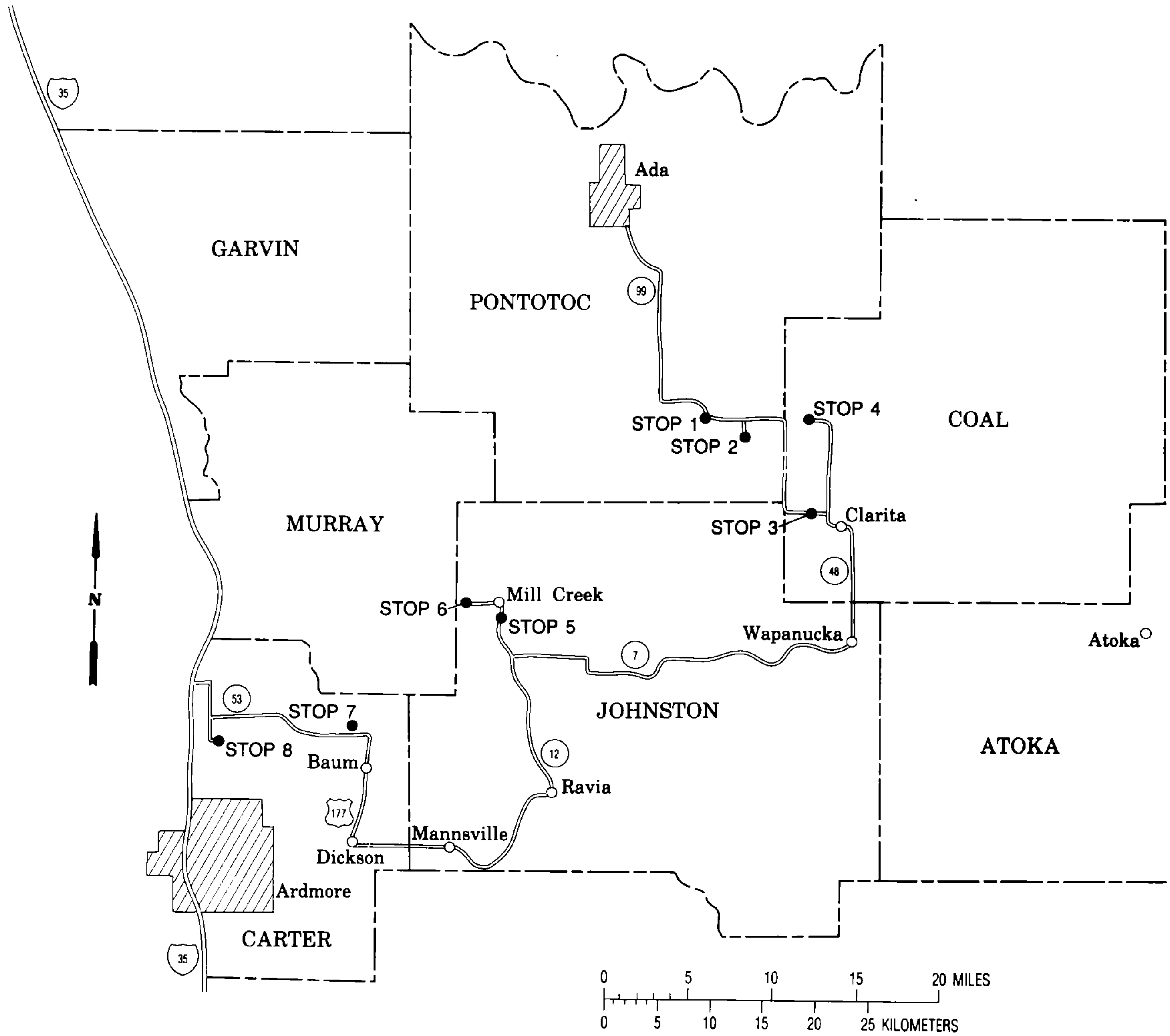
Lower and Middle Pennsylvanian Stratigraphy in South-Central Oklahoma

Oklahoma Geological Survey 1982 GUIDEBOOK 20



Locality and Route Map

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LOWER AND MIDDLE PENNSYLVANIAN STRATIGRAPHY IN SOUTH-CENTRAL OKLAHOMA

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1982

PREFACE

The Atokan Series was first named by Spivey and Roberts in 1946, but the name was used informally in a chronostratigraphic sense even earlier. Yet, the type area for the Atokan Series has not previously been visited on a formal field trip. Recent detailed field work on Lower and Middle Pennsylvanian strata in the western Arkoma Basin in the Arbuckle Mountains area make possible for the first time a detailed regional stratigraphic analysis of both the depositional history and faunal relationships of the Atokan Series in its type region.

This field trip is being conducted in conjunction with a symposium on the "Atokan Series and Its Boundaries," to take place in Norman, Oklahoma, on March 29, 1982, at the annual meeting of the South-Central Section of the Geological Society of America. It is hoped that the field trip and the symposium will provide the occasion for a thorough discussion of Early and Middle Pennsylvanian chronostratigraphic terminology as used throughout North America.

I would like to thank William D. Rose, editor for the Oklahoma Geological Survey, for his expert attention to detail in the production of this guidebook, and Charles J. Mankin, director of the Oklahoma Geological Survey, for his continued support of regional analyses of the extensive Carboniferous strata in Oklahoma.

PATRICK K. SUTHERLAND
March 1, 1982

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Lower Atoka Formation, Mill Creek Syncline, Stop 6, unit 39, Lewis Ranch. Photomicrograph of fusulinid crinoidal packstone. The fusulinids are *Fusulinella* sp. aff. *F. devexa* Thompson.

Back Cover

Chart showing correlation of formations and members of Chesterian (Mississippian) and Morrowan and Atokan (Pennsylvanian) Series from the Ardmore Basin to the Ozark Shelf, Oklahoma and Arkansas (from Morris and Sutherland, in press).

MORROWAN AND ATOKAN (PENNSYLVANIAN) STRATIGRAPHY IN THE ARBUCKLE MOUNTAINS AREA, OKLAHOMA

Patrick K. Sutherland
Bruce E. Archinal
R. Kent Grubbs

INTRODUCTION

Early and Middle Pennsylvanian (Morrowan and Atokan) strata crop out extensively in eastern, southeastern, and southern Oklahoma. Coeval rocks in the Ozark Mountains region of northeastern Oklahoma and northwestern Arkansas have been described by Sutherland and Henry (1977) and Sutherland and Manger (1977). Those in the Ouachita Mountains of southeastern Oklahoma have been described by Grayson (1979), Sutherland and Manger (1979), and Morris and Sutherland (in press). The present study is concerned with Morrowan and Atokan strata in the following areas of south-central Oklahoma: (1) on the northeastern and eastern flanks of the Arbuckle Mountains, (2) in the Mill Creek Syncline of the central Arbuckles, and (3) in the northern part of the Ardmore Basin (fig. 1). There are marked differences in the lithologic character and thickness of biostratigraphically equivalent units in these three areas. The first two represent shelf facies, characterized by the occurrence of unconformities, that are situated on the eastern and southern flanks of the Hunton Arch (fig. 2). The third represents a basinal facies, with no known unconformities, deposited in the northern part of the Southern Oklahoma Aulacogen (fig. 2). Figure 3 shows the geographic location and structural position of the three areas. A cross section across the region (fig. 4) illustrates the change from shelf facies in the north to basinal facies in the south.

NORTHEASTERN ARBUCKLE MOUNTAINS

Introduction

The stratigraphic sequence in the northeastern Arbuckle Mountains area consists of the "Springer" Shale and Wapanucka Limestone (Morrowan), the Atoka Formation (Atokan), and the Hartshorne and McAlester Formations (Desmoinesian) (fig. 5). In general, these units thin toward the Hunton Arch to the west. This thinning resulted partly from the westward truncation of the Wapanucka and Atoka Formations and partly from the westward onlap of the Atoka, Hartshorne, and McAlester Formations. Evidence of this onlap can be seen a mile and a half west of Canyon Creek, Stop 1, where the McAlester Formation rests directly on the "Springer" Shale (fig. 3).

Morrowan Series

The Mississippian–Pennsylvanian boundary is poorly defined on the northeastern flank of the Arbuckle Mountains, because it falls within a poorly exposed shale sequence. The primary unit of late Mississippian age in this area is the Caney Shale, named by Taff (1901). Taff's original description included shales in both the Arbuckle and Ouachita regions. In the Arbuckle Mountains, the Caney extended from the top of the Woodford (Devonian) to the base of the Wapanucka Limestone (see back cover, this guidebook). Consequently, both Chesterian and Morrowan shales were included. Later usage has restricted the term "Caney" to a part of the late Mississippian sequence. Elias and Branson (1959), who defined a new type section for the Caney on the eastern flank of the Arbuckle Mountains, discuss the nomenclatural history of this unit.

Elias (1956) gave the name "Rhoda Creek" to what he thought were basal Pennsylvanian shales. It is now known that this poorly exposed unit, 126 feet thick in its type section, is Mississippian in age and contains the goniatite *Fayettevillea friscoense.* This occurrence correlates with the *Eumorphoceras richardsoni–Fayettevillea friscoense* Zone that occurs in the Imo Formation in northern Arkansas (Saunders, 1973). It represents the youngest Mississippian ammonoid fauna in North America.

The Mississippian–Pennsylvanian boundary lies in poorly exposed and poorly fossiliferous shales above the Rhoda Creek (fig. 5). These shales, generally called "Springer," are presumed to be Pennsylvanian in age and extend in most areas upward to the base of the Wapanucka Formation. At Canyon Creek, Stop 1, intermittent exposures of this unit can be seen in the creek bed south of the section illustrated in figure 4.

A sandstone and limestone interval, termed the Union Valley Formation (fig. 5), occurs in the middle portion of the "Springer" Shale on the Lawrence Uplift only. In this region, situated at the northernmost extremity of the Arbuckle Mountains (fig. 3), the lower part of the poorly exposed "Springer" Shale is about 270 feet thick. The Union Valley has two members: a lower, well-sorted, fine-grained sandstone, about 180 feet thick, and an upper sandy glauconitic limestone 12 feet thick (Barker, 1951). The Union Valley Limestone Member is overlain, on the Lawrence Uplift, by about 400 feet of shale, which is

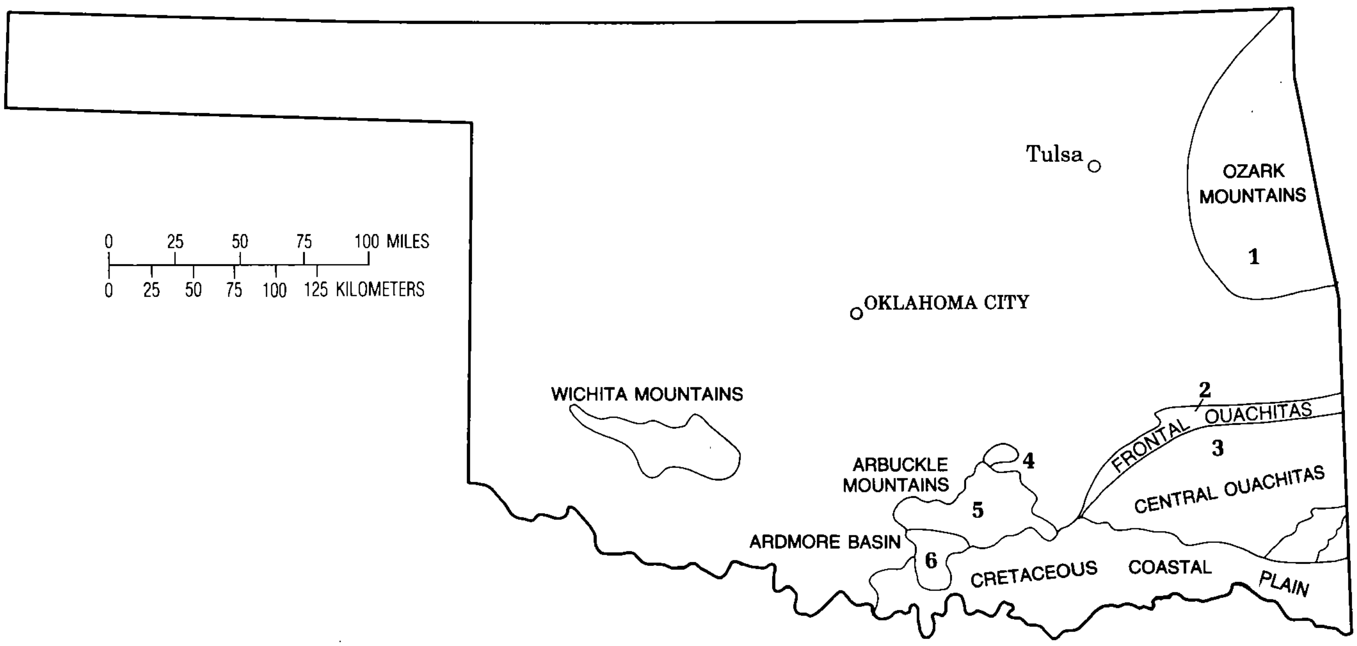


Figure 1. Map showing areas of exposure of Early Pennsylvanian strata in Oklahoma: (1) southwestern Ozark region, (2) frontal Ouachita Mountains, (3) central Ouachita Mountains, (4) northeastern Arbuckle Mountains, (5) Mill Creek Syncline, and (6) Ardmore Basin.

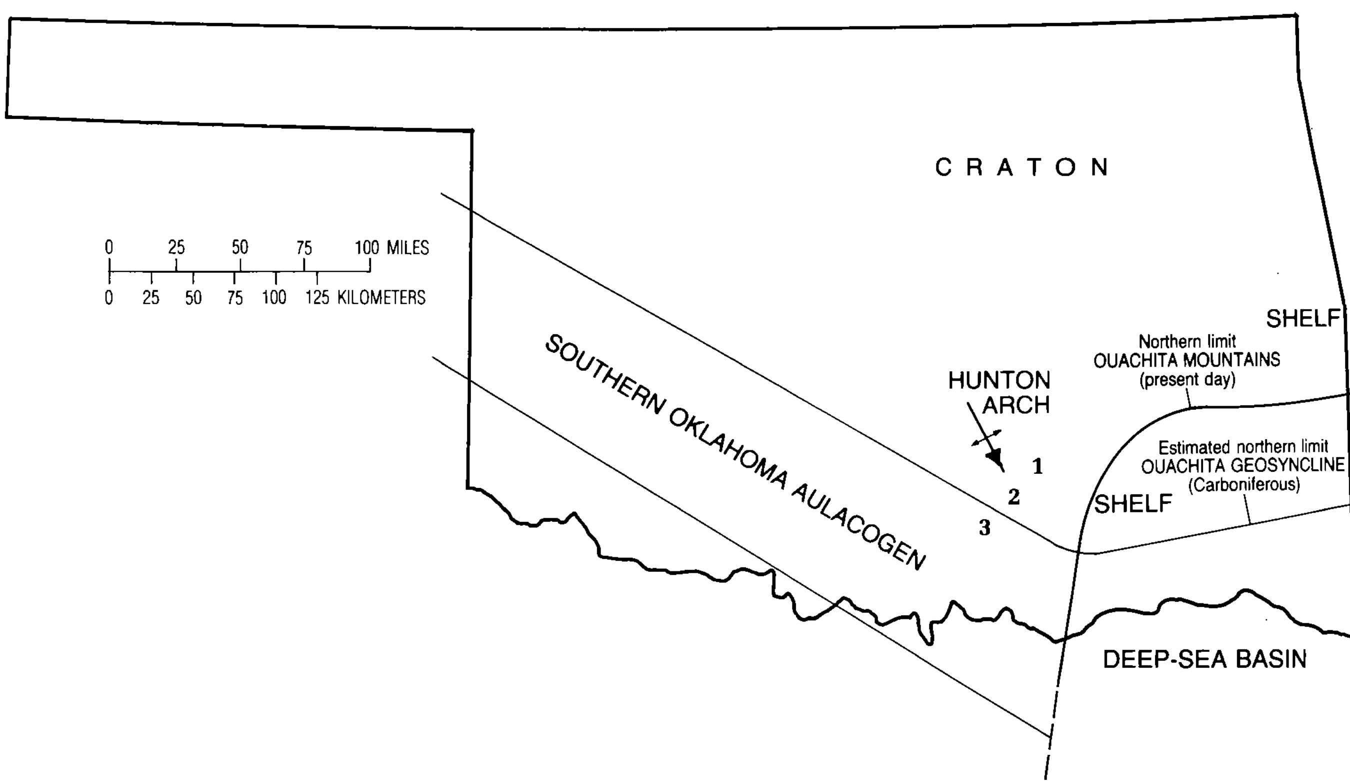


Figure 2. Map showing major structural and depositional areas in Oklahoma during the Early Pennsylvanian (Morrowan). Numbers refer to the three areas included in present study: (1) northeastern flank of Arbuckle Mountains, (2) Mill Creek Syncline, and (3) northern Ardmore Basin.

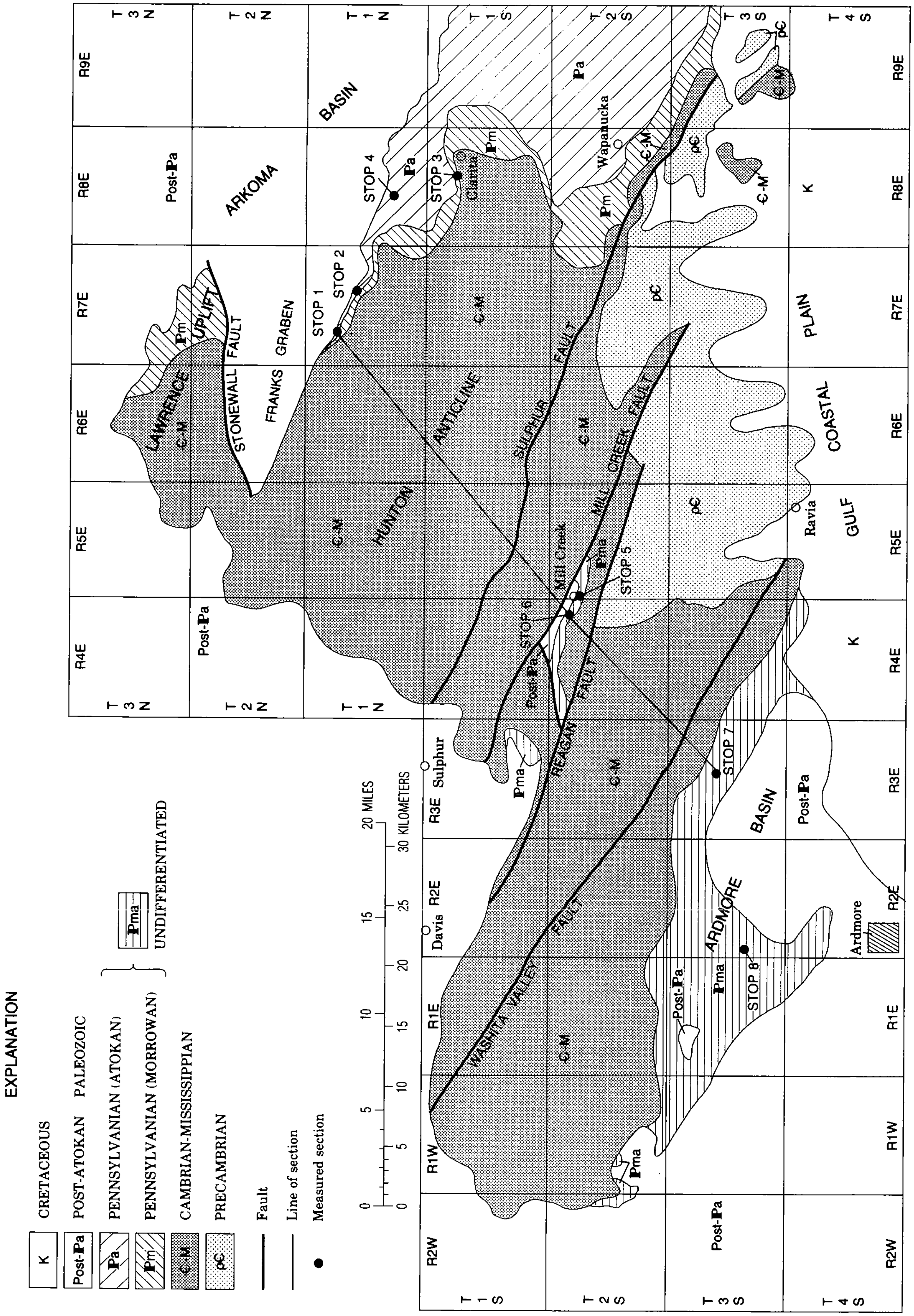


Figure 3. Generalized map of Arbuckle Mountains showing field-trip stops in relation to regional structural and stratigraphic features.

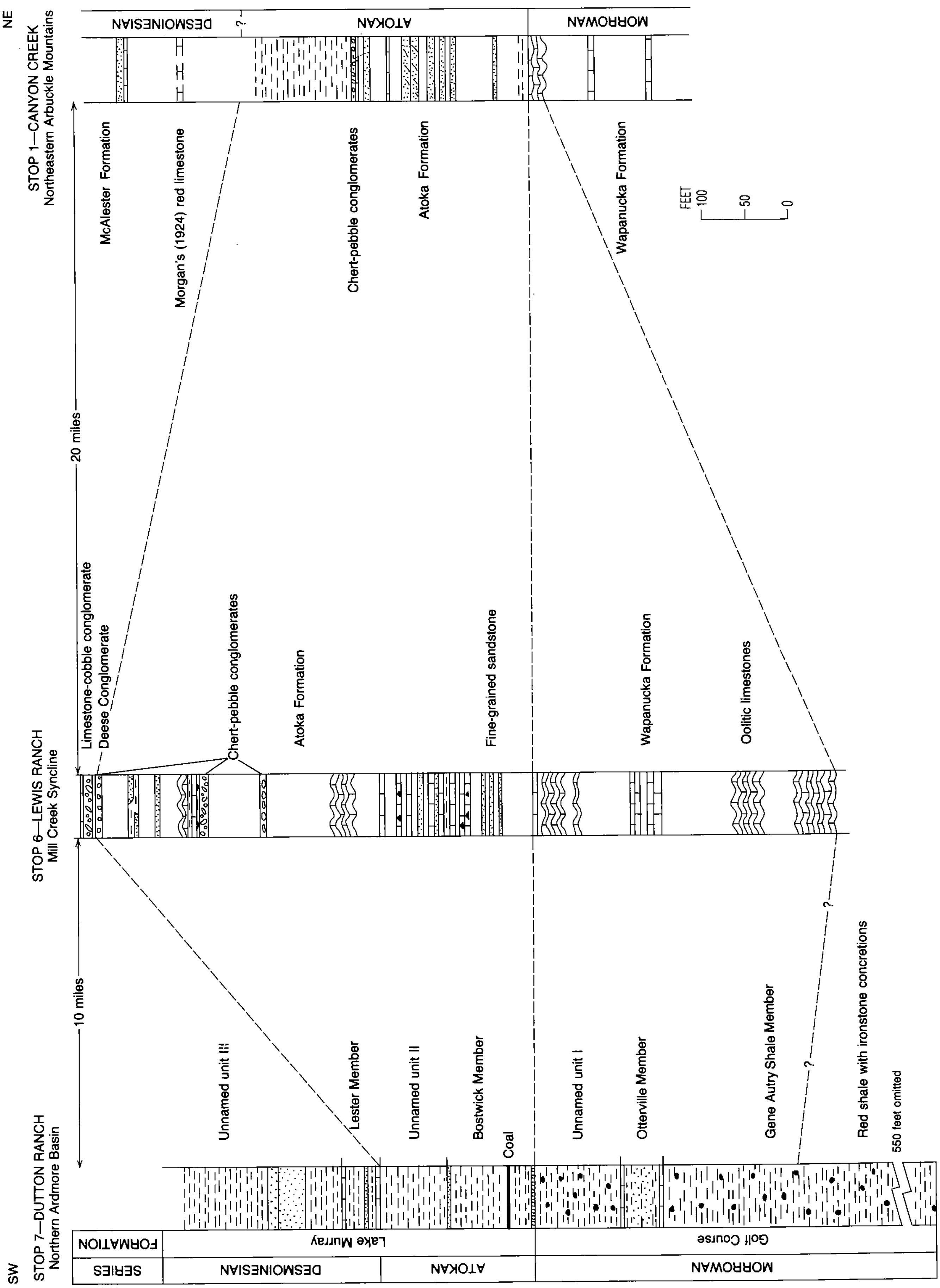


Figure 4. Cross section showing correlation of Lower and Middle Pennsylvanian strata between Stop 1, Canyon Creek; Stop 6, Lewis Ranch; and Stop 7, Dutton Ranch. See figure 3 for location of each section.

