THE GEOLOGY OF THE EASTERN ARBUCKLE MOUNTAINS IN PONTOTOC AND JOHNSTON COUNTIES, OKLAHOMA

AN INTRODUCTION AND FIELD-TRIP GUIDE

The Nature Conservancy®

OKLAHOMA GEOLOGICAL SURVEY 1908

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OPEN-FILE REPORT OF 4-97

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AN INTRODUCTION AND FIELD-TRIP GUIDE

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INTRODUCTION

The Nature Conservancy's Pontotoc Ridge Preserve is located in extreme southern Pontotoc County along the Pontotoc - Johnston County line (Fig. 1). It is located in a geological province known as the Arbuckle Mountains, which undoubtedly is one of the more interesting and most visited parts of Oklahoma for geologists, for reasons given below. Immediately east of the Arbuckle Mountains in this part of Oklahoma is a geologic province known as the Arkoma basin, which extends east to west-central Arkansas. The eastern part of the Arbuckle Mountains and western part of the Arkoma basin are divided into a number of subprovinces, many of which we will cross on this field trip. These include, from north to south, the Lawrence uplift, Franks graben (down-dropped block), Hunton anticline, and Tishomingo-Belton anticlines, and Wapanucka syncline (Fig. 2).

In part, the geologic provinces and subprovinces are defined by the kinds and ages of rocks that are exposed at the surface. In general, the rocks of the Arkoma basin are considerably younger (mostly Pennsylvanian, or about 330 to 290 million years old) than those of the Arbuckle Mountains, which range in age from Precambrian (here, about 1.4 billion years old) to the late Mississippian (about 330 million years old). Although it might appear that the rocks of the Arbuckle Mountains and adjoining Arkoma basin would record over 1 billion years (nearly quarter) of the Earth's history, there is a gap in the rock record - the 1.4 billion-year-old granites are directly overlain in places by volcanic rocks that are 550 to 520 million years old. Therefore, nearly 900 million years of the Earth's history is missing in the rocks of the Arbuckle Mountains, but that still leaves 200 million years that we can learn about.

The geology of the Arbuckle Mountains was first described in detail by one of Oklahoma's foremost geologists, Dr. William E. Ham of the Oklahoma Geological Survey. Much of his work, done in the 1950's and 1960's, still stands, and any geologist studying the Arbuckles today will start with Dr. Ham's work. Dr. Ham's explanation of the geological significance of the Arbuckle Mountains has never been improved upon:

"Reference to the Arbuckle outcrops as the Arbuckle "Mountains" likewise is misleading because about 80 percent of the area consists of gently rolling plains. Only in the western area - that of the Arbuckle anticline - is the topographic relief sufficient to evoke comment from the newcomer. The greatest relief is along U.S. Highway 77. In this area, the Washita River flows at an elevation of 770 feet, and 3 miles away is the top of the East Timbered Hills - the crest of the Arbuckle anticline and, with an altitude of 1,377 feet, the highest point in the Arbuckle Mountains. This total relief of 607 feet is impressive only because it is some six times greater than that of any other topographic feature between Oklahoma City and Dallas.

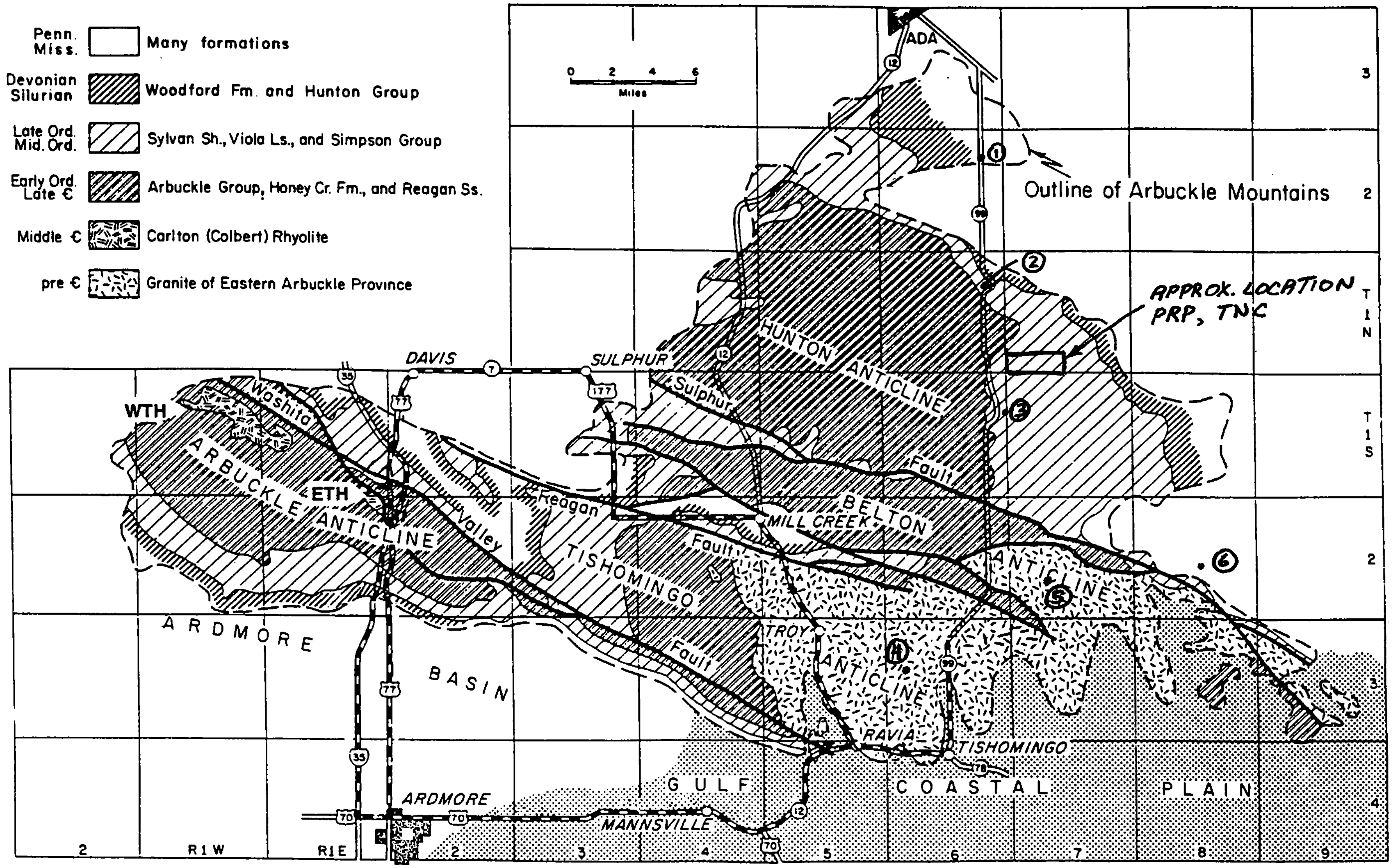

Figure 1. Simplifed geologic map of the Arbuckle Mountains (from Denison, 1995; modified from Ham, 1969). Locations of field-trip stops are shown by circled numbers.

