THE GEOLOGY OF THE GULF COASTAL PLAIN IN MARSHALL COUNTY, OKLAHOMA

AN INTRODUCTION AND FIELD-TRIP GUIDE

OKLAHOMA GEOLOGICAL SURVEY
OPEN-FILE REPORT OF1-97

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AN INTRODUCTION AND FIELD-TRIP GUIDE

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INTRODUCTION

PURPOSE OF THE FIELD TRIP

Members of the Oklahoma Academy of Science have briefly visited rocks of the Gulf Coastal Plain twice in the recent past. On the spring 1995 field trip, we collected the echinoid *Enallaster texanus* (Roemer) from the Goodland Limestone at the Meridian Aggregates Company quarry just north of the town of Idabel. On the spring 1996 field trip, we saw a major unconformity just south of Lake Murray where the very tilted Pennsylvanian Pumpkin Creek Limestone (about 310 million years old) was overlain by the nearly horizontal Cretaceous Antlers Sandstone (about 108 m.y. old) (note - this age is more accurate than that given in the Lake Murray guidebook).

This year, members of the OAS will once again visit the sedimentary rocks of the Oklahoma Gulf Coastal Plain, but our objectives will be slightly different. We will apply some fundamental geologic principles to what we see in the rocks and attempt to determine under what environmental conditions the sediments were deposited about 100 m.y. ago. Were the sediments deposited in a river valley, on a beach, a delta, or in the ocean? How deep in the ocean? We will consider how the Cretaceous sea level changed in this part of Oklahoma and we will construct our own "sea-level curve" for this time period. We will then compare our curves to published worldwide sea-level curves of the Cretaceous. All along, we will try to picture what this part of Oklahoma looked like during the time of *T. rex.*, or even better, our own *Acrocanthosaurus atokensis.*

SOME GENERAL GEOLOGICAL PRINCIPLES (AND ASSUMPTIONS)

There are many, many clues that geologists use to give them information about the conditions under which a geologic formation (or sediments that make up the formation) was deposited. Sometimes the context of the particular formation is important, i.e., what kinds of rocks are directly above and below the one you're interested in? You wouldn't expect coal, known to have been deposited as peat in swamps and marshes, to be adjacent to rocks you know were deposited in a deep-marine environment. Sometimes it's important to know how a particular formation changes as you follow it to the north, south, east, or west. Most of the time this isn't possible, because uplifted rocks are typically eroded and/or buried beneath younger rocks. If a formation is eroded, the evidence for how it changes is gone ... lost forever. If a formation is buried by younger rocks, oil and gas wells might have drilled into it and may provide some information about it.

In addition, there are many features in the rocks themselves that give geologists information about the rock's environment of deposition. We will see some of these features on our field trip. Some features are unique to a certain environment; others (most?) are not. The underlying assumption is that the sedimentary features we observe in recent sediments in known environments have an origin similar to the same features we observe in the rock record, and that modern environments are similar to those of ancient times. In this way, geologists use certain sedimentary features, or combination of features, to infer ancient depositional environments.

Given this assumption (some would call it a limitation), we can make the following broad generalizations. **Sandstone** characterizes a river or near-shore environment, e.g., the sand bars in a river, a beach, the shoreface (Fig. 1). The larger the size of the individual sand grains, the stronger the current that deposited them. **Shale**, being very fine-grained (originally mud), is deposited where there is little current or wave action, but some input of sediment. **Limestone** is deposited in a marine environment, typically where there is little sediment in the water to kill the critters that deposit the lime. The water is not so deep, however, that photosynthesis cannot occur. Some **fossils** prefer living in shallow water, others prefer deep water. Broken fossils indicate lots of current or wave action. Sedimentary features such as ripple marks and cross-beds also indicate current or wave action.

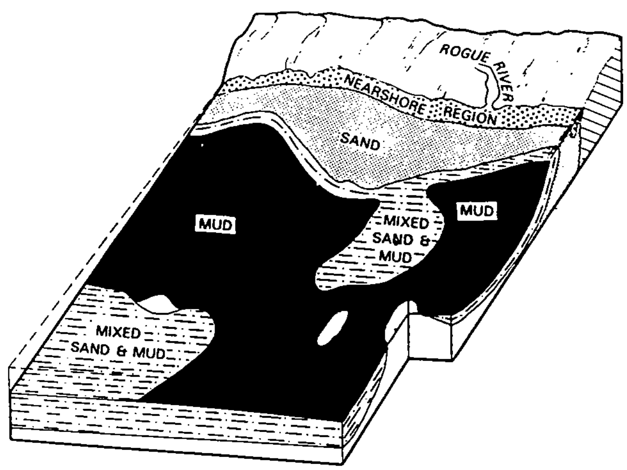

Fig. 1. Schematic distribution of sediment types off the coast of Oregon. Limestone would be deposited further offshore if the water was warmer and sediment-supply less (from Reading, 1978, p. 223).

SEQUENCE STRATIGRAPHY

One of the most exciting developments in geology in recent years is the concept of "sequence stratigraphy". In the late 1970's, research geologists with Exxon published a paper suggesting that they could recognize sequences of geologic strata on a worldwide basis. They related these sequences to worldwide sea-level changes. If sea level drops, the coastline migrates seaward, and sand and silt delivered to the coast by rivers is distributed across the continental shelf and occasionally reaches the deep ocean basins. If sea level rises, the coastline migrates inland, and areas that were formerly covered by terrestrial sediments are buried beneath marine sediments and shallow-marine sediments are covered by deep-marine sediments. The Exxon researchers claimed these packages, or "sequences", of rocks that represented changing sea levels could be correlated throughout the world.

Figure 2 is the global sequence stratigraphic chart for the Triassic. There are far too many details on this chart for us to worry about, but a few features are important. (Those OAS members who attended our fall 1995 field trip in the Ozarks might recognize the term "Absaroka". The older literature recognized the Absaroka as a "major transgressive sequence"; the Exxon geologists considered the upper part of the Absaroka a "megacycle".) The Triassic is divided into Lower, Middle, and Upper, and even further into stages based on the presence or absence of key micro- and macro-fossils. These fossils are shown on the chart under "biochronozones". The Exxon workers correlated these with features associated with advances and retreats of coastlines. On the chart, a leftward shift of the shaded gray areas means the coastline moved landward. A rightward shift means the coastline moved seaward. What appears to be a gradual advance of the sea compared to the sudden retreat is artificial - retreats expose sediments to erosion, which is represented in the rock record by a single event, or unconformity. An advance is represented by a thick sequence of sedimentary rocks.

Analysis of these observations result in the eustatic, or sea-level curve. A left deflection represents rising sea level, and right deflection falling sea level. Note that two curves are shown - a long-term (first-order) curve and short-term (second-order) curve. Detailed study of the second-order curve would undoubtedly reveal many shorter-term (third-order) sea-level fluctuations superposed on it.

Since the introduction of "sequence stratigraphy", geologists have refined and modified the concept. An important restriction to its use is that it doesn't work in areas of active uplift or subsidence; if the land is rising rapdily, the effects of sea-level changes are completely masked.

On this trip, we will see evidence for changing Cretaceous sea levels. At the end of the trip, we'll draw our own sea-level curves, compare them to published versions, and argue about what order they represent!

GENERAL GEOLOGY OF THE GULF COASTAL PLAIN

Most of the southeastern corner of Oklahoma is covered by rocks that are part of what geologists call the Gulf Coastal Plain. In the southern U.S., the Gulf Coastal Plain represents the former extent of a "paleo" Gulf of Mexico and forms a rim around what is known as the Gulf of Mexico basin (Fig. 3). The Gulf of Mexico basin is a roughly circular depression about 1200 miles in diameter, centered on the Gulf of Mexico. The basin includes, from east to west, all of Florida; southern Georgia, Alabama, and Mississippi; all of Louisiana; extreme southern Arkansas, and southeastern Texas (Dallas, Austin, and San Antonio are just outside the basin). The edge of the basin in Arkansas and Texas is marked by a number of down-to-the-south or -southeast normal faults.

The Gulf of Mexico is undergoing active subsidence and sediments are slowly accumulating in it. The Mississippi River delta is one place where tremendous volumes of sediment are being transported into the basin and being deposited. In fact, the Gulf of Mexico, or perhaps more properly a "paleo" Gulf of Mexico, has been subsiding since the Late Jurassic, about 150 million years ago. The largest the "paleo" gulf ever got occurred in the Early Cretaceous, about 110 million years ago; it has been contracting (albeit with fits and starts) ever since. As a result of this contraction, the oldest rocks representing the former extent of the "paleo" gulf are found at its very rim; as one goes toward the center of the basin, i.e., towards the present Gulf of Mexico, the rocks become younger. In Houston, the rocks are so young they aren't even rocks yet - they're sand, silt, and mud.

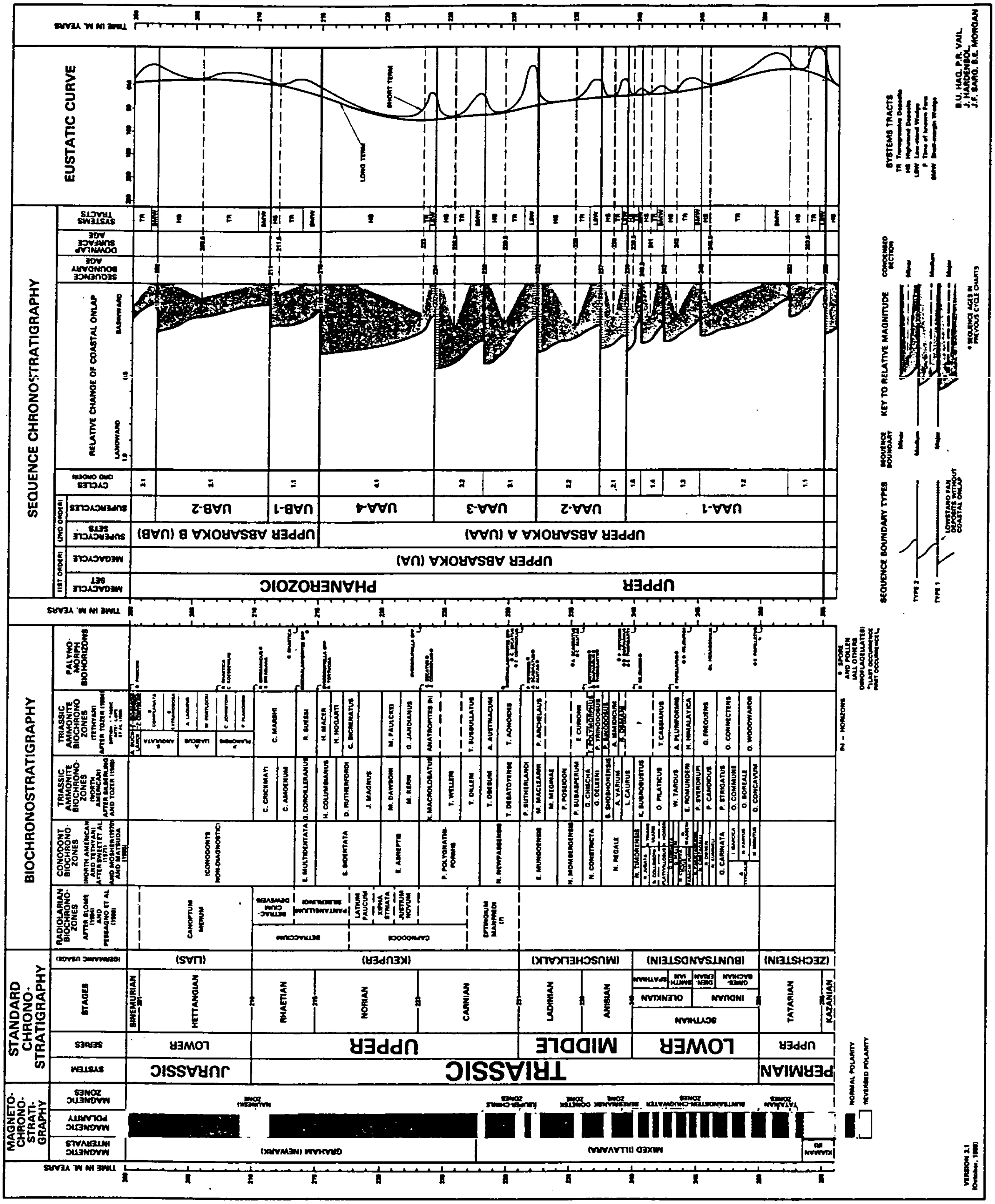

Fig. 2. Triassic chronostratigraphic- and eustatic-cycle (sea-level) chart (from Haq and others, 1988, p. 100). Note that the Triassic had generally higher sea levels than either the immediately preceding Upper Permian or immediately following Lower Jurassic.

