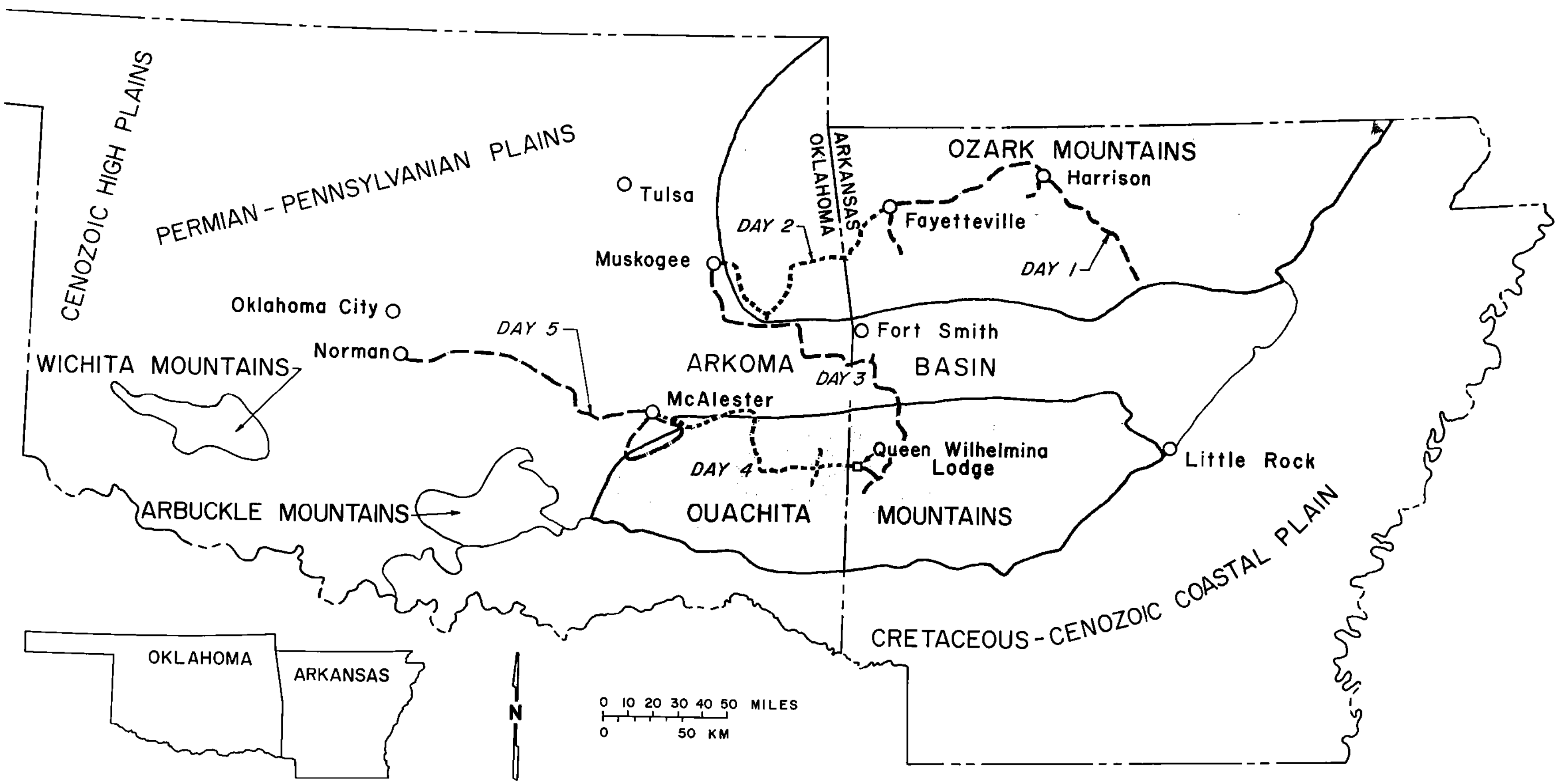
Ozark and Ouachita Shelf-to-Basin Transition Oklahoma-Arkansas

FIELD TRIP 11—Ninth International Congress of Carboniferous Stratigraphy and Geology



Locality and Route Map

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MISSISSIPPIAN-PENNSYLVANIAN SHELF-TO-BASIN TRANSITION OZARK AND OUACHITA REGIONS, OKLAHOMA AND ARKANSAS

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Front Cover

Photograph of sole markings on bottom surface of turbidite sandstone layer, lower Atoka Formation (Pennsylvanian), Stop 31, Windingstair Mountain, central Ouachita Mountains, Oklahoma.

Back Cover

Chart showing correlation of formations and members of Meramecian and Chesterian (Mississippian) and Morrowan and Atokan (Pennsylvanian) Series from the Ozark Shelf to the Ouachita Geosyncline, Oklahoma and Arkansas.

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PREFACE

This guidebook was prepared for Field Trip no. 11, which followed the Ninth International Congress of Carboniferous Stratigraphy and Geology, held in Urbana, Illinois, May 21-26, 1979. The field trip encompassed 5 days and emphasized an examination of the Chesterian through Atokan lithostratigraphy and biostratigraphy of the Ozark and Ouachita regions. Although these two areas have been the subject of numerous field trips in the past, the occasion of this trip represents the first attempt to document the details of the shelf-to-basin transition represented by the Carboniferous strata of this region. This guidebook is a complement to Guidebook 18 of the Oklahoma Geological Survey, edited by Sutherland and Manger, which described the Chesterian and Morrowan stratigraphy and biostratigraphy of the Ozark Shelf area.

Publication of this guidebook continues our association with William D. Rose, editor for the Oklahoma Geological Survey. He served as technical editor for this guidebook, and his care and diligence in its preparation are greatly appreciated. Drafting was done primarily by Roy D. Davis and Joseph M. Zovak of the Oklahoma Geological Survey staff. We wish also to thank Charles J. Mankin, director of the Oklahoma Geological Survey, for his willingness to publish this guidebook and for his continued encouragement of our studies of Carboniferous stratigraphy.

Patrick K. Sutherland
Walter L. Manger
March 22, 1979

CONTENTS

COMPARISON OF OZARK SHELF AND OUACHITA BASIN FACIES FOR UPPER MISSISSIPPIAN AND LOWER PENNSYLVANIAN SERIES IN EASTERN OKLAHOMA AND WESTERN ARKANSAS

Patrick K. Sutherland
Walter L. Manger

INTRODUCTION

Strata of Late Mississippian (Chesterian) and Early Pennsylvanian (Morrowan and Atokan) ages crop out extensively on the southwestern and southern flanks of the Ozark Dome, in northeastern Oklahoma and northwestern Arkansas, and in the Ouachita Mountains of southeastern Oklahoma and southwestern Arkansas (fig. 1). There are marked differences in the lithologic character, thickness, and depositional pattern of equivalent units between these two general areas.

OZARK REGION

Introduction

Upper Mississippian and Lower Pennsylvanian strata in the Ozark region of northeastern Oklahoma and northwestern Arkansas are dominated by shallow-water carbonate-platform facies, including shales, separated by numerous unconformities (fig. 2). The sequence is thin when compared to the clastic, geosynclinal facies that crop out in the Ouachita Mountains, 50 to 60 miles to the south (fig. 3). The maximum outcrop thicknesses recorded for Chesterian (Upper Mississippian) formations in the southwestern Ozark region total about 1,200 feet, but the total preserved thickness for Chesterian strata in the outcrop belt nowhere exceeds 600 feet. The maximum recorded outcrop thickness for the Lower Pennsylvanian Morrowan Series in its primary type area of Washington County, Arkansas, is about 320 feet (excluding the Trace Creek Shale). Morrowan strata increase in thickness eastward across northern Arkansas and southward into the Arkoma Basin. The Atokan Series caps the Boston Mountains of northern Arkansas. Thicknesses of the Atoka Formation range from a few feet along its northern limit to more than 10,000 feet in the Arkoma Basin. The Atokan Series is about 600 feet thick in Muskogee County, Oklahoma, where it is in sequence with overlying Desmoinesian strata. The thickness of the Atokan Series in Oklahoma also increases markedly southward into the subsurface of the Arkoma Basin.

Unconformities punctuate the middle Carboniferous geologic record of the Ozark region, and major breaks divide the section into easily considered intervals. Important unconformities include: (1) base of Chesterian Series, (2) Mississippian-Pennsylvanian boundary, (3) mid-Morrowan Series, and (4) Morrowan-Atokan boundary. Each of these unconformities is a regional truncating surface that results in variable stratigraphic units bounding that surface.

The base of the Chesterian section is a widespread unconformity most commonly developed on Osagean strata but in some places involving Meramecian beds (fig. 2). The Upper Mississippian Pitkin Formation is truncated northward by pre-Pennsylvanian erosion and is absent in Arkansas north of T. 16 N. and in Oklahoma north of T. 18 N. The unconformity

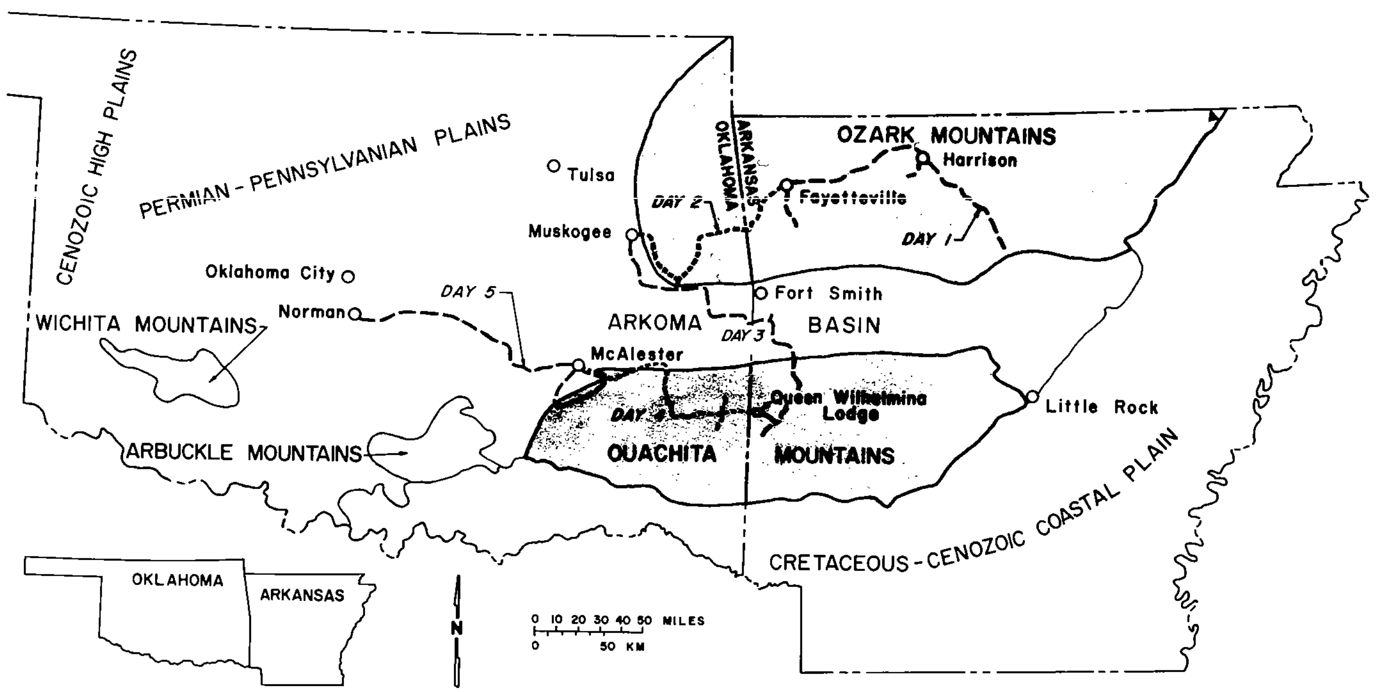


Figure 1. Index map of Oklahoma and Arkansas, showing field-trip route.

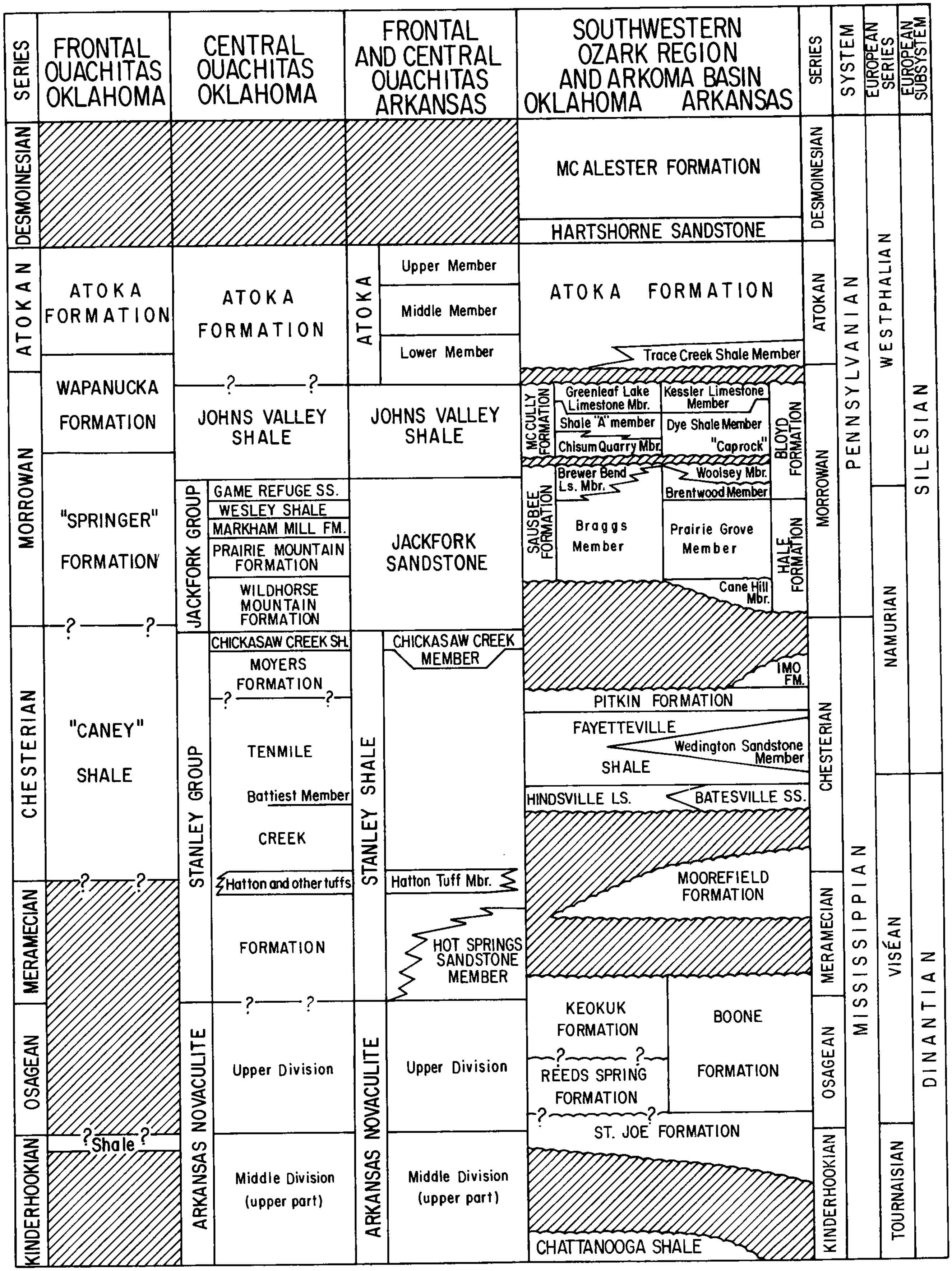


Figure 2. Correlation chart of Mississippian and Pennsylvanian formations, Ouachita and Ozark regions, Oklahoma and Arkansas.

within the Bloyd Formation (base of Dye Shale Member) and its equivalents in Arkansas, and between the Sausbee and McCully Formations in Oklahoma, provides an important datum for correlation of this interval across the Ozark region. The Morrowan Series is truncated by pre-Atokan erosion in T. 20 N. in Oklahoma. In T. 22 N., in Oklahoma, Desmoinesian strata overlap the Atoka Formation and rest directly upon the eroded surface of the Chesterian Fayetteville Formation.

Kinderhookian, Osagean and Meramecian Series

The Chattanooga Shale is typically 30 to 70 feet thick but is locally much thinner. It is mostly Late Devonian in age but may be as young as Early Mississippian (Kinderhookian) in Oklahoma. It correlates with the Woodford Shale in southern Oklahoma (Hass, 1956).

The Chattanooga is overlain unconformably by the "Boone

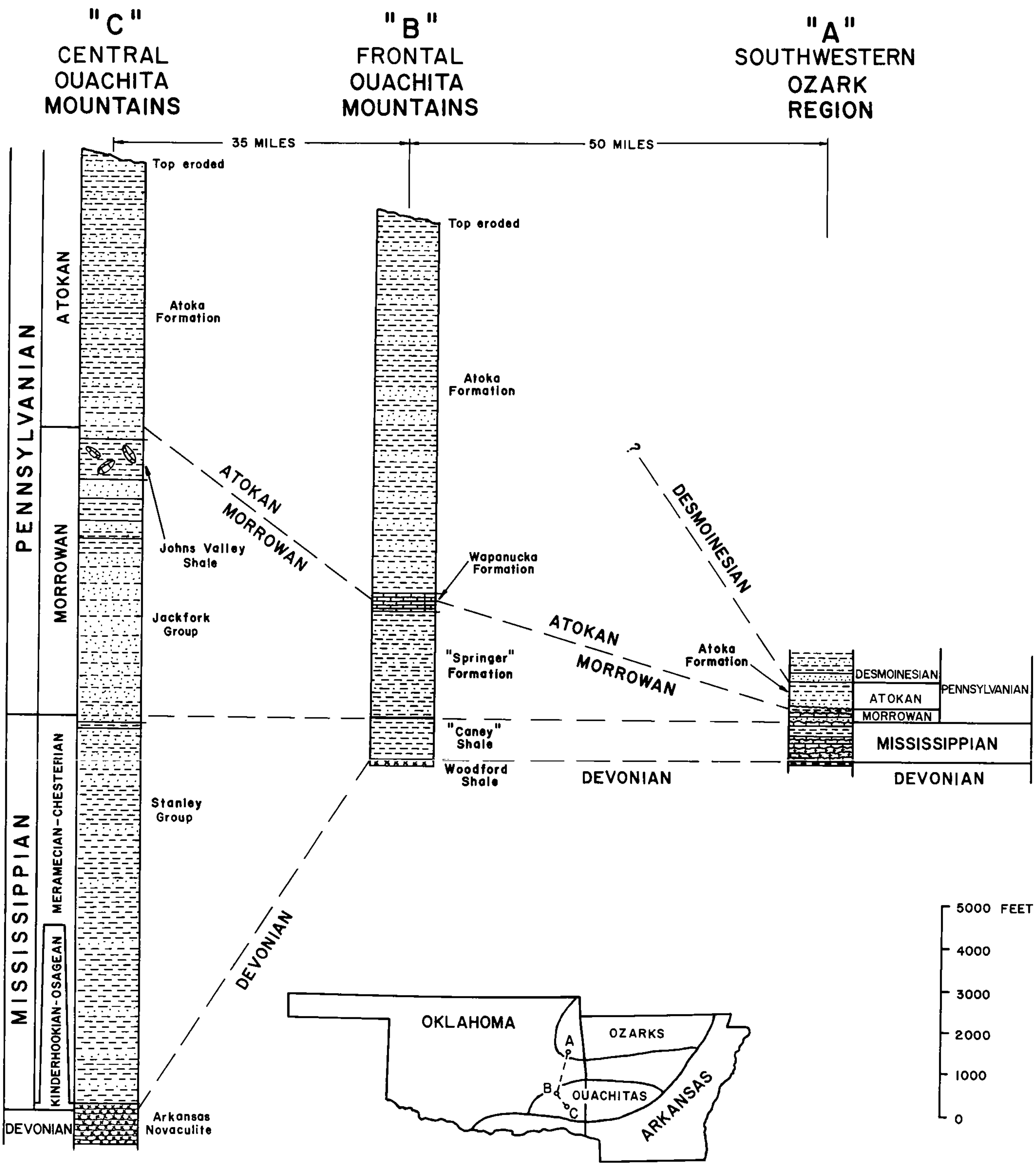


Figure 3. Cross section of Mississippian and Pennsylvanian strata, Ouachita Mountains to Ozark region, Oklahoma.

Group," which consists of chert and limestone. This group ranges in age from middle Kinderhookian to early Meramecian but is predominantly Osagean. The maximum recorded thickness for this interval is about 400 feet, but it is locally variable in thickness because of an unconformity at its top. There are some differences in nomenclature between Arkansas and Oklahoma. In both areas the comparatively thin, noncherty sequence of limestone at the base of the "Boone" succession is separated as a formation termed the St. Joe Limestone, which exhibits thicknesses commonly ranging from 20 to 45 feet. In Arkansas, the highly distinctive overlying cherts and limestones are currently termed the Boone Formation (Manger and Shanks, 1976). In Oklahoma, the "Boone" is utilized as an informal group, and this interval is subdivided into the Reeds Spring and Keokuk Formations. Huffman (1958) recorded unconformities in Oklahoma separating the St. Joe, Reeds Spring, and Keokuk.

The Keokuk, or upper "Boone," is particularly distinctive lithologically, consisting of white- to buff-weathering chert that forms distinctive fractured rubble surfaces in both Arkansas and Oklahoma. It contains abundant fossils, mostly in the form of molds and casts. The top of the "Boone Group" is an unconformity overlain by the Moorefield Formation, the Hindsville Limestone, and, locally, the Fayetteville Shale. The "Boone" is locally missing in the southern part of the Ozark outcrop area in Oklahoma, where the Moorefield Formation rests directly on the Chattanooga Shale.

The Moorefield Formation, where present, rests unconformably on the "Boone" and is about half Meramecian in age and half Chesterian. This formation consists mostly of dark-gray shale in its type region, northern Independence County, north-central Arkansas. The Moorefield is absent in most of northwestern Arkansas, but westward in Oklahoma argillaceous limestones and a variety of other facies, including oolitic and pelmatozoan grainstone and calcareous siltstone, are referred to the Moorefield Formation. The type Moorefield is 325 feet thick in north-central Arkansas but is thinner and generally absent in western Arkansas. It reaches a maximum thickness of about 100 feet in Oklahoma but is missing over large areas where the Hindsville rests directly on the "Boone."

Chesterian Series

The middle part of the Moorefield Formation contains a basal Chesterian ammonoid assemblage that is approximately equivalent to the base of the upper Viséan P_1c Subzone of the western European Carboniferous section (Saunders and others, 1977). The upper Moorefield and the overlying Hindsville Limestone-Batesville Sandstone interval are roughly equivalent to the European P_2 Zone (Saunders and others, 1977).

The Hindsville Limestone, Fayetteville Shale, Pitkin Limestone, and Imo Formation, all of Chesterian age, form an essentially continuous depositional sequence in the Ozark region. The Hindsville (Stop 4) is a fossiliferous oolitic limestone that rests unconformably on the Moorefield Formation or on the "Boone." It has a maximum thickness of 50 feet but averages 25 to 35. In northern Arkansas, the Hindsville is a lateral facies and intertongues with the Batesville Sandstone, a prograding sand body that reaches a thickness of 225 feet near Batesville, Arkansas.

The Hindsville-Batesville units are overlain conformably by the Fayetteville Shale (Stops 2, 10, 16). The Fayetteville consists predominantly of black or gray-green shale, but it is interbedded locally, near the base or near the top, with dark beds or nodular layers of carbonate mudstone (Stops 2 and 16). The formation reaches a maximum thickness in Oklahoma of about 165 feet but is nearly 400 feet thick in Arkansas. The deltaic Wedington Sandstone Member occurs in the upper-middle part of the Fayetteville Shale in the western part of the Arkansas outcrop area. It has a maximum thickness of about 80 feet in surface exposures but is generally much thinner.

In some areas a P_2 fauna found typically in the Hindsville-Batesville interval extends into the lower few feet of the Fayetteville Formation and is succeeded by an E_1 fauna. Thus, the Viséan-Namurian boundary correlates with some horizon in the lower part of the Fayetteville Shale (Saunders and others, 1977). The middle and upper part of the Fayetteville is only sparsely fossiliferous but is correlated with the basal Namurian E_1 Zone of western Europe.

The Pitkin Limestone (Stops 2, 5, 6, 16) conformably overlies the Fayetteville Shale and shows marked local variations in facies, ranging from cross-bedded oolites to skeletal grainstones to dark carbonate mudstones. The formation reaches a maximum thickness in Oklahoma of about 60 feet, and it is about 50 feet thick in its type area in Washington County, Arkansas. The formation thickens eastward, and Gordon (1965) reported a thickness in Stone County, Arkansas, of 400 feet.

The lower part of the Pitkin carries an ammonoid fauna similar to the underlying Fayetteville and is thought to correlate with the E_1 Zone of western Europe (Saunders and others, 1977). The upper part of the Pitkin, in the thickened area of outcrop, in Searcy County, Arkansas, contains the *Eumorphoceras bisulcatum-Cravenoceras richardsonianum* ammonid zone, which represents an important and well-established biostratigraphic reference (Saunders and others, 1977). It appears to be equivalent to the Grove Church Shale, the youngest interval in the type Chesterian of Illinois, and to the Namurian E_2a Zone in western Europe, based on conodonts (Lane, 1977) and ammonoids (Saunders and others, 1977).

Throughout most of Arkansas and Oklahoma the Pitkin is the highest occurring Mississippian unit and is unconformably overlain by Lower Pennsylvanian strata. However, in a small area in Searcy and Van Buren Counties, Arkansas, 95 miles east of Fayetteville, the Imo Formation (Stop 1) of latest Chesterian age rests conformably on the Pitkin Formation. It consists of interbedded concretionary shales, thin sandstones, and limestones, totaling about 160 feet in thickness. The unit carries a diverse molluscan fauna dominated by ammonoids. This unit was named the *Eumorphoceras richardsoni-Fayettevillea friscoense* Zone by Saunders (1973), and it has been correlated with the E_2b-c Zones in western Europe.

Mississippian-Pennsylvanian Unconformity

The Chesterian sequence is partly truncated northward in both Arkansas and Oklahoma by the unconformity at the base of the Pennsylvanian. Pennsylvanian strata rest on either the Imo (Stop 1), the Pitkin (Stops 5, 6, 10, 16), the Fayetteville (Stops 8, 12), or, locally, the Hindsville. The post-Mississippian unconformity in northeastern Oklahoma has a regional relief of up to 80 feet (Sutherland and Henry, 1977b), and the base of the Morrowan is generally marked by a thin basal conglomerate (Stop 8).

The least datable gap at the Mississippian-Pennsylvanian boundary in northern Arkansas appears to represent the H_1 and H_2 stages of western Europe. This conclusion is suggested by the presumption that the Imo E_2b-c ammonoid assemblages are overlain by basal R_1a assemblages of the Cane Hill Member, Hale Formation. However, this relationship has not been demonstrated, and where the Cane Hill yields ammonoids it rests on the older Pitkin Limestone.

Morrowan Series

The lower part of the Morrowan Series in both Arkansas and Oklahoma is generally marked by the occurrence of sandstones and shales that contrast markedly in character with the underlying nonsandy limestones of the Upper Mississippian. The Morrowan Series in Arkansas is, in fact, dominated by shales and secondarily by sandstones, with only two well-developed limestone intervals (Brentwood and Kessler Members). Regionally there is a decrease in sand content in the Morrowan westward into Oklahoma, where the series is dominated by clean limestones (Stops 14, 15), with sandstones occurring only at the base.

In northwestern Arkansas the Morrowan Series is subdivided into the Hale and Bloyd Formations (ascending) on the basis of the cliff-forming nature and mappability of the upper member of the Hale. The section at Evansville Mountain (Stop 9), near the Arkansas-Oklahoma border, was recognized by Henbest (1962a) as the most important reference section for the Morrowan Series in the area. The thickness for the Morrowan at Evansville Mountain is 270 feet (excluding the Trace Creek Shale at the top).

The Hale Formation, 136 feet thick at Evansville Mountain, is subdivided into the Cane Hill and overlying Prairie Grove Members. The Cane Hill typically consists of dark-gray silty shale interlaminated with thin-bedded fine-grained sandstone. The Prairie Grove includes irregularly alternating calcareous sandstone and sandy oolitic and skeletal grainstone.

The Bloyd Formation, which conformably overlies the Hale, is 134 feet thick at Evansville Mountain (excluding the Trace Creek Shale at the top). The Bloyd is subdivided into the Brentwood Limestone, Woolsey, Dye Shale and Kessler Limestone Members. A regional disconformity occurs at the base of the Dye Shale.

