short period of time before it shut down. The Nagdo Oil Company dug a 6x7 foot well at a depth of 115 feet in the Nacogdoches Oil Field in 1935. Approximately fifteen barrels of oil were produced each day during the excavation of the well. Upon completion of the shaft, it was pumped using tubing along with an automobile engine. Due to the vast quantities of water produced, the well was soon abandoned. H. M. Prince dug a similar well in the same year, but found little oil. As a result, the well was soon abandoned (Youngmeyer, 1950). As other, more productive, oil fields were developed in the early 1900's, production in the Nacogdoches Oil Field began to decline. By the early 1950's, operators returned to the area and began producing gas. As of August 2019 more than 1,000 wells have been drilled in the Nacogdoches Oil Field (Enverus, 2019) (Figures 8, 9 and 10)

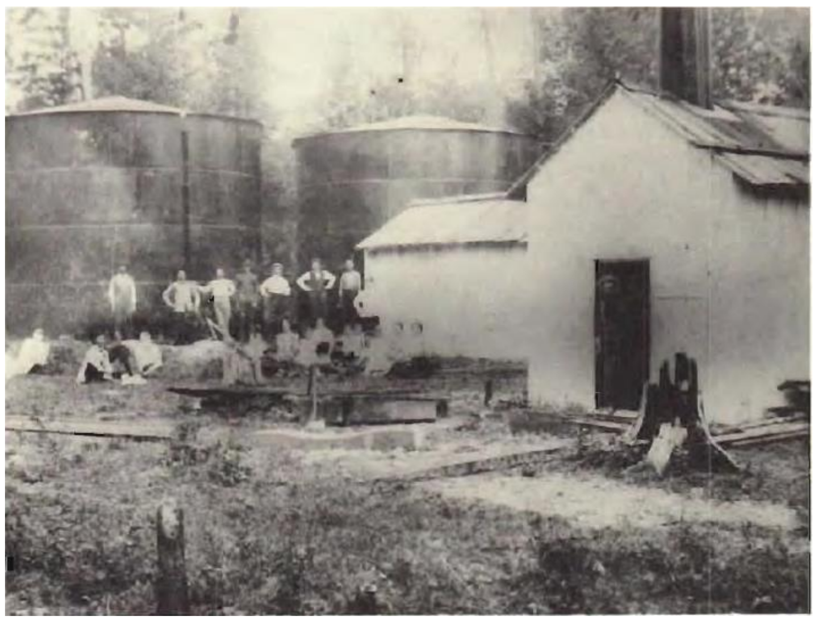

Figure 8: Image of the storage and oil refining equipment at Oil Spring, Texas.

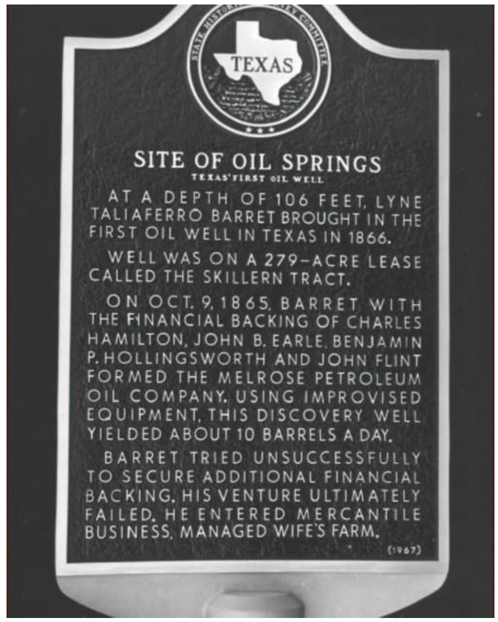

Figure 9: Oil Springs Marker showing the location of the first oil well in Texas.

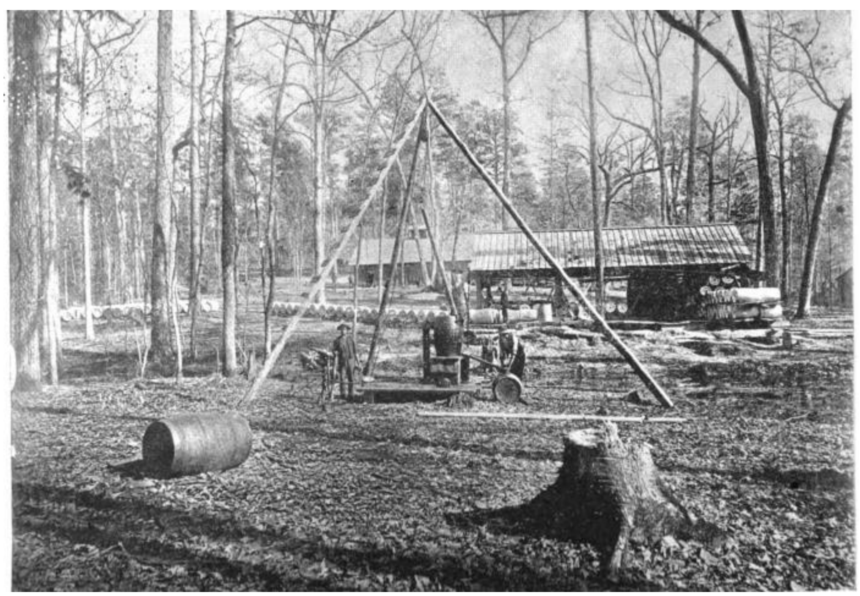

Figure 10: Image of the drilling equipment used in the Nacogdoches Oil Field.

Old Stone Fort

As we assemble for the field trip we are going to walk over to the Old Stone Fort that is one of the earliest buildings in Nacogdoches. It was originally constructed on the square in downtown Nacogdoches where Regions Bank is currently located. Before the construction of the bank the Stone Fort was disassembled and reassembled at its current location on the Stephen F. Austin State University campus.

The building stones that makes up the walls of the Old Stone Fort were quarried locally from fossiliferous, iron-rich mudstone (shale) units of the Weches Formation. We are going to examine these building stones in the walls. Many of these blocks contain pellets, bivalves and gastropods (Figure 11 and title page).

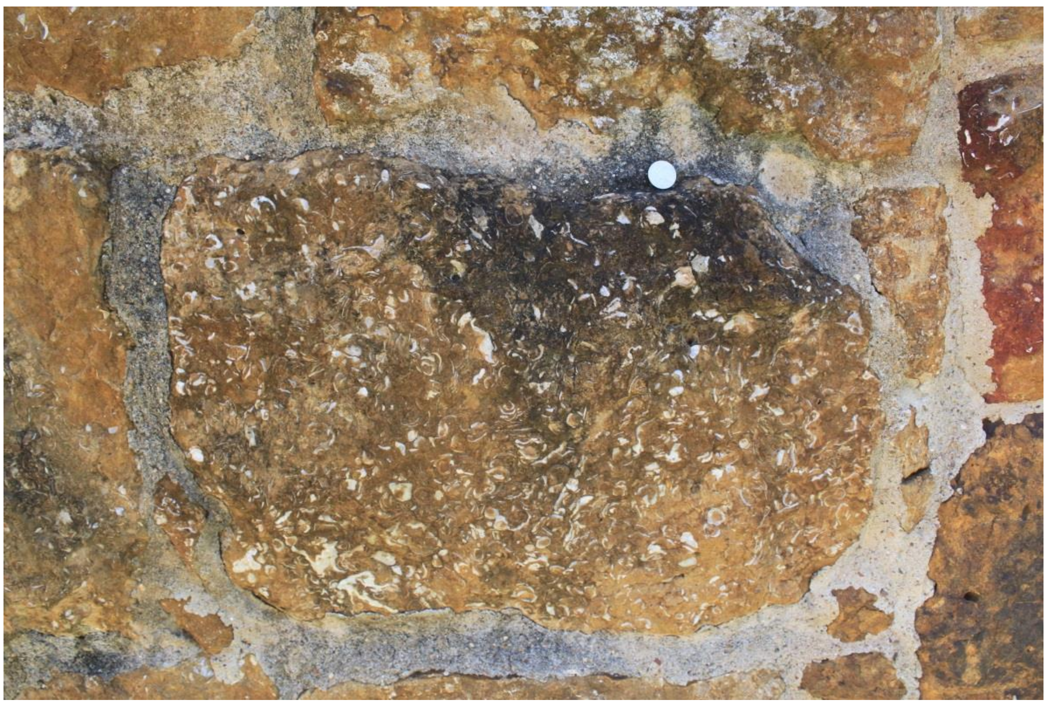

Figure 11: Fossils present in the fossiliferous iron-rich mudstone (shale) from the Weches Formation found in the walls of the Old Stone Fort. This rock was quarried locally and used in many of the older buildings in Nacogdoches.

Ginkgo (Maidenhair) Tree
Ginkgo biloba

In front of the Miller Science building is a Ginkgo tree (*Ginkgo biloba)* that was planted forty years ago by the Biology and Geology Departments. Ginkgo as a species were thought to be extinct before being found in China and reintroduced throughout the world. Ginkgoales, or Ginkgophyte, is a gymnosperm order containing only one species: *Ginkgo biloba*, the ginkgo tree. Ginkgoales includes five families, of which only the Ginkgoaceae remains. The order is monotypic, meaning it only includes the one taxon. The first *Ginkgo* leaves were found in rocks of the Permian age. The group diversified during the Jurassic and Cretaceous. They started to decline during the Late Cretaceous, and the decline continued to the Pliocene Epoch. The Ginkgo was abundant in Europe at the start of the Pliocene, but it was gone from that region by about 2.5 million years ago. There are no Ginkgo fossils known from the Pleistocene Epoch.