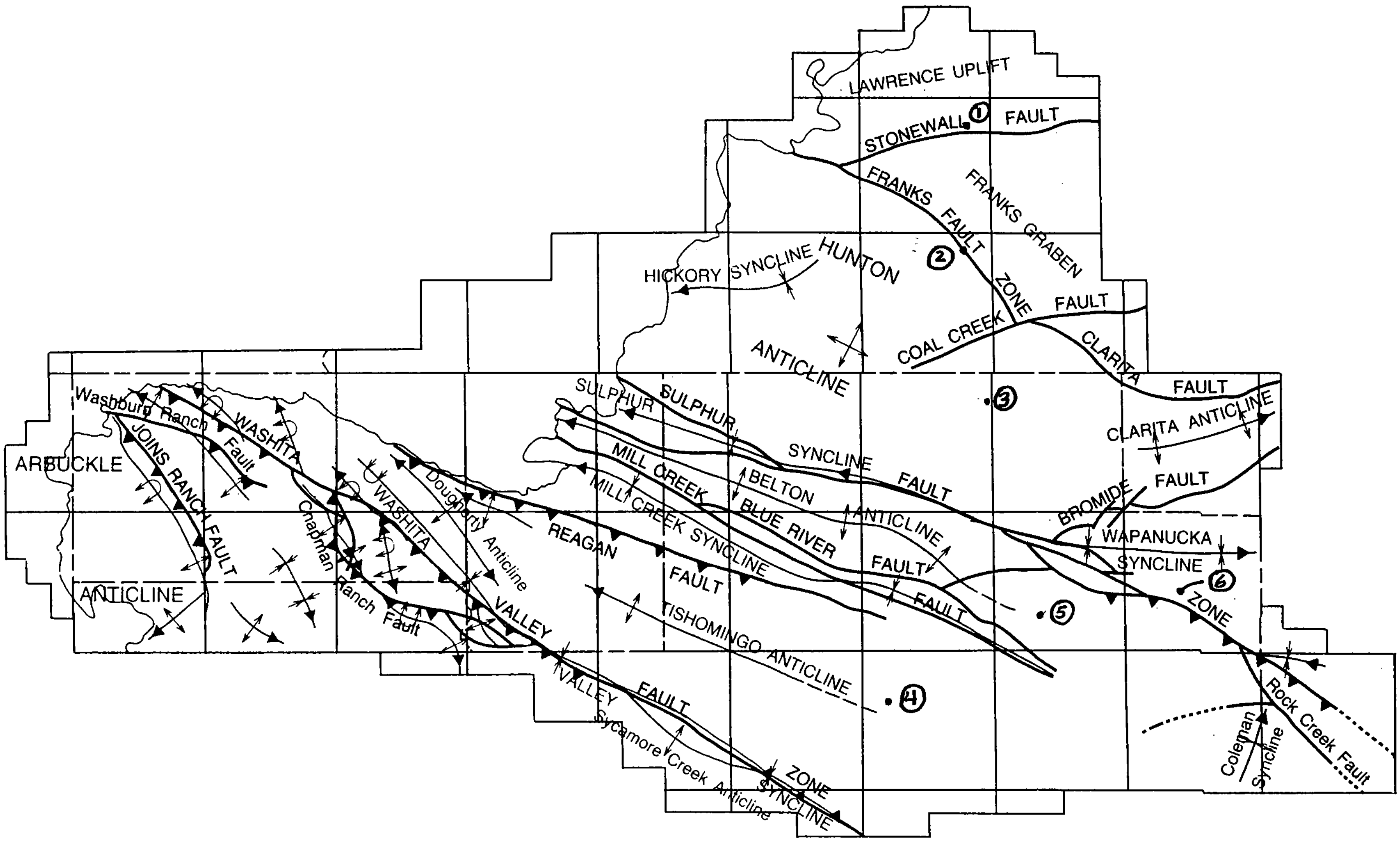

Figure 2. Index map of Arbuckle Mountains showing principal structural features (from Ham and McKinley, 1954). Faults are shown by thick lines (thrust faults with sawteeth), folds (anticlines and synclines) are shown by thin lines. Locations of field-trip stops are shown by circled numbers.

"Whether plain or hill country, the Arbuckle Mountains region is of irresistible interest to geologists. Its 11,000 feet of fossiliferous Late Cambrian through Devonian strata constitute the best outcrops and greatest area of exposure of this sequence in all the Midcontinent region. Stratigraphic names taken from the Arbuckles, such as Arbuckle, Simpson, Viola, Sylvan, Hunton, and Woodford, have been widely applied in the subsurface as far away as West Texas, Illinois, and Nebraska. The 150-square-mile exposure of Precambrian granites in the eastern Arbuckle Mountains is the largest and best outcrop of such rocks in the central United States between the Llano area of Texas and the Black Hills of South Dakota. ...

"The processes of strong uplift and deep erosion that have produced the Arbuckle Mountains of today have also resulted in the surface exposure of rocks that normally are deeply buried. Among the rocks are many that are commercially valuable, such as limestones ... that are extensively quarried as a source of crushed stone, high-purity silica sand ... for glass making and other industrial uses, cement-making raw materials ..., high-purity dolomite ..., and building and monumental stone ...

"Of much greater economic value are the resources of petroleum and natural gas in southern Oklahoma. The intensive search for petroleum has resulted in the drilling of perhaps 75,000 wells. Pauls Valley, Fitts, Cumberland, Eola, Tatums, and Fox-Graham are well known to Oklahoma geologists as near-giant oil fields that occur as subsurface extensions of the Arbuckle Mountains. Thus, south-central Oklahoma, with its excellent outcrops and vast store of subsurface information, is one of the better known geological provinces in the world." (Ham, 1973).

GEOLOGIC HISTORY OF THE ARBUCKLE MOUNTAINS

The Arbuckle Mountains, together with the basins that border the mountains, have a long and complicated geologic history. The most impressive aspects of this history are (1) the extraordinary thickness of late Cambrian to middle Mississippian (about 520 to 340 million years ago) sediments (mostly limestone) that accumulated in the Arbuckle Mountains area compared to most of the North American craton to the north (Fig. 3); (2) the extraordinary thickness of late Mississippian and Pennsylvanian (about 340 to 290 million years ago) sediments that accumulated in the basins that border the mountain area (Fig. 3); and (3) the complexly folded and faulted nature of the rocks in both the mountains and basins. The unusual geology of the area has its underpinnings in what happened in southern Oklahoma just over half a billion years ago.

The oldest exposed rocks in Oklahoma are the Tishomingo and Troy Granites; these crop out on the surface in the Tishomingo-Belton horst north, northwest, and northeast of the town of Tishomingo. These granites are about 1.35 to 1.4 billion years old and form much of what geologists call the "basement" of southern Oklahoma. Beginning about 550 million years ago and lasting for about 25 million years (during the Cambrian period of geologic time), the granite basement of the North American continent began to extend and a series of northwest-trending faults formed in a broad zone across southern and southwestern Oklahoma and extending to near Amarillo, Texas. With continued extension, a rift (or opening) formed and a series of volcanic rocks erupted and filled the rift (Fig. 4A). (One of these volcanic formations, the Colbert Rhyolite, is present beneath the radio towers just west of I-35 at the top of the Arbuckles.) At the same time as the volcanic rocks were being erupted, magma intruded the crust to shallow levels and cooled. (The granites of the Wichita Mountains and Quartz Mountain are examples.) This intense igneous activity was concentrated in southern Oklahoma because the "basement" of the continental crust had been weakened by the faulting associated with the rifting.

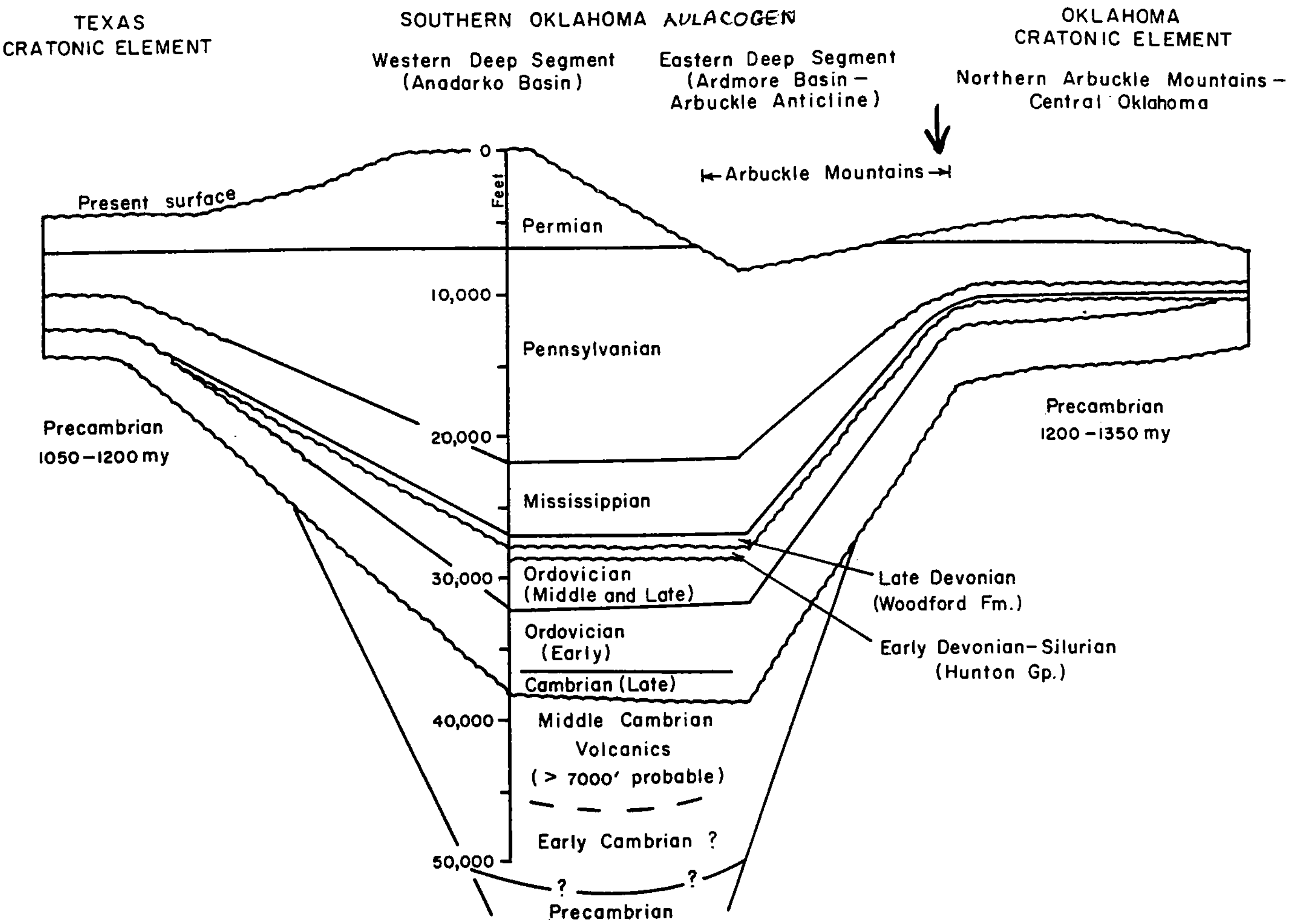

Figure 3. Thickness of Cambrian through Pennsylvanian sedimentary rocks that accumulated in the Arbuckle Mountains (and Anadarko basin) compared to that on North American craton (from Ham, 1973, p. 5). Note that thicknesses in the eastern Arbuckle Mountains (area of field trip) (arrow) are more like those of the craton than the western Arbuckle Mountains.

This zone of weakness in the crust is called the "Southern Oklahoma aulacogen". In the terms of plate tectonics, an aulacogen is a "failed arm", or a place where the continents tried to separate (like South America did from Africa, and where east Africa is currently splitting), but failed. For our purposes, this zone of weakness was the site of future tectonic activity, i.e., folding and faulting. But more about that later.