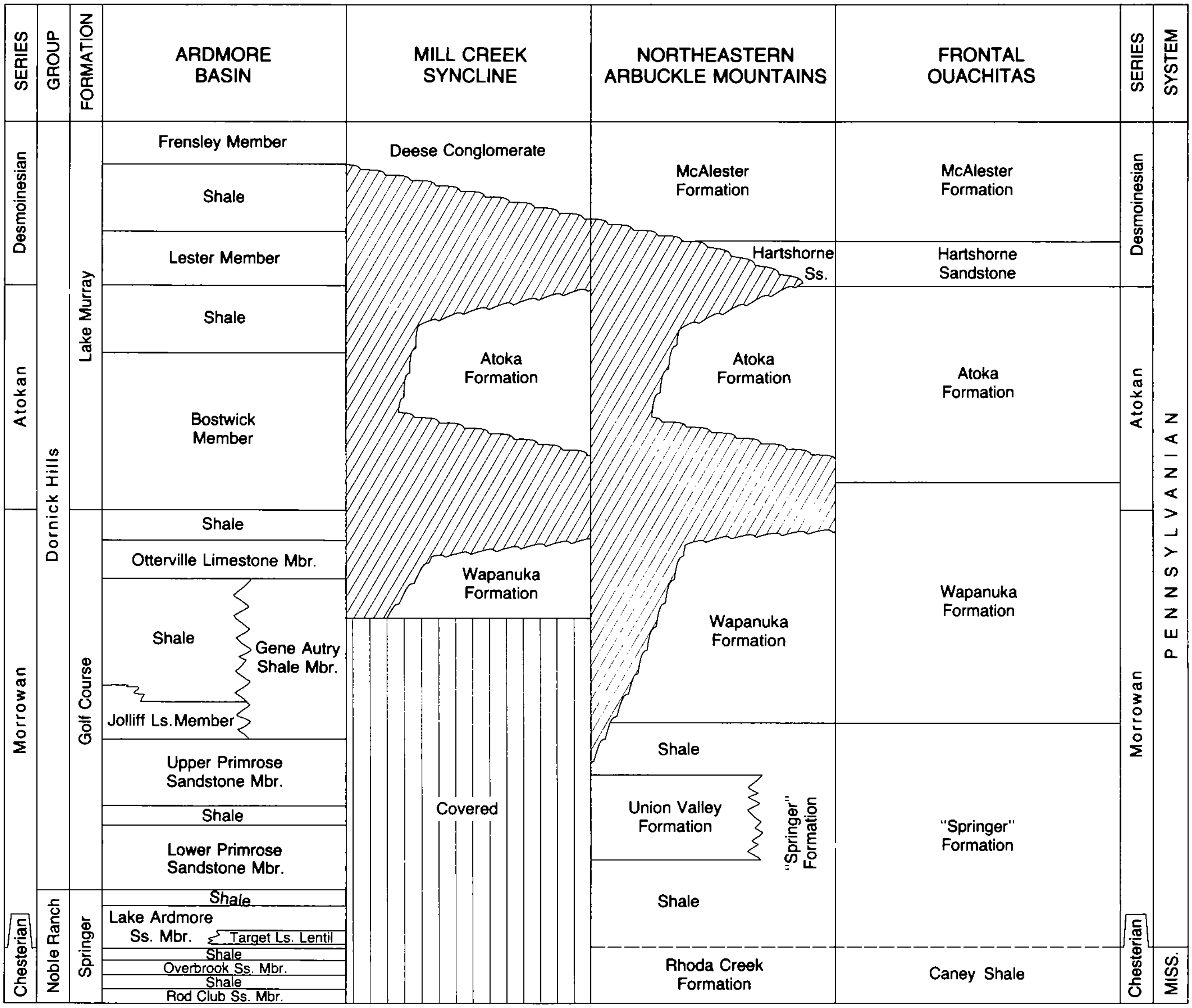


Figure 5. Correlation chart of Lower and Middle Pennsylvanian formations in frontal Ouachita, Arbuckle, and Ardmore Basin regions of southern Oklahoma.

informally called the "Wapanucka Shale." This shale interval is in turn overlain by the Wapanucka Limestone.

The lowest Pennsylvanian fossils described from the northeastern flank of the Arbuckle Mountains are from the Union Valley Limestone Member. This unit has produced the Morrowan *Branneroceras branneri* ammonoid zone, which is also found in the Brewer Bend Limestone Member of the Sausbee Formation in northeastern Oklahoma and the Brentwood Limestone Member of the Bloyd Formation in northwestern Arkansas. Thus, the lower "Springer" Shale and the Union Valley Sandstone Member have a combined stratigraphic position equivalent to that of the Hale Formation in northwestern Arkansas (see back cover).

The Wapanucka Limestone overlies the "Springer" Shale in the northeastern, eastern, and central (Mill Creek Syncline) parts of the Arbuckle Mountains and also in the frontal Ouachita Mountains. In the frontal Ouachitas, an outer-shelf facies is represented where deposition took place immediately adjacent to the deep Ouachita Trough (Grayson, 1979; Sutherland and Manger, 1979). In the Arbuckle Mountains, the Wapanucka is represented by a shallow-shelf carbonate facies (fig. 6) that shows marked lateral variations in facies and local intraformational unconformities (Rowett and Sutherland, 1964).

The Wapanucka Formation was first described by Taff (1901), with the type area near the town of Wapanucka, at the eastern margin of the Arbuckle Mountains (fig. 3). The lower part of the formation in the Clarita–Wapanucka area consists of interbedded bioclastic limestones and shales overlain by cherty micritic limestones in the middle part of the forma-

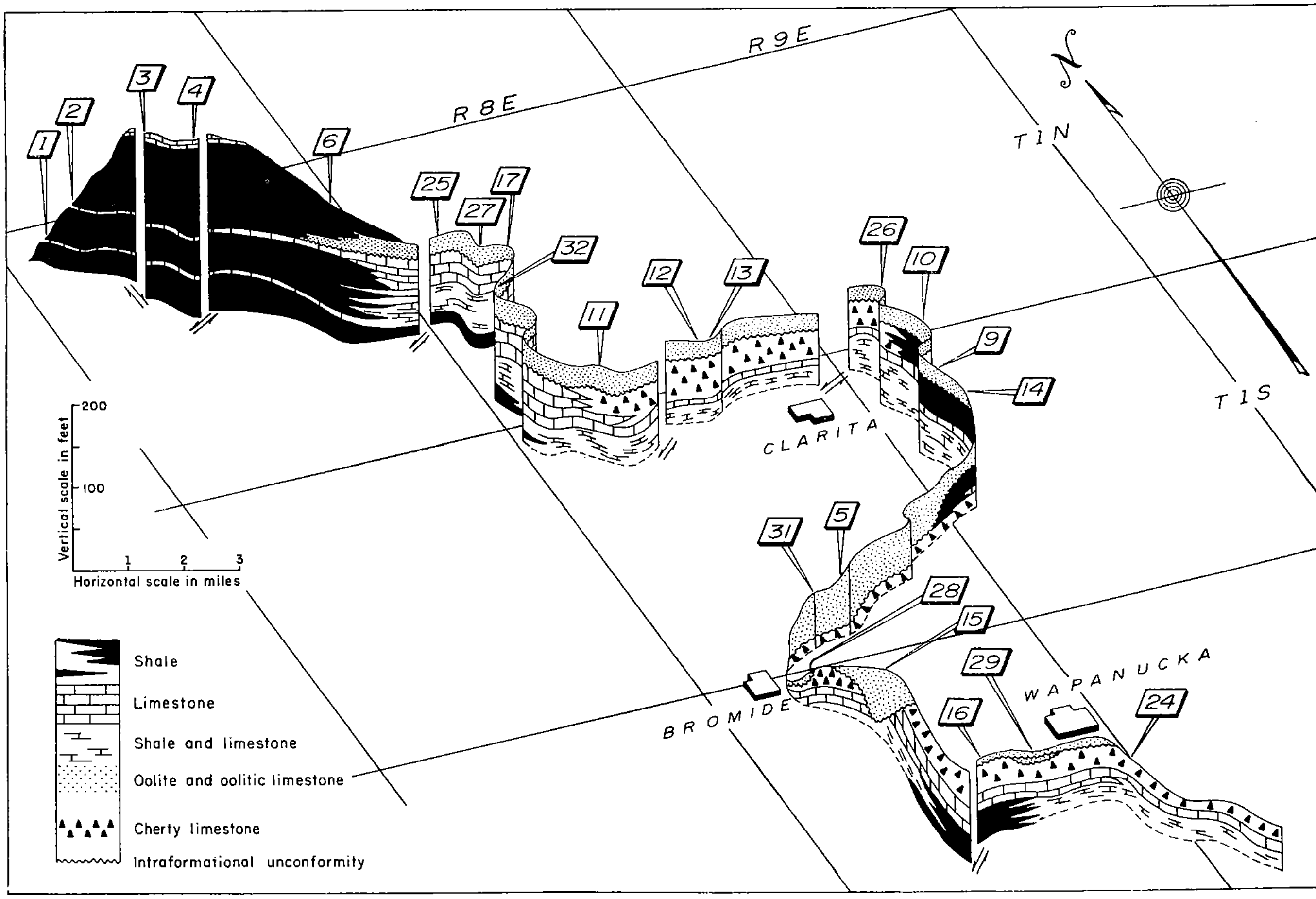


Figure 6. Ribbon diagram of Wapanucka Formation in eastern Arbuckle Mountain region. Base of diagram approximates present outcrop, and top indicates unconformable contact with Atoka formation. Vertical breaks indicate major faults (from Rowett and Sutherland, 1964). Locality 3 equals Stop 1, and locality 6 equals Stop 2 in this guidebook.

tion. The upper part of the formation in this area is characterized by the occurrence of cross-bedded oolitic grainstones that locally truncate lower layers. The thickness of the Wapanucka Formation in the eastern Arbuckles does not exceed 115 feet. Northwestward (fig. 6, locs. 3, 4), the formation changes facies to highly fossiliferous calcareous shale, dark-gray unfossiliferous shale, and thin bioclastic and oolitic limestones. The shales are believed to have been derived from a "landward" source to the west. This westward facies change to shale is believed to be the first indication of the beginning of uplift of the Hunton Arch.

The most detailed information concerning the age of the Wapanucka comes from its conodonts. Grayson (1979) found the Wapanucka Formation in the frontal Ouachitas to be partly Morrowan and partly Atokan in age. He described four conodont zones in that sequence. The lower two, the *Idiognathoides convexus* and *I. ouachitensis* Zones are Morrowan. At the type Wapanucka, in the eastern Arbuckles, the whole of the formation, except for the top 19 feet, falls in the *I. convexus* Zone. The uppermost portion is in the *I. ouachitensis* Zone. At Canyon Creek (Stop 1), a similar case is found with most of the sequence falling into the *I. convexus* Zone. Only the highest limestone layer, the top 10 feet, is included in the *I. ouachitensis* Zone (R. C. Grayson, Jr., oral communication, 1982).

The *I. convexus* Zone occurs in the Kessler Limestone Member of the Bloyd Formation in the Ozark Mountains of northwestern Arkansas. The *I. ouachitensis* Zone is missing in the Ozark area, where it is believed to fall in the hiatus at the regional unconformity that overlies the Kessler and separates strata of Morrowan and Atokan age in that area (Grayson, 1979).

Goniatites are rare in the Wapanucka of the Arbuckle Mountains, but specimens of *Axinolobus quinni* were described by Strimple and Nassichuk (1965) from a locality on the Lawrence Uplift (fig. 3). This occurrence, although from an uncertain zone in the Wapanucka, also indicates a correlation of at least part of the Wapanucka with the Dye Shale Member or Kessler Limestone Member in northwestern Arkansas.

Atokan Series

Type Area

The Atoka Formation was first described by Taff and Adams (1900), but no type locality was designated. The name was taken from either the town or county of the same name. The town of Atoka is on the formation, but there are few if any exposures near the town. A well drilled a few miles southwest of the town penetrated about 5,000 feet of mostly shale with a few thin sandstones. Branson (1962) states that the area "in and near the northwestern corner of Atoka County . . . must serve as type for the formation and series." He adds, however, that "the area has not been studied, the section has not been measured, and no fossils have been found there." The area mentioned by Branson, about 12 miles west of the town of Atoka, serves no useful purpose as a reference since the rocks there are very poorly exposed and cannot be evaluated.

The Atokan Series was proposed by Spivey and Roberts (1946), but no type section was designated. Most published biostratigraphic data from the Atoka Formation in this region has come from fossiliferous exposures in Coal County, T. 1 S. and T. 1 N., R. 8 E. (figs. 3, 7). This area extends 6 miles to the northwest of the town of Clarita and includes the Goose Creek Valley. Strimple and Watkins (1969) proposed the area as the type for their "Atokan Stage." Sutherland and Manger (in press), in a review of problems concerning the Morrowan–Atokan boundary, support the designation of this area as type for the Atokan Series but include the exposures farther west, in Pontotoc County, on Coal and Canyon Creeks, which have newly discovered fusulinid occurrences (see Stops 1 and 2). This designation extends the reference area for the type Atokan to 12 miles northwest of Clarita (fig. 7). No single exposure can serve as a type section, owing to marked lateral variations in thickness, lithologic character, and fossil content.

No unfaulted section of the Atoka Formation is found in the Clarita–Goose Creek area. The lower Atoka in this area is everywhere separated from the upper Atoka by the Jack Hills Fault (fig. 7), with the north block dropped down into the Arkoma Basin. Subsurface studies in the basin suggest that the upper Atoka in this area may have been cut by small-scale thrust faults (Gary W. Hart, Oklahoma City, oral communication, 1978).

Atoka Character

The Atoka Formation in the area northwest of Clarita rests unconformably on the underlying Wapanucka Formation. This contact is marked in scattered localities by a limestone-pebble conglomerate. The conglomerate occurs in discontinuous lenses that are typically less than 1 foot thick; however, a thickness of 3 feet has been observed. This conglomerate was studied in detail by Rowett (1963) who concluded that all the clasts are derived from erosion of the underlying Wapanucka Limestone.

Archinal (1977, 1979) has described and mapped the Atoka Formation in the type-Atokan area northwest of Clarita (fig. 7). In this region, the formation consists of more than 80 percent gray, marine shale. These shales are very poorly exposed. A few thin limestones occur in the lower and middle parts of the Atoka Formation in this area. Although the limestones comprise less than 1 percent of the formation, the fusulinids collected from them provide the primary basis for correlation.

Sandstones make up less than 20 percent of the Atoka Formation, but they form the most prominent exposures owing to their resistance to weathering. Most are fine to very fine, well-sorted, subangular quartz arenites; most have a silica or a clay and silt matrix. The sandstones are thin to medium bedded and horizontally stratified and laminated. Low-angle cross-bedding is seen in some units at Coal Creek (Stop 2). No sandstone unit was observed to be more than 30 feet thick. Many of these units can be traced laterally for several miles (fig. 7). The fine-grained, well-sorted sandstones and the parallel, even beds and laminations suggest deposition along a coastal shoreline, in the shoreface and foreshore portions of beaches, barrier bars, and longshore bars. The linear, relatively thin form of the sand bodies supports these environmental designations. No channeloid sandstone bodies have been observed (Archinal, 1977, 1979).

Regional Stratigraphic Patterns

Morrowan–Atokan–Desmoinesian deposition appears to have been continuous in the frontal Ouachita and southern Arkoma Basin areas, but was discontinuous on the shallow shelf, which now crops out in the northeastern Arbuckle Mountains area (fig. 5). In the latter region, unconformities separate the Wapanucka from the Atoka Formation and the Atoka from the McAlester Formation.

There is a marked thinning of the Atoka Formation westward in the western Arkoma Basin, which results from both onlap and truncation. The formation is about 5,000 feet thick in the subsurface near the town of Atoka, but reaches 8,000 feet in the subsurface only 10 miles north of Atoka (Bellis, 1961). In a distance of less than 20 miles northwest and west of this area, the formation thins to about 3,000 feet in the area north of Clarita (Bellis, 1961), and in an additional 7 miles, to about 500 feet at Coal Creek (Stop 2) and to about 300 feet at Canyon Creek (Stop 1) (fig. 3). The entire Atoka Formation is truncated about 1 mile west of Canyon Creek by an unconformity at the base of the overlying McAlester Formation (fig. 7).

Post-depositional structural movement has complicated stratigraphic interpretations in the area. Archinal (1977) was able to trace the Hartshorne Sandstone (basal Desmoinesian) westward with cer-

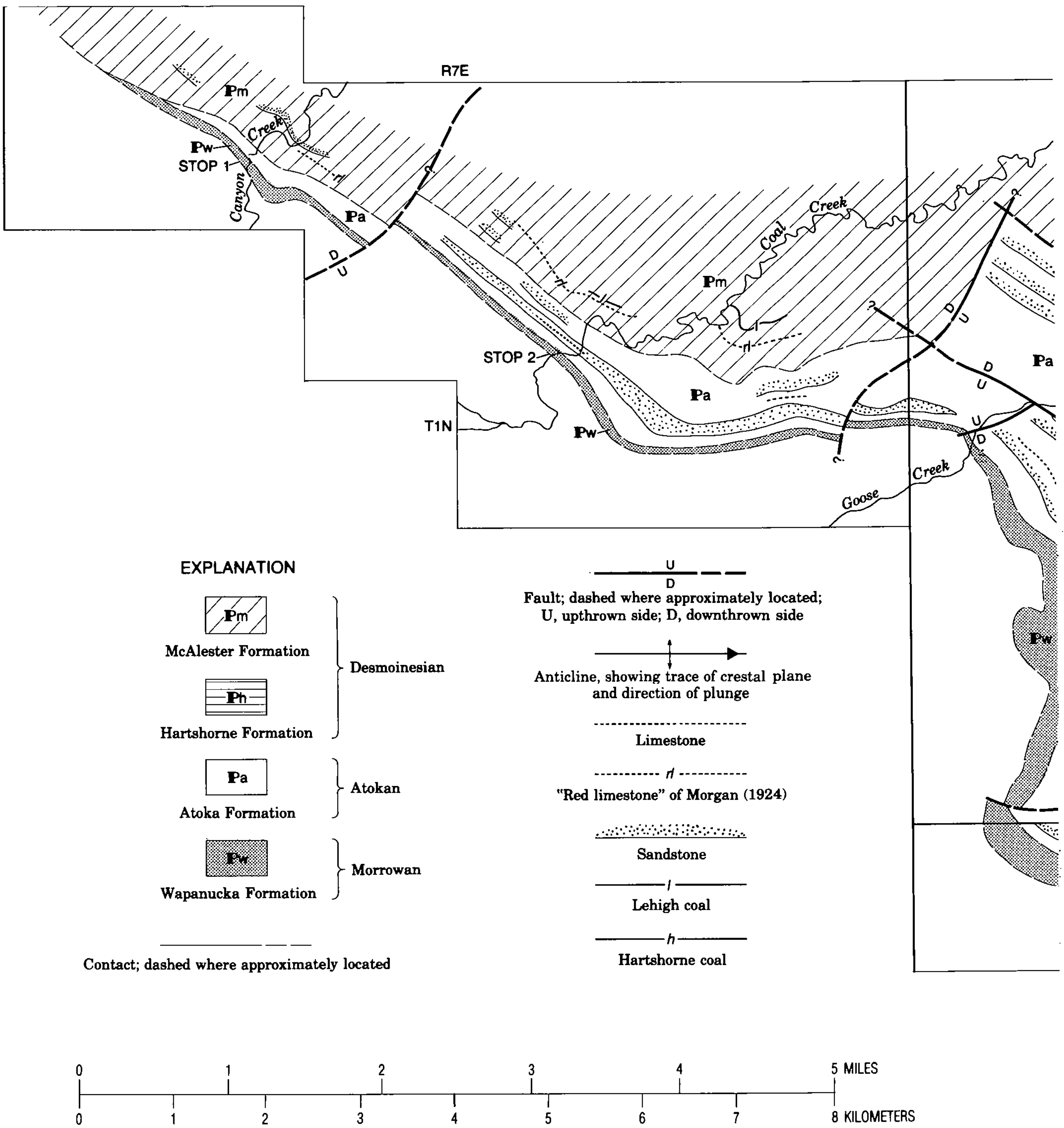
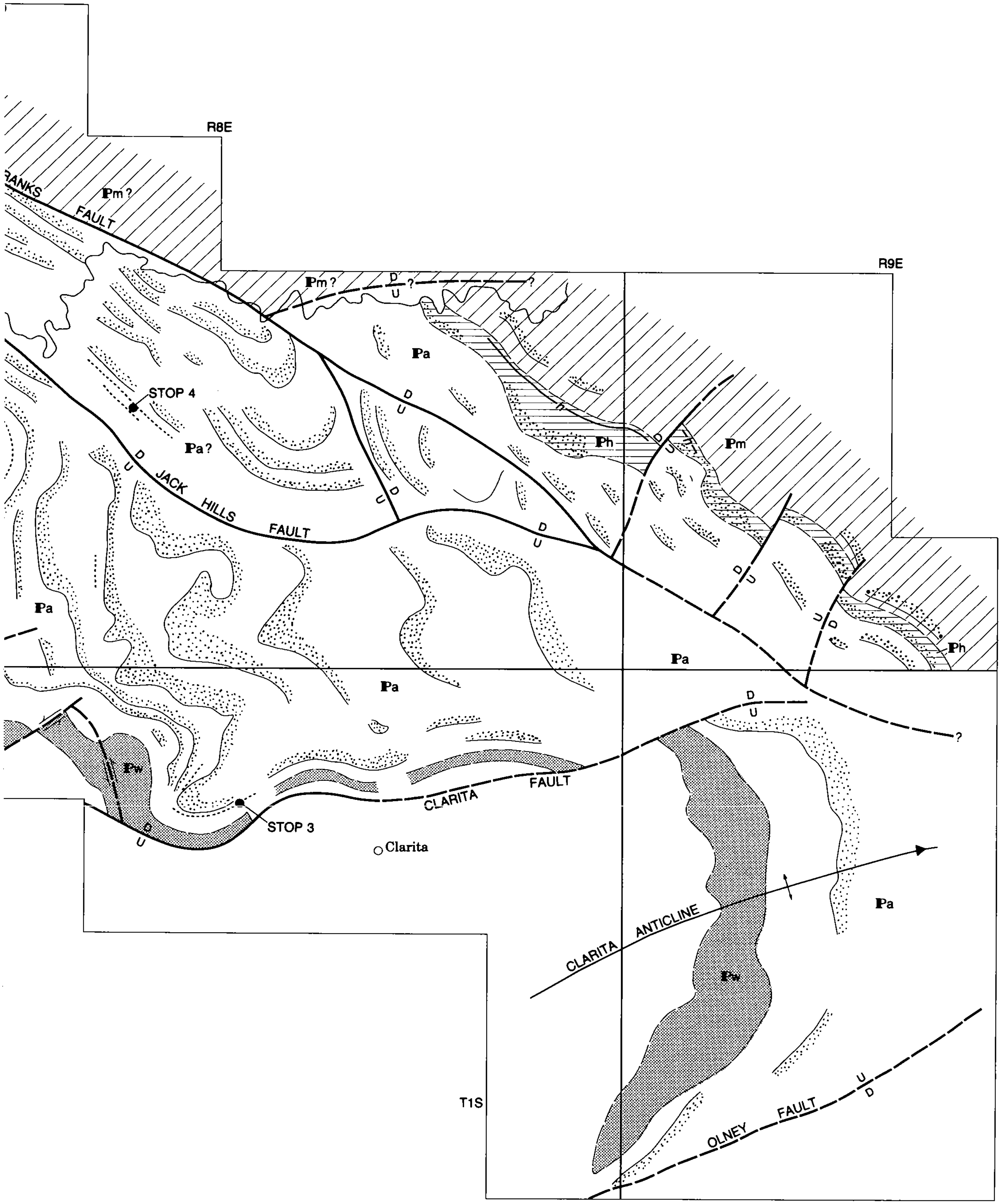


Figure 7. Geologic map of Atoka Formation on northeastern margin of Arbuckle Mountains, Oklahoma, by Bruce E. Archinal (1977).