Although the genus was thought to be extinct, *G*. *biloba* survived in China until recent times. The surviving trees were mainly found to occur in courtyard of Buddhist monasteries in the mountains. The Ginkgo was reintroduced throughout Asia by approximately 1100 AD. It was first planted in Europe during the early 1700's and in America shortly thereafter.

The foliage of the Ginkgo has remained relatively unchanged since the Mesozoic Era. Fossilized Ginkgo wood is uncommon in the fossil record, as it does not typically preserve well. Additionally, it is often difficult to differentiate fossilized Ginkgo wood from that of the more common conifer trees.

Ginkgo trees reproduce by way of ovulate, pollen-bearing structures. These reproductive structures are dioecious, meaning that individual trees are either male or female. The fruit of the female ginkgo has a very unpleasant in the fall as it deteriorates.

Figure 12: In the fall, Ginkgo trees have a beautiful gold color. Fruiting bodies of the female Ginkgo deteriate in the fall and have an unpleasant odor.

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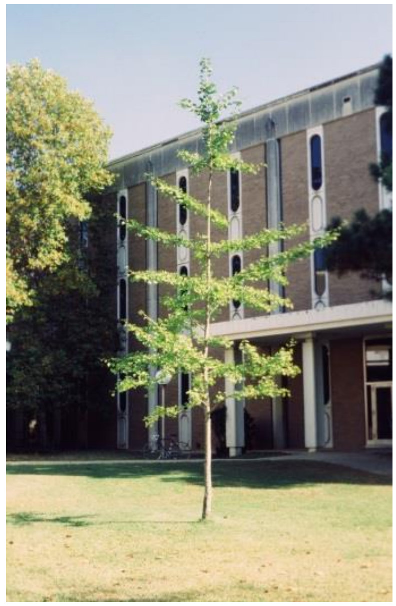

Figure 13. Ginko tree(*Ginkgo biloba*) in front of the Miller Science building as seen in 1983 just after it was planted

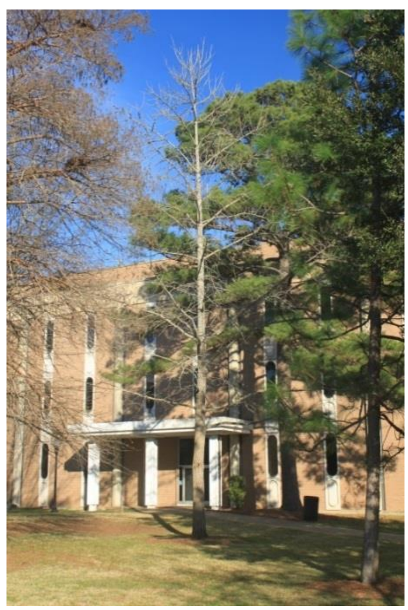

Figure 14: Ginko Tree (*Ginkgo biloba*) as seen today on StephenF. Austin State University campus.

Figure 15: Comparison of leaves from a modern *Ginkgo biloba* (left) and a carbonized early Eocene *G*. *biloba* (right). The fossil *G*. *biloba* specimen is from the lower Eocene (approx. 49 Ma; Ypresian Stage) Klondike Mountain Formation, Ferry County, Washington, U.S.A.

Stop 1:

Bonita Creek flood plain near University Club Apartments (GPS: 31.629167 N, -94.657909 W). Nacogdoches is built on the drainage divide between Bonita and Lanana Creeks. To the southeast, near the center of town Bonita Creek joins Lanana Creek. . During periods of significant rainfall the low areas of Nacogdoches are often flooded. These apartments are built on the flood plain and are regularly flooded. Note the lack of levees or dirt banks along the margin of the stream at this location (Figure 8). Several of the western most University Club Apartments are built on the lower part of the flood plain of Bonita Creek. The lower buildings in the complex are below the yearly flood level of Bonita Creek and are flooded most years (Figure 16, 17, 18 and 19).

Figure 16: Image showing annual flood level on the side of the University Club Apartments.

Figure 17: Image taken from Bonita Creek illustrating the lack of a levee and the relationship between Bonita Creek and the University Club Apartments. The apartments are 30 cm above the top of the stream channel. This allows flooding to occur on a regular basis.

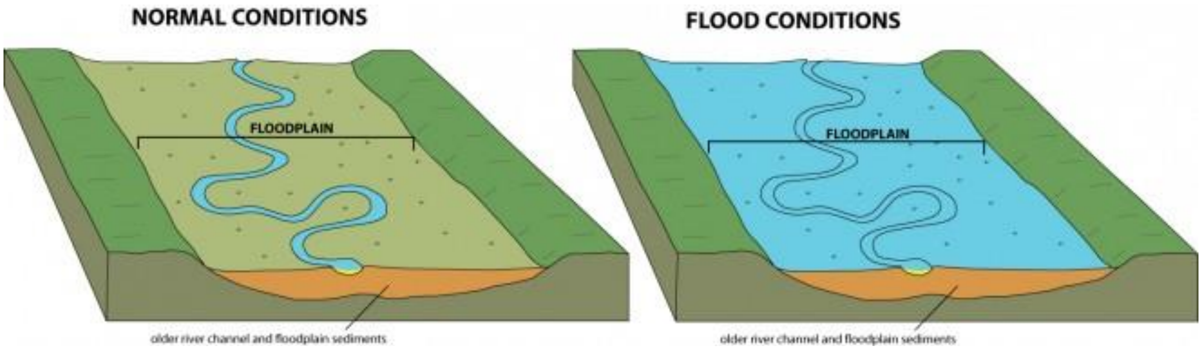

Figure 18: Diagram showing how flood plains work. If you build in this area your buildings will be flooded (https://ethiopiaflooding.wordpress.com/).

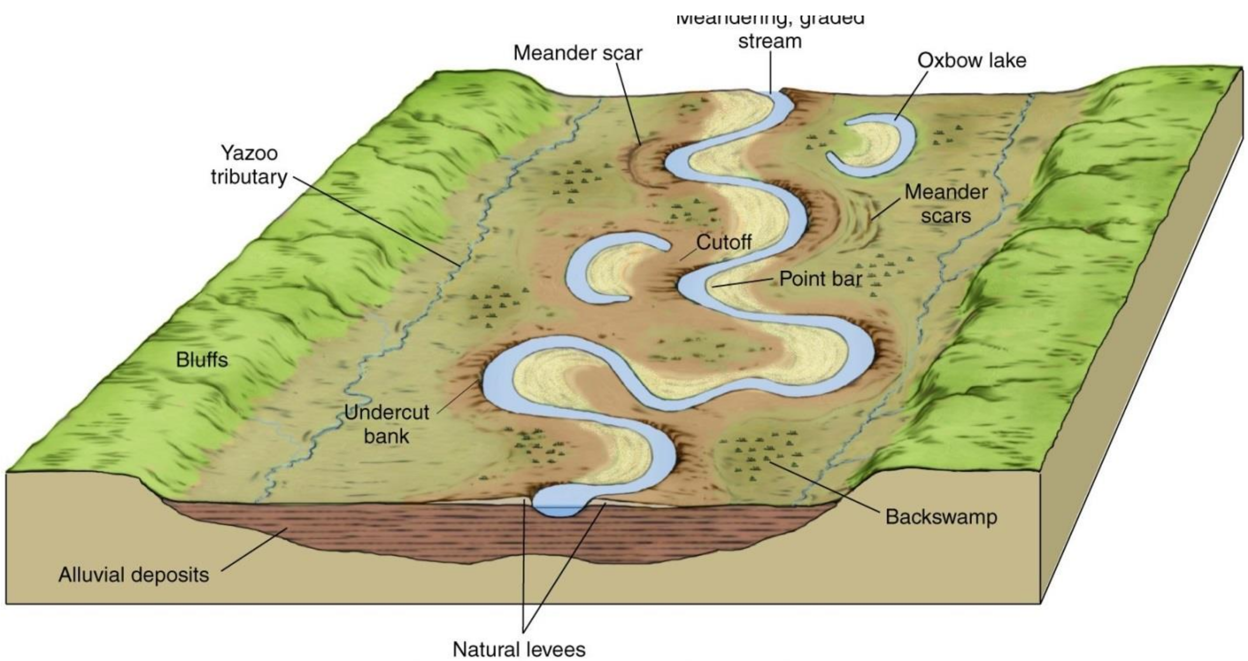

Figure 19: Geologic features found on a flood plain (https://ethiopiaflooding.wordpress.com/).

Stop 2:

Weches Formation (Shale) and slope stability problems at Pruitt Hill behind Wrap-It-Up and ABC Auto Parts (GPS: 31.605561 N, -94.641871 W) (Figure 8 and 9). This stop is located behind Wrap-It-Up at the base of the cliff. Excellent exposures of the Weches Formation make up the cliff behind the businesses on the east side of University Drive. Pellets and broken disarticulated fossils are common in the Weches Formation at this location. These fossils are principally gastropods (snails) and bivalves (clams). To facilitate the commercial development of University Drive, a large amount of the Weches Formation was removed from this area. This has produced a significant geologic hazard by overstepping the slope that resulted in major rock falls and could result in a landslide that would destroy one or several of the Wind Hill Apartments and the businesses below. White pipes have been placed in the Weches Formation to drain the water from the formation to decrease the chance of landsides. Joint sets (fractures where no movement has occurred) are common throughout the outcrop. Several small faults are present in this area (Figure 20, 21, 22, 23, 24 and 25).