Beginning in the late Cambrian (between about 520 and 500 million years ago) and lasting until the late Mississippian (about 340 million years ago), southern Oklahoma was the site of a broad, epicontinental sea that extended across most of the southern midcontinent. Shallow-marine limestone and lesser amounts of sandstone and shale were deposited throughout the area. These late Cambrian through late Mississippian formations are relatively thin throughout Oklahoma, including the Clarita horst (Hunton anticline) area of our field trip; in the Southern Oklahoma aulacogen, however, they are considerably thicker (Fig. 4B, C). The late Cambrian to Mississippian (520 to 330 million years ago) sediments deposited in the aulacogen may have been as thick as 17,000 ft; this contrasts with the approximately 7,500 ft of equivalent strata deposited on the adjacent cratonic shelf in southern Oklahoma and Baja Oklahoma (sometimes referred to as Texas). Many geologists believe that the reason unusually thick accumulations of sediments were deposited in the Southern Oklahoma aulacogen is that the crust there cooled, contracted, and subsided after the Cambrian igneous episode ceased.

Beginning as early as the middle Mississippian (about 350 million years ago), and certainly by the beginning of the Pennsylvanian (330 million years ago), southern Oklahoma began to experience a major period of folding, faulting, and mountain building (Fig. 4D). This was particularly true in southeastern Oklahoma where the Ouachita Mountains provide evidence for the orogeny. However, effects of the orogeny were more widespread and extended to southern and southwestern Oklahoma; perhaps it is not surprising that the area that had previously experienced an unusual degree of geologic activity, the Southern Oklahoma aulacogen, would be affected the most by the late Mississippian - Pennsylvanian tectonic activity.

Most of the evidence for the orogeny is contained in the rocks deposited in the basins adjacent to the old mountain range. It is only in the basins where the evidence is preserved. The most direct evidence - the mountains themselves - are largely eroded away.

THE GEOLOGY OF THE FIELD-TRIP AREA

The eastern Arbuckle Mountains and, in particular, the Hunton anticline area (which includes The Nature Conservancy's Pontotoc Ridge Preserve) (Fig. 1) is a hybrid between the Arbuckle Mountains most people are familiar with along I-35, and the lower and middle Paleozoic rocks (Cambrian through Mississippian) that are present in the subsurface throughout the southern midcontinent. The area was uplifted during the same orogeny that affected the "classic" Arbuckle Mountains to the west; for this reason, the area can legitimately be considered as part of the Arbuckle Mountains geologic province. However, the lower and middle Paleozoic formations are considerably thinner here than they are to the west (Fig. 5); the thicknesses are more like those found to the north on the North American craton. Therefore, the Hunton anticline area probably is immediately north of the Southern Oklahoma aulacogen.

Further evidence that our field-trip area is outside the Southern Oklahoma aulacogen is that the oldest sedimentary rock (the Reagan Sandstone) lies on Precambrian granite. In the aulacogen, the Reagan Sandstone overlies about 7,500 feet of Cambrian volcanic rocks.

THE LAWRENCE UPLIFT

The northernmost geologic subprovince of the Arbuckle Mountains that our field trip will touch on is the Lawrence uplift (Fig. 2). The Lawrence uplift is a roughly triangular-shaped area that extends from near Fitzhugh on the west, to Ahloso on the north, to just north of Stonewall on the east. It is composed of gently northeast-dipping Ordovician (on the southwest) to early Pennsylvanian rocks. Locally, the northern boundary is the Ahloso fault (down-to-the-north) but, more typically, the eastern, northern, and northwestern boundaries are where middle Pennsylvanian rocks unconformably overlie older rocks. The southern boundary of the Lawrence uplift is the Stonewall fault (down-to-the-south). The field trip will visit a splay, or subsidiary fault, off of the main Stonewall fault.

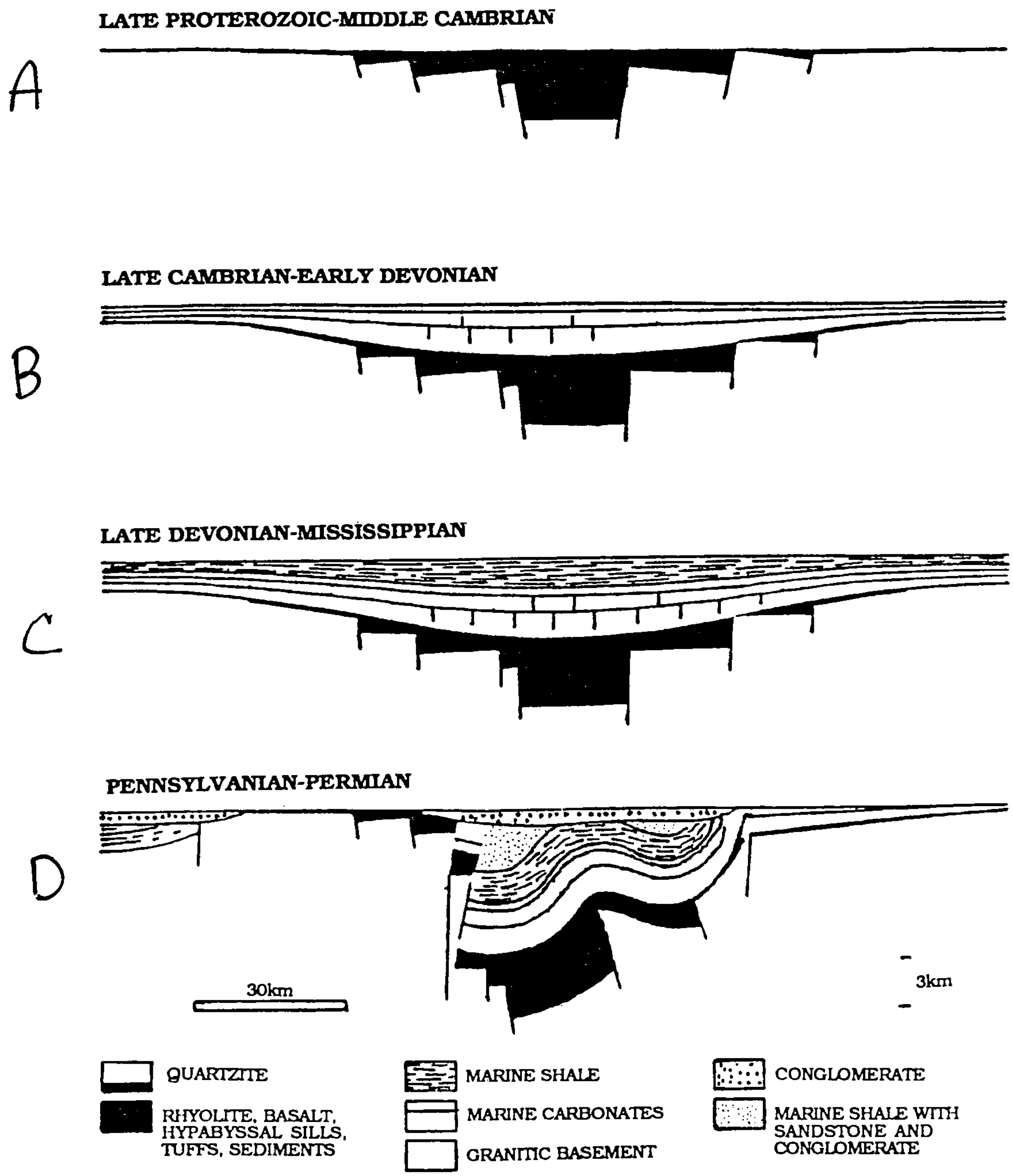

Figure 4. Structural development of the Southern Oklahoma aulacogen (from Bixler, 1993). A. Middle Cambrian extension, faulting (rifting), and filling of rift with volcanic rocks. B. Late Cambrian to Early Devonian subsidence and accumulation of mostly marine limestone and lesser sandstone and shale. C. Continued subsidence in Late Devonian to Late Mississippian and deposition of mostly marine shale and minor sandstone and limestone. D. Folding, faulting, and formation of the Arbuckle Mountains.

The Lawrence uplift was raised unequally relative to the areas to the north and south; the western end was uplifted more than the eastern end. Because of this, older rocks (Ordovician) are exposed at the west end of the uplift and younger rocks are exposed progressively east. Movement on the faults (and therefore age of the uplift) is entirely Pennsylvanian.

THE FRANKS GRABEN

The Franks graben is the westernmost extension of the Arkoma basin (Fig. 2). It is triangular in shape, with its western apex a few miles southeast of Fitzhugh. It is open to the east, where it merges with the main part of the Arkoma basin. It is composed of gently west-dipping rocks; older rocks (middle Pennsylvanian) are exposed to the east, younger rocks (upper Pennsylvanian) to the west. The boundary between the Franks graben and Lawrence uplift is the Stonewall fault (Fig. 2); the observation that rocks of the uplift dip east and those of the graben dip west indicates the Stonewall fault had a kind of scissors movement, with the north side still moving up relative to the south side. The southern boundary of the Franks graben is a narrow area of very complicated down-to-the-north faulting known as the Franks fault zone (or Clarita fault zone, to the east) (Fig. 2). At many places along this fault zone, rocks as old as Ordovician that underlie the surface Pennsylvanian rocks of the Franks graben have been dragged up along the fault and have gentle to moderately steep dips. We will visit an outcrop of Ordovician Viola Limestone that is within in the Franks fault zone.