R8E
R9E
T1S
FRANKS FAULT
JACK HILLS FAULT
CLARITA FAULT
CLARITA ANTICLINE
OLNEY FAULT
STOP 4
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Pm?
Pm
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tainty only to sec. 23, at the eastern margin of T. 1 N., R. 8 E., on the southeastern side of Goose Creek (fig. 7). Well data north of this locality indicate that in this area the Atoka is 2,500 to 3,000 feet thick (Bellis, 1961). The Hartshorne is apparently cut out by the Franks Fault in the 5-mile interval west of this exposure. Still farther to the west, northwest of Goose Creek in T. 1 N., R. 7 E., the Hartshorne is again missing but is absent here owing to westward onlap. In this area, the McAlester rests directly on the Atoka, which is no more than about 500 feet thick at Coal Creek (Stop 2). The westward thinning of the Atoka is accentuated by faulting at the eastern margin of T. 1 N., R. 7 E., north of Goose Creek.

Growth Folding

The Atoka Formation in this area demonstrates an unusual depositional pattern that is important in the reconstruction of the geologic history of the area and in the understanding of faunal distributions and correlations. In the north-central portion of T. 1 S., R. 8 E., there is an abrupt thickening of the Atoka to the north and a multiplication of one sandstone unit into several (fig. 7). Farther north, in the southwestern portion of T. 1 N., R. 8 E., the formation continues to thicken; several sandstones that are not present to the southeast crop out in the lower portion of the formation. These features are evidence that early Atoka deposition occurred while the Clarita anticline, to the south, was a rising structural feature. The Clarita anticline first became active during deposition of the lower part of the Atoka Formation in this area, resulting in a depocenter on the northern flank of the anticline. This depocenter began to fill with shallow-marine sediments. Even as the anticline was still rising during the middle Atokan, the regional westward-transgressing Atokan sea overlapped the anticline. As a result, a thin Atokan sequence was deposited on the crest of the structure while a greatly thickened Atokan sequence was deposited in the depocenter on the flank of the anticline (Archinal, 1979).

Biostratigraphic Interpretations

A reevaluation of biostratigraphic interpretations of the Clarita–Goose Creek area needs to be made in the light of the realization of growth folding during Atokan time. For example, Thompson (1935) described the type locality for *Fusulinella prolifica*, about 0.6 mile northwest of Clarita, as lying 200 feet above the base of the Atoka Formation (interval measured as 350 feet by Archinal, 1977). This locality, however, occurs in the "condensed" sequence of the Atoka Formation on the northern flank of the Clarita Anticline. If the thin fossiliferous zone containing *F. prolifica* is traced westward and then northward into the thicker "basinal" sequence, then the *F. prolifica* zone is approximately 1,000 feet above the base of the formation (fig. 7). It should be remembered that, with the regional onlap of the Atoka Formation westward, the lowest part of the formation in the Clarita–Goose Creek area must be well above the base of the Atokan in comparison with a more complete depositional sequence in the frontal Ouachita area.

Fusulinid occurrences in the Atoka Formation in the area northwest of Clarita are few and scattered, but they do provide some basis for correlation. Collections from this area are currently being studied by Raymond C. Douglass and Merlynd K. Nestell. Preliminary photographs from Douglass are illustrated in Stops 1, 2, 3, and 4.

Thompson (1935) described *Profusulinella fittsi* as occurring 100 feet above the base of the Atoka Formation on a tributary of Goose Creek, northwest of Clarita, Coal County, Oklahoma. Thompson did not collect the specimens personally, and the description, given as NW¼ sec. 10, T. 1 N., R. 8 E., lies on Desmoinesian strata well away from the basal Atokan. An intensive search of the Goose Creek area has failed to locate the *P. fittsi* zone or any other fusulinid zones within the lowest few hundred feet of the formation.

The lowest fusulinids that we have found are a group of closely related species of *Fusulinella* that include *F. prolifica* Thompson and *F. devexa* Thompson (as tentatively identified by R. C. Douglass). This group occurs at several localities in the region, and can be used as a basis of correlation within the area and for correlation with the Mill Creek Syncline (Stops 5, 6). At Stop 3 (South Jack Hills Syncline), the group occurs 410 feet above the base of the formation in a "condensed" sequence. This zone is believed to be the same as that containing *F. prolifica* at its type locality along the strike, 0.8 mile to the east (fig. 7). To the west, at Stops 2 (Coal Creek) and 1 (Canyon Creek), these forms have their lowest occurrences at 340 and 200 feet, respectively, above the base of the formation.

The conodonts of the Atoka Formation from the area northwest of Clarita are being studied by R. C. Grayson, Jr. As with the fusulinids, no conodonts have been recovered from the lower part of the Atoka Formation in this area. Grayson's (oral communication, 1982) preliminary conclusions are that the upper part of the Morrowan *Idiognathoides ouachitensis* Zone and the whole of the two early Atokan conodont zones (*Diplognathodus orphanus* Zone and *Streptognathodus elegantulus* Zone), as described by him (Grayson, 1979) in the Wapanucka Formation of the frontal Ouachitas, are missing in this area. The conodonts indicate that in this area the lowest fossiliferous zones in the Atoka Formation, containing the *Fusulinella prolifica* group, are middle Atokan in age and contain such conodonts as *Neognathodus medadultimus* Merrill.

MILL CREEK SYNCLINE

Introduction

Pennsylvanian strata in the Mill Creek Syncline are divided into four formations (fig. 5). In ascending order, they are the "Springer" Formation (early and middle Morrowan), the Wapanucka Formation (late Morrowan), the Atoka Formation (Atokan), and the Deese Conglomerate (Desmoinesian). The Morrowan and Atokan rocks here had not been examined critically prior to the study by Grubbs (1981), because of poor exposures and the limited areal extent of the Mill Creek Syncline. Furthermore, previous studies have treated these strata inconsistently. Ham (1969 and unpublished notes) certainly believed that the Morrowan and Atokan rocks in the Mill Creek Syncline were properly placed in the Wapanucka and Atoka Formations. However, on the *Geologic Map and Sections of the Arbuckle Mountains, Oklahoma*, by Ham and others (1954), and on the *Geologic Map of Oklahoma* by Miser (1954), these strata are mapped as the Dornick Hills Formation [a group name borrowed from the Ardmore Basin (see fig. 5)]. To those familiar with Oklahoma stratigraphy, the terms "Wapanucka and Atoka Formations" and "Dornick Hills Group" imply different geographic provinces, tectonic settings, and depositional products. The Morrowan and Atokan rocks in the Mill Creek Syncline clearly have lithologic affinities with the Wapanucka and Atoka Formations on the northeastern and eastern flank of the Arbuckle Mountains, 20 to 25 miles northeast and east of the Mill Creek Syncline, and should not be considered part of the Dornick Hills Group, whose nearest exposures are only 10 miles to the southwest, in the Ardmore Basin (fig. 3).

"Springer" Formation

The term "Springer" Formation is applied in the Mill Creek Syncline to the low-lying covered interval immediately below the Wapanucka Limestone (fig. 8). We have followed Ham (1969) in assuming that this covered shale interval is the same "Springer" Formation, of early to middle Morrowan age, that crops out on the northeastern flank of the Arbuckles. It should also be pointed out that the upper part of this covered interval probably includes shales equivalent to the lower and middle part of the Wapanucka Formation at Canyon Creek (fig. 6, loc. 3).

Wapanucka Formation

The Wapanucka Formation in the Mill Creek Syncline consists of about 400 feet of limestone and covered intervals. The limestones are dominated by coarse, skeletal to oolitic grainstones and packstones. Mud-supported carbonate rock types are uncommon. Crinoid fragments and ooids are the dominant grain types, but bryozoan, brachiopod, mollusk, and phylloid algal fragments and onkoids are also common. The limestones are medium to thick bedded, and bedding surfaces are generally wavy to lenticular. Trough cross-bedding is also common. The Wapanucka in this area represents deposition in a shallow, high-energy, carbonate-shelf environment.

Conodont faunas recovered from the Wapanucka Formation are dominated by the genera *Adentognathus* and *Idiognathoides*. The lowest sample contains both *Idiognathoides ouachitensis* (Harlton) and *Neognathodus* n. sp., in addition to *Idiognathoides convexus* (Ellison and Graves). The conodonts indicate a late Morrowan age and assignment to the *Neognathodus* n. sp.–*Idiognathoides ouachitensis* Zone, which Grayson (1979, 1980) defined in the Wapanucka of the frontal Ouachitas. Thus, the whole of the Wapanucka Formation exposed in the Mill Creek Syncline correlates with only the top few feet of the formation at Canyon Creek (Stop 1) and at the type Wapanucka at the town of Wapanucka, on the northeastern and eastern flanks of the Arbuckle Mountains. The covered interval below the Wapanucka in the Mill Creek Syncline, presumed to be shale, is believed to correlate with the strata in the *I. convexus* Zone in the northeastern and eastern Arbuckles. In the type-Wapanucka section, at the town of Wapanucka (fig. 6, loc. 16), this interval is primarily limestone, but at Canyon Creek it is mostly shale (fig. 6, loc. 3).

Atoka Formation

The Atoka Formation in the Mill Creek Syncline consists of two basic units: a lower sandstone that is succeeded by a variable unit of interbedded limestones, sandstones, shales, and chert-pebble conglomerates. The basal sandstone, about 100 feet thick, is fine grained and mature, medium to thick bedded, and it typically displays either parallel or low-angle tabular cross-bedding. The overlying variable unit is about 400 feet thick. The lower half of the variable unit includes interbedded sandstones, shales, and two types of limestones: coarse-grained, crinoidal grainstones and packstones that contain fusulinids, and finer grained, spiculiferous mudstones and packstones. The upper portion of the Atoka Formation is characterized by terrigenous clastics, predominantly noncalcareous shale, and chert-pebble conglomerates; limestones are rare. The chert-pebble conglomerates are believed to have been derived from weathering of the Upper Devonian Woodford Formation on the Hunton Arch.

The conodont faunas of the Mill Creek Syncline have been described by Grubbs (1981). Faunas recovered from Atoka limestones are dominated by the genera *Idiognathodus, Neognathodus* and *Streptognathodus*. Important species that occur immediately above the basal sandstone include *Neognathodus colombiensis* (Stibane), *Diplognathodus coloradoensis* (Murray and Chronic), *Diplognathodus orphanus* (Merrill), and *Streptognathodus* sp. aff. *S. wabaunsensis* Gunnel (Stop 6). These occurrences suggest a middle Atokan age for the lower part of the Atoka Formation, immediately above the basal sandstone.

Fusulinids have been collected by Grubbs (1981) from seven zones in the Atoka Formation of the Mill Creek Syncline, and these collections are currently being studied by Raymond C. Douglass and Merlynd

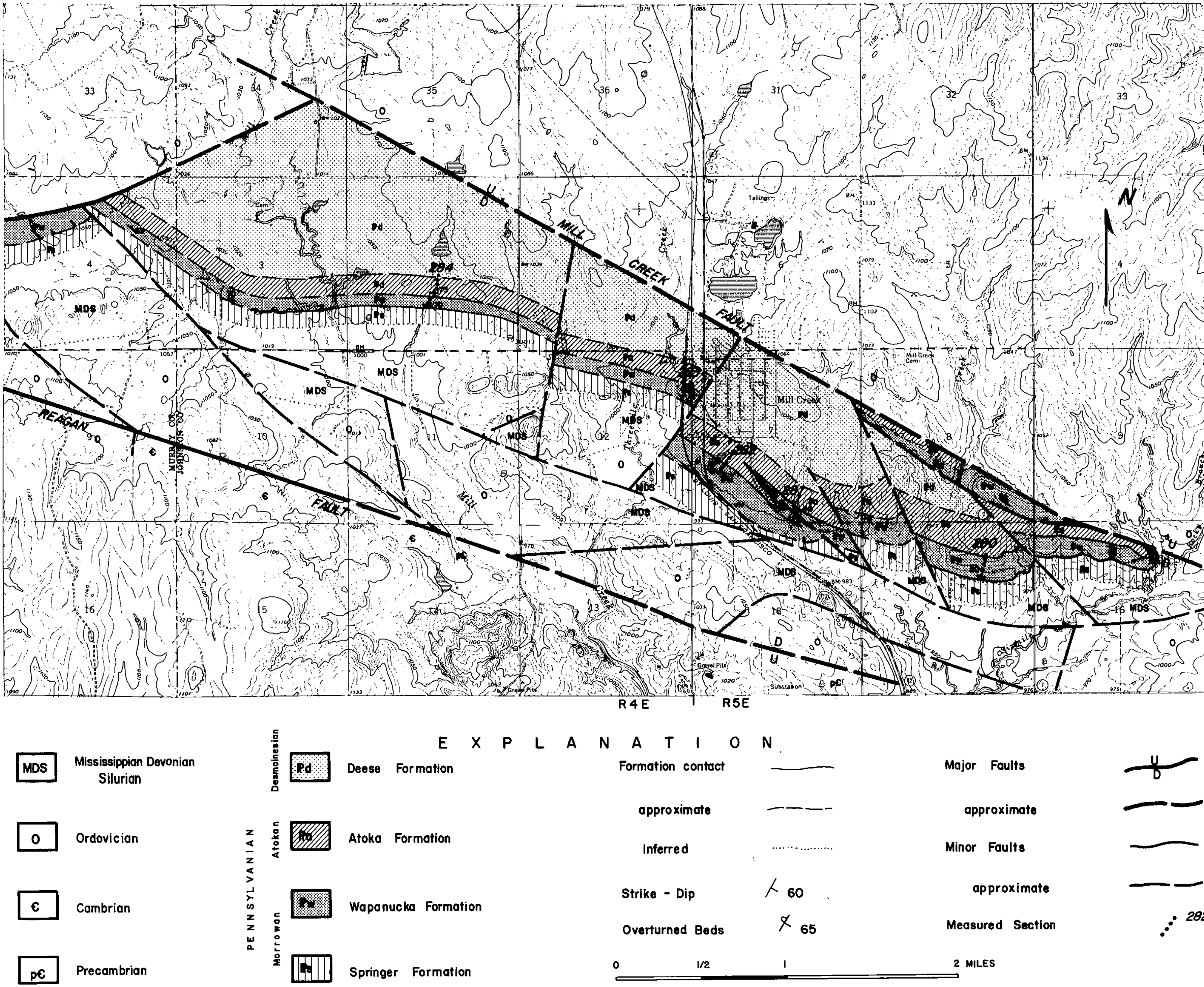

Figure 8. Geologic map of Mill Creek Syncline, central Arbuckle Mountains, Oklahoma, by R. Kent Grubbs, 1981. Based on unpublished map by William E. Ham. Section 282 equals Stop 5, and section 284 equals Stop 6.

K. Nestell. Photographs from Douglass are illustrated in Stops 5 and 6. *Profusulinella* sp. aff. *P. kentuckyensis* Thompson and Riggs, has been recovered from the base of the basal Atoka sandstone at the Pipeline Trench Section in Mill Creek (fig. 8, loc. 282) (Stop 5). At Stop 6 (fig. 8, loc. 284), fusulinids occur in every coarse-grained limestone (six) above the basal sandstone. This sequence, which includes both the base and the top of the Atoka Formation, becomes the most important Atokan fusulinid reference section in the Arbuckle Mountains. In this section, units 27, 31, 39, and 43, which range from 80 to 220 feet above the base of the formation, contain species of *Fusulinella* of the group that includes *F. prolifica* and *F. devexa*. Higher in that section, in unit 52, the occurrence of *Fusulinella* sp. aff. *F. iowensis leyi* indicates a late Atokan age for this part of the formation. This unit is interbedded with chert-pebble conglomerates.

Nature of the Morrowan–Atokan Boundary

As stated earlier, Morrowan–Atokan deposition was continuous in the frontal Ouachitas (Grayson, 1979, 1980), but a regional unconformity is present in the northeastern and eastern Arbuckles. An unconformity is also present at this horizon in the Mill Creek Syncline. Lithostratigraphic evidence includes the transgressive nature of the basal Atoka sandstone. However, more compelling evidence comes from the conodonts and fusulinids. The simultaneous first occurrence of at least three (*N. colombiensis, D. orphanus, S.* sp. aff. *S. wabaunsensis*), and probably four (*D. coloradoensis*), conodont species in the first conodont sample taken immediately above the basal sandstone (Stop 6) is considered to be evidence of a faunal gap. In this hiatus, the two early Atokan conodont zones proposed for the upper Wapanucka in the frontal Ouachitas by Grayson (1979, 1980), the *Diplognathodus orphanus* and the *Streptognathodus elegantulus* Zones, are missing. Wapanucka fusulinid faunas in the Mill Creek area are dominated by *Millerella*. The base of the basal Atoka sandstone at one locality (fig. 8, loc. 283) produced *Profusulinella* sp. aff. *P. kentuckyensis*, apparently an "advanced" form of the genus. The hiatus is thus indicated by the lack of a stratigraphic interval that contains *Eoschubertella, Pseudostaffella*, and primitive *Profusulinella*.

Deese Conglomerate

The Deese Conglomerate is Desmoinesian in age and consists of limestone-cobble conglomerates. Ham (1969) estimated it to be about 2,000 feet thick in the Mill Creek Syncline. The basal part of this unit can be observed at the top of the section at Stop 6. The Desmoinesian age is indicated by the occurrence of *Beedeina* sp. aff. *Fusulina? insolita* Thompson in a limestone that is 10 feet above the base of the conglomerate. The cobbles in the Deese Conglomerate are derived primarily from the Hunton and Viola Limestones (Ham, 1969), and reflect a time of major uplift of the Hunton Arch.

NORTHERN ARDMORE BASIN

Introduction

Lower and Middle Pennsylvanian strata in the northern part of the Ardmore Basin comprise a thick sequence of shale with minor amounts of sandstone and limestone. No unconformities are known in this sequence.

Morrowan Series

The Mississippian–Pennsylvanian boundary in the Ardmore Basin is placed approximately at the base of the Lake Ardmore Member of the Springer Formation (fig. 5). Of particular importance is the occurrence of the Target Limestone Lentil in the lower part of this member. In the northern part of the basin, it occurs in a limited area about 50 feet above the base of the member, and contains the earliest Pennsylvanian *Rhachistognathus primus* conodont zone. The overlying interval, from the upper part of the Lake Ardmore Sandstone Member to the lower part of the lower Primrose Sandstone Member of the Golf Course Formation, contains the *Idiognathoides sinuatus* Zone (Lane, 1977). This zone occurs in the lower part of the Prairie Grove Member of the Hale Formation in northwestern Arkansas.

In the northern part of the Ardmore Basin, the Lake Ardmore Member consists of 450 feet of shales interbedded with three thick beds of ridge-forming, fine-grained sandstone (Tomlinson and McBee, 1962). The overlying Golf Course Formation (Morrowan) extends from the base of the ridge-forming lower Primrose Sandstone to the base of the Bostwick Formation (Atokan). The Golf Course Formation comprises the following members, in ascending order: Primrose Sandstone, Gene Autry Shale (in the north only), Jolliff Limestone (in the south only), Otterville Limestone, and an unnamed shale. The Golf Course attains a thickness of approximately 1,800 feet (Tomlinson and McBee, 1962).

The Primrose Sandstone Member is 130 to 220 feet thick. Goniatites of the *Arkanites relictus* Zone have been recovered from the lower Primrose Sandstone (Manger and others, 1974). This zone correlates with the upper part of the Prairie Grove Member of the Morrowan Hale Formation in northwestern Arkansas.

North of Ardmore, the Primrose is overlain by the Gene Autry Shale Member, which is about 900 feet thick. The Gene Autry is a distinctive unit of reddish-brown- to maroon-weathering shales with intervals of ironstone concretions. The late Morrowan *Axinolobus modulus* assemblage occurs in the Gene Autry, but its precise distribution within the formation has not been established. Such forms also occur in the

Wapanucka Formation in the northeastern Arbuckle Mountains, and in the Dye Shale and Kessler Limestone Members of the Bloyd Formation in northwestern Arkansas. The red shale of the Gene Autry in the northern part of the Ardmore Basin has not produced conodonts. However, in the southern part of the basin, a limestone that occurs in a gray shale, and which occupies the same stratigraphic position as the upper part of the Gene Autry, has produced the *Neognathodus* n. sp.–*Idiognathoides ouachitensis* Zone (R. C. Grayson, Jr., oral communication, 1982). Consequently, the upper Gene Autry may correlate in part with the Wapanucka in the Mill Creek Syncline and with the highest part of the Wapanucka in the northeastern Arbuckle Mountains.

The Gene Autry Shale Member is overlain by the Otterville Limestone Member of the Golf Course Formation. Typically, the Otterville is a skeletal and oolitic grainstone. Its thickest development in the northern part of the basin is 17 feet, at Buzzard Creek (Stop 8). Faunal evidence is limited, but it is apparently latest Morrowan in age. The Otterville is overlain by an unnamed shale, as much as 200 feet thick, that extends to the base of the Bostwick.

Atokan Series

The Atokan Series in the Ardmore Basin comprises the Bostwick Member and an overlying unnamed shale that extends to the base of the Lester Limestone Member. These two units form the lower part of the Lake Murray Formation (fig. 5).

The Bostwick Member shows a marked change in thickness and facies from south to north in the Ardmore Basin. In the south, it reaches a thickness of 500 feet and is characterized by thick layers of limestone and chert-cobble conglomerates interbedded with sandstones and limestones (Cromwell, 1975). The limestone cobbles, as much as 6 inches in diameter, were derived from the weathering of lower and middle Paleozoic formations exposed to the southwest in the Criner–Wichita positive area. The Bostwick forms a prominent topographic ridge across the southern half of the Ardmore Basin. Northward, the percentage and size of limestone clasts decrease. Due west of Ardmore, the member is composed of coarse sandstones and chert, and limestone-pebble conglomerates, with interbedded limestone and shale layers near the top.

In the northern part of the Ardmore Basin, the stratigraphic interval that is approximately equivalent to the Bostwick is predominantly shale. Limestone and chert clasts are rare, and there are only a few locally occurring, ridge-forming sandstone layers. The Bostwick is difficult to differentiate from underlying and overlying shales. The change in facies is apparently due to the greater distance from the terrigenous source to the southwest. Tennant (1981) has arbitrarily assigned the name "Bostwick" to the interval formed by the lowest and highest nonshale strata stratigraphically between the Otterville and Lester Members. This highly variable interval, which cannot be correlated precisely with the Bostwick south of Ardmore, is 140 feet thick at Buzzard Creek (Stop 8) and 100 feet thick at Dutton Ranch (Stop 7). The unit at Dutton Ranch (fig. 55) does include a conglomerate, 1.5 feet thick, that contains limestone pebbles, and a thin coal. Tennant (1981) records a report (1980) from L. R. Wilson that this coal contains a palynomorph assemblage similar to that recovered from a Bostwick coal south of Ardmore.