The Trace Creek Shale (Stop 9C), traditionally included as the highest member of the Bloyd Formation (Henbest, 1962b), was reassigned to the Atoka Formation by Sutherland and Grayson (1978). They discovered that the Trace Creek in Washington County, Arkansas, is a lateral facies, westward in Oklahoma, of the lower part of the overlying Atoka Formation and that it is separated from the underlying Kessler Limestone by a regionally significant disconformity. This disconformity is marked by the nonoccurrence of some part of two conodont zones, both thought to be of late Morrowan age, based on a comparison of the Ozark section with apparently more continuous sequences in the frontal Ouachitas (see section on Frontal Ouachita Mountains—Oklahoma).

Eastward across northern Arkansas, the Hale and Bloyd Formations thicken and develop a more nonmarine aspect. The Cane Hill Member becomes dominated by increasingly thicker sandstone intervals and is raised to formation rank. The Prairie Grove Member and the overlying Bloyd Formation also develop more pronounced sandstone sequences and are combined as the Witts Springs Formation (Glick and others, 1964). The most dramatic facies change within the Morrowan succession in this area is shown by lateral equivalents of the Woolsey and basal Dye Members of the Bloyd. This interval increases from approximately 50 feet of shale, coal, and thin sandstone to more than 100 feet of massive cross-bedded, pebble-bearing sandstone deposited as a braided stream, finally transgressed by marine deposits (Zachry, 1977) (Stop 3).

The Morrowan strata abruptly change facies westward from Washington County, Arkansas, into Oklahoma. The terms Hale and Bloyd can be employed only in Adair County, Oklahoma. Farther west the lithologic distinction is lost, as there is an increase in the percentage of shale in the upper part of the Hale Formation, an overall marked westward increase in the percentage of limestones, and a corresponding decrease in the percentage of sandstones. Sutherland and Henry (1977a) subdivided this carbonate facies into the Sausbee and McCully Formations (Stops 14 and 15) on the basis of a regional disconformity at the top of the Sausbee. This break coincides in Washington County, Arkansas, with a regional disconformity at the base of the Dye Shale Member of the Bloyd Formation. The Sausbee Formation consists typically of skeletal grainstones interbedded with shale (Braggs Member), overlain by algal wackestones and mudstones (Brewer Bend Limestone Member). The formation reaches a maximum thickness of 200 feet. The Sausbee correlates eastward with the Hale Formation plus the Brentwood and Woolsey Members of the Bloyd Formation. The overlying McCully Formation is composed of interbedded limestones and shales and reaches a maximum recorded thickness of 75 feet. That formation includes the Chisum Quarry, shale "A," and Greenleaf Lake Limestone Members, and it correlates with the Dye Shale and Kessler Limestone Members of the Bloyd in Arkansas.

It appears likely that the thin shale "B" member, described by Sutherland and Henry (1977a) as occurring at the top of the McCully, is a part of the overlying Atoka Formation and should no longer be considered a separate member. Its use should be discontinued.

Seven assemblages of ammonoids, based on collections of thousands of specimens, have been reported from the Hale and Bloyd Formations in northwestern Arkansas (Saunders and others, 1977). In terms of the standard European succession, the lowest part of the Hale Formation contains a basal R_1a assemblage, succeeded by R_1, R_2, and G_1 equivalents. The lower part of the Brentwood Limestone Member of the Bloyd Formation is also G_1 in age and represents the top of the Namurian in the Arkansas-Oklahoma sequence. The middle and upper parts of the Brentwood contain a distinct ammonoid fauna characterized by *Branneroceras.* The assemblage is also found in abundance in the upper part of the Braggs Member and the overlying Brewer Bend Limestone Member of the Sausbee Formation in Oklahoma. This fauna is of lower G_2, Westphalian A, age.

The Dye Shale and Kessler Limestone Members of the Bloyd Formation in Arkansas and the McCully Formation in Oklahoma are characterized by occurrences of *Axinolobus,* suggesting a Westphalian A (G_2 Zone) correlation.

The Morrowan Series in the southwestern Ozark region has been zoned on the basis of conodonts by Lane (1967, 1977). He recognized eight zones for the Morrowan of this area, including the Trace Creek Shale. As stated earlier, Sutherland and Grayson (1978) proposed the exclusion of the Trace Creek Shale from the Morrowan, and Grayson (this report, introduction to fifth day) has recorded a gap of two conodont zones at the Kessler-Trace Creek contact in the Ozark region, when a comparison is made with the sequence of conodont faunas found in the Wapanucka Formation in the frontal Ouachita Mountains (see Frontal Ouachita Mountains—Oklahoma).

Atokan Series

Rocks of the Atokan Series, which include in the Ozark region only the Atoka Formation, crop out in a wide belt along the south and west flanks of the Ozark Dome in northwestern Arkansas and northeastern Oklahoma. The Atoka consists of interbedded thick shales and thinner sandstones with a few thin, discontinuous impure limestones. Wilson (1935) gave member names to six of the ridge-forming sandstones in Muskogee County, Oklahoma, but Blythe (1959) was unable to differentiate most of these members in areas directly north of Muskogee County. The Atoka Formation is about 600 feet thick in that county.

The Atoka Formation is truncated northward in Oklahoma, in T. 23 N., R. 19 E., by a regional unconformity at the base of the overlying McAlester Formation.

Sutherland and others (1978) recorded the occurrence of physical evidence for a regional disconformity at the base of the Trace Creek Shale (previously included in the Morrowan Series) in Washington County, Arkansas, and Adair County, Oklahoma. They also reported that the Trace Creek Shale in that area (Stop 9) is a facies of the lower part of the Atoka Formation exposed farther west in Oklahoma (Stop 11), where the base of the Atoka Formation becomes a regionally truncating unconformity. That the disconformity at the base of the Trace Creek represents a significant time break is supported by the absence of two conodont zones at this horizon and the occurrence in the Trace Creek of the Atokan *Streptognathodus elegantulus* conodont zone (Grayson, this report, introduction to fifth day).

Desmoinesian Series

Southward into the Arkoma Basin, the marine beds of the upper Atoka Formation are succeeded conformably by a complex of distributary-channel and outer-fringe deltaic sandstones referred to the Hartshorne Sandstone (Stops 18, 19). The Atoka-Hartshorne contact marks the Atokan-Desmoinesian boundary in Oklahoma and Arkansas (fig. 2). The Hartshorne approaches 300 feet in thickness and is conformably overlain by the McAlester Formation (Stops 18, 19). The McAlester is a thick (up to 2,500 feet) sequence of siltstone and shale interrupted by thinner sandstone intervals. Many of these sandstone and shale units are given member names, but the repetition of similar lithologies makes regional differentiation impractical. Two workable coal beds (lower and upper Hartshorne coals) are present near the base of the McAlester, and other thinner coals occur sporadically through the formation. The McAlester Formation represents probable overbank and associated delta-plain deposits. The Hartshorne and McAlester Formations are included with the Savanna and Boggy Formations as the Krebs Group. Strata of this group are confined to the Arkoma Basin in Arkansas and extend from the western portion of the Arkoma Basin in Oklahoma (=McAlester Basin) northeastward into Kansas.

FRONTAL OUACHITA MOUNTAINS—OKLAHOMA

Introduction

The facies described here, characterized particularly by the occurrence of the Wapanucka Formation (figs. 2, 3), crop out only in the frontal part of the Ouachita Mountains in southeastern Oklahoma. These facies represent both outer-shelf and slope environments, and they differ distinctly from both the shallow-shelf facies of the southwestern Ozark region and the basinal-plain, turbidite facies that characterize outcrops in the central Ouachitas in Oklahoma (fig. 3). The frontal Ouachitas in Arkansas also expose the deep-water-turbidite facies typical of the central Ouachitas in Oklahoma.

Describing and interpreting Carboniferous strata in the frontal Ouachitas of Oklahoma is complicated by both faulting and lateral facies changes from one fault block to another. It should be pointed out that the column in figure 2 labeled "Frontal Ouachitas—Oklahoma" is a composite section for the several fault blocks that all lie north of the Ti Valley Fault (fig. 4). Those blocks that lie directly south of the Choctaw Fault, which is the leading edge of the frontal Ouachitas, expose (in ascending order) the "Caney" Shale, "Springer" Formation, Wapanucka Formation, and Atoka Formation. The block south of the Pine Mountain Fault, which is directly north of the Ti Valley Fault, exposes the Woodford Shale (Devonian), "Caney," "Springer," and Atoka.

Kinderhookian Series

Rocks of Kinderhookian age have been reported only from a single locality in the frontal Ouachitas. Hass and Huddle (1965) recovered conodonts of this age from the basal 0.5 foot of shale that directly overlies the Woodford Shale at a locality near Pine Top School in Pittsburg County, Oklahoma, between the Pine Mountain and Ti Valley Faults. No rocks of Meramecian age appear to be present in this region.

Chesterian Series

The "Caney" Shale of Chesterian age reaches a maximum thickness in the frontal Ouachita Mountains of possibly 900 feet, but in the frontal block directly south of the Choctaw Fault only the upper 50 feet or so is exposed. Farther south, in the fault block that lies between the Pine Mountain and Ti Valley Faults, the "Caney" Shale rests directly on the Woodford Shale (Devonian).

The term "Caney" is inappropriate as a permanent name for the unit it is intended to represent, since the type locality for the "Caney" is apparently a large erratic shale mass in the Johns Valley Shale of the central Ouachitas of Oklahoma (Ulrich, 1927). No alternate name is readily available, however, since the interval in question in the frontal Ouachitas is almost invariably covered; it has not been and probably cannot be studied in detail either lithologically or faunally. The Chesterian age assignment (fig. 2) is based on several occurrences in isolated exposures of goniatites and microfossils. Hart (1974, sheet 1) used the term Delaware Creek Shale for this interval, which was borrowed from the Arbuckle Mountain terminology.

Morrowan Series

Overlying the "Caney" Shale is the "Springer" Formation, which consists mostly of shale. The Springer contains, at a few localities, goniatites of Morrowan age that correlate with the Hale Formation and the Brentwood Limestone Member of the Bloyd Formation in northwestern Arkansas (Gordon and Stone, 1977). Hendricks and others (1947) stated that the "Springer" apparently rests conformably on the "Caney" but that both units are poorly exposed. The Mississippian-Pennsylvanian boundary has not, in fact, been established precisely within the frontal Ouachita outcrop belt. Hendricks and others (1947) reported a thickness of up to 2,500 feet for the "Springer" in the fault block directly southeast of the Choctaw Fault. The Arbuckle Mountains term "Goddard" was used by Hart (1974, sheet 1) in the Ouachita Mountains for the interval here termed "Springer." The "Springer" interval in the Ouachita Mountains has, however, not been studied in detail either lithostratigraphically or biostratigraphically, primarily because of its extremely poor exposures. Its detailed correlation with the Arbuckle Mountains sequence is as yet uncertain.

The Wapanucka Formation overlies the "Springer" in the frontal Ouachita Mountains. This interval has recently been studied in detail for the first time by Grayson (1978; this report, Stops 36-40). Directly south of the Choctaw Fault the Wapanucka is well exposed at many localities along Limestone Ridge. It consists of interbedded spiculiferous packstones, carbonate mudstones, pelmatozoan and oolitic grainstones, and shales (Stops 36, 38, 39) and is typically about 300 feet thick. Basinward (southward), successive fault blocks, still well north of the Ti Valley Fault, show a more poorly exposed, primarily slope facies of the Wapanucka Formation, which has been referred to the Chickachoc Chert Member (fig. 112). The typical lithologies of this unit are thick shales and interbedded dark-gray to black spiculites, with a few thin spiculiferous limestones. On the Indian Nation Turnpike a sequence measured on one of these ridges has a thickness of 714 feet (Sutherland and Grayson, 1977; this report, fig. 112). Conodonts have been recovered from this facies, and they make possible a correlation with the limestone facies of the frontal ridge, exposed a mile or so to the north.

Grayson (this report, introduction to fifth day) recognizes four conodont zones in the Wapanucka Formation (fig. 105). The lowest, the *Idiognathoides convexus* Zone, indicates equivalence of the lower part of the Wapanucka Formation to the Kessler Limestone Member of the type Morrowan Series in the Ozark region. The succeeding *Neognathodus kanumai-Idiognathoides ouachitensis* Zone and the *Diplognathodus orphanus* Zone are new zones represented by an erosional gap between the Kessler and overlying Trace Creek Shale in northwestern Arkansas. The *Streptognathodus elegantulus* Zone occurs in the uppermost part of the Wapanucka Formation in the frontal Ouachitas, and its occurrence is thought to indicate an earliest Atokan age. It occurs also in the Trace Creek Shale Member of the Atoka Formation in northwestern Arkansas and northeastern Oklahoma (Sutherland and Grayson, 1978).

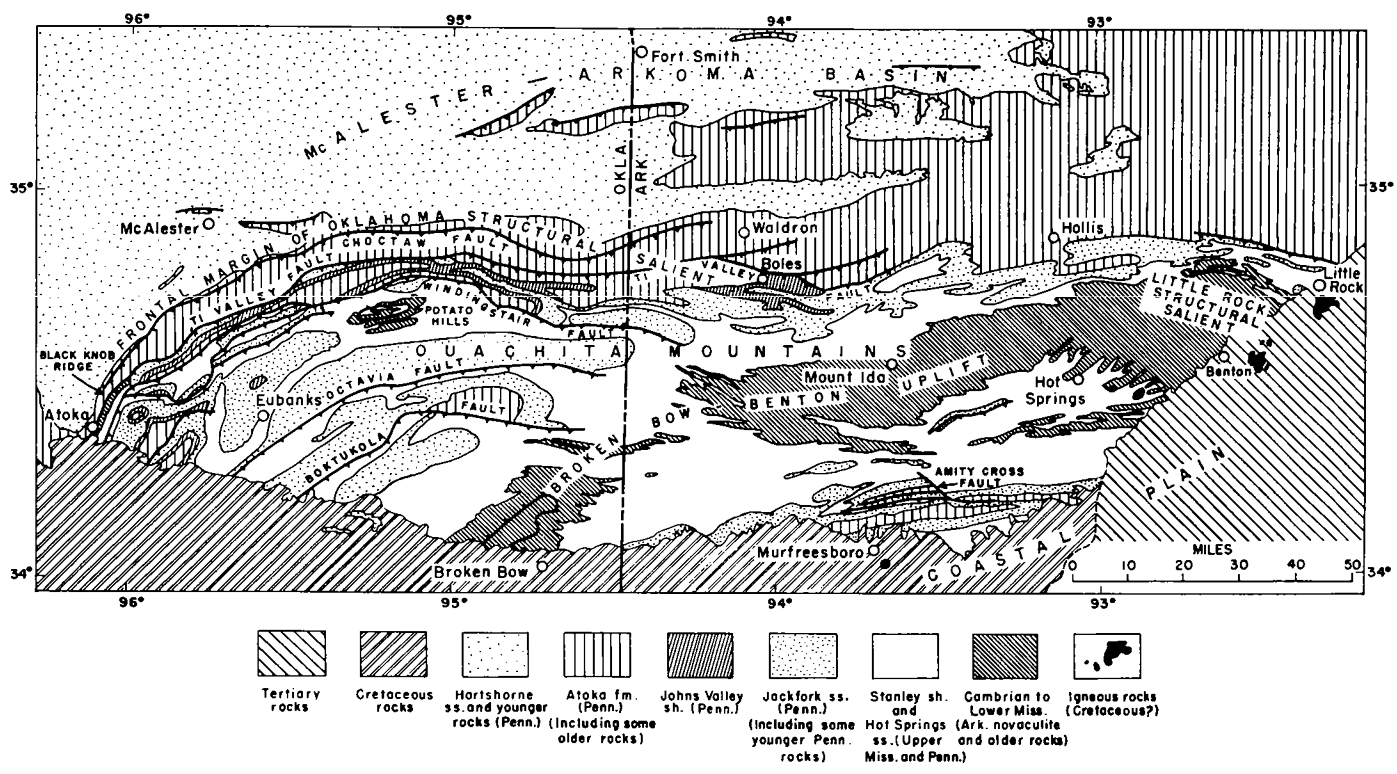


Figure 4. Geologic map of Ouachita Mountains (modified from Miser, 1959, fig. 3).

Atokan Series

The uppermost parts of the Wapanucka Formation in the frontal Ouachita Mountains are Atokan in age, based on conodonts (Grayson, this report, introduction to fifth day), and these units are overlain conformably in the frontal Ouachitas by the Atoka Formation. In this area the Atoka consists mostly of gray silty micaceous shale containing a few beds of medium-grained sandstone. The Atoka is poorly exposed, and only the lower part is preserved in the frontal Ouachitas, where Hendricks and others (1947) estimated the maximum thickness preserved to be possibly 9,000 feet.

The middle part of the Atoka Formation thickens markedly to the south across the Arkoma Basin because of the effect on deposition of down-to-the-southeast growth faults that were active in the Arkoma Basin area during the deposition of this interval (fig. 5).

CENTRAL OUACHITA MOUNTAINS—OKLAHOMA FRONTAL AND CENTRAL OUACHITAS—ARKANSAS

Introduction

Upper Mississippian and Lower Pennsylvanian strata in the central Ouachita Mountains in Oklahoma and in the Ouachita Mountains in Arkansas consist of thick deep-water flysch and associated facies. The interval is subdivided into the Stanley-Jackfork-Johns Valley-Atoka units and reaches an estimated maximum composite thickness of about 38,000 feet (Gordon and Stone, 1977, table 9). Briggs (1974) estimated the depositional thickness to be greater than 25,000 feet. The primary environment is that of a geosynclinal trough paralleling the cratonic margin in which the primary paleocurrent direction of flow was parallel to the basin axis (westward) (see following section on Depositional History).

Indigenous fossils are extremely rare in the flysch facies, and mostly are confined to microfossils and trace fossils. All of the megafossils found in the Stanley and Jackfork Groups are believed by Gordon and Stone (1977) to have been transported and redeposited, either in exotic blocks or in turbidite intervals that moved from shallow-water environments adjacent to the trough. A few indigenous megafossils have been found in the Johns Valley Shale. The paucity of fossils has not resolved many problems resulting from attempts to correlate the thick turbidite sequences of varying ages but similar lithologic character from one fault block to another.

Kinderhookian and Osagean Series

These series are represented in the Ouachita Mountains by the highest part of the Middle and Upper Divisions of the pre-flysch Arkansas Novaculite (Stop 22). Most of the Arkansas Novaculite is Devonian in age, but Hass (1951) recorded a Kinderhookian age for the top 28.5 feet of the Middle Division of the formation at Caddo Gap, Montgomery County, Arkansas, based on conodonts. In addition, he assigned a tentative uppermost Kinderhookian or Osagean age for another conodont collection made 80 feet below the top of the 127-foot-thick Upper Division of the formation at a locality in Polk County, Arkansas. Thus, Hass considered the upper 155 feet of the formation to be Mississippian in Arkansas. Hass (1951) quoted H. D. Miser as stating that the Upper Division of the Arkansas Novaculite occurs in Oklahoma only in McCurtain County. The only conodonts recovered by Hass (1951) from the Arkansas Novaculite on Black Knob Ridge, near Atoka, Oklahoma, were Devonian in age.

Meramecian and Chesterian Series

Rocks of the Stanley Group are apparently conformable with the underlying Arkansas Novaculite in most areas in both Arkansas and Oklahoma (Stop 22). At Black Knob Ridge, in the westernmost Ouachita outcrop area in Oklahoma (fig. 4), however, there is a local conglomerate at the base of the Stanley at some localities (Goldstein and Hendricks, 1962). Nowhere can an unfaulted sequence of the Stanley be seen, but a maximum thickness of 11,000 feet has been estimated in the central Ouachitas of Oklahoma, and the group thins abruptly westward and northward toward the frontal Ouachitas (Cline, 1960). Sellars (1966) made an estimate of 12,000 feet for the thickness of the Stanley in Polk County, Arkansas.

Harlton (1938) subdivided the Stanley Group in Oklahoma into the Tenmile Creek, Moyers, and Chickasaw Creek Formations on the basis of the occurrence of several thin siliceous shales that are apparently widespread and locally mappable in Oklahoma.

The Tenmile Creek Formation makes up most of the Stanley Group. It is 5,650 feet in its type area in Oklahoma, with the base covered (Harlton, 1938). It consists largely of shale with frequent alternations of thin layers of very fine-grained turbidite sandstone, chert, and siliceous shale (Battiest Member) and tuff (Hatton and Beavers Bend Members). The grain size remains fairly constant throughout the outcrop region, but some coarser sediments are more common in the southeast (Johnson, 1968). In the central Oklahoma Ouachitas about 15 percent of the formation is sandstone, but this percentage is higher southeastward (Johnson, 1968). The Hatton, Beavers Bend, and associated tuffs are altered pumiceous vitric-crystal and vitric tuffs produced from pyroclastic debris and ash clouds deposited with turbidite sequences (Niem, 1977). Isopach and isopleth maps suggest a southerly source for these tuffs (Niem, 1977).

The overlying Moyers Formation is a turbidite sand-shale unit in which the sandstones make up approximately 60 percent of the formation. The formation is approximately 1,000 feet thick.

The Chickasaw Creek Formation (Stop 26) is up to 200 feet thick. In western Arkansas it consists of black shales, with two hard, siliceous-shale intervals separated by a tuffaceous interval (Morris, 1974a). The Chickasaw Creek Formation can be traced across much of the outcrop area in the central Oklahoma Ouachitas and in the western Ouachitas in Arkansas.

Stanley sandstones are generally feldspathic, with percentages of feldspar in the frontal Ouachitas in Arkansas being as high as 9 to 12 percent. These sandstones have matrix contents that classify them as wackes (Morris, 1974a). In contrast, the Hot Springs Sandstone Member, locally found at the base of the Stanley in Arkansas (Stop 22), is a mainly fine-grained quartz arenite with only traces of feldspar. On the basis of its stable mineral composition and its limited areal extent, Morris (1974a) interpreted the Hot Springs as being deposited at the base of a submarine canyon and with a different source than the turbidite sands of the middle and upper Stanley. At the east end of the Ouachitas, near Little Rock, the uppermost beds of the Hot Springs Sandstone Member contain erratic blocks of limestone 3 to 13 feet in diameter.

Paleocurrent patterns for the Stanley Group suggest movement of turbidity flows in Arkansas to be primarily toward the northwest (Morris, 1974a). In southeastern Oklahoma, paleocurrents moved to the west-northwest, changing to westward and west-southwest in the north-central and western Ouachita areas, where the paleocurrent directions coincide with the present structural strike rather closely (Johnson, 1968). Morris (1974a) postulated two southern point sources and possibly an eastern source in Arkansas for Stanley turbidite flows. In contrast, a northern source is postulated for the basal Hot Springs Sandstone Member (Gordon and Stone, 1977).

The Stanley Group is poorly fossiliferous, but evidence indicates that it spans the Meramecian-Chesterian boundary. The erratic limestone blocks at the top of the basal Hot Springs Sandstone Member near Little Rock, Arkansas, contain a microfauna of foraminifers and conodonts of Meramecian age (Gordon and Stone, 1977). Also, Hass (1950) collected conodonts of Meramecian age from the lower part of the group in both Oklahoma and Arkansas. Conodonts collected 75 to 145 feet above the base of the Stanley in Arkansas, an interval including the Hatton Tuff Lentil, were believed by Hass (1950) to be of Meramecian age but are now considered of early Chesterian age (Gordon and Stone, 1977). Plant fossils of Chesterian age have been recovered from the upper middle part of the group in Arkansas, and marine invertebrate fossils of Chesterian age have been recovered from erratic blocks of Pitkin Limestone in the Chickasaw Creek Shale, at the top of the Stanley in the frontal belt of the Ouachitas in Arkansas (Gordon and Stone, 1977). Also, the assignment of a Chesterian age for most of the Stanley is supported by its stratigraphic position. The Stanley Group is gradational with the overlying Jackfork Group. Chesterian plants, probably reworked, have been collected from the basal beds of the Jackfork (see following section).

Morrowan Series

The Jackfork Group (Stops 23-25, 27) is conformable with the underlying Stanley Group. Sandstone is the prevailing Jackfork rock type, although shales make up as much as 40 percent of the group in some areas (Shelburne, 1960). The Jackfork is more resistant to erosion than the underlying Stanley Group, which is composed mostly of shale, and thus is one of the main ridge-forming units in the Ouachitas. The Jackfork Group is typically about 5,700 feet thick in the central Oklahoma Ouachitas, but the group thins abruptly northward toward the frontal Ouachitas.

The Jackfork was subdivided by Harlton (1938) in the western Ouachitas of Oklahoma into the following formations (ascending): Wildhorse Mountain, Prairie Mountain, Markham Mill, Wesley, and Game Refuge. These divisions were based primarily on the occurrence of several thin siliceous shales. The Wesley Shale (fig. 2) is the most widespread and readily recognizable formation of the Jackfork Group (Shelburne, 1960). Cline (1960) and Shelburne (1960) were able to show that the formations of the Jackfork Group, described by Harlton, could be recognized and mapped in the eastern Oklahoma Ouachitas. However, the diagnostic siliceous shales, with the exception of the Chickasaw Creek Shale at the top of the underlying Stanley Group, do not extend eastward into Arkansas, which precludes the recognition of Harlton's formations in Arkansas (Morris, 1974a).

Sandstones of the Jackfork Group can be distinguished from those of the Stanley Group by their better sorting, slightly larger grain size, predominantly quartz content with no more than 1 percent feldspar, small amount of matrix material, and greater degree of cementation (Morris, 1974a). The Jackfork sandstones are fine to medium grained, although granules and pebbles of quartz and chert are present in several places in Arkansas as discontinuous, irregular seams (Morris, 1971).

The Jackfork Group is poorly fossiliferous, and there is considerable disagreement in the literature as to its precise age. Of particular importance is the recovery from the lowermost beds of the group, a short distance west of Talihina, Oklahoma, of plants of Chesterian age (Gordon and Stone, 1977). These plants are possibly reworked (Gordon and Stone, 1977, p. 81), however, and the sediments they are associated with may be Morrowan in age. Collections of marine invertebrate fossils from the middle and upper parts of the Jackfork Group in the vicinity of Little Rock, Arkansas, include several poorly preserved but identifiable Morrowan species of goniatites and brachiopods (Gordon and Stone, 1977). The underlying Chickasaw Creek Shale (at the top of the Stanley Group) contains reworked Pitkin erratics in Arkansas.

The Johns Valley Shale (Stops 20, 30, 32) conformably overlies the Jackfork Group. It is predominantly a shale with minor sandstone turbidites. It is well known for its great variety of erratic limestone boulders and for its huge slump blocks, some more than 3,000 feet in length, of "Caney" Shale. All of these come from a shelf source, and the limestone blocks represent various formations ranging in age from Cambrian to Early Pennsylvanian, with Ordovician specimens dominating (fig. 68). The limestone erratics are distributed through the central Oklahoma Ouachitas but extend eastward only into the western parts of the frontal Arkansas Ouachitas. The limestone erratics are predominantly of the Arbuckle facies, but in eastern Oklahoma and in western Arkansas they become mixed with Ozark facies (Shideler, 1970).

The Johns Valley is typically 425 to 900 feet thick in the central Ouachitas in Oklahoma (Cline, 1960). Gordon and Stone (1977) recorded a maximum thickness of more than 1,800 feet in western Arkansas but did not give a locality.

An indigenous fauna from the lower part of the Johns Valley Shale, from localities in both Oklahoma and Arkansas, contains cephalopods of the *Branneroceras branneri* Zone (Gordon and Stone, 1977). This fauna occurs also in the upper part of the "Springer" Formation in the frontal Ouachitas, in the Brewer Bend Limestone Member of the Sausbee Formation in northeastern Oklahoma, and in the upper Brentwood Limestone Member of the Bloyd Formation in northwestern Arkansas. From the middle part of the Johns Valley Shale, Gordon and Stone (1977) recorded the *Axinolobus modulus* goniatite zone. This zone occurs in the frontal Ouachitas in the lower part of the Wapanucka Limestone, in northeastern Oklahoma in the McCully Formation, and in northwestern Arkansas in the Dye Shale and Kessler Limestone Members of the Bloyd Formation. Distinctive fossils have not as yet been reported from the upper part of the Johns Valley.

Morrowan and Atokan Series

The Atoka Formation in the central Ouachitas (Stops 28, 29, 31, 33) consists of interbedded gray shale and fine-grained sandstone with common convolute bedding and sole markings. Shelburne (1960) recorded no more than 25 percent sandstone in the Boktukola syncline in Oklahoma and a maximum preserved thickness in that area of 6,800 feet. The top of the formation is eroded (fig. 3). In the frontal Ouachitas of Arkansas, however, Gordon and Stone (1977) reported an estimated thickness for the Atoka Formation greater than 16,000 feet.

The remnants of the Atoka Formation preserved in the central Ouachitas of Oklahoma have not received the detailed attention that has been given to other units. Paleocurrent directions are apparently mostly to the west. In the frontal Ouachitas, Latimer and Le Flore Counties, Oklahoma, Briggs and Cline (1967) recorded a westerly paleocurrent direction (in the vicinity of the present-day Choctaw Fault), with current directions to the south in areas directly north of the fault.