The Franks graben contains one of the larger oilfields in this part of Oklahoma. The Fitts oilfield is centered near Harden City. Oil is produced from a number of different formations, but the most productive has been the Ordovician McLish Formation (essentially the same formation that is exposed at Pontotoc Ridge). The traps for the oil are gentle anticlines in the older rocks; these folds are not obvious on the surface because they are separated from the surface rocks by an angular unconformity (Fig. 6).

HUNTON ANTICLINE AND PONTOTOC RIDGE

South of the Franks graben is the large structural block known as the Hunton anticline (Figs. 1, 2). It is roughly rectangular in shape and extends from near Roff on the northwest, to just east of Sulphur on the southwest, to about 5 miles southwest of Bromide on the southeast, to Clarita on the northeast. It is bounded by the Franks/Clarita fault zone on the northeast and the Sulphur fault zone on the southwest. The Franks/Clarita fault zone is up-to-the-southwest; the Sulphur fault zone is mostly up-to-the-southwest, but locally is the opposite. One "steps" up out of the Franks graben onto the Hunton anticline and then "steps" up onto the Tishomingo-Belton anticlines. The Hunton anticline is unconformably overlapped by younger rocks on its western side and merges with rocks of the Arkoma basin on its eastern side.

The general form of the Hunton anticline is that of a broad dome of nearly horizontal rocks. Although there are a number of small folds and faults throughout the "dome" that complicate the structure, in general, older rocks (mostly Ordovician Kindblade Formation) crop out near the center and the rocks become younger outwards. The best-preserved and most-complete section of these younger formations is to the east in western Coal County just north of Bromide.

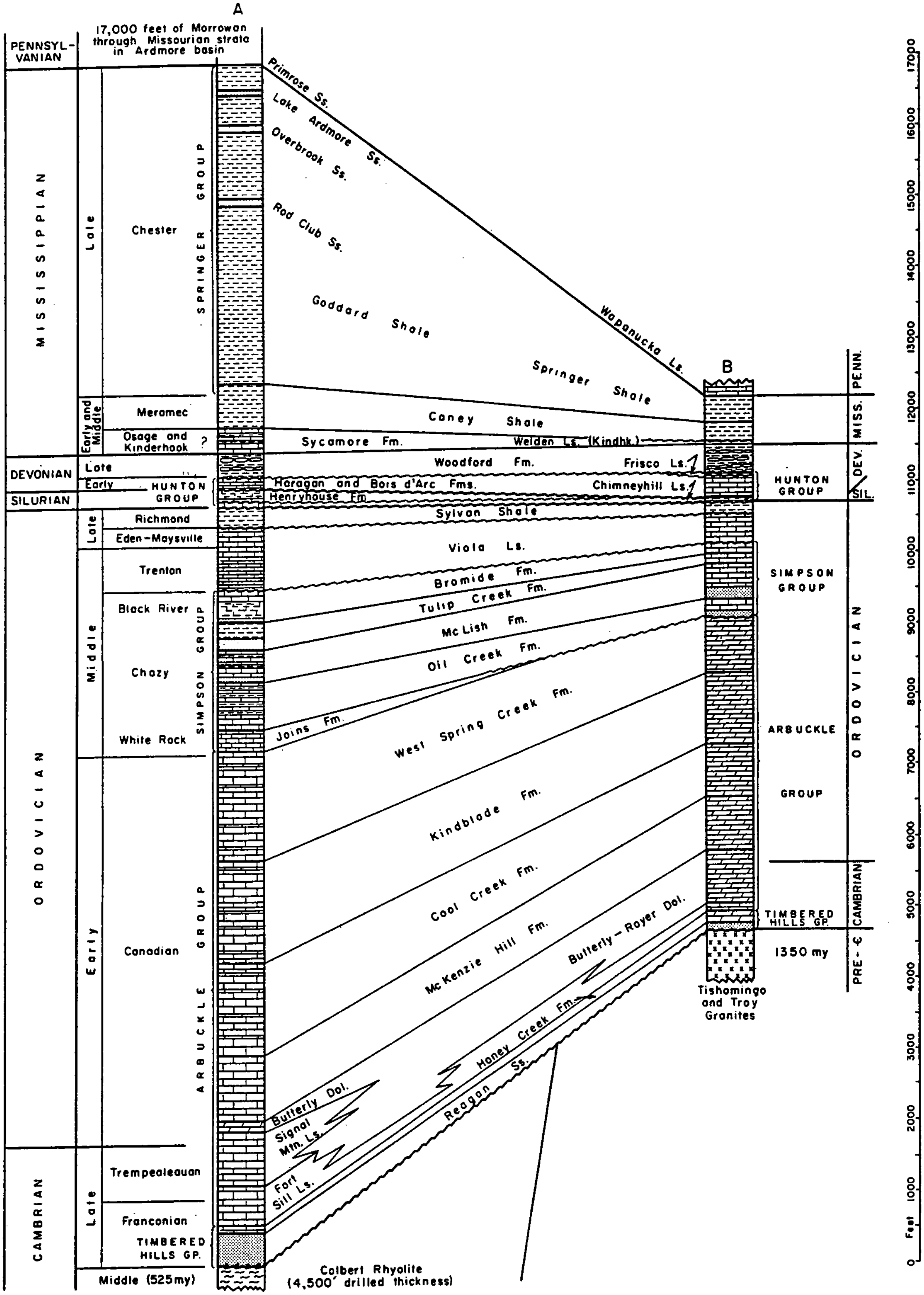

Figure 5. Pre-Pennsylvanian stratigraphic columns for: A. western Arbuckle Mountains (Arbuckle anticline, Fig. 2) and B. eastern Arbuckle Mountains (Hunton anticline, Fig. 2)

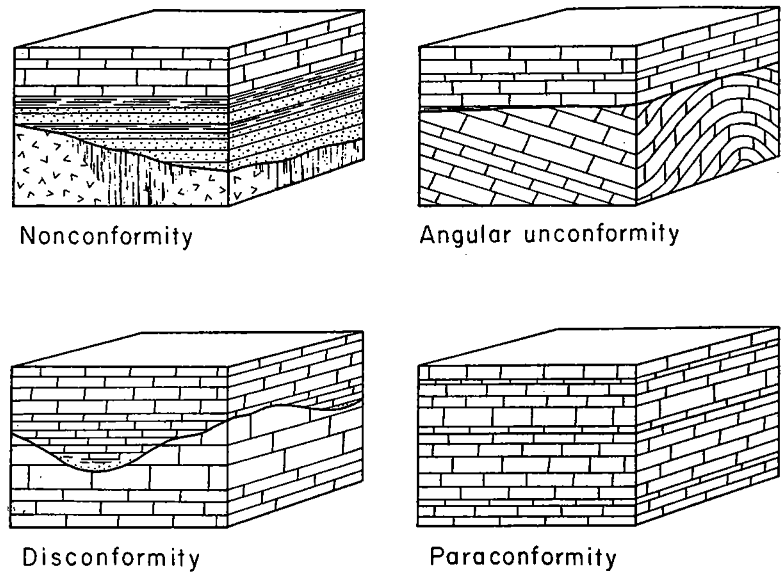

Figure 6. Different types of unconformities (from Dunbar and Rodgers, 1957, p. 117). A nonconformity is represented in the field trip area by the Cambrian Reagan Sandstone overlying 1.4 b.y.-old granites. An angular unconformity separates lower and middle Paleozoic rocks from upper Paleozoic rocks in the Fitts oilfield.

The geology of the Nature Conservancy's Pontotoc Ridge Preserve consists of gently dipping limestone and lesser amounts of sandstone of the Middle Ordovician Simpson Group (Figs. 5, 7). The Simpson Group in the eastern Arbuckle Mountains consists of the following formations, from oldest to youngest: Oil Creek, McLish, Tulip Creek, and Bromide. In the Pontotoc Ridge area, the younger three formations have been mapped together. Each of the formations consists of a basal sandstone many tens of feet thick overlain by a thick section of limestone with lesser amounts of sandstone and shale. Faults cut through the area but generally juxtapose the same formation on both sides of the fault. The exception to this is a fault that runs along the slope of the east-west trending hills in the north-half of sections 31, 32, and 33 (Fig. 7). This down-to-the-south fault juxtaposes McLish/Tulip Creek/Bromide exposed on the hills against Oil Creek to the north in the Coal Creek drainage basin.

TISHOMINGO-BELTON ANTICLINES

The southernmost structural block of the eastern Arbuckle Mountains is the Tishomingo-Belton anticlines. The geology of this block is extremely interesting because the oldest rocks exposed in it are 1.4-billion-year-old granites. In detail, the Tishomingo-Belton anticlines are actually two blocks, the Belton anticline to the north and Tishomingo anticline to the south. In the extreme eastern part of the Arbuckle Mountains, the two blocks are separated by a fault zone (down-to-the-north) about 1/4 mile wide. To the west, near the town of Mill Creek, the fault zone is nearly 2.5 miles wide with very distinguishable faults on the north (Blue River fault) and south (Reagan fault) sides. The overall displacement on the faults separating the Belton and Tishomingo anticlines is consistently up-to-the-south. In reviewing the general structural geology of the eastern Arbuckle Mountains, one takes a giant step up out of the Franks graben onto the Hunton anticline, then a small step up onto the Belton anticline, then another small step uo onto the Tishomingo anticline.