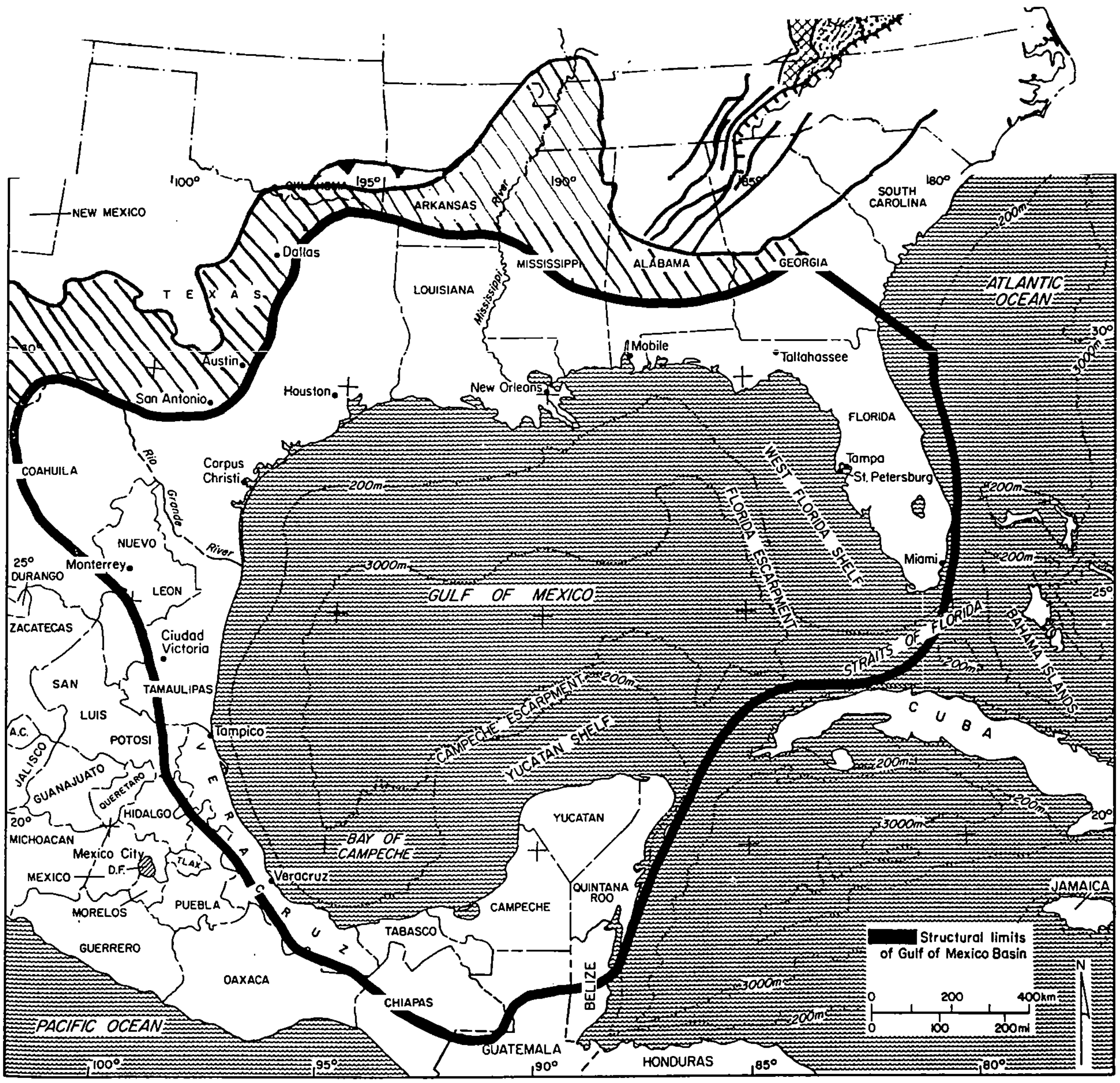

Fig. 3. Map showing the Gulf of Mexico basin (outline by heavy line), Gulf Coastal Plain (cross-hatched area), and Ouachita Mountains of Oklahoma and Arkansas (line with sawteeth) (modified from Salvador, 1991).

GENERAL GEOLOGY OF MARSHALL COUNTY

GEOLOGY

Most of the rocks in Marshall County are Cretaceous in age (Fig. 4). These rocks cover the highly folded and faulted rocks of the Ardmore basin, Arbuckle Mountains, and Ouachita Mountiains (Fig. 5). The Cretaceous period of the Earth's history lasted

SYSTEM	SERIES	GROUP, FORMATION, MEMBER	LITHOLOGY	THICKNESS (feet)	DESCRIPTION
QUATERNARY	Holocene	Alluvium		15–25	Clay, sand, and silt of modern flood plains.
QUATERNARY	Pleistocene	Terrace deposits		0–120	Sand, silt, clay, and gravel deposited at various levels by Red River and Washita River. Levels are designated Qt_2, Qt_3, Qt_4, and Qt.
CRETACEOUS	Gulfian	Woodbine Formation; Dexter Member		0–35	Reddish-brown, ferruginous pebble conglomerate, overlain by light-brown, fine-grained sandstone with medium-scale cross-bedding; exposed thickness, 17 feet.
CRETACEOUS	Comanchean	Washita Group; Grayson Marlstone		0–20	Thin-bedded, greenish-gray marlstone with interbeds of white nodular limestone; upper beds are olive-green calcareous shale.
CRETACEOUS	Comanchean	Washita Group; Bennington Limestone		1.5-2.5	Blue-gray to brown, heavy-bedded, fine- to medium-crystalline, fossiliferous limestone with *Ilymatogyra arietina* (Roemer).
CRETACEOUS	Comanchean	Washita Group; Bokchito Formation; Pawpaw Sandstone Member		55	Yellow to reddish-brown ferruginous sandstone interbedded with lenses of grayish-brown sandy shale and clay; abundant molds of *Protocardia*.
CRETACEOUS	Comanchean	Washita Group; Bokchito Formation; McNutt Limestone Member		1–20	Reddish-brown, sandy, fossiliferous limestone with abundant *Lopha quadriplicata* (Shumard). "Quarry limestone" of older reports.
CRETACEOUS	Comanchean	Washita Group; Bokchito Formation; Weno Clay Member		60–90	Gray to brown, iron-stained, ferruginous sandy shale with molds of *Protocardia* and *Turritella*; grades upward into yellow-orange, fine-grained, massive sandstone.
CRETACEOUS	Comanchean	Washita Group; Bokchito Formation; Soper Limestone Member		1–2	Brown, fossiliferous limestone containing *Arctostrea carinata* (Lamarck), *Texigryphaea washitaensis* (Hill).
CRETACEOUS	Comanchean	Washita Group; Bokchito Formation; Denton Clay Member		45–55	Blue clay shale in lower part; bed of brown, ripple-marked sandstone near middle; upper part is brownish-yellow and silty and grades into shaly, fossiliferous marlstone at the top.
CRETACEOUS	Comanchean	Washita Group; Caddo Formation; Fort Worth Member		40	Light-gray shale interbedded with gray to white to buff limestones which weather cream-colored; fossiliferous.
CRETACEOUS	Comanchean	Washita Group; Caddo Formation; Duck Creek Member		110–130	Lower part includes gray shale and interbedded blue-gray silty limestone containing large cephalopods; upper part mainly blue-gray unfossiliferous shale.
CRETACEOUS	Comanchean	Fredericksburg Group; Kiamichi Formation		35–40	Black, fissile clay shale with scattered siltstone lenses; 1-foot bed of siltstone near middle; thin interbeds of yellow-gray, fossiliferous limestone near the top, forming the "shell beds," composed of abundant *Texigryphaea navia* (Hall).
CRETACEOUS	Comanchean	Fredericksburg Group; Goodland Limestone		15–25	White, massive, biomicritic limestone; weathers gray to yellow; upper beds weather into thin curved plates; lower beds argillaceous and locally nodular; Walnut Clay facies with *Ceratostreon texanum* (Roemer) at base of some exposures.
CRETACEOUS	Comanchean	Trinity Group; Antlers Formation; Antlers sandstone facies		200–600	White to dull-orange, fine- to medium-grained quartz sand; locally cross-bedded; ferruginous, with lenses of clay.
CRETACEOUS	Comanchean	Trinity Group; Antlers Formation; Baum Limestone Member		0–13	Upper part: light-gray, fine-grained, micritic limestone. Lower part: pale-yellow to white, coarsely crystalline conglomeratic limestone.

Fig. 4. Stratigraphic sequence of Cretaceous rocks in Marshall County (modified from Huffman and others, 1987, p. 16-17).

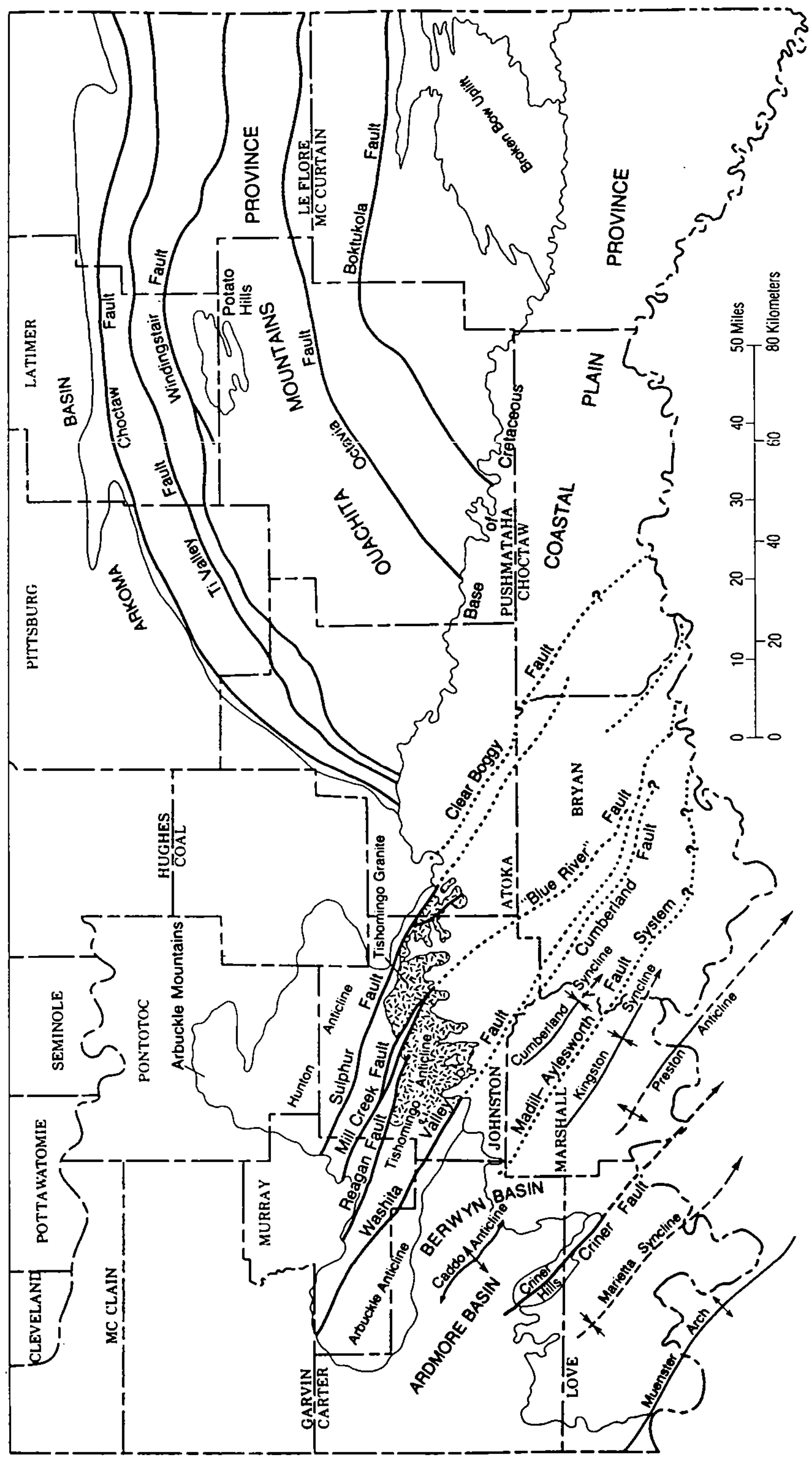

Fig. 5. Map showing location of Marshall County in relation to the Ouachita Mountains, Arbuckle Mountains, and Ardmore basin (from Huffman and others, 1987, p. 45). Dotted lines are faults that are buried by younger rocks; dashed lines are folds of inexact location; solid lines are well-located faults and folds. The line labelled "base of Cretaceous" is the northern limit of the Cretaceous rocks of the Gulf Coastal Plain. This field trip is in the southeastern corner of Marshall County.

from about 131 to 66.5 million years ago. (The Cretaceous period is the third and last period of the Mesozoic era, popularly known as "The Age of the Dinosaurs". And, in fact, bones of the carnivore *Acrocanthosaurus atokensis* have been discovered in the Antlers Sandstone in Atoka and McCurtain Counties.) The oldest Cretaceous formation in Marshall County, the Antlers Sandstone (Fig. 4), is about 108 m.y. old; the youngest is the Woodbine Formation, which is about 94 m.y. old.