The Atokan age assignment of the Bostwick is based primarily on fusulinids recovered from limestones within the member south of Ardmore. Waddell (1966) defined his Fusulinid Zone I as including the Bostwick Member and part of the overlying shale. This zone is characterized by several species of *Fusulinella*, and the interval is correlated with the Atoka Formation in both the Mill Creek Syncline and the northeastern part of the Arbuckle Mountains. Waddell (1966) included in the Atokan Series an unnamed shale overlying the Bostwick, which has a maximum thickness in the Ardmore Basin of about 680 feet. In the northern part of the basin, this interval is 300 feet thick at Buzzard Creek (Stop 8) and 80 feet thick at Dutton Ranch (Stop 7).

Desmoinesian Series

Waddell (1966) placed the base of the Desmoinesian Series at the base of the Lester Limestone Member of the Lake Murray Formation (figs. 51, 55) on the basis of the lowest occurrence in the southern Ardmore Basin of the genera *Fusulina* (equal *Beedeina* of present-day usage) and *Wedekindellina*. No fusulinids have been recovered as yet from the units termed "Lester" by Tennant (1981) at Buzzard Creek (Stop 8) and Dutton Ranch (Stop 7).

DEPOSITIONAL HISTORY

Introduction

Depositional patterns in southern Oklahoma during the Late Mississippian and Early Pennsylvanian were controlled by the deep Ouachita Trough to the southeast, the Southern Oklahoma Aulacogen to the south and southwest, and the shelf to the north at the junction of these two basins (fig. 2). In addition, a local positive feature on the shelf, the Hunton Arch, provided a local terrigenous source that began in the Morrowan and continued through the Pennsylvanian. This source area was situated, during the Morrowan and Atokan, in the western part of the present-day Hunton Anticline (fig. 3).

Both the Ouachita Trough and the Southern Oklahoma Aulacogen were sites of abnormally thick sedimentation during Early and Middle Pennsylvanian time. Both areas show continuous sedimentation in contrast to the shelf areas (fig. 2, nos. 1, 2), which are characterized by unconformities in much thinner stratigraphic sequences.

Northeastern and Central Arbuckle Mountains Region

Morrowan Series

During the late Mississippian and early Pennsylvanian, a shelf extended westward from the margin of the Ouachita Trough to include the northeastern and central Arbuckle Mountains area. During the Chesterian and early Morrowan, muds were deposited across all areas of the shelf (Caney Shale and "Springer" Formation, fig. 5). The source of the muds is uncertain, and the resulting shales are poorly known owing to their poor exposure. In the late Morrowan, the shelf shallowed, the influx of terrigenous muds declined, and conditions were conducive for the development of shallow-shelf carbonates (lower and middle part of Wapanucka Formation). An outer shelf was situated near the margin of the Ouachita Trough (present-day frontal Ouachitas), and shallow-shelf conditions existed in the northeastern Arbuckle area (fig. 6). Deposition on the shelf was divided into two episodes by a regional intraformational unconformity, due to a general trend of shallowing which possibly resulted from regional uplift of the shelf in the Arbuckle area. The lower-middle interval consists of a complex group of highly fossiliferous skeletal grainstones and packstones interbedded with nodular, cherty wackestones and, in the lower part, calcareous shales. This interval carries *Idiognathoides convexus* Zone conodonts.

This sequence is overlain by a regional intraformational unconformity marked by the truncation and dissection of the lower-middle sequence (fig. 6). Little relief can be seen on this surface at most localities, but at Delaware Creek (fig. 6, no. 15) a large, channel-shaped body of oolitic grainstones cuts out the entire lower-middle Wapanucka interval. The thickness of the oolite channel is at least 70 feet, and individual steep-angle cross-bed sets are as much as 8 feet in height. The direction of the cross-bed sets indicates that the shoals that produced the oolites were to the northwest. The cross-bedding increases in scale southeastward toward the axis of the channel. The upper oolitic unit carries the *Neognathodus* n. sp.–*Idiognathoides ouachitensis* Zone conodonts, indicating a latest Morrowan age.

While Wapanucka carbonates were being deposited in the eastern Arbuckle area, there was an influx of terrigenous mud from the west (fig. 6, locs. 1–6). The highly diverse marine fauna in the basal shale at Canyon Creek (fig. 10, unit A) indicates deposition on an open-marine shelf, but the interbedded, noncalcareous shales and oolitic and skeletal grainstones suggest alternating periods of restricted and open-marine conditions. These thin limestones carry the *I. convexus* Zone conodonts. In contrast, only the highest limestone layer of the Wapanucka at Canyon Creek, a skeletal and oolitic grainstone (fig. 10, unit F), produces conodonts of the *Neognathodus* n. sp.–*Idiognathoides ouachitensis* Zone. This 9-foot layer apparently represents a pre-Atokan erosional remnant of the oolitic grainstone facies that is better preserved to the east and in the Mill Creek Syncline. The shales in the Canyon Creek area, developed "landward" from the shallow carbonate shelf, are believed to be the result of the initial uplift of the Hunton Arch to the west.

During the late Morrowan in the Mill Creek area (20 miles southwest of Canyon Creek, fig. 3), conditions similar to those at Canyon Creek prevailed. Shales at Mill Creek, now covered below the lowest Wapanucka Limestone, are believed to include both the "Springer" Formation and shales equivalent to those deposited at Canyon Creek during the time represented by the *I. convexus* conodont zone. The Hunton Arch was north of Mill Creek and was shedding mud southward (to the Mill Creek area) as well as eastward (to the Canyon Creek area).

In the latest Morrowan (time represented by the *Neognathodus* n. sp.–*Idiognathoides ouachitensis* Zone), oolite shoals were the dominant environment throughout the Arbuckle area. In the Mill Creek Syncline, this facies is about 400 feet thick and the shoals were oriented apparently northwest-southeast along the northern margin of the Southern Oklahoma Aulacogen. The aulacogen continued to subside, receiving vast thicknesses of terrigenous clastics. Conodonts indicate a correlation of the entire Wapanucka in the Mill Creek Syncline with only the upper oolitic facies in the eastern Arbuckle Mountain area. Beds coeval with the bulk of the Wapanucka at Mill Creek have been mostly removed by pre-Atoka erosion in localities such as Canyon Creek.

It is interesting to note that in the northwesternmost part of the Mill Creek Syncline, 6.5 miles northwest of Stop 6 (fig. 3), in the Buckhorn area, the Desmoinesian Deese Conglomerate rests directly on the "Springer" Formation. The Wapanucka and Atoka Formations, totaling 860 feet in thickness at Stop 6 (fig. 40), have been removed in that area by pre-Deese erosion. Apparently, the Buckhorn area, being northwest of Mill Creek, experienced earlier and more intensive uplift than the Lewis Ranch area at Stop 6.

Atokan Series

In the Arbuckle Mountains area, the Atoka Formation is underlain by a regional unconformity. Rowett and Sutherland (1964) suggested that pre-Atokan strata in the eastern Arbuckle area were tilted eastward during this period of emergence, and Rowett (1963) has documented the occurrence of Wapanucka clasts only in the basal Atoka limestone-pebble conglomerate. Grubbs (1981) suggests that, before deposition of Atokan strata, the Wapanucka Limestone in the Mill Creek area may have been tilted to the south or southwest toward the Southern Oklahoma Aulacogen. These contrasting views can be reconciled by considering the uplift of the Arbuckle region as domal in nature, with pre-

Atokan strata dipping both eastward and southward from the Hunton Arch.

It is interesting to note that the early Atokan was a period of widespread uplift over large portions of the Midcontinent. Ham and Wilson (1967) have stated that "the pre-Atokan or early Atokan unconformity is probably the most profound of all unconformities involving strata of Pennsylvanian age upon the craton, judging by its widespread areal extent and by the intensity of uplift and erosion of underlying rocks." However, deposition was apparently continuous in the northern Ardmore Basin (Tennant, 1981) and in the frontal Ouachitas (Grayson, 1979).

In early and middle Atokan time, deposition returned to the Arbuckle area with a major regional transgression. In the eastern Arbuckles this transgression was to the west. In the Clarita–Goose Creek area (fig. 7), the fine-grained, well-sorted sandstones that show parallel bedding are interpreted by Archinal (1977) as having been deposited in the foreshore portion of beaches, barrier bars, or longshore bars. Fossil evidence is lacking in the lower part of the Atoka Formation in this area, but the lowest fusulinids and conodonts, recovered a few hundred feet above the base, are middle Atokan in age.

The Atoka Formation in the Mill Creek Syncline is also considered to reflect a transgressive sequence, but a direction cannot be determined. The sequence can be compared to the model of Visher (1965) in which a basal mature sandstone is followed abruptly by "fossil-fragmental" limestones. In this view, the basal Atoka sandstone would be a beach or barrier-bar deposit, and the succeeding strata would represent offshore but relatively shallow deposits.

The dominance of terrigenous clastics in the upper Atoka of the Mill Creek Syncline represents a fundamental change in environmental conditions. In particular, multiple layers of chert-pebble conglomerates in the upper Atoka (fig. 40), derived from weathering of the Upper Devonian Woodford Formation, indicate major uplift on the Hunton Arch in the Atokan. Ham and others (1969) had previously considered these conglomerates to be Desmoinesian, but the conglomerates are interbedded with limestones that carry Atokan fusulinids. One such chert-pebble conglomerate occurs also at the top of the highest exposure of the Atoka Formation at Canyon Creek (fig. 10).

In the northeastern Arbuckle area, Atokan uplift is also indicated by growth folding on the Clarita anticline (fig. 7), an easterly extension of the Hunton anticline. Archinal (1977) documented the occurrence of a greatly thickened sequence of strata in the basin to the north, as compared with that deposited on the flanks of the anticline, as a part of the Atoka Formation.

Desmoinesian Series

The early Desmoinesian is marked by further uplift of the Hunton Arch, a cessation of deposition for a time in the eastern Arbuckle area, and further transgression westward of the Hartshorne–McAlester Formations (figs. 5, 7). More intensive uplift on the Hunton Arch produced limestone-cobble conglomerates composed of Viola and Hunton clasts, in the lower part of the Deese Conglomerate in the Mill Creek Syncline, and limestone-pebble conglomerates composed of Hunton clasts in the middle and upper parts of the McAlester Formation in its westernmost areas of exposure in the northeastern Arbuckle area (Morgan, 1924).

Northern Ardmore Basin

Introduction

The Southern Oklahoma Aulacogen was a rapidly subsiding trough during the late Mississippian and Pennsylvanian that extended into the North American craton at a high angle from the Ouachita Geosyncline (fig. 2). Exposures of Pennsylvanian strata that were deposited in the eastern part of this aulacogen can be seen today in the Ardmore Basin. Most of the sediments are terrigenous.

The Morrowan and Atokan sequence preserved in the Ardmore Basin is more than 3,000 feet thick; there are no known unconformities in the section. It is totally different in character from that deposited on the shelf to the northeast.

In the Mill Creek Syncline, the total thickness of Morrowan and Atokan strata is 860 feet, and at least two major unconformities are known. In that area of the shallow shelf, the main source of terrigenous sediments was the Hunton Arch to the north. In contrast, in the northern part of the Southern Oklahoma Aulacogen, Tennant (1981) recorded evidence for transport of terrigenous sediments to the north or northeast, during the Atokan and early Desmoinesian.

Morrowan Series

In the late Morrowan, the Criner–Wichita axis southwest of the Southern Oklahoma Aulacogen was uplifted, producing limestone-cobble conglomerates preserved in the Jolliff Limestone Member of the Golf Course Formation in the southern part of the Ardmore Basin. At the same time, in the northern part of the aulacogen, the Gene Autry Shale Member was deposited in somewhat deeper water. Indirect conodont evidence suggests correlation of the upper part of these deeper water shales with at least part of the shoaling Wapanucka oolites on the shelf to the northeast, in the Mill Creek Syncline. There was a general shallowing as the basin filled, and the Gene Autry was followed in latest Morrowan time by deposition of the oolitic Otterville Limestone Member.

Atokan Series

In the Atokan, major uplift of the Criner–Wichita axis resulted in the deposition of the thick Bostwick

Member of the Lake Murray Formation in the southern Ardmore Basin area. Adjacent to the Criner Hills, the Bostwick is mostly a limestone-cobble conglomerate consisting of clasts of lower and middle Paleozoic units. In the northern part of the basin, the sequence is predominantly shale with locally thick, rippled and cross-bedded sandstone sequences, thin limestone-pebble conglomerates, and coal (fig. 51). These represent deposition in shallow water, possibly in a deltaic environment (Tennant, 1981).

Tennant (1981) recorded evidence of growth folding, during the Atokan and early Desmoinesian, of both the Caddo Anticline and Berwyn Syncline in the northern part of the Ardmore Basin.

Desmoinesian Series

The lower Desmoinesian Series in the northern part of the Ardmore Basin is characterized by shallow-water, open-marine limestones interbedded with thick, gray shales and thinner, fine-grained, well-sorted sandstones deposited possibly in deltaic environments (Tennant, 1981).

Wrench Model and Stratigraphic Relations

Recent investigations have suggested that the Arbuckle Mountains–Ardmore Basin area was deformed by wrench tectonics in the Pennsylvanian Period. Left-slip displacements are suggested by the trend of fold axes at acute angles to major faults, the distribution of fractures, and possibly by the overall *en-echelon* arrangement of folds (Wickham and others, 1975; Booth, 1978).

Paramount to the reconstruction of Early and Middle Pennsylvanian depositional history is the question of whether or not major lateral displacements have taken place on the faults subsequent to deposition of the units being studied. There is no doubt that the three Pennsylvanian areas described in this paper (fig. 3; northeastern Arbuckles; Mill Creek Syncline; and northern Ardmore Basin) are closer together today than they were in the Early–Middle Pennsylvanian. This has resulted in part from obvious crustal shortening due to folding, but could these present locations be significantly different in relative geographic position from those at the time of deposition?

Estimates of left-slip displacement for the Washita Valley Fault have included 3 miles (Ham, 1950), 20 miles (Carter, 1979), and 40 miles (Tanner, 1969):

(1) Ham (1950) based his figure on the premise that the axial trend of a plunging anticline had been offset.

(2) Carter's (1979) interpretation is that a post-Hunton–pre-Woodford structural-erosional feature has been offset 20 miles. Amsden (1960, and oral communication, 1982) believes that the Hunton Group provides no compelling evidence for significant lateral offset on the Washita Valley Fault, and he attributes these variations in thickness of the Hunton Group to post-Hunton–pre-Woodford uplift and erosion.

(3) Tanner (1969) based his estimate of 40 miles on his interpretation of offset of the basal Oil Creek Sandstone. In response to this estimate, Brown (1981), after making a palinspastic restoration of the Washita Valley Fault area, concluded that "crustal shortening represented by folds and reverse faults alone can account for the present-day basal Oil Creek sand distribution and thus very little strike-slip movement is needed along the Washita Valley fault system."

The correlation of Lower and Middle Pennsylvanian strata presented in this paper is not intended to provide evidence for or against the wrench model. The stratigraphic relations outlined do not depend on a particular tectonic model, but it is important to keep in mind what the effect would be on the interpretation if significant displacement had taken place.

To the southwest, the Washita Valley and Reagan Faults lie between the Mill Creek Syncline and the Ardmore Basin (fig. 3). Left-lateral displacement along these faults would have the effect of moving the Ardmore Basin southeastward relative to the Mill Creek Syncline. If such displacement has occurred, then the area in the vicinity of Dutton Ranch (Stop 7), used for correlation in figure 4, has been moved closer to the Mill Creek area (Stop 6). There is no evidence, however, to suggest that the dramatic change in lithology between the Ardmore Basin and the Mill Creek Syncline is the result of laterally offset facies. Since the strike of the Washita Valley Fault is parallel to the depositional strike of the Southern Oklahoma Aulacogen, any movement has occurred only along the depositional strike. This lithologic change is considered to reflect true environmental differences between a sinking-trough facies to the southwest and a shallow-shelf facies to the northeast.

To the northeast, the Mill Creek and Sulphur Faults occur between the Mill Creek Syncline and the northeastern Arbuckle area. No postulations have been made about strike-slip displacement on these faults. The net effect of left-lateral movement along these faults would be to move the Mill Creek strata southeastward relative to the northeastern Arbuckles. Thus, these two regions may be closer together today than they were in the Pennsylvanian. If this is true, then the pre-fault position of the Mill Creek strata could be approximated by moving the strata northwestward along the fault trend. Stratigraphic problems that would result from such an interpretation are that the Wapanucka and Atoka Formations in the Mill Creek Syncline are lithologically and faunally related to the same formations that crop out in the northeastern Arbuckles. If the Mill Creek Syncline were moved to the northwest, it would further separate these two areas and would tend, as the distance is increased, to place the Mill Creek area on the west instead of the south side of the Hunton Arch.

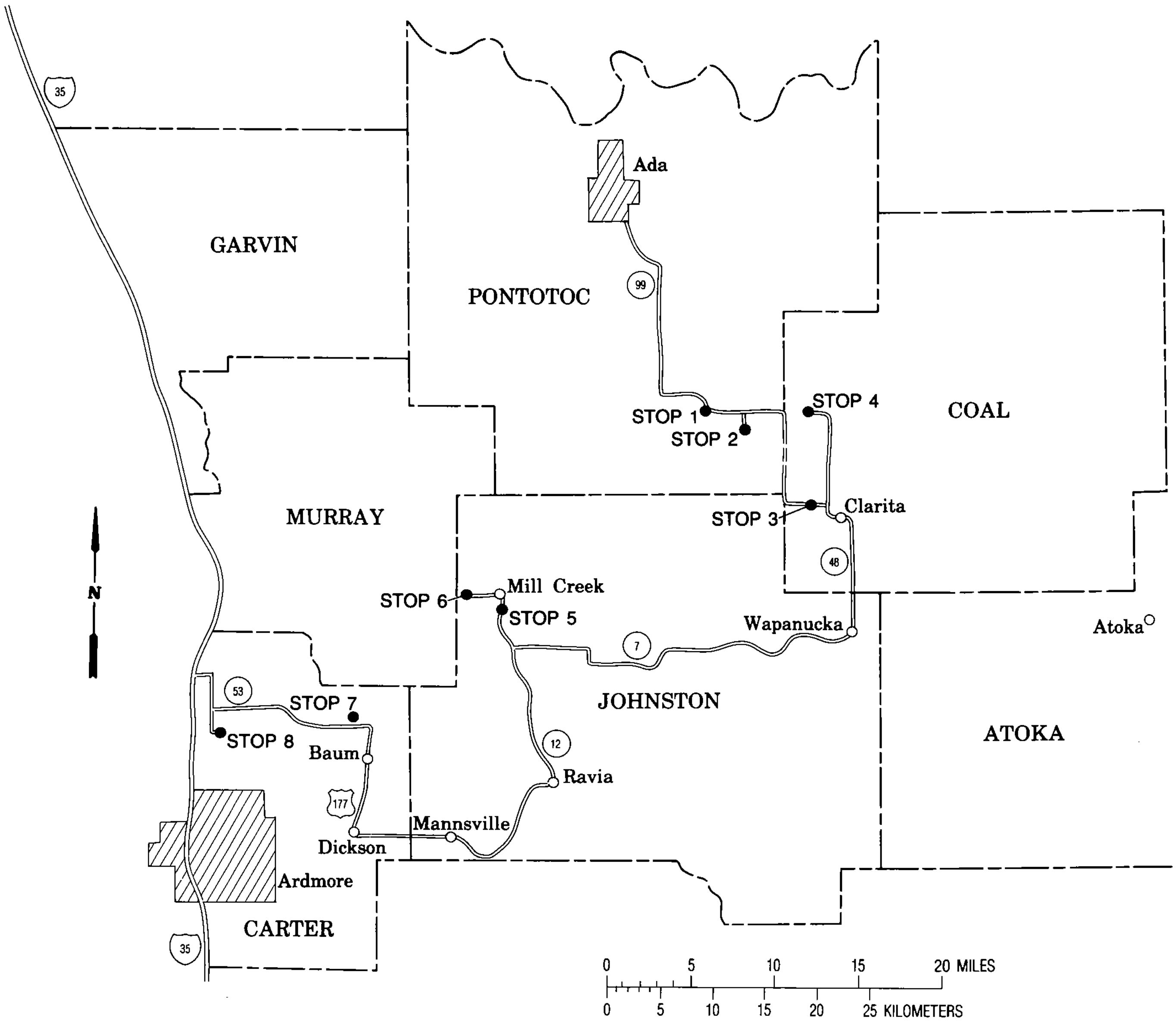

Figure 9. Locality and route map.

STOP DESCRIPTIONS–NORTHEASTERN ARBUCKLE MOUNTAINS

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INTRODUCTION

The locations of the stops for this field trip are shown in figure 9. The first four stops will be seen on the first day and are in the type area of the Atokan Series on the northeastern flank of the Arbuckle Mountains. The designation of this area as the type area for the Atokan Series is discussed in an earlier part of this guidebook, by Sutherland, Archinal, and Grubbs. The type area for the Atokan Series extends from the town of Clarita northwestward to just west of Canyon Creek (Stop 1), where the Atoka Formation has been completely truncated. There is a marked westward thinning of the Atoka Formation from about 3,000 feet in the area north of Clarita, to 500 feet at Coal Creek (Stop 2), to 300 feet at Canyon Creek (Stop 1) (fig. 7).

The Atoka Formation throughout the area consists predominantly of poorly exposed shales. Sandstones, which make up less than 20 percent of the formation, are generally fine grained, well sorted, and horizontally stratified. Thin, sandy limestones make up less than 1 percent of the formation but are vitally important because they have produced both fusulinids and conodonts, which have provided some basis for correlation.

Conodonts from the Wapanucka and Atoka Formations are being studied by R. C. Grayson, Jr., and the fusulinids from the Atoka Formation are being studied by R. C. Douglass and M. K. Nestell. These workers have provided the preliminary observations on those fossil groups that are presented in the stop descriptions.

STOP 1—CANYON CREEK

Location: Along banks of Canyon Creek, 0.4 mile south of section-line road and 3.7 miles west of Jesse, Oklahoma. SW¼NE¼ sec. 8, T. 1 N., R. 7 E., Pontotoc County, Oklahoma. (Measured section 14 of Archinal, 1977.)

The whole of the Wapanucka Formation and at least the lower two-thirds of the Atoka Formation are exposed in the banks of Canyon Creek (fig. 10). The strata dip 35° to 40° NE and strike N. 70° W.

We see here the unusual western shaly facies of the Wapanucka (fig. 6, loc. 3), where the formation consists mostly of shale interbedded with a few thin limestone beds. Unit A, the shale at the base of the section, is now almost completely covered. This has been the result of a change in the pattern of recent sedimentation along the creek after the construction in 1963 of a large U.S. Government flood-control dam on Canyon Creek a half-mile downstream. Before 1963, there was an extensive exposure of this highly fossiliferous shale that formed a low bank on the north side of the stream, above normal water level. Vast numbers of exceptionally preserved, uncrushed fossil specimens were removed from this exposure over the decades. The fauna is dominated by spiriferid and productid brachiopods, but includes pelecypods, cephalopods, gastropods, solitary rugose corals (Rowett and Sutherland, 1964), blastoids, and crinoids (Moore and Strimple, 1973). This was one of the most famous fossil localities in southern Oklahoma, and specimens from here are found in many museum collections in both the United States and abroad.

Approximately 0.5 mile south of the Wapanucka outcrop on Canyon Creek, there is a good exposure of Upper Devonian Woodford Shale. Between the two localities there are intermittent exposures of shale in the creek bed that must be in part Mississippian Caney Shale and in part Pennsylvanian "Springer" Shale. These exposures have not been studied, and a Mississippian–Pennsylvanian contact has not been established. Shale A in the measured section would properly be termed "Springer" Formation, but virtually all collectors have termed it Wapanucka Formation.

