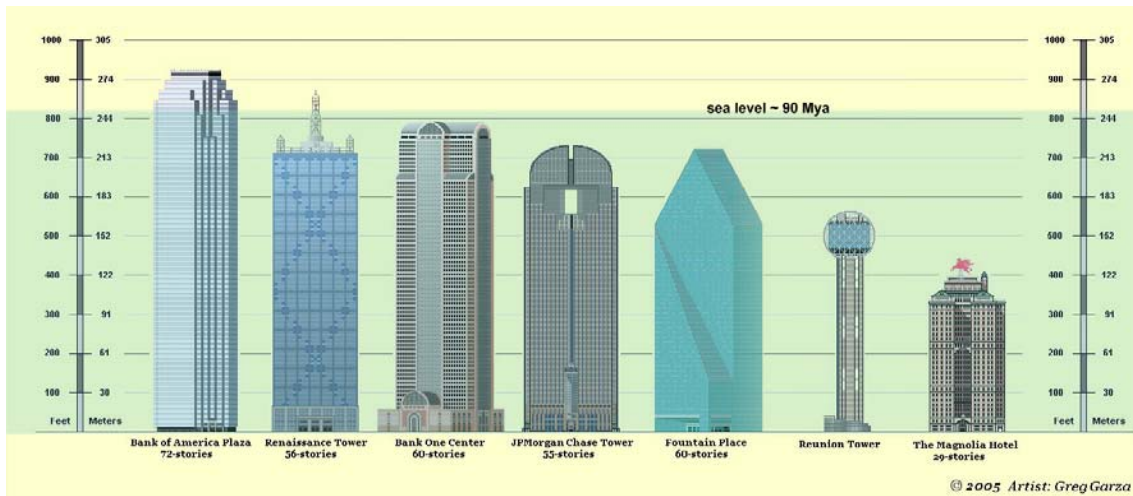


OCEAN DALLAS

<http://smu.edu/isem/oceandallas.html>

Second Edition



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INTRODUCTION

Ocean Dallas is the story of rocks and fossils in what is now the Dallas-Fort Worth region, called the Metroplex by many of the people who live here. It explains the changing geographic arrangement of land and sea during the time interval from 96 Ma to 86 Ma (mega-annum, which means millions of years ago). It also explains the consequences of this geologic history for the current lay of the land and the plants that grow on it. The tools to figure out this area's geologic history are the characteristic features and fossils found in the rocks we see and the order of rock layers through time. *Ocean Dallas* is meant to be used as a field guide and as a classroom supplement for teachers who wish to share the exciting history of this part of our planet with students of any age. The Metroplex is densely populated but it always has major construction projects underway that create new rock outcrops, expose strata, and bring fossils to the surface. *Ocean Dallas* should facilitate your building a road log for your own special field trip in the Metroplex area. If you need help making your own road log, you are welcome to contact Louis Jacobs at jacobs@smu.edu.

The youngest rocks in the Metroplex are Ice Age river gravels found along the Trinity River and its tributaries. These loose, unconsolidated Pleistocene rocks are much less than a million years old. They contain the bones of mammoths, ground sloths, saber-toothed tigers, and other Ice Age animals. The river deposits were formed as the Trinity flowed across and eroded older rocks. Most of the rocks of the Metroplex older than the Pleistocene gravels are sedimentary in origin and Cretaceous in age, and looking broadly around the region, range from approximately 119 Ma to about 83 Ma. For every rock you see in the Metroplex, you should note such lithologic features as composition, grain size, sorting and rounding of constituent particles, sedimentary structures such as ripple marks, and color. Keep your eyes peeled for faults, or breaks along which the rocks have moved. You will no doubt find fossils, including lots of invertebrate shells, perhaps a crab, sometimes a bit of wood, probably fish or shark teeth, and who knows what else. It could be something new! Responsible science requires that if the fossil you find adds to the scientific story of the Metroplex it should be repositied in a museum collection. SMU would be a good place. If it is a common fossil of value in education, then by all means that is the purpose to which it should be put. Many common and beautiful fossils might well serve an educational purpose for use with your students. At every rock outcrop you see in the Metroplex you should try to understand the depositional environment and the age of the site relative to the other sites in the Metroplex. The purpose is to generate a regional picture of what this area was like and how it was changing during the time interval represented by the rocks you see. [A point to ponder: There is a gap representing well over eighty million years between the youngest Metroplex Cretaceous bed and the oldest Pleistocene gravel. Why?]

The map and cross section shown in Figure 1 illustrate important tools in the study of geology: the sequence and spatial relationships of rock units as measured in outcrop or in the subsurface. Maps depict rocks in plan view. The fundamental mapping unit is a formation, that is, a recognizable body of rock

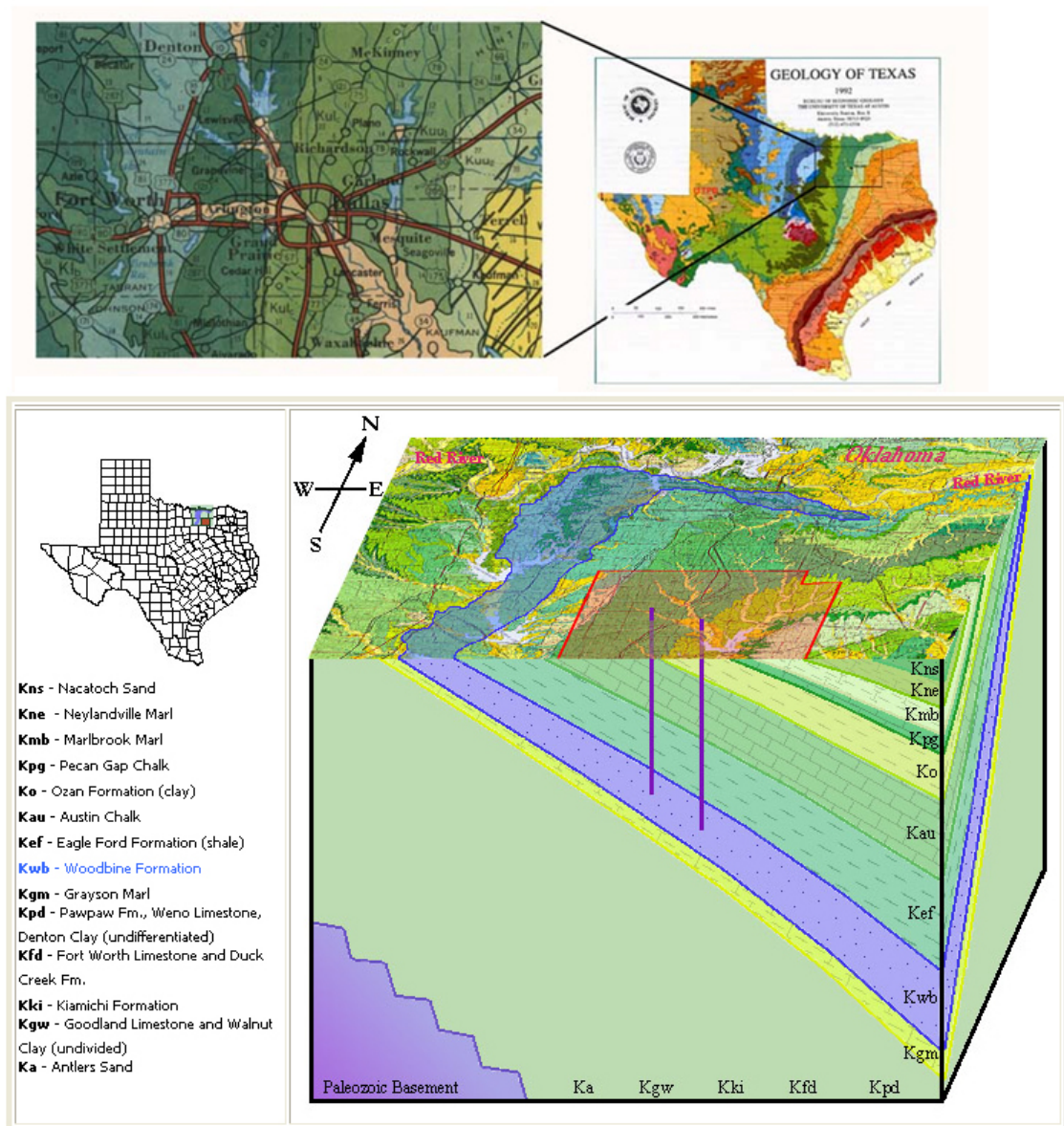


Figure 1. Geology of North Texas. Top: geologic map; bottom: cross section.

characterized by its lithology, perhaps a uniform (or uniformly variable) composition, such as limestone or shale, or an alternation of the two. Formations should be mappable generally at a scale of 1 to 25:000. That usually means that a body of strata should be 25 meters (approaching 100 feet) or more in thickness to show up on a map as more than a thin line. The cross section at the bottom of Figure 1 is particularly interesting and we will refer back to it when we discuss East Texas oil.

To place the regional picture in perspective, here is a little background to some of the major goings-on in the history of life during this interval. In the marine realm, sea

level was high and ocean surface temperatures appear to have been quite warm. This interval is particularly significant for mosasaur evolution, a group of ocean-going lizards. In fact, the Metroplex preserves America's oldest known mosasaur (92 Ma). This is also the interval of time when sea turtles diversified, and as documented in the eastern Mediterranean, the time of the first known invasion of the sea by python-like snakes. In the terrestrial realm, this time encompasses significant biotic changes, including the rise of flowering plants, the decline of conifers, and the transition from more primitive mammals to easily recognizable marsupials and placentals. The oldest marsupial in Texas is represented by a tiny tooth found on DFW airport (Figure 2). There was a major change in dinosaurs from those around in previous times, most obviously duck-billed dinosaurs, or hadrosaurs, were on the rise.