The general aspect of the Belton-Tishomingo anticlines is that of a gently west-dipping block; this results in the oldest rocks (granite) being exposed to the east, and progressively younger rocks being exposed to the west. Like most of the eastern Arbuckle, this picture is oversimplified and there are many places where faults or folds interrupt the simple picture. This is especially true in the wide fault zone near Mill Creek, which is downdropped relative to the Belton and Tishomingo blocks, and contains some very highly folded rocks.

South of the Belton-Tishomingo anticlines, the Precambrian and Paleozoic rocks of the Arbuckle Mountains are covered by nearly horizontal rocks of the Gulf Coastal Plain. These are much younger (the oldest formation, the Cretaceous Antlers Formation, is about 110 million years old) and represent the northern extent of a paleo-Gulf of Mexico. All our knowledge of the Arbuckle Mountains (and, for that matter, the Ouachita Mountains) from this point south comes from interpretation of drill holes.

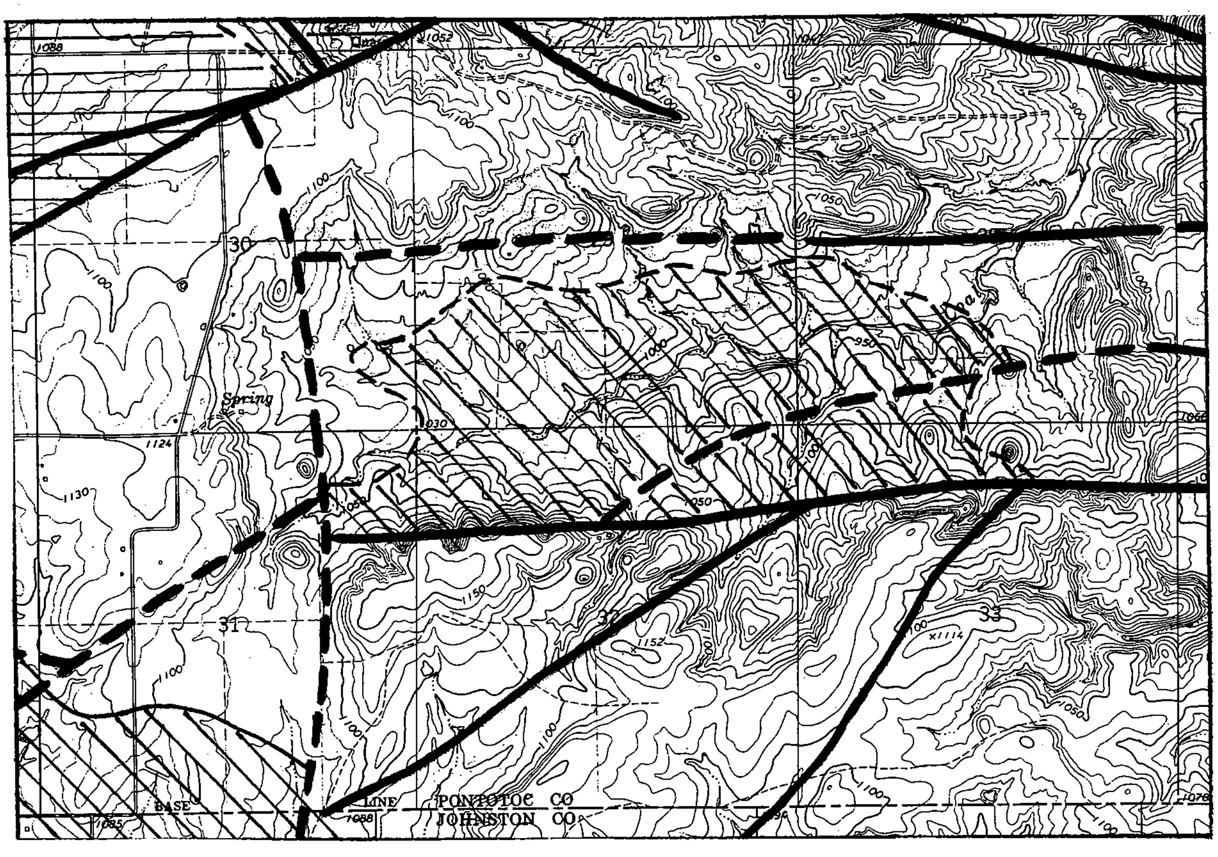

Fig. 7. Sketch geologic map of The Nature Conservancy's Pontotoc Ridge Preserve (from Ham and McKinley, 1954). Geologic units are (oldest to youngest): West Spring Creek Formation (horizontal lines); Oil Creek Formation (diagonal lines); McLish, Tulip Creek, and Bromide Formations (no pattern). Heavy lines are faults.

ROAD LOG

The geology field trip for The Nature Conservancy - Oklahoma Chapter's annual meeting will start at the Pontotoc Community Center. (The Community Center is Stop 3 on this field trip, and we will return here later.) Drive west to Highway 99 and turn north (right). The highway goes almost due north for a little over five miles, then takes a broad turn to the right.

As we descend through several good exposures on the west (left) side of the road, be sure to look straight ahead (off to the north or northeast) every now and then. Note that the area to the north is quite a bit lower in elevation than the area to the south. The area to the north is the Franks graben, a downdropped block underlain mostly by Pennsylvanian shale with minor sandstone, conglomerate, and limestone. To the south is the Hunton anticline, which is underlain mostly by considerably older (Ordovician) limestone. The topographically low area of the Franks graben is not low because is has been downdropped, but because the shales that are exposed there are more easily eroded than the limestones to the south.

After passing junction with Highway 99A just south of Fittstown, continue north on Highway 99 for 3.5 miles. Immediately before crossing Bois d'Arc Creek, park on the east (right) side of the road at the entrance to Ebey Ranch. Stop 1 is on both sides of Highway 99.

HIGHWAY 99 IS VERY BUSY,
THE BRIDGE OVER BOIS D'ARC CREEK IS NARROW,
AND TRAFFIC OFTEN DOESN'T SLOW DOWN FOR IT.

BE VERY CAREFUL CROSSING THE HIGHWAY.

STOP 1. FAULT SEPARATING HUNTON LIMESTONE AND WOODFORD SHALE

Faults are rarely this well exposed in Oklahoma, especially ones that mark (or almost mark) the boundary between structural provinces. The fault exposed at this outcrop is a splay (or subsidiary fault) off of the Stonewall fault, which separates the Lawrence uplift to the north from the Franks graben (downthrown block) to the south. The actual trace of the Stonewall fault is about 0.3 miles to the south, where it separates shales of very different ages. As it typical in this part of Oklahoma, shales erode readily; as a result, the Stonewall fault is poorly exposed.

Look carefully at the outcrops on both sides of the road. The small outcrop on the east side is mostly gray-weathering limestone with abundant crinoid fragments. The gray color is not the real color of the rock, but a weathering feature. If you don't believe me, break open a piece of the limestone. Note that the south side of this small outcrop is a different rock type. Try scratching a piece with a geology hammer or knife blade. Limestone scratches easily, but this rock type doesn't. Note also the extremely broken, fragmented character of the rock, as well as the iron-oxide (the mineral limonite) staining. The rock on the south side of the outcrop is a chert breccia; chert is almost pure silica (hence, its very hard nature) and breccia refers to the fragmental appearance. Why is the rock broken and why is there chert when most of the outcrop is limestone? (Hint - and why is the rock iron-oxide stained?) Read on.

Now look at the outcrop on the west side of Highway 99. Most of the outcrop is crinoidal limestone. Note the very faint, nearly horizontal layering. These are bedding planes that mark the original depositional surfaces of the limey sediment. Walk south along the outcrop. The limestone abruptly ends and at your feet (road level) is a large block of chert breccia. If you want to, climb up the steep slope through the brush and look at what rock type is next to the end of the limestone outcrop. More chert breccia! Continue walking south. What kind of rock (also nearly horizontal) is now exposed? Is it the same gray limestone as just to the north? The very platy-weathering rock is shale and the bedding planes in the shale project directly into the bedding planes in the limestone. How could these two very different rock types, which project into each other, have come so close together? Might the answer have anything to do with the chert breccia?

Walk back to the south end of the limestone outcrop. Note the large, nearly vertical fracture about 2 to 5 ft from the end of the outcrop. Could this have anything to do with the abrupt end of the limestone?

The limestone is part of the Hunton Group, which is late Ordovician - Silurian - early Devonian in age. The shale is a typical exposure of the Woodford Shale, which is Devonian - early Mississippian in age (Fig. 5). Therefore, the limestone is older than the shale. If you think that the chert breccia represents a fault zone along which the rock has become totally fragmented, which side went up? If this fault is a splay off the Stonewall fault, does it have the same sense of offset as the Stonewall fault? (See Figure 8.)