The limestones in the Wapanucka Formation at Canyon Creek are oolitic or skeletal grainstones. The highest of these (fig. 11) forms a prominent cliff along the bank of the creek. The unconformable contact with overlying shale of the Atoka Formation is irregular and undulating.

The whole of the Wapanucka Formation at Canyon Creek belongs to the *Idiognathoides convexus* conodont zone of Lane (1977), except for the highest limestone interval (unit F), which belongs to the *Idiognathoides ouachitensis* Zone of Grayson (1979). Both of these are late Morrowan zones that can be correlated with a more complete depositional sequence of the Wapanucka Formation in the frontal Ouachita Mountains, described by Grayson (1979).

The Atoka Formation at Canyon Creek has a minimum thickness of 212 feet (units 2–18). Overlying the Atoka is a covered shale interval that is approximately 150 feet thick. It extends to the approximate position of the "red limestone" of Morgan (1924). The

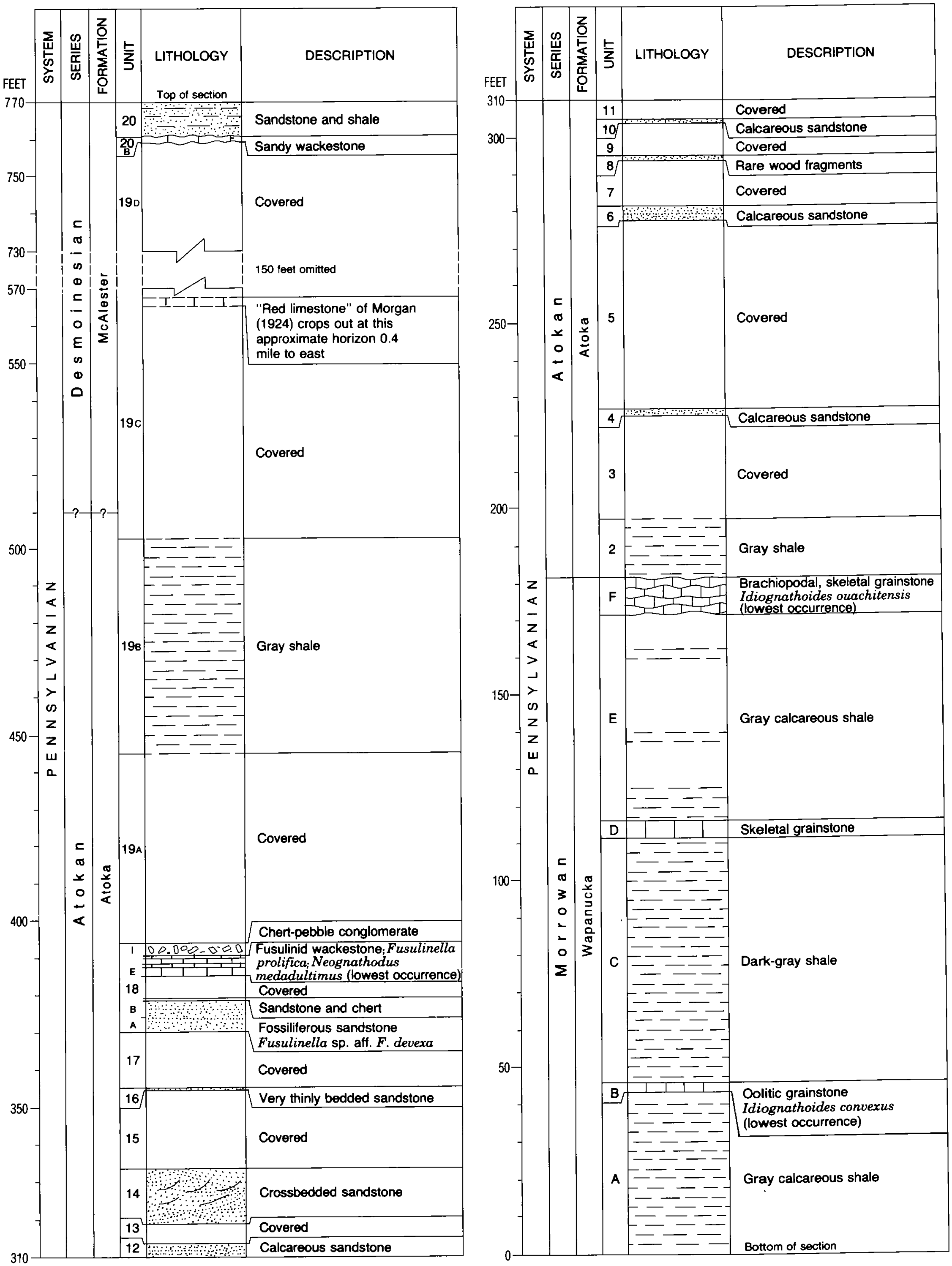

Figure 10. Graphic columnar section for Stop 1, Canyon Creek. Stratigraphic units A–F from Rowett and Sutherland (1964); units 2–20 measured by B. E. Archinal (1977).

Figure 11. Oolitic, skeletal grainstones at top of Wapanucka Formation, unit F, overlain unconformably on dip slope, behind man, by poorly exposed shales of Atoka Formation (fig. 10). (Stop 1.)

Atokan–Desmoinesian contact falls either within or at the top or bottom of this covered interval. Morgan traced his "red limestone" for about 4 miles to the east of Canyon Creek (well exposed at Stop 2). He used the westward convergence of the "red limestone" and lower Atoka strata to show that the Atoka Formation has been truncated by the Desmoinesian McAlester Formation. The Atoka Formation pinches out about 0.5 mile west of Canyon Creek.

At Canyon Creek, the Atoka Formation consists of thick covered intervals, presumed to be shale, alternating with several thin, noncalcareous or calcareous sandstones (fig. 12) and a few thin, sandy limestones (fig. 13). All of the sandstones are very fine grained and well sorted. Exposures are not extensive enough for an evaluation of bedding forms. A single layer of chert-pebble conglomerate is exposed in unit 18I (fig. 14).

Figure 12. Fine-grained, well-sorted calcareous sandstone in Atoka Formation, unit 18B, which contains fusulinids (see fig. 15). (Stop 1.)

Fusulinids have been recovered from units 18B and 18E. These include *Fusulinella* sp. aff. *F. devexa* and *Fusulinella prolifica* (fig. 15). Similar forms occur at Stop 2 (Coal Creek), in unit 15, and in the Mill Creek Syncline, at Stop 6, in units 27 to 43. These occurrences indicate a middle Atokan age for these zones.

Idiognathoides noduliferous (Ellison and Graves) has been recovered from unit 6. Unit 18G has pro-

Figure 13. Fine-grained, sandy, skeletal wackestone in Atoka Formation, unit 18G, which contains fusulinids and conodonts. (Stop 1.)

Figure 14. Chert-pebble conglomerate from Atoka Formation; unit 18I. Angular fragments are derived from Upper Devonian Woodford Formation. (Stop 1.)

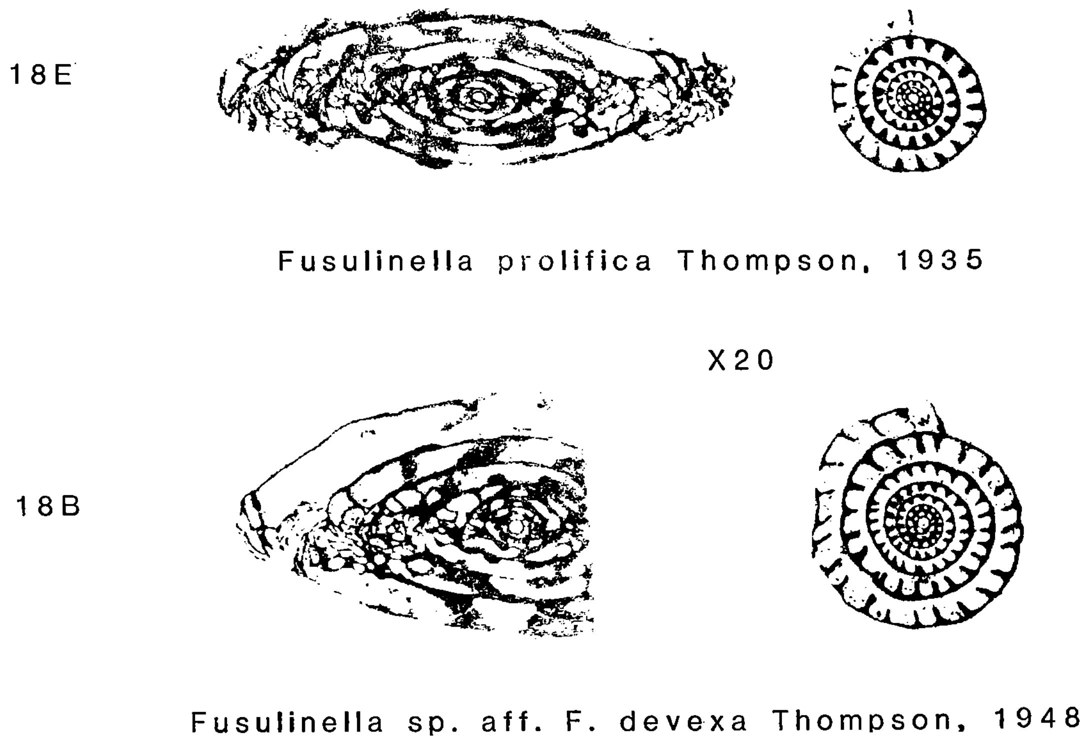

Figure 15. Fusulinid species from Atoka Formation at Stop 1, Canyon Creek. Numbers at left represent unit numbers; see figure 10.

duced *Neognathodus medadultimus* Merrill, indicating a middle Atokan age for this horizon. Neither of the early Atokan conodont zones described by Grayson (1979) from the upper part of the Wapanucka Formation in the frontal Ouachitas (*Diplognathodus orphanus* and *Streptognathodus elegantulus* Zones has been recovered at any of the exposures in the type-Atokan region.

STOP 2—COAL CREEK

Location: In east bank of Coal Creek, 3.2 miles southwest of Jesse, Oklahoma. Base of section (Wapanucka): SE¼SE¼ sec. 15, T. 1 N., R. 7 E.; top of section (Lehigh coal): NE¼SE¼ sec. 15, T. 1 N., R. 7 E.; Pontotoc County, Oklahoma. (Measured section 13 of Archinal, 1977.)

This is the most continuous exposure of the Atoka Formation in the northeastern part of the Arbuckle Mountains (fig. 16). However, the Atoka is thin (about 500 feet) in comparison with the 3,000 feet recorded in the area north of Clarita, 7 miles to the east. As at Stop 1, there is a long covered, probably shale, interval (unit 24) above the main Atoka outcrop that is presumed to be partly the Atoka Formation and partly the Desmoinesian McAlester Formation. North of the covered interval, Morgan's (1924) "red limestone" and the Lehigh coal are well exposed.

Less than 20 feet of the Wapanucka Formation is exposed at Coal Creek. A poorly exposed shale is overlain by a ridge-forming limestone. The limestone is variable in character and contains fine to coarse, oolitic and skeletal grainstones. The unit is thin bedded to nodular, and brachiopods are fairly common.

The Atoka Formation consists of numerous ridge-forming sandstones interbedded with covered shales. The sandstones, which may be as thick as 30 feet, are all very fine grained and well sorted; in addition, some are calcareous. Several show obvious bedding features, particularly parallel bedding and low-angle cross-bedding (figs. 17–20), which are interpreted as representing deposition in the foreshore portions of beaches, barrier bars, and (or) longshore bars. Two limestones occur in the sequence: the lower one (unit 15) (fig. 21) is a sandy skeletal wackestone containing fusulinids, whereas the upper one (unit 23) is a ridge-forming carbonate mudstone (fig. 22).

The Desmoinesian "red limestone" is a thick-bedded, coarse skeletal grainstone that is approximately 4 feet thick (fig. 23). It is well exposed in Coal Creek, below a high south-facing bluff. About 15 feet higher in the section, above a shale, is the Lehigh coal. With accompanying underclay, it is about 14 inches thick.

The highest exposed unit in the Atoka Formation (unit 23) strikes N. 50° W. and dips 42° NE. In contrast, 0.2 mile to the north, the "red limestone" strikes N. 70° W. and dips 14° NE. This difference is attributed to an angular unconformity between the Atoka and McAlester Formations (fig. 7). Presumably the Atoka Formation was tilted before it was overlapped by the McAlester.

Fusulinids have been recovered from units 12, 15, and 17 (fig. 24). *Fusulinella* sp. aff. *F. devexa* occurs commonly in parts of unit 15 and indicates a middle

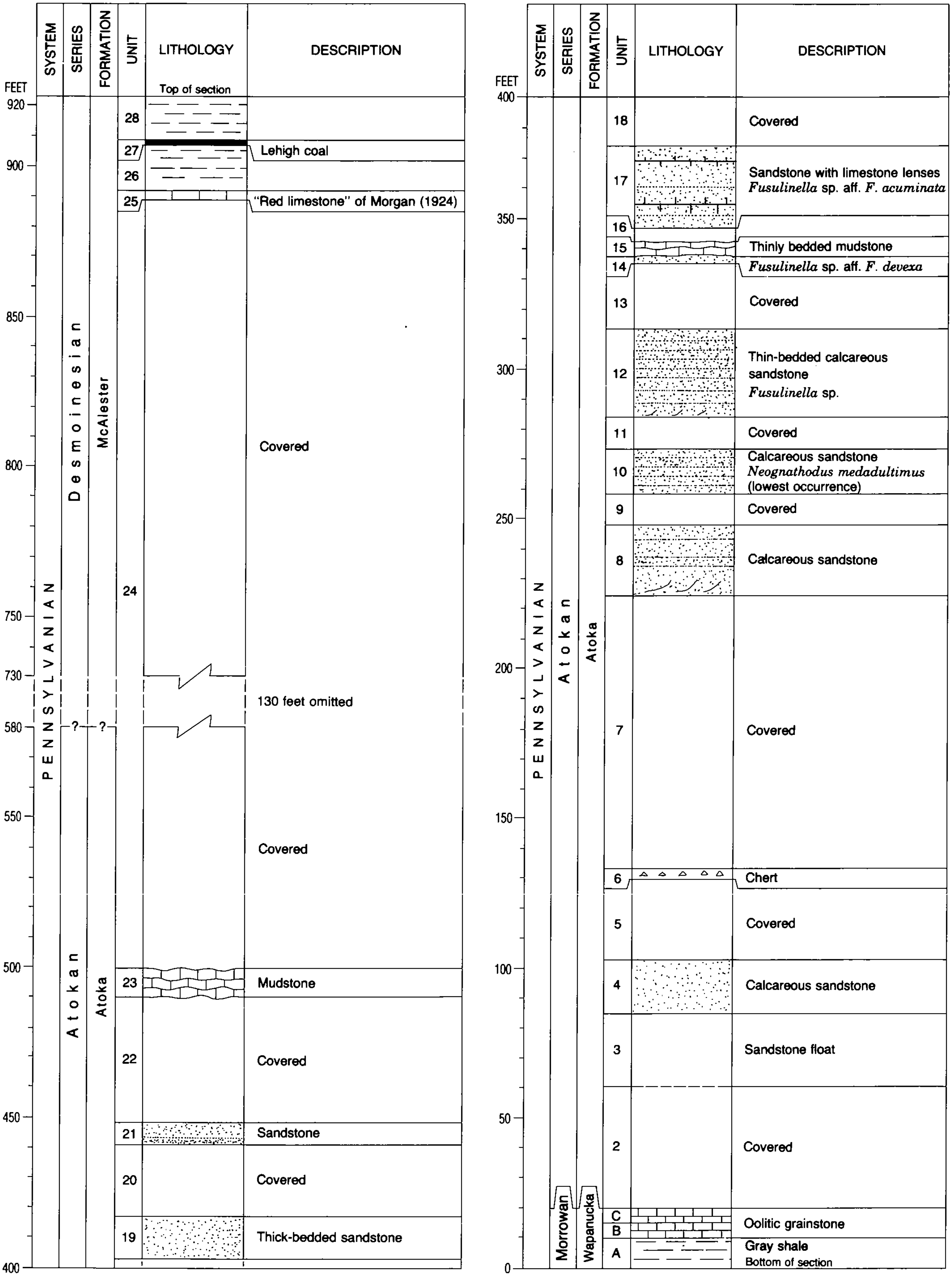

Figure 16. Graphic columnar section for Stop 2, Coal Creek. Stratigraphic units A–C from Rowett and Sutherland (1964); units 2–23 measured by B. E. Archinal (1977); unit 24 from map calculation; units 25–28 from Morgan (1924).

Figure 17. Low-angle cross-bedding in Atoka Formation; lower unit 10. (Stop 2.)

Figure 19. Very fine-grained, thin-bedded sandstone in Atoka Formation, characterized by parallel bedding and low-angle truncation; upper unit 10. (Stop 2.)

Figure 18. Fine-grained, thin-bedded sandstone in Atoka Formation showing low-angle cross-bedding, possibly two-directional; unit 10. (Stop 2.)

Figure 20. Very fine-grained, well-sorted sandstone in Atoka Formation showing parallel bedding; unit 12. (Stop 2.)

Figure 21. Skeletal wackestone from Atoka Formation, containing common fusulinids (see fig. 24); unit 15. (Stop 2.)

Atokan age (compare with fusulinid occurrences at Stops 1, 3, and 6).

Idiognathoides noduliferous has been recovered from unit 4, and *Neognathodus medadultimus* Merrill has its lowest occurrence in unit 10. *Neognathodus medexultimus* Merrill has its lowest occurrence in the upper part of unit 17. This species also occurs in the upper part of the Bostwick Formation in the Ardmore Basin, and possibly indicates a late Atokan age for these zones.

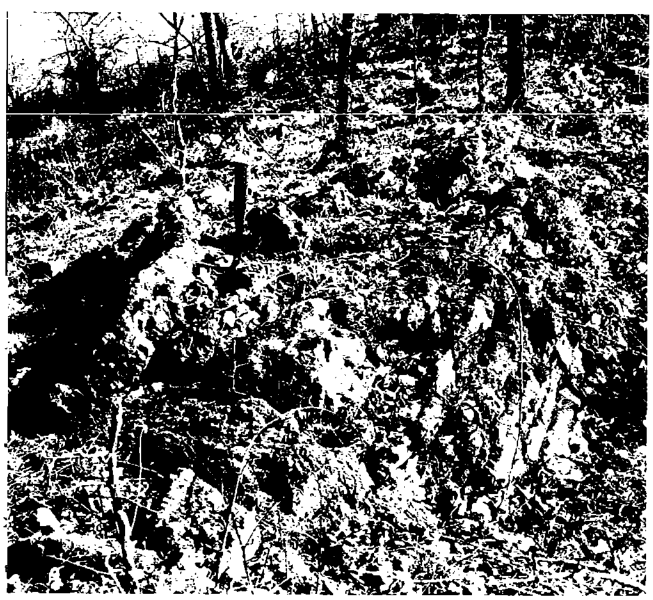

Figure 22. Thin-bedded carbonate mudstone forming ridge at top of Atoka Formation (fig. 16). (Stop 2.)

Figure 23. Men are standing on Morgan's (1924) Lower Desmoinesian "red limestone," with Lehigh coal well exposed in cliff beyond Coal Creek (fig. 16). (Stop 2.)

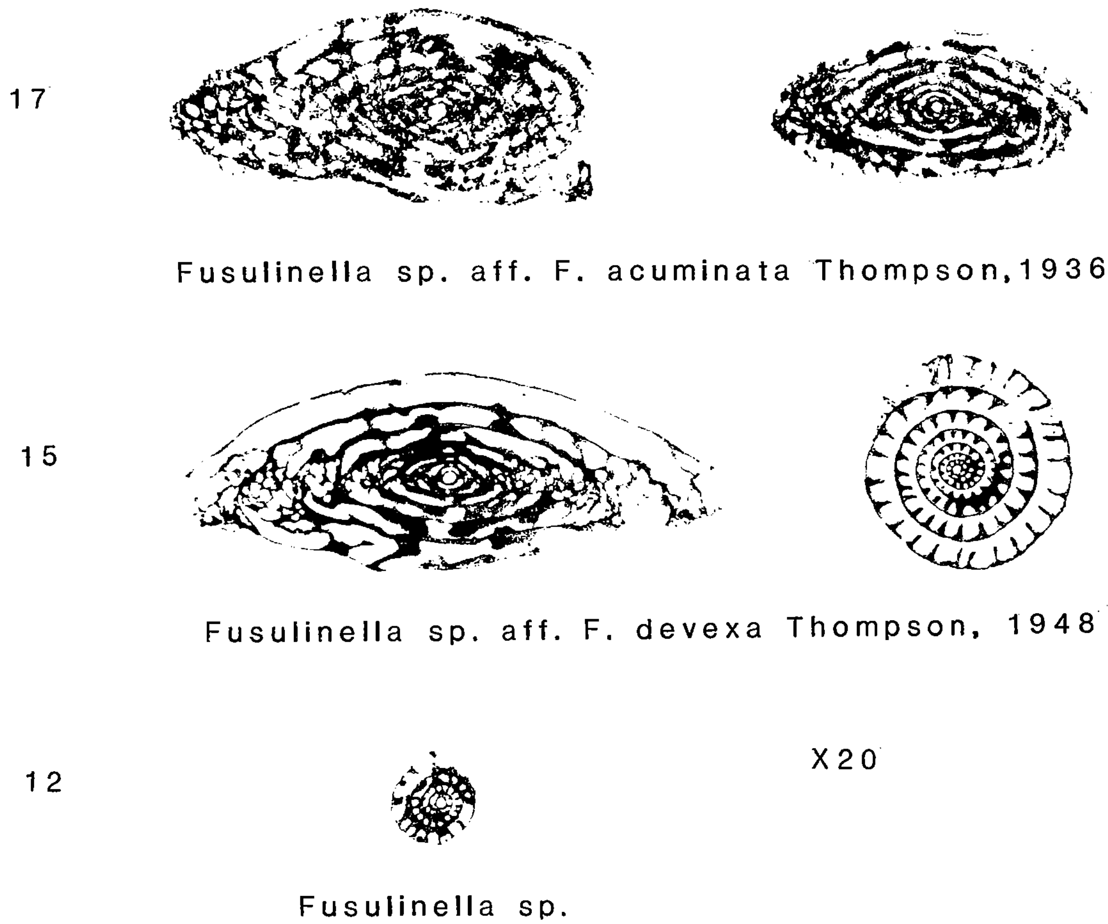

Figure 24. Fusulinid species from Atoka Formation at Stop 2, Coal Creek. Numbers at left represent unit numbers; see figure 16.

STOP 3—SOUTH JACK HILLS SYNCLINE

Location: About 1.4 miles west of Clarita, Oklahoma, adjacent to section-line road. Base of section is about 0.2 mile south of road, on thin ridge of Wapanucka Limestone in SE¼NE¼ sec. 9, T. 1 S., R. 8 E. Top of small offset section is in a brushy creek bottom, 150 feet north of road, near base of hill, E½NW¼NW¼ sec. 10, T. 1 S., R. 8 E., Coal County, Oklahoma. (Measured sections 3 and 3A of Archinal, 1977.)

The Wapanucka Limestone is not well exposed at this section (fig. 25), but it can be traced continuously around the south side of the syncline (fig. 7). The thickness of the covered unit OE was obtained from a map calculation.

The main Atoka section was measured mostly south of the road, almost due north up the hillside, in the eastern part of sec. 9. Unit 7, a calcareous sandstone containing fusulinids, was traced eastward, and then northeastward, across the road into a deep, brushy creek bottom where the offset section was measured. The sandstones in this section are typical for the formation, being very fine grained and well sorted. The thin skeletal limestones in the offset section are sandy and interbedded with shales (fig. 26).