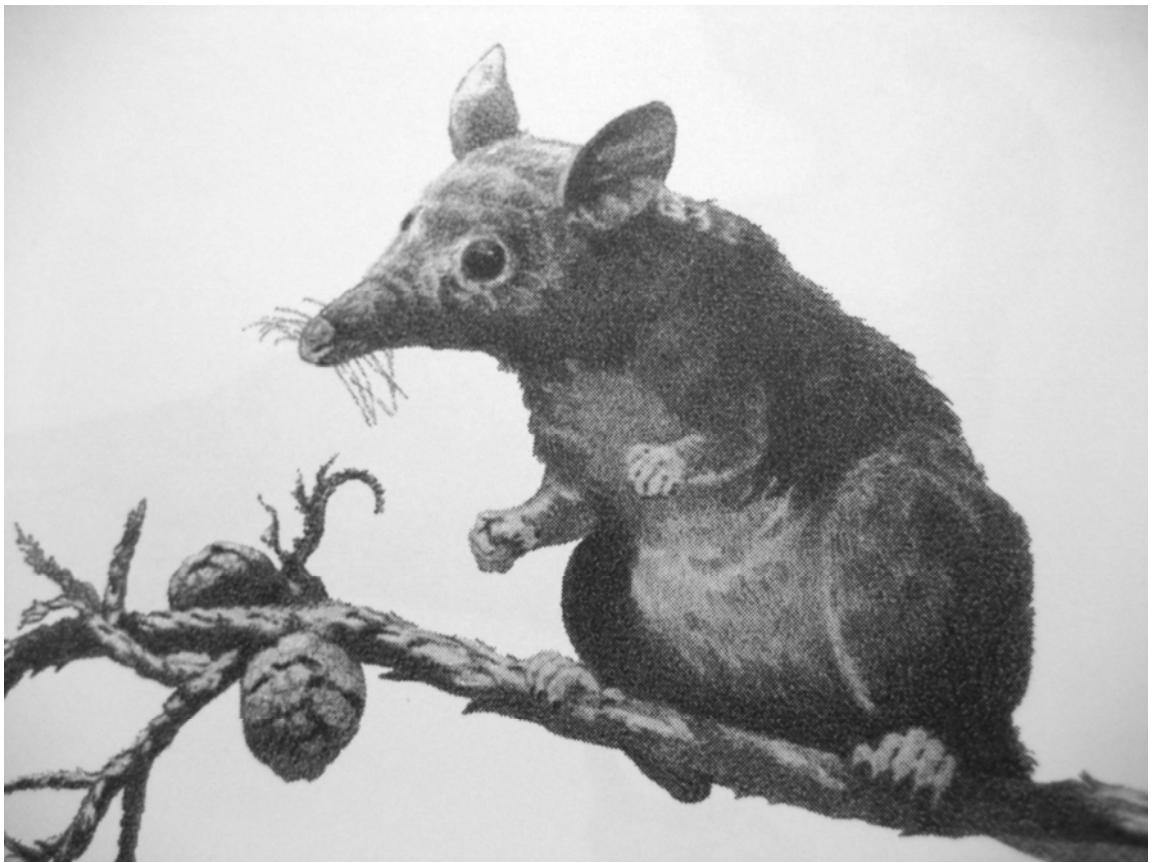


Figure 2. Reconstruction by Karen Carr of a marsupial, an early opossum from the Woodbine Formation.

In telling a story of ancient rocks, geologists like to begin at the bottom, by which we mean, with the oldest rocks. Lake Grapevine northwest of DFW airport is a convenient place to begin because it heralds the flooding of the land by the sea. There is only one natural lake in Texas; all the rest were made by damming rivers to form reservoirs for drinking water and irrigation. Lake Grapevine was formed by damming Denton Creek, a tributary of the Elm Fork of the Trinity River. In driving to Lake

Grapevine from downtown Dallas one traverses two distinct bands of vegetation (ignoring all the urban development). The first is the grassland called Black Prairie. Watch for slumping in road cuts along highways through the prairies. To the west of the Black Prairie is the Eastern Cross Timbers, which Washington Irving in 1832 referred to as a “forest of cast iron” because of its thickets of tough oak trees. Although one can drive through a town called Grand Prairie east of the Cross Timbers, the real prairie called Grand Prairie is west of the Eastern Cross Timbers (someone must have gotten lost). Then, continuing west, another belt of oaks is known as the Western Cross Timbers. The cross timbers are bands of trees that run north to south across the prairies. During the 19th Century, the prairies were valued as rich, flat farmland with deep soil; the cross timbers were valued for other reasons, but cursed when a wagon trail had to be chopped through them the first time. Can you think of how this pattern of vegetation may have come about?

One of the oldest duck-billed dinosaurs in North America was found in the rocks of the Eastern Cross Timbers. It was named *Protohadros byrdi* after the discoverer, Gary Byrd, a member of the Dallas Paleontological Society, by former SMU student Jason Head. The dinosaur was found in dark, plant rich sediments, similar to ancient peaty mud, surrounded by much redder and sandier sediments.



Figure 3. Reconstruction of the duck-billed dinosaur *Protohadros byrdi* by Karen Carr (compare this to the image on page 92 of Lone Star Dinosaurs, which shows an earlier reconstruction made before the skull of *Protohadros* was known. Gary Byrd, for whom this dinosaur was named, was a member of the Dallas Paleontological Society and the discoverer of the fossil.

WOODBINE FORMATION

Cretaceous rocks are usually shades of green on geologic maps, which as we discussed above, are representations of the areas of the ground surface where specific rock units are found. Again, the fundamental mapping unit of rocks is called a formation, and a formation must be large enough to show up on a map. The pattern of rock units on a map is an important tool for understanding Earth history. Can you think of another pattern that we have discussed that would, in a sense, be analogous to a pattern of formations on a map? The growth of plants that comprise the cross timbers, as opposed to the prairies, are controlled at least in part by the rocks on which they grow, creating in effect, a 1:1 geologic map.

The west side of Lake Grapevine is in the Woodbine Formation (Figure 4). Is this rock unit mappable? Why or why not? What features make it characteristic and recognizable? The color of the Woodbine varies from nearly black to deep reddish through orange to buff and tan. The skull of *Protohadros* was found in dark sediments. How would you explain the color differences seen in the Woodbine? Why would rocks of varying texture and composition be in the same formation?

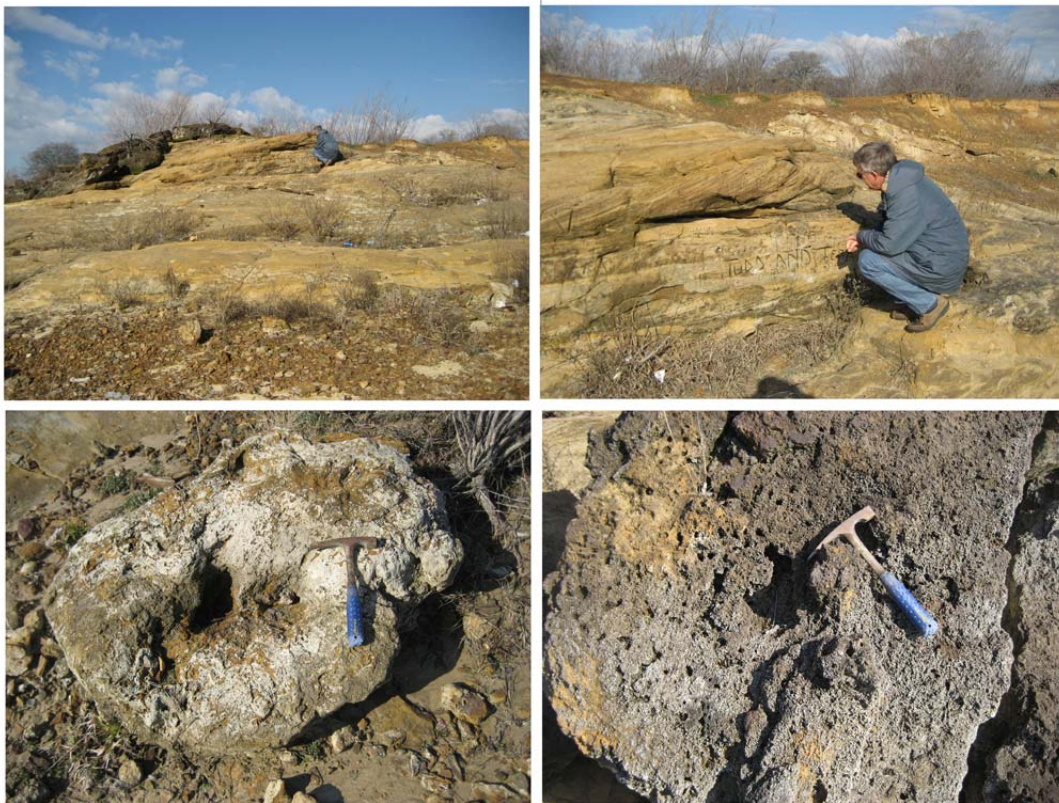


Figure 4. Woodbine Formation outcrops at Lake Grapevine. Clockwise from upper left: Dune sands capped with dark bioturbated sand; crossbedded beach sand with distributary channel shown above and behind teacher (Paul Ballou); sand bioturbated by fiddler crabs; dinosaur track in boulder.

Besides dinosaurs and opossums, numerous other fossils of plants, vertebrates, and invertebrates, have been recovered from the Woodbine Formation. The diversity of kinds of fossils discovered stems from the variety of depositional environments preserved, from nearshore marine to terrestrial. In addition to *Protohadros* and the early marsupial, other vertebrates known from the Woodbine Formation include the skeleton of the crocodile *Woodbinesuchus byersmauricei*, teeth of meat-eating theropod dinosaurs, and bones and teeth of an armored dinosaur. The area on the west side of Lake Grapevine is particularly interesting because it has produced a *Protohadros* thigh bone, dinosaur footprints, and the burrows of fiddler crabs, as well as ripple marks, cross beds, and other indications of depositional environment.

The main objective of looking at rocks at Lake Grapevine is to observe and interpret sedimentary structures, concretions, and most of all, trace fossils. What are all those things, when were they formed, what do they mean? The definition of a fossil is any evidence of past life, that is, older than 10,000 years, but what is the definition of a trace fossil? A trace fossil is a sedimentary structure, but it is a special kind of sedimentary structure that formed as a result of an organism's ordinary activity, such as walking, burrowing, or feeding. The stirring up of mud and other sediments by organisms is called bioturbation, and if done by dinosaurs, dinoturbation. On the west side of Lake Grapevine there are two kinds of trace fossils that are particularly intriguing: fiddler crab condominiums and dinosaur footprints.