As stated above, the rocks of the Gulf Coastal Plain become younger to the south or southeast, but that younging of rocks occurs on a very broad, perhaps continental, scale. In Marshall County, there are two factors that complicate the simple picture: topography and folding. The rocks of the Gulf Coastal Plain in Oklahoma are nearly horizontal; as a result, topography plays an important role in how the different formations are portrayed on a map (Fig. 6A). For example, if an east-west oriented stream erodes into some almost flat-lying rocks (similar to those in Marshall County), the older rocks will be exposed in the stream bottom and progressively younger rocks on the banks of the stream valley. If one looks only at the north bank of the stream, old rocks will be exposed in the stream bottom (south) and young rocks will be exposed to the north, exactly the opposite of the *general* southward-younging of Gulf Coastal Plain rocks.

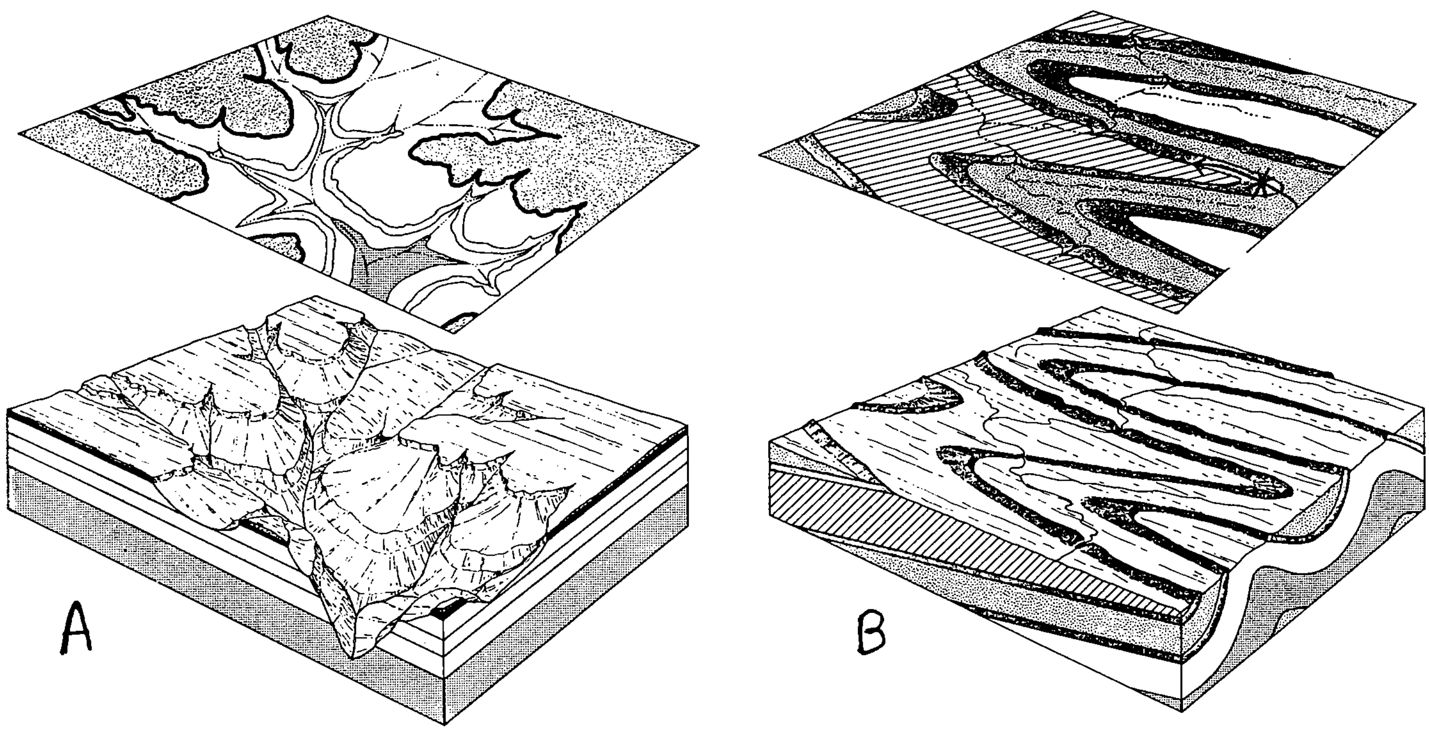

Fig. 6. Map pattern (top) and block diagram (bottom) of horizontal or almost horizontal strata (A) and folded strata (B) (from Hamblin and Howard, 1971, p. 121, 125).

In addition, the Gulf Coastal Plain rocks of Marshall County are very gently folded. Anticlines (upfolds) expose older rocks in their cores; synclines (downfolds) expose younger rocks in their cores. Also, the folds are tilted (or plunge) very gently to the southeast. If the surface of Marshall County were flat and all we had to worry about were the folds, the geology of the county would look something like Figure 6B. But the county is not absolutely flat, and the simple picture of folded rock layers is complicated by topography, as discussed above. This yields an outcrop picture that looks like a series of very squiggly S's (Fig. 7). But overall, the Cretaceous strata of Oklahoma's Gulf Coastal Plain are younger to the south.

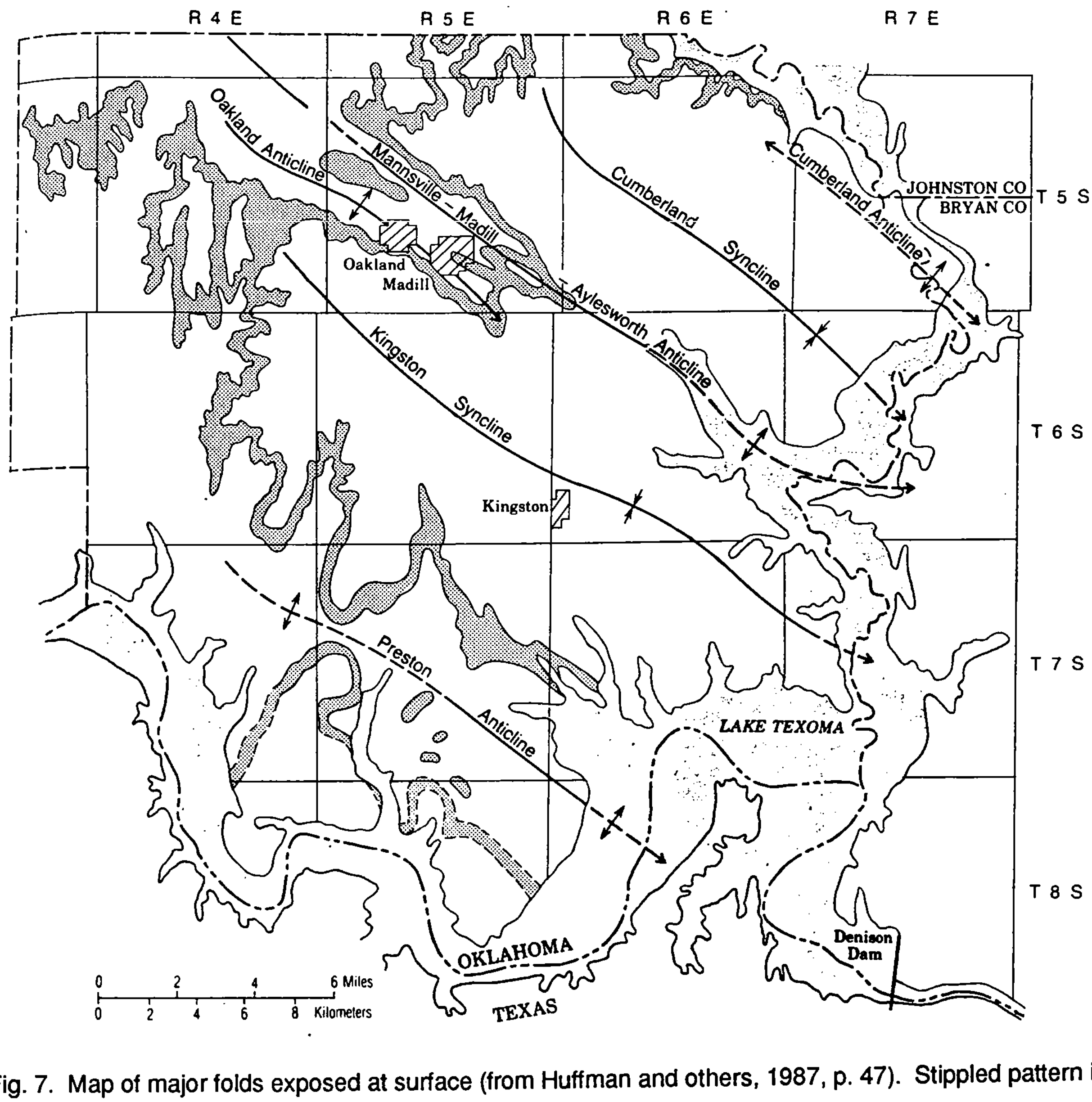

Fig. 7. Map of major folds exposed at surface (from Huffman and others, 1987, p. 47). Stippled pattern is outcrop of Goodland Limestone.

The exact origin of the folds is unknown, but the fact that they trend parallel to the major faults and folds of the Arbuckle Mountains and Ardmore basin suggest they are related. Huffman and others (1987, p. 48) suggest the "Cretaceous rocks have responded to structural adjustments along these older, preexisting Paleozoic structures." Exactly what the words "responded" and "adjustments" mean is anybody's guess.

FOSSILS

Like the assumption stated above regarding the use of certain features in sedimentary rocks to interpret ancient depositional environments, geologists also use the fossils they find in the rocks to say something about the conditions under which the rocks were deposited. Most of the fossils in the Cretaceous rocks of Marshall County are similar to the living creatures we see today in the marine environment. Therefore, geologists are pretty sure that most of the rocks in Marshall County were deposited in an ancient ocean. The following is a very simplifed and shortened list of the major kinds of fossils found in Marshall County:

I. Mollusks. "Shellfish" with solid, limy, external shells.

A. Pelecypods. A bivalve with bilaterally symmetrical shells, hinged along its back. Includes, for example,

1. Oysters (App. IA)
2. Scallops (App. IA)
3. Clams (App. IB)

B. Gastropods. A univalve with a spirally coiled, unchambered, asymmetrical shell. Includes, for example,

1. Snails (App. II)

C. Cephalopods. A univalve with a shell shaped like a slender cone, either straight, curved, or coiled, and chambered. If coiled, generally in a flat spiral. Includes, for example,

1. Ammonites (extinct) (App. III)

II. Echinoderms. Animal with short, commonly globular body. Develops shell of limy plates, typically with 5-rayed symmetry. Includes, for example:

A. Echinoids (sea urchins) (App. IV)

III. Brachiopods (App. V). Bivalve that is bilaterally symmetrical through the middle of each shell. In life, attached to bottom by fleshy stalk.

There are other rarer fossils in the rocks of Marshall County, but we will not discuss them in this paper.

RESOURCES

There are a number of geologic resources in Marshall County. Most of the oil and gas is produced from Paleozoic rocks that are considerably older than and buried beneath the Cretaceous rocks. A minor amount of oil, however, is produced from the Antlers Sandstone. The Goodland Limestone is a major source of agricultural lime, road material, and concrete aggregate and is currently mined by Meridian Aggregates Company at their Rushing Quarry. Sand and gravel are abundant near Lake Texoma and are used for road-surfacing materials. Water supplies are abundant in Lake Texoma and the Washita River, and the Antlers Sandstone is a major aquifer in the region.

ROAD LOG FOR FIELD TRIP

The site of the spring 1997 field meeting of the Oklahoma Academy of Science is at Cross Point Methodist Camp, located about 5 miles due south of Kingston, Oklahoma, on the shores of beautiful Lake Texoma. The geology field trip will be entirely in Marshall County; for those interested in a more detailed report on the geology of Marshall County, I suggest reading Oklahoma Geological Survey Bulletin 142, "Geology and Mineral Resources of Marshall County, Oklahoma", by George G. Huffman and others. Dr. Huffman was a professor of geology at the University of Oklahoma and worked with many, many students throughout Oklahoma.

All the field trip stops are on the Kingston South 7.5' topographic map. Driving directions to each stop are given, as well as section-township-range location. The field trip starts in the Cross Point Methodist Camp.

A NOTE ABOUT COLLECTING ROCKS AND FOSSILS

All of our stops are on public (Corps of Army Engineers) or private land. We have been given permission by the landowners to collect on their land. You are free to collect whatever fossils (or rocks) strike your fancy. But don't be greedy. While it may appear there are plenty of fossils to go around, and in some cases there probably are, there are limits (e.g., see Stop 3).

In camp, drive (or walk) towards the large cross on the east side of camp. This cross is on a point of land jutting into Lake Texoma. About 100 yards before getting to the cross, turn south and descend the bank to the lake.

BE CAREFUL!

CHOOSE WHERE TO DESCEND TO THE LAKE CAREFULLY!

SOME PLACES ARE VERY STEEP!

STOP 1. ANTLERS SANDSTONE (TRINITY GROUP)

Location: extreme south-center sec. 19, T. 7 S., R. 6 E.