The fusulinids *Fusulinella* sp. aff. *F. prolifica* and *Fusulinella* sp. aff. *F. devexa* occur in unit A (fig. 27), 410 feet above the base of the formation. This zone is believed to be the same as that containing *F. prolifica* at its type locality 0.8 mile to the east along the strike (fig. 7). The South Jack Hills Syncline sequence is a depositionally "condensed" sequence on the northern flank of the Clarita Anticline, a positive feature during Atokan time. See the discussion on growth folding in this area during Atokan time by Sutherland, Archinal, and Grubbs in this guidebook. They point out that the thin fossiliferous zone, unit A, can be traced westward and then northward into the thicker "basinal" sequence, where the *F. prolifica* horizon is approximately 1,000 feet above the base of the formation (fig. 7). The fusulinid occurrences in this section can be compared with those at Stops 1, 2, and 6.

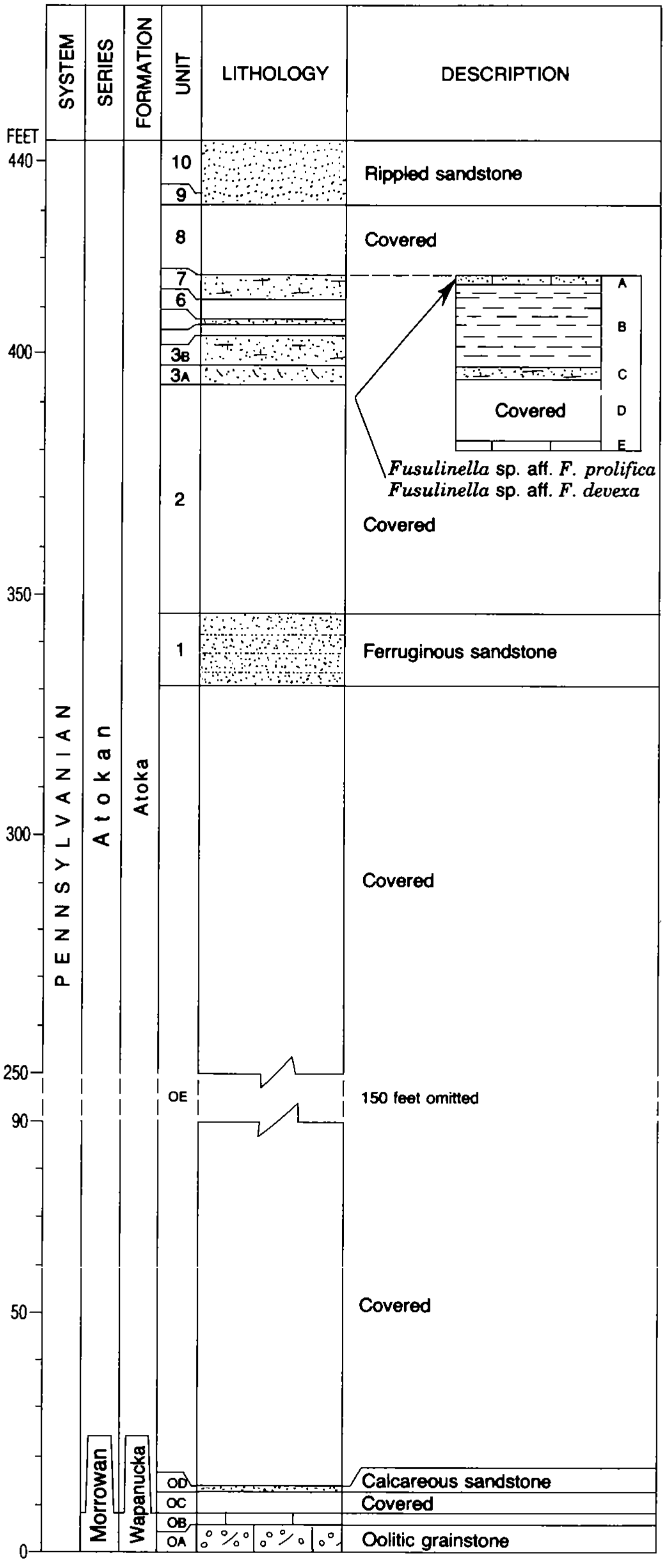

Figure 25. Graphic columnar section for Stop 3, South Jack Hills Syncline. Section measured by B. E. Archinal (1977).

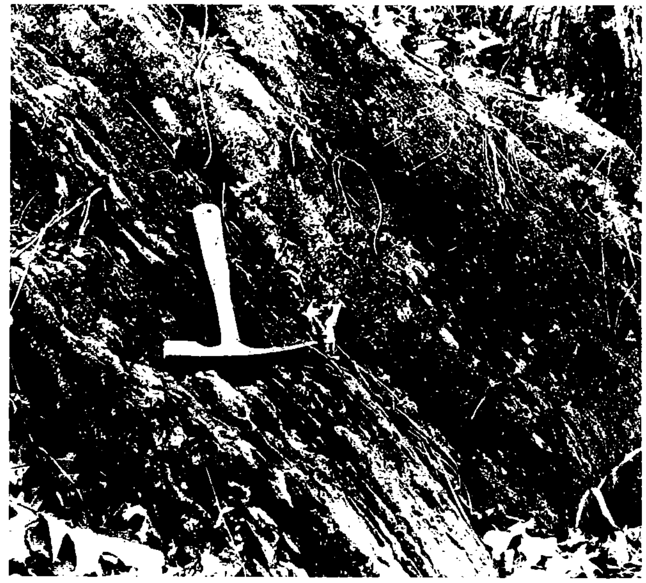

Figure 26. Unit A, at top of short offset section shown in figure 25. See figure 27 for fusulinid species. (Stop 3.)

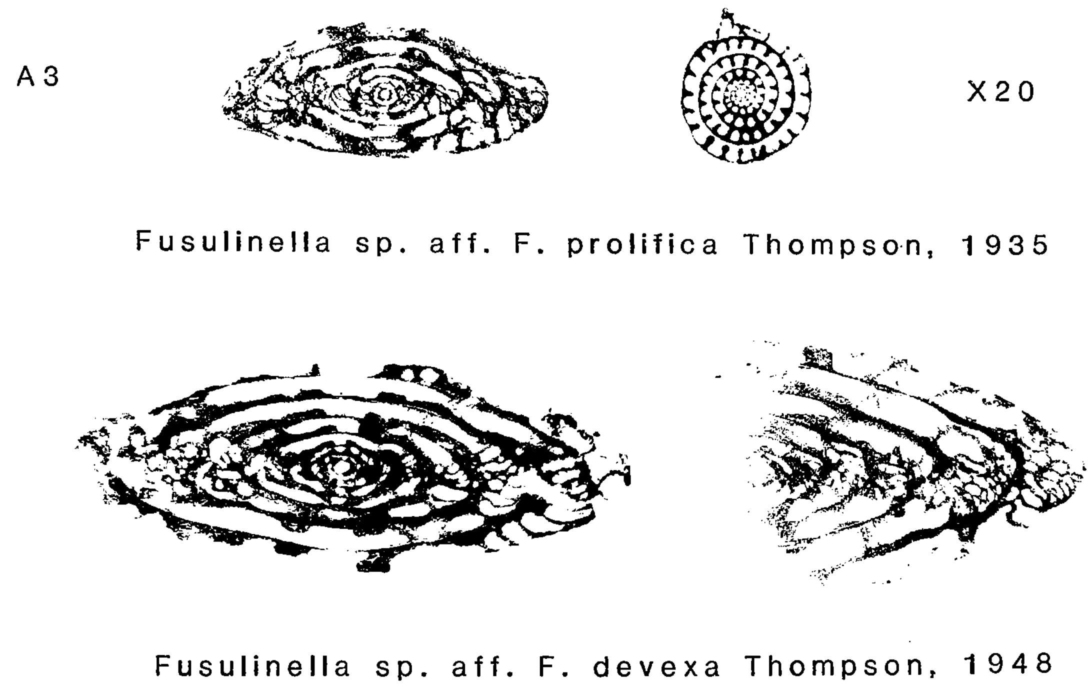

Figure 27. Fusulinid species at top of unit A, in offset section at Stop 3. Numbers at left represent unit numbers; see figure 25.

STOP 4—"GRILEY" LIMESTONE

Location: Adjacent to section-line road, about 3.5 miles north then 2.7 miles west from Clarita, Oklahoma. Exposure to be visited is in shallow ravine about 200 feet south of road. NW¼NE¼NW¼ sec. 28. T. 1 N., R. 8 E., Coal County, Oklahoma. (Measured section 4 of Archinal, 1977.)

This locality lies north of the Jack Hills Fault (fig. 7) and is apparently on the Atoka Formation. Archinal (1977) was unable to trace the Hartshorne Sandstone (basal Desmoinesian) farther west than sec. 23, at the eastern margin of T. 1 N., R. 8 E. In the fault block that contains Stop 4 (fig. 7), bounded on the north by the Franks Fault, he was unable to find any sandstone ridges that could be identified as Hartshorne and concluded that the formation had been cut out by the Franks Fault. Still farther west, in T. 1 N., R. 7 E., the Hartshorne is missing owing to westward onlap by the McAlester. In that area, the Atoka Formation is much thinner, owing at least in part to truncation below the McAlester Formation. The sequence there is typified by the section at Stop 2 on Coal Creek.

The "Griley" limestone has not been properly defined in the literature as a lithostratigraphic unit. It was informally named after Horace Griley, a former Sun Oil Co. geologist, who found it and collected the first fusulinids (Waddell, 1959). It consists of two thin, discontinuous limestones about 50 feet apart (fig. 28). The lower limestone (unit 1) is a limestone lentil that reaches 1.5 feet in thickness. In the early 1960s, there were a few scattered blocks from this unit just north of the fence, about 0.75 mile west of the southeastern corner of sec. 21, T. 1 N., R. 8 E. Today, such blocks are extremely scarce; most have apparently been removed by collectors. It was from this lower limestone that Waddell extracted a new species of *Fusulinella* (1959, pl. 3, figs. 1–9). He described the species as being an extremely advanced *Fusulinella,* in the transition between *Fusulinella* and *Fusulina.*

The second "Griley" limestone is a thin, discontinuous skeletal grainstone, typically less than 0.3 foot thick, underlain by about 10 feet of calcareous shale. Loose slabs of this limestone were noted in the early 1960s just north of the fence, on the east side of a small valley, about 0.7 mile west of the southeastern corner of sec. 21, T. 1 N., R. 8 E. Now, slabs near the road are scarce, but a few can be seen in ravines 0.1 to 0.2 mile along the strike to the northwest.

The locality to be visited on this field trip is a small ravine south of the road, which exposes about 6 feet of calcareous, highly fossiliferous shale. This location is well known and was found apparently by M. K. Elias in about 1960. Particularly common are crushed fragments of *Antiquatonia,* a large productid brachiopod. The shale also contains bryozoans, crinoid fragments, echinoid spines, fusulinids, ostracods, and shark teeth. Strimple and Watkins (1969) report the excavation of a rich crinoid colony at this locality. They also reported the recovery of minute fusiform fusulinids, which they submitted to M. L. Thompson for identification. He identified them as *Profusulinella fittsi* and therefore indicated an early Atokan age for this locality. However, Sutherland has extracted shale samples from six successive 1-foot intervals at this locality. Although four of the six samples contained only minute fusulinids, two of the samples contained large fusulinids (10 mm in length) in addition to the smaller forms. Both the large and small specimens are being studied by R. C. Douglass. He has identified both sizes as representing a primitive species of *Beedeina*. This indicates that the "Griley" limestone is early Desmoinesian.

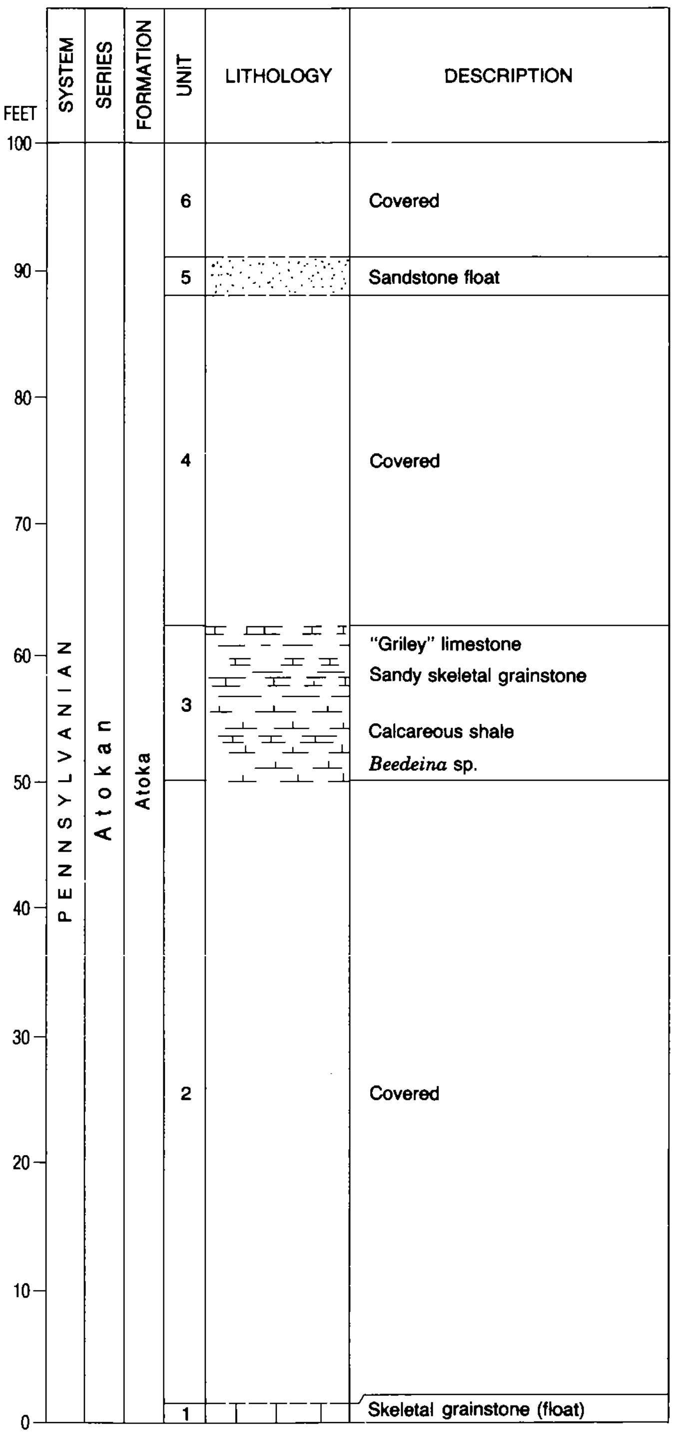

Figure 28. Graphic columnar section for Stop 4, "Griley" limestone. Section measured by B. E. Archinal (1977).

Figure 29. Highly fossiliferous shale below "Griley" limestone; unit 3. Shale carries fusulinids shown in figure 31. (Stop 4.)

Figure 30. Collecting fossils from shale below "Griley" limestone; unit 3. (Stop 4.)

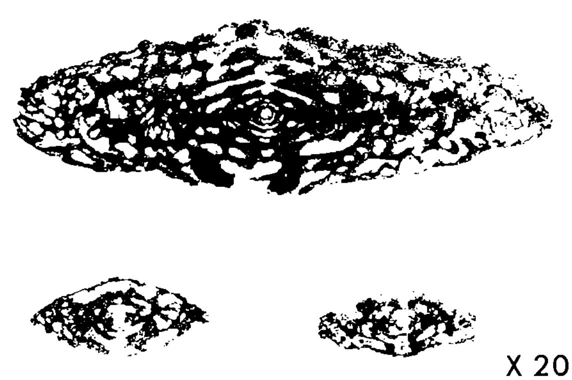

Figure 31. Mature and immature specimens of *Beedeina* sp. from shale below "Griley" limestone at Stop 4. Specimens are from unit 3, figure 28.

STOP DESCRIPTIONS—MILL CREEK SYNCLINE

R. Kent Grubbs
Patrick K. Sutherland
Raymond C. Douglass
Merlynd K. Nestell

INTRODUCTION

The Mill Creek Syncline is a downfaulted block in the central part of the Arbuckle Mountains that preserves strata of Early and Middle Pennsylvanian age. These rocks clearly have affinities with the Wapanucka and Atoka Formations on the northeastern flank of the Arbuckle Mountains, 20 miles to the northeast. In contrast, the strata in the Mill Creek Syncline represent a totally different geological province relative to exposures only 10 miles to the southwest, in the northern part of the Ardmore Basin.

The Mill Creek Syncline, 1.5 to 2.0 miles in width, is bounded by the Mill Creek Fault on the north and the Reagan Fault on the south (fig. 8). Ham (1969) first recorded the occurrence of the Wapanucka and Atoka Formations in the Mill Creek Syncline, but these units were not described in detail prior to the study by Grubbs (1981). These formations, 860 feet thick at Stop 6, have been removed by pre-Deese erosion in the Buckhorn area of the Mill Creek Syncline, 6.5 miles to the northwest. In that area, the Deese Conglomerate (Desmoinesian) rests unconformably on the "Springer" Formation (Morrowan).

Conodonts from the Wapanucka and Atoka Formations in the Mill Creek Syncline have been studied by R. K. Grubbs, and the fusulinids from the Atoka Formation are being studied by R. C. Douglass and M. K. Nestell. Those workers have provided the observations on these fossil groups that are presented in the stop descriptions.

STOP 5—MILL CREEK QUARRY

Location: Abandoned quarry on south edge of the town of Mill Creek, 0.7 mile south of junction of State Highway 12 with Main Street. Quarry is on east side of the highway. C W½SW¼ sec. 7, T. 2 S., R. 5 E., Johnston County, Oklahoma. (Measured section 282 of Grubbs, 1981.)

The quarry on the southern edge of Mill Creek (fig. 32) exposes a limited portion of the Wapanucka Formation (units 2–4) (fig. 33). The limestones here are dominated by oolitic grainstones (fig. 34), but these are interbedded locally, particularly in the lower half of the quarry, with skeletal grainstones, packstones, and skeletal wackestones. These strata are also characterized by trough cross-bedding and locally by extensive burrowing and bioturbation. Conodont faunas from the Wapanucka Limestone in the quarry are dominated by *Idiognathoides convexus* (Ellison and Graves) and *Idiognathoides sinuatus* Harris and Hollingsworth.

The basal Atoka sandstone is exposed in the pasture north of the quarry (units 10–12). This outcrop is typical of other basal Atoka sandstone exposures in the Mill Creek Syncline. About 340 feet above the base of the sandstone is a single limestone exposure (unit 14) that crops out in a creek bed just south of Mill Creek School. This outcrop produced a large conodont fauna that includes *Neognathodus colombiensis* (Stibane), *Diplognathodus coloradoensis* (Murray and Chronic), and *Diplognathodus orphanus* (Merrill). This interval also contains undescribed fusulinids.

An exceptional exposure of the upper Wapanucka Formation and basal Atoka Formation was created briefly in January, 1980, during construction of a sewer pipeline in the town of Mill Creek (fig. 35). A narrow trench, nearly 200 feet long, was blasted through limestone, exposing the uppermost 125 feet of the Wapanucka Formation (fig. 36) and the base of the Atoka Formation (fig. 37). The trench was along the east side of the block, between the second and third streets south of Main Street, one block west of State Highway 12 (measured section 283 of Grubbs, 1981). Compared with the Mill Creek quarry, the interval exposed in the trench corresponds to the mostly covered interval between the highest exposure in the quarry and the basal Atoka sandstone (units 5–9). The trench section was measured and sampled by Grubbs several days before it was filled in.

The trench section revealed two important intervals that are covered in all other sections in the Mill Creek Syncline. Unit 11, an oolitic grainstone, may be the top of the Wapanucka Formation. However, this 5-foot unit has a sharp basal contact with large borings into the underlying unit. In addition, it contains abundant rounded limestone pebbles within 2 inches of the basal contact (fig. 38). These pebbles represent typical Wapanucka rock types. Although unit 11 is similar to the Wapanucka limestones, it is possible that the sharp basal contact is the Wapanucka–Atoka boundary, with the limestone pebbles representing a "basal Atoka" conglomerate (the Morrowan-Atokan boundary is unconformable in the Mill Creek Syncline). The top of unit 11 produced only nondiagnostic conodonts; hence there is no fossil evidence concerning the age of this unit.

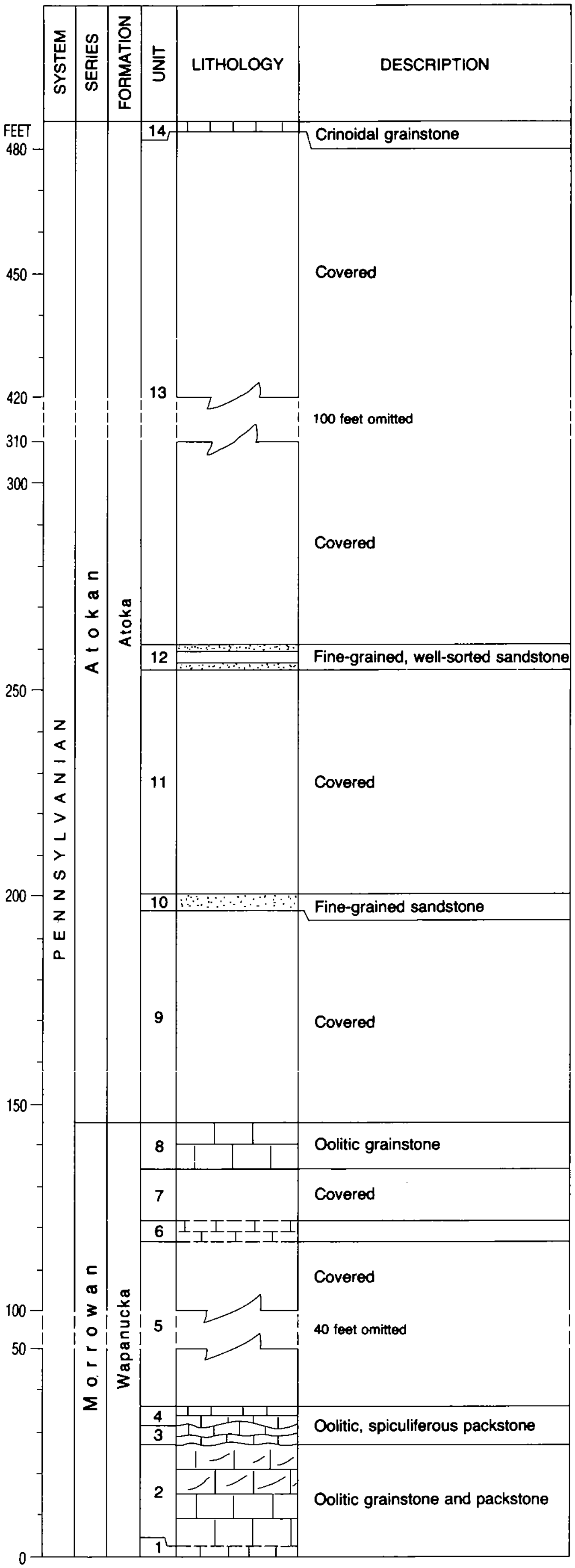

Figure 33. Oolitic grainstones, packstones, and wackestones of Wapanucka Formation in north wall of quarry; units 2–4. (Stop 5.)

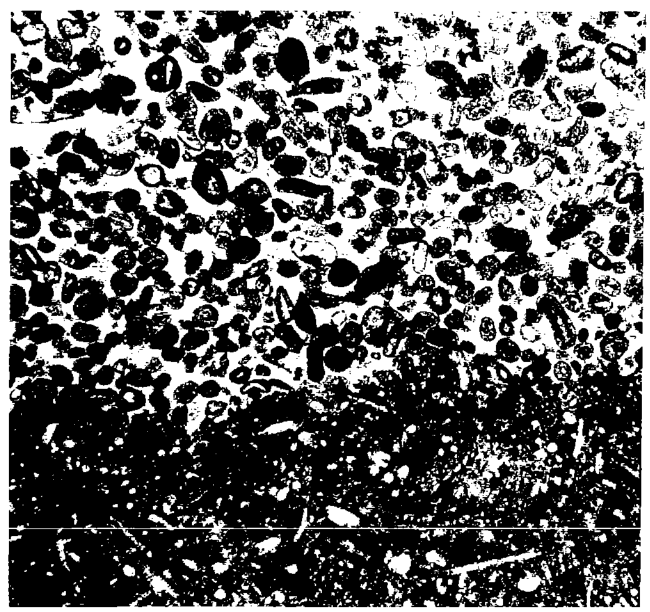

Figure 34. Sharp scour surface between oolitic grainstone (unit 4) and underlying wackestone; unit 3 (fig. 33). (Stop 5.)