The Atoka Formation is virtually unfossiliferous in the central Oklahoma Ouachitas. However, L. R. Wilson (oral communication, 1978) reported that the lower part of an Oklahoma section sampled contains palynomorphs of Morrowan age. Also, Shelburne (1960) inferred a Morrowan age for the lower part of the Atoka in the Boktukola syncline.

DEPOSITIONAL HISTORY

Introduction

Depositional patterns in eastern Oklahoma and western Arkansas during the Mississippian and early Pennsylvanian Periods were controlled by the Ozark Dome to the northeast and north and the Ouachita Geosyncline to the south. A broad shelf defined by these two features existed along the cratonic margin. The Ouachita Geosyncline during this time experienced major flysch deposition in contrast to the "starved-basin" sequences characterizing the underlying lower and middle Paleozoic strata.

Ozark Dome

The shelf south of the Ozark Dome was a region of typical shallow-marine deposition throughout the Late Mississippian and Early Pennsylvanian Periods. Carbonate environments predominated, particularly in the Late Mississippian, but these were periodically disrupted by the influxes of terrigenous clastic sediments. The Ozark Dome, to the northeast and north, provided a source for at least some of these clastic sediments.

Chesterian strata reflect an alternation of shelf carbonates, commonly oolitic (Hindsville, Pitkin), with dark shales (Moorefield, Fayetteville, Imo). The early Chesterian transgression produced a basal conglomerate and initiated prograding deltaic sequences, particularly in northeastern Arkansas (Batesville). Deltaic sandstones such as the Wedington Member of the Fayetteville Formation are also associated with shifts in the shoreline that were accompanied by a change from carbonate to shale deposition. Chesterian deposits are typically clean, well-sorted sediments produced in open, shallow-shelf environments; but these deposits were occasionally interrupted by reducing bottom conditions that formed black shales.

The Morrowan Series is characterized by a marked increase in terrigenous sediment, reflecting nearshore and strandline conditions. In the southern Ozark region, both the total percentage of terrigenous clastic rocks and the percentage of coarser terrigenous clastic rocks increase eastward. There is a corresponding eastward decrease in the percentage of carbonate rocks in the Morrowan Series. Glick (1975) explained this relationship by postulating a source east of the Ozark Dome for most of the clastic sediments found in northern Arkansas. He suggested that a "southwest flowing ancestral Mississippi River" was responsible for a vast deltaic sequence in northeastern and north-central Arkansas. Glick (1975) also attributed the volume of Morrowan terrigenous clastic rocks on the shelf in northwestern Arkansas to westward-flowing longshore currents that crossed the main delta front and swept detritus with them westward along the continental shelf. Superimposed on this depositional setting were oscillations of the shoreline that resulted in a complex of shallow-marine and terrestrial deposits with associated unconformities. Southward tilting of the Early Pennsylvanian shelf occurred in conjunction with subsidence of the Ouachita trough to the south. Regression, followed by differential erosion, resubmergence, and transgression, produced a characteristic wedging out northward of all of the formations from the Chesterian Pitkin Limestone upward.

The deposition of the Atoka Formation represented a marked change in depositional regimen following the late Morrowan emergence and subsequent erosion. The Atoka in the Ozark region is partly shallow marine and partly deltaic in origin, with the direction of the terrigenous source from the northwest, in contrast to the northeast and east directions of terrigenous source during the Morrowan. Vertical sequences in the lower Atoka record a history of coastal depositional complexes prograding southward. Periodically these coastal systems were interrupted by transgressions and expansion of open-shelf environments (Zachry, 1975).

The maximum outcrop thickness for Chesterian, Morrowan, and Atokan strata in the Ozark outcrop region totals less than 2,500 feet, but some of the formations thicken southward and change facies into the Arkoma Basin and frontal Ouachita areas (fig. 3).

Arkoma Basin and Frontal Ouachita Region

The Arkoma Basin is an arcuate tectonic element between the Ozark and Ouachita Mountains (fig. 1). The southern margin of this structural feature is marked by the Choctaw Fault, which forms the northern margin of the present-day Ouachita Mountains.

Disagreement exists as to whether the Arkoma structural basin was a sedimentary basin during Chesterian and Morrowan time. According to Laudon (1958, p. 7), the Arkoma Basin was bounded on the north by "a hinge-like line of basin flexure, which had a fairly constant position during all of late Mississippian and early Pennsylvanian time." Laudon's line would place the southern two-thirds of the Arkoma Basin (fig. 1) in the "basin" and the northern third on the "shelf."

Alternatively, Buchanan and Johnson (1968, fig. 7) showed that the Arkoma Basin area became a rapidly subsiding sedimentary basin with major lateral increases in strata thicknesses no earlier than the beginning of deposition of the middle part of the Atoka Formation (fig. 5).

Laudon's (1958) hinge-like line of basin flexure marks the approximate southern limit of major shallow-water carbonate deposition during both Chesterian and early Morrowan time. A change occurs along an approximate east-west line located in southern Muskogee County, Oklahoma, T. 10 N., about 10 to 12 miles south of Webbers Falls, Oklahoma (fig. 1). Southward from this line, a distinct decrease occurs in the percentage of limestone in the Chesterian and in the Morrowan interval below the Wapanucka Limestone.

Sutherland and Henry (1977a) believe that the southern part of the Arkoma Basin was occupied during Chesterian and Morrowan time primarily by an unstable, southward-sloping outer-shelf margin. The southern margin sank at a more rapid rate than the shallow shelf to the north, but presumably at a much slower rate than the Ouachita Geosyncline still farther to the south.

During the Chesterian and Morrowan Epochs, the shoreline fluctuated several times across the shallow inner shelf, at times even southward onto the outer-shelf area, with continuous deposition possibly occurring only on the southern part of the outer shelf (Sutherland and Henry, 1977a, fig. 12).

The "Caney" Shale (Chesterian), which crops out in the frontal Ouachita Mountains in Oklahoma (fig. 2), is believed to have been deposited on the outer shelf. It is transitional between the shallow-shelf carbonate deposits of Chesterian age in the Ozark region and the deep-trough deposits of the central Ouachitas (fig. 3). The maximum thickness of the "Caney" Shale is reported to be no more than 900 feet in the frontal Ouachitas, but structural complexity lends some uncertainty to this estimate. This thickness is only slightly greater than that for Chesterian strata of the carbonate facies on the Ozark Shelf.

The "Springer" Formation (lower Morrowan), consisting mostly of gray shales, continues the outer-shelf depositional pattern of the "Caney" Shale, presumably without break. However, the estimated thickness of 2,500 feet for this unit in the frontal Ouachitas (Hendricks and others, 1947) suggests an increase in the rate of subsidence of the outer shelf in early Morrowan time, compared to the underlying Chesterian (fig. 3).

During the time of deposition of the Wapanucka Limestone in late Morrowan and early Atokan time, the outer shelf became increasingly more shallow, with oolitic grainstone, carbonate mudstone, and cross-bedded sandstone common constituents in the upper part of the formation.

The limestones in the lower part of the Wapanucka Formation, as seen in the frontal fault ridges of the Ouachitas, change facies basinward (southward) to the thick shales and spiculites of the Chickachoc Chert Member of the lower Wapanucka (figs. 5, 111). A deeper water, outer-shelf or continental-slope facies is represented. This more basinward area also became shallower through time, as shown by the cap of shallow-water carbonate mudstones and tabular, cross-bedded sandstone of the Wapanucka Formation in the more basinward fault ridges (fig. 110).

The Wapanucka Formation in the frontal Ouachita Moun-

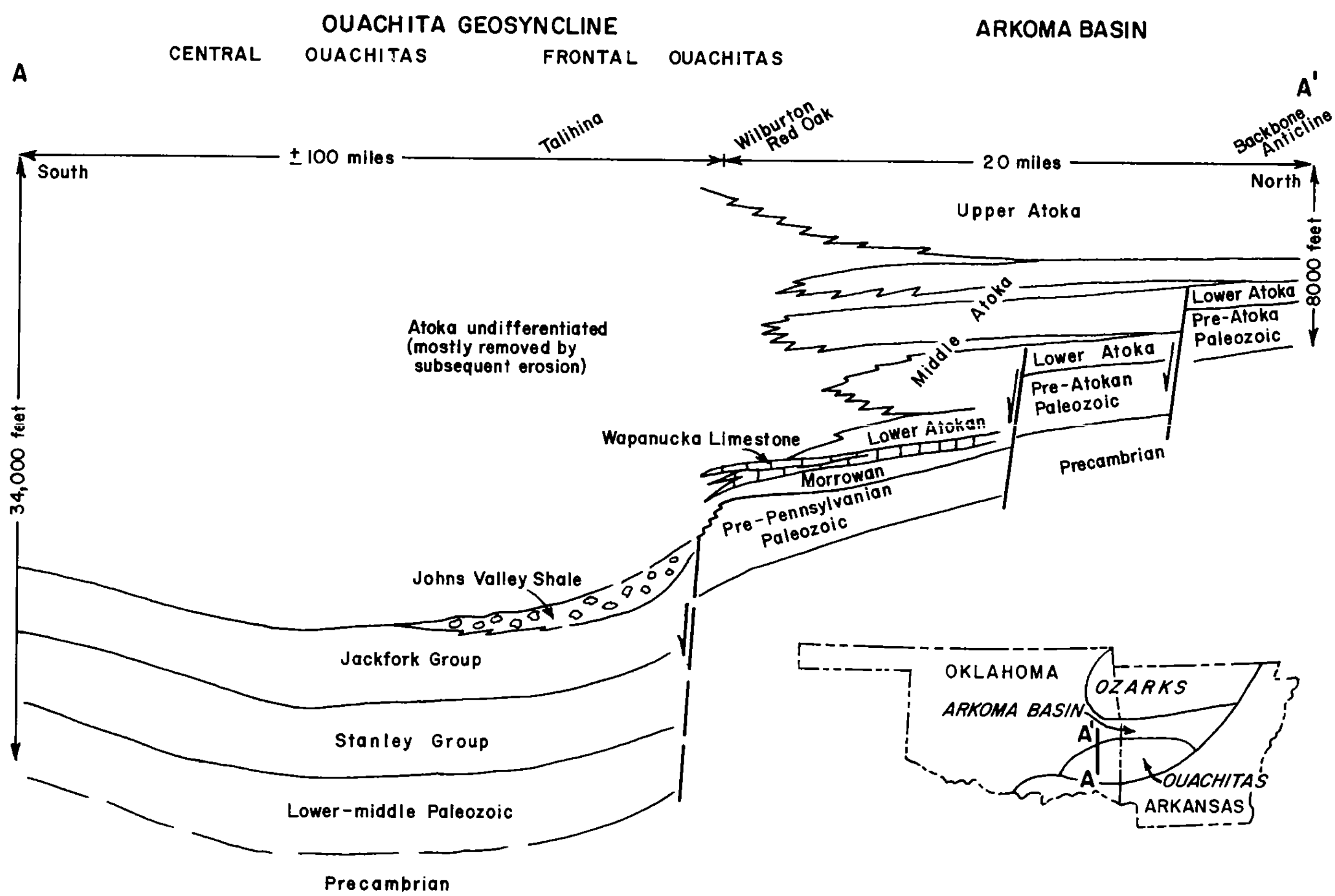


Figure 5. Cross section of depositional reconstruction during Morrowan and Atokan time; pre-Ouachita orogeny, Oklahoma (modified from Buchanan and Johnson, 1968, and Chamberlain and Basan, 1978).

tains spans the Morrowan-Atokan boundary (fig. 105) in a sequence of apparent continuous deposition. But the depositional relationship of the Wapanucka Formation to the overlying Atoka Formation in that area is not clear because of faulting. The uppermost beds of the Wapanucka Formation in the frontal Ouachita outcrops are shallow-marine deposits. Apparently most of the inner- and outer-shelf areas, across the Arkoma Basin area in Oklahoma, then became regionally emergent. In the eastern Arkoma Basin in Arkansas, this regression is also recognized, but the area was not emergent. The regression was accompanied by constructional lobate deltas interrupted by periodic marine transgressions. Lumsden and others (1971, fig. 6) described, in the subsurface of the Arkoma Basin area of Oklahoma, stream valleys cut into the post-Wapanucka surface with relief of at least 120 feet. The "Foster sand" trends were deposited as the basal discontinuous unit of the Atoka Formation and are believed to represent river deposits (Lumsden and others, 1971, fig. 6). These streams brought detritus, derived from the northwest, to the basin to the south, where marine sedimentation was continuous (beginning just north of the present-day location of the Choctaw Fault), and the "Spiro sand" was formed in a shore-zone complex (Lumsden and others, 1971, p. 254). During the northward marine transgression that followed, the "Spiro sand" was deposited across the eroded surface as a blanket sand, locally overlying the "Foster sand" channels. These strata are termed lower Atoka on figure 5. During the time of deposition of the middle Atoka, a series of major down-to-the-southeast growth faults developed across the Arkoma Basin area. This apparently coincided with a northward migration of the northern border of the Ouachita Trough. Thicknesses of the middle Atoka are much greater on the southeast side of these faults than on the northwest (fig. 5).

Central Ouachita Region

The depositional history of the Ouachita Mountains is marked by a striking change in depositional character that took place in Mississippian time. Ordovician through Lower Mississippian strata consist mostly of dark shales and cherts with minor sandstones that attain maximum thicknesses in the Oklahoma Ouachitas of only about 4,000 feet but which may reach 6,000 feet in Arkansas (Ham, 1961). Most authors have interpreted this sequence as having been deposited in a deep "starved trough." Hass (1951) recovered conodonts of Kinderhookian and Osagean age from the upper 155 feet of the Arkansas Novaculite in Arkansas.

The Meramecian Epoch marked the beginning of the development of the Ouachita area as a major geosyncline. Morris (1974b) and Wickham and others (1976) used plate-tectonic models for the development of this geosyncline. Deposition within the trough extended, without apparent break, through the Meramecian, Chesterian, Morrowan, and Atokan Epochs, depositing possibly as much as 40,000 feet of turbidite sandstones and dark shales with minor interlayered wildflysch and volcanic ash.

Sedimentary structures indicate predominantly westward sand dispersal along the axis of the trough, which is parallel with tectonic strike. One turbidite source was apparently from some point east of Little Rock, along the Ouachita Trough axis. There were possibly also several other sources along the south margin of the trough. Thus, the turbidites in any one vertical succession possibly came from several different sources.

In general, the percentage of shale is higher in Oklahoma than in Arkansas. In Oklahoma the sandstones are almost invariably fine grained and evenly bedded and generally contain the sedimentary structures of classic turbidites (fig. 96A, B). Such sequences are considered to represent mostly basin-plain deposits. Farther east, in Arkansas, sandstones are thicker, indicating that the sediment source was nearer, and some units exhibit coarsening-upward and fining-upward intervals possibly representing outer-fan deposits. Lacking in Oklahoma and western Arkansas, however, are extensive coarse-grained turbidites or marked variations in bed thickness that might indicate a nearby location of feeder channels for submarine fans as described by Walker (1978).

Paleocurrent patterns for the Stanley Group (Meramecian-Chesterian) suggest movement of turbidity flows in Arkansas to be mainly to the northwest, apparently from more than one marginal source to the south (Morris, 1974a). Farther west in Oklahoma there is a change to an axial direction along the trough, westward and then southwestward (Johnson, 1968). The Stanley turbidites are generally feldspathic. The nonfeldspathic basal Hot Springs Sandstone Member, confined mainly to the eastern part of the Arkansas Ouachitas, is believed to have had a northern source (Gordon and Stone, 1977) and to represent a deposit at the base of a submarine canyon (Morris, 1974a).

For the Jackfork Group (lower Morrowan), paleocurrent directions are primarily westward and axial (Morris, 1974a). Sandstones of the Jackfork Group differ from those of the Stanley by their better sorting, slightly larger grain size, virtual lack of feldspar, and greater degree of cementation (Morris, 1974a).

The Johns Valley (upper Morrowan) is predominantly a shale with minor turbidites. Its great number of erratic limestone boulders and huge blocks of "Caney" Shale came from the shelf or slope to the north and mostly slid into the trough. They represent various formations ranging in age from Cambrian to Early Pennsylvanian, with Ordovician specimens dominating (fig. 68). They mostly represent Arbuckle facies, but these become mixed with Ozark facies in western Arkansas (Shideler, 1970). Deposition of the Johns Valley is depicted in figure 5 and coincides with deposition of the Wapanucka Formation on the outer shelf.

Atoka (upper Morrowan and Atokan) paleocurrent patterns are not extensively described in the literature. Those in the lower Atoka were apparently dominantly westward, and middle and upper Atoka currents were directed southwestward, with lithologic distribution suggesting diminishing sedimentation by turbidity currents coincident with increasing importance of deltaic progradation from the shelf to the north (Morris, 1974a). During Atoka time the northern margin of the Ouachita Trough shifted northward. Rapid infilling raised the level of the sea floor to allow interfingering of deltaic sediments and turbidites (Morris, 1974a).

Summary

The Meramecian and Chesterian Series are characterized by limestone-shale alternations, reflecting shoreline oscillations over the Ozark Shelf region. Numerous unconformities punctuate this sequence, and prograding deltaic sandstones are common, particularly in northeastern Arkansas. The Arkoma Basin was not yet active, and shelf conditions extended much farther south than the present northern basin margin. However, there is a southward facies change toward the outer-shelf environments of the frontal Ouachita region (Oklahoma), where the equivalent interval is entirely shale. Simultaneously, the Ouachita Geosyncline began to receive flysch deposits in contrast to the preceding "starved-basin" sequences. The turbidites of fine-grained, evenly bedded sandstones and shale were deposited, with lesser amounts of volcanic ash, from a southerly source and siliceous shale. A composite thickness of approximately 1,400 feet of Meramecian-Chesterian shelf sediments is equivalent to nearly 12,000 feet of Stanley turbidites. This comparison is even more striking when it is noted that unconformities have reduced the preserved thickness of Meramecian-Chesterian strata to no more than 800 feet in the Ozark region.

Morrowan strata reflect the reestablishment of shelf conditions following the major Mississippian-Pennsylvanian unconformity. However, these strata differ from the older Meramecian-Chesterian beds by the marked increase in terrigenous sediments. In addition, terrestrial units associated with coal are found within the Morrowan interval. Limestones were deposited during the Morrowan, but are more commonly encountered in eastern Oklahoma. These limestones typically contain quartz sand and usually represent high-energy mixtures of fossil detritus, ooliths, and intraclasts. The frontal Ouachita region (Oklahoma) maintained its outer-shelf depositional regime. There, the bulk of Morrowan time is represented by shale, but the late Morrowan and early Atokan are represented by more shallow-water conditions, resulting in oolitic grainstones, mudstones, and cross-bedded sandstones (Wapanucka). The Ouachita Geosyncline continued to receive an unbroken sequence of turbidites characterized by greater thicknesses of sandstone (Jackfork) in comparison to similar deposits of Chesterian age. Wildflysch deposits derived from the Ozark Shelf region characterize late Morrowan time (Johns Valley) and indicate active tectonism along the geosyncline-shelf margin preceding formation of the Arkoma Basin. Morrowan strata on the Ozark Shelf reach a maximum thickness in the outcrop belt of about 320 feet. This interval thickens to nearly 3,000 feet along the outer shelf in the frontal Ouachitas. In the Ouachita Geosyncline, the equivalent section may reach 8,000 feet.

The Atoka Formation caps the Ozark upland, and only the lower sequences are preserved below the present-day erosion surface. The Atoka Formation in this area records a series of prograding coastal systems interrupted by transgressions and open-shelf conditions. The Arkoma Basin became an active tectonic feature in middle Atokan time with the development of major down-to-the-basin growth faulting and rapid subsidence. Prograding lobate deltas characterize deposition in the Arkoma Basin area. A general regressive character for the lower Atokan Series is shown by shallow-water carbonates continuing from the late Morrowan in the frontal Ouachitas. Middle and upper Atokan sediments, and those of the succeeding Desmoinesian Series, where preserved, indicate a continuation of this deltaic-open-marine oscillation with final establishment of coastal conditions and coal swamps. The Atoka Formation of the Ouachita Geosyncline continued turbidite deposition, but the rapid infilling of the basin gave rise to an interfingering of turbidites and deltaic sediments. Comparison of Atokan sedimentary thicknesses is difficult because of the present-day erosion surface. However, a thickness of more than 16,000 feet of Atokan strata has been estimated in the frontal Ouachitas in Arkansas, compared to about 600 feet in the Ozark region.

STOP DESCRIPTIONS—FIRST DAY

Walter L. Manger

SUMMARY

The first day of the excursion will introduce the general succession of Chesterian and Morrowan strata in northern Arkansas. The interval from the Hindsville Formation at the base of the Chesterian Series through the Dye Member of the Bloyd Formation, type Morrowan Series, will be examined at eight stops. Specific features of interest are: (1) basal Chesterian unconformity; (2) variable truncation of Chesterian strata at the Mississippian-Pennsylvanian unconformity; (3) fossiliferous upper Chesterian strata of the Imo Formation; (4) nonmarine to marine facies change and associated unconformity, Woolsey Member, Bloyd Formation; (5) biostratigraphy of upper Chesterian-Morrowan strata. Unfortunately, the distribution of roads and outcrops in northern Arkansas does not allow a sequential look at the Chesterian-Morrowan succession. Figure 2 summarizes the lithostratigraphic units that will be examined.

STOP 1—PEYTON CREEK ROAD CUT

Location: Road cut on east side of U.S. Highway 65 beginning directly south of the Peyton Creek Bridge, 0.2 mile south of Searcy-Van Buren County line and 3.4 miles south of Leslie. NE¼ sec. 11 and NW¼ sec. 12, T. 13 N., R. 15 W., Van Buren County, Arkansas.

The field excursion begins at the famous Peyton Creek road cut, exposing Chesterian strata of the upper Pitkin and Imo Formations overlain by presumed Morrowan-age strata of the Witts Springs? Formation. The type locality for the Imo Formation is in Sulphur Springs Hollow, a tributary to Bear Creek, in adjacent Searcy County (Gordon, 1965). However, the Peyton Creek exposure has produced the bulk of the Imo fossils, and understanding of the age and correlation of the unit is based primarily on this exposure.

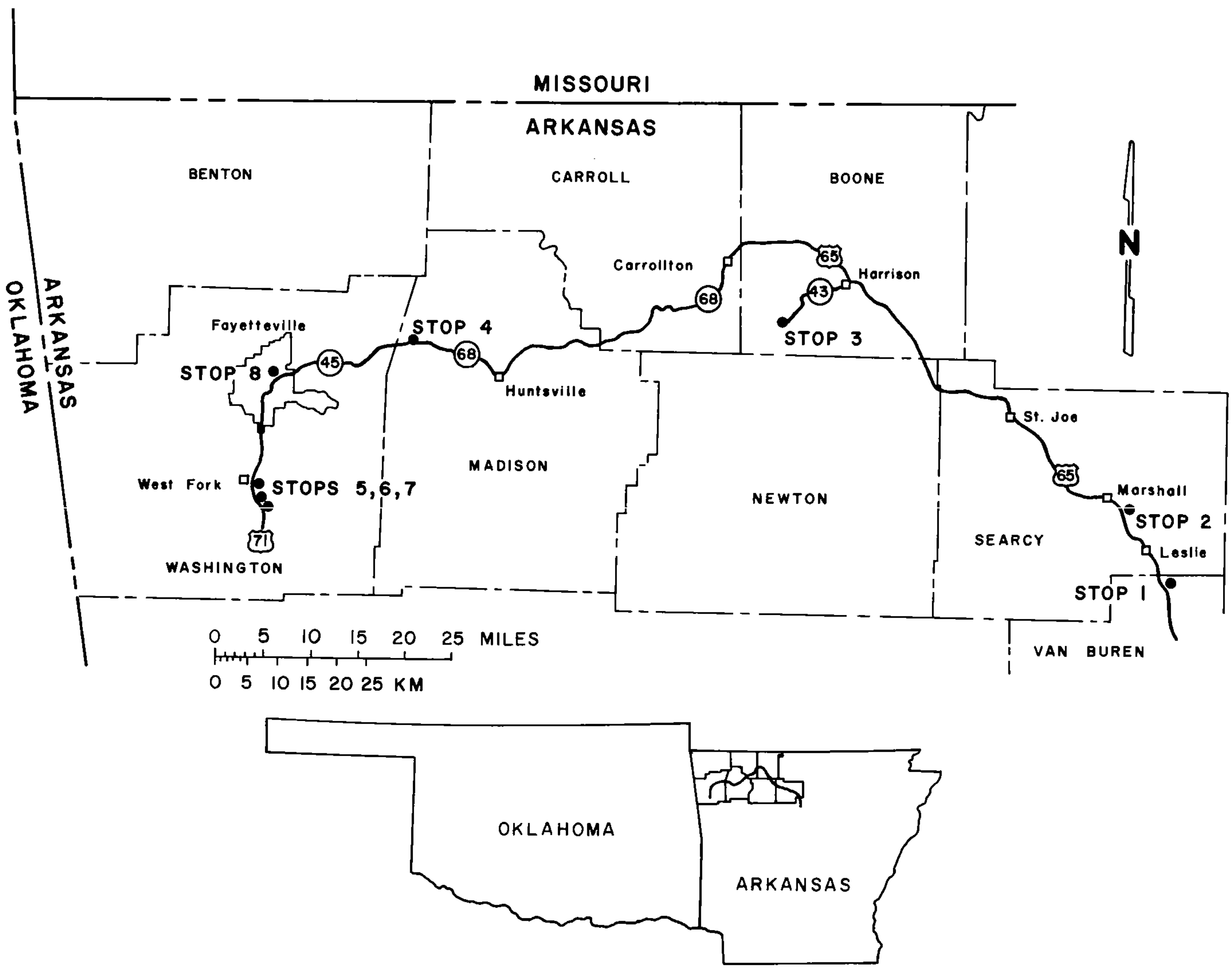


Figure 6. Locality and route map, first day.

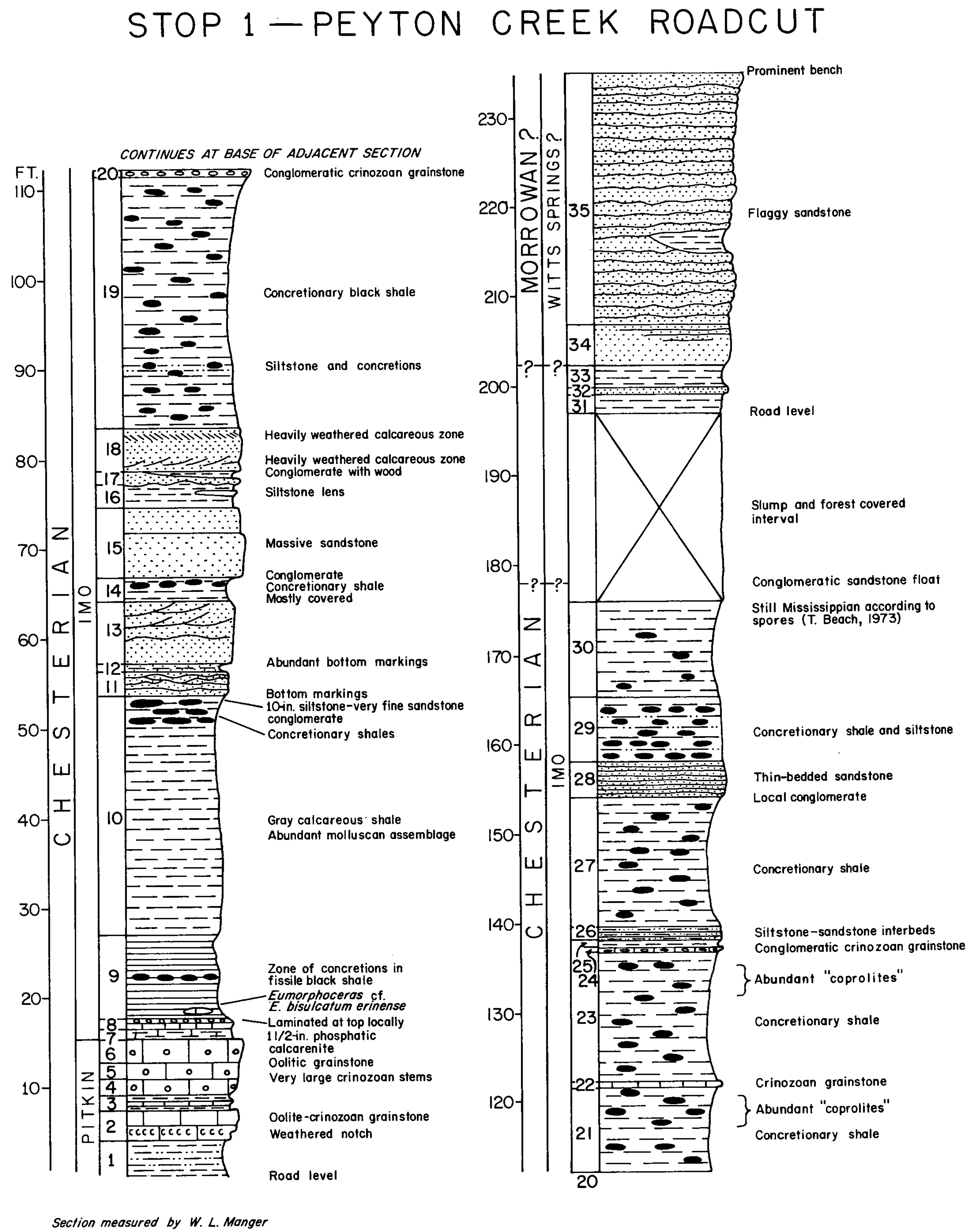


Figure 7. Graphic columnar section for Stop 1.