Figure 5. Clockwise from upper left: Fiddler crab (*Uca*); fiddler crab with feeding boluses; fiddler crab burrow and bolus trace fossils from the Woodbine Formation; fiddler crab at burrow with boluses.

Fiddler crabs (genus *Uca*) are small semi-terrestrial marine crabs that today live in burrows along tidal creeks, salt marshes, lagoon margins, and estuarine shorelines. They feed by extracting organic matter from a bolus of sand. Bites of substrate are plucked from a soft bottom surface using the claws and transferred to the mouth. After the organic matter has been removed, the indigestible sand grains are spit out as a small round ball. Females use both claws to gather food. Males are territorial and have one large claw for show and a regular sized claw with which they feed. Having only half the feeding claws as the female, the males must gather food rapidly, causing a saw-like movement toward the large claw, and hence the name fiddler crab. Burrows of 96 million-year old fiddler crabs are abundant along an ancient Woodbine channel and capping beach dune deposits at Lake Grapevine. Modern fiddler crab species differ in the shape of the burrows they make and their favored environments. Fossil fiddler crabs and their traces are good indicators of paleoenvironment.

Several kinds of dinosaur tracks were studied at Lake Grapevine by former SMU student Yuong Nam Lee (Figure 6). *Fuscinapedis woodbinensis* is the track of a theropod, and *Magnoavipes lowei* is a fascinating large birdlike print. The most common is *Caririchnium protohadrosaurichnos*, the presumed track of the duck-billed dinosaur *Protohadros*. The hind prints of *Caririchnium* have three broad toes, and the fore print is a small half-moon shaped hoof without distinct fingers.



Figure 6. Dinosaur footprints at Lake Grapevine. Counterclockwise from upper left: Trackway trails; *Caririchnium protohadrosaurichnos*; *Magnoavipes lowei* (named for Dallas Paleontological Society founding member Bill Lowe); *Fuscinapedis woodbinensis*; *Caririchnium protohadrosaurichnos*; dinoturbated surface. Courtesy of Yuong-Nam Lee.

EAGLE FORD FORMATION

The Eagle Ford Formation is named for the 19th Century Eagle Ford community now subsumed by Dallas. The community was on the south side of the West Fork of the Trinity River at a place where the crossing was easy; hence the name. It is the area now covered by Pinnacle Park along I-30, which parallels the West Fork of the Trinity. All that is left of the original community is the old Eagle Ford school (Figure 7).



Figure 7. Counterclockwise from upper left: Eagle Ford School (cup sitting on Kamp Ranch Limestone); teacher (Paul Ballou) kneeling on Kamp Ranch Limestone, Britton Member below and Arcadia Park Member above; calcite crystals in septarian nodule; fossil crab *Homolopsis pikeae* from the Eagle Ford Formation, named after Dallas Paleontological Society member Arlene Pike (scale bar = 1 cm); impression of the ammonite *Collignonicerias woollgari* in the Kamp Ranch Limestone.

The Eagle Ford Formation is easily eroded. Where the overlying Austin Chalk forms an erosion resistant ridge, the Eagle Ford forms soft slopes. Slopes and road cuts

often show slumping, where masses of the rain-soaked Eagle Ford slid downhill. This happens under houses and apartment buildings too, causing foundation problems and structural damage. Lesson: Use geology to choose a house. The Eagle Ford Formation is a sequence of dark shale beds with minor amounts of limestone. (What makes the Eagle Ford dark? What makes it shale?) The lower Eagle Ford contains a series of volcanic ashes that blew into this area in from distant eruptions. The upper part of the Eagle Ford is very similar to the lower part, but there is a thin, carbonate layer that separates the two. The carbonate layer is called the Kamp Ranch Limestone, below it is the Britton Shale, and above it is the Arcadia Park, both of which are named for old communities. Although we do not agree, the Eagle Ford has often been called a stratigraphic group, containing the Britton and Arcadia Park Formations, with the Kamp Ranch marking the base of the Arcadia Park. What would determine whether a rock unit is a group or a formation? What would you say about the environments of deposition of the Eagle Ford compared to the Woodbine?

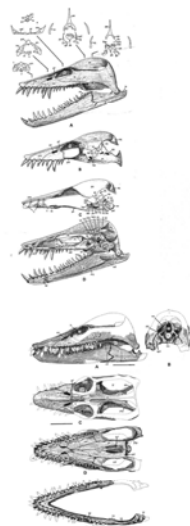
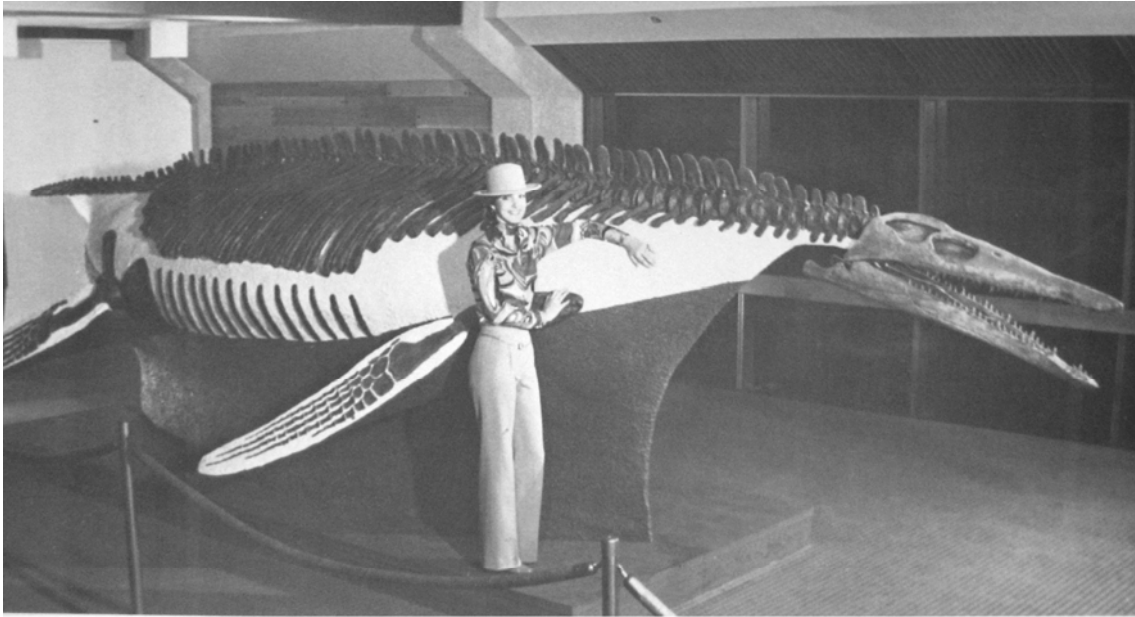


Figure 8. Plesiosaurs of the Eagle Ford Formation. The short-necked form is *Polytychodon hudsoni* found in the excavation for the old Braniff terminal at DFW airport; the long-necked form is *Libonectes morgani*, first discovered at Cedar Hill in southern Dallas County. *L. morgani* is named for SMU alumnus Charles Gill Morgan, a member of Admiral Byrd's Antarctic expedition.

Many kinds of beautiful fossils are found in the Eagle Ford. Among the most famous are plesiosaurs, both short and long-necked, the kind of animal after which the mythical Loch Ness monster was modeled (Figure 8). Plesiosaurs have been found at DFW airport and at other places in the Metroplex, including along Lake Lewisville.

Fossils are found throughout the Eagle Ford section but in the lower part they are especially obvious in the red concretionary layers. The red concretions are made of the iron mineral siderite (FeCO_3). Be especially on the lookout for little marine lizards called *Coniasaurus* and other lizard-like marine vertebrates. Siderite nodules are not the only concretions in the Eagle Ford Formation. There are also septarian nodules, which are the result of dewatering of the sediments, which causes cracks to form, and the subsequent deposition of minerals to fill the crack spaces. Some of the septarian nodules are quite attractive and often show beautiful crystals of calcite (Figure 7).

The Kamp Ranch Limestone is persistent from Ellis County near Midlothian to Denton County near Little Elm. When you see the Kamp Ranch Limestone for the first time you will be struck by how thin it is and how different it is from the shale. Is the Kamp Ranch a formation? Why or why not? Describe the Kamp Ranch Limestone and the fossils found in it. Use the SEM (scanning electron microscope) image to help in the description. In what sort of condition are the fossils? What would you say about the environment of deposition of Kamp Ranch?

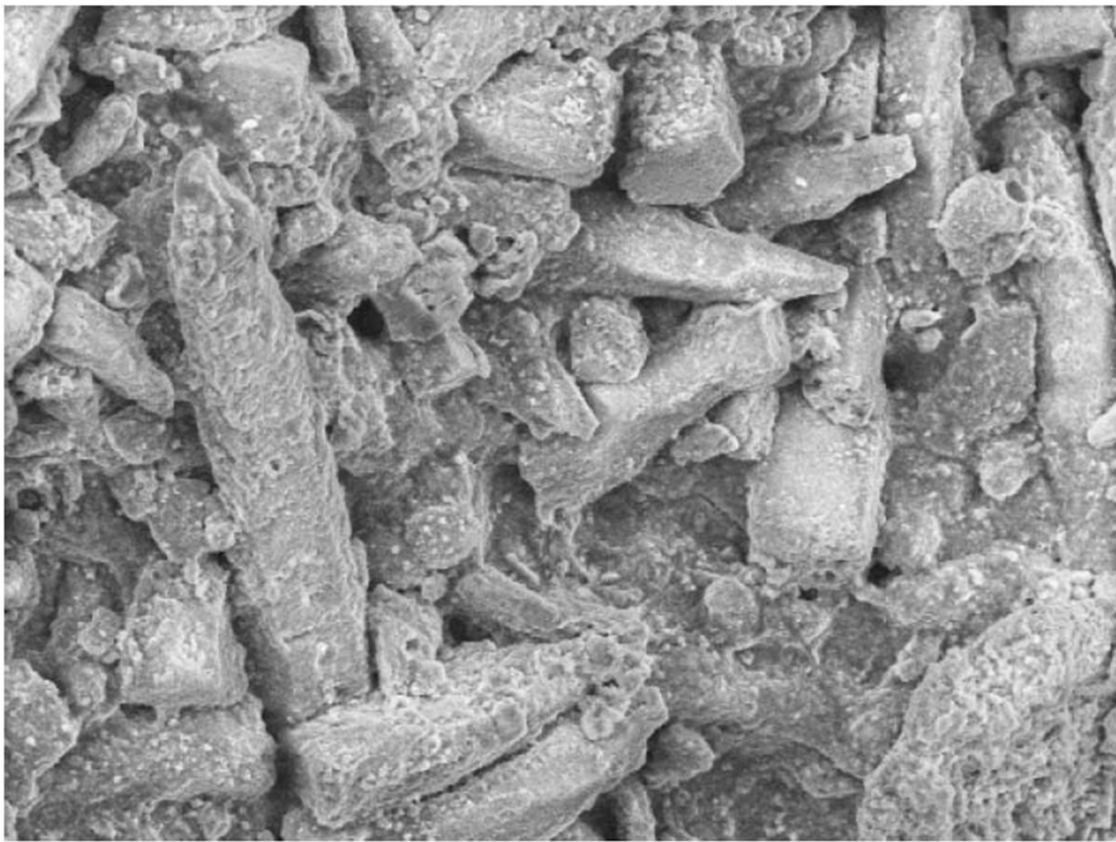


Figure 9. SEM image of Kamp Ranch Limestone showing prisms of Inoceramus shell.