The Antlers Sandstone is the oldest Cretaceous formation in most of southern Oklahoma. In the eastern part of McCurtain County, there are two slightly older Cretaceous formations (Holly Creek Formation and DeQueen Limestone), but these are not present here. The Antlers Sandstone unconformably overlies the much older rocks of the Ouachita and Arbuckle Mountains. In this case, the unconformity is a special kind called an angular unconformity because the Ouachita/Arbuckle rocks are very deformed and are typically steeply tilted, whereas the Antlers is essentially flat-lying. This results in an "angle" between the rock layers above and below the unconformity.

Those of you who attended our Lake Murray field trip a year ago may remember we saw the unconformity at Stop 5. There, the Antlers Sandstone (about 108 m.y. old) overlies the tilted Pumpkin Creek Limestone Member of the Big Branch Formation (about 310 m.y. old). The angular unconformity at Lake Murray represents 200 million years of Earth's history that is missing - we must look elsewhere to learn what went on in Oklahoma at that time. In Marshall County, the youngest rocks the Antlers overlies are about the same age, based on the subsurface rocks penetrated by drill holes.

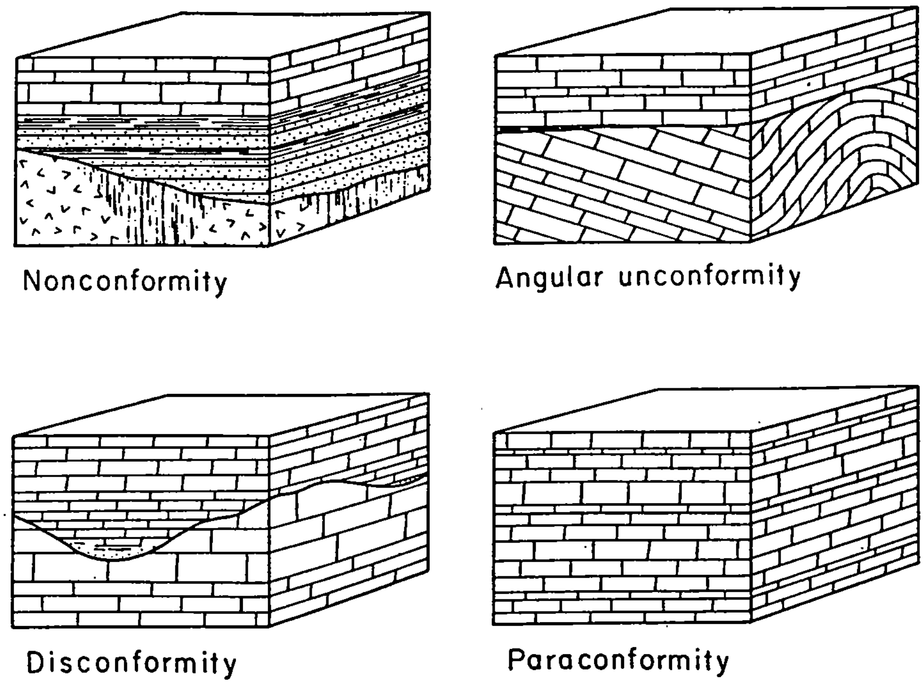

Fig. 8. The four types of unconformities, each of which represents a significant erosional gap in the rock record. A nonconformity occurs between sedimentary rocks and older plutonic and/or metamorphic rocks. An angular unconformity occurs between folded and/or otherwise tilted sedimentary rocks and less tilted rocks. The bedding planes above and below a disconformity are parallel but there is an irregular erosional surface separating the two. A paraconformity is a simple bedding plane, but one that marks a significant period of non-deposition.

Huffman and others (1987, p. 23) describe the Antlers Sandstone as follows:

"The Antlers (Sandstone) ... consists of loosely consolidated, weakly cemented, white to yellow, cross-bedded, unfossiliferous pack-sand with subordinate amounts of clay. The sand is fine- to medium-grained, soft, and friable, some layers being better indurated than others. The clays are gray to black to dark grayish purple, slightly silty, and locally stained a reddish orange or yellow from iron oxides and other minerals that form in the weathering zone. The clays and sands offer little resistance to erosion and are exposed in deep ravines and on steep slopes developed beneath the Goodland escarpment."

Based on the outcrop of Antlers Sandstone at Cross Point, it is easy to see why many geologists call it the Antlers "sand" and not sandstone; it is, indeed, very poorly consolidated. In places, more indurated blocks of the sand"stone" are covered with small bumps or knobs. Calcite, possibly derived from weathering of the overlying Goodland Limestone just upslope and reprecipitated in the sandstone, typically weathers to such small bumps. Note also the brown "nodules" in the sandstone - these are limonite concretions. Limonite is an iron-oxide mineral, and several of the limonite concretions have the form of burrows (Fig. 9D, left behind by some long-dead critter.

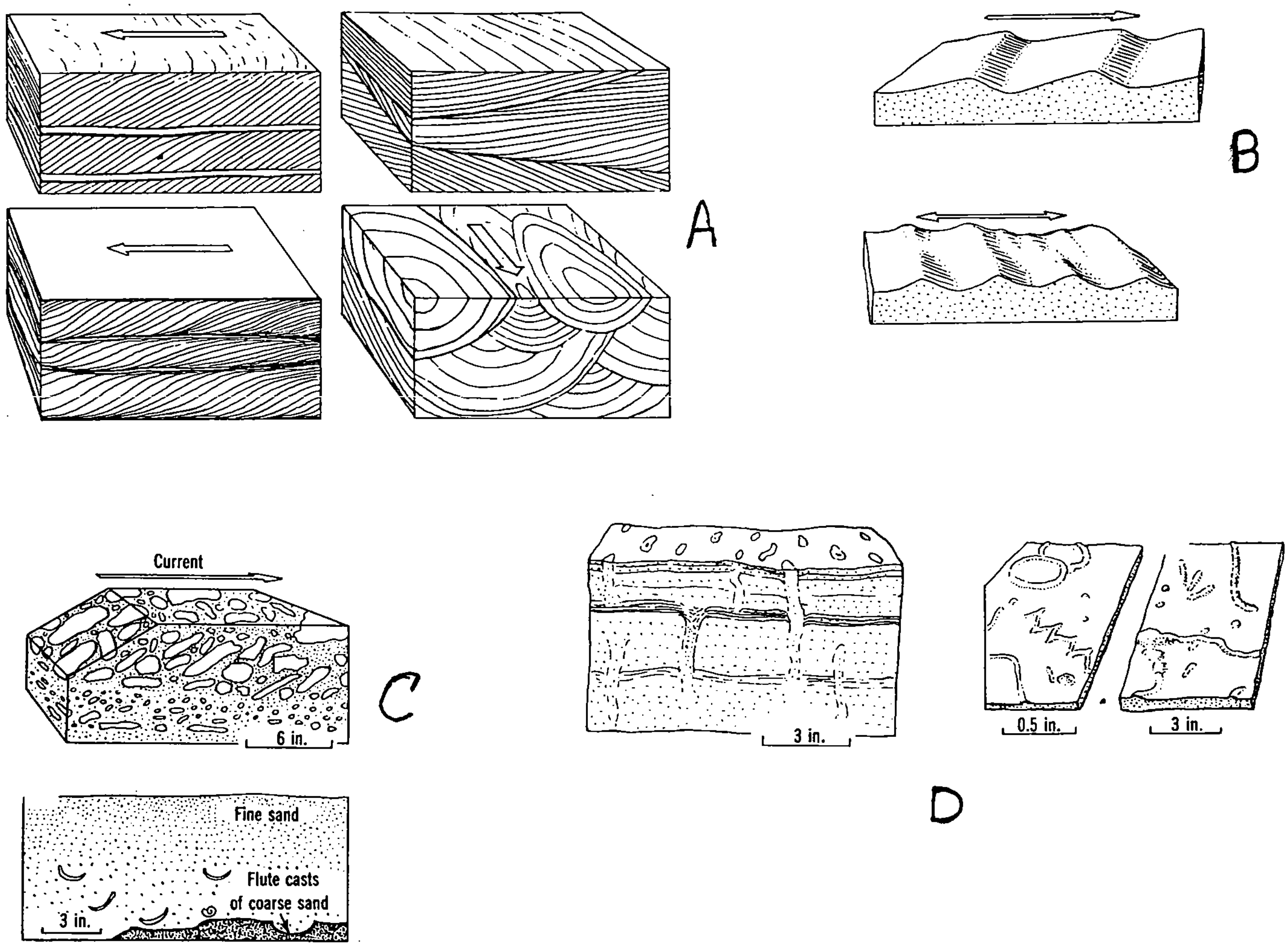

Fig. 9. Common features in sedimentary rocks. A. Cross-bedding, including festoon cross-bedding (upper left). B. Ripple marks. C. Pebbles (top) and shells (bottom) in sandstone. D. Trace fossils (burrows) (from Compton, 1962).

Several other features to note in this outcrop are the thin outcrops of dark gray shale. Although the Antlers is referred to as "Sandstone", it does include other rock types. (See discussion at Stop 5, Pawpaw Sandstone.) Note also that some layers consist of small pebbles and, in places, cobbles (Fig. 9C). Huffman and others (1987, p. 24) noted that the basal part of the Antlers contains conglomerate beds, but here the conglomerates are present very near the top of the Antlers (the Goodland Limestone is just above us!). What rock types make up the pebbles and cobbles? If geologists could positively tie the pebbles to a source area, we'd know what area was eroding to provide the material that makes up the Antlers Sandstone. No one has convincingly done that, but there is evidence in this outcrop to tell us the general direction of the source area.

Note the cross-bedding in some of the sandstones in this outcrop. They are a particular type called "festoon" cross-bedding (Fig. 9A). Note the direction they dip. This direction is the down-current direction. Based on this outcrop, what direction was the current flowing when it deposited these sands. Be sure not to look at just one layer of festoon cross-bedding, but several. Is the direction of current-flow consistent? What direction was the source area?

How strong was the current to form the cross-beds and deposit the pebbles and cobbles? Do you see any evidence for marine life, such as fossil shells? What do you think the environment of deposition was for the Antlers Sandstone? Does the Antlers Sandstone represent a sea-level highstand or lowstand (assuming this part of the world was stable during this part of the Cretaceous)?

Get in cars, drive out of camp to north. Cross two low-water arms of Lake Texoma. After crossing the second arm (where Rock Creek empties into Lake Texoma), the road climbs for about 0.2 miles, bears left, and heads due north into Kingston. Just after the road bears left (and before you start heading due north), turn right (east) towards Caney Creek. Drive 1 mile, turn right (south) (the road turns right as well, so you have to do it, too!). Drive south 1 mile, the road bears left. In about 0.2 miles, there is an entrance station to the Caney Creek Campground. Immediately after going through the entrance station, bear right. Drive about 0.2 miles to where the road swings left and park. Walk south to edge of Lake Texoma.

STOP 2. GOODLAND LIMESTONE (FREDERICKSBURG GROUP)

Location: center s 1/2 sw 1/4 sec. 20, T. 7 S., R. 6 E.

As we saw (albeit poorly) at Stop 1, the Goodland Limestone directly overlies the Antlers Sandstone. In places in Marshall County, there is a thin bed of shale at the base of the Goodland called the Walnut Clay. Since it is so poorly exposed and may not be present everywhere, it is considered part of the Goodland Limestone here. For those of you who attended the OAS 1995 spring field meeting and went on the geology trip, you may remember we saw the Goodland Limestone at the Meridian Aggregate Company quarry near Idabel. The Goodland Limestone is quarried at several places along it's outcrop belt, mostly for aggregate. In fact, many of the graded gravel roads we will be driving on appear to be "paved" with Goodland Limestone.

This outcrop of Goodland is a spectacular example of geology in action. The primary force for most examples of active geology is GRAVITY. Here, the outcrop of nearly horizontal Goodland Limestone is being undercut by the wave action of Lake Texoma, vertical fractures are forming, and large blocks are breaking off and sliding into the lake. Slowly, but irrevocably, the shoreline will work its way back, exposing new outcrops of Goodland Limestone.

Note that the Goodland Limestone at this outcrop has a very knobby weathering appearance. This is very typical of limestone in a humid environment. Remember the small (and large) knobs we saw in the calcite-cemented Antlers Sandstone at Stop 1?

The Goodland is loaded with many varieties of fossils at this outcrop. What, in your opinion, would you identify as the most common? (It's OK to suggest a common name for now.) In a brief visit I made here a month ago, I identified oysters, two varieties of snails, and a single piece of coral. Using the appendices, can you give some of the fossils you observe their Latin names, possibly even to the species level? Given the absolute profusion of one variety of fossil, can you guess at the possible environment of deposition? When the OAS visited the Meridian quarry near Idabel, we found abundant echinoids (fossil sea urchins)(especially *Enallaster texanus* (App. IV)) but there are none here. Can you offer an explanation for why echinoids are present to the east, but not here?

Look now at the lower brownish-colored platform below the main ledge of gray limestone. Break off a piece. Look at it closely and determine what kind of rock it is. Does it have any fossils? What kind are they? Look along the shore and try to determine what kind of rock lies between the lower, brown, platform-forming rock and the gray limestone ledge. Bear in mind that this intermediate rock type is poorly exposed, but it is there! Can you find it?

The sequence here, from youngest to oldest (top to bottom), looks like:

1. gray limestone
2. poorly exposed shale, possibly 3 feet thick
3. fossiliferous sandstone.