The upper Pitkin Limestone comprises a series of oolitic-crinozoan grainstones with minor dark shale (figs. 7, 8). These beds are significant in that they have yielded biostratigraphically sensitive assemblages of conodonts and calcareous foraminifers. The conodonts, described by Lane (1967) and Lane and Straka (1974), are referable to the *Adetognathus unicornis* Zone of the standard Mississippian succession. This occurrence indicates equivalence of the Pitkin at Peyton Creek to the Grove Church Shale and thus to the top of the type Chesterian Series (Lane, 1967). Smaller calcareous foraminifers from the Pitkin are reported by Brenckle (1977) to be dominated by eosigmoilinids characteristic of Mamet Zone 19. Re-collection of the type Chesterian has produced similar assemblages supporting the correlations based on conodonts (Brenckle and others, 1977). No ammonoids have been recovered from the Pitkin at this locality. At Leslie, 5 miles north, the Pitkin yields an ammonoid assemblage with *Eumorphoceras bisulcatum* and *Cravenoceras richardsonianum* (Saunders and others, 1977). This assemblage may be correlated intercontinentally with Arnsbergian zone E_2a of the standard Namurian succession. The conodonts and foraminifers support this correlation. Ammonoids are not known from type Chesterian strata in this interval. The Imo succeeds the Pitkin with apparent conformity at the Peyton Creek locality. The bulk of the formation is fossiliferous gray to black shale with scattered beds of sandstone and conglomeratic limestone (figs. 7, 9). Well-known ammonoid assemblages from the Imo provide a basis for precise intercontinental correlation. The assemblage is dominated by *Anthracoceras discus* but includes more sensitive taxa such as *Fayettevillea, Eumorphoceras, Delepinoceras,* and *Cravenoceras* (Saunders, 1973). These forms suggest equivalency to the upper Arnsbergian Stage (E_2b-c) of the standard Namurian succession (Saunders and others, 1977). The basal black shale of the Imo also contains an assemblage of crushed ammonoids characterized by *Eumorphoceras bisulcatum erinense*. This occurrence suggests that the lower portion of the Imo Formation is equivalent to E_2a of the standard Namurian succession. Conodonts of the *Adetognathus unicornis* assemblage zone have been recovered from limestone and calcareous sandstone zones extending through the primary ammonoid-bearing zone (Lane, *in* Brenckle, 1977). These occurrences suggest that the *Adetognathus unicornis* zone is equivalent to most of the Arnsbergian Stage (E_2) of the standard Namurian succession. Limestones of the Imo yield Mamet Zone 19 foraminifers (Brenckle, 1977). Data from the ammonoids, conodonts, and calcareous foraminifers suggest that the Imo Formation is in part younger than the youngest type Chesterian formation (Grove Church Shale). Biostratigraphic relationship to other youngest Chesterian strata such as the Bird Spring Limestone of Nevada cannot be established precisely at this time because of the lack of sensitive faunal elements in common.

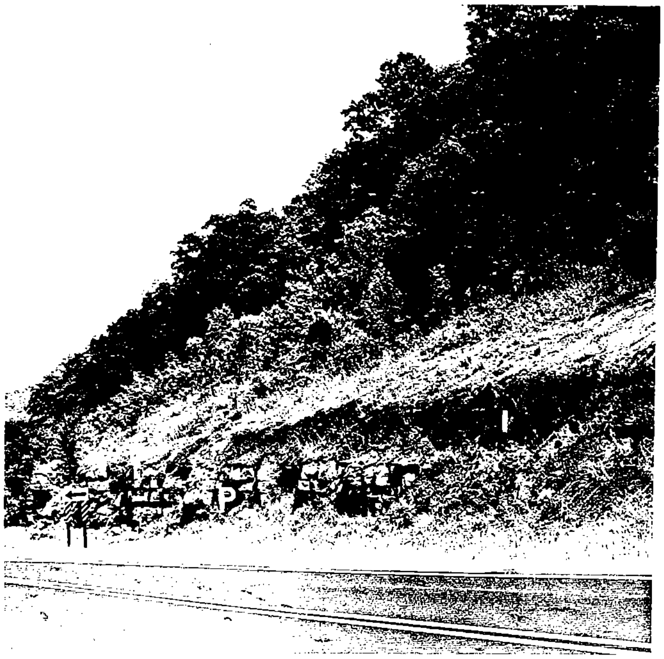


Figure 8. Oolitic grainstones of Pitkin Limestone (*P*), overlain by black and gray shale of lower Imo Formation (*I*). (Stop 1.)

Figure 9. Dark shales and interbedded limestones (*L*) of primary fossil-bearing zone in upper Imo Formation. (Stop 1.)

At the Peyton Creek exposure, the highest dark shales in the road cut still yield Mississippian palynomorphs (T. Beach, University of Texas-Dallas, personal communication, 1973). Above this zone is an extensive covered interval. Conglomeratic sandstone float is common in the lower part of this covered interval, but no outcrops are known. The next exposures exhibit an apparently gradational contact of dark shale and quartz sandstone overlain by a thick sequence of flaggy sandstone (fig. 7). The top of the Imo Formation has not been adequately defined. The boundary cannot be placed with assurance in the Peyton Creek road cut. It may fall within the covered interval at the horizon indicated by the conglomeratic sandstone, at the base of the first massive sandstone, or somewhere in between. The top of the Imo is also presumed to coincide with the Mississippian-Pennsylvanian boundary in this area.

Assignment of the sandstones above the Imo to a formation is unclear. The name Imo was initially withdrawn by Gordon (1965), to be replaced by the term Cane Hill Formation of

Chesterian and Morrowan age (Glick and others, 1964). Usage of Cane Hill as a formation in north-central Arkansas was questioned by Quinn (1966) and Saunders (1973); and the name Imo has continued in recent literature (e.g., Gordon, 1970), although it does not appear on the *Geologic Map of Arkansas*(Haley, 1976). The Witts Springs Formation of Morrowan age was proposed for strata overlying the "Cane Hill Formation" in north-central Arkansas (Glick and others, 1964). Since the relationship of the top of the Imo Formation to Morrowan strata has not been clearly established, the sandstone sequence above the Imo is assigned questionably to the Witts Springs to avoid confusion with the name Cane Hill. Although it is common practice to show the Imo Formation overlain by the strata referred to the Cane Hill Member of the Hale Formation (type Morrowan), this relationship has never been demonstrated. In addition, the Mississippian-Pennsylvanian boundary has never been assessed faunally in the region of Imo exposures in north-central Arkansas.

The Imo ammonoid assemblage has received the bulk of taxonomic and biostratigraphic attention (Furnish and others, 1964; McCaleb and others, 1964; Gordon, 1965; Saunders, 1966, 1973, 1975; Saunders and others, 1977; Manger and Quinn, 1972). However, the fauna is actually dominated by gastropods and bivalves; yet neither of these groups has received taxonomic treatment. Published studies of other Imo fossils include crinoids (Burdick and Strimple, 1973), phyllocarids (Copeland, 1967), plant petrifactions (Taylor and Eggert, 1967), and palynomorphs (Sullivan and Mischell, 1971).

STOP 2—MARSHALL ROAD CUT (PICTURE STOP)

Location: Road cut on east side of U.S. Highway 65 approximately 0.9 mile south of Marshall, Arkansas. NE¼ NE¼ sec. 6, T. 14 N., R. 15 W., Searcy County, Arkansas.

This spectacular, though largely inaccessible, series of road cuts exposes nearly two hundred feet of the upper Fayetteville and lower Pitkin Formations (Chesterian). The Fayetteville Formation in this area differs in two respects from exposures in the type area of northwestern Arkansas. The Wedington Sandstone Member, which divides the interval informally into upper and lower members, is absent in north-central Arkansas. Yet the formation can still be divided informally by the development of interbedded dark micritic limestone and black shale in the upper Fayetteville in north-central Arkansas. This facies is absent in the type area of Washington County but is developed at some localities in northeastern Oklahoma. The carbonate beds are black, dense, recrystallized micrites that lack a benthic fauna. *Lingula* is common on some bedding planes, which may represent accumulations of shells from the water column. Thin, persistent, phosphatic carbonate beds and shaly carbonate beds also occur sporadically through the section. These beds contain an ammonoid assemblage of small *Eumorphoceras* and *Cravenoceras*. Orthoconic nautiloids are also present. The ammonoids suggest correlation to the Namurian Series, Pendleian Stage (E_1).

The Fayetteville-Pitkin contact is marked by a change to light-colored bioclastic and oolitic carbonates (fig. 10). The contact is sharp and slightly undulatory, but no unconformity is thought to be present. Intertonguing relations of the carbonate facies can be seen in this exposure, with the oolitic facies distinguished by their lack of bedding. Black chert in irregular masses occurs in some beds at the top of this outcrop. The upper Pitkin Formation contains black shale alternating with thick beds of carbonate, as seen at Stop 1.

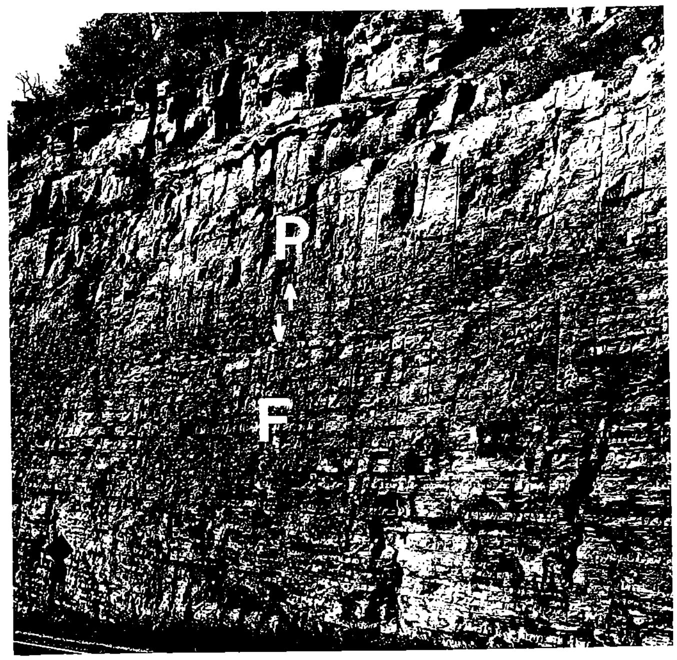


Figure 10. Upper Fayetteville Formation (*F*) contains interbedded dark micritic limestone and black shale. Its conformable contact with overlying Pitkin Limestone (*P*) is drawn at change to light-colored bioclastic, oolitic grainstones and packstones (arrows). (Stop 2.)

STOP 3—GAITHER MOUNTAIN

Location: Road cut and bluff exposures along west side of Arkansas Highway 43 on east side of Gaither Mountain, approximately 1.5 miles southwest of junction of Arkansas Highways 43 and 206. C sec. 27, T. 18 N., R. 21 W., Boone County, Arkansas.

Gaither Mountain exposes a section from the Cane Hill Member, Hale Formation, through strata equivalent to the Woolsey Member, Bloyd Formation, and is thus entirely Morrowan in age. Facies developed here are quite different from those found in the Washington County type sections 80 miles to the west. However, the succession is still recognizable in terms of the type Morrowan lithostratigraphic nomenclature (fig. 11).

The Hale Formation (Taff, 1905) is divided into the Cane Hill and Prairie Grove Members (Henbest, 1953). The Cane Hill at Gaither Mountain exhibits a fluvial character with a predominance of channeloid conglomeratic sandstones (fig. 12) in contrast to the tidal-flat complexes of finer sediments found in the type area. Unusual lithologies in the Gaither Mountain exposure include a quartz-granule conglomerate (fig. 11, unit 5) and a quartz-sand-bearing bryozoan-oolitic grainstone (fig. 11, unit 6). The Cane Hill-Prairie Grove contact is sharp and planar, lacking the basal conglomerate and unconformable character of the type region. The Prairie Grove lithologies of calcareous sandstones are similar to those in Washington County but are approximately half the normal thickness.

The Bloyd Formation (Purdue, 1907) is divided into four members (Henbest, 1962b), but only the Brentwood (Ulrich, 1904) and Woolsey (Henbest, 1953) Members are exposed on Gaither Mountain. The Brentwood Member in its type area (Stop 7) is an alternation of dark shale and dark quartz-bearing crinozoan grainstones (fig. 21). In contrast, the Gaither Mountain section is an alternation of shale and quartz sandstone (fig. 11). Most beds lack persistency here, and facies changes are pronounced.

Gaither Mountain is a famous ammonoid collecting locality for the upper Brentwood Member (fig. 11, unit 13; fig. 13).

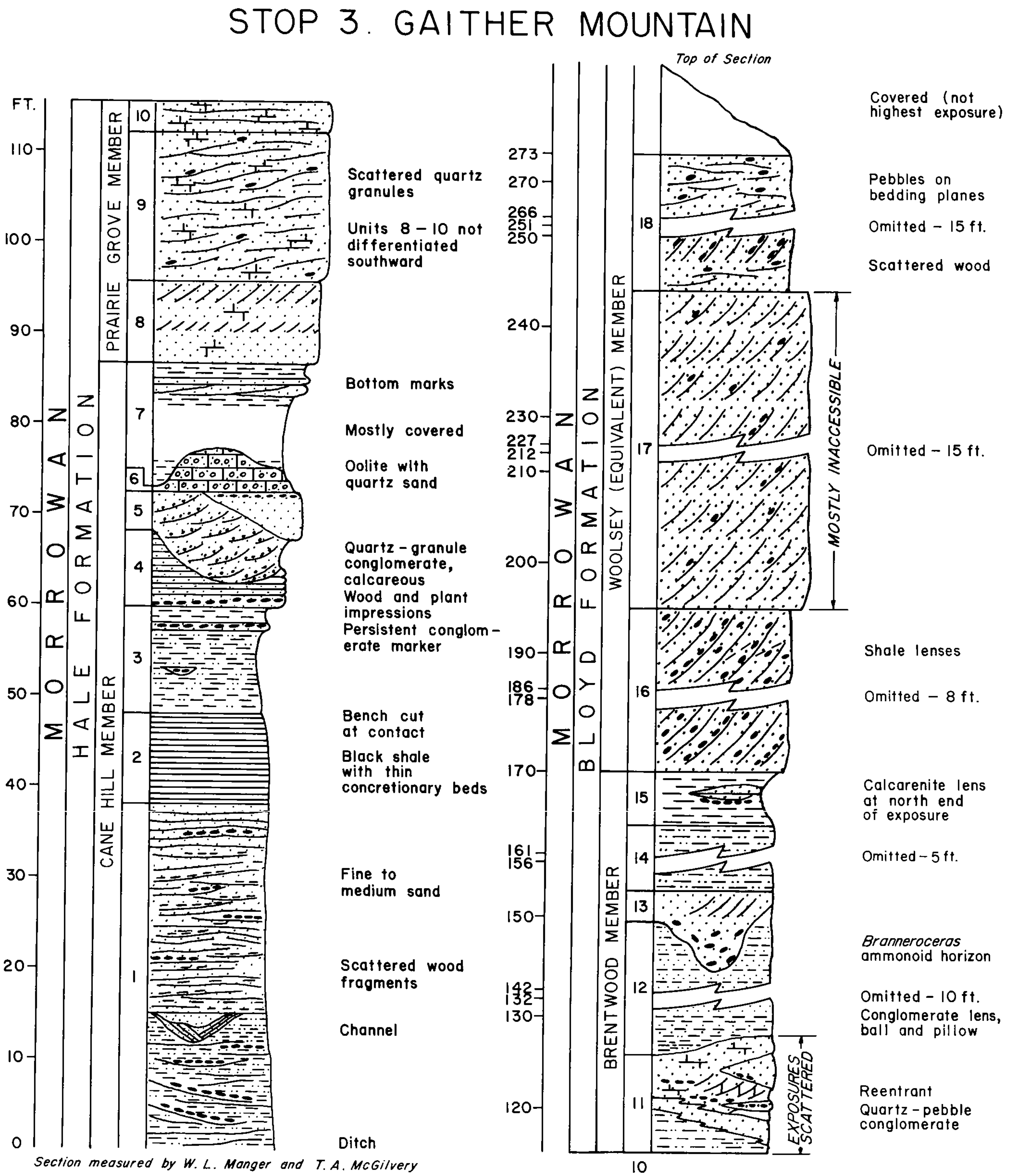


Figure 11. Graphic columnar section for Stop 3.

The assemblage characterized by *Branneroceras branneri*, *Gaitherites morrowensis*, *Gastrioceras fittsi*, and six other taxa was described by McCaleb (1968). The ammonoids occur with an *Idiognathodus sinuosis* conodont assemblage (Lane, 1977). The Gaither Mountain zone is slightly younger than the *Branneroceras* zone that occurs at the top of the type Brentwood with *Neognathodus bassleri* zone conodonts. However, both zones can be correlated to basal Westphalian A of the standard European Carboniferous succession.

Above the Brentwood Member there is a spectacular sandstone bluff equivalent to the Woolsey Member of the type Bloyd succession (figs. 11, 13). This unit was studied by Zachry (1977) and Zachry and Haley (1975). Lithologically, the middle Bloyd sandstone is a fine- to medium-grained quartz arenite with abundant rounded quartz pebbles in the lower part. Large-scale cross-strata and ripple-laminated beds are common (fig. 13). Previously misidentified as the Atoka Formation (Arkansas Geological Survey, 1929), this sand unit has been shown to be a braided-stream system capped by a transgressive marine-beach sequence (Zachry, 1977). The fluvial facies in exposures such as at Gaither Mountain are contemporaneous with the thinner terrestrial shale and coal of the Woolsey Member in the type Morrowan region (Zachry, 1977). The marine transgressive phase ended the Woolsey coastal plain and initiated deposition of the marine Dye Shale Member.

East of Gaither Mountain, the type Morrowan lithostratigraphic nomenclature cannot be used, owing to pronounced changes in the lithologic character of the units. The Cane Hill has been elevated to formation rank, spanning the Mississippian-Pennsylvanian boundary and including the Imo Formation, seen at Stop 1 (Glick and others, 1964); but this proposal has not been widely followed. The strata equivalent to the Prairie Grove Member, Hale Formation, and the entire Bloyd Formation have been combined as the Witts Springs Formation (Glick, and others, 1964). This lithostratigraphic framework is still unsettled but illustrates the problem of correlating units across northern Arkansas because of changes in facies. Some additional comments on stratigraphic nomenclature for this interval are included in the discussion for Stop 1.

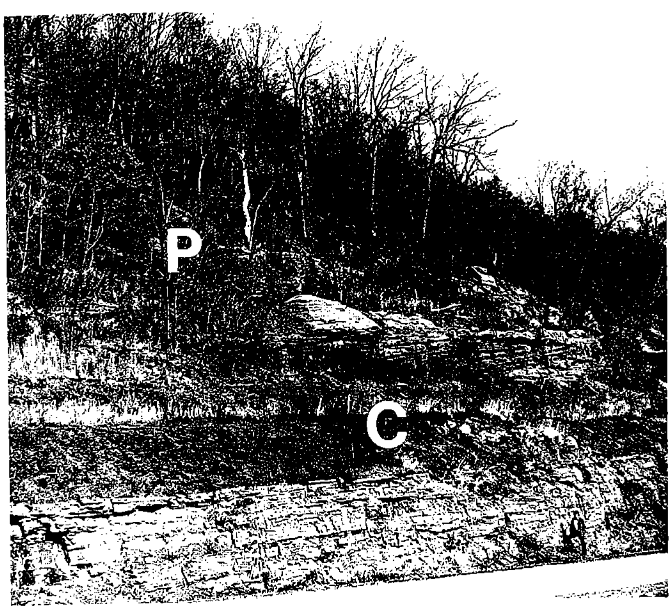


Figure 12. Cane Hill (*C*) and Prairie Grove (*P*) Members of Hale Formation in lower part of Gaither Mountain section (Stop 3).

Figure 13. Upper Brentwood Member and equivalent of Woolsey Member, Bloyd Formation, in upper part of Gaither Mountain section (Stop 3). Well-known ammonoid zone is at lower right, just above road level.

STOP 4—HINDSVILLE SINK

Location: Sinkhole and adjacent hillside on farm approximately ¼ mile north of Arkansas Highway 45, 7 miles east of Goshen and 1 mile southwest of Hindsville. NE¼ SW¼ SW¼ sec. 17, T. 17 N., R. 27 W., Madison County, Arkansas.

Purdue and Miser (1916) named the Hindsville Limestone as a member of the Batesville Formation for exposures of chert-bearing oolitic limestone in the vicinity of Hindsville, Madison County, Arkansas. No type section was designated. In this area, the Hindsville disconformably overlies the Boone Formation (Osagean) and is overlain by the Fayetteville Shale (Chesterian) (fig. 14); it is the only representative of the Batesville, a sandstone. Subsequent investigations have disagreed on the stratigraphic rank assigned to the Hindsville (compare Garner, 1967, and Ogren, 1968). Recent studies by Grayson (1974, 1975, 1976) have demonstrated an intertonguing relationship of the contemporaneous Hindsville and Batesville Formations. Grayson's (1975, 1976) proposal to treat the Hindsville as a separate formation is followed herein.

The Hindsville Formation is predominantly oolite, but four macrofacies can be recognized (Grayson, 1975, 1976). These are: (1) basal mudstone, (2) chert-bearing mudstones and skeletal packstones, (3) skeletal and oolitic grainstones, (4) shaly, skeletal packstone and wackestone. The chert-bearing facies is the most striking and distinctive unit found in the Hindsville (fig. 15). The chert clasts vary from granule to cobble size and are angular to well rounded. The chert was derived from the underlying Boone Formation during pre-Chesterian erosion, although the chert-bearing facies is frequently not the base of the Hindsville. Isolated chert clasts can be found in all macrofacies.

The Hindsville Formation at this locality yields an abundant conodont assemblage characterized by *Cavusgnathus, Gnathodus, Lonchodina,* and rare *Kladognathus* (Grayson, 1974, 1976). This fauna can be assigned to a portion of the

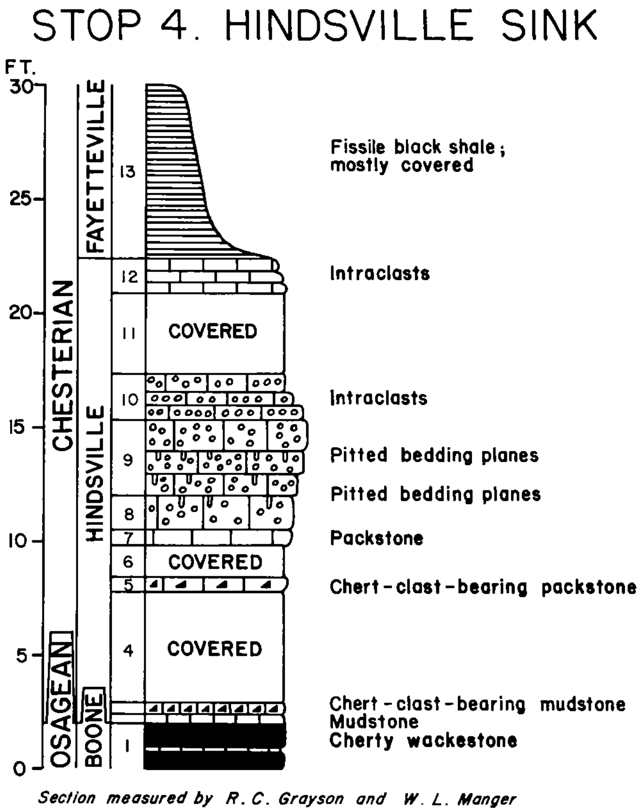


Figure 14. Graphic columnar section for Stop 4.

Figure 15. Crinozoan packstone, bearing chert clasts, characteristic of lower Hindsville Formation. From unit 2, Hindsville Sink section (Stop 4).

Gnathodus bilineatus-Kladognathus mehli Zone of the standard Mississippian section (Collinson and others, 1971). This zone is middle Chesterian and suggests correlation to the Glen Dean Formation of the type Chester sequence. The Hindsville also yields common productid and spiriferid brachiopods, basal cups of the crinoid *Agassizocrinus,* and rare *Archimedes.* Elsewhere, the ammonoids *Goniatites* sp. and *Lusitanites subcircularis* have been recovered from Hindsville strata, supporting the age assignment based on conodonts.

STOP 5—PITKIN QUARRY

Location: Abandoned quarry approximately 200 yards east of U.S. Highway 71, 1.5 miles south of West Fork. NE¼ NW¼ SW¼ sec. 4, T. 14 N., R. 30 W., Washington County, Arkansas.

The Pitkin Limestone was proposed by Adams and Ulrich (1904) to replace the "Archimedes Limestone" of Owen (1858).

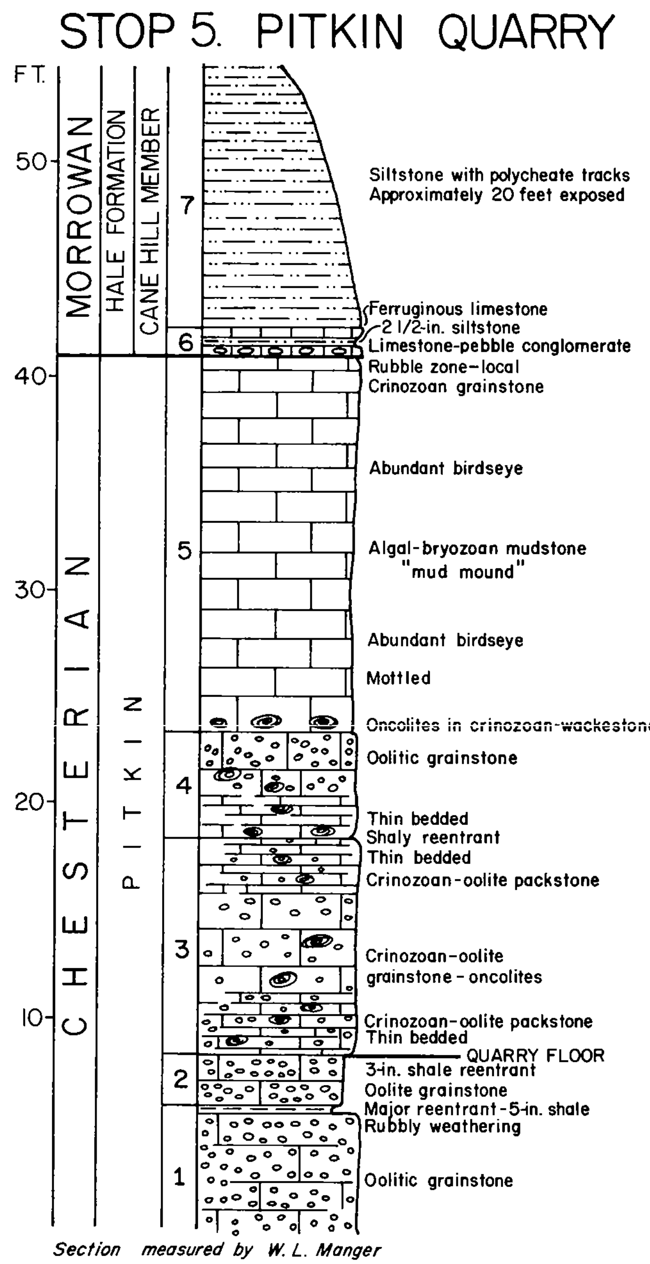


Figure 16. Graphic columnar section for Stop 5.

Figure 17. Pitkin Limestone in quarry face, exhibiting a variety of carbonate facies, overlain by platy siltstone of Cane Hill Member, Hale Formation (Morrowan, *C*). Contact is marked by resistant ledge of sandy, ferruginous conglomerate containing rounded cobbles of Pitkin lithology (arrow). (Stop 5.)

Figure 18. Bedding-plane surface of bed from unit 3 (fig. 16), with abundant axes of the cryptostomous bryozoan *Archimedes*. (Stop 5.)

Henbest (1962a) designated as type this bluff on the east side of the West Fork of the White River at the base of Bloyd Mountain. Two stops (5 and 6) are planned along the type locality to provide an opportunity to examine the lithostratigraphy of the Pitkin and its contacts with adjacent units.