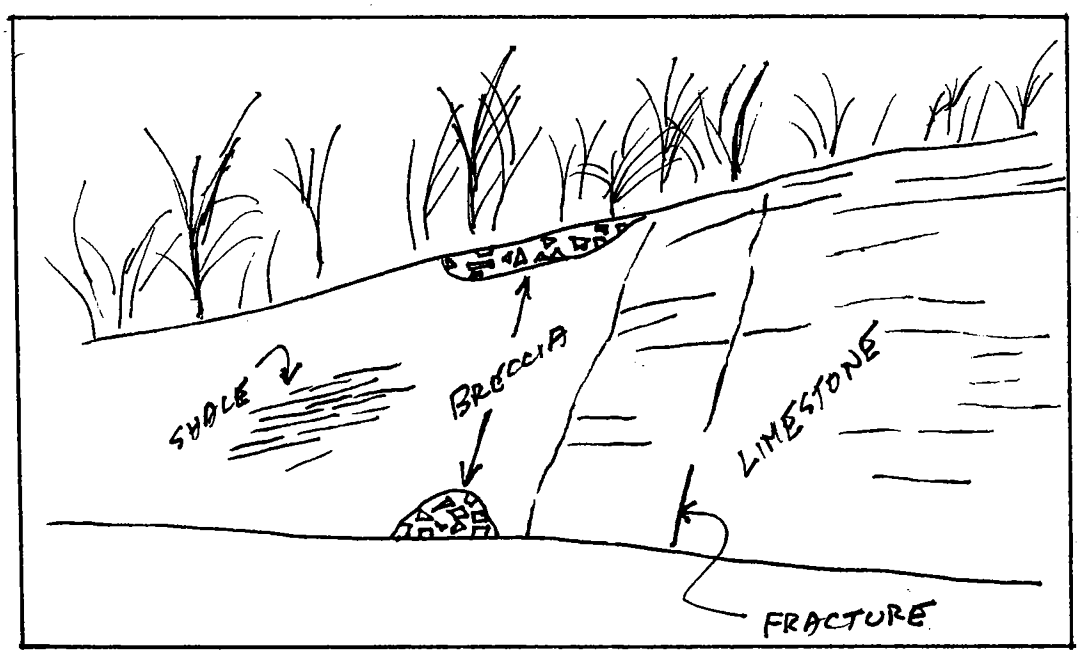

Figure 8. Sketch of Woodford - chert breccia - Hunton outcrop along Highway 99 (Stop 1, TNC field trip).

Exercise: Break some small pieces of Woodford Shale into your hand and quickly smell them. Recognize the smell? The Woodford Shale has a very high organic content and is one of the best source rocks for petroleum in Oklahoma.

Return to cars, and retrace route south on Highway 99. About 2.7 miles past (south of) the intersection with Highway 99A, there is a large flat area on the west (right) side of the highway. Pull off and stop there. We will walk up the road to the south

A REMINDER - HIGHWAY 99 IS VERY BUSY.
KEEP WELL OFF THE ROAD.

STOP 2. VIOLA LIMESTONE

The gap in the outcrop where we will park marks the location of a small fault that separates Hunton Limestone (to the north) from Viola Limestone (to the south). Knowing that the Hunton is younger than the Viola, did the north side of the fault go relatively up or down? Is this sense of movement consistent with the Franks graben being a down-dropped block relative to the Hunton anticline?

The first observation to make as we walk up the road is the direction the strata are tilted. Assuming that sediments are originally deposited horizontally, and assuming that these rocks haven't been turned completely upside down by the folding and faulting that accompanied formation of the Arbuckle Mountains, are we walking into older or younger rocks as we walk up the road? (Hint - a couple hundreds yards up the road we will see the contact between the Viola and underlying Bromide Formation.)

The first outcrops of Viola Limestone along the road consist of relatively thick-bedded to platy limestone with very abundant brachiopods (Fig. 9) Farther up the road, crinoids become very abundant, and Alberstadt (1973) also identified bryozoans, echinoderms (similar to "sea urchins"), and at the base of the formation, graptolites (resemble sawteeth). Can you find any of the fossils Alberstadt identified?

Karst features are very common in limestone terranes. Karst features result from the dissolution of limestone by groundwater, and the most spectacular kind of karst features are caverns and sink holes. But karst features occur on all scales. Note that lichen are growing at one place on the limestone where water is seeping out of the outcrop. There are several places where "mini-caverns" can be observed and "micro"-stalactites can be seen in some of them. No doubt these "mini-caverns" serve as home for a large variety of mammals and/or reptiles.

Farther up the road, chert layers become very abundant in the limestone. Chert is almost pure silica (SiO_2), in contrast to limestone which is almost pure calcium carbonate ($CaCO_3$). As a result, chert is much harder than limestone and tends to stand out in relief on the outcrop. The chert occurs as relatively continuous beds and nodules. Note that the interbedded limestone/chert overlies bedded and massive limestone, some of which has a "birdseye" texture (see description of "birdseye" at Stop 3). Also note the presence of abundant burrows (trace fossils) on some of the bedding planes. This bedded/massive limestone is the uppermost part of the Bromide Formation and the bedded limestone/chert is the lowest part of the Viola Formation. In contrast to the Hunton - Woodford contact at Stop 1 which was a fault, this Bromide - Viola contact is depositional.

Alberstadt (1973) measured 212 feet of Viola over the Bromide along this highway. The upper part of the Viola is cut off by the fault near where the cars are parked.

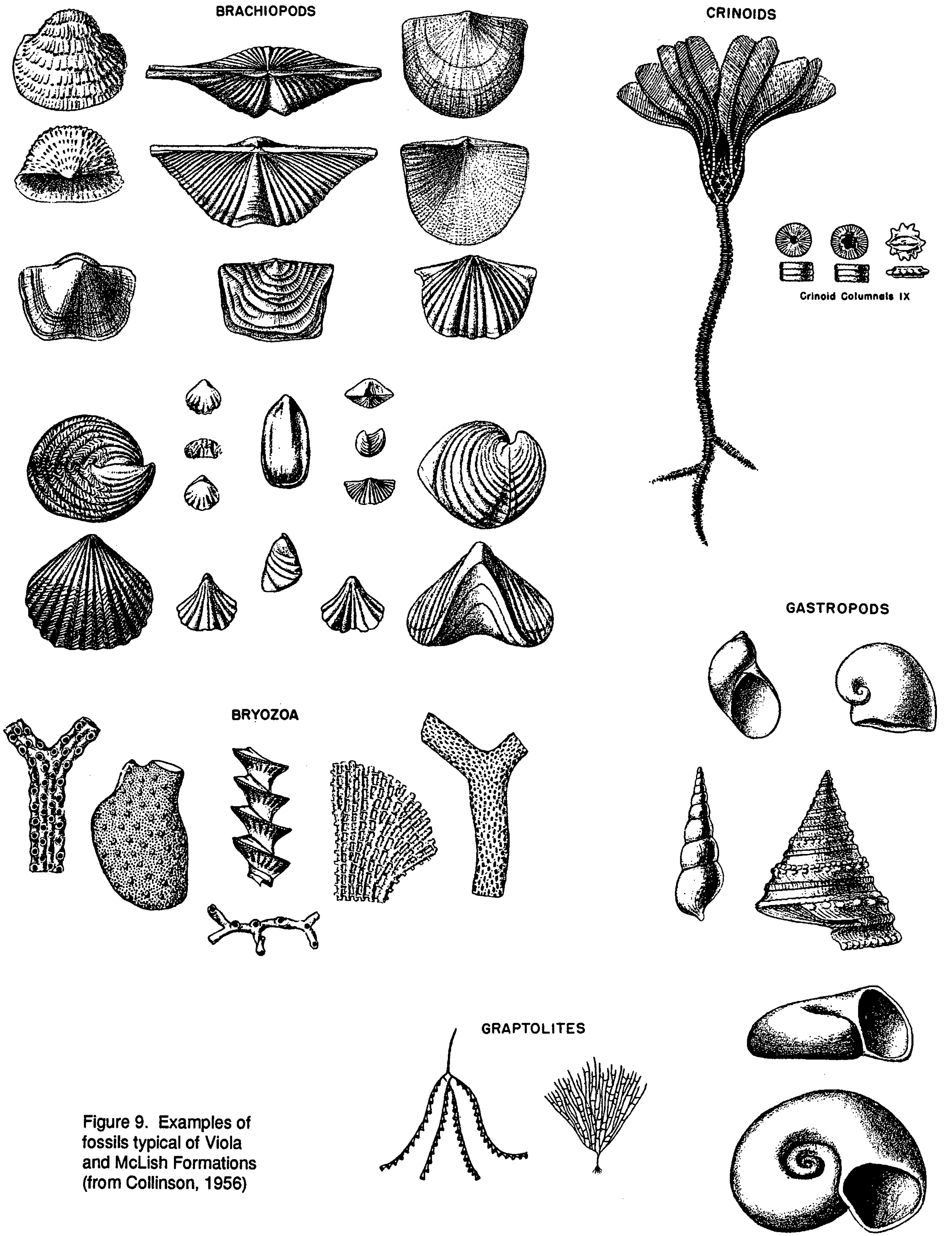

Figure 9. Examples of fossils typical of Viola and McLish Formations (from Collinson, 1956)

Return to cars, and continue to retrace route south of Highway 99. In Pontotoc, turn east to the Community Center.

STOP 3. "BIRDSEYE LIMESTONE", PONTOTOC COMMUNITY CENTER

The Pontotoc Community Center is built from a commonly quarried limestone known as "birdseye limestone". Louise Jordan (1957, p. 18) described it thusly:

"Descriptive of spotted appearance made by areas of clear calcite in lithographic limestone in the McLish Formation of south-central Oklahoma. Name should not be used formally."

While the "birdseye" texture is characteristic of limestones in the McLish Formation, it also occurs in other formations in the Arbuckle Mountains, for example, in the upper part of the Bromide Formation at Stop 2.

Look closely at the different blocks of limestone. You can see original sedimentary bedding in many pieces. There are many other features typical of limestones in some of the blocks. How many can you find?