Perhaps the fossiliferous sandstone is transitional from the unfossiliferous Antlers to the highly fossiliferous Goodland, and represents the sand-dominated, but marine, part of a delta. The shale (Is this the Walnut Clay?) may represent a more distal part of the delta where only more fine-grained material was deposited. And the Goodland clearly represents a marine deposit with very little sand, silt, or clay input. Has the sea level risen or fallen since the Antlers was deposited?

Return to cars and retrace route 2.4 miles to the north-south road to Kingston. Turn right (north) and drive into Kingston. Once you get to the residential area, take the fourth right; this will take you to Highway 70B. Turn right (southeast) on Highway 70B towards Soldier Creek Public Use Area. In about 4.3 miles you will pass a large water tank on your left. 0.8 miles past the water tank, turn right (west) at small sign that reads "Caney Creek Yacht Club". This is directly across Highway 70B from Vernon's Fish-n-Camp. Drive a couple hundred feet to the large outcrops of shale and limestone on both sides of the road and park.

STOP 3. DUCK CREEK MEMBER, CADDO FORMATION (WASHITA GROUP)

Location: extreme east-center sec. 20, T. 7 S., R. 6 E.

The Caddo Formation is the oldest formation in the Washita Group, and the Duck Creek Member is the oldest (of two) member of the Caddo. The Duck Creek is, or should be, the most widely known rock unit in southern Oklahoma among fossil collectors, if for no other reason than that "giant ammonites" (formally *Eopachydiscus brazoensis* (Shumard) and *Idiohamites fremonti* (Marcou)) are found in the Duck Creek.

Huffman and others (1987, p. 30) describe the Duck Creek as follows:

"The Duck Creek Member consists of thin, sility, argillaceous (sandy) limestone alternating with beds of blue-gray shale and clay. It can be divided into two parts by the relative abundance of limestone interbeds. ..."

Does the outcrop at this locality look like what Huffman described? If we visit this outcrop after it's rained, you will appreciate why Huffman referred to the Duck Creek as containing clay. It is incredibly gooey and sticky and even the best four-wheel-drive vehicle would get stuck in wet Duck Creek clay.

Two features are noteworthy at this outcrop. Note the large worm-like features in the limestone beds. These are some kind of burrow and geologists call them "trace fossils" (Fig. 9D). Perhaps these represent the feeding trace of some animal who was burrowing in the soft lime mud. Another feature are abundant molds of the pelecypod *Inoceramus comancheanus* Cragin (App. IB, A). In southern Oklahoma, this fossil is present only in the Duck Creek Member of the Caddo Formation. OAS members may be able to find pieces of the large ammonites noted above. In other places (not convenient to get to for this field trip), they are so common it's hard to avoid stepping on them. It is entirely possible that they used to be common here, but collectors have removed them. This is one reason we ask you not to be greedy when it comes to collecting fossils - leave some for future field trips!

Note that this outcrop of the Duck Creek Member is almost at the water level of Lake Texoma. Stop 2, the Goodland Limestone, is about 3/4 of a mile southwest of here. Stop 1, the Antlers Sandstone, is about 3/4 mile west of Stop 2. So, at the same elevation (lake level), the rocks get progressively older as one goes from east to west. Does this suggest to you that the Cretaceous rock formations near here are flat-lying? If they were, the same formation would be exposed everywhere around the shores of Lake Texoma. As discussed above in the section on general geology of Marshall County, the rocks near here are very gently folded into a series of synclines and anticlines. In what direction is the center (axis) of the syncline and in what direction is the center (axis) of the anticline? Remember that older rocks are exposed in the centers of anticlines and younger rocks are exposed in the centers of synclines. Referring to figure 4, you can see that the axis of the Kingston syncline is to the northeast and the Preston anticline is to the southwest.

Return to cars, return to Highway 70B, and turn left (north). About 1.7 miles past (north of) the water tank, Highway 70B swings left, but the trip will continue due north and immediately turn right (east). Drive 1 mile and turn right (south). Drive 1 mile and turn left (east). Drive 1 mile to where the road crosses a low creek with lots of boulders in it. Park safely and walk to the creek.

STOP 4. UPPER PART OF DENTON CLAY MEMBER AND SOPER LIMESTONE MEMBER, BOKCHITO FORMATION (WASHITA GROUP)

Location: extreme southeast corner sec. 10, T. 7 S., R. 6 E.

This is an excellent outcrop of the very top of the Denton Clay Member of the Bokchito Formation, although it is entirely uncharacteristic of most of the member. Like most of the rock units in Marshall County that consist predominantly of shale, the Denton erodes easily and tends not to form bold outcrops like the Goodland Limestone. However, the Denton Clay also contains a few thin beds of sandstone, and we are looking at one in this outcrop. The very fossiliferous cobbles and boulders in the creekbed are pieces of Soper Limestone, which immediately overlies the Denton, and can be seen in outcrop along the road where we parked the cars.

Huffman and others (1987, p. 33-34) describe the Denton Clay as follows:

"The lower part of the Denton consists of blue-gray, calcareous clay shale with thin beds of siltstone. Overlying beds become increasingly sandy, and a prominent bed of hard, thinly laminated, brown, ripple-marked sandstone or siltstone occurs 30-35 ft above the base. ... The upper part of the Denton consists of blue-gray to yellow, silty and sandy clay shale. In places, two or three thin beds of calcareous siltstone are interbedded with the shale. The siltstones are reddish brown to maroon, well sorted, and slightly micaceous. Thin beds of fossiliferous marlstone (shaly limestone) are present near the top of the Denton. ... The Denton Clay Member is sparingly fossiliferous ..."

What kind of rock forms the impressive outcrop in the creekbed? Keeping in mind that the Soper Limestone is immediately upstream, are we near the top of the Denton? Do your observations agree with Huffman's description? Note that some of the sandstone blocks just below the outcrop are ripple-marked, a characteristic of some of the beds Huffman noted in the lower part of the Denton. Ripple marks are indicative of current action. If they are symmetrical, they suggest the swash and backswash of ocean waves; if they are asymmetrical, they suggest unidirectional current (Fig. 9B). What kind of ripples are these? Note also the large horizontal burrows in the sandstone (Fig. 9D).

Perhaps the most impressive feature in the sandstone here are the very large-scale, low-angle cross-beds. Some of the cross-beds are so large they appear to form a large wave or "mega-ripple" in the top of the sandstone bed in the creek bed. This feature is known as "hummocky cross-stratification" (geologists "in-the-know" refer to this as HCS) and most typically is the result of storm waves acting on sand that is below "normal" wave base, but above storm wave base. I.e., these sands were too deep to be affected by the swash and backswash of normal waves, but the sands were moved by the larger waves associated with storms. My guess is that we are standing on the evidence for a rather significant Cretaceous hurricane!

The Soper Limestone averages only 1 foot thick, but is remarkably persistent and extends over several counties in southern Oklahoma (Huffman and others, 1987, p. 34). Some of the older literature refer to it as the "*Ostrea carinata*" bed because of the abundance of that particular species of oyster. Because it is so widespread yet so thin, Huffman and others (1987) believe it represents a time plane, and was deposited everywhere at the same time.

Given your observations and Huffman and others' (1987) descriptions, under what conditions were the Denton Member and Soper Limestone deposited? There is sandstone in this outcrop, but does it look like the Antlers at Stop 1? (Ignore the fact that one is cemented and one isn't.) Also consider that the sandstone is sandwiched between a dominantly shale unit and a limestone and some of the features you see in the sandstone.

Return to cars, continue east on east-west section-line road 0.3 miles to junction with Highway 70A. Turn left (north), drive 1.1 miles, turn right (east). The small community here is Woodville. Drive 0.3 miles, turn left (north), drive a few hundred feet to where the road turns right (east) and park. Walk north to the railroad tracks and head west to the railroad cut. CAUTION - WATCH FOR TRAINS AND GET OUT OF THE WAY IF ONE COMES!

STOP 5. PAWPAW SANDSTONE MEMBER, BOKCHITO FORMATION (WASHITA GROUP)

Location: border between sw 1/4 sw 1/4 sw 1/4 sec. 2 and se 1/4 se 1/4 se 1/4 sec. 3, T. 7 S., R. 6 E.

No field trip to this part of Marshall County would be complete without visiting the Pawpaw Sandstone. How can anyone resist visiting a rock unit with a name like Pawpaw?

Huffman and others (1987, p. 37) describe the Pawpaw Sandstone Member as follows:

"The Pawpaw ... consists of a lower clay shale ... and an upper sandstone ... . The lower clay shale is gray to blue, weathers yellow, and is interbedded with thin sandstone and siltstone and clay-ironstone concretions. The upper sandstone is gray to brown, fine-graine, and well sorted; it weathers yellow to reddish orange and locally contains ripple marks and cross-bedding. Mica flakes, glauconite, clay-ironstone concretions, and macerated (broken) pelecypod shells have been observed."

Based on this description, what part of the Pawpaw do you think this outcrop represents?

It is important to note that geologists do not always name rock units (be they members or formations) for a single rock type. Even though this unit is called the Pawpaw Sandstone, a significant part of it is shale. Generally, but not always, a unit is named for the rock type that is most common. In this way geologists can get away with including sandstone beds in the Denton Clay and shale beds in the Pawpaw Sandstone.

The Pawpaw isn't mostly sandstone everywhere. It was named for "exposures along Pawpaw Creek, near Denison, Grayson County, Texas; there the unit (is a) fossiliferous, light-drab, thinly laminated clay. It was reported as becoming increasingly sandy northward in northern Texas" (Huffman and others, 1987, p. 36). This observation clearly applies to the Pawpaw in Marshall County, where it is mostly sandstone. If the Pawpaw is mostly shale to the south and mostly sandstone to the north (here), in what direction did the ocean deepen? (We know the Pawpaw was deposited in the ocean given the presence of marine fossils in this outcrop.)

This feature - how a formation changes in character in different directions - is very important to geologists because it gives them an idea of where different environments occurred at the time the sediments were deposited. This feature is called "facies change" and is marked by the disappearance of some rock types or features in the rocks and the appearance of others.

Return to cars, continue east for a couple hundred feet, turn right (south) and drive a couple hundred feet to the intersection with the main road through Woodville. Turn left (east) and drive 1.1 miles to a small road on your left (Allen Road). Turn left (north) on Allen Road, which immediately turns left (west) and then right (north). Park as soon as you cross the railroad tracks and walk west on the tracks a few hundred feet to the large outcrops. AGAIN WATCH FOR TRAINS!

STOP 6. DEXTER MEMBER, WOODBINE FORMATION

Location: se 1/4 sw 1/4 sw 1/4 sec. 1, T. 7 S., R. 6 E.

Aside from the color, does this sandstone look like any other sandstone we've visited today? If you're not sure, look very closely at the outcrops on the north side of the tracks. Is the outcrop, in fact, all sandstone?

The Dexter Member of the Woodbine Formation is the youngest Cretaceous unit in Marshall County. Younger members of the Woodbine and the still younger (but still Cretaceous) Eagle Ford Formation are present in southern Bryan County. Most of the Dexter has been eroded in Marshall County and only the lowest 17 ft remains. The very lowest part of the Dexter is not exposed in this outcrop, but was described by Huffman and others (1987, p. 39) from elsewhere:

"The basal conglomerate ... consists of rounded, medium- to pebble-sized clasts, mostly chert and quartz. The pebbles are bound together with clay and very fine-grained ferruginous sand, giving the conglomerate a brown color. Hard, dark-brown ironstone layers are present as partings within the unit. ... Above the basal conglomerate is a section of sandstone (that is) light brown to reddish brown, ferruginous, and cross-bedded. ... The Dexter Member of the Woodbine Formation rests on the eroded surface of the Grayson Marlstone."

Do any parts of this description match what you see in this outcrop? Note the very top of the outcrop. Is this the Dexter Member or something different?

A feature in the sandstone of the Dexter Member that we haven't seen before are contorted sandstone layers. In some cases, individual 1-inch-thick layers appear to have been completely peeled over on themselves (Fig. 10B). In other cases, it almost looks as though individual masses of sandstone have become completely detached from adjacent beds (Fig. 10C). Under what conditions would this happen? Is this indicative of quiet sedimentation on a flat surface? Or is it more likely that the surface on which some of the sands were deposited was irregular, and that shortly after the sand was buried, it began to move and slide and fold within itself? What would cause partially consolidated sand to move? (Think back to Stop 2 and our discussion of "active geology". What's the primary force that causes sediments to move?)

Under what conditions was the Dexter Member of the Woodbine Formation deposited? Consider these observations:

1. mostly sandstone, but with some pebble layers;
2. some large shale "rip-up" cobbles;
3. folded sandstone, probably while the sand was soft, but not entirely unconsolidated;
4. elsewhere, cross-bedded.

Here's what Huffman and others (1987, p. 39-40) say about the Dexter:

"The basal conglomerate in southern Marshall County ... indicated renewed sedimentation in southern Oklahoma following an episode of regional erosion. (Several features) suggest an alluvial-channel environment for part of the basal Dexter."