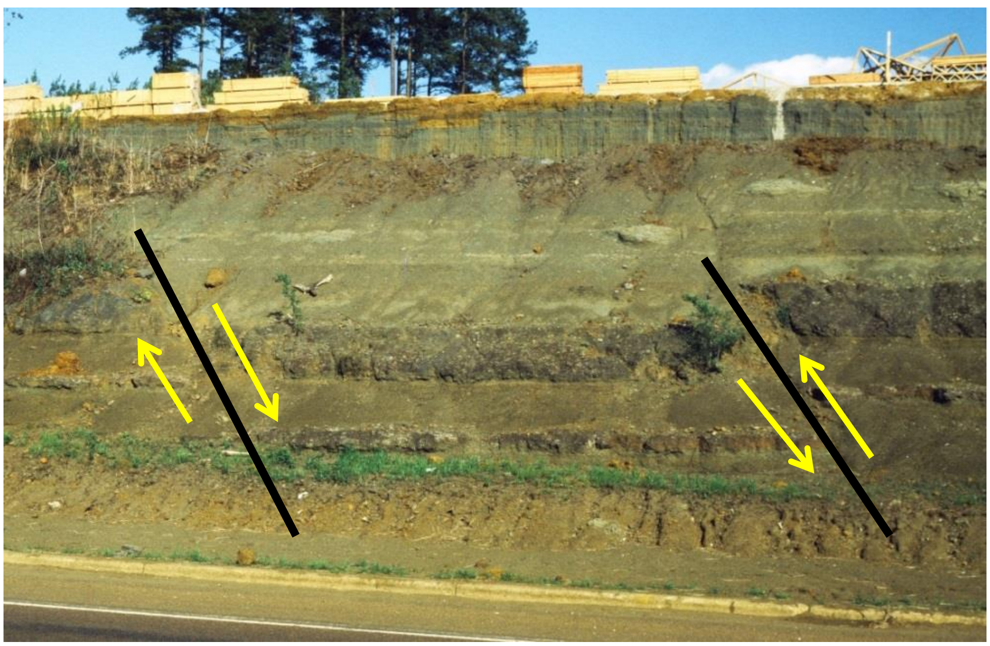

Figure 20: Two small faults that form a graben in the Weches Formation on University Drive as seen in 1984 during the construction of the Wind Hill Apartments.

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Figure 21: Exposures of the Weches Formation behind Wrap-It-Up on University Drive.

Figure 22: Weches Formation behind ABC Auto Parts. Note the iron cemented mudstone beds often referred to as ironstone beds.

Figure 23: Fossils and fossil fragments within the Weches Formation behind ABC Auto Parts Store. Ironstone beds in the Weches Formation contain fossils and weather to form ledges. Similar ledges were quarried for building stone as seen in the Old Stone Fort on the SFA campus. Keys are for scale.

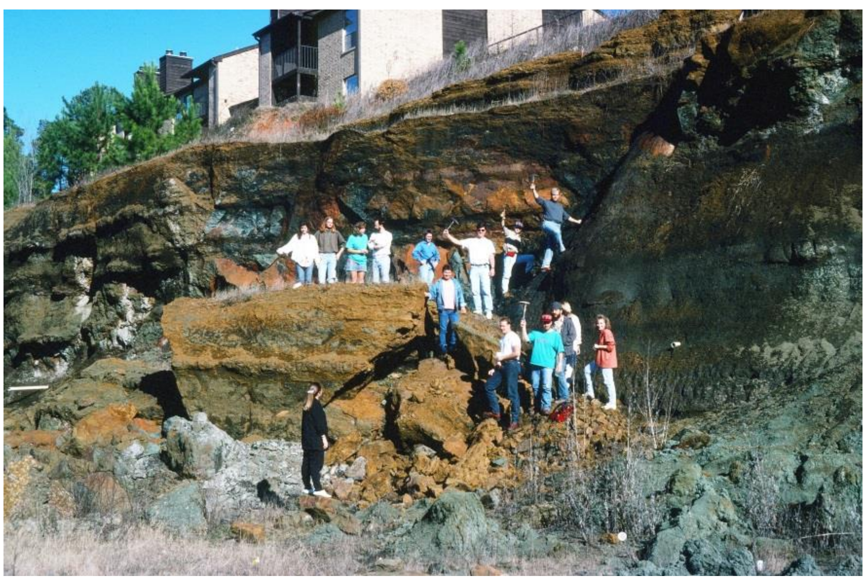
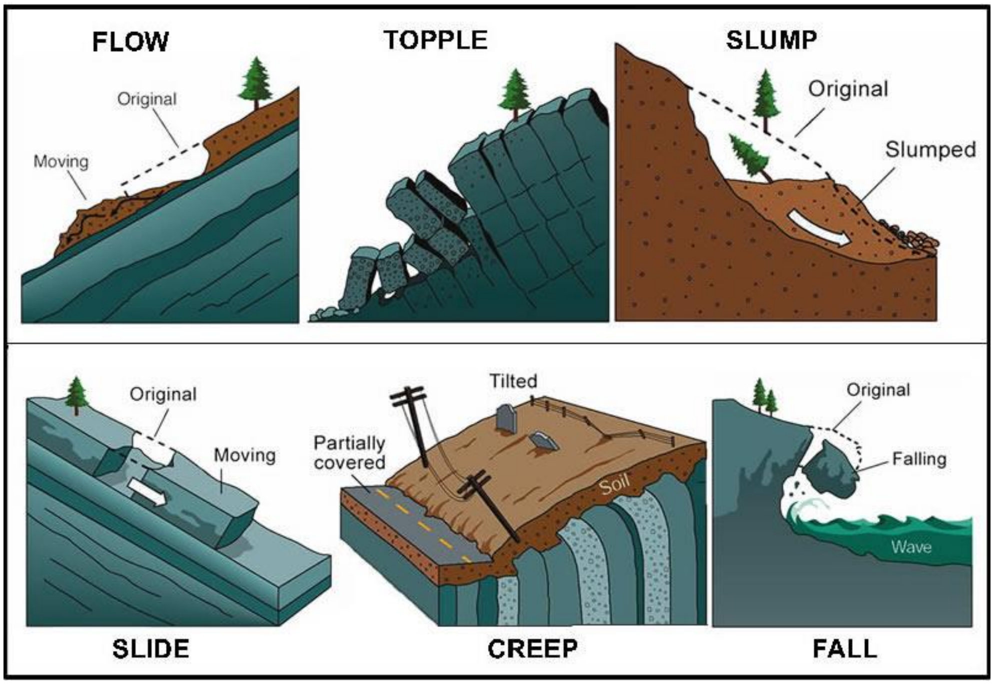


Figure 24: A slump block that developed in October of 1989 caused concern for the business on University Drive and residences of Windhill Apartments. (GPS 31.607589 N, -94.641426 W)

Figure 25: Diagram showing different types of mass wasting (https://www.slideshare.net/wwlittle/natural-disasters-topic-7-drainage-basins-mass-wasting)



Stop 3:

Windhill Apartments (GPS 31.607421 N, -94.640774 W) Proceed to the west parking lot of Windhill Apartments and study the sub-parallel cracks, joints and fractures in the concrete of the parking lot (Figure 26). These indicate that this is an unstable area that could detach and produce a landslide or rock fall. The westernmost apartment building lies very close to the cliff that was generated from the excavation for the business below. The bedrock under this building could easily detach and slump to produce a landslide that would destroy some of the apartment buildings on the hill and businesses below (Figure 9). Note the outcrops of the Sparta Sandstone exposed at the top of the hill near the buildings in the center of the complex (Figures 26 and 27)

Figure 26: Fractures in the concrete showing the beginning of the development of rotational blocks at the top of the cliff. These fractures indicate that movement is occurring behind the cliff.

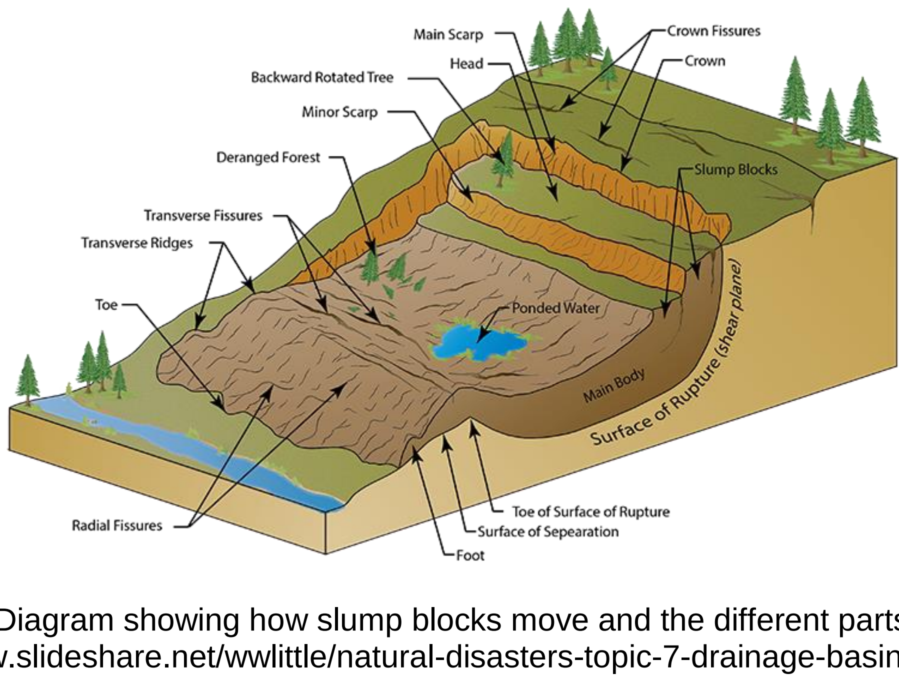


Figure 27: Diagram showing how slump blocks move and the different parts of a slump (https://www.slideshare.net/wwlittle/natural-disasters-topic-7-drainage-basins-mass-wasting).