The Pitkin Limestone is a complex of shallow-water, shelf carbonates. Oolitic and crinozoan grainstones predominate, but muddy facies are also present. Dark shale, which is a common component of the formation in north-central Arkansas, is scarce in the type region. At this stop, the lower portion of the Pitkin represents high-energy, wave-base accumulations of oolite and crinozoan detritus (fig. 16). This interval is succeeded by algal-bryozoan mudstones described by Tehan and Warmath (1977) as lime-mud mounds (fig. 16). Mounds of this type are common and characteristic of the Pitkin in northwestern Arkansas. Girvanellid blue-green algae and fenestrate bryozoans are thought to trap carbonate mud in low mounds that expand and are reduced as a reflection of the energy-level changes during accumulation. Crinozoans provide a current baffle that aids in accumulation of mud (Tehan and Warmath, 1977).

The Pitkin-Cane Hill contact (Mississippian-Pennsylvanian boundary) is well exposed at the top of the working face of this quarry (fig. 17). The top of the Pitkin is a rubble zone of highly weathered carbonate and soft clay shale. Overlying this rubble is a thin ferruginous, sandy carbonate and conglomerate bearing rounded cobbles and boulders of typical Pitkin lithology. The conglomerate also contains pebbles of phosphate and pyrite grains. Similar conglomerates mark the base of the Cane Hill elsewhere, even if the Pitkin is absent (e.g., Stop 8). The conglomerate is succeeded by thin-bedded, ripple-marked, essentially unfossiliferous siltstone with polycheate tracks on the upper bedding surfaces. Upper Chesterian fossils are abundant in the Pitkin, particularly the cryptostomous bryozoan *Archimedes wortheni* (fig. 18). The fauna has been described by Easton (1942, 1943), who listed 208 species dominated by bryozoans, brachiopods, and molluscans.

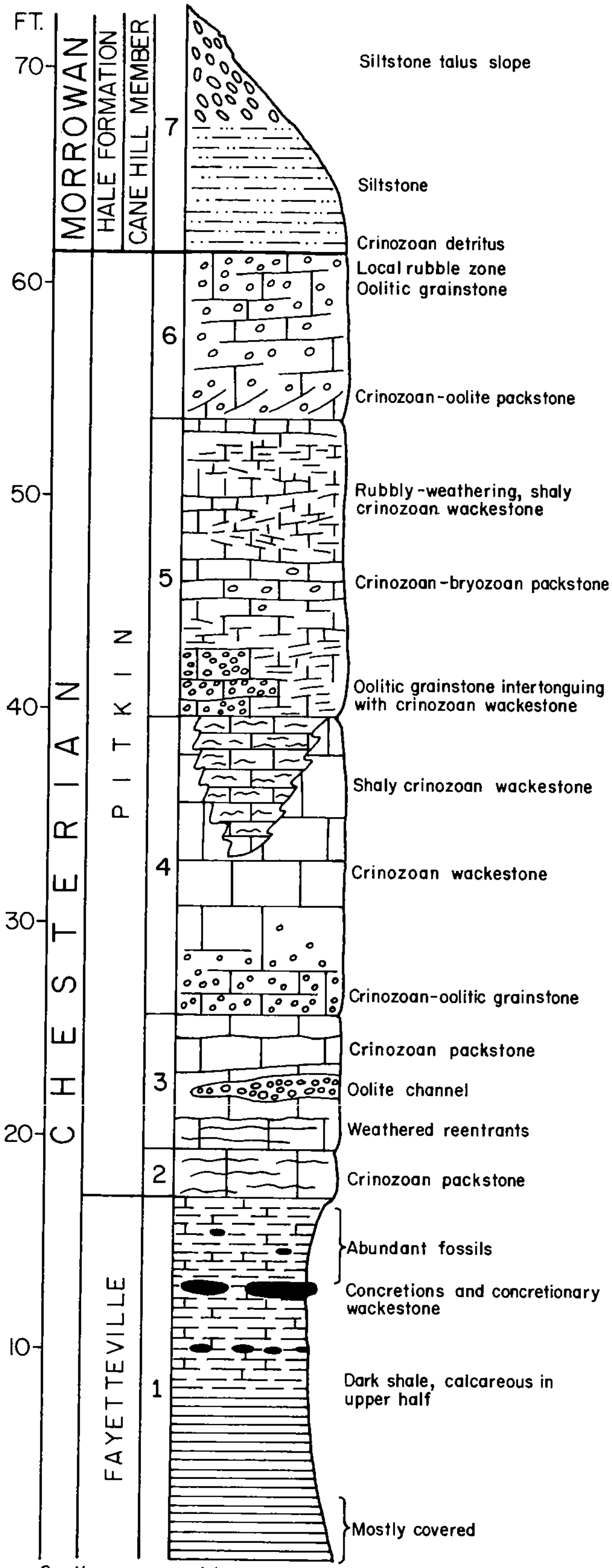
Conodonts obtained from the upper Pitkin in northwestern Arkansas are referable to the *Kladognathus-Cavusgnathus naviculus* Zone of the standard Chesterian succession (Lane, 1967; Lane and Straka, 1974). This occurrence indicates that the top of the type Pitkin is older here than in north-central Arkansas (Stop 1), presumably because of increased pre-Cane Hill erosion. Mamet Zone 19 foraminifers occur in abundance in the Pitkin (Brenckle, 1977), but no ammonoids have been recovered from exposures in northwestern Arkansas.

STOP 6—PITKIN BLUFF

Location: West-facing bluff on east side of U.S. Highway 71, 1.8 miles south of West Fork. NE¼ SW¼ SW¼ sec. 4, T. 14 N., R. 30 W., Washington County, Arkansas.

The Pitkin-Fayetteville contact and adjacent strata are well exposed at this locality, which is still within the type Pitkin bluff. The uppermost Fayetteville Formation contains calcareous shale with lenses and nodules of carbonate (figs. 19, 20). The entire interval is highly fossiliferous, being dominated by shelly fauna. This occurrence is in marked contrast to other Fayetteville exposures in northern Arkansas of

STOP 6 - PITKIN BLUFF



Section measured by W. L. Manger

Figure 19. Graphic columnar section for Stop 6.

dark to black shale and dense concretions yielding only a pelagic fauna, predominantly cephalopods. Knowledge of Fayetteville faunal elements, except for cephalopods, is based primarily on occurrences near the base of the unit. Some of these belong lithostratigraphically to the underlying Hindsville Formation (Chesterian). The fossils at this stop have not been studied in detail, although Brenckle (1977) recovered calcareous foraminifers similar to those of the Pitkin from the uppermost Fayetteville shale. The Fayetteville is succeeded by the Pitkin Limestone, with a sharp but apparently conformable contact.

The Fayetteville Formation has been correlated with the Pendleian Stage (E_1) of the standard Namurian succession, based on its cravenoceratid-eumorphoceratid cephalopod assemblage (Saunders and others, 1977).

The Pitkin Limestone is similar though not identical to exposures at Stop 5. No mud mounds are present here, and rubbly-weathering carbonates with shale partings are more commonly developed (fig. 20). Oolitic- and crinozoan-dominated lithologies are similar to those previously seen.

The Cane Hill Member of the Hale Formation exhibits characteristic siltstone lithology, which may rest directly on the Pitkin without conglomerate development in this immediate area.

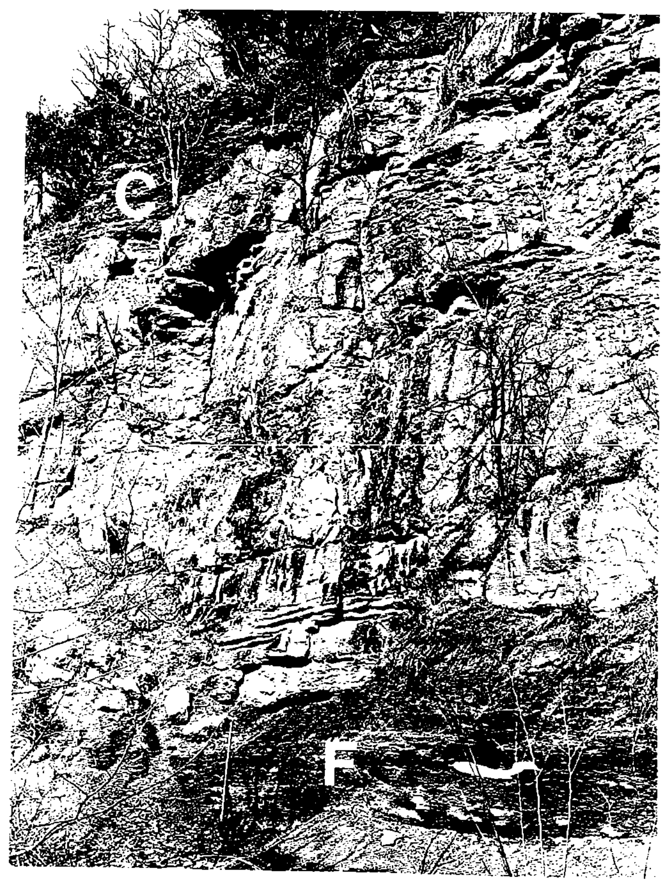


Figure 20. Fossiliferous calcareous shale and carbonate lenses in upper Fayetteville Formation (*F*), overlain by massive Pitkin Limestone. Cane Hill Member of Hale Formation (Morrowan, *C*) rests unconformably on Pitkin at top of bluff. (Stop 6.)

STOP 7—TYPE BRENTWOOD

Location: Bluff exposed on northwest corner of Bloyd Mountain, east side of U.S. Highway 71, approximately 2.1 miles south of West Fork. SW¼ NE¼ sec. 16, T. 14 N., R. 30 W., Washington County, Arkansas.

These exposures on the east side of Highway 71 were designated the type section for the Brentwood Limestone Member, basal Bloyd Formation (Morrowan), by Henbest (1962a). The unit is represented by an alternation of dark, quartz-sand-bearing crinozoan grainstones and dark shales (figs. 21, 22). The Brentwood overlies the Prairie Grove Member of the Hale Formation conformably and is overlain by the Woolsey Member of the Bloyd Formation with apparent unconformity (fig. 23).

The Brentwood Limestone Member was originally described as the "Pentremital Limestone" by Owen (1858). The abundance of this echinoderm influenced correlation of the interval with the Chesterian until well past the turn of the century. Blastoids occur in profusion in local lenses through northern Arkansas and eastern Oklahoma. They are not abundant at this locality, but large collections of well-preserved specimens can be made from equivalent strata in the upper Braggs Member of the Sausbee Formation at Stop 15. The blastoid *Pentremites rusticus* is the only species recognized in Morrowan strata of this region (Horowitz and Macurda, 1977; Katz and Sprinkle, 1977). Crinoids are common in the Brentwood Member. *Arkacrinus* and *Metacromyocrinus* are common, the latter taxon being recognizable from disarticulated plates by its characteristic ornament. The assemblage is well known through the report by Moore and Strimple (1973). Occurrences are summarized by Strimple (1977).

Biostratigraphic studies of the Brentwood Limestone Member have concentrated on ammonoids, conodonts, and brachiopods. The contact of the Prairie Grove Member of the Hale Formation and the Brentwood is gradational both lithostratigraphically and faunally. Zones based on sensitive taxa span the lithostratigraphic boundary without change. Thousands of ammonoids have been collected from the Brentwood Member throughout northern Arkansas. The most distinctive member of the Brentwood assemblage is *Branneroceras branneri*, which, with the appearance of true *Gastrioceras*, marks the beginning of Westphalian A (G_2). The *Branneroceras* zone occurs in the upper half of the member at this locality (McCaleb, 1968). Consequently, the Namurian-Westphalian boundary falls within the Brentwood Member. The basal part of the Member contains the *Verneuilites-Cancelloceras* assemblage also characteristic of the top of the Prairie Grove Member of the Hale Formation (Saunders and others, 1977). The diverse ammonoid assemblage from the Brentwood was monographed by McCaleb (1968).

The Brentwood Member begins in the *Neognathodus symmetricus* conodont Zone and ranges through a part of the *Idiognathodus sinuosis* Zone of Lane and Straka (1974). At this locality, the top of the Brentwood falls within the *Neognathodus bassleri* Zone, but regionally it may become as young as the *Idiognathodus sinuosis* Zone (Lane and Straka, 1974), as can be seen at the Evansville Mountain section (Stop 9).

Brachiopods of the upper Prairie Grove and the Brentwood fall within the *Plicochonetes*? *arkansanus* Zone of Henry and Sutherland (1977). In addition to the name bearer, species of *Beecheria, Rhynchopora, Tesuquea, Linoproductus, Echinaria,* and *Anthracospirifer* are common.

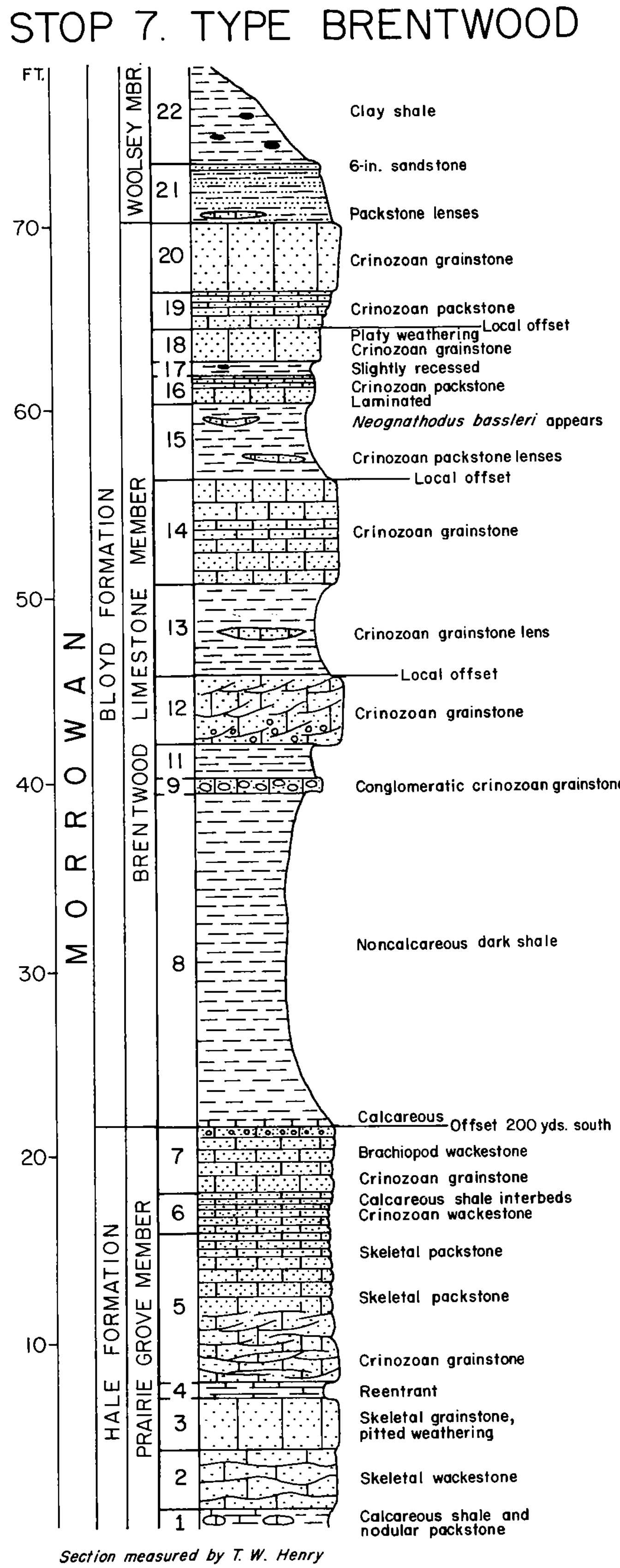


Figure 21. Graphic columnar section for Stop 7.

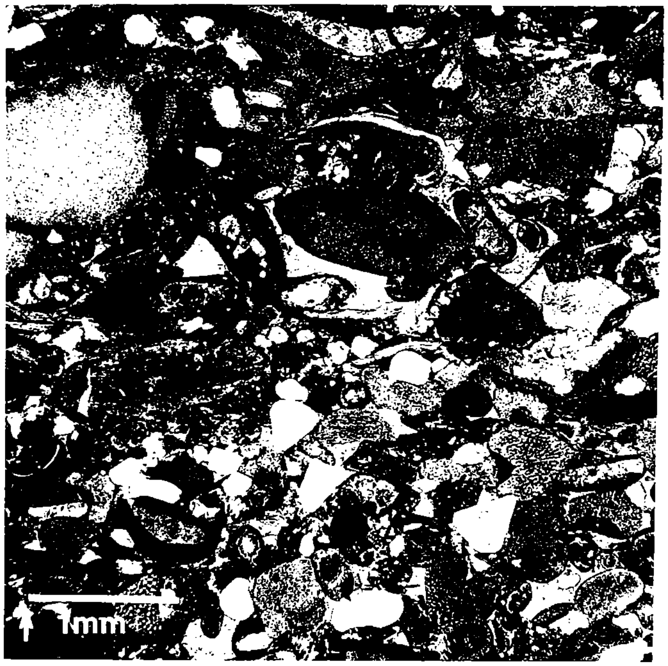


Figure 22. Bryozoan-crinozoan grainstone bearing quartz sand from base of unit 12 (fig. 21) at type Brentwood (Stop 7). This lithology is also typical of underlying Prairie Grove Member, Hale Formation.

Figure 23. Upper Prairie Grove Member (*PG*), Hale Formation, succeeded conformably by dark shales and sandy crinozoan grainstones of type Brentwood Limestone Member, Bloyd Formation. Highest part of this bluff exposes shale of Woolsey Member (*W*), Bloyd Formation. (Stop 7.)

STOP 8—FAYETTEVILLE RAILROAD CUT

Location: Exposure in east of St. Louis and San Francisco railroad cut, beginning approximately 60 yards north of Maple Street bridge and extending to Lafayette Street bridge, near east side of University of Arkansas campus, Fayetteville. SE¼ SW¼ sec. 9 and NW¼ NE¼ sec. 16, T. 16 N., R. 30 W., Washington County, Arkansas.

A cut for the St. Louis and San Francisco Railroad through the city of Fayetteville has been a well-known and important fossil locality for more than 10 years. Here, strata of the Cane Hill Member of the Hale Formation rest unconformably on black shale of the upper Fayetteville Formation (figs. 24, 25). The Pitkin Formation has been removed by erosion, and its former presence is indicated only by rounded cobbles of characteristic lithologies in a basal Cane Hill conglomerate (figs. 25, 26). The Fayetteville Shale at this locality yields a typical lower Namurian-upper Chesterian palynomorph assemblage (James Urban, University of Texas-Dallas, per-

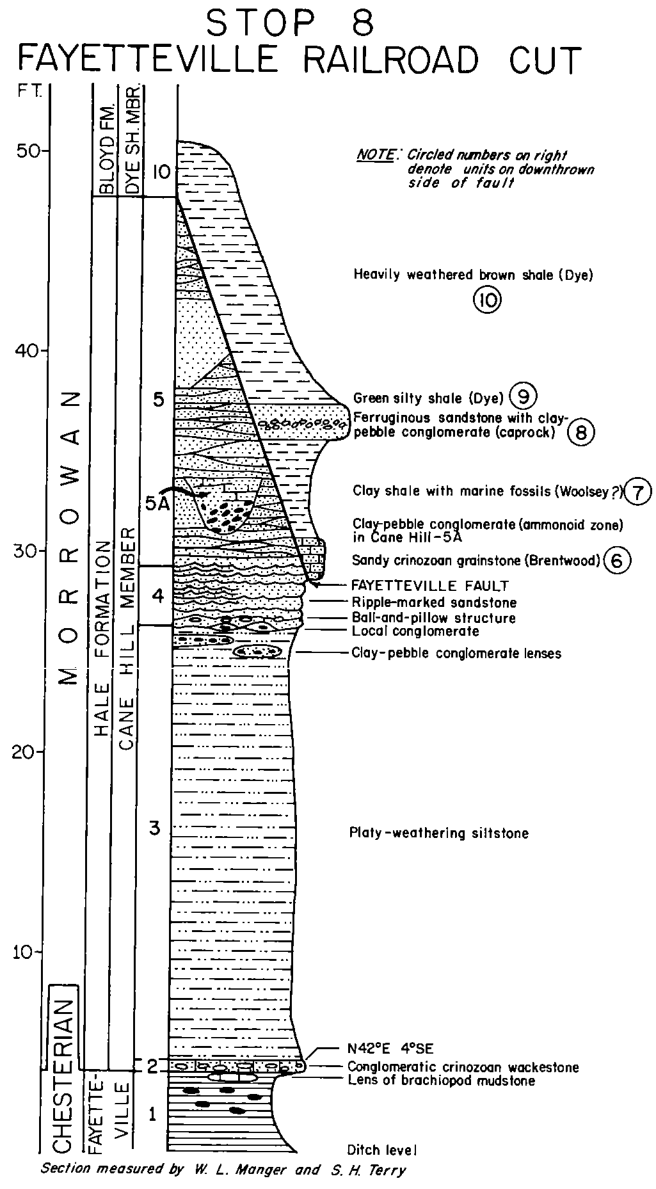


Figure 24. Graphic columnar section for Stop 8.

sonal communication). However, the basal Cane Hill conglomerate and succeeding siltstone are devoid of biostratigraphically sensitive fossils. Similar conditions also have been seen at the Pitkin quarry (Stop 5) and are common elsewhere, precluding precise biostratigraphic definition of the Mississippian-Pennsylvanian boundary in northwestern Arkansas.

The basal Cane Hill conglomerate is overlain by approximately 22 feet of unfossiliferous, ripple-marked siltstone with shale partings similar to the lithology seen at the Pitkin quarry (Stop 5) (fig. 16). This siltstone is succeeded by irregularly bedded, fine- to medium-grained sandstone, which is also unfossiliferous for the most part. However, within this sandstone succession is a lens of highly fossiliferous, calcareous, clay-pebble conglomerate with a quartz-sand matrix. This lens yields a rich assemblage of ammonoid cephalopods characterized by the index taxa *Retites semiretia, Reticuloceras tiro, Reticuloceras wainwrighti,* and *Hudsonoceras moorei.* These and other Cane Hill ammonoid taxa have been described in papers by Gordon (1965, 1969), McCaleb (1964), Quinn (1966), and Quinn and Saunders (1968). The ammonoid assemblage provides precise correlation to zone R_1a of the Kinderscoutian Stage, Namurian Series, of Europe (Saunders and others, 1977). This ammonoid zone also represents the lowest occurrence of biostratigraphically sensitive fossils in type Morrowan strata.

Conodonts of the *Rhachistognathus primus* Zone of Lane and Straka (1974) have been recovered from the ammonoid-bearing lens (Straka, 1972; erroneously reported as basal Cane Hill). This assemblage zone is regarded by Lane (Lane and Straka, 1974; Lane, 1977) as equivalent to parts of the *Homoceras* interval (Chokierian and Alportian Stages H_1-H_2) of Europe in apparent conflict with the correlations based on ammonoids. The lens also yields a diverse fauna of other invertebrates.

The Fayetteville Fault, a major northeast-trending lineament, intersects the south end of the exposure. The fault is downthrown to the southeast and brings Brentwood through Dye strata of the Bloyd Formation into juxtaposition with the Cane Hill Member of the Hale Formation (fig. 24).

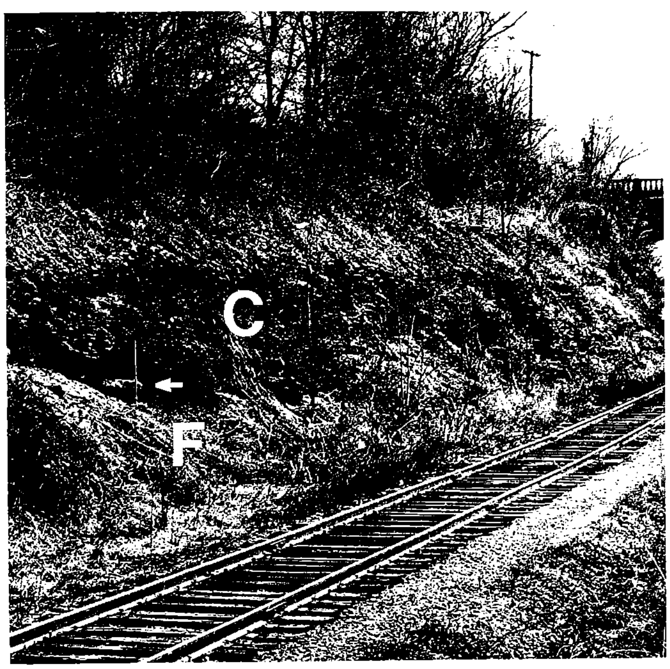


Figure 25. Unconformable contact of Chesterian Fayetteville Formation (*F*) and Morrowan Cane Hill Member (*C*) of Hale Formation. Contact is marked by thin basal conglomerate (arrow), succeeded by platy-weathering siltstone. Jacob staff is 5 feet long. (Stop 8.)

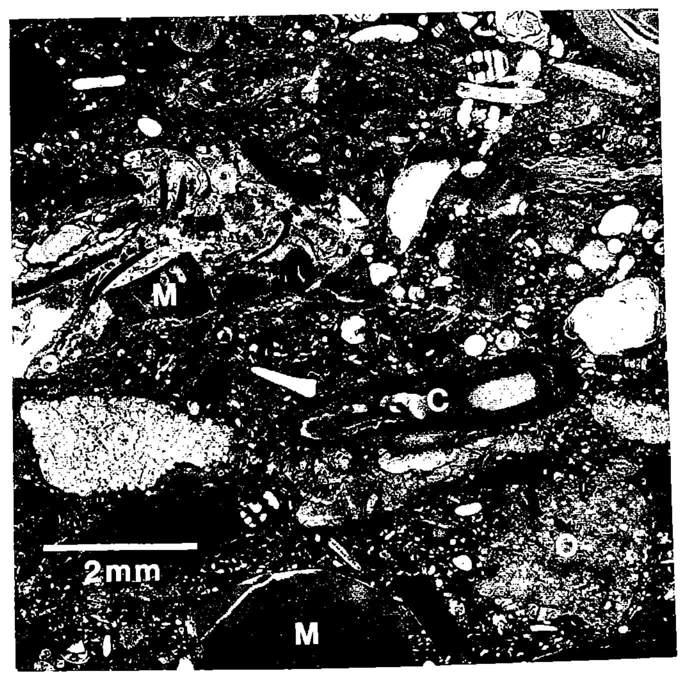


Figure 26. Polished slab of basal Cane Hill conglomerate from horizon shown in figure 25. Conglomerate consists of rounded micritic (*M*), oolitic (*O*), and concretionary (*C*) clasts of Pitkin and Fayetteville Formations in a matrix of crinozoan grainstone bearing quartz sand. (Stop 8.)

STOP DESCRIPTIONS—SECOND DAY

Patrick K. Sutherland

SUMMARY

The second day of the trip (fig. 27) examines primarily Chesterian and Morrowan stratigraphy in northeastern Oklahoma. Of particular interest are: (1) lateral variations in character and thickness of the Chesterian Pitkin Formation, (2) the Mississippian-Pennsylvanian unconformity at three localities, (3) the famous Evansville Mountain section, southwesternmost Washington County, Arkansas, which exposes the complete Morrowan sequence and is considered the single most important reference section for the type Morrowan Series, and (4) the new Morrowan formations described by Sutherland and Henry (1977a) in the more predominantly carbonate facies of Cherokee, Muskogee, and Sequoyah Counties, Oklahoma.

STOPS 9A, 9B, 9C—EVANSVILLE MOUNTAIN

Location: Road cuts on west side of Arkansas Highway 59, extending from 2.7 to 4.0 miles south of Evansville, Arkansas. S½ sec. 26 and sec. 35, T. 13 N., R. 33 W., Washington County, Arkansas.