If Huffman and others (1987) are correct, the lower contact of the Dexter Member of the Woodbine Formation is an unconformity. Unlike the basal contact of the Antlers, which is an angular unconformity (Fig. 8), the base of the Dexter is either a disconformity or paraconformity (Fig. 8), depending on how irregular the contact is.

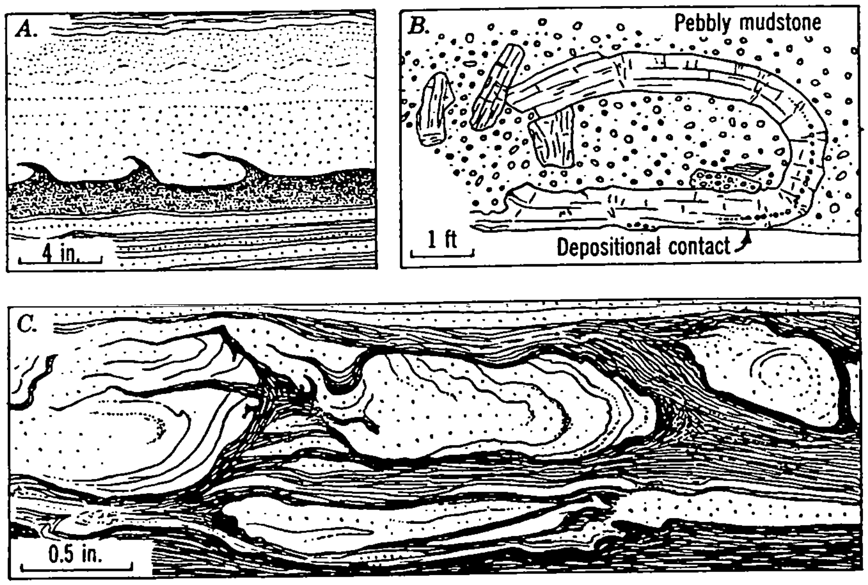

Fig. 10. Soft-sediment deformation features formed as a result of slump, creep, and flowage. A. Flame structures. B. Slump overfold. C. Flow folds, rolls, and pull-apart structures (from Compton, 1962, p. 231).

Does the Dexter represent a rise or fall of sea-level? Drastic or not-so-drastic?

Return to cars, retrace route through Woodville to Highway 70A. Turn right (northwest) on Highway 70A, drive 3 miles to Kingston, and return to Cross Point Methodist Camp.

SUMMARY AND "EXAMINATION"

Now that you've had a chance to look at some of the Cretaceous rocks of southern Oklahoma and you've learned something about how geologists determine under what environmental conditions those rocks were deposited, it's time to draw your own Lower Cretaceous sea-level curve. Use Fig. 12, what you've seen today, and the description of the other formations (Fig. 5), to draw the curve. Consider the following:

1. Sandstones generally represent a very shallow marine environment, beaches, or rivers. The presence/absence of marine fossils can help you decide which. Coarse grains (pebbles, cobbles) generally point to a river or stream environment.
2. Shales generally represent a shallow-marine environment, probably too far from shore to be affected by normal wave action.
3. Limestones generally represent deeper marine waters, or (to confuse things,) slightly shallower water where there is no input of mud and sand.
4. If a formation is mostly limestone with a little shale, make it slightly shallower than a formation with all limestone. If its shale with a little limestone, make it slightly deeper than a pure-shale formation.
5. If you have reason to believe the sandstone was not deposited in shallow water (e.g., Stop 4), take that into consideration.

To do things properly, a geologist would decompact the rocks, i.e., make them back into sediments again, to calculate their original thickness. Then the geologist would try to establish a sedimentation rate and set an absolute time scale to the different formations. We won't do this. Rather, we'll base our sea-level curve on the average thicknesses of the formations at the present time and assume the sedimentation rate was the same for all of them.

Compare your sea-level curve with the one that's been published by the "experts" (Figs. 13a and 13b).

Thank you for attending this geology field trip with the Oklahoma Academy of Science. If you have any questions about this trip, or the geology of Oklahoma, the best place to start is:

Oklahoma Geological Survey
Sarkeys Energy Center
100 East Boyd St., Rm. N-131
Norman, OK 73019

ph: (405) 325-3031
(800) 330-3996
fax: (405) 325-7069
website: http://ou.edu/special/ogs-http

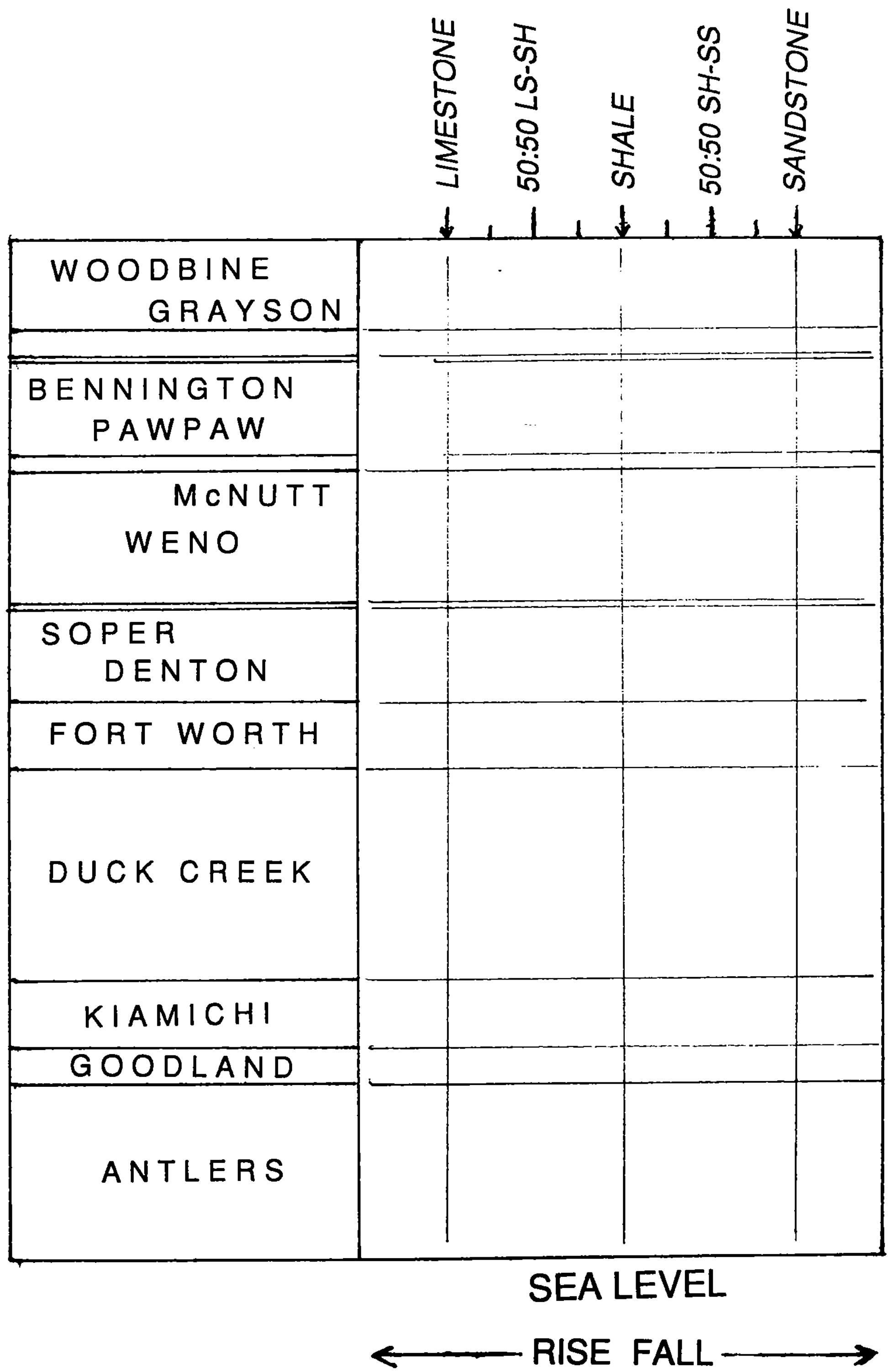

Fig. 12. "Connect-the-dots draw-your-own sea-level-curve stratigraphic-column" of Cretaceous rocks in Marshall County (adjusted for thickness).

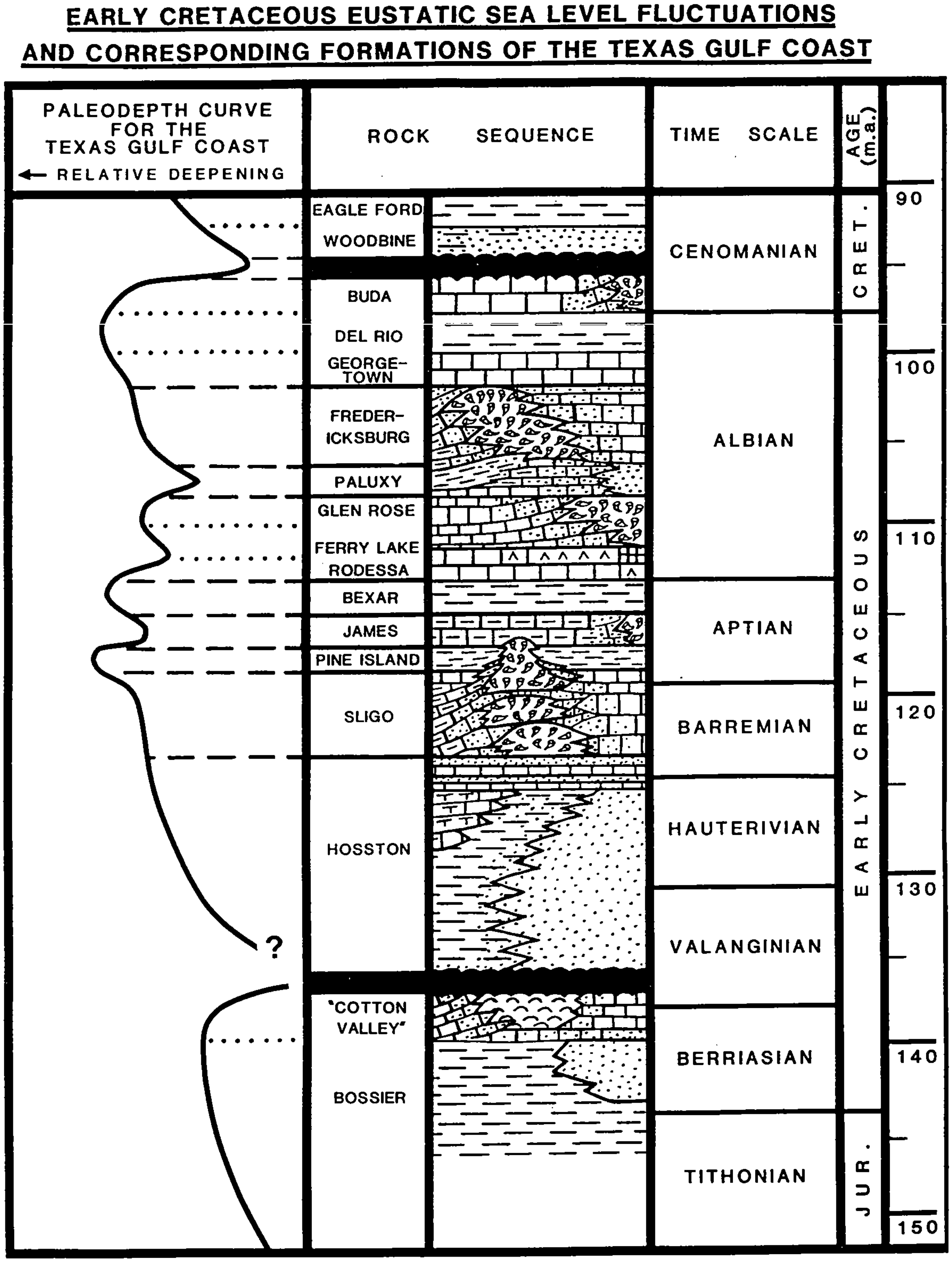

Fig. 13a. Sea-level curve for Early Cretaceous formations in North Texas (Scott and others, 1988, p. 278). On this chart, Paluxy = Antlers and Buda, Del Rio, and Georgetown Formations = Washita Group. Note that on this chart, relative deepening is to the left.