Stop 4:

Nacogdoches Cemetery (GPS 31.603387 N,-94.649737 W) We are going to walk around and look at how weathering and creep affects the different types of rock used for headstones. This is done by determining with what ease the lettering can be read on the headstone and the condition of the headstone surface. Weathering can be divided into two types: chemical and mechanical. Both types of weathering can be found affecting the headstones (Figures 28 and 29).

Chemical Weathering
- Oxidation
- Hydration
- Carbonization

Mechanical Weathering
- Frost action – ice wedging
- Pressure release
- Thermal expansion and contraction
- Salt crystal growth
- Plant root growth
- Lichens growth

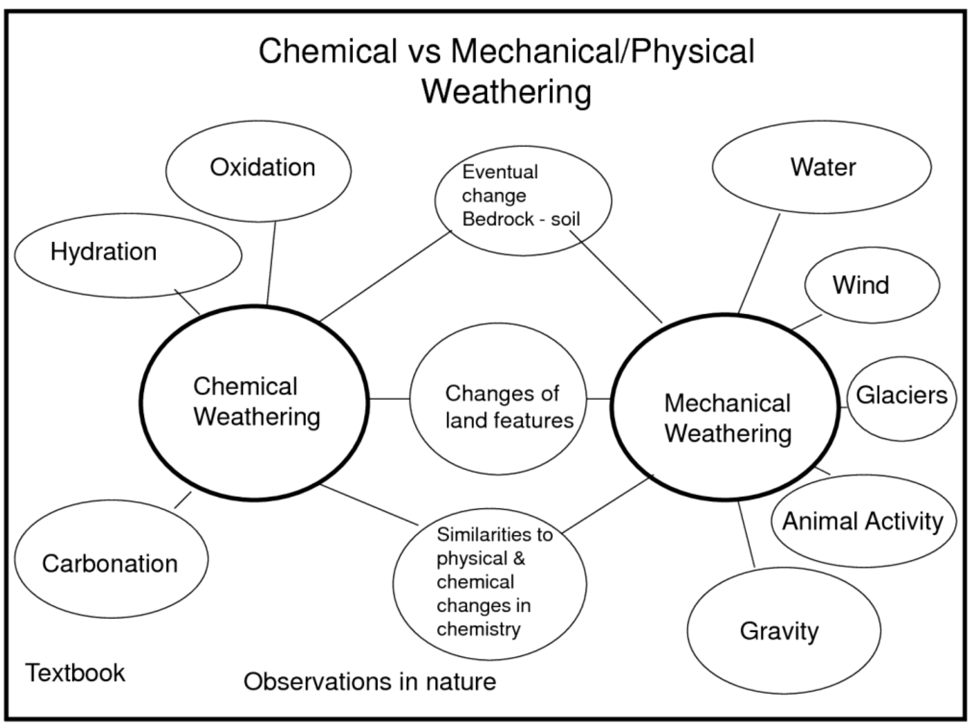


Figure 28: Relation between chemical and mechanical weathering

Figure 29: Mechanical weathering in the form of creep has tilted the headstone on the left and chemical weathering has destroyed the lettering.

Stop 5.

Indian Mound on Mound Street in Nacogdoches, Texas (GPS 31.606615 N, -94.650738 W) Caddo Indians occupied the Nacogdoches area as early as 800 CE, with the Caddo Indians settling along Lanana and Bonita creeks. These names were given to the streams later by Spanish settlers. The Caddoan Mississippian culture sites were composed of a village with a high ceremonial mound in the center and a burial mound in the area. The settlement surrounded the ceremonial mound and contained dwelling mounds where the Indians lived. The village was located on the drainage divide and on an ancient Native American trail later named by the Spanish as El Camino Real de los Tejas. This settlement developed hundreds of years before the arrival of Europeans to the region. Archaeologists believe the site was founded in approximately 800CE, with most major construction taking place between 1100CE and 1300CE. The Caddo Indians lived in huts made of limbs lashed together and covered with grass on low mounds. They gathered the food and materials from the East Texas forests and streams and established elaborate trade relationships with other native cultures (Figures 14, 15 and 16).

Nacogdoches remained a Caddo Indian settlement until 1716. At that time, Domingo Ramon established five religious missions in the area and a military presidio in East Texas, which including Nuestra Senora de Guadalupe de los Nacogdoches del Pilar. This was the first European activity in the area. However, missions were not towns. They were church complexes where people live. The missions struggled until strengthened by the Marques de Aguayo in 1721, but even then, they endured more than prospered. The “town” of Nacogdoches was established after the Spaniards decided that the French were no longer a threat and that maintaining the mission was far too costly. After France gave up its claims to lands west of the Mississippi River to Spain in 1763, Spain’s government required all settlers and priests in East Texas to withdraw to San Antonio. Some of the settlers were eager to escape the wilderness, but others had to be forced from their homes by soldiers (https://en.wikipedia.org/wiki/Caddo).

Mounds found on Mound Street show where the Caddo Indian village was. There are three types of mounds found in the area: living, worship and burial mounds. This area has a number of mounds where the Caddo Indians would have lived (Figures 30, 31, 32, and 33).

Figure 30: Image of one of the mounds that are present on Mound Street for which the street was named. This was likely a living mound.

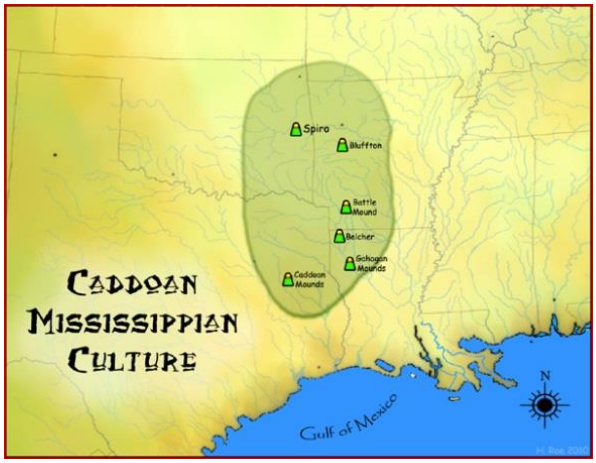


Figure 31: Map showing the extent of Mississippian Caddoan cultural. (https://en.wikipedia.org/wiki/Caddo).

Figure 32: What Nacogdoches would have looked like during the time of the Caddoan times (https://en.wikipedia.org/wiki/Caddo).

Figure 33: Method for constructing a Caddo Indian house.
(https://en.wikipedia.org/wiki/Caddo)

Stop 6:

Outcrop of the Weches Formation and Sparta Sandstone behind Metro PC Communications (GPS 31.596315 N, -94.661502 W) At this location, horizontal beds are seen in the Weches Formation. Poorly cemented Sparta Sandstone forms the upper part of the cliff and is yellow in color. Sand from the Sparta Sandstone has been removed from the quarry at the top of the hill to the east and was used for building material. The Weches Formation was removed at this location to allow the construction of the business here. It contains pellets and fossils (bivalve and gastropods) in an iron cemented mudstone (Figure 34).

Figure 34: Weches Formation and Sparta Sandstone exposures behind Metro PC Communications. The Weches Formation at this location contains pellets and fossils in a mudstone that is cemented by iron oxide to form ledges. It also contains joints (fracture where no movement has occurred) noted by the red arrow. The contact between the Weches Formation and Sparta Sandstone is placed at the top of a tan silty mudstone marked by a yellow line. It is about 1 meter in thickness. On top of the Weches Formation is an orange-yellow cross-bedded sandstone of the Sparta Sandstone. The Sparta Sandstone contains, moderately to well sorted, sub rounded grains.

Stop 7:

Fossil collecting location at the west end of Lake Nacogdoches Dam (GPS: 31.591429 N, -94.835716 W) At Lake Nacogdoches we will walk down the trail that leaves from the west side view area. Excellent exposures of the Weches Formation are present here (Figure 35). The invertebrate fossils that may be found include: coral, gastropods, bivalves and echinoids, all of which are abundant at this location. Many shark teeth have been collected here as well. During dry periods gypsum can be collected on the west side of the boat ramp parking area. Gypsum and iron concretions have been collected between the restroom and the swimming area north and west of the parking lot for the boat ramp (GPS: 31.595295 N, -94.837911 W). Gypsum is produced by water evaporation from the soil during the summer months. Gypsum rhombs and rams horn crystals have been collected (Figures 36, 36. 37. 38, 39, 40, 41, 42, 43, 44 and 45).