Figure 32. Graphic columnar section for Stop 5, Mill Creek quarry. Section measured by R. K. Grubbs (1981).

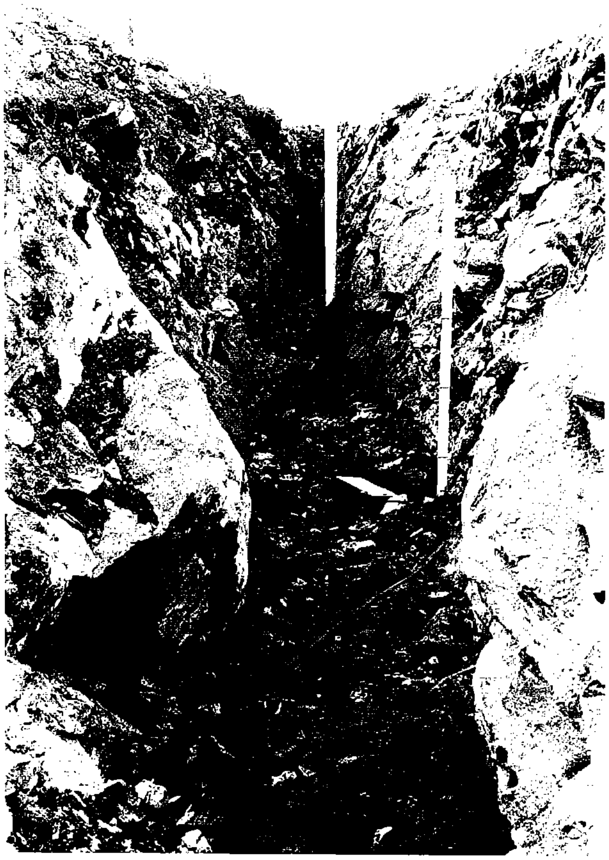

Figure 35. Pipeline trench through uppermost Wapanucka Limestone, as it appeared when exposed briefly in January, 1980, in town of Mill Creek, near Stop 5.

Figure 36. Interbedded oolitic grainstone and mixed skeletal grainstone of Wapanucka Formation; unit 8. (Pipeline trench near Stop 5.)

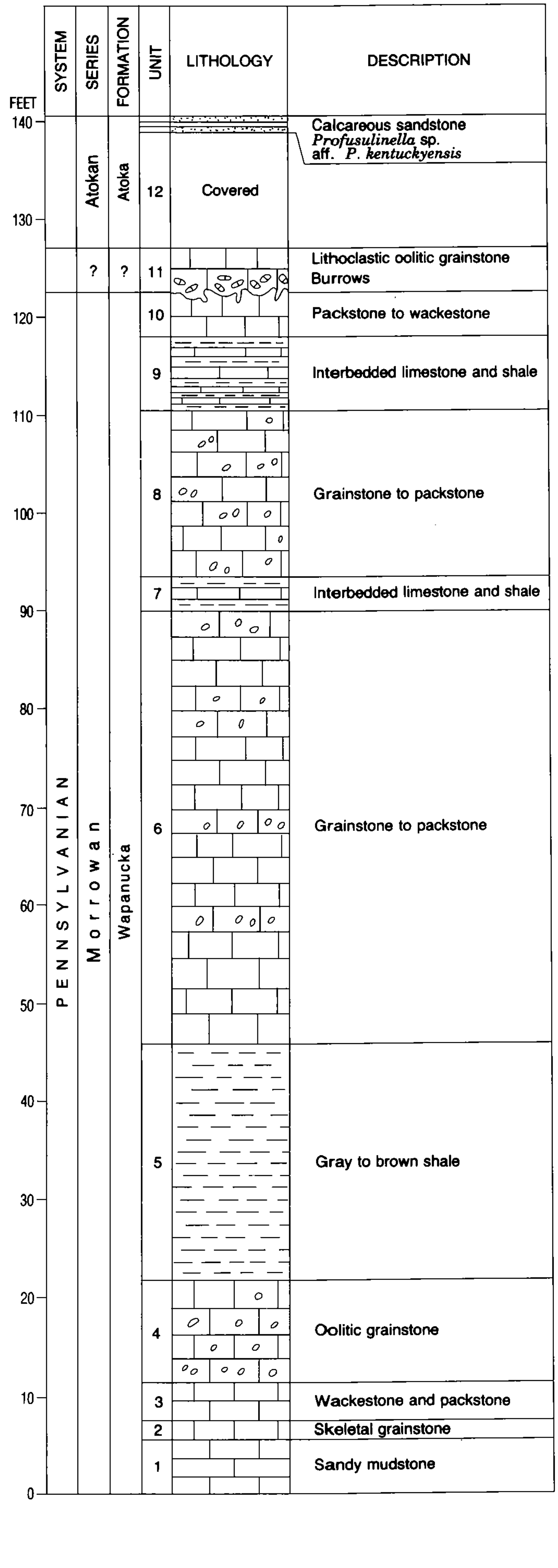

Figure 37. Graphic columnar section for pipeline-trench section, in town of Mill Creek, near Stop 5. Section measured by R. K. Grubbs (1981).

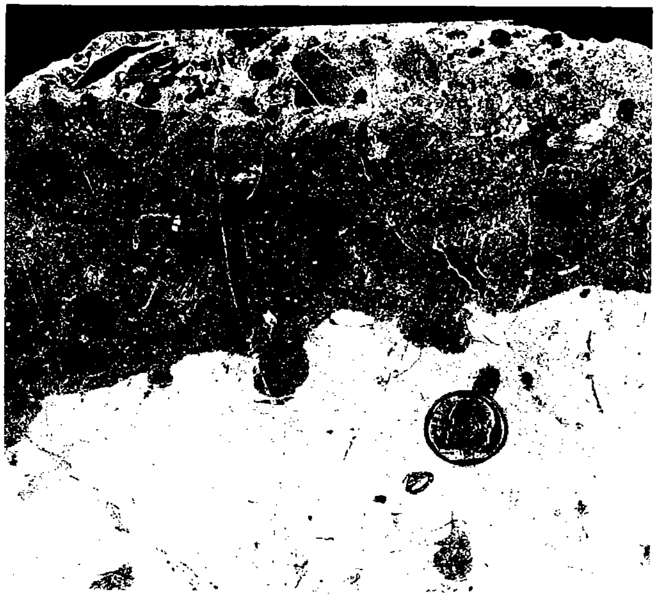

Figure 38. Rock slab showing irregular contact between pelloidal wackestone, unit 10, and oolitic, lithoclastic grainstone, unit 11, which may represent Wapanucka–Atoka unconformity (fig. 37). (Pipeline trench near Stop 5.)

Also exposed in the trench was the base of the basal Atoka sandstone interval (unit 13). This calcareous sandstone is 11 feet stratigraphically above unit 11 and contains fusulinids that have been identified by Douglass as *Profusulinella* sp. aff. *P. kentuckyensis* (fig. 39). This is an advanced form of the genus. Thus, the Morrowan–Atokan unconformity, situated either at the base of unit 11 or in the covered interval of unit 12, is represented by a missing stratigraphic interval containing *Eoschubertella*, *Pseudostaffella*, and primitive *Profusulinella*.

Profusulinella sp. aff. P. kentuckyensis Thompson and Riggs, 1959

Figure 39. Fusulinid species from near the base of the Atoka Formation in the pipeline-trench section near Stop 5. Specimens are from base of unit 13, figure 37. Magnification, ×20.

STOP 6—LEWIS RANCH

Location: In creek bed of unnamed tributary of Mill Creek, 0.3 to 0.5 mile north of section-line road at point 1.6 miles west on Main Street from its junction with State Highway 12 in the town of Mill Creek. C N½S½ sec. 2, T. 2 S., R. 4 E., Johnston County, Oklahoma. (Measured section 284 of Grubbs, 1981.)

This is the most continuously exposed section of the Wapanucka and Atoka Formations in the Mill Creek Syncline (fig. 40). The abundant fusulinid limestones make this the best locality in south-central Oklahoma for Atokan age determinations.

At this locality the Wapanucka Formation is 350 feet thick. It is relatively well exposed, especially in the lower portion (figs. 41, 42). Oolitic and skeletal grainstones and packstones are exposed in wavy to lenticular beds. The lower Wapanucka limestones produced abundant conodont faunas, generally dominated by the genera *Idiognathoides* and *Adentognathus*. *Idiognathoides ouachitensis* (Harlton), *Idiognathoides convexus* (Ellison and Graves), and *Neognathodus* n. sp. were all recovered from the lowest conodont sample in the Wapanucka (unit 3). *I. ouachitensis* and *I. convexus* continue to appear in higher sample intervals in the formation. These conodonts indicate a late Morrowan age and assignment of the entire Wapanucka in this area to the *Neognathodus* n. sp.–*Idiognathoides ouachitensis* Zone as defined by Grayson (1979, 1980) in the Wapanucka Formation of the frontal Ouachitas. *Millerella* is the only diagnostic foraminifer to be found in the Wapanucka of the Mill Creek Syncline.

The Atoka Formation is 515 feet thick in this section. It consists of a basal sandstone (75 feet thick), which is fine grained and medium to thick bedded, followed by a variable interval of limestone, sandstone, shale, chert, and chert-pebble conglomerate. The lower half of the variable interval includes interbedded sandstones, shales, and two types of limestones: coarse-grained crinoidal grainstones and packstones that contain fusulinids (figs. 43–45), and finer grained spiculiferous mudstones and pack-

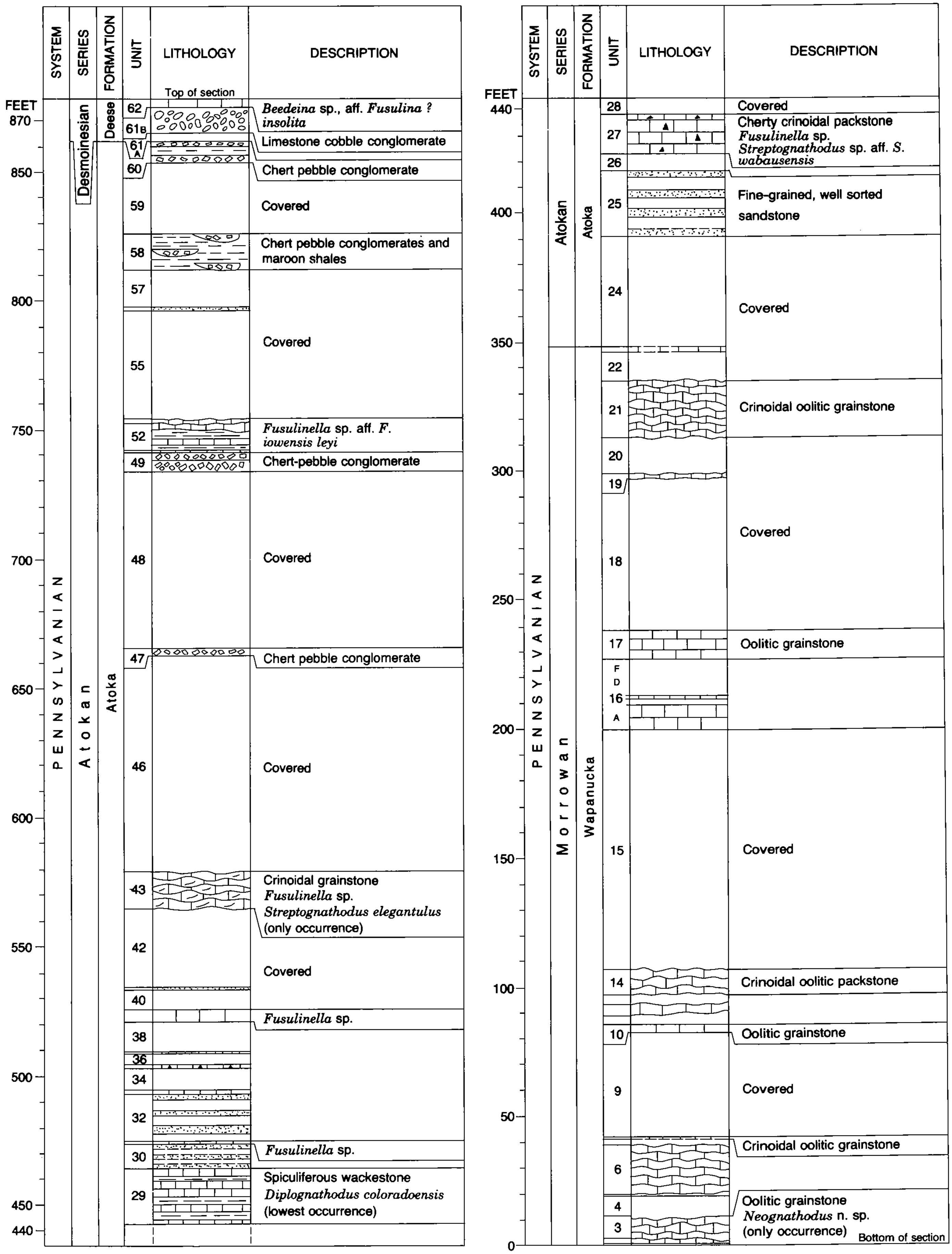

Figure 40. Graphic columnar section for Stop 6, Lewis Ranch. Section measured by R. K. Grubbs (1981).

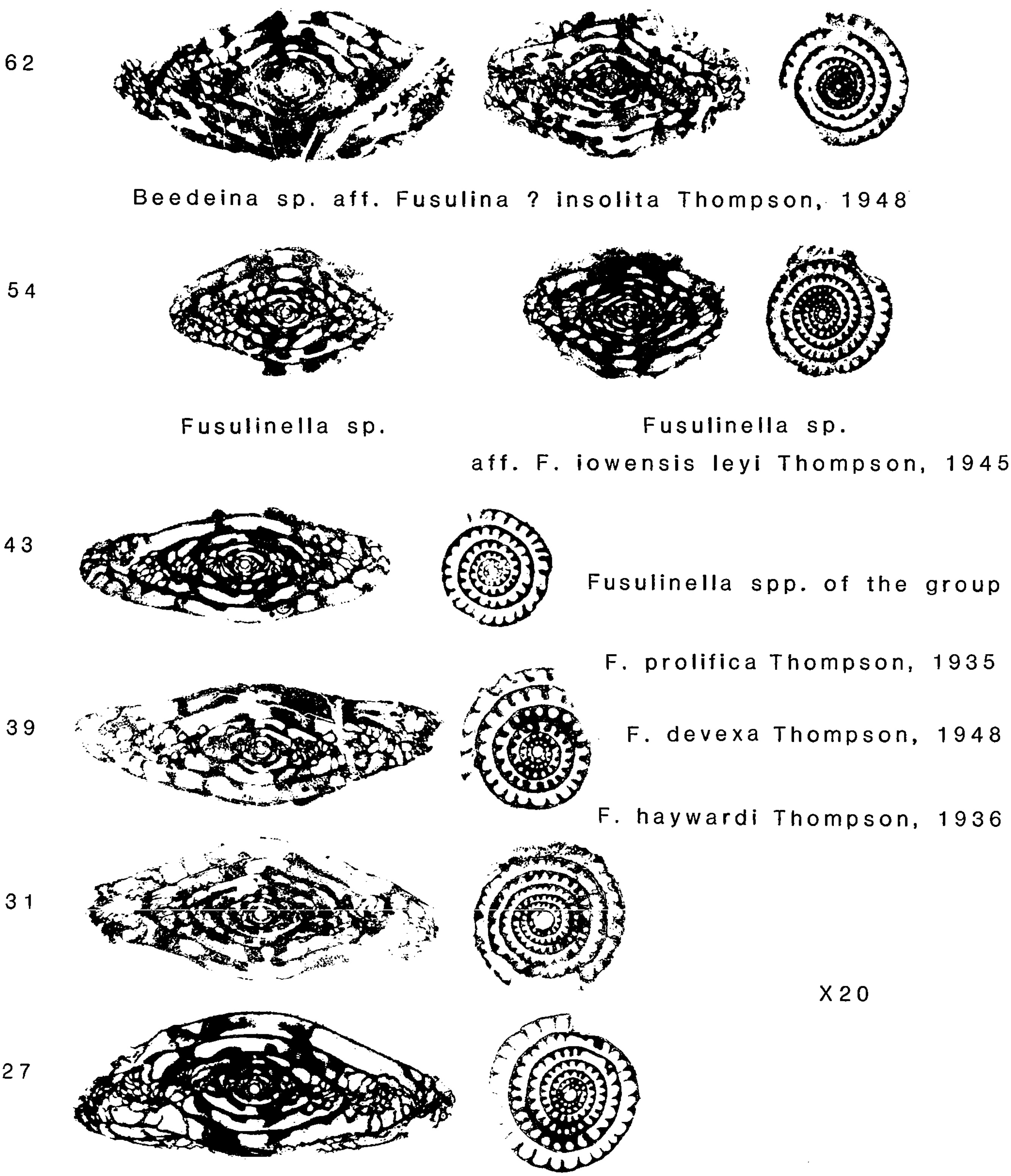

Figure 41. Fusulinid species from Atoka Formation at Stop 6, Lewis Ranch. Numbers at left represent unit numbers; see figure 40.

stones. The upper portion of the Atoka Formation is characterized by noncalcareous shales and chert-pebble conglomerates (figs. 46, 47). These conglomerates were deposited as a result of uplift to the north on the Hunton Arch (see Ham, 1969), and were derived from the Woodford Formation (Upper Devonian).

Figure 42. Wavy, lenticular bedding in oolitic and crinoidal grainstones near base of Wapanucka Formation; unit 3. Strata have produced abundant conodonts. (Stop 6.)

Figure 43. Poorly sorted crinoidal, oolitic grainstones in lower Wapanucka Formation; unit 6. (Stop 6.)

Fusulinids have been collected by Grubbs (1981) from six zones in the Lewis Ranch section, including units 27, 31, 39, 43, and 54 from the Atoka Formation. Preliminary identifications by R. C. Douglass are shown in figure 48. These fusulinids indicate a middle to upper Atokan age for the lithologically variable part of the Atoka Formation that lies above the basal sandstone.

The lowest Atoka conodont sample from the Lewis Ranch section, unit 27, produced an abundant fauna that includes *Neognathodus colombiensis, Diplognathodus orphanus*, and *Streptognathodus* sp. aff. *S. wabaunsensis*.

The base of the Deese Conglomerate (Desmoinesian) is recognized in this section by the first occurrences of limestone-cobble conglomerates (figs. 49,

Figure 44. Crinoidal packstone in lower Atoka Formation, containing fusulinids; unit 39 (fig. 41). (Stop 6.)

Figure 45. Wavy to lenticular beds of crinoidal grainstone in Atoka Formation, containing fusulinids; unit 43 (fig. 41). (Stop 6.)

Figure 46. Close-up of medium-bedded layers of crinoidal grainstones in Atoka Formation; unit 43. (Stop 6.)

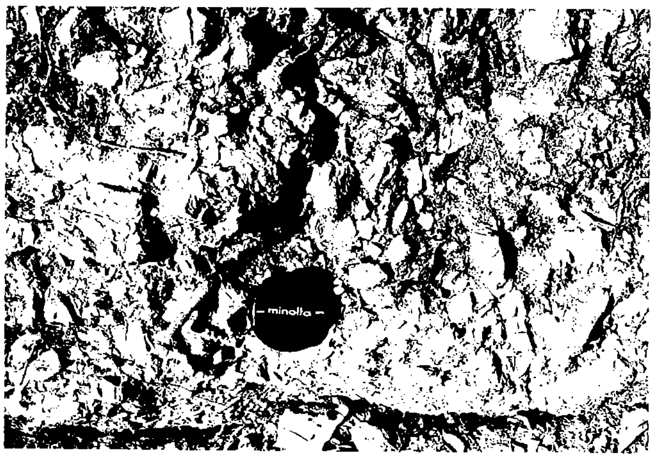

Figure 47. Chert-pebble conglomerate in upper Atoka Formation, derived from weathering of Upper Devonian Woodford Formation; unit 49. (Stop 6.)

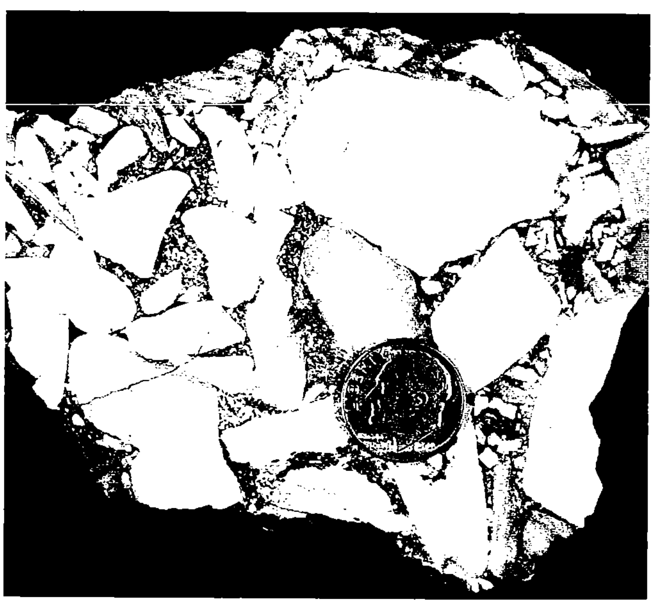

Figure 48. Slab of chert-pebble conglomerate from top of Atoka Formation; unit 60. (Stop 6.)

Figure 49. Limestone-cobble conglomerate at base of Deese Conglomerate, unit 61, overlain, in upper right corner of picture, by crinoidal packstone, unit 62, containing Desmoinesian fusulinid genus *Beedeina*. (Stop 6.)

Figure 50. Close-up of block of limestone-cobble conglomerate at base of Deese Conglomerate; unit 61. (Stop 6.)

50) and the fusulinid genus *Beedeina*. Unit 61 is a 12-foot covered interval that contains a loose rubble of limestone-cobble conglomerate in the creek bed. Because this rubble is not found in the creek bed upstream or downstream, it is presumed to be weathering out in place. Limestones immediately above this interval (unit 62) contain the lowest occurrence of the Desmoinesian fusulinid genus *Beedeina*. Therefore, the base of the Deese Conglomerate is placed at the base of the limestone-cobble conglomerate (unit 61). These cobbles were derived primarily from the Hunton and Viola Limestones (Ham, 1969).

STOP DESCRIPTIONS—NORTHERN ARDMORE BASIN

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INTRODUCTION

The Ardmore Basin is a narrow structural basin that lies immediately south of the Arbuckle Mountains (fig. 3) and was a part of the Southern Oklahoma Aulacogen during the Pennsylvanian Period (fig. 2). The Lower and Middle Pennsylvanian facies in this area, which represents a predominantly terrigenous basinal facies, differs markedly from the shallow-shelf carbonate facies found in the Mill Creek Syncline, located only 10 miles to the northeast (figs. 4, 5).

STOP 7—DUTTON RANCH

Location: Valley in northern slope of broad hogback; 800 feet south of unnamed road, 1.1 miles west of Highway 177, 2.5 miles north of Baum. NW¼NW¼SW¼ sec. 15, T. 3 S., R. 3 E., Carter County, Oklahoma. (Measured section 363 of Tennant, 1981.)