Impressions of the ammonite *C. woollgari* are common in the Kamp Ranch (Figure 7). This is a valuable fossil for telling time because it indicates a short interval dated 92 Ma and it can be recognized throughout the world. Just as you can correlate rocks along Lebanon Road in Frisco, with rocks at Pinnacle Park, you can also correlate rocks from

Asia to Africa to Europe to Texas to Colorado using *C. woollgari*.

Isn't it odd that *C. woollgari* is preserved as an impression and yet clams, oysters, and other mollusc shells are present in the same rock? The answer lies in the difference in crystal structure between the minerals calcite and aragonite. Both are comprised of calcium carbonate (CaCO_3), but aragonite is more soluble. The shells of ammonites like *C. woollgari* are composed of aragonite and those of oysters are made of calcite. The water conditions to which the shells of both were subjected must have been sufficient to dissolve aragonite but not calcite, and therefore the oyster shells preserved by the ammonite shells dissolved and left their impressions. Most specimens of *C. woollgari* from the Eagle Ford are smaller than the one illustrated above. What factors might affect the size distribution of ammonites in the fossil record?

The parking lot near I-30 at Pinnacle Park marks one of the sites where the oldest mosasaur in North America is recorded. Mosasaurs (Figures 10-12) are lizards that evolved and adapted to life in the oceans during the final phase of the age of dinosaurs, the Late Cretaceous. The specimen from Pinnacle Park, a jaw fragment of *Russellosaurus*, came from the Kamp Ranch Limestone. How old geologically do you think that *Russellosaurus* specimen is?

The oldest mosasaurs retain complete limbs including clawed fingers and toes and were able to navigate on land as well as in the water. These early forms evolved against a backdrop of global warm temperatures and rising sea levels. The most highly evolved forms, those that developed fin-like limbs, are known from rocks between about 90 and about 65 million years old. They became extinct at the end of the Cretaceous period, a fate shared with the land-dwelling dinosaurs.

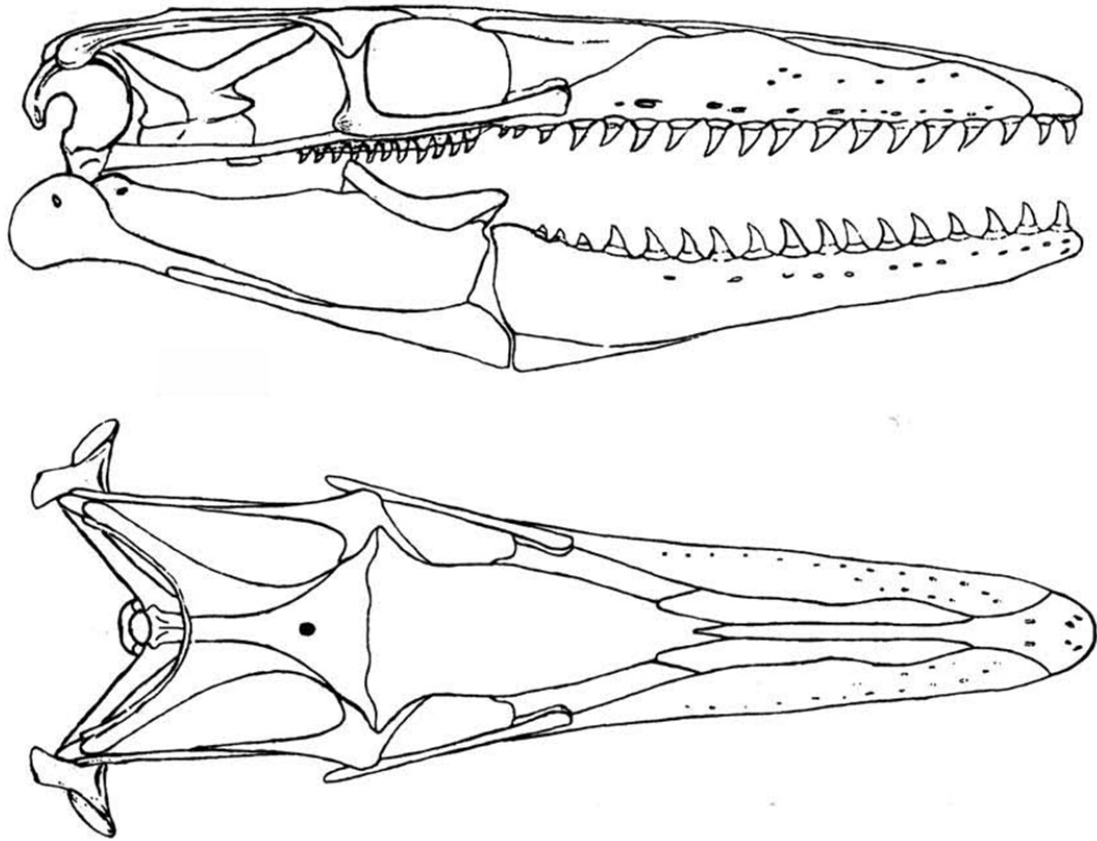


Figure 10. The oldest most complete mosasaur skull from North America. Russellosaurus coheni (named for Mark Cohen of the Dallas Paleontological Society who discovered the specimen) is known from the C. woollgari Zone.

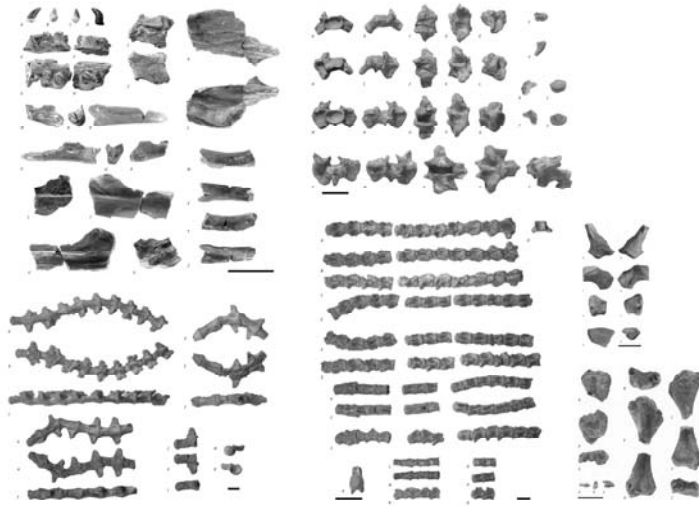


Figure 11. Dallasaurus turneri, named for the city of Dallas and for Van Turner of the Dallas Paleontological Society who discovered the specimen, is a primitive-limbed mosasaur belonging to a separate group of mosasaurs from Russellosaurus. Both Russellosaurus and Dallasaurus are from the Eagle Ford Formation.

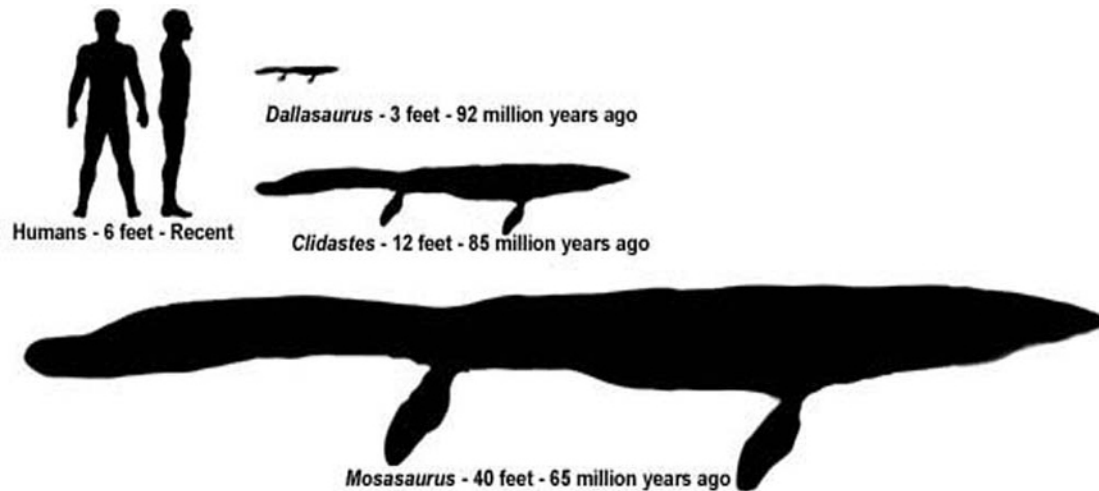


Figure 12. Dallasaurus turneri is not only a primitive mosasaur, it is also small compared with later related mosasaurs.

AUSTIN CHALK

The top of the Eagle Ford Formation is marked by its contact with the overlying Austin Chalk, or more properly, the Austin Group. For comparative purposes, it is worthwhile to describe the rock on either side of the contact. Is the contact sharp or gradational? Here you should find shark teeth, which are concentrated in a lag, or condensed zone, at the contact (Figure 13). A condensed zone is a stratigraphic horizon that is sediment starved so deposition is slow. Therefore, a condensed zone represents a relatively large amount of time for its thickness.