Figure 35: Image of the fossil collecting location at Lake Nacogdoches. The most prolific beds are the black shale units above the level of the lake.

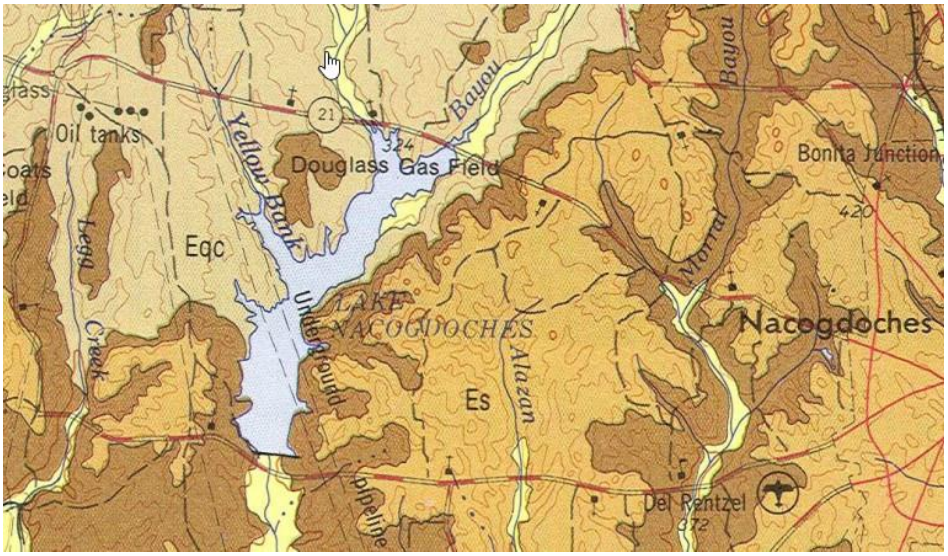


Figure 36: Geologic map of the Lake Nacogdoches. Fossils are collected from the Weches Formation on the west side of the dam. The hills are caped with the Sparta Sandstone. Stratigraphic units include: Eqc – Queen City Sandstone, Weches Formation – Ew and, Sparta Sandstone – Es (www.twdb.texas.gov/groundwater/aquifer/GAT).

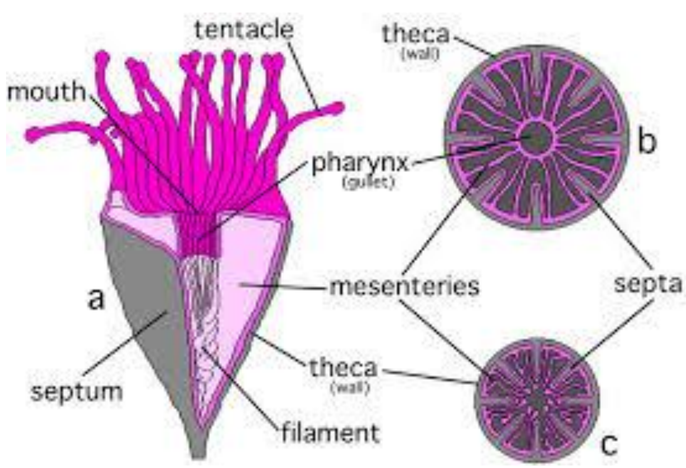


Figure 37: Diagram of a scleractinian horn coral illustrating internal morphology and anatomy.

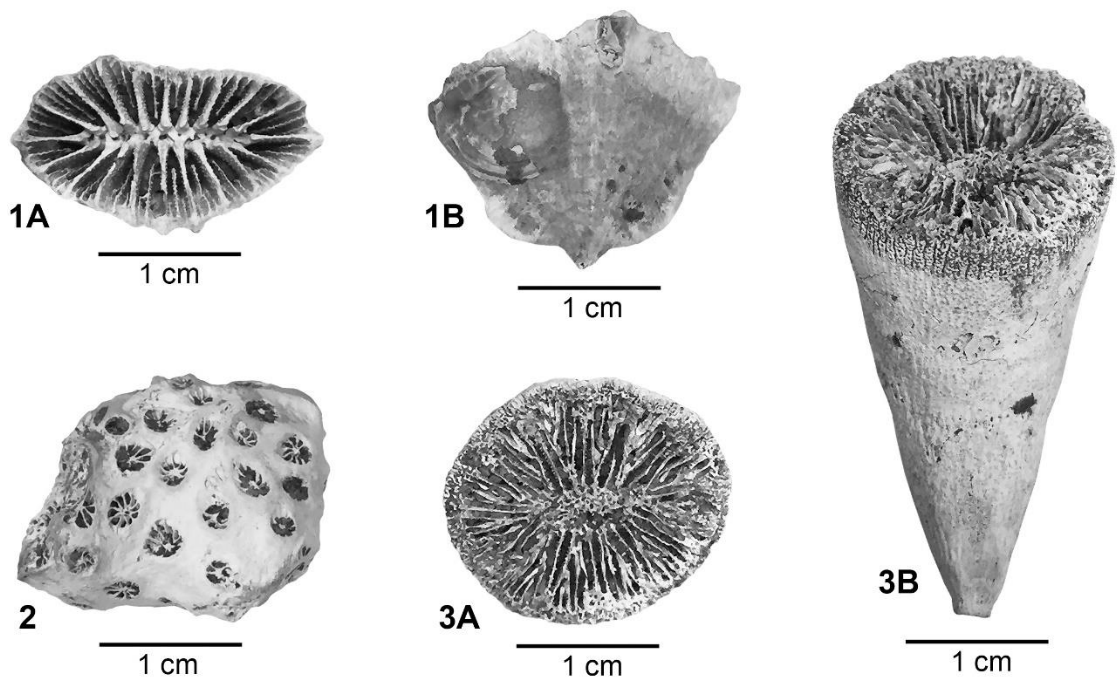


Figure 38: Commonly occurring scleractinian coral specimens known from the Weches Formation; 1 – *Flabellum cuneiforme* Lonsdale, 1845, from the Weches Formation, southern edge of Lake Nacogdoches, Nacogdoches County, Texas (Stop 7); 2 – *Madracis* sp., from the Weches Formation, southern edge of Lake Nacogdoches, Nacogdoches County, Texas (Stop 7);
3 – *Balanophyllia desmophyllum* Milne, Edwards, and Haime, 1848, from the Weches Formation, southern edge of Lake Nacogdoches, Nacogdoches County, Texas (Stop 7).