The upper Gene Autry Member (Morrowan) and the Otterville (Morrowan) and Bostwick Members (Atokan) of the Dornick Hills Group are exceptionally well exposed (fig. 51) at this section. However, the base of the Morrowan Series is not exposed at the Dutton Ranch.

Approximately 400 feet of the upper Gene Autry Member (Morrowan) crops out near the base of a small, steep valley, and forms the bank above a small stock pond. This shale sequence characteristically weathers reddish brown, and contains abundant pebble-size limonitic ironstone concretions. They are concentrated in zones as much as 10 feet thick (fig. 52). The upper Morrowan ammonite *Axinolobus* occurs elsewhere in the Gene Autry shale in the northern Ardmore Basin, but it has not been found as yet at this locality.

The Otterville Member (Morrowan) on the Dutton Ranch consists of two thin, rust-brown, skeletal limestone beds (units 2, 4) separated by 50 feet of olive-gray shale containing orange-brown siltstone laminae (figs. 53, 54). This sequence is notably different from the thicker oolitic and coated skeletal grainstones of the Otterville Member in the central and southern parts of the Ardmore Basin (compare with Stop 8, Buzzard Creek). Approximately 100 feet of unnamed olive-gray shale containing ironstone concretions crops out in the valley, stratigraphically above the Otterville Member.

The Bostwick Member (Atokan) is a stratigraphic interval of mostly shale interbedded with a thin basal conglomerate, a coal, and an upper, burrowed calcareous sandstone. The Bostwick is 98 feet thick on the Dutton Ranch. The poorly exposed basal conglomerate (unit 6) contains worn pebbles and cobbles of limestone, chert, and ironstone concretions in a sandy hematitic matrix. Limestone clasts include coarse, skeletal and oolitic grainstones similar to the Otterville Member, and gray to tan, carbonate mudstones similar to much older Paleozoic formations (for example, the Hunton and Viola). In the southern part of the Ardmore Basin, the Bostwick Member reaches a thickness of 500 feet and contains limestone-cobble conglomerates derived from lower and middle Paleozoic units in the Criner Hills (Jacobsen, 1959).

The Bostwick coal crops out 29 feet above the conglomerate. This shaly coal and underclay are exposed in the creek bank, where they reach a thickness of approximately 2 feet. This coal is overlain by a 65-foot sequence of blue to olive-gray shale interlaminated with orange-brown siltstone in the basal 3.5 feet. The upper part of the shale sequence contains calcareous concretions.

The uppermost unit in the Bostwick Member on the Dutton Ranch is a medium- to thick-bedded, burrowed, calcareous sandstone which contains rare molluskan skeletal fragments and *Calamites* casts. A similar unit has been recognized in the upper Bostwick Member in two other measured sections, 5 miles along the strike to the southeast. The apparent continuity of this burrowed sandstone contrasts with the typically discontinuous deposits of the Dornick Hills Group.

The base of the Desmoinesian Series begins with the very coarse, *Osagia*-coated skeletal grainstone (unit 12) at the base of the Lester Member, approximately 85 feet above the burrowed sandstone of the upper Bostwick Member (fig. 51). The intervening interval is an unnamed sequence of blue-gray shale containing local siltstone laminae and thin zones of ironstone concretions near the base.

It should be pointed out that we have no specific biostratigraphic age information for any of the units in the Dutton Ranch section. Tennant (1981) assigned formation and member names based on stratigraphic position and lithostratigraphic correlation with adjacent sections. Conodont samples collected from units 2 and 4 (Otterville) are nondiagnostic (R. C. Grayson, Jr., oral communication, 1982). Tennant (1981) used the term "Bostwick interval" for the Bostwick Formation, as here used, because of the marked changes in facies from the southern Ardmore Basin.

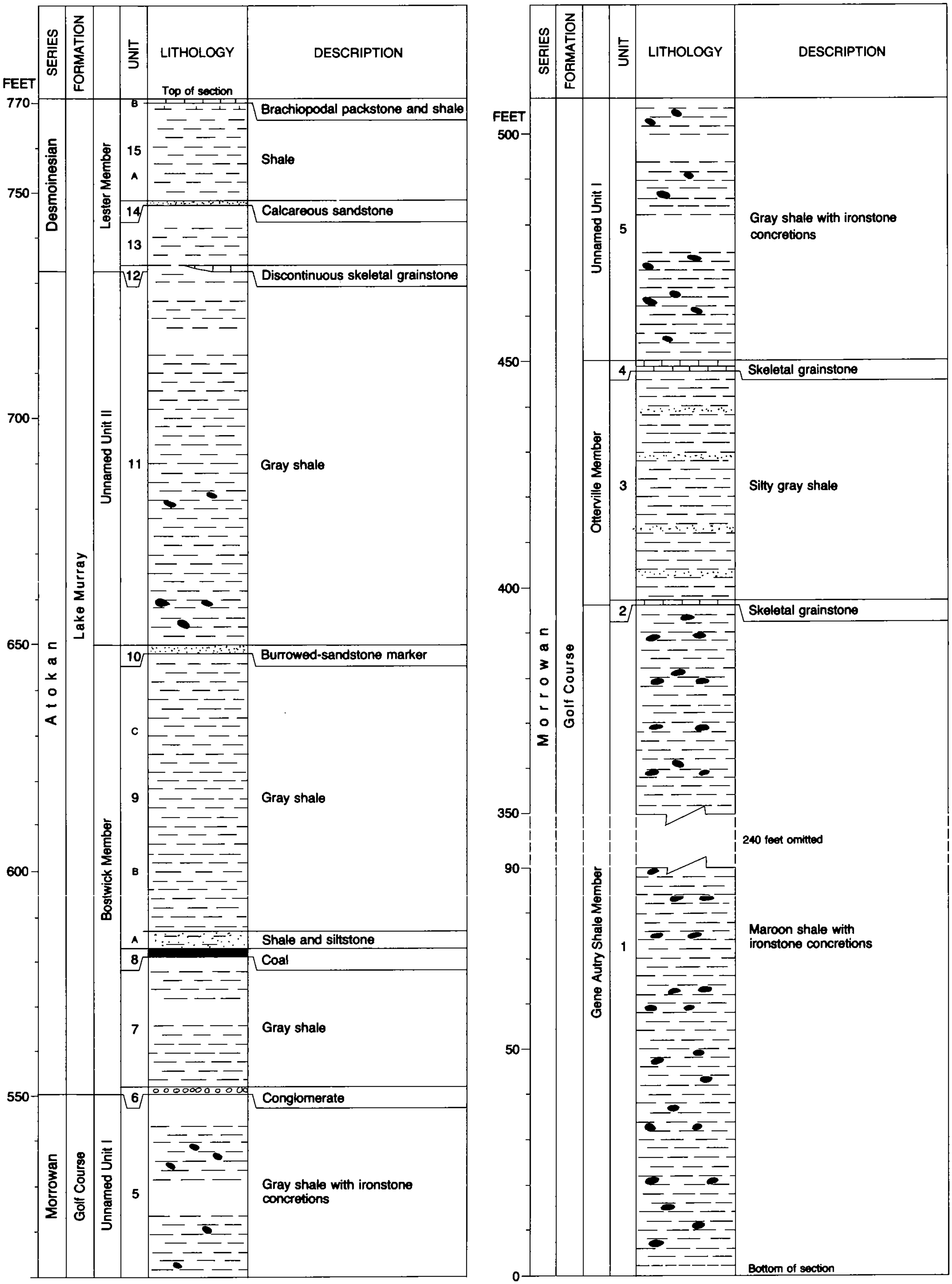

Figure 51. Graphic columnar section for Stop 7, Dutton Ranch. Stratigraphic unit 1 from map calculation; units 2–15 measured by S. H. Tennant.

Figure 52. Upper 400 feet of Gene Autry Shale (Morrowan), unit 1, which weathers maroon to red and commonly contains ironstone concretions. (Stop 7.)

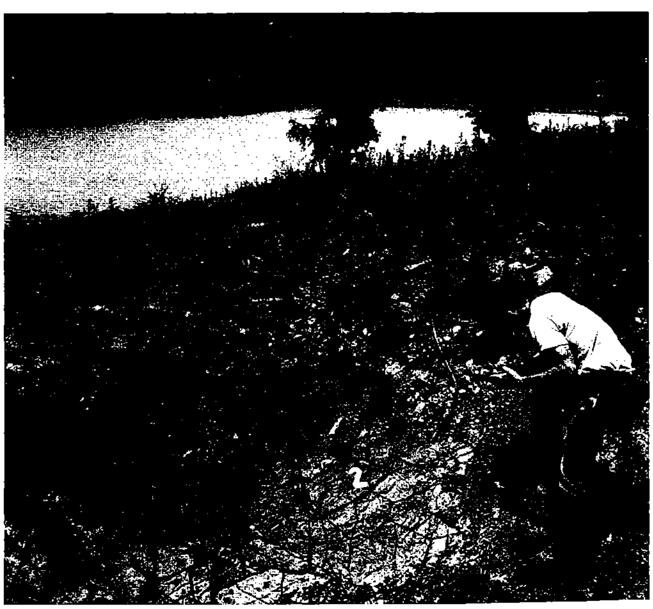

Figure 53. Thin, skeletal grainstone at base of Otterville Member, unit 2, of Golf Course Formation. (Stop 7.)

Figure 54. Skeletal packstone at top of Otterville Member, unit 4, of Golf Course Formation. (Stop 7.)

STOP 8—BUZZARD CREEK

Location: Beginning near east side of Highway 77 and continuing east for ¼ mile, across Buzzard Creek, to large pond, 7.2 miles north of Highway 70 in Ardmore. SW¼SW¼ sec. 19, T. 3 S., R. 2 E., Carter County, Oklahoma. (Measured section 346 of Tennant, 1981.)

Only the resistant limestone and sandstone units within the Otterville (Morrowan) and Bostwick Members (Atokan) of the Dornick Hills Group are exposed at the Buzzard Creek stop. These units are seen as a series of low hogbacks separated by covered intervals (fig. 55). The lowest Bostwick exposure is a discontinuous oolitic grainstone (unit 3) that crops out approximately ¼ mile north of the pond that lenses out to the south. The west side of this pond is bordered by a forested hogback formed by Bostwick sandstone (unit 7). This interval is a 12-foot-thick sequence of rippled and cross-bedded sandstone with thin shale interbeds (fig. 57). Samples collected from this unit contain limestone and ironstone granules and rare skeletal grains.

The first exposure is a prominent forested hogback formed by Otterville limestone on the east side of Highway 77. The Otterville Member is a medium- to thick-bedded, cross-bedded limestone sequence, which reaches a thickness of approximately 17 feet (fig. 56). The dominant rock type is a coarse, oolitic to coated skeletal grainstone. This is the thickest exposure of Otterville limestone in the northern part of the Ardmore Basin. Stratigraphically above the Otterville is a 200-foot-thick, unnamed covered interval (presumably shale).

The Bostwick Member (Atokan) consists of three limestone and sandstone outcrops separated by wide covered intervals. The Bostwick reaches a total thickness of approximately 140 feet at this locality.

Lower Pennsylvanian strata at Buzzard Creek (Stop 8), near the center of the Ardmore Basin, are distinctly different from the rocks exposed at the Dutton Ranch (Stop 7), in the northern part of the Ardmore Basin. In addition to lithologic changes throughout the section, the Lower Pennsylvanian interval is much thicker at Buzzard Creek than it is at the Dutton Ranch.

Figure 56. Oolitic, skeletal grainstone of Otterville Member (Morrowan), unit 1, of the Golf Course Formation. (Stop 8.)

Figure 57. Fine-grained, well-sorted sandstone interval in Bostwick Member (Atokan), unit 7, of Golf Course Formation. Unit forms distinctive forested ridge. (Stop 8.)

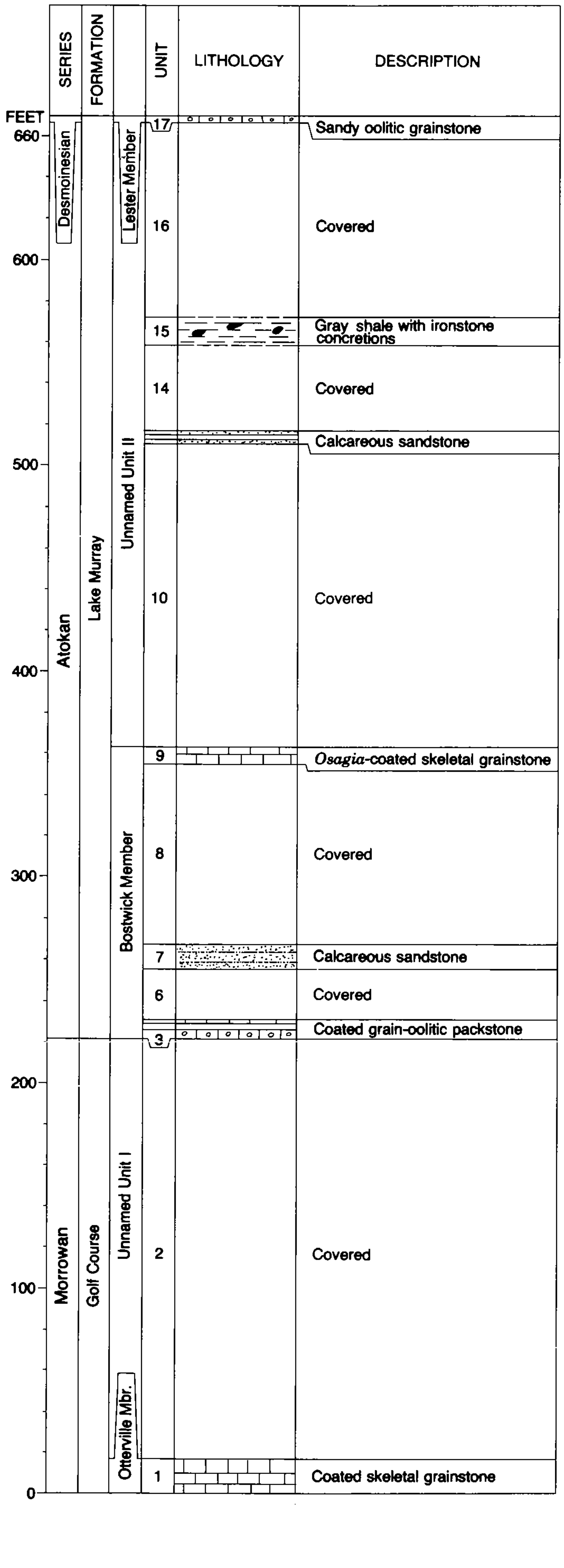

Figure 55. Graphic columnar section for Stop 8, Buzzard Creek. Section measured by S. H. Tennant (1981).

At the top of the Bostwick is an 8-foot limestone that crops out beside the road on the southeastern side of the pond (fig. 58). It is medium to thick bedded, cross-bedded, and is mainly a sandy skeletal grainstone with local concentrations of *Osagia*-coated grains and ooliths.

Stratigraphically above the Bostwick Member is an unnamed sequence of shale(?) containing thin, convolute sandstone beds that cannot be traced laterally. The base of the Desmoinesian Series begins with a thin-bedded, fine oolitic grainstone at the base of the Lester Member (unit 17), approximately 300 feet above the Bostwick Member. This outcrop is approximately ¼ mile southeast of the large pond, near a smaller pond.

Conodont samples from the Otterville (unit 1) and the Bostwick (units 3 and 9) are nondiagnostic (R. C. Grayson, Jr., oral communication, 1982). As at Dutton Ranch, Stop 7, the interval here termed "Bostwick Member" is almost totally different in facies from that found south of Ardmore.

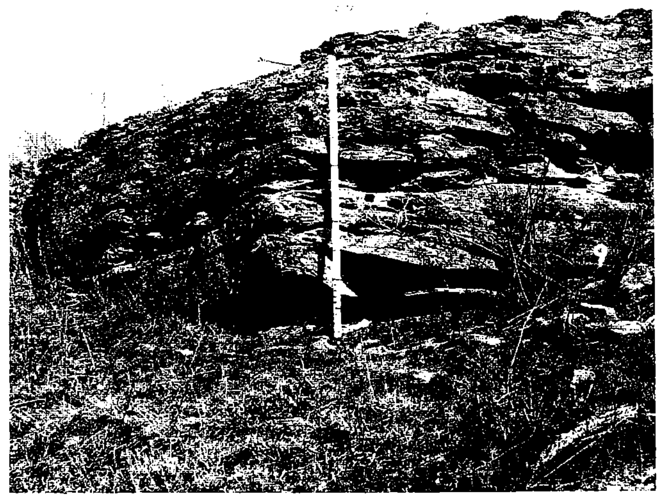

Figure 58. Oolitic, skeletal grainstones at top of Bostwick Member (Atokan), unit 9, of Golf Course Formation. (Stop 8.)

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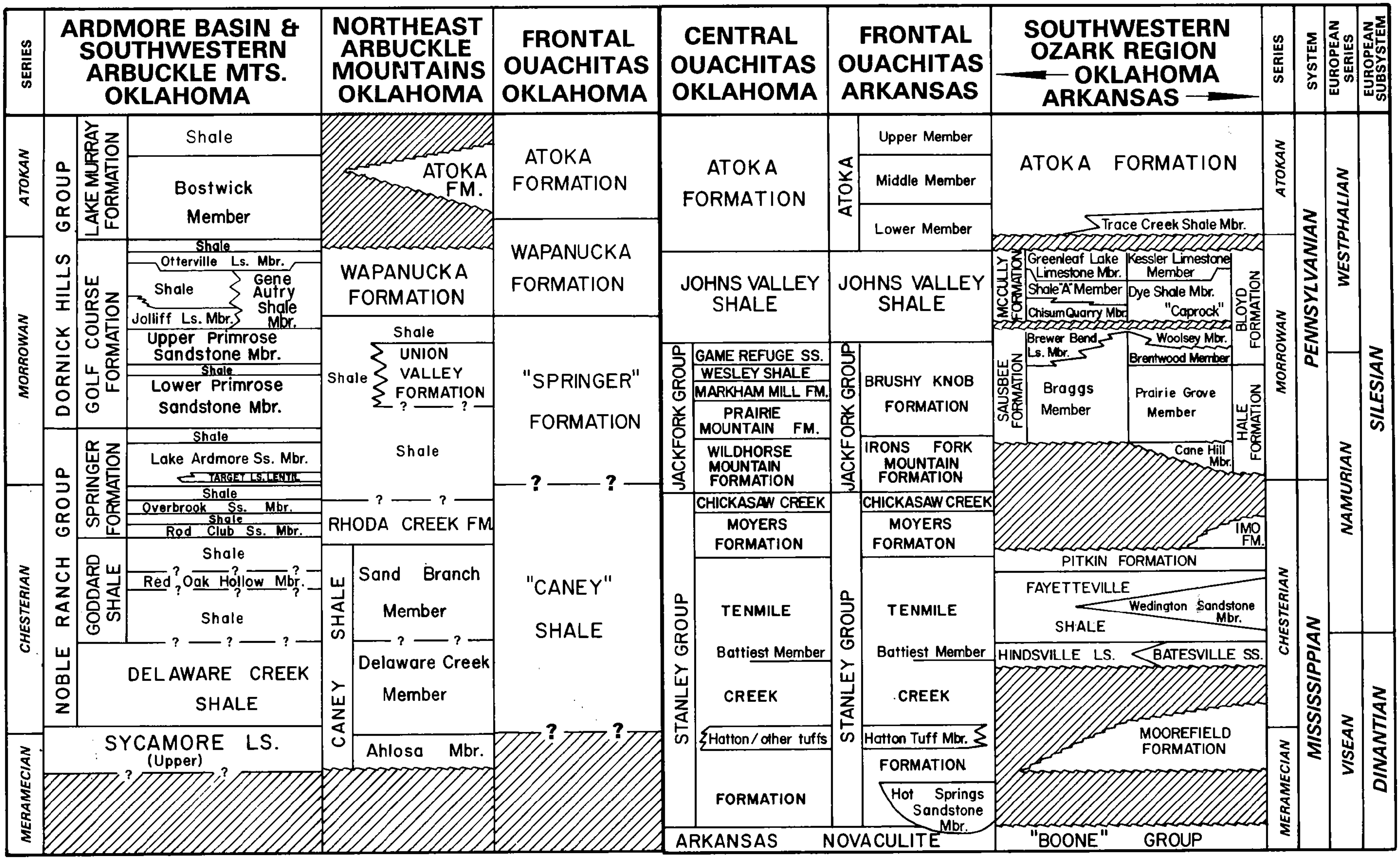
SERIES
ARDMORE BASIN & SOUTHWESTERN ARBUCKLE MTS. OKLAHOMA
NORTHEAST ARBUCKLE MOUNTAINS OKLAHOMA
FRONTAL OUACHITAS OKLAHOMA
CENTRAL OUACHITAS OKLAHOMA
FRONTAL OUACHITAS ARKANSAS
SOUTHWESTERN OZARK REGION ← OKLAHOMA ARKANSAS →
SERIES
SYSTEM
EUROPEAN SERIES
EUROPEAN SUBSYSTEM
ATOKAN
MORROWAN
CHESTERIAN
MERAMECIAN
DORNICK HILLS GROUP
NOBLE RANCH GROUP
LAKE MURRAY FORMATION
Shale
Bostwick Member
GOLF COURSE FORMATION
Shale
Otterville Ls. Mbr.
Shale
Gene Autry Shale Mbr.
Jolliff Ls. Mbr.
Upper Primrose Sandstone Mbr.
Shale
Lower Primrose Sandstone Mbr.
SPRINGER FORMATION
Shale
Lake Ardmore Ss. Mbr.
TARGET LS. LENTIL
Shale
Overbrook Ss. Mbr.
Shale
Rod Club Ss. Mbr.
GODDARD SHALE
Shale
Red Oak Hollow Mbr.
Shale
DELAWARE CREEK SHALE
SYCAMORE LS. (Upper)
ATOKA FM.
WAPANUCKA FORMATION
Shale
UNION VALLEY FORMATION
Shale
Shale
RHODA CREEK FM.
CANEY SHALE
Sand Branch Member
Delaware Creek Member
Ahlosa Mbr.
ATOKA FORMATION
WAPANUCKA FORMATION
"SPRINGER" FORMATION
"CANEY" SHALE
ATOKA FORMATION
JOHNS VALLEY SHALE
JACKFORK GROUP
GAME REFUGE SS.
WESLEY SHALE
MARKHAM MILL FM.
PRAIRIE MOUNTAIN FM.
WILDHORSE MOUNTAIN FORMATION
STANLEY GROUP
CHICKASAW CREEK
MOYERS FORMATION
TENMILE
Battiest Member
CREEK
Hatton / other tuffs
FORMATION
ARKANSAS NOVACULITE
ATOKA
Upper Member
Middle Member
Lower Member
JOHNS VALLEY SHALE
JACKFORK GROUP
BRUSHY KNOB FORMATION
IRONS FORK MOUNTAIN FORMATION
STANLEY GROUP
CHICKASAW CREEK
MOYERS FORMATON
TENMILE
Battiest Member
CREEK
Hatton Tuff Mbr.
FORMATION
Hot Springs Sandstone Mbr.
ATOKA FORMATION
Trace Creek Shale Mbr.
MCCULLY FORMATION
Greenleaf Lake Limestone Mbr.
Shale "A" Member
Chisum Quarry Mbr.
Kessler Limestone Member
Dye Shale Mbr.
"Caprock"
BLOYD FORMATION
Brewer Bend Ls. Mbr.
Woolsey Mbr.
Brentwood Member
SAUSBEE FORMATION
Braggs Member
Prairie Grove Member
HALE FORMATION
Cane Hill Mbr.
IMO FM.
PITKIN FORMATION
FAYETTEVILLE SHALE
Wedington Sandstone Mbr.
HINDSVILLE LS.
BATESVILLE SS.
MOOREFIELD FORMATION
"BOONE" GROUP
PENNSYLVANIAN
MISSISSIPPIAN
WESTPHALIAN
NAMURIAN
VISEAN
SILESIAN
DINANTIAN