This section is exposed in a series of cuts and natural exposures along Arkansas Highway 59, beginning with the top

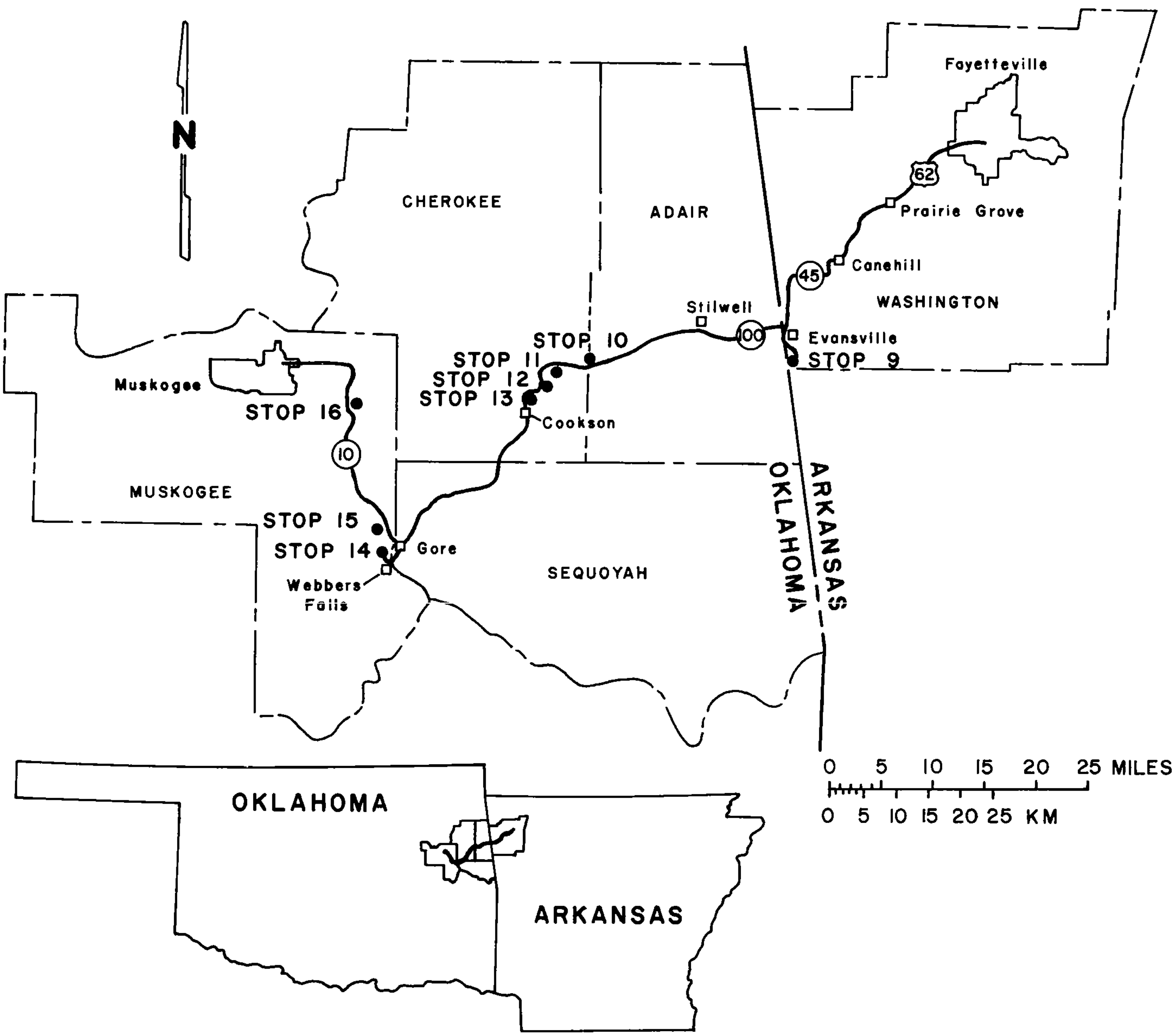


Figure 27. Locality and route map, second day.

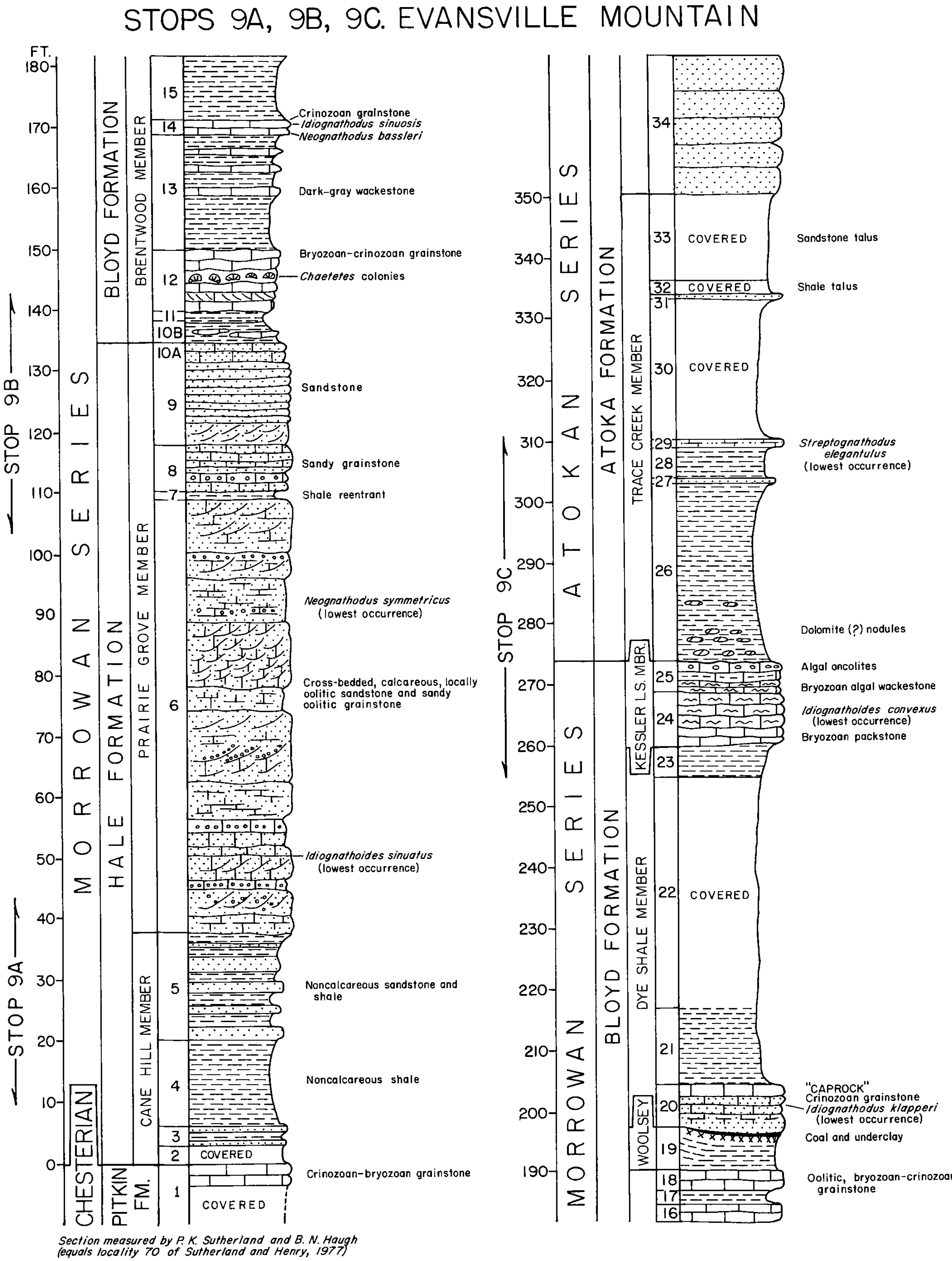


Figure 28. Graphic columnar section for Stops 9A, 9B, and 9C.

of the Pitkin Limestone, 100 feet north of the Washington-Crawford County line and continuing northward for 1.3 miles along the road to the Kessler Limestone, at the crest of the gap.

The type localities for the various formations and members of the Morrow Group are scattered in Washington County, Arkansas, but the Evansville Mountain section constitutes, for all practical purposes, the primary overall reference section for the Morrowan Series (Henbest, 1953, 1962a). All the Morrowan units are well exposed except for the middle part of the Dye Shale. Henbest (1962a) designated the Evansville Mountain sequence as the type section for both the Cane Hill and the Prairie Grove Members of the Hale Formation.

At Evansville Mountain, the Morrow Group is 270.5 feet thick, the Hale Formation, 136.5 feet thick, and the Bloyd Formation, 134 feet thick.

Figure 29. Interbedded shales and sandstones in upper part of Cane Hill Member of Hale Formation at its type locality. Base of Prairie Grove Member of Hale is exposed at top of cut. Photo shows units 4 and 5 and base of unit 6. (Stop 9A.)

The Evansville Mountain section begins at the top of the Pitkin Limestone, but that unit is poorly exposed at this locality as is the lower few feet of the Cane Hill Member of the Hale Formation. At Stop 9A (fig. 28) the middle and upper parts of the Cane Hill (type locality) are well exposed (fig. 29). The sandstone layers in the upper part of the Cane Hill are typically noncalcareous (unit 5). At this outcrop, the contact between the Cane Hill and the overlying calcareous sandstones of the Prairie Grove appear to be gradational. However, at an exposure of the contact in a road cut 0.2 mile to the north the contact appears to be unconformable.

The middle part of the Prairie Grove (unit 6) is exposed in a series of road cuts between Stops 9A and 9B. These exhibit the typical massive bedding, local large-scale cross-bedding, and the pitted, "honeycombed" weathered surfaces that are characteristic of the unit (fig. 30). These rocks are composed of complexly interbedded calcareous sandstones and quartz-sandy crinozoan grainstones, all locally oolitic.

At Stop 9B, the sequence is continually exposed from the top of unit 6 to the top of unit 12 (fig. 28). This interval includes the upper Prairie Grove Member (fig. 31) and the lower part of the Brentwood Limestone Member of the Bloyd Formation (fig. 32). Deposition was continuous from the Prairie Grove (Hale) to the Brentwood (Bloyd). The top of the Prairie Grove Member is marked throughout Washington County by the uppermost thick-bedded calcareous sandstones or quartz-sandy grainstones. The Brentwood Limestone Member is characterized in the county by limestones with lower quartz-sand content and by the first appearance, above the base of the Prairie Grove Member, of shale beds that are more than 2 feet thick. As a consequence of the latter feature, the Brentwood in Washington County does not form the kind of distinctive cliffs characteristic of the Prairie Grove Member. These distinctions cannot be made to the west in Oklahoma, where prominent shales occur much lower stratigraphically (see Stop 14).

The lower part of the Brentwood at Stop 9B consists of

Figure 30. Prairie Grove Member of Hale Formation, showing typical massive cliffs that weather with pitted and "honeycombed" surfaces; upper part of unit 6. (Between Stops 9A and 9B.)

Figure 31. Upper Prairie Grove Member of Hale Formation; units 6 (top) to 9. (Stop 9B.)

laterally changing thin to medium-bedded layers of grainstones and packstones (units 10B, 11, 12). A distinctive local feature is the occurrence of a bed composed of colonies of *Chaetetes* (fig. 33), a problematical organism traditionally considered to be a tabulate coral.

The nonmarine Woolsey Member of the Bloyd (fig. 28) is only 6.2 feet thick at Evansville Mountain and is observable only by digging. A thin coal, 0.2-foot thick, occurs locally at the top of the unit, directly overlain unconformably by the sandstones and sandy grainstones (Henbest, 1953, "caprock of the Baldwin coal") that form a basal transgressive marine unit of the Dye Shale Member of the Bloyd.

At Stop 9C, the sequence is well exposed from the top of unit 23 to unit 29. Of particular interest here is the Kessler Limestone Member of the Bloyd. This unit is highly variable in character in Washington County. It is characteristically micritic but varies from skeletal wackestones and packstones to oolitic grainstones. At Evansville Mountain, there is a distinctive interval of algal oncolites near the top of the unit.

The contact between the Kessler Limestone and the overlying Trace Creek Shale is sharp and undulating (fig. 34), and is believed to be unconformable. Sutherland and Grayson (1978) reported the occurrence of a conglomerate at the base of the Trace Creek at other localities in Washington and Adair Counties. Those authors have found Atoka conodonts within 3 feet of the base of the Trace Creek elsewhere in Washington County, and the distinctive Atokan species *Streptognathodus elegantulus* has been recovered at Evansville Mountain from unit 29. Sutherland and Grayson (1978) shifted the Trace Creek Shale Member from the Bloyd to the Atoka Formation (fig. 28).

At Stop 9C, the lower part of the Trace Creek Shale is well exposed (units 26-29). There are dolomitic or sideritic(?) nodules in the lower 9 feet of these noncalcareous shales. The upper part of unit 26, and higher units, can be examined along a steep, unpaved road that intersects Arkansas Highway 59 from the east, at Stop 9. On figure 28, the covered interval at the top of the section (unit 33) has been arbitrarily included in the Trace Creek.

Figure 32. Top part of Prairie Grove Member of Hale Formation and lower part of Brentwood Limestone Member of Bloyd Formation; units 10 and 11. (Stop 9B.)

Figure 33. *Chaetetes* colonies (at hammer) in Brentwood Limestone Member of Bloyd Formation; unit 12. (Stop 9B.)

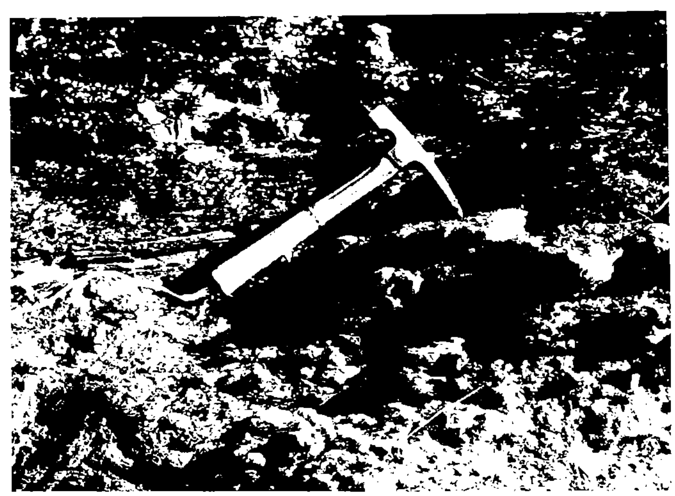


Figure 34. Unconformable contact between upper Kessler Limestone Member of Bloyd Formation and lower Trace Creek Shale Member of Atoka Formation. (Stop 9C.)

STOP 10—ADAIR-CHEROKEE COUNTY LINE

Location: Each side of east-west road cut on Oklahoma Highway 100, on Adair-Cherokee County line, 11.2 miles west of junction with U.S. Highway 59 in Stilwell. Near C W. line, sec. 19, T. 15 N., R. 24 E., Adair County, Oklahoma.

The upper part of the Fayetteville, the whole of the Pitkin, and the base of the Sausbee Formations are continuously exposed in this road cut (figs. 35, 36). The Fayetteville Formation in this area consists almost exclusively of dark-gray to black shale, and the contact with the overlying Pitkin is sharp but apparently conformable. This contrasts with the sections at Stop 2 in Searcy County, Arkansas, and Stop 16, in Muskogee County, Oklahoma, where the upper Fayetteville contains interbedded carbonate mudstones, oolitic grainstones (Stop 16 only), and black shale.

The Pitkin consists predominantly of interbedded carbonate

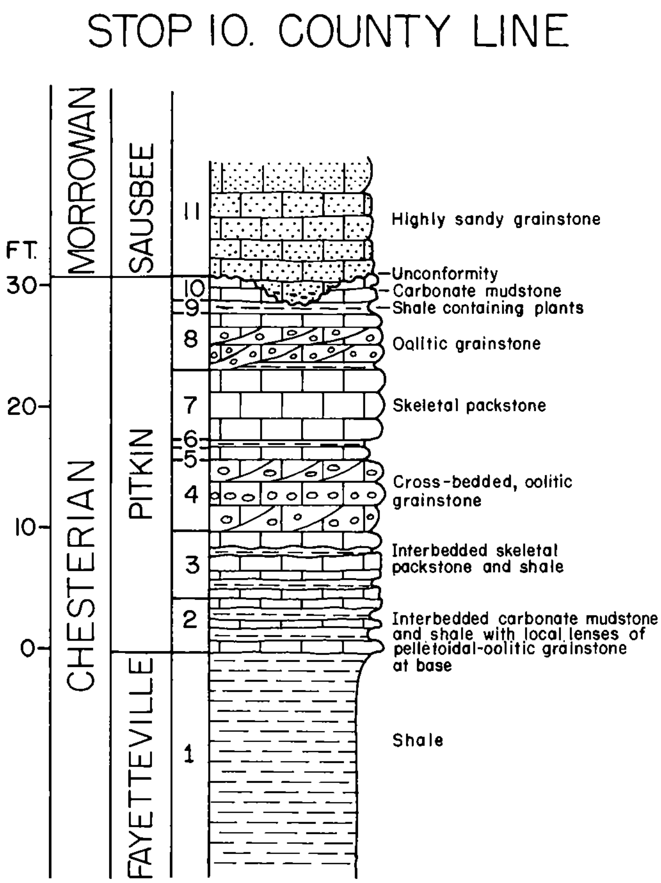


Figure 35. Graphic columnar section for Stop 10.

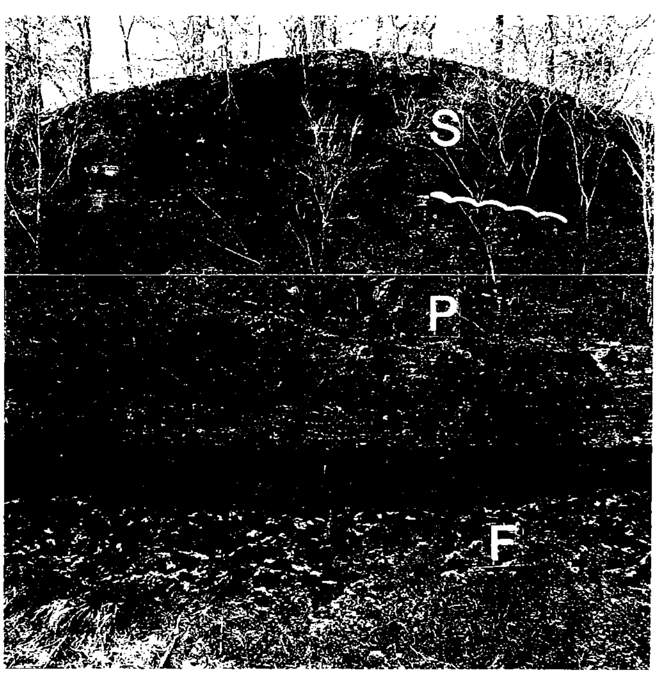


Figure 36. Fayetteville Shale (*F*), upper part; Pitkin Limestone (*P*); Sausbee Formation (*S*), Braggs Member, basal part. Man points to Mississippian-Pennsylvanian unconformity. Bed 10 (see fig. 35), to left of man, is cut out by unconformity. (Stop 10.)

mudstone and shale at the base, grading upward into cross-bedded, oolitic grainstone and skeletal packstone. The formation is locally highly fossiliferous. Bedding-plane surfaces in the upper part of unit 3 (found on top of bench north of highway) contain numerous brachiopods and bryozoans. Unit 9, a thin shale near the top of the Pitkin at this locality, contains plant fossils (south side of highway).

The unconformable Pitkin-Sausbee (Mississippian-Pennsylvanian) contact can be observed on the steep bluff on the south side of the highway. Unit 10, a carbonate mudstone at the top of the Pitkin, is cut out laterally in the road cut by the unconformity.

The Pitkin Formation is only 31.0 feet thick at this locality and is missing (owing to pre-Morrowan erosion) only 7 miles to the north.

The lowermost Sausbee Formation at this locality consists of highly sandy skeletal grainstone with an irregularly distributed conglomerate at the base.

STOP 11—FISHING DOCK

Location: Natural exposure near bank of Tenkiller Ferry Lake, on narrow Dry Creek arm, at Caney Ridge Fishing Dock. About 0.1 mile south of point on Oklahoma Highway 100, 0.6 mile northeast of junction with Oklahoma Highway 82 just southeast of major steel bridge over northern end of Tenkiller Ferry Lake. SE¼ NW¼ sec. 20, T. 15 N., R. 23 E., Cherokee County, Oklahoma.

At this locality the top 5 feet of the Greenleaf Lake Limestone Member of the McCully Formation (=Kessler Limestone Member of Bloyd Formation of Arkansas) is overlain unconformably by shales and sandstones of the Atoka Formation (fig. 37).

At Evansville Mountain (Stop 9C) the Kessler Limestone is overlain by the Trace Creek Shale Member of the Atoka Formation, with only limited evidence of erosion at the top of the Kessler. At Stop 11, 18.5 miles to the west, the limestone shows major evidence of erosion (fig. 38) with several feet of local relief on the surface. The limestone is a carbonate mudstone that shows apparent pseudobrecciation and redeposition in a partly silty matrix. The only megafossils observed in the limestone are solitary corals.

The basal Atoka Formation at this locality consists of 1.5 to

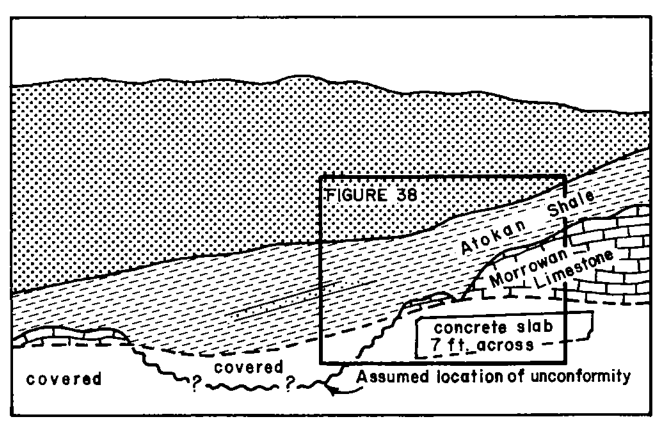


Figure 37. Sketch of unconformity between Greenleaf Lake Limestone Member of McCully Formation, below (limestone), and Atoka Formation. (Stop 11.)

6.0 feet of gray shale, which has irregularly distributed concretions and poorly sorted sandstone lenses in the lower part. The shale was deposited irregularly into the solution crevases of the underlying limestone surface. The shale is overlain by thick-bedded, fine-grained sandstone.

This locality is of interest, since it demonstrates the unconformable nature of the Morrowan-Atokan boundary in this area. Farther to the west and northwest many exposures show this unconformable relationship (Sutherland and Manger, 1977, p. 36, fig. 3), and the entire Morrowan sequence is truncated by the basal Atoka unconformity 40 miles to the northwest, in T. 20 N.

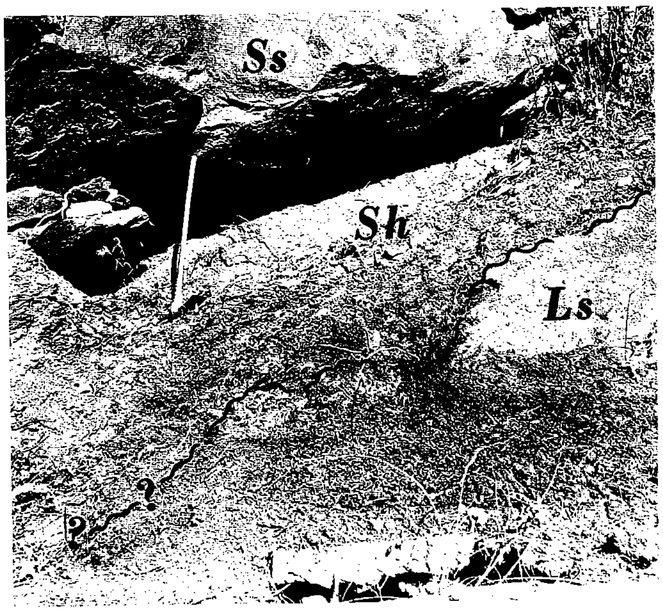


Figure 38. Closeup of Morrowan-Atokan unconformity, as outlined in figure 37. (Stop 11.)

STOP 12—ELK CREEK

Location: North side of Elk Creek near steel-girder bridge on Oklahoma Highway 82, 2.2 miles south of junction with Oklahoma Highway 100. NW¼ SE¼ sec. 31, T. 15 N., R. 23 E., Cherokee County, Oklahoma.

STOP 13—COOKSON

Location: Road cuts on east side of Oklahoma Highway 82, 0.4 to 0.6 mile north of village of Cookson, Oklahoma; beginning in ditch opposite entrance to Fort Chickamauga and extending for ¼ mile southwestward to top of hill. SE¼ sec. 1, T. 14 N., R. 22 E., Cherokee County, Oklahoma.

The Elk Creek (Stop 12) and Cookson (Stop 13) sections, 1.2 miles apart, together form an important reference section for the northern Lake Tenkiller Reservoir area (fig. 39). They are 25 miles west of Evansville Mountain (fig. 28) and 23 miles northeast of the type section for the new formations proposed by Sutherland and Henry (1977a), at the Webbers Falls Lock and Dam on the Arkansas River (Stop 14).

The Elk Creek section is on the north side of Elk Creek. Units 1-4 were measured east of the highway, and the section begins at the top of a river bluff formed by the Hindsville Limestone, about 300 yards upstream, to the east of the bridge. Units 6 through 11 were measured in road cuts and natural exposures west of the highway up to 0.2 mile north of the bridge.

At Stop 12, the Pitkin Limestone is missing, and the Sausbee Formation rests directly on the weathered surface of the Fayetteville Formation. A 1- to 2-foot regolith is preserved at the top of the Fayetteville. The irregularity of the pre-Pennsylvanian erosional surface in this area is shown by the presence of the Pitkin Limestone no more than 0.4 mile to the north.

A 0.2-foot shaly coal and underclay is present at the base of the Braggs Member of the Sausbee Formation, overlain by a thick sequence of fine-grained, well-sorted, cross-bedded sandstone, equivalent to some part of the lower Prairie Grove Member of the Hale Formation in Arkansas.

No equivalent of the Cane Hill shale (Hale Formation) occurs west of central Adair County, nor has the conodont zone *Rachistognathus primus* been found in northeastern Oklahoma.

The correlation of the upper part of the Elk Creek with the lower part of the Cookson section is based partly on general lithologic similarity but more importantly on the lowest occurrences in both sequences of two important conodont form-species, *Neognathodus symmetricus* and *Neognathodus bassleri*. Using the base of the *N. symmetricus* zone as a datum gives a composite thickness of 209 feet for the Morrow Group in this area.

The Braggs Member of the Sausbee at Elk Creek and Cookson is equivalent to the Prairie Grove Member of the Hale and the lower part of the Brentwood Limestone Member of the Bloyd at Evansville. Thick shales occur much lower stratigraphically at Cookson than at Evansville (compare figs. 39 and 28).

The Brewer Bend Limestone Member of the Sausbee, which consists primarily of algal wackestones, is the most distinctive lithologic unit in the Morrowan in northeastern Oklahoma (fig. 40). At this locality, it is characterized by the occurrence of the colonial rugose coral *Petalaxis*. In the northern Tenkiller Reservoir area these colonies are invariably found in growth position.

Figure 40. Algal wackestone of Brewer Bend Limestone Member of Sausbee Formation. Shown are units 16-21. (Stop 13.)

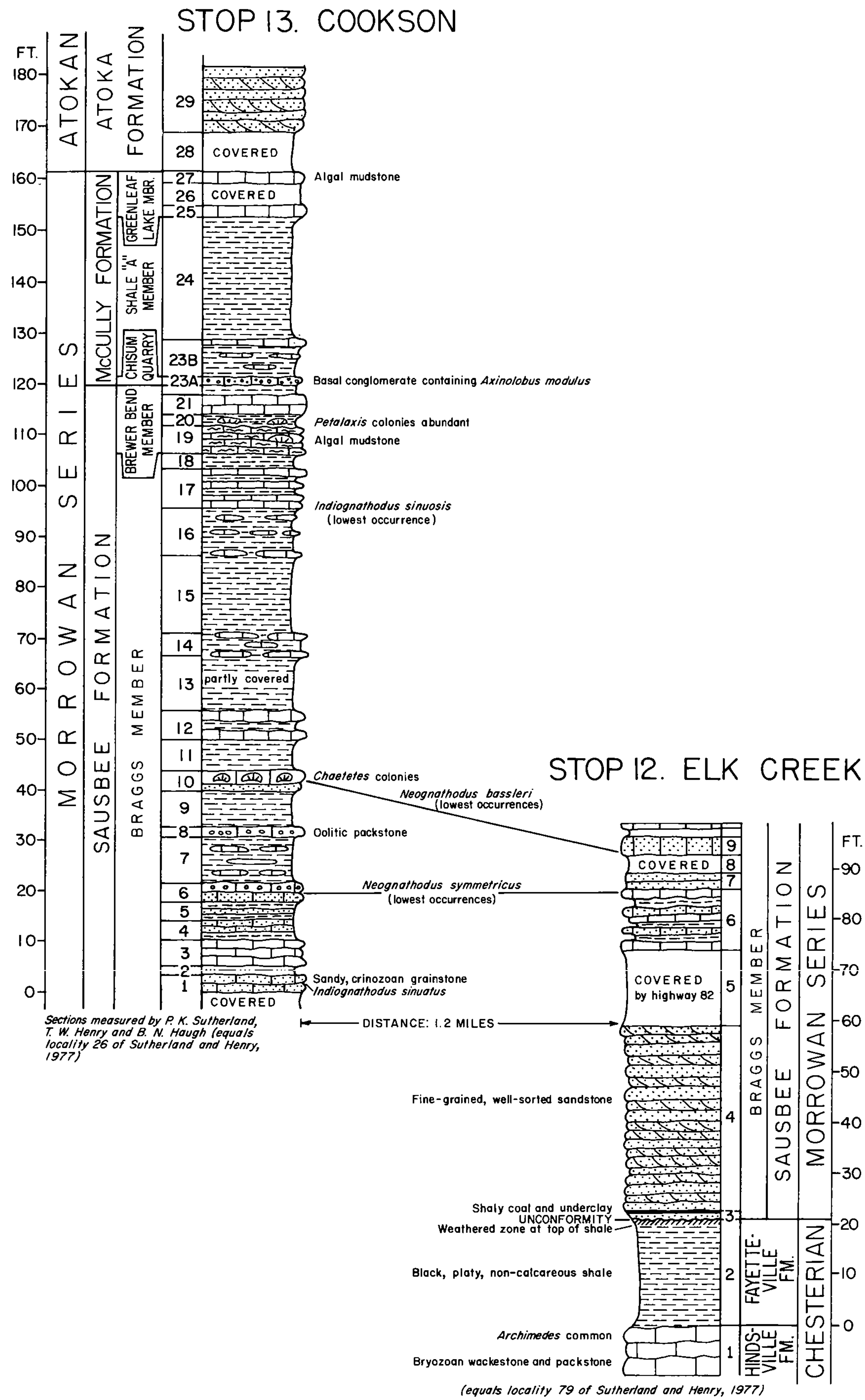


Figure 39. Graphic columnar sections for Stops 12 and 13.