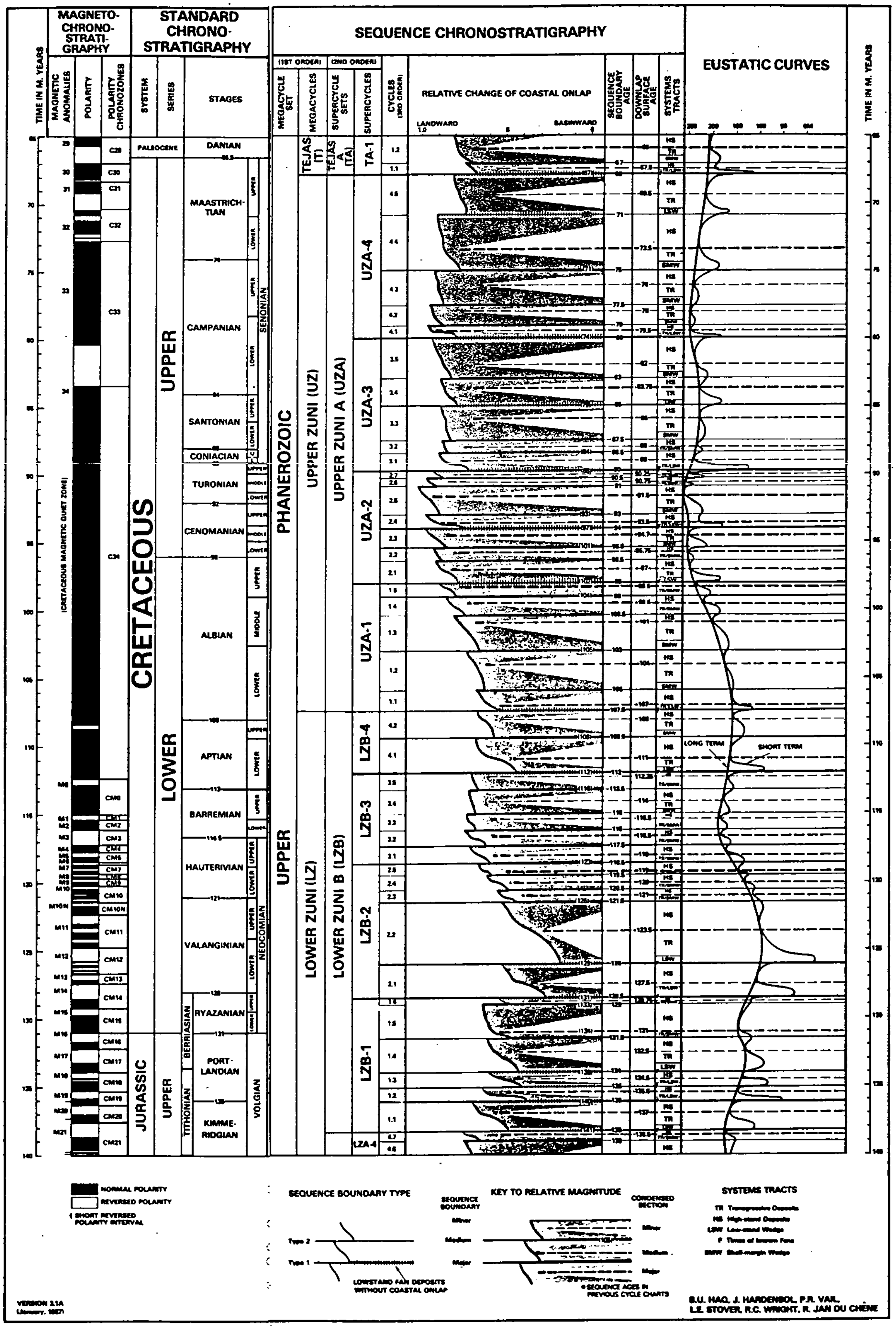

Fig. 13b. Sea-level curve for the Early Cretaceous worldwide (modified from Haq and others, 1988, p. 96-97). Note that we are talking about a very small part of the Cretaceous.

PRINCIPAL REFERENCE

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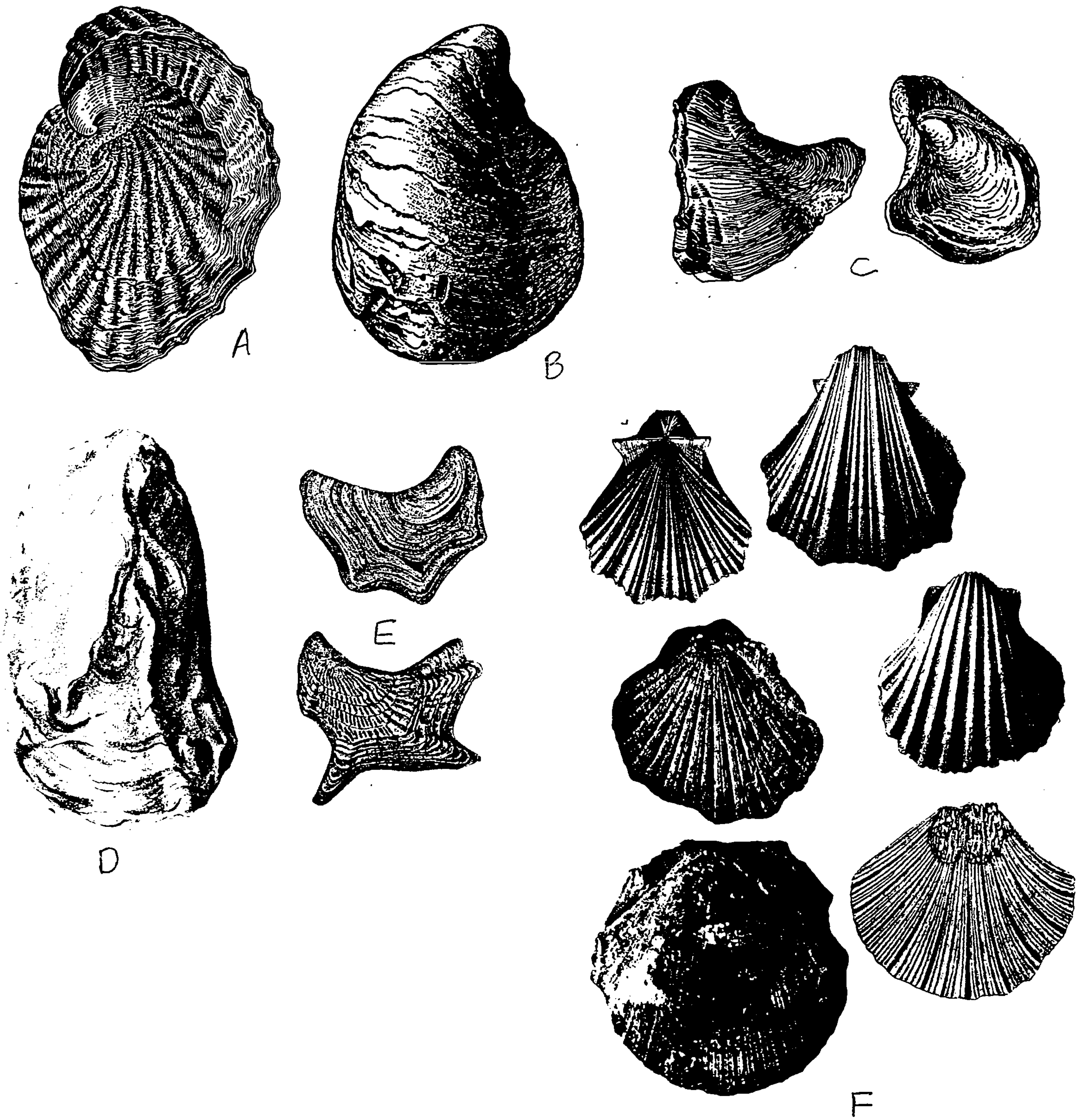
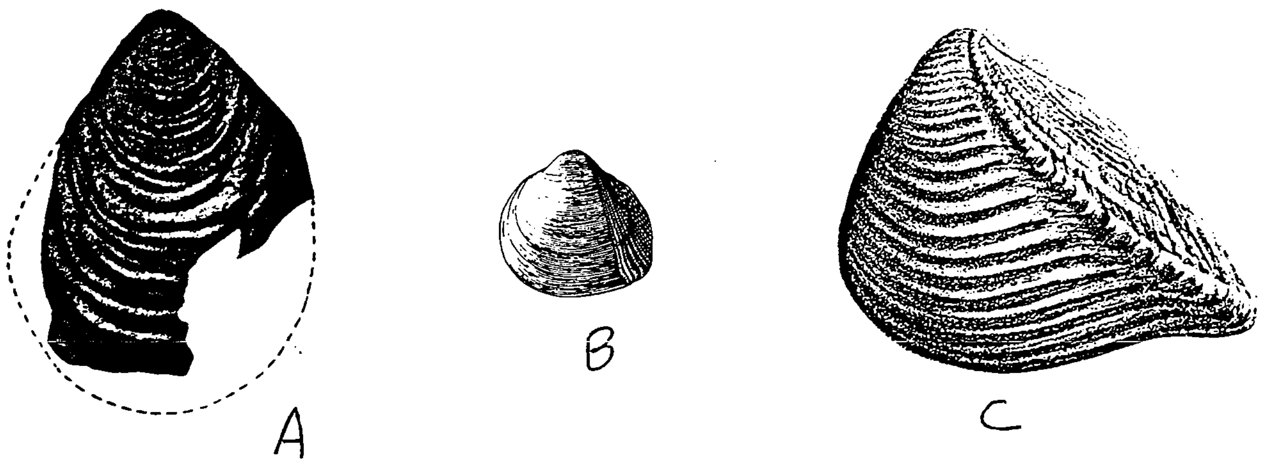
APPENDIX IA



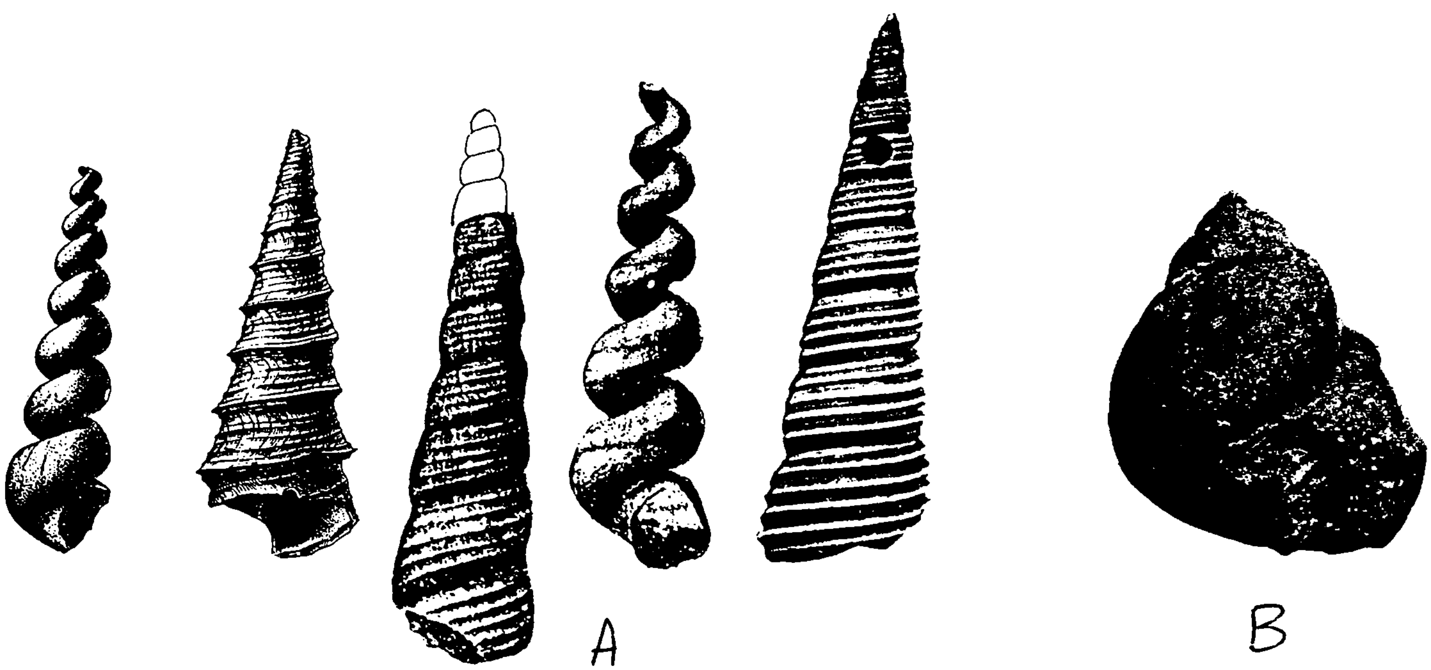
Some common "oyster" (A through E) and "scallop" (F) fossils (all pelecypods) from the Cretaceous of Marshall County. A. *Exogyra texana*. B. *Gryphaea corrugata* (now? *Texigryphaea corrugata*). C. *Gryphaea navia* (now? *Texigryphaea navia*). D. *Ostrea subovata*. E. *Ostrea quadriplicata* (now *Rastellum* (*Arctostrea*) *quadriplicatum*). F. several Pectinidae (Neithea Group). (A through E from Shimer and Shrock (1944); F from Moore (1969)).