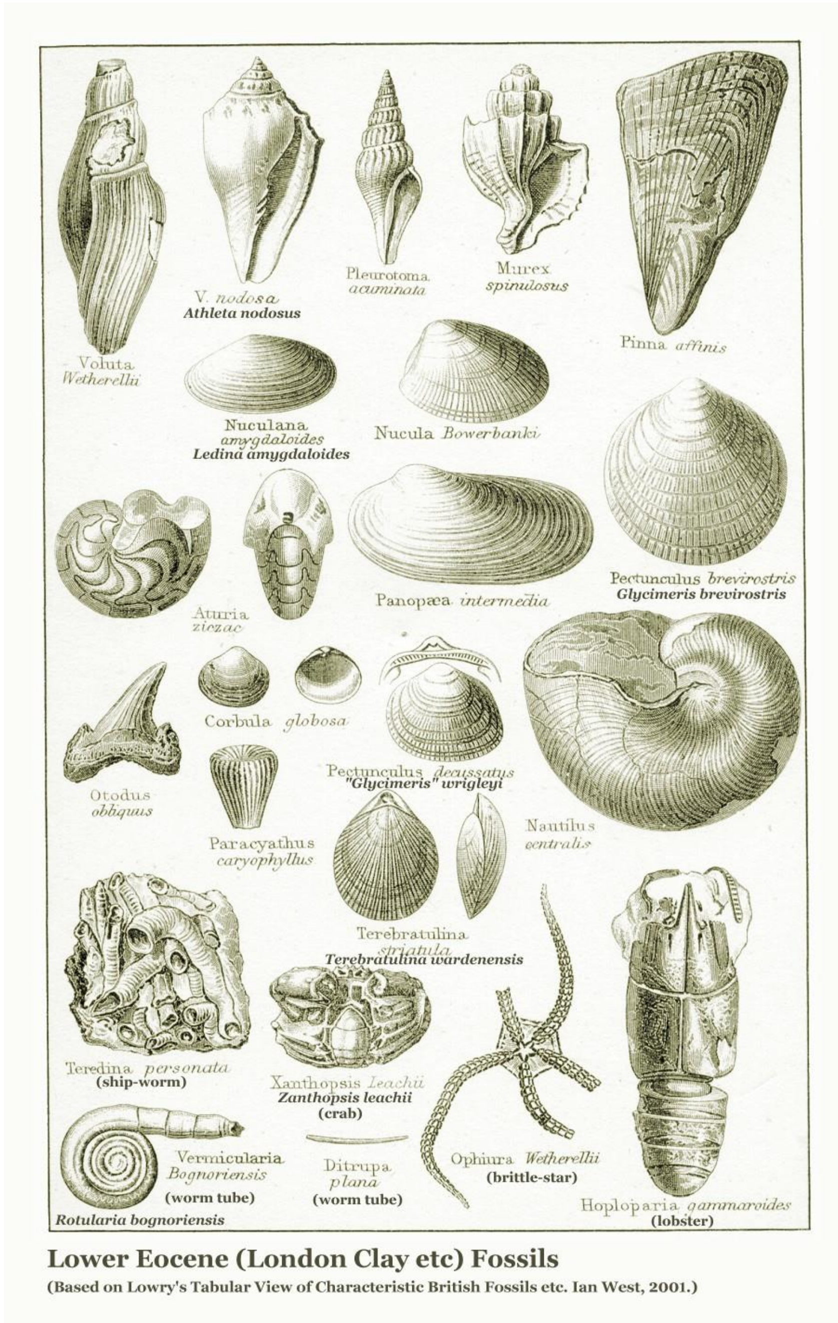
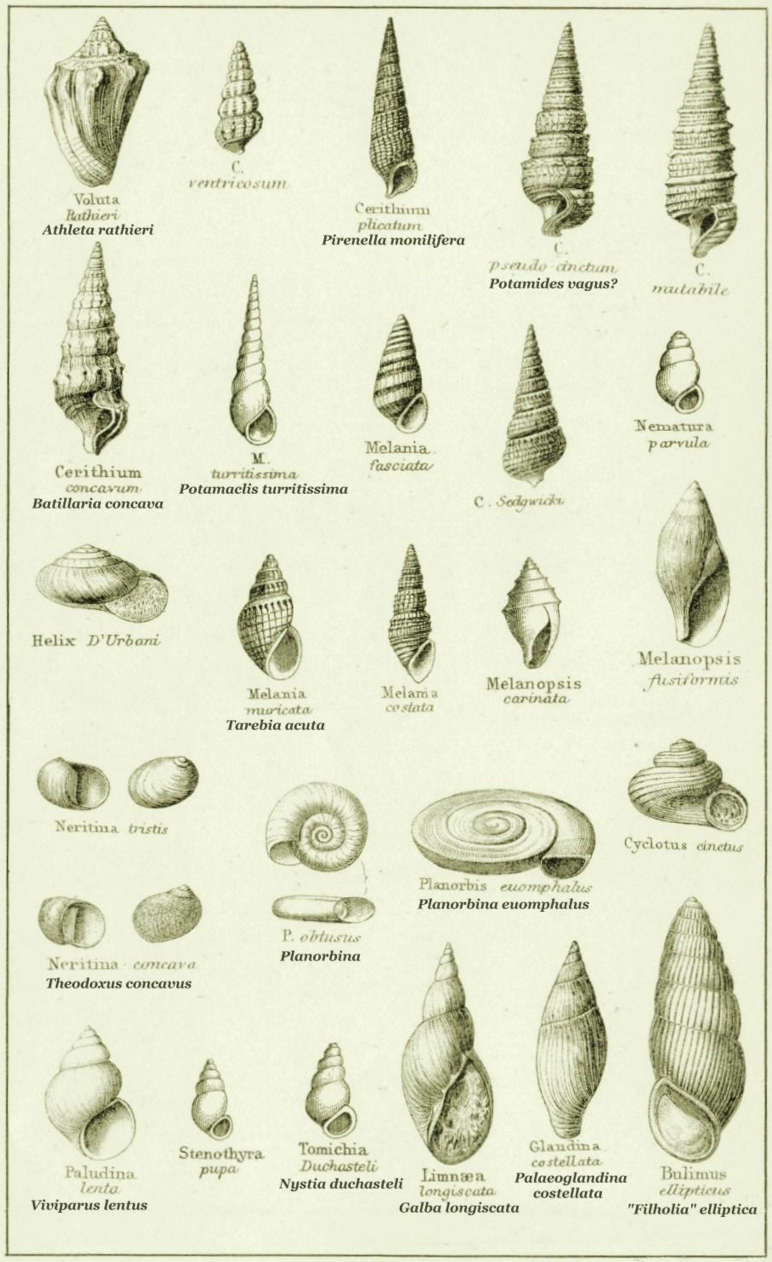


Figure 39: Common gastropods, bivalves and echinoids found in the Weches Formation at Lake Nacogdoches.



Solent Group Fossils 2. (Upper Eocene - Oligocene), mostly lagoonal or lacustrine
Based on Lowry's Tabular View of Characteristic British Fossils etc. (Ian West, 2001)
(With some names updated)

Figure 40: Gastropods that may be found in the Weches Formation at Lake Nacogdoches

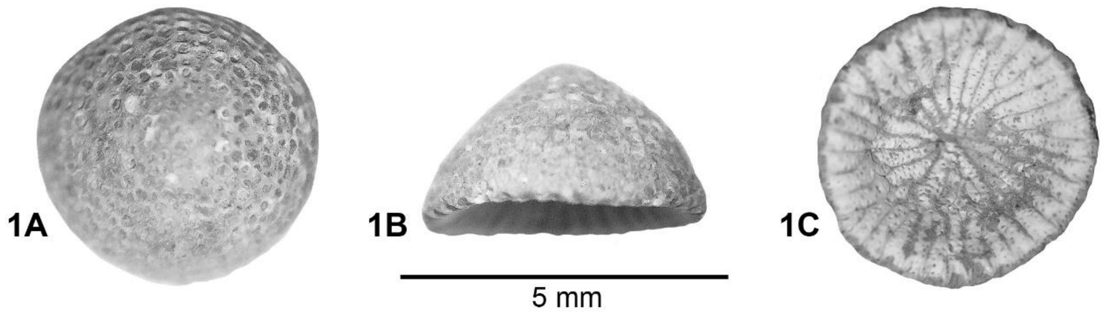


Figure 41: *Discoporella* sp., a small cupuladriid bryozoan colony known from the Weches Formation; 1A – Frontal view of colony; 1B – Lateral view of colony; 1C – Basal view of colony.

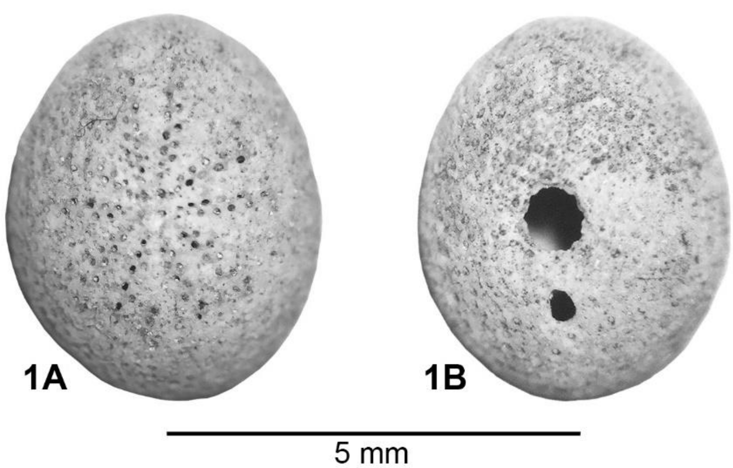


Figure 42. *Fibularia texana* (Twitchell, 1915), a common irregular echinoid species from the Weches Formation; 1 – *F. texana*, from the Weches Formation, southern edge of Lake Nacogdoches, Nacogdoches County, Texas (Stop 7); 1A – Aboral view; 1B – Adoral view. *Fibularia texana* occurs most abundantly in the uppermost part of the Weches Formation, just below the contact with the overlying Sparta Formation.

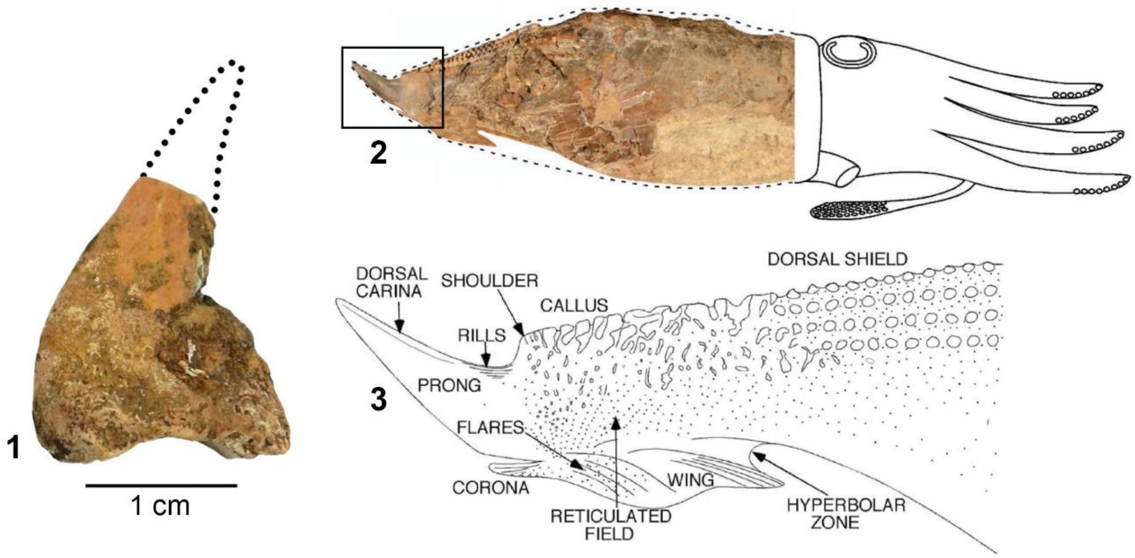


Figure 43: *Belosaepia ungula* Gabb 1860, a cuttlefish-like coleoid cephalopod known from the Weches Formation; 1 – Lateral view of the posterior portion of the guard from a partial specimen (missing fractured prong), from the Weches Formation, southern edge of Lake Nacogdoches, Nacogdoches County, Texas (Stop 7); 2 – Skeleton of *B*. *ungula* (TMM 21-T-100, Little Brazos River, Brazos County, Texas) with inferred reconstruction of anterior soft tissue (from Yancey et al., 2010). Boxed inset encloses the portion of interest (prong and shoulder), which is commonly found disarticulated from the rest of the skeleton; 3 – Labeled reconstruction of the posterior portion of the guard indicating position of key morphological features (from Yancey et al., 2010).