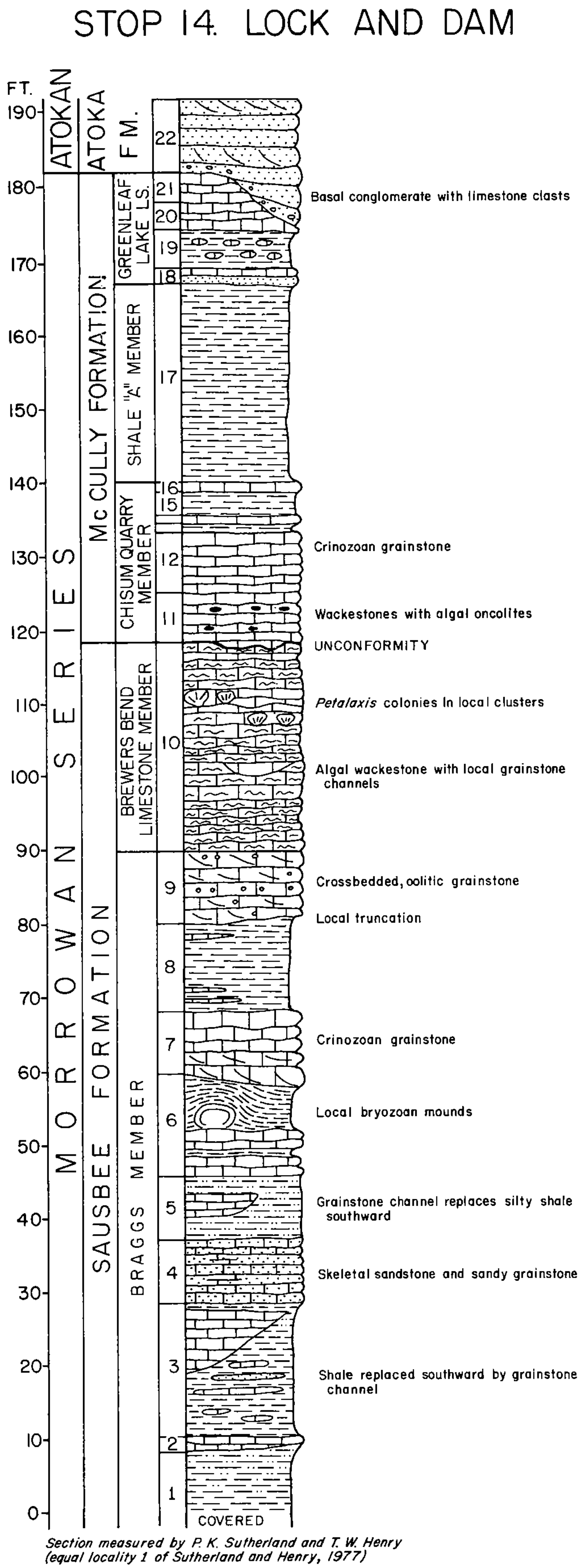


Figure 41. Graphic columnar section for Stop 14.

STOP 14—LOCK AND DAM

Location: Large bluff on west side of Arkansas River, just below Webbers Falls Lock and Dam 16; 0.6 mile east of unnumbered paved road that leads to Lock and Dam Lookout, 2.9 miles north of junction with U.S. Highway 64. Lower part of section (fig. 42): SW¼ SW¼ SE¼ sec. 34. Upper part (fig. 43): SE¼ SE¼ SW¼ sec. 34, T. 13 N., R. 20 E., Muskogee County, Oklahoma.

The exposures at the southwestern end of the Webbers Falls Lock and Dam (fig. 41) form the most important Morrowan section in northeastern Oklahoma. This sequence was designated by Sutherland and Henry (1977a) as the type section, jointly with the McCully Mountain section 0.3 mile to the northwest, for both the Sausbee and McCully Formations.

The base of the Sausbee Formation is not exposed at the Lock and Dam (fig. 42). The partial thickness averages 118.5 feet, compared with a total thickness for the formation of 132 feet at the McCully Mountain section, 0.3 mile to the north, where the underlying Pitkin Limestone is exposed. The covered interval at the base of the Lock and Dam section is therefore assumed to be no more than 20 feet. The thickness for the partial Morrowan section at Stop 14 is 182.5 feet.

The Lock and Dam exposure is only 1 mile southwest, across the Arkansas River, from Stop 15 (Chisum Quarry). The small bryozoan mounds in unit 6 at the Lock and Dam correlate with those in unit 6 at Chisum Quarry. No mounds are developed at a higher level equivalent to the large algal-bryozoan mounds that occur in unit 8 at Chisum Quarry.

The unconformities between the Sausbee and McCully and between the McCully and Atoka Formations are well exposed on the bluff west of the west end of Webbers Falls Dam (fig. 43). The lower unconformity is undulating but shows only slight downcutting. The Atoka Formation rests directly on the Greenleaf Lake Limestone Member of the McCully Formation. As can be seen in the upper left part of figure 43, the basal

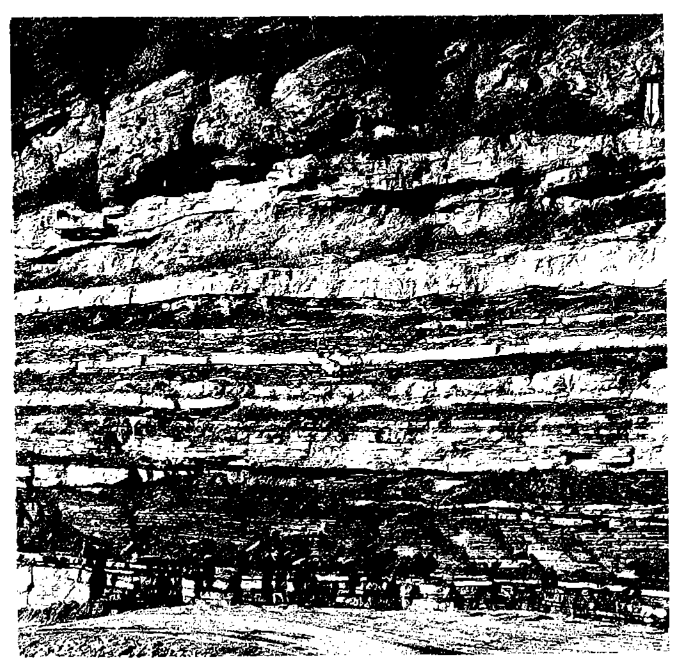


Figure 42. Sausbee Formation: Braggs Member, below, forms most of cliff; Brewer Bend Limestone Member forms highest rounded cliff. Contact marked by arrow. Exposure is 110 feet high and includes units 1-10. (Stop 14.)

Atoka unconformity, within a lateral distance of less than 15 feet, downcuts locally through 7.5 of the 8.0 feet of limestones making up units 20 and 21.

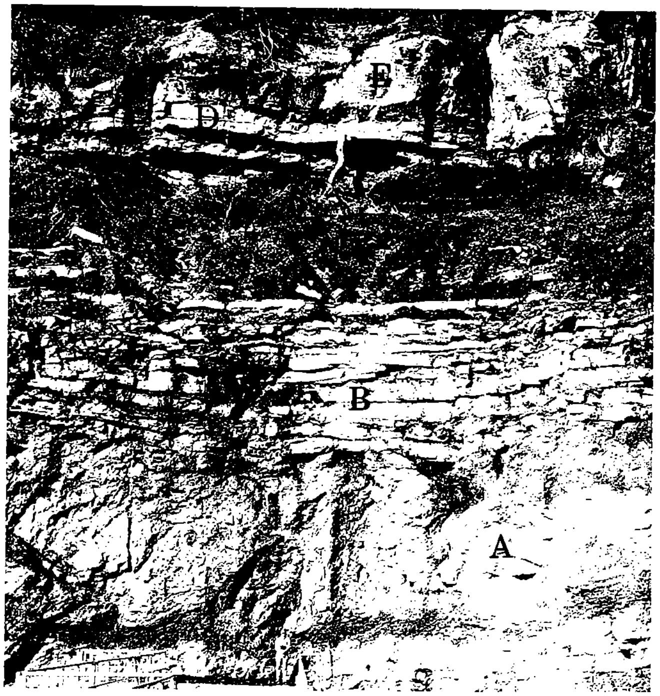


Figure 43. Sausbee Formation: upper part of Brewer Bend Limestone Member (*A*). McCully Formation: Chisum Quarry Member (*B*), shale "A" member (*C*), Greenleaf Lake Limestone Member (*D*). Atoka Formation: *E*. Arrow to left of *E* points to truncating unconformity at base of Atoka Formation. Unconformity also exists between *A* and *B*. (Stop 14.)

STOP 15—CHISUM QUARRY

Location: North side of central part of large inactive quarry in bluff on east side of Arkansas River opposite Webbers Falls Lock and Dam 16. SW¼ NW¼ NW¼ sec. 35, T. 13 N., R. 20 E., Muskogee County, Oklahoma.

The base of the Morrowan Series is not exposed in the Chisum Quarry, but the middle and upper Braggs and the Brewer Bend Limestone Members of the Sausbee Formation and the Chisum Quarry Member of the McCully Formation are exceptionally well exposed and accessible (fig. 44).

Of particular note in this quarry is the occurrence of well-developed algal-bryozoan mounds at two intervals, units 6 and 8 (fig. 45). These mounds were studied in detail by Bonem (1977).

The calcareous shale surrounding the mounds in the upper mounding interval (unit 9) are locally highly fossiliferous and contain *Pentremites* (Katz and Sprinkle, 1977) and various brachiopod species including *Spirifer goreii*. Also to be found in this quarry in the upper Braggs Member (unit 7) are goniatites of the *Branneroceras branneri* zone, including, in addition to the name bearer of the zone, *Proshumardites morrowanus*, *Syngastrioceras morrowense*, *Pseudopronorites arkansiensis*, and *Gaitherites solidum*. This goniatite zone ranges upward through the Brewer Bend Limestone Member.

STOP 15. CHISUM QUARRY

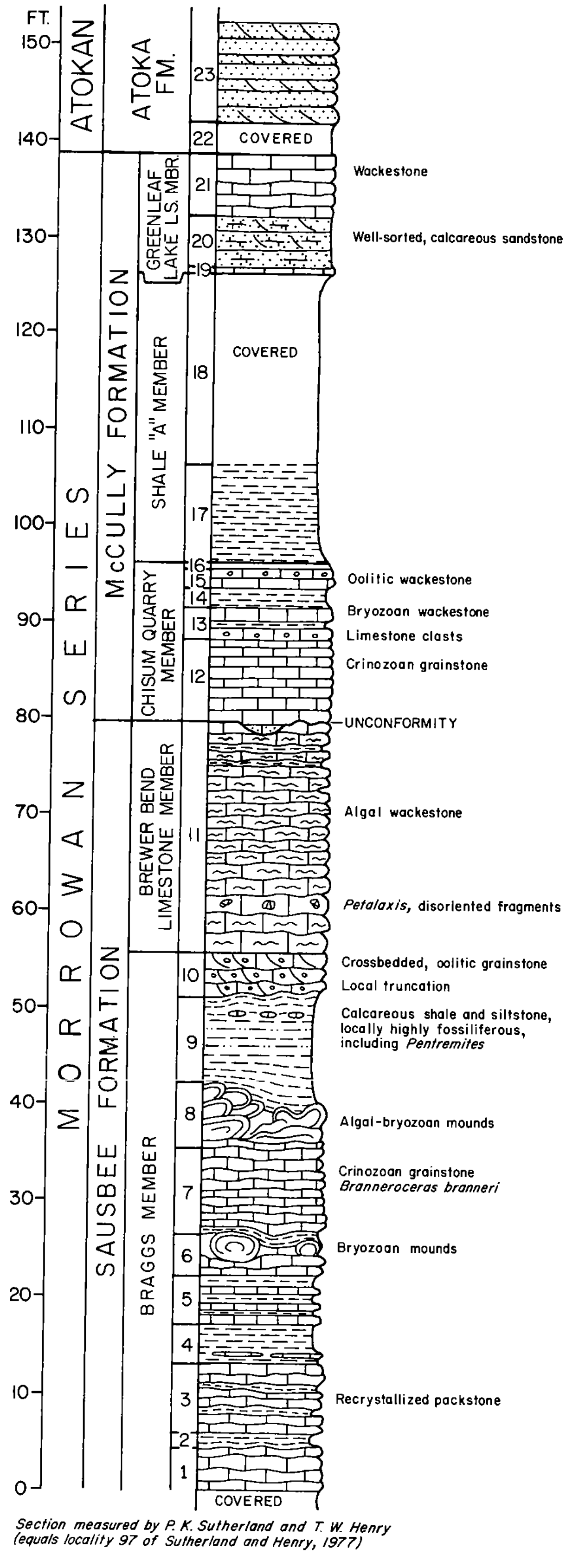


Figure 44. Graphic columnar section for Stop 15.

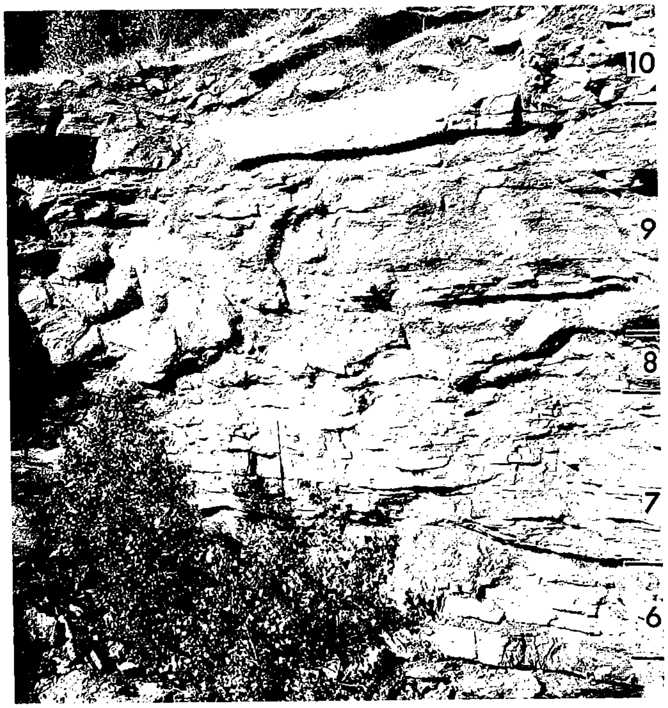


Figure 45. Braggs Member of Sausbee Formation. Note mounds in units 6 and 8. (Stop 15.)

STOP 16—BRAGGS MOUNTAIN

Location: Series of road cuts along east side of Oklahoma Highway 10, beginning at point 5.3 miles east then south of junction with U.S. Highway 62, 1.7 miles east of east end of major bridge over Arkansas River at Muskogee. Section exposed in cuts extending for about 0.5 mile south from initial point on Oklahoma 10. NW¼ NW¼ sec. 28, T. 15 N., R. 20 E., Muskogee County, Oklahoma.

The middle and upper parts of the Fayetteville Shale and the whole of the Pitkin Limestone are particularly well exposed here. In this area, the upper Fayetteville is characterized by a long sequence of interbedded limestones and shales (also seen at Stop 2) that form a transitional sequence between the black to dark-gray shales of the lower Fayetteville and the overlying Pitkin (fig. 46). To the east, in Adair County, Oklahoma, and in Washington County, Arkansas, the change from the Fayetteville Shale to the Pitkin Limestone at Braggs Mountain is highly fossiliferous and contains *Archimedes*, fenestrate bryozoans, and numerous brachiopods. Conodont information is not available for this sequence. The Pitkin-Sausbee unconformable contact is well exposed (fig. 47), and the base of the overlying unit is marked by a thin pebble conglomerate (fig. 48). The limestones in the lowest part of the Sausbee Formation are commonly characterized by the occurrence of quartz sand in contrast to the underlying Pitkin Limestone, which is normally almost quartz free.

The total Morrowan thickness at Braggs Mountain is 142 feet. At this locality the Pitkin Limestone is 47 feet thick, and the upper 27 feet of the underlying Fayetteville Shale is exposed.

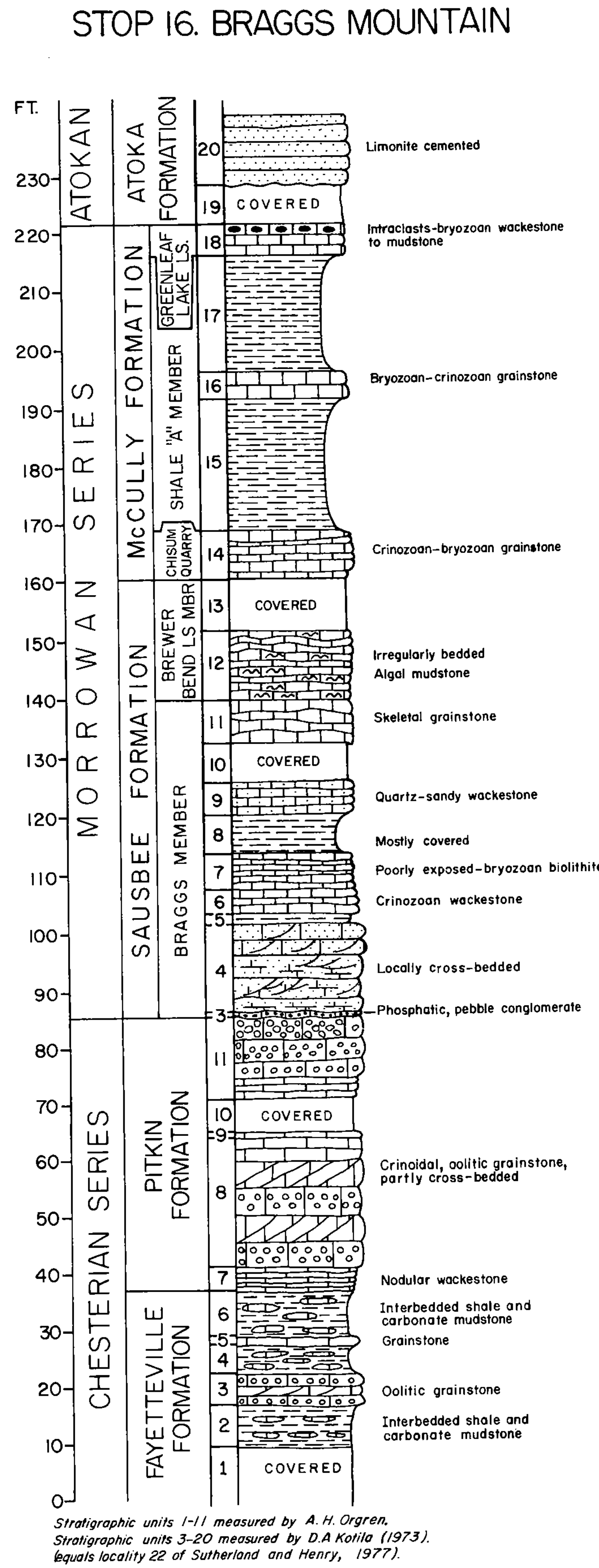


Figure 46. Graphic columnar section for Stop 16.

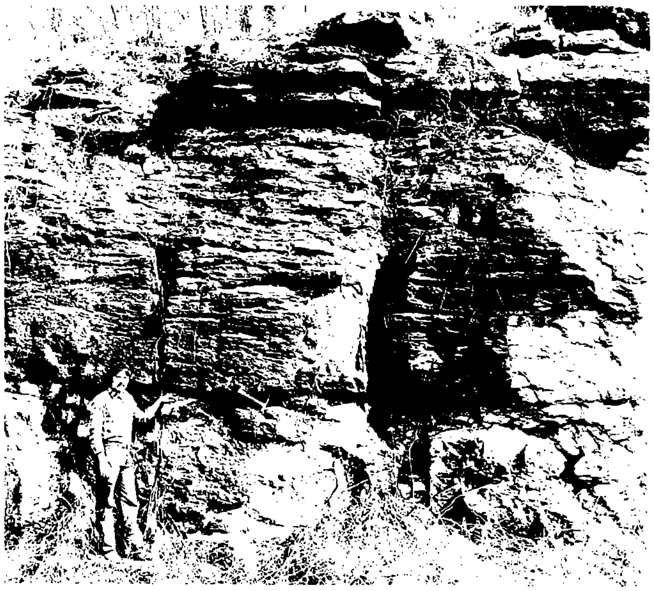


Figure 47. Man points to unconformity between quartz-free Mississippian Pitkin Limestone, below, and sandy, cross-bedded limestone of Pennsylvanian Sausbee Formation, above. (Stop 16.)

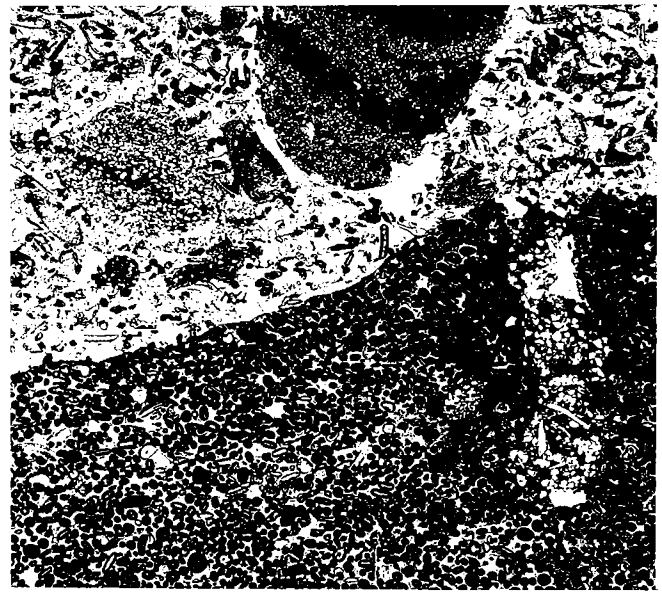


Figure 48. Photomicrograph of unconformable contact between Mississippian Pitkin Formation (oolitic packstone) and Pennsylvanian Sausbee Formation (quartz-sandy conglomeratic grainstone), from locality pictured in figure 47 (Stop 16). Note boring at right filled with material from overlying unit. (This photo was featured on cover of Oklahoma Geological Survey Guidebook 18.)

STOP DESCRIPTIONS—THIRD DAY

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John D. McFarland III

SUMMARY

This part of the trip begins near Fort Smith, Arkansas, with initial stops in the central Arkoma Basin and proceeds southward with subsequent stops in the frontal and central Ouachita Mountains in Arkansas, ending the day near Mena. The purpose is to illustrate (1) the characteristic lithologies of the various Carboniferous formations of this region, (2) the

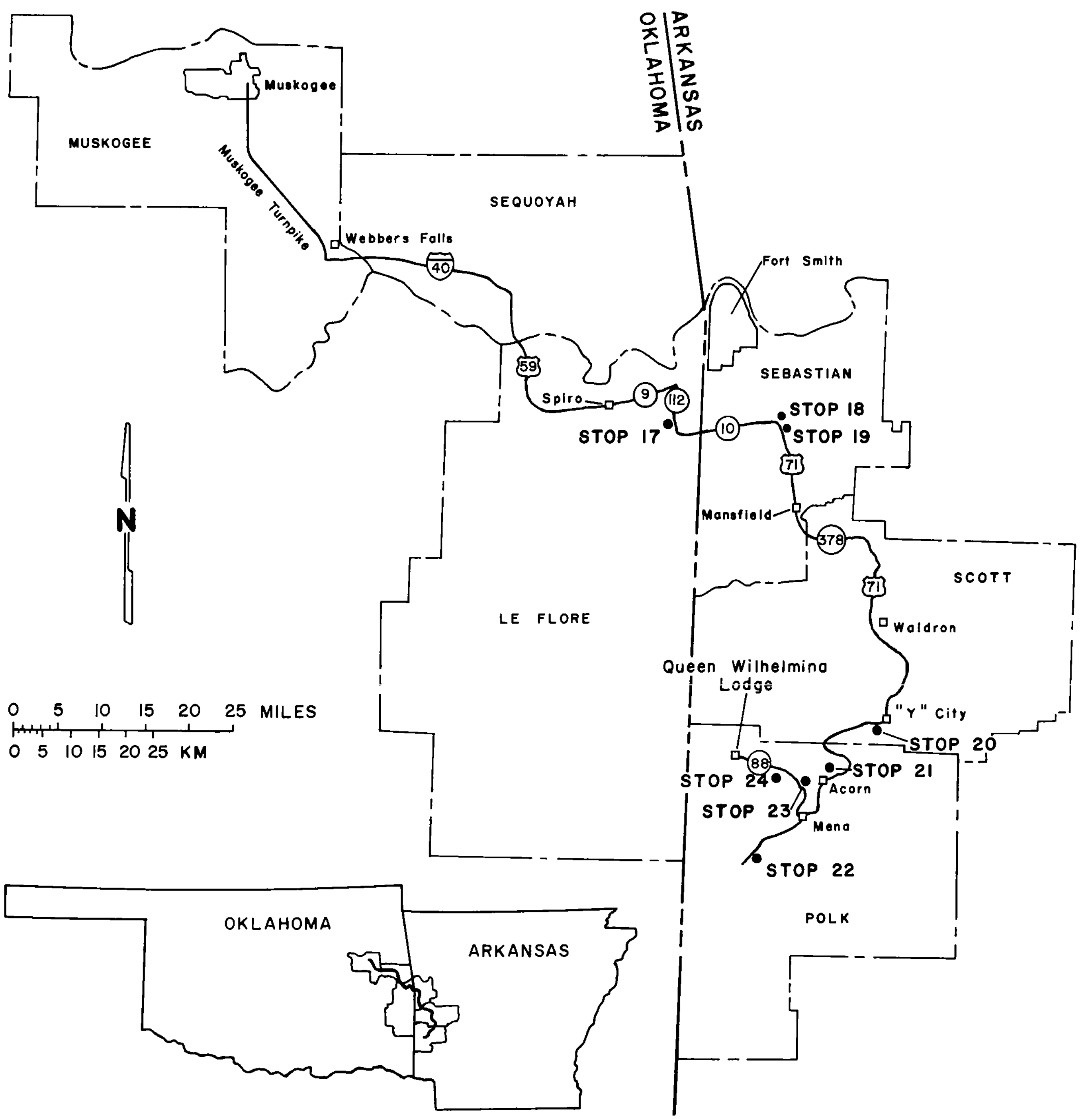


Figure 49. Locality and route map, third day.

rapid southward increase in thickness for most of these formations to a maximum thickness of more than 40,000 feet of Carboniferous section in the central Ouachita Mountains, and (3) the sedimentary features that indicate the north-to-south progression of continental and (or) shallow-marine (deltaic) to deep-water-marine (wildflysch, submarine-fan) and possibly basinal-plain depositional environments. Figure 49 is the locality and route map for the third day of the trip. Figure 2 summarizes the lithostratigraphic units to be examined.

STOP 17—BACKBONE MOUNTAIN

Location: Road cut across Backbone Mountain on Oklahoma Highway 112, 4.3 miles south of U.S. Highway 271 and 1.6 miles south of Pocola. NW¼ SW¼ sec. 31, T. 9 N., R. 27 E., Le Flore County, Oklahoma.