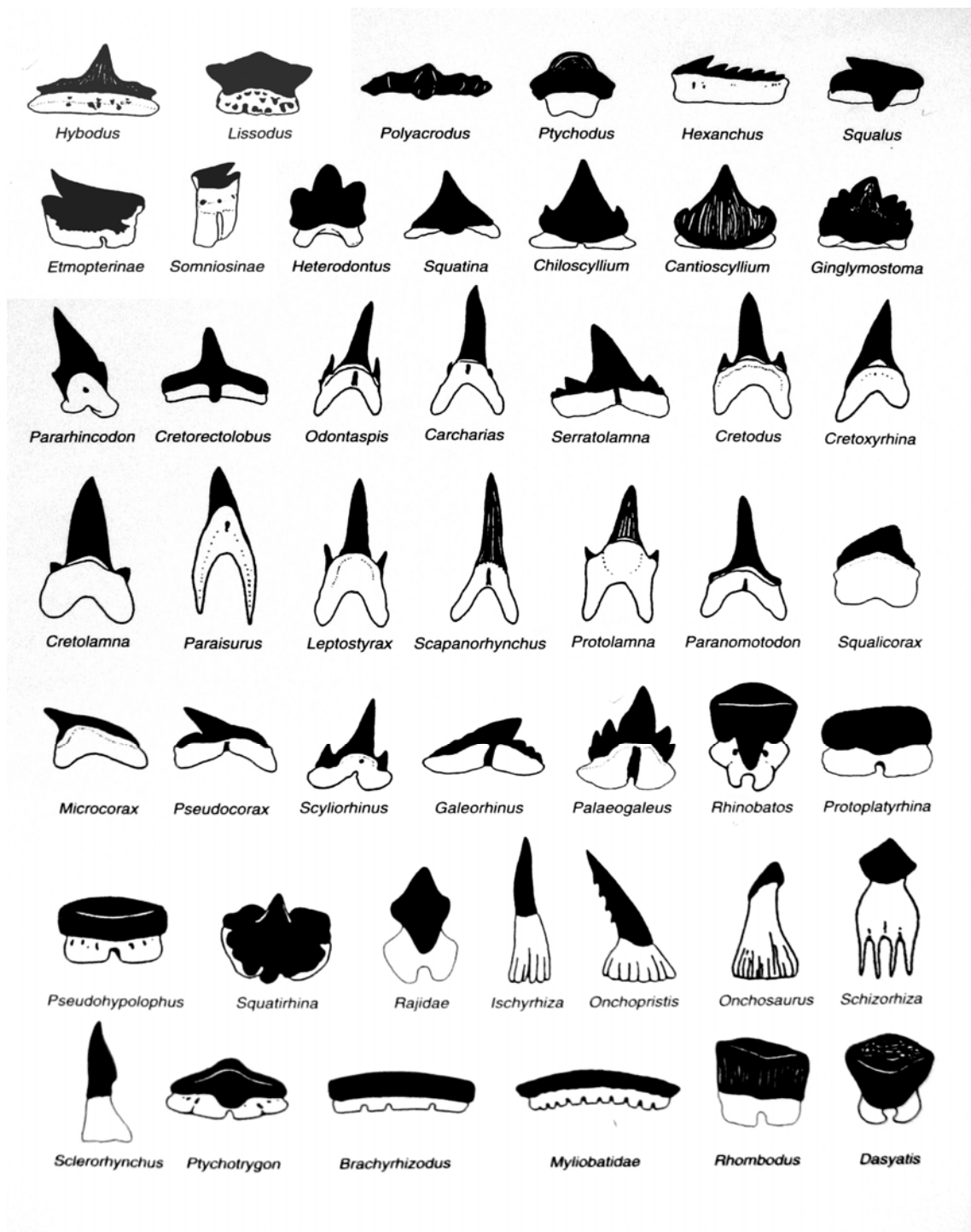


Figure 13. Shark teeth are common in the Texas Cretaceous This illustration, courtesy of Roger Farish of the Dallas Paleontological Society, shows common species, not just those of the Austin Chalk.

The industrial and retail area of Pinnacle Park is built in an old Texcrete Quarry, from which limestone was mined for cement. The condensed zone at the base of the Austin Chalk here is covered (although it is exposed nearby to the south). Nevertheless,

where the condensed zone is observed in this area, it is sharper than to the north in Collin County, which means that less sediment was deposited here, making the condensed zone more exaggerated. This is an example of how rock units and their contacts vary with the environment of deposition over distance, sometimes representing more or less geologic time, or representing the time in different ways.

The Austin Chalk is composed almost entirely of fossils, especially coccoliths (Figure 14) that you cannot see with the naked eye. Coccoliths are minute scales of calcite derived from coccolithophores, a kind of phytoplankton. Coccolithophores dump an estimated 1.4 billion kilograms of calcite per year into the modern ocean.

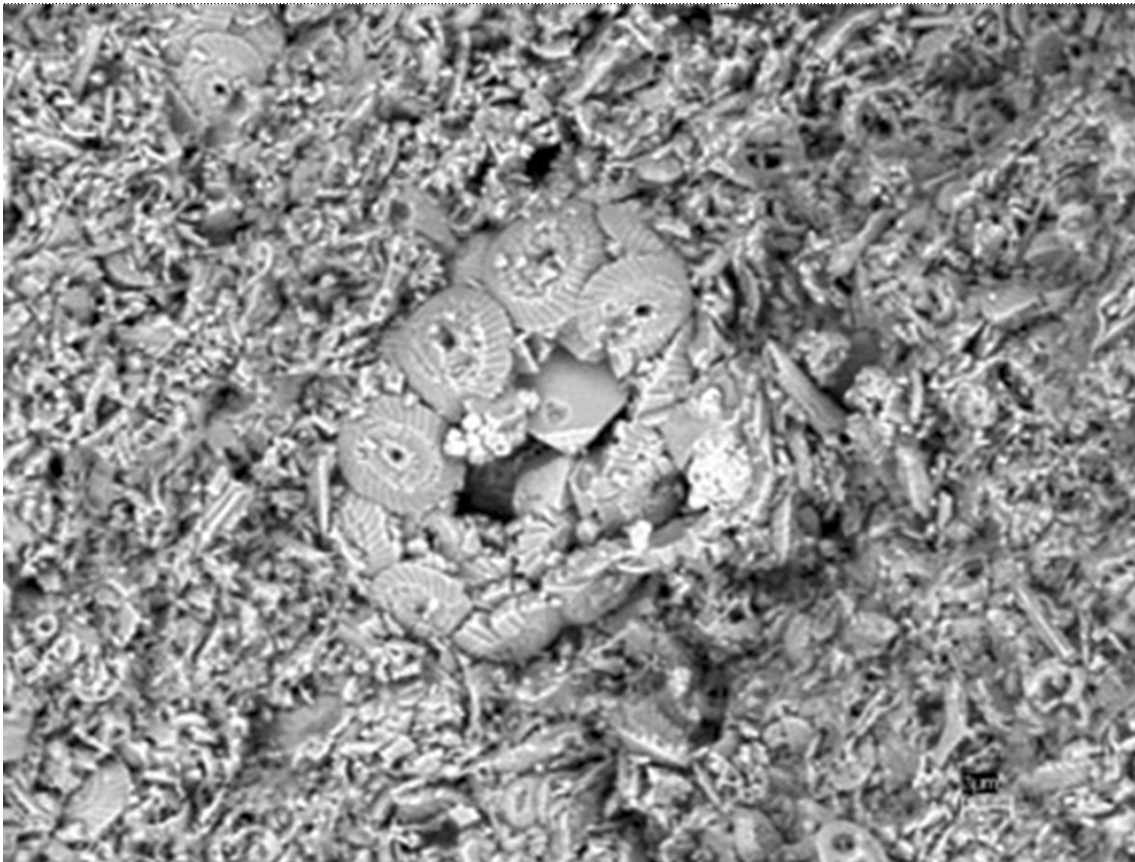


Figure 14. SEM image of coccoliths from the Austin Chalk.

The Austin Chalk ranges in age from about 89 to 85 million years old. Its lower boundary with the Eagle Ford Shale is at the condensed zone, characterized by reduced sedimentation rates and abundant phosphate nodules. The Austin Chalk is a sequence of chalk and marl beds with some volcanic ashes that have been altered to bentonite clay. The bentonite has been radiometrically dated at 86 Ma. Pyrite nodules and the thick-shelled clam *Incoceramus* are common.

You should notice the sharp vertical displacement of the horizontal beds (Figure 15). What are such breaks called? What mineral is found along the breaks?

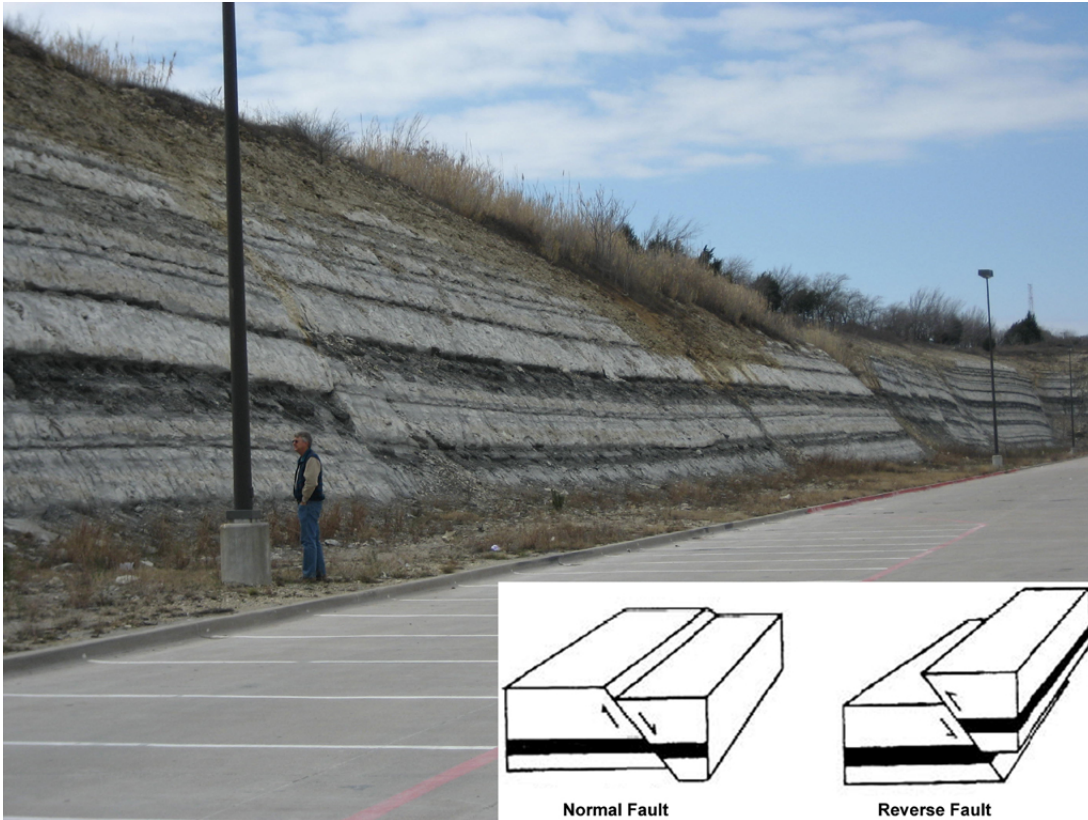


Figure 15. Faults in the Austin Chalk.