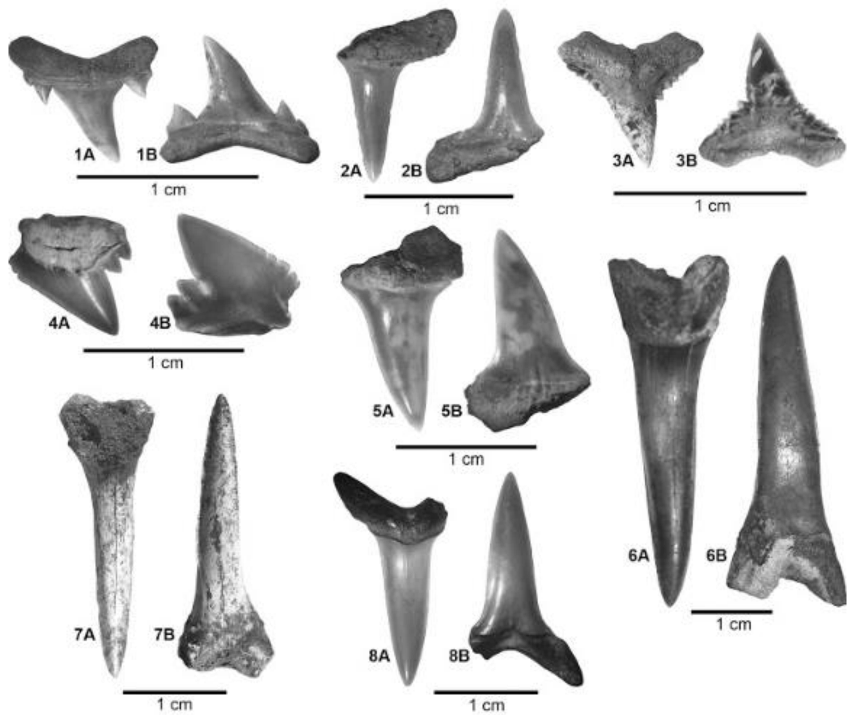


Figure 44: The prized fossil everyone wants to collect from the Weches Shale are shark teeth. Lamniform and Carcharhiniform shark teeth collected from the Weches Formation: 1 - lingual (A) and labial (B) views of *Brachycarcharias* tooth; 2 - lingual (A) and labial (B) views of *Carcharias* tooth; 3 - lingual (A) and labial (B) views of *Carcharhinus* tooth; 4 - lingual (A) and labial (B) views of *Galeorhinus* tooth; 5 - lingual (A) and labial (B) views of *Carcharias* tooth; 6 - lingual (A) and labial (B) views of *Striatolamia* tooth; 7 - lingual (A) and labial (B) views of *Striatolamia* tooth; 8 - lingual (A) and labial (B) views of *Striatolamia* tooth. The genus *Carcharias* includes modern sand tiger sharks, though the teeth found from this genus likely represent an extinct species rather than the modern sand tiger. *Brachycarcharias* and *Striatolamia* are within the same family as *Carcharias*, the Odontaspididae, so they are closely related to the modern sand tiger. All three of these genera are lamniform sharks. There are over thirty extant species in the genus *Carcharhinus*, the gray sharks. *Galeorhinus* is part of the hound shark family, Triakidae, and has one extant species. The genera *Carcharhinus* and *Galeorhinus* are both carcharhiniform sharks.

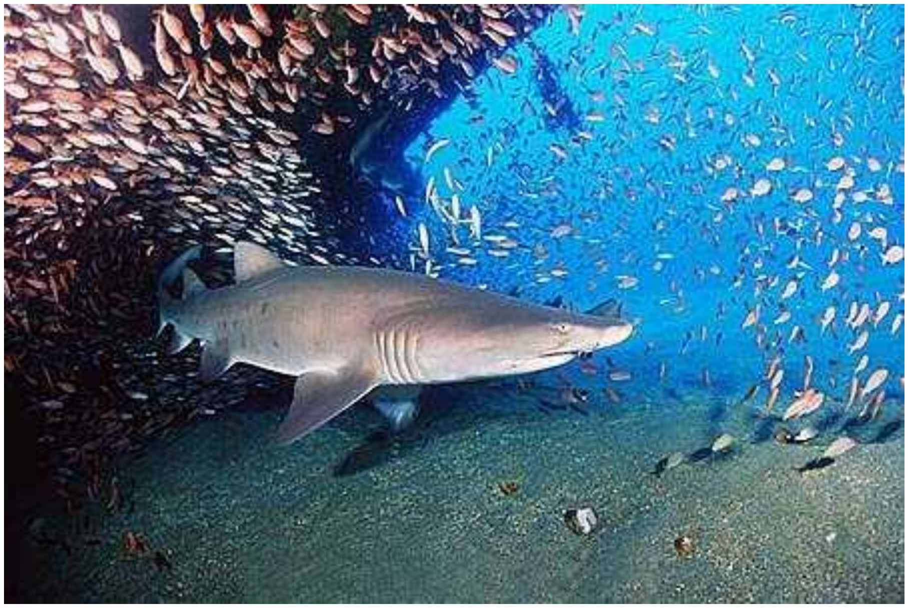


Figure 45: A modern sand tiger shark, *Carcharias taurus*.
https://www.floridamuseum.ufl.edu/discover-fish/species-profiles/carcharias-taurus/

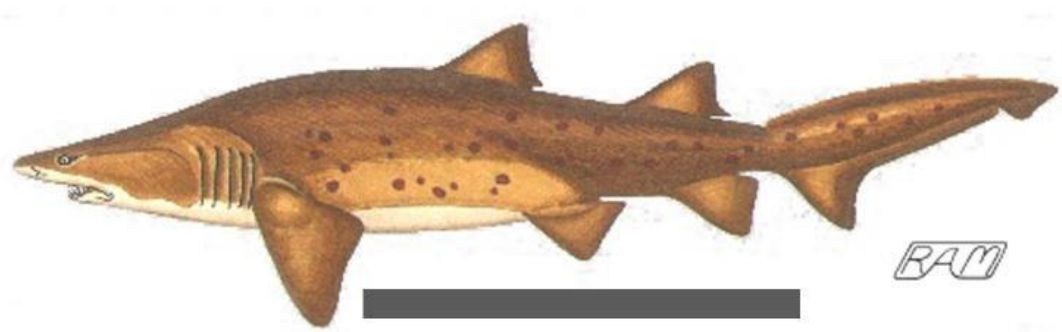


Figure 46: One depiction showing what the extinct genus *Striatolamia* may have looked like. http://donhuysmans.ca/shark02.html

Figure 47: A bull shark, *Carcharhinus leucas*, one of the numerous extant species within the genus *Carcharhinus*. https://www.floridamuseum.ufl.edu/discover-fish/species-profiles/carcharhinus-leucas/

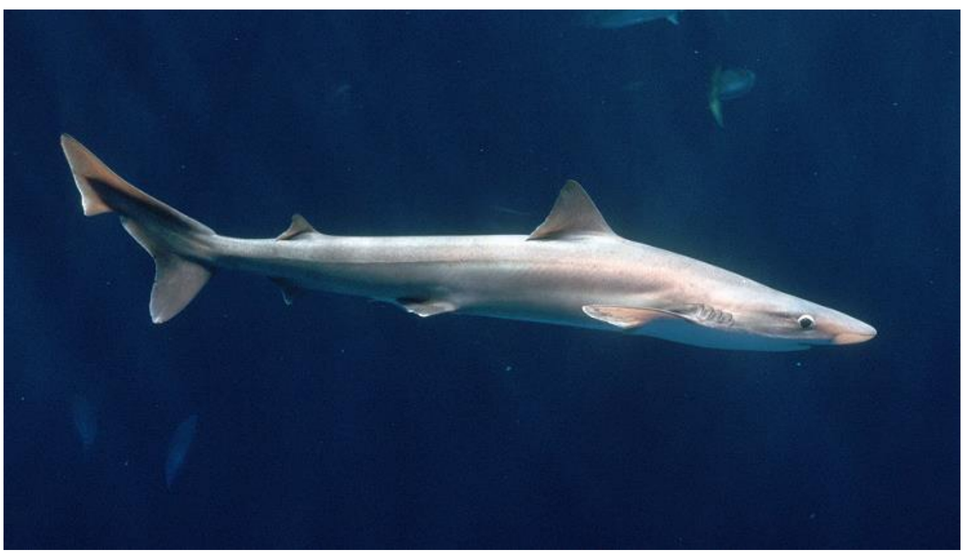


Figure 48: *Galeorhinus galeus, the only living species in the genus.* https://www.montereybayaquarium.org/animal-guide/fishes/soupfin-shark

Stop 8:

Mt. Enterprise Fault (GPS 31.913754 N, -94.680962 W) The Mt. Enterprise Fault system is seen in downtown Mt. Enterprise and consist of an east-west graben that developed during the Tertiary Period. The hill to the north of the intersection of U.S. 84 and U.S.259 is a fault line scarp. The faults are normal dip-slip faults. The horst and graben extend into the Sabine Uplift and cuts across the East Texas Basin. The graben was produced by salt dissolution or from extension along the western margin of the United State. No slicken lines are seen along the fault scarp suggesting that time has passed since it moved at this location (Figure 24). The scarp that is present is produced by the fault being eroded back and is classified as a fault line scarp. In recent years a number of earthquakes associated with the Mt. Enterprise fault zone have had magnitudes as high as 4.8 on the Richter Scale (Frohlich, et al, 2014) (Figure 49, 50, 51 and 52)..