APPENDIX IB



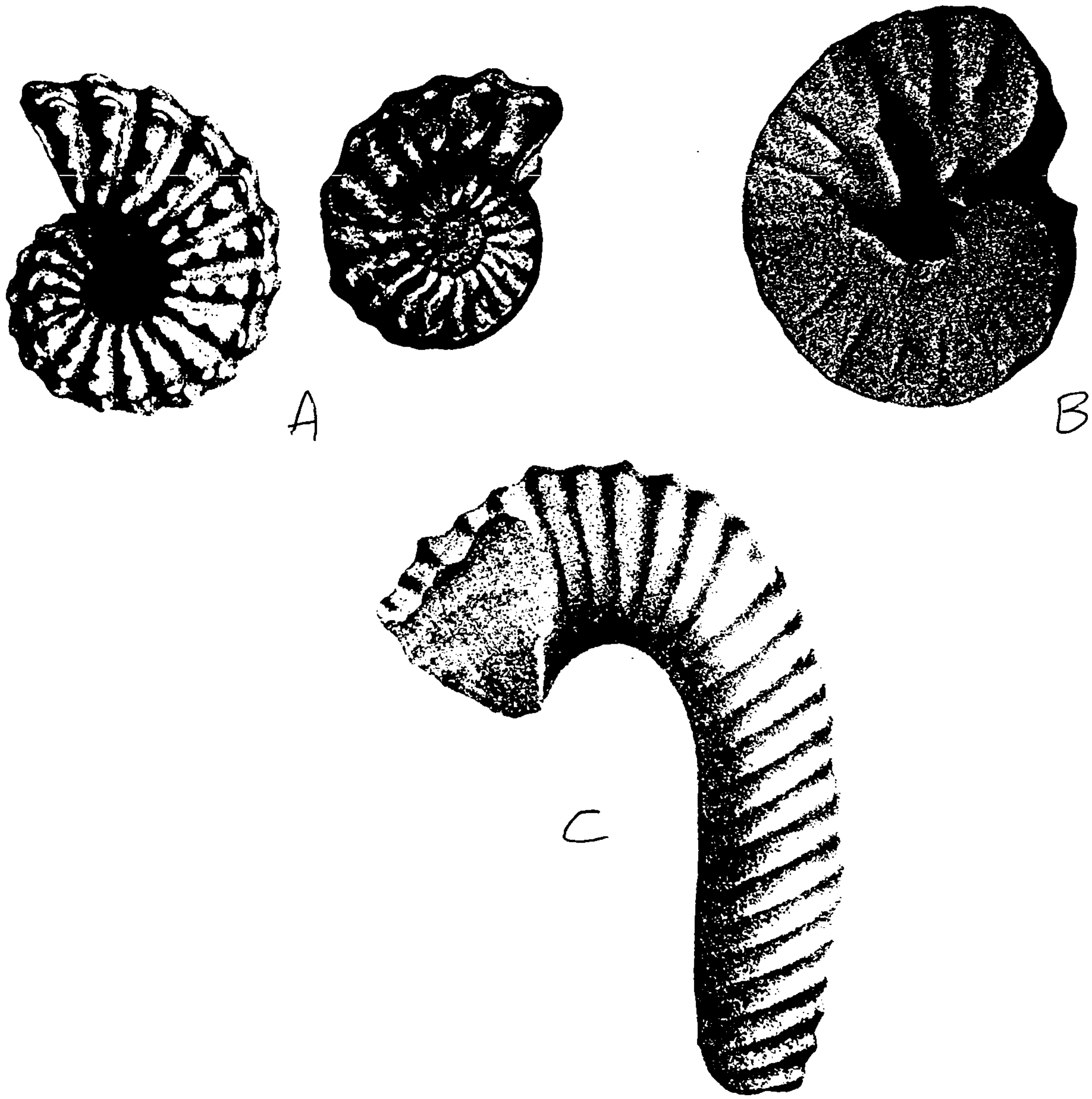
Some common "clam" (pelecypod) fossils from the Cretaceous of Marshall County. A. *Inoceramus comancheanus*. B. Protocardia. C. Trigonia. (A from Shimer and Shrock (1944); B and C from Moore (1969))

APPENDIX II



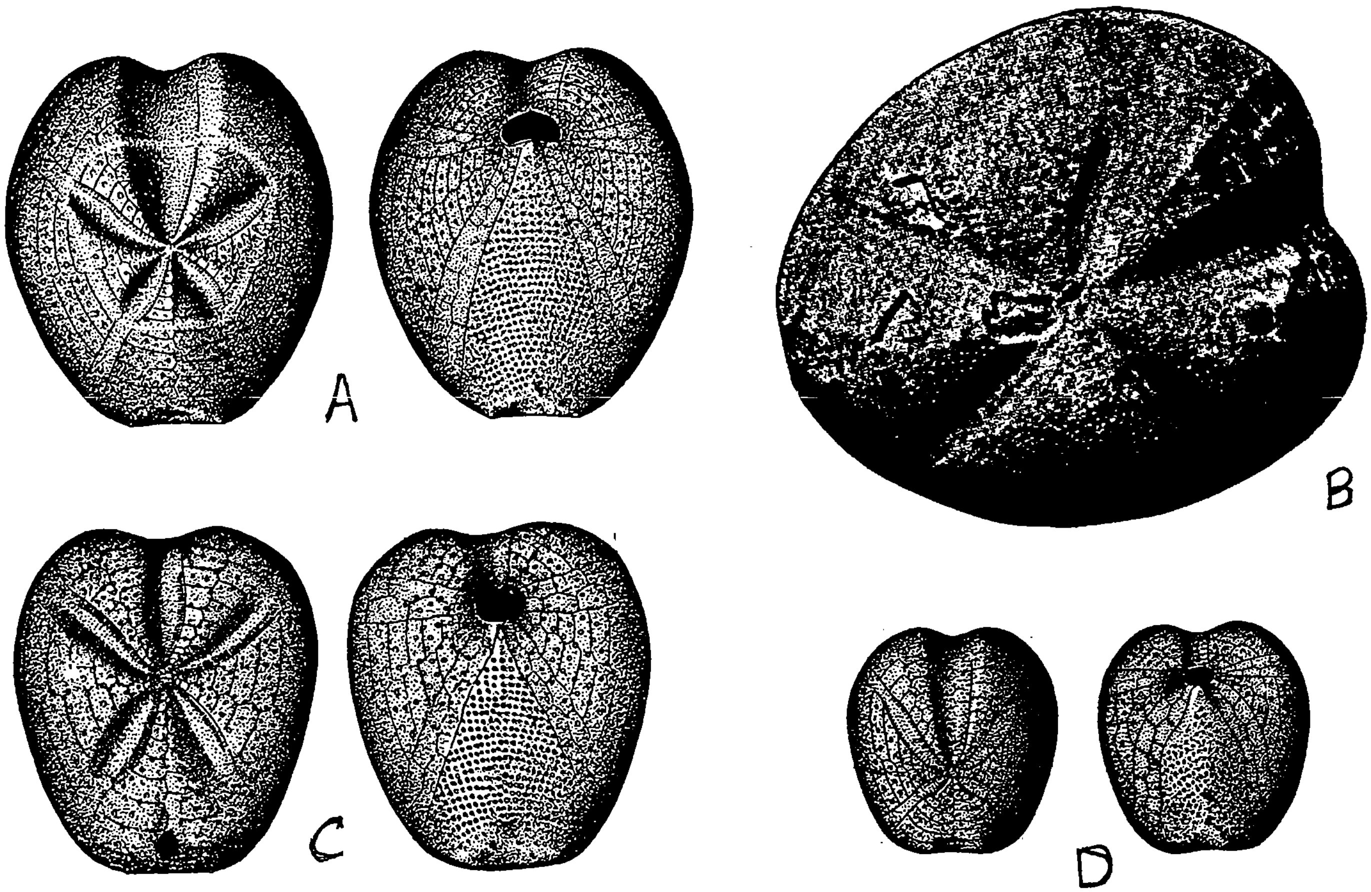
Some common "snail" (gastropod) fossils from the Cretaceous of Marshall County. A. several Turritella. B. *Tylostoma elevatum*. (from Shimer and Shrock (1944))

APPENDIX III



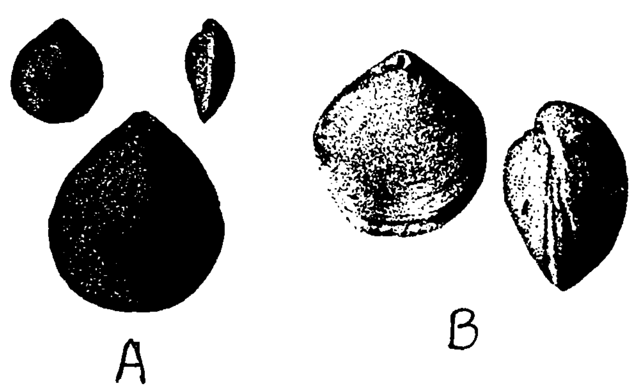
Some common Cephalopod (ammonite) fossils from the Cretaceous of Marshall County. A. Mortoniceras. B. Engonoceras. C. *Hamites* (now *Idiohamites*) *fremonti*. (from Shimer and Shrock (1944))

APPENDIX IV

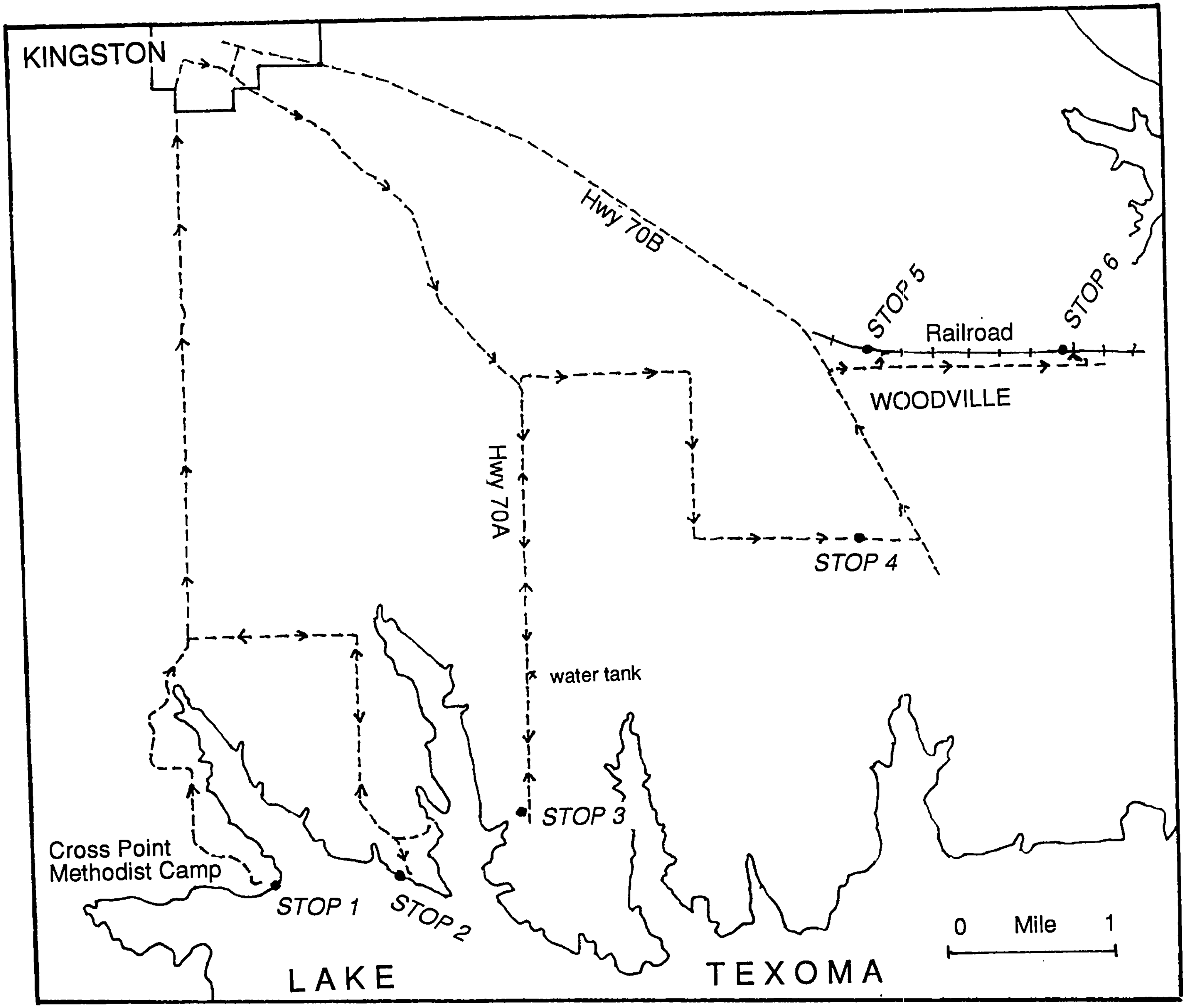


Some common "sea urchin" (enchinoid) fossils from the Cretaceous of Marshall County. A. *Hemiaster* (*Macraster*) *texanus*. B. *Hemiaster* (*Macraster*) *elegans*. C. *Epiaster whitei*. D. *Enallaster texanus*. (from Shimer and Shrock (1944))

APPENDIX V



Some common brachiopod fossils from the Cretaceous of Marshall County. A. Terebratulina. B. *Kingena wacoensis*. (from Shimer and Shrock (1944))


KINGSTON
Hwy 70B
STOP 5
Railroad
STOP 6
WOODVILLE
Hwy 70A
STOP 4
water tank
STOP 3
Cross Point
Methodist Camp
STOP 1
STOP 2
0
Mile
1
LAKE
TEXOMA