1. Fractures filled with crystalline calcite.
2. Stylolites. Stylolites are thin seams or contacts "marked by an irregular and interlocking mutual interpenetration of the two sides, the colums, pits, and teeth-like projections on one side fitting into their counterparts on the other. ... Stylolites are supposedly formed ... by differential vertical movement under pressure, accompanied by solution." (from Glossary of Geology, American Geological Institute)
3. Fossils. Can you find any brachiopods? Crinoids? Gastropods? Miscellaneous shells? (Fig. 9)
4. Trace fossils. These are the burrows or trails left behind by different organisms. Many of the "birdseye" features are elongate and may be burrows.
5. Pyrite crystals.

Return to cars, drive back to Highway 99, and turn left (south). About 2.5 miles south of Connerville, Highway 99 crosses the trace of the Sulphur fault. The Sulphur fault separates the Hunton anticline block of the eastern Arbuckle Mountains to the north from the Belton anticline block of the eastern Arbuckle Mountains to the south. In this area the fault is not easy to see because Ordovician limestone is on both sides of the fault. Detailed work by geologists familiar with the stratigraphy of the area has shown that Simpson Group limestones (Oil Creek Formation) are north of the fault, whereas Arbuckle Group limestones (West Spring Creek, Kindblade Formations) are south of the fault.

In another two miles the highway crosses another fault that juxtaposes limestone to the north against granite to the south. Look carefully in the fields and bar ditches for the change from gray or buff limestone to reddish-brown granite. You might also notice a change to very "sandy" soil which forms on the granite.

Intersection with Highway 7 to the east. Continue south on Highway 99. A couple of tenths of a mile after passing the Highway 7 intersection, note the outcrops of gray limestone in the field on both sides of the highway. This narrow band (about one-half mile wide) of limestone marks the trace of the Reagan - Mill Creek - Blue River fault zone which, in this area, separates the Belton anticline block from the Tishomingo anticline block of the eastern Arbuckle Mountains.

One mile south of the intersection with Highway 7 east, Highway 7 to the west intersects Highway 99. Turn west (right), and follow Highway 7 about 5 miles through the Tishomingo National Fish Hatchery to the town of Reagan. Where Highway 7 turns sharply north (right), turn south (left). Drive 0.2 miles to the end of the road and turn east (left). Drive 0.5 miles and turn south (right). The road goes south for about 1.8 miles, southwest for .2 miles, west for about 0.3 miles, then turns sharply south again. About 0.5 miles after the road turns south, turn east (left) into the Slippery Falls Camp, which is run by the Boy Scouts of America. Follow the signs first to the camp office, then to Slippery Falls. (I would like to thank the Last Frontier Council, Boy Scouts of America, for permission to examine the granite at the falls.)

STOP 4. TISHOMINGO GRANITE, SLIPPERY FALLS SCOUT CAMP

Some of the oldest rocks in Oklahoma and, in fact, the southern mid-continent, are exposed in the Arbuckle Mountains. Four different plutonic rocks have been mapped in the eastern Arbuckles; these rocks are 1) an unnamed granodiorite; 2) the Troy Granite; 3) the Blue River Gneiss, and 4) the Tishomingo Granite. The Troy Granite is 1.399 +/- 0.095 billion years old (that's 1,399,000,000 years old!!!); the Tishomingo Granite is slightly younger at 1.374 +/- 0.015 billion years old, and the Blue River Gneiss is 1.396 +/- 0.040 billion years old (Bickford and Lewis, 1979). Field relations show that the granodiorite is older than the Troy which is older than the Tishomingo; the Blue River is also older than the Tishomingo, but its age relationships to the granodiorite and Troy are unknown. Denison (1973) has suggested that the Blue River Gneiss may be the metamorphosed equivalent of the granodiorite and Troy, in which case it would be the youngest of the three.

Even though the Tishomingo Granite is the youngest of the four major plutonic rock units in the Arbuckles, it is very, very old. There are some igneous rocks that are younger than the Tishomingo Granite (diabase, granite, and rhyolite dikes), but these are relatively minor volumetrically.

The principal feature of the Tishomingo Granite that distinguishes it from the other plutonic rocks are the large pink potassium feldspar crystals (Fig. 10). The actual mineral is perthitic microcline, which consists of intergrown microcline ($KAlSi_3O_8$) and plagioclase (a Na-Ca feldspar). The other smaller minerals present in the granite that make up the material surrounding the big crystals (geologists call them phenocrysts) are pink perthitic microcline, whitish plagioclase, and clear quartz. The extremely coarsely crystalline nature of the minerals that make up the Tishomingo Granite indicate is cooled very slowly, probably deep within the Earth's crust, and has since been exposed by erosion.

Look around this exposure of Tishomingo Granite. Do you see anything in the rock that doesn't look like granite? Try to find the following:
1. Pods (xenoliths, literally "foreign rocks") of a darkish rock within the granite. Could these be fragments of the granodiorite mentioned above caught up in the granite?
2. Faint banding within an otherwise massive granite. This could be original magmatic banding showing the magma churned or "convected" or it could represent nearly completely melted fragments of granodiorite.
3. Extremely coarsely crystalline segregations of almost pure pink microcline or quartz. These represent places in the original magma where fluids collected permitting unusually large crystal growth.

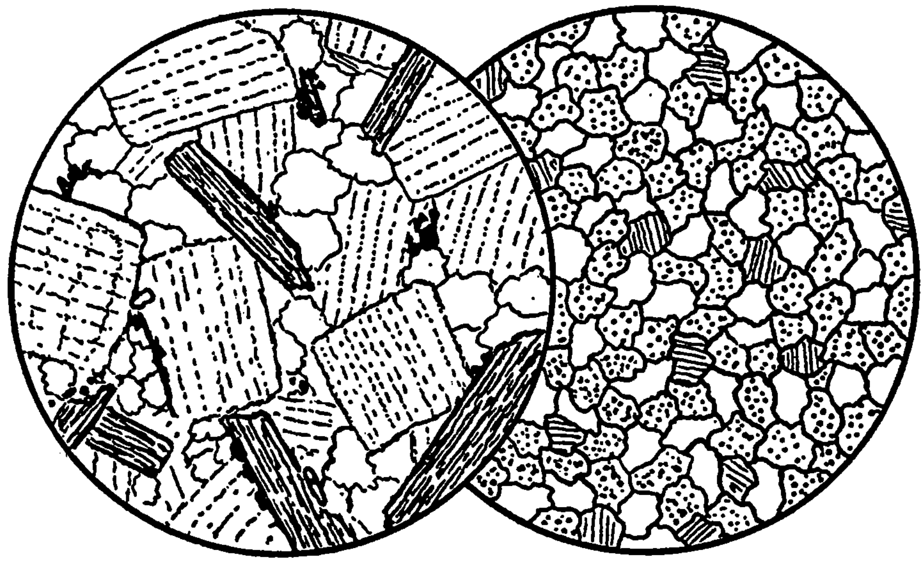

Figure 10. Contrasting texture of granite. Left - crystals are different sizes, and include large, well-formed pink feldspar. Right - crystals are nearly equidimensional (from Spock, 1953). The texture on the left is similar to the Tishomingo Granite, and that on the right is similar to the Blue River Gneiss and Troy Granite.

Other features to note in the granite are two kinds of fractures. One set is nearly vertical (these are called "joints", which are fractures along which no movement has occurred, in contrast to faults, which are fractures along which movement has occurred) and vegetation typically grows in them. Another set of joints is nearly horizontal and is a weathering feature of granites. (If you've ever been to Yosemite National Park, you've seen this feature in many of the granites.) This feature is called exfoliation and contributes to the erosion of the granite.

Be sure to also note that the granite weathers to a very coarse sandy material. Geologists call this material "grus", and many of the shallow "quarries" in the area scrape the weathered granite or grus off the surface for use as roadbed material.

An historical note - About 3.5 miles northwest of Slippery Falls and about 1 mile east of the town of Troy is Ten Acre Rock, probably the best-known locality of the Tishomingo Granite. As Denison (1973) points out, "in early days of settlement it served as a prominent landmark for the region, and its achieved some fame when in 1915 a quarry was opened on its north slope for the production of dimensional granite for constructing the ground floors of the state capitol at Oklahoma City. Since that time it has been known as the Capitol quarry, although the quarry face itself has not been actively worked in succeeding years."

Return to cars and retrace route back to Reagan, back to Highway 99, and back to Highway 7 east. Turn east (right) on Highway 7. Drive 2.7 miles to bridge over Blue River. Stop on right side of road immediately east of the bridge to look at small granite outcrop.

To see the granite in its "more natural" state, continue driving a few hundred yards further east on Highway 7, turn south (right) into the Oklahoma Department of Wildlife's Blue River Public Hunting and Fishing Area, and drive to the parking area at the end of the road. Park, walk to the river, and follow the trail downstream about 400 feet to the falls. The Blue River is the only creek in this part of the eastern Arbuckles that has waterfalls and rapids. What do you think it the reason for this?

STOP 5. BLUE RIVER GNEISS

This unit has been mapped by geologists as the Blue River Gneiss, which implies that it is a metamorphic rock. More complete descriptions of it call it "granitic gneiss", i.e., a granite that has suffered some degree of metamorphism as evidenced by metamorphic features such as a crude layering or banding. This outcrop, however, shows little in the way of metamorphic features and looks more like a "plain old" granite (Fig. 10). But it is clearly different from the Tishomingo Granite at Slippery Falls. What do you think distinguishes the two kinds of granite - this one (Blue River Gneiss) and the Tishomingo Granite?