Figure 49: The Mt. Enterprise Fault is located behind the buildings in Mt Enterprise producing a marked fault line scarp. The red-line notes the location of the fault.

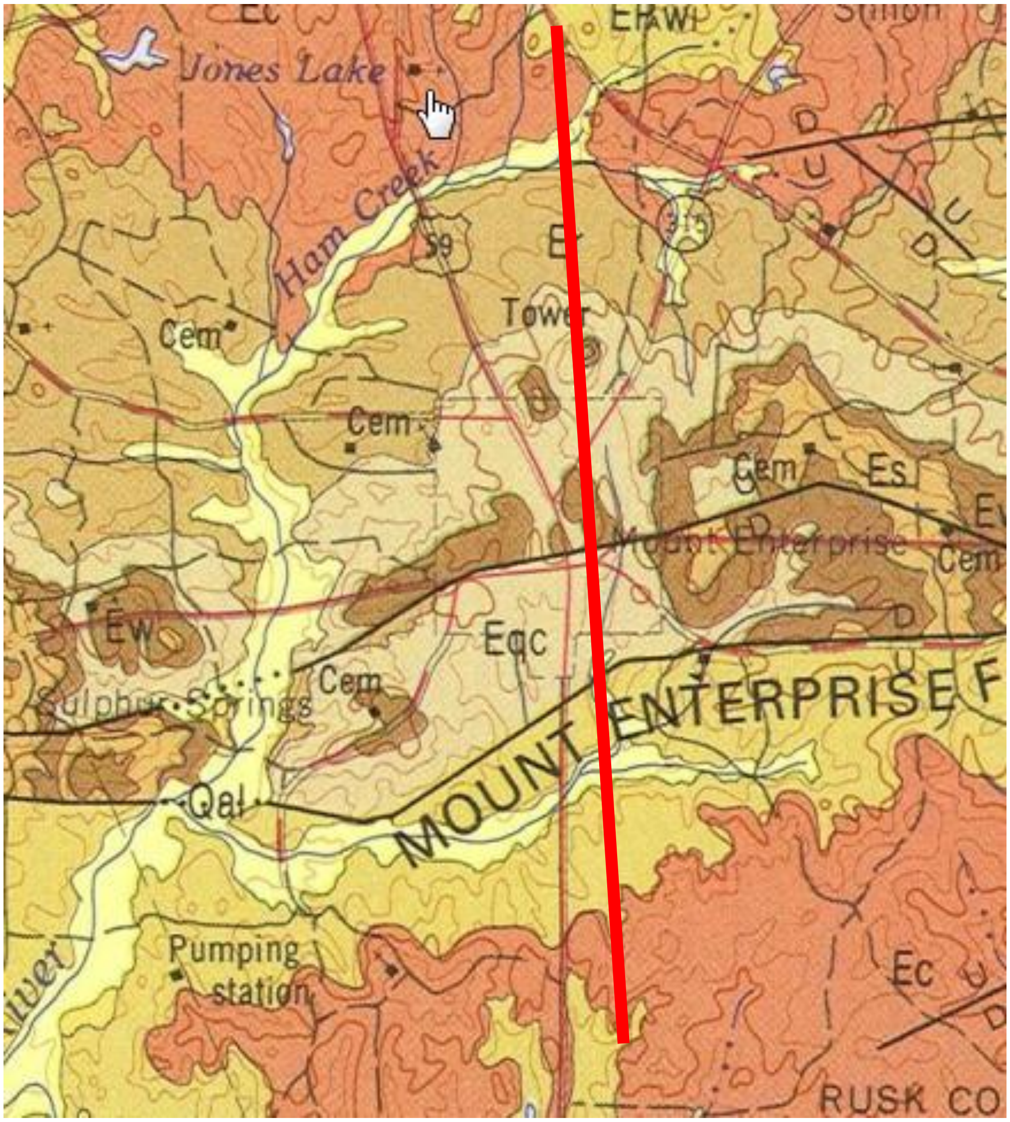


Figure 50: Geologic map of the Mt. Enterprise Fault System and geology of the Mt Enterprise area. Stratigraphic units: (Eqc) – Queen City Sandstone, (Erwi) Willcox Group undifferentiated, (Ew) - Weches Shale and (Es) - Sparta Sandstone. The red line indicates the location of the cross section. (www.twdb.texas.gov/groundwater/aquifer/GAT).

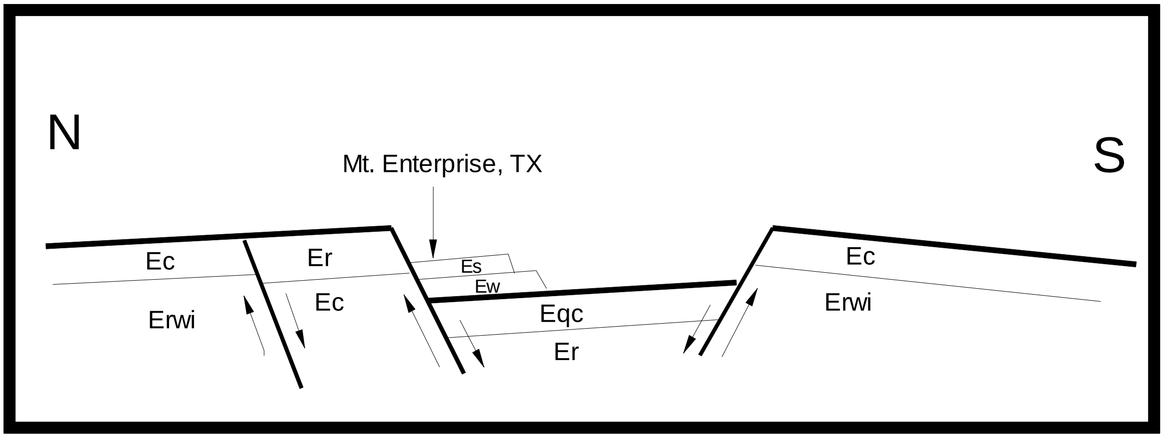


Figure 51: North-south idealized cross-section through the Mt. Enterprise Fault system along U. S. 259. At several locations stratigraphic units do not show off set by the fault. At other locations, young stratigraphic units are in contact with older stratigraphic units but no fault is present on the map. The area needs careful mapping to resolve the structural and stratigraphic problems. Stratigraphic units: Erwi - Willcox Group undifferentiated, Eqc – Queen City Sandstone, Ew - Weches Shale and Es Sparta Sandstone

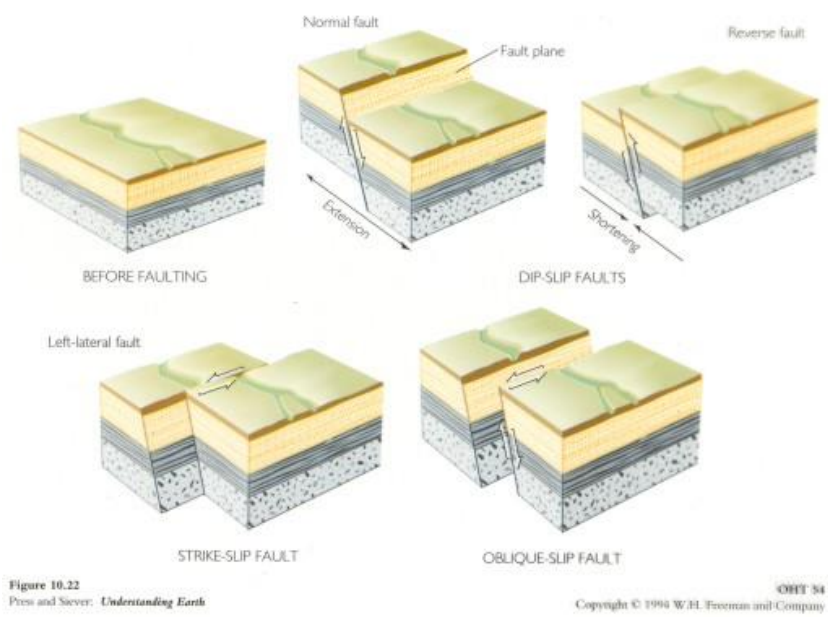


Figure 52: Types of fault movement.

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