The Austin Chalk is cut by a number of faults, or breaks in the rocks along which movement occurred. The direction of movement is determined by the forces acting on the rocks, and therefore the structure of a fault will reflect the forces that made it occur. There are two walls of rock adjacent to a fault, one on either side of the break. One wall, the hanging wall, lies above the plane of the fault; the foot wall lies below the plane of the fault.

The sense of movement on the fault can be determined by the relationship of the hanging wall to the foot wall. A normal fault is a fault in which the sense of movement displaces the hanging wall downward relative to the foot wall. Normal faults result from tensional forces. The sense of movement in a reverse fault displaces the hanging wall up relative to the foot wall. Reverse faults result from compressional forces. Are the faults in the Austin Chalk normal or reverse? How much displacement occurred along each fault? Estimate the total displacement of all the faults added together.

SUMMARY OF OCEAN DALLAS GEOLOGY

The Cretaceous strata of the Metroplex are inclined gently to the east so that as one travels from Dallas toward Fort Worth and Lake Grapevine, the road lies on progressively older rocks. Because sedimentary rocks are originally laid down horizontally, the tilt, or dip, of the strata in the Metroplex is a structural change that occurred after the strata were deposited. The Black Prairie of Dallas County is part of a rich, flat farmland with deep soil developed on the Eagle Ford Formation and Austin Chalk. Because the Woodbine Formation is sandy and composed of relatively large particles (compared to clay) that do not pack tightly together, it contains pore spaces that allow water to percolate down, and therefore the Woodbine stays wet. The result is that it supports tree growth even during dry spells because trees can obtain water stored in the pores of the Woodbine through their deep roots. The band of trees crossing the prairie and growing on the Woodbine is called the Eastern Cross Timbers. Because the formations of this area are tilted slightly, their outcrop patterns are like stripes on a map, or bands of prairies and cross timbers on the ground.

The Woodbine and Eagle Ford formations extend from northeast of Dallas toward the city of Austin, paralleling the Balcones Fault Zone, movement along which raised Lower Cretaceous rocks relative to Upper Cretaceous rocks. The faults you can observe at Pinnacle Park and the U.S. Postal Service Bulk Mail Center along Interstate 30 are an extension of the Balcones Fault Zone. Those faults have dropped the Austin Chalk and underlying strata down by some seventy meters between Pinnacle Park and downtown Dallas.

There is a gap representing well over eighty million years between the youngest Metroplex Cretaceous bed and the oldest Pleistocene gravel. The contact between the Cretaceous and Pleistocene rocks in the Metroplex is an unconformity, a major gap in the rock record. Because the Cretaceous rocks are gently tilted, we can infer that uplift occurred, and whatever rocks of intermediate age that may have existed between the Cretaceous strata and the Pleistocene strata have long since eroded away.

We have been examining geology by looking at the composition and features of rock units, or formations. The definition of a formation is a body of rock generally characterized by some degree of internal lithologic homogeneity or distinctive lithologic features, and by being mappable at the surface (or traceable in the subsurface) at scales on the order of 1:25,000. A formation is the product of uniform or uniformly alternating conditions of formation. Therefore, we can use the geographic and stratigraphic relationships among formations to infer changes in environmental conditions through time and across geography.

The sizes of particles that comprise sedimentary rocks provide important clues about the environment in which the sediments were deposited. Sand is a particle size, as are clay and silt. Of the three, sand is the coarsest. You can see and feel the individual grains. Clay is the finest particle size. You cannot see the individual grains of clay. You can think of clay as chocolate; when you bite into it, there is no grit. In fact, clay is sometimes used as filler in chocolate bars.

Over all, the kinds of rocks and fossils found in each formation are reflective of the marine or terrestrial environments that were dominant at the time of deposition. Fossils of dinosaurs, mammals, and other land dwelling creatures are found in sedimentary

deposits laid down by rivers, streams, and lakes traversing the landscape. Oysters, clams, ammonites, sharks, and fish, among others, inhabited the oceans and are preserved as fossils in the sediments laid down on the floors of ancient seas.

As a general rule, in water-lain deposits, the larger the grain size, the higher the energy of the water necessary to transport the grains. Thus, in a deposit like the Woodbine that has some clay but lots of sand, the water from which the sand grains were deposited had enough energy to carry away most of the clay and silt, leaving behind the heavier sand. The sand grains of the Woodbine Formation are mainly composed of rounded grains of the mineral quartz. The Woodbine has both marine and terrestrial fossils because of the mixed depositional environments bordering the sea. The sedimentary structures and the fiddler crab colony at Lake Grapevine indicate deposition in a near intertidal setting. Dinosaurs walked along that same intertidal zone. The location where the skull of *Protohadros* was found has more clay and organic matter indicating a swampy environment near the shore.

After its deposition at sea level, the Woodbine was buried by hundreds, if not thousands, of meters of younger sediment, which has since been eroded away, leaving Woodbine strata once again exposed on the surface. While it was buried, the soft sands of which it was composed lithified to sandstone. Ground water percolating through the pores and spaces of the sandstone left iron mineral crusts and concretions. These younger diagenetic minerals are superimposed on the original Woodbine sediments and the structures developed in it while it was soft.

Two former SMU graduate students studied vertebrate fossils from the Woodbine Formation. One named the new duck-billed dinosaur *Protohadros byrdi* and the other named a new crocodylian *Woodbinesuchus byersmauricei* (after Johnny Byers and John Mautice of the Dallas Paleontological Society) and described the remains of an armored dinosaur and a meat-eating dinosaur. One of the most interesting sets of sedimentary structures found in the Woodbine Formation is two kinds of dinosaur tracks and the tracks of a purported bird. These tracks are, of course, fossils because they are evidence of past life. But they are also sedimentary structures. And they can inform us about the animals that made them. The youngest dinosaurs in this part of Texas (96 million years old) are found in the Woodbine. The farthest east in Texas where dinosaurs are found is in the Woodbine on the west side of DFW airport. Other Woodbine fossils include diverse invertebrates, excellent flowering-plant (angiosperm) leaves, fish, sharks, turtles, and an opossum. The Woodbine is a series of river, delta, swamp, and near shore deposits.

The shales of the Eagle Ford were deposited in a marine environment, in relatively calm water, and within the photic zone as inferred from the diverse fauna that inhabited the Eagle Ford sea bottom. The shales are recognizably different from the intervening Kamp Ranch Limestone that they enclose. The Kamp Ranch is a thin unit that has not been mapped in the traditional way because it is a small unit. It is a member of the Eagle Ford Formation, rather than a formation itself. It is a thin, coarse-grained member sandwiched between much thicker, finer grained shale members, and which together compose the Eagle Ford Formation. It is different from the muddy shales above and below it, indicating that a different depositional environment occurred when the Kamp Ranch was deposited, as compared to the beds above and below it. The sedimentary grains of the Kamp Ranch are sand-sized calcite particles, much more angular, sharp, and

elongate than the rounded quartz sand grains of the Woodbine Formation. The grains of the Kamp Ranch Limestone are mostly calcite prisms of broken *Inoceramus* clam shells.

Ripple marks, larger grain size, and other features indicate a higher energy environment of deposition for the Kamp Ranch relative to the shale of the Eagle Ford. A higher energy environment could be the consequence of a lowering of sea level, in which case the environment of deposition of the Kamp Ranch would be more closely analogous to near shore environments such as those seen in the Woodbine. However, the Kamp Ranch has little quartz sand or other sediments derived from land. Conversely, storm-generated waves may have stirred the ocean bottom, churning and grinding shells, washing in shell fragments in bottom currents, and winnowing away the clay. Or, as a third possibility, the depositional setting of the Kamp Ranch Limestone could have been the consequence of both a short period of minor sea level fall that allowed normal storm-generated waves to register on the bottom. The Eagle Ford ocean in which the shales and the Kamp Ranch were deposited was not particularly deep, probably on the order of a hundred meters or so, and the setting was only a few tens of kilometers from shore at most.

The Austin Chalk was deposited in clean, relatively deep water, perhaps up to 250 meters in depth. Chalk is a limestone rock composed almost entirely of tiny phytoplankton coccoliths. Very little sediment derived from the land made its way into this deeper marine depositional setting. The Austin Chalk is resistant to erosion and forms the high ridge - the White Rock Cuesta - on the west side of Dallas. Volcanic ashes in the Austin Chalk blew in from distant eruptions and have been dated at 86 Ma.

Note that in going from the Woodbine, up through the Eagle Ford, then up to the Austin Chalk the net grain size of sediments decreases. This sequence represents high-energy shore, shallow marine, and deeper, clean marine waters. It reflects a classic transgressive sequence as the sea spread over this area.

North-central Texas lay adjacent to the southern extent of the North American Western Interior Seaway during the Late Cretaceous Period. Because of its geographic position, sea level fluctuations governed sedimentary regimes. The Cretaceous rocks of the Metroplex were deposited in a series of marine transgressive and regressive events; that is, times when sea level rose followed by drops in sea level. Marine and non-marine interfingering produced complex facies relationships. Distant volcanic eruptions supplied volcanic ash, but the volcanic contribution was minor.

How Deep was the Water?