Some geologists have noted that this rock unit resembles the Troy Granite and, in fact, the bulk mineral composition of the two units overlaps. However, nowhere are the two units in physical contact, so geologists can't determine their exact relationship. The principal minerals in the Blue River Gneiss are oligoclase (a plagioclase feldspar) (45%), quartz (30%), and perthitic microcline (20%), with lesser amounts of biotite, muscovite, iron oxides, sphene, apatite, and zircon (Denison, 1973, p. 46). Geologists will tell you that there is too much plagioclase feldspar relative to potassium feldspar for this rock to be a true granite, and that it's proper classification is a quartz monzonite.

Denison (1973, p. 46) has described the appearance of the Blue River Gneiss at a locality about three miles south of here, but much of what he says is appropriate for this part of the Blue River. "The small waterfalls or rapids along the Blue River are caused by the growth of travertine evidently over original bedrock outcrops. The headwaters of the Blue are in the Hunton anticline, which is underlain by carbonates (limestone) of the Arbuckle Group. The carbonate is taken into solution there and is precipitated when passing over a natural rapids. Honey Creek in the western Arbuckles, particularly notable at Turner Falls, has an ananlogous travertine buildup. No other creek flowing through the Precambrian shows this feature."

Return to cars and continue driving east on Highway 7. In about 4.5 miles, the highway makes a gentle turn to the north (left). About 0.7 miles after the highway begins to turn, it drops in elevation. At this point, the highway is crossing the Sulphur fault zone, which in this area separates the eastern Arbuckle Mountains block to the south from the Wapanucka syncline, which is within the Arkoma basin geologic province. The Wapanucka syncline is topographically lower than the Arbuckle Mountains because, like the Franks graben, it is underlain mostly by easily eroded shale, in contrast to the more resistant granite and limestone of the Arbuckle Mountains.

The highway swings right and heads directly east for a little over a mile. It then turns gently south (right) and then turns back to the north (left) as it passes just north of Wapanucka Lake (to the right of the highway). Park on the right side of the road immediately past the dam that holds in Wapanucka Lake. We will walk across the dam and look at the exposure on the far side of Sandy Creek just below the dam.

Total distance from Blue River bridge to Wapanucka Lake dam - 8.7 miles.

WATCH OUT FOR POISON IVY!

STOP 6. WAPANUCKA LIMESTONE

The Wapanucka Limestone is the youngest rock unit we will look at on this field trip. It is Pennsylvanian in age or, more specifically, Morrowan (earliest Pennsylvanian). Pennsylvanian rocks form the bedrock in the Franks and Wapanucka grabens, which mark the eastern end of the Arbuckle Mountains. This area was used by Joseph Taff in 1901 to name the Wapanucka Limestone, hence, this area is considered by geologists to be the "type area" of the formation.

This very outcrop was described in great detail by Rowett and Sutherland (1964). Rowett and D.M. Strong measured and described on an inch-by-inch basis the 88 feet of Wapanucka Limestone that forms this outcrop and extends up the hill. Most of the section consists of limestone, including fossiliferous and unfossiliferous varieties, with lesser amounts of shale and chert. The bottom part of the section, exposed along the creek, consists mostly of well-stratified, abundantly fossiliferous limestone. A cursory examination revealed crinoids, gastropods, bryozoans, and brachiopods. Rowett and Sutherland (1964) also noted coral fragments (Fig. 11).

An important feature to note in this outcrop is that some of the beds thicken and thin - they do not maintain a uniform thickness across the entire width of the outcrop. This is evidence for irregular deposition, probably caused by current and/or wave action. Most geologists would agree that this limestone was deposited under relatively shallow marine conditions.

This is the last stop of the field trip. To return to the Community Center, retrace your route back west on Highway 7 and turn north (right) on Highway 99 to Pontotoc. Please drive carefully, and don't try to look at the geology at 65 mph!

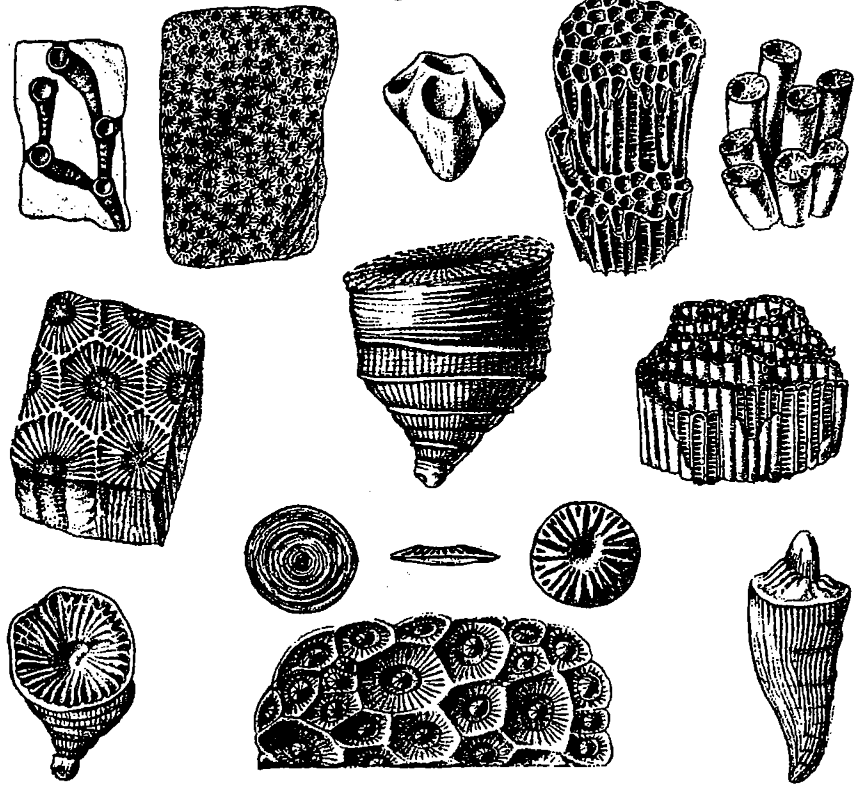

Figure 11. Corals typical of those found in the Wapanucka Limestone (from Collinson, 1956).

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about *THE OKLAHOMA GEOLOGICAL SURVEY*

The Oklahoma Geological Survey (OGS), a State research and public-service agency, was provided for in the Oklahoma Constitution and began operation on July 25, 1908, under an enabling act of the First Legislature. The OGS is responsible for investigating the geology and mineral resources of the State and for preparing and publishing bulletins, reports, and maps describing these investigations.

The research activities of the OGS can be grouped into the following catagories: geologic mapping, water-resources studies, mineral- and energy-resources investigations, geophysical research, environmental-geology studies, and basin research. The Survey also is involved in public information and assistance, acquisition of mineral-production data, and maintenance of a state repository of well cores and samples. Some of these activities, including water-resources studies and data acquisition, are conducted on a cooperative basis with federal agencies.

While scientific investigations are the cornerstone of the Survey's work, translating this technical information for the public also is a vital OGS activity. This is especially important to those formulating public policy, recruiting industry, or communicating information about Oklahoma's natural environment.

The OGS responds to a multitude of requests from within and outside the State for information about local and regional aspects of Oklahoma's geology and natural resources. In addition, the staff presents scientific and public lectures, conducts field trips, attends conferences and exhibits, testifies before various state and federal boards and agencies, and participates in a number of professional organizations.

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Eon or Eonothem	Era or Erathem	Period, System, Subperiod, Subsystem		Epoch or Series		Age estimates of boundaries in mega-annum (Ma)[1]
		Subdivisions (and their symbols)				
Phanerozoic[2]	Cenozoic[2] (Cz)	Quaternary[2] (Q)		Holocene		0.010
				Pleistocene		1.6 (1.6–1.9)
		Tertiary (T)	Neogene[2] Subperiod or Subsystem (N)	Pliocene		5 (4.9–5.3)
				Miocene		24 (23–26)
			Paleogene[2] Subperiod or Subsystem (Pɛ)	Oligocene		38 (34–38)
				Eocene		55 (54–56)
				Paleocene		66 (63–66)
	Mesozoic[2] (Mz)	Cretaceous (K)		Late	Upper	96 (95–97)
				Early	Lower	138 (135–141)
		Jurassic (J)		Late	Upper	
				Middle	Middle	
				Early	Lower	205 (200–215)
		Triassic (T̄R)		Late	Upper	
				Middle	Middle	
				Early	Lower	~240
	Paleozoic[2] (Pz)	Permian (P)		Late	Upper	
				Early	Lower	290 (290–305)
		Carboniferous Systems (C)	Pennsylvanian (IP)	Late	Upper	
				Middle	Middle	
				Early	Lower	~330
			Mississippian (M)	Late	Upper	
				Early	Lower	360 (360–365)
		Devonian (D)		Late	Upper	
				Middle	Middle	
				Early	Lower	410 (405–415)
		Silurian (S)		Late	Upper	
				Middle	Middle	
				Early	Lower	435 (435–440)
		Ordovician (O)		Late	Upper	
				Middle	Middle	
				Early	Lower	500 (495–510)
		Cambrian (Ꞓ)		Late	Upper	
				Middle	Middle	
				Early	Lower	~570[3]
Proterozoic (P̶)	Late Proterozoic (Z)	None defined				900
	Middle Proterozoic (Y)	None defined				1600
	Early Proterozoic (X)	None defined				2500
Archean (A)	Late Archean (W)	None defined				3000
	Middle Archean (V)	None defined				3400
	Early Archean (U)	None defined				3800 ?
pre-Archean (pA)[4]						

Divisions of geologic time as recognized by the U.S. Geological Survey.