The relative position of sea level is shown in Figure 16, drawn from many sources, which encompasses the time in which the sea was inundating the Dallas area. Sea level rose through the early part of the Cretaceous Period to a high in the middle portion of the Cretaceous. It was not a smooth curve. Short-term variation was overprinted on long-term trends. An example of a possible small-scale event was the minor drop in sea level at 92 Ma, during the *Collignonicerias woollgari* Zone. You may have collected *C. woollgari* from the Kamp Ranch Limestone. Overall, the Eagle Ford ocean was moderately deep, but the Kamp Ranch Limestone, a small layer in the middle, was probably deposited in shallower water when sea level was temporarily lower.

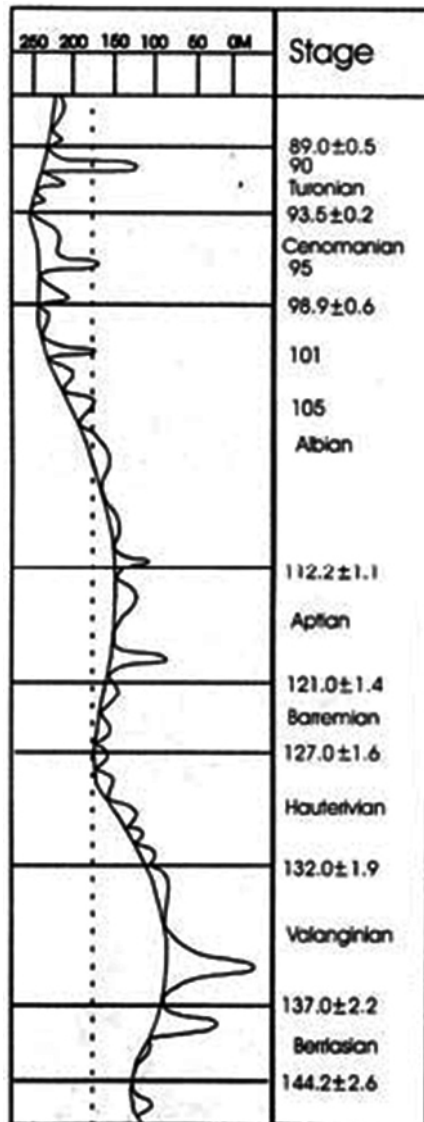


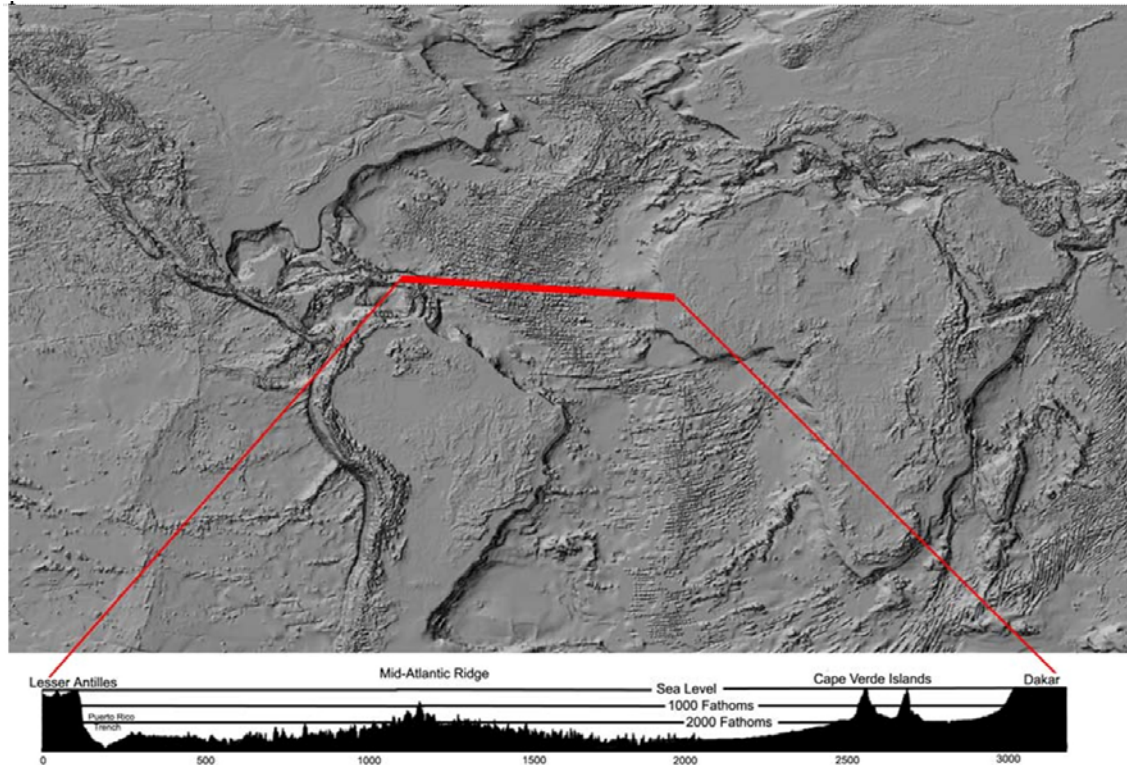
Figure 16. Sea level curve during the Cretaceous.

It is usually quite difficult to determine absolute water depth. Grain size, sedimentary structures, and fossils are useful. Clearly the Woodbine, at least in its intertidal portion, was never more than a few meters deep and periodically completely emergent. The Eagle Ford has been estimated to have been deposited in waters ranging in depth from 50 to 100 meters. Water depths for the Austin Chalk sea were estimated to range up to a maximum of 250 meters.

Why and How does Sea Level Change?

A lowering of sea level is obtained during Ice Ages when water is sequestered on land in glaciers. Another possible explanation for sea level change is variation in the size of ocean basins, which controls the amount of water they can hold in any given interval. In times when the volume of the basins is less, the oceans spill over the land. As you know from plate tectonics, oceanic crust is added to the edges of plates at mid-ocean ridges. The rock making up the new lithospheric crust is igneous and hot; therefore, it is

less dense than old, cooled crustal rock. Both young-and-hot and cool-and-old lithospheric plate rocks rest in buoyant equilibrium on the underlying plastic asthenosphere. As the hot rock at the spreading center gets older and moves away from the spreading center, it gets cooler. As it becomes cooler, it becomes denser and settles lower in the asthenosphere. That is why the profile of the ocean floor is concave (Figure 17).



In the plate tectonic context, the depth of any given spot of oceanic crust increases with the square root of time according to the following equation:

$$d_t = d_o + Kt^{1/2}$$

where d_o = initial depth (2500 – 2600 m)
 d_t = depth (in meters) at time t (in Ma)
 K = a constant (320 – 360 m)

The relationship between depth and age is shown by the following relationship:

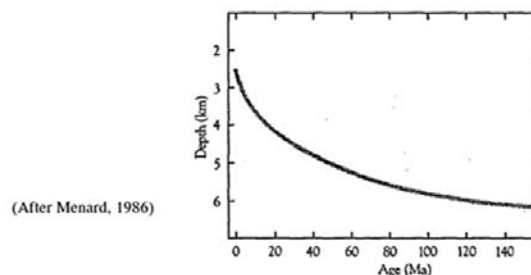


Figure 17. Diagram showing Digital elevation model of the Atlantic Ocean and profile of Sea floor between the Lesser Antilles and the Cape Verde Islands and the relationship between depth and age of the ocean floor. (One fathom = 1.83 m or 6 ft.)

As cooler rock sinks lower in the asthenosphere, the volume of the ocean basin increases. Conversely, when sea floor spreading is rapid, more of the sea floor is hotter, resting higher on the asthenosphere, and the volume of the ocean basin is reduced. When that happens, water spills over onto the continents.

The difference between climatic and tectonic sea level changes can be manifested in their magnitudes and in the rapidity of sea level change. Superimposed on either can be regional effects of basin formation, subsidence, and uplift. It is not always a simple matter to determine which is the cause, or even the major constituent in a particular sea-level change.

East Texas Oil

We have seen that the structure and dip of the rock formations on the surface of the Metroplex dip downward to the east. One of the most prolific regions for oil production in North America is called the East Texas Basin. Oil was first struck in the East Texas Field at the Daisy Bradford Number 3 well on October 5, 1930. The significance of the East Texas Oil Field lies first in its tremendous size and in its geological simplicity as an oil trap. The East Texas Field encompasses approximately 132,000 acres in Gregg, Rusk, Upshur, Smith, and Cherokee counties between Longview and Tyler. Since the Daisy Bradford came into production, 6,000,000,000 barrels of oil have been produced.

The eastern margin of the East Texas Basin, the structural basin containing the East Texas Oil Field, is the Sabine Uplift, a structural high that lies along the Texas-Louisiana border. The Sabine Uplift was active during the Cretaceous during the interval when the Woodbine, Eagle Ford, and Austin Chalk formations were being deposited. However, do not think that you can see the Sabine Uplift on a leisurely drive to the casinos of Louisiana; it is entirely subsurface with no expression above ground.

The main oil-producing layer in the East Texas Basin is the Woodbine Formation, on the surface in the Metroplex as seen on the shore of Lake Grapevine (Figure 18). As we have seen, the Woodbine Formation dips down to the east, extending far underground as much as 1,000 meters below the surface in the East Texas Field, and approaching twice that at its greatest depth. From the area of its deepest depth, the center of the East Texas Basin, the strata begin to rise toward the surface, powered by the Cretaceous rising of the Sabine Uplift. As the Sabine Uplift became elevated, the eastern edge of the Woodbine and Eagle Ford formations were raised above sea level and eroded away. Subsequent sea level rise brought about the deposition of the Austin Chalk, blanketing the formerly exposed erosional edge of the Woodbine and Eagle Ford and sealing the petroleum reservoir below the eroded edge of the Woodbine.

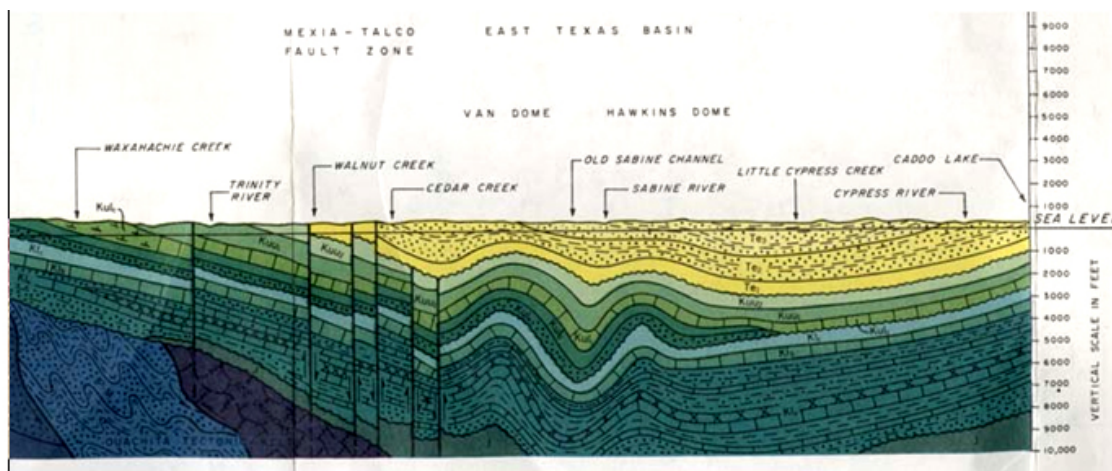


Figure 18. Cross section of the East Texas Basin. Note the pinch-out of the Woodbine Formation.

The Woodbine Formation is sandy because it was formed from beach dunes and deltas, but it also contains organic deposits formed from rotting plants and muck deposited in swampy areas along the ancient Woodbine coast. The reason the Woodbine is such a good reservoir for oil is the same reason it supports trees in the cross timbers: sand grains are relatively large compared to clay or silt particles so pore spaces between the sand grains can hold water – or in the case of the East Texas Field, oil. The Eagle Ford itself is dark and highly organic, meaning that it is a good source rock for oil and gas, as are the dark swampy organic layers of the Woodbine. The uplifting of the eastern flank of the East Texas Basin changed the geometry of the Eagle Ford and Woodbine formations so the petroleum formed from the organic Eagle Ford could flow into the Woodbine reservoir, along with oil produced from organic Woodbine layers, and the entire package was sealed by the Austin Chalk.

Along the western edge of the East Texas Basin, faulting related to the uplift of the Edwards Plateau on the west and subsidence in the East Texas Basin to the east resulted in the Balcones Fault Zone and related bands of faulting. On the western edge of the East Texas Basin where the Austin Chalk is broken by underground faults, it too is a good hydrocarbon source rock, and the fractures produced by the faults help to trap oil and gas.

ACKNOWLEDGMENTS

This guide and educational tool was first written for the National Earth Science Teachers Association Field Trip on 30 March 2005 when the NESTA Annual Meeting was held in Dallas. There has been continuing demand for this resource, and that is the reason we have modified, expanded, updated, and hopefully improved it, using as a catalyst the initiative taken by the Mesquite Independent School District in organizing a teacher field trip in March, 2007. In the interim, Norm Poff has passed away but his contribution to the original edition was so great that we are honored to retain him as co-author in recognition of that fact. In addition, Paul Ballou has joined our team. Thanks to all our friends in the Texas Earth Science Teachers Association and the Dallas Paleontological Society who have enjoyed the rocks and fossils of Texas with us. Thanks also the undergraduate and graduate students of Southern Methodist University who have

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REFERENCES AND FURTHER READING

INTRODUCTION

- Alexander, N. 1976. Father of Texas Geology: Robert T. Hill. SMU Press, Dallas.
- American Association of Petroleum Geologists. 1973. Geological Highway Map of Texas, 1:1,875,000. AAPG, Tulsa, Oklahoma.
- Diggs, G.M., Jr., Lipscomb, B.L., and O'Kennon, R.J. 1999. Shinner and Mahler's Illustrated Flora of North Central Texas. Botanical Research Institute of Texas.
- Francaviglia, R.V. 2000. The Cast Iron Forest. University of Texas Press.
- Jacobs, L.L. 1993. Cretaceous Airport: The Surprising Story of Real Dinosaurs at DFW. The Saurus Institute, Dallas.
- Jacobs, L.L. 1995. Lone Star Dinosaurs. Texas A&M Press.
- Jacobs, L.L., Ferguson, K. Polcyn, M.J., and Rennison, C. 2005. Cretaceous $\delta^{13}\text{C}$ stratigraphy and the age of dolichosaurs and early mosasaurs. Netherlands Journal of Geosciences, 84: 257-268.
- Jacobs, L.L., Polcyn, M.J., Taylor, L.H., and Ferguson, K. 2005. Sea-surface temperatures and palaeoenvironments of dolichosaurs and early mosasaurs. Netherlands Journal of Geosciences, 84: 269-281.
- Jacobs, L.L., and D.A. Winkler. 1998. Mammals, archosaurs, and the early to late Cretaceous transition in north-central Texas. In Tomida, Y., L.J. Flynn, and L.L. Jacobs (eds.) Advances in Vertebrate Paleontology and Geochronology in honor of Everett H. Lindsay. National Science Museum, Tokyo, Monograph 14: 253-280.
- Reaser, D.F. 2002. Geology of the Dallas-Fort Worth Metroplex and local geologic/meteorologic hazards. Pearson Custom Publishing, Boston.
- Shuler, E.W. 1918. The Geology of Dallas County. University of Texas Bulletin 1818.
- Kennedy, W.J., and Cobban, W.A. 1990. Cenomanian ammonite faunas from the Woodbine Formation and lower part of the Eagle Ford Group, Texas. Palaeontology, 33:75-154.

WOODBINE FORMATION

- Allen, E.A., Curran, H.A. 1974. Biogenic sedimentary structures produced by crabs in lagoon margin and salt marsh environments near Beaufort, North Carolina. Journal of Sedimentary Petrology, 44(2):538-548.
- Head, J.J. 1998. A new species of basal hadrosaurid (Dinosauria, Ornithischia) from the

- Cenomanian of Texas. *Journal of Vertebrate Paleontology*, 18(4): 718-738.
- Lee, Y.-N. 1997. The Archosauria from the Woodbine Formation (Cenomanian) in Texas. *Journal of Paleontology*, 71(6): 1147-1156.
- Lee, Y.-N. 1997. Bird and dinosaur footprints in the Woodbine Formation (Cenomanian), Texas. *Cretaceous Research*, 18: 849-864.
- Stephenson, L.W. 1952. Larger invertebrate fossils of the Woodbine Formation (Cenomanian) of Texas. *USGS Professional Paper* 242.

EAGLE FORD FORMATION

- Bell, G.L., Jr., and Polcyn, M.J. 2005. *Dallasaurus turneri*, a new primitive mosasauroid from the middle Turonian of Texas and comments on the polyphyly of Mosasauridae. *Netherlands Journal of Geosciences*, 84: 174-194.
- Bishop, G.A., and Brannen, N.A. 1992. *Homolopsis pikeae*, new species (Decapoda), a crab from the Cretaceous of Texas. *Journal of Crustacean Biology*, 12(2): 317-323.
- Dodge, C.F. 1952. Stratigraphy of the Woodbine Formation in the Arlington area, Tarrant County, Texas. *Field & Laboratory*, 20(2): 66-78.
- Hensleigh, D.E. 1983. Depositional setting of the Turonian Kamp Ranch Member, Eagle Ford Group, Northeast Texas. M.S. Thesis, University of Texas at Arlington.
- Hill, Lloyd E. 1976. Upper Cretaceous Vertebrates of North Central Texas. Taylor Publishing Company, Dallas, 48 pp.
- Kennedy, W.J., Cobban, W.A., and Landman, N.H. 2001. A revision of the Turonian members of the ammonite subfamily Collignoniceratinae from the United States Western Interior and Gulf Coast. *American Museum of Natural History Bulletin*, 267.
- Polcyn, M.J., and Bell, G.L., Jr. 2005. *Russellosaurus coheni* n. gen., n. sp., a 92 million-year-old mosasaur from Texas (USA), and the definition of the parafamily Russellosaurina. *Netherlands Journal of Geosciences*, 84: 321-333.
- Reid, W.T. 1952. Clastic limestone in the upper Eagle Ford Shale, Dallas County, Texas. *Field and Laboratory*, 20(3): 111-122.
- Shuler, E.W. 1950. A new elasmosaur from the Eagle Ford Shale of Texas: The elasmosaur and its environment. *Fondren Science Series*, SMU, 1(2): 1-31.
- Stephenson, L.W. 1955. Basal Eagle Ford fauna (Cenomanian) in Johnson and Tarrant Counties, Texas. *USGS Professional Paper* 274-C.
- Welles, S.P. 1949. A new elasmosaur from the Eagle Ford Shale of Texas. *Fondren Science Series*, SMU, 1(1): 1-28.

AUSTIN CHALK

- Stephenson, L.W. 1937. Stratigraphic relations of the Austin, Taylor, and equivalent formations in Texas. *USGS Shorter Contributions to General Geology*, 1936: 133-146.
- Welton, B.J., and Farish, R.F. 1993. The Collector's Guide to Fossil Sharks and Rays from the Cretaceous of Texas. *Before Time*, Dallas.

SUMMARY OF OCEAN DALLAS GEOLOGY

How Deep was the Water?

Sageman, B.B., and Arthur, M.A. 1994. Early Turonian paleogeographic/paleobathymetric map, Western Interior, U.S. In: Caputo, M.V., Perterson, J.A., and Franczyk, K.J. (eds.), *Mesozoic Systems of the Rocky Mountain Region, USA*. Rocky Mountain Section, SEPM (Denver): 457-469.

Why and How Does Sea Level Change?

Menard, H.W. 1986. *Islands*. Scientific American Library.

East Texas Oil

Clark, James A., and Halbouty, M.T. 1972. *The Last Boom: The Exciting saga of the Discovery of the Greatest Oil Field in America*. Random House, New York.

Halbouty, Michael T., and Halbouty, James J. 1982. Relationships between East Texas Field Region and Sabine Uplift in Texas. *American Association of Petroleum Geologists Bulletin*, 66(8): 1042-2054.

Robison, C.R. 1997. Hydrocarbon source rock variability within the Austin Chalk and Eagle Ford Shale (Upper Cretaceous), East Texas, U.S.A. *International Journal of Coal Geology*, 34: 287-305.