This exposure is on the south flank of the Backbone Anticline and is on the upthrown side of the northward-thrusted Backbone Fault. The beds dip 45° to the south. This section

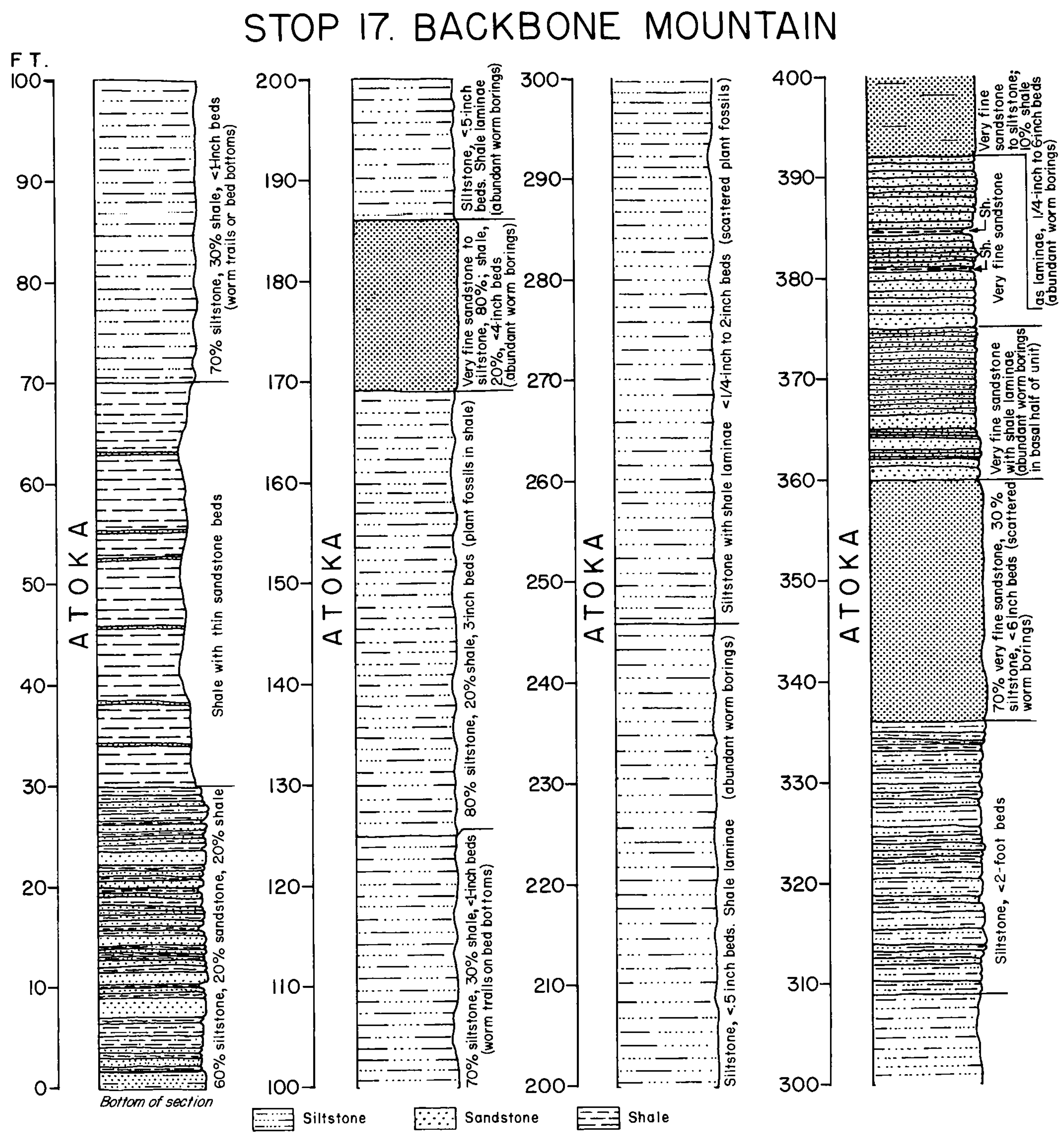
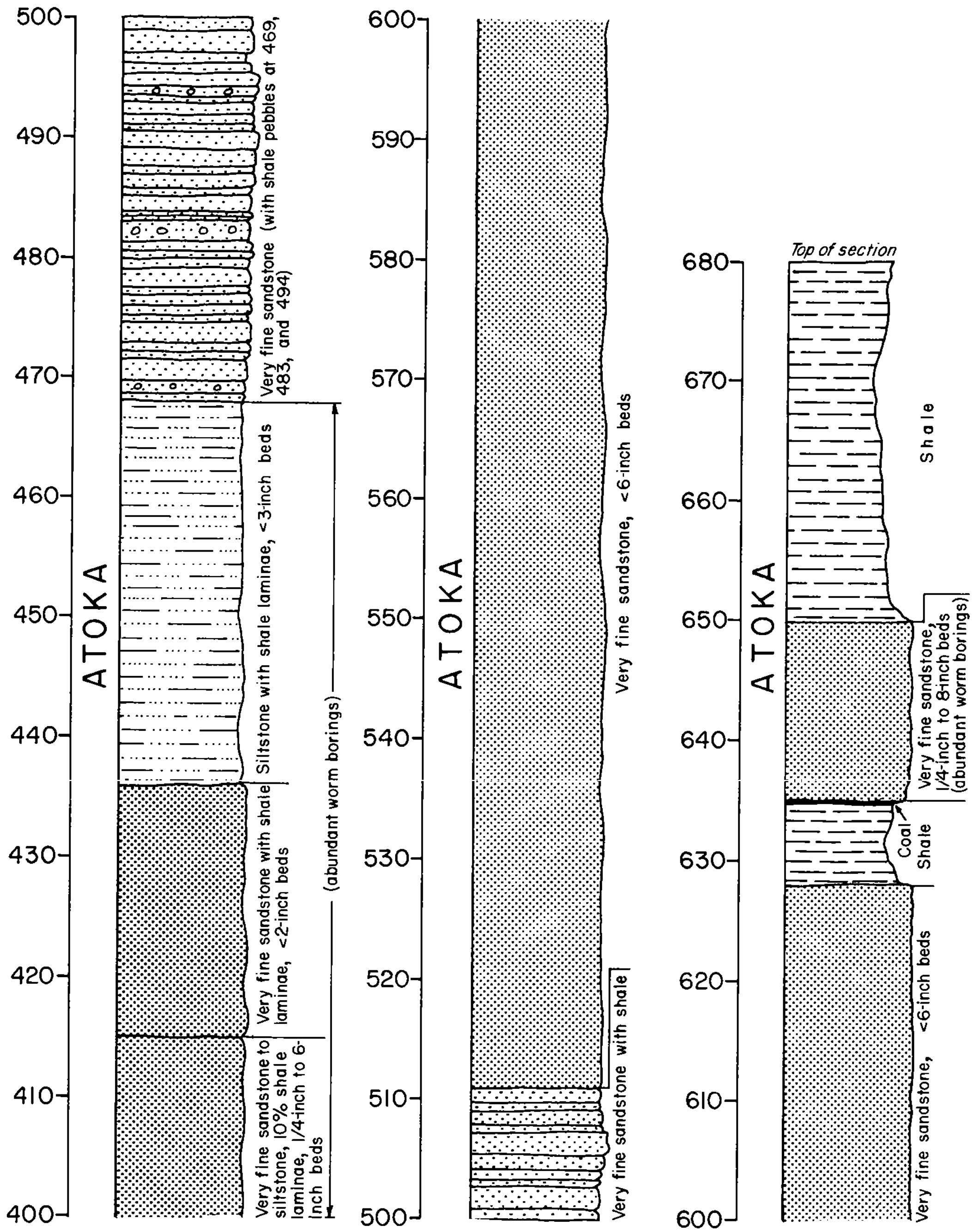


Figure 50. Graphic columnar section for Atoka Formation at Stop 17.

represents an interval approximately 2,500 feet below the top and 5,400 feet above the base of the Atoka Formation. These interbedded sandstones, siltstones, and shales represent deltaic sequences in the middle part of the Atoka Formation (Atokan Series) (figs. 50, 51). The 680 feet of exposure has four and possibly five cycles of clastic intervals that thicken and coarsen upward. These cycles typically represent progradation from outer-fringe to distributary-channel deltaic depositional environments. Figure 52A and B shows the sedimentological model of LeBlanc (1977) used to interpret deltaic sequences. In most of the outer-fringe intervals, flaser bedding is well developed and associated with a high degree of bioturbation (figs. 53-55). Cross bedding is a prominent feature of some inner-fringe and distributary-channel intervals (fig. 55). Fragments of coal from a thin seam exposed in a pipeline southwest of this exposure demonstrate the progradation of this mostly fringe sequence by a delta-plain environment that was later transgressed by marine shales.



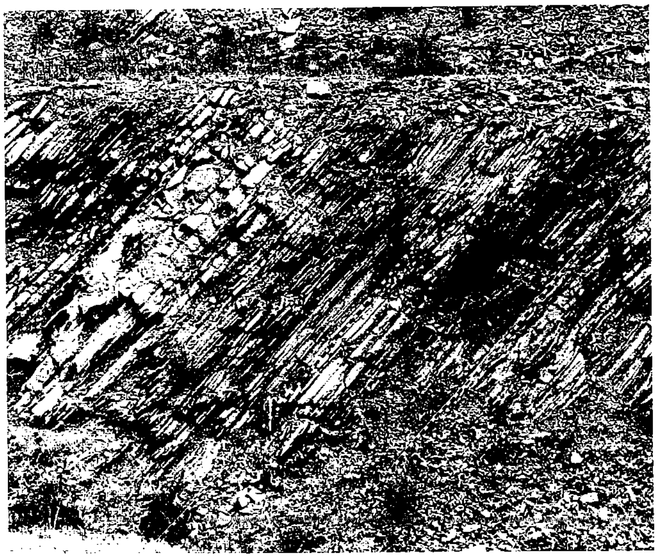


Figure 51. Sequences of middle Atoka deltaic (mostly fringe) deposits representing several prograding deltas, looking west. Bases of sequences marked by dashed lines. (Stop 17.)

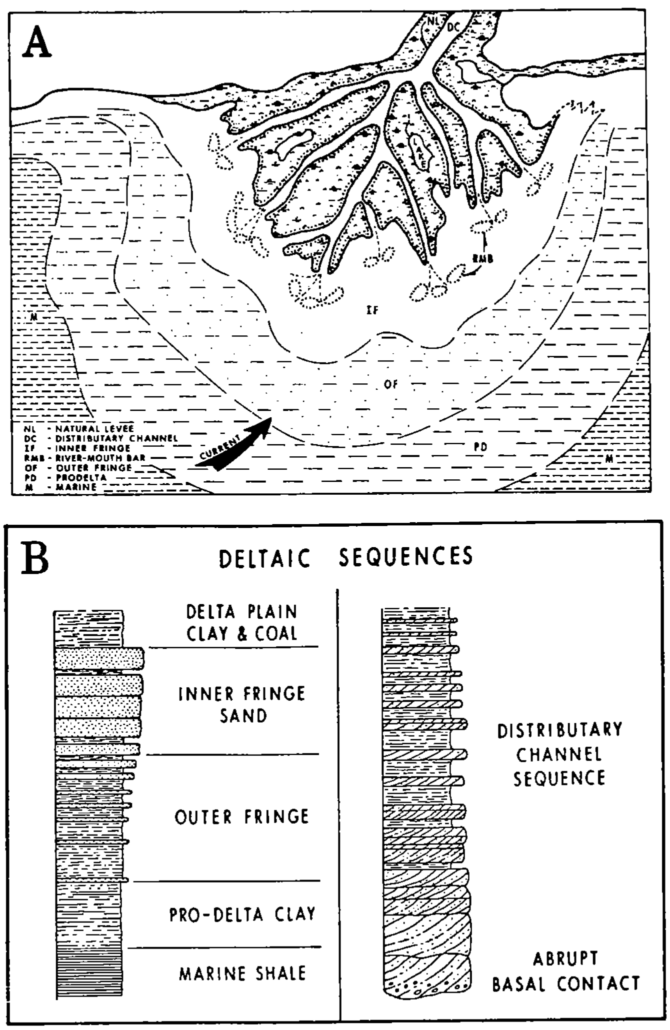


Figure 52. *A*, depositional environments and sequences typical of modern deltas used as model for interpreting sequences seen during first part of today's trip (from LeBlanc, 1977). *B*, typical sequences of deltaic deposits.

Figure 53. Bioturbations in flaser-bedded outer-delta-fringe sandstones of middle Atoka Formation, looking west. Note cross section of *Conostichus* in center. (Stop 17.)

Figure 54. Trails on top of thin-bedded sandstone layer, looking north. (Stop 17.)

Figure 55. Burrows, shale clasts, and siderite nodules in cross-bedded distributary-channel deposits, looking west. (Stop 17.)

STOP 18— SAND RIDGE

Location: Road cut on east side of U.S. Highway 71 at junction of Arkansas Highway 10 on Sand Ridge about 2 miles west of Greenwood. NW¼ NW¼ sec. 15, T. 6 N., R. 31 W., Sebastian County, Arkansas.

These massive to thin-bedded rather clean sandstones of the Hartshorne Sandstone (Desmoinesian Series; fig. 56) are on the north flank of the Greenwood Syncline and dip to the south at about 20°. Deposition of marine black shales at the top of the Atoka Formation was succeeded by distributary-channel and outer-fringe deltaic sandstones (fig. 52A and B) of the Hartshorne Sandstone (fig. 57). Channels with basal truncation are present throughout most of the Hartshorne (fig. 58). Sedimentary structures seen here include small sandstone diapirs present at the top of a massive sandstone (fig. 59) and small soft-sediment deformation structures (fig. 60). Festoon cross-bedding is prominent at the top of the exposure. Abandoned strip coal mines in the overlying lower Hartshorne coal bed in the lower McAlester Formation (Desmoinesian Series) can be seen to the southwest. This coal bed represents an extensive development of delta-plain deposits.

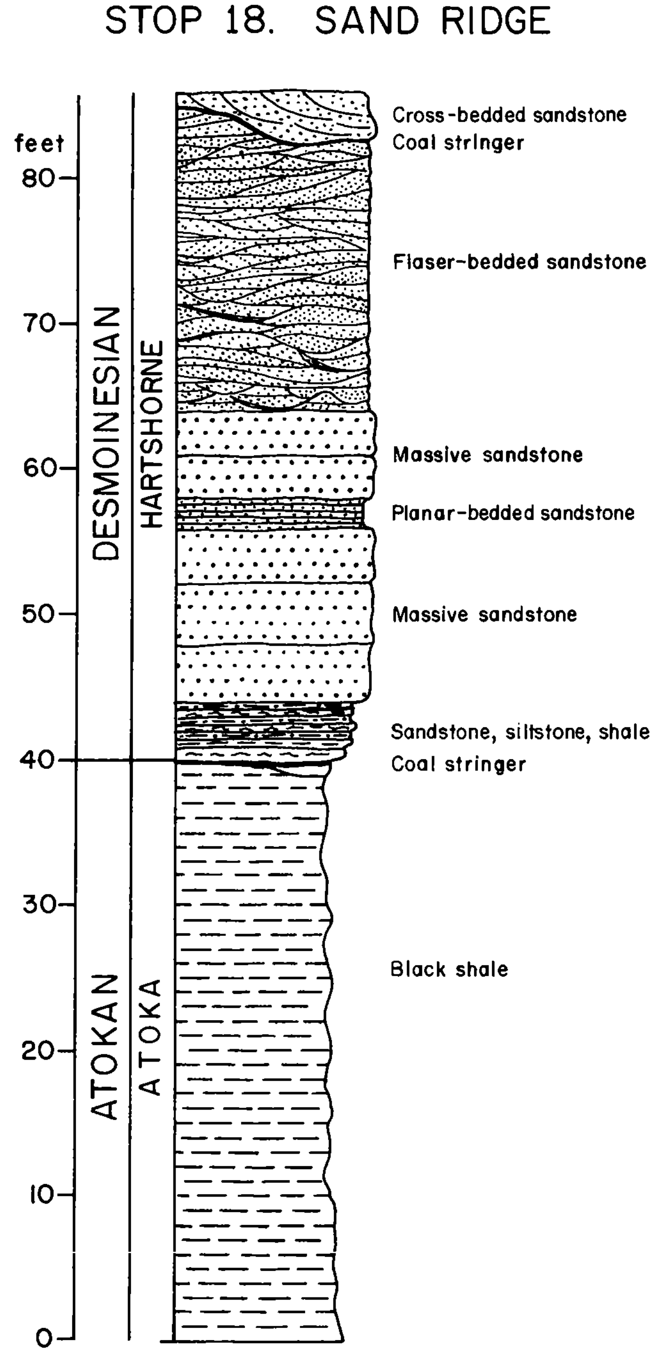


Figure 56. Graphic columnar section for Stop 18.

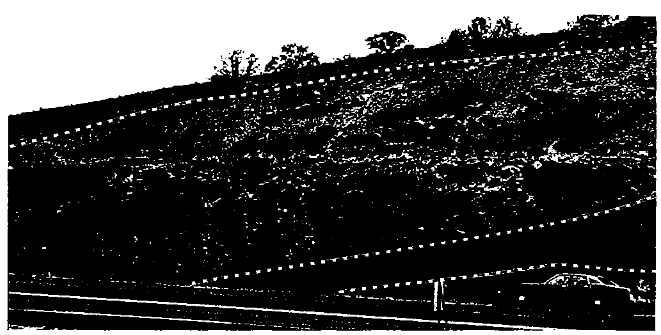


Figure 57. Stream-channel and fringe deposits in Hartshorne Sandstone, looking west. Bases of channels marked by dashed lines. (Stop 18.)

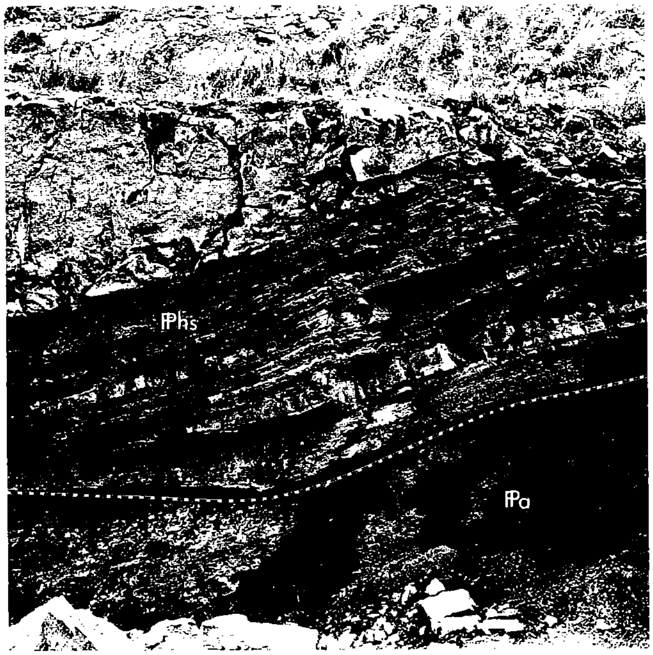


Figure 58. Closeup of parts of figure 57, showing stream channel at base of Hartshorne Sandstone overlying black marine shale of upper Atoka Formation. (Stop 18.)

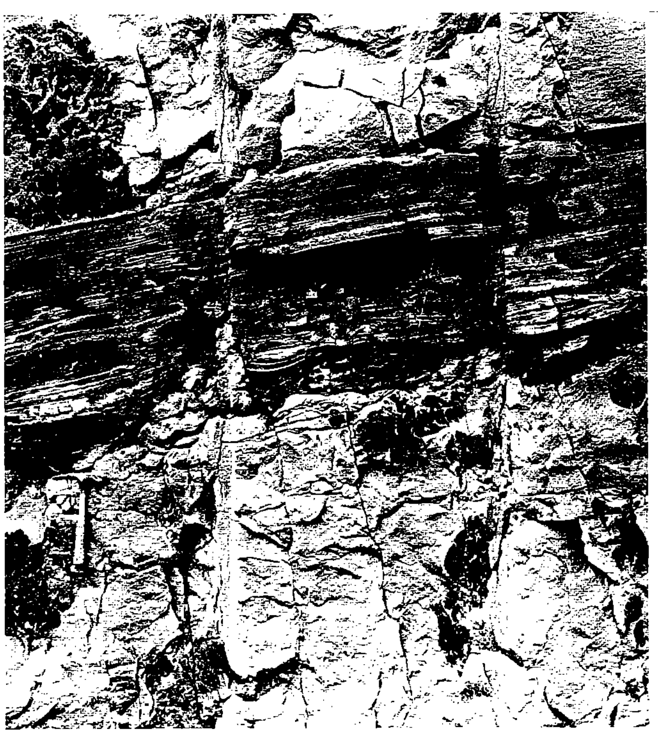


Figure 59. Planar-bedded fringe deposits with small sandstone diapirs formed from underlying massive channel sandstone in Hartshorne Sandstone, looking west. (Stop 18.)

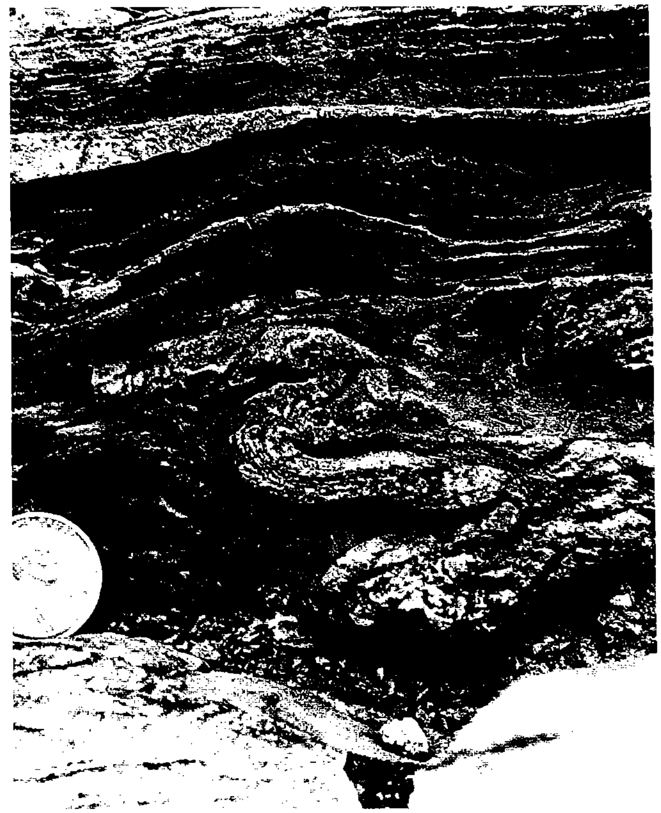


Figure 60. Soft-sediment deformation in channel sequence in Hartshorne Sandstone, looking west. (Stop 18.)

STOP 19—DEVILS BACKBONE RIDGE

Location: Road cut along U.S. Highway 71 across Devils Backbone Ridge, 1.2 miles south of Stop 18 and about 2.5 miles southwest of Greenwood. NW¼ NE¼ sec. 22, T. 6 N., R. 31 W., Sebastian County, Arkansas.

This steeply northward-dipping sequence occurs on the south flank of the Greenwood Syncline and the north flank of the Washburn Anticline. The black marine shales and prodelta siltstones (fig. 52A and B) of the upper Atoka Formation, at the south end of the exposure, are overlain by a thick (about 215-foot) sandstone sequence of fluvial-point-bar (stream-channel) deposits of the Hartshorne Sandstone (Desmoinesian Series: figs. 61, 62). The lower Hartshorne coal consists of two beds at this locality. Note also the shale-clast conglomerates (fig. 63), plant fragments, and stringers of coal near the base of the channels (fig. 64) in the lower Hartshorne. Festoon and other cross-bedding types are excellently developed throughout most of the Hartshorne.

The overlying siltstones and thin sandstones of the McAlester Formation (Desmoinesian Series) represent probable overbank and other delta-plain deposits (fig. 65). Delicate flaser bedding is characteristic of most of these deposits in the lower McAlester (fig. 66).

STOP 19. DEVILS BACKBONE RIDGE

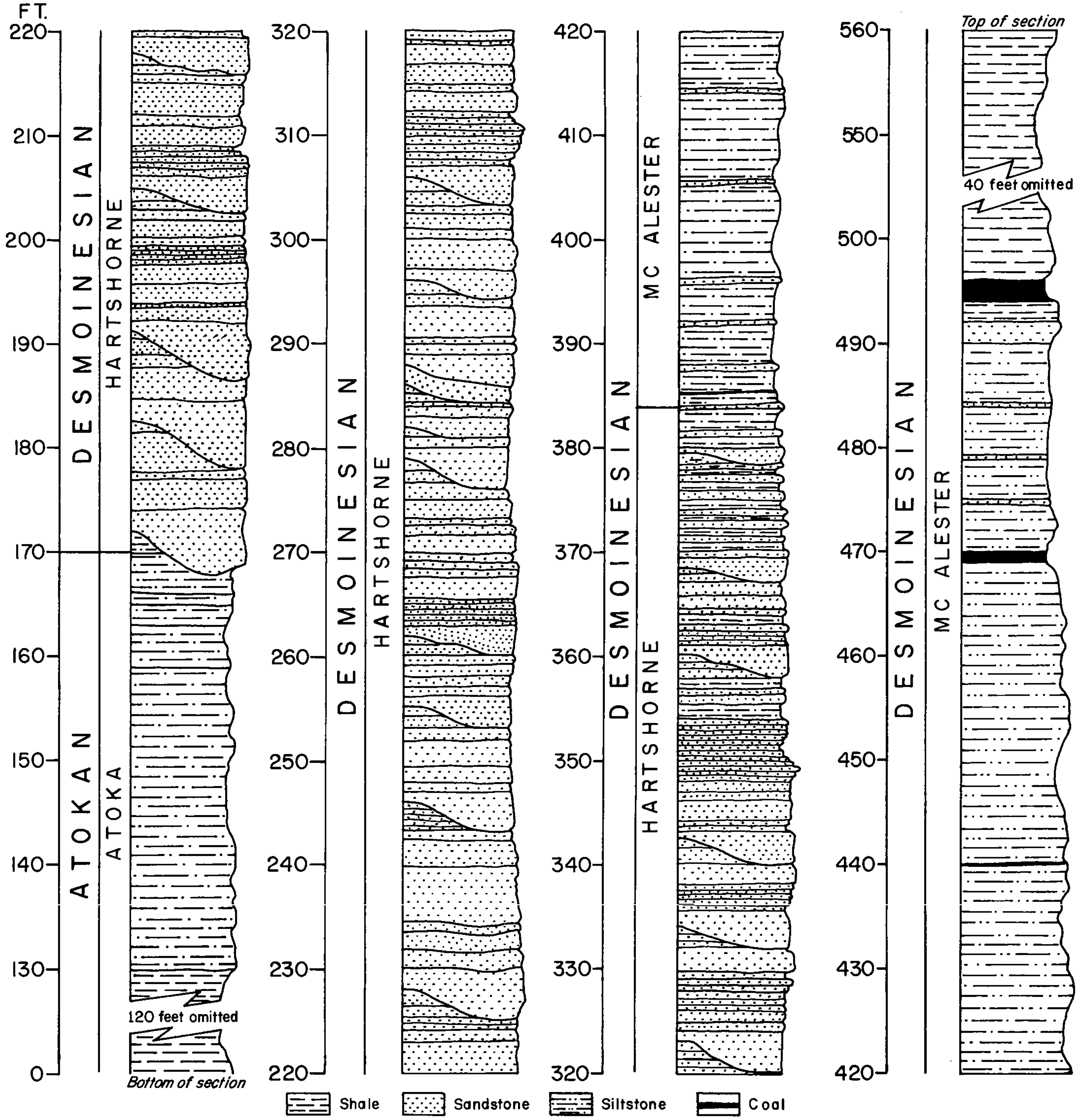


Figure 61. Graphic columnar section for Stop 19.

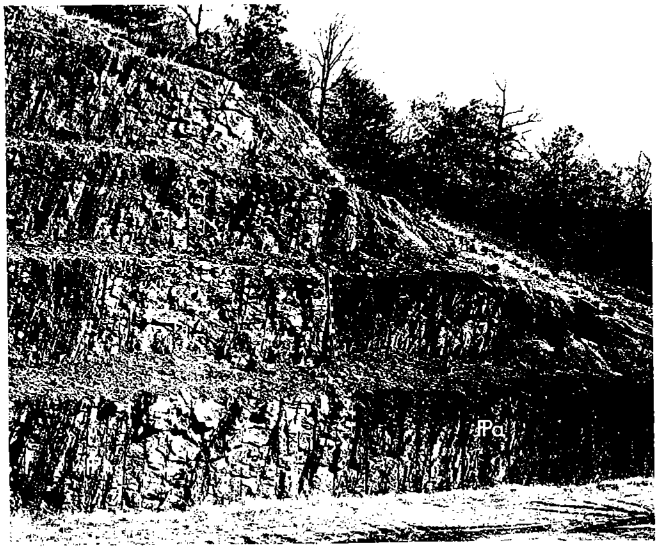


Figure 62. Stream-channel deposits of Hartshorne Sandstone, overlying prodelta and marine deposits of Atoka Formation, looking east. (Stop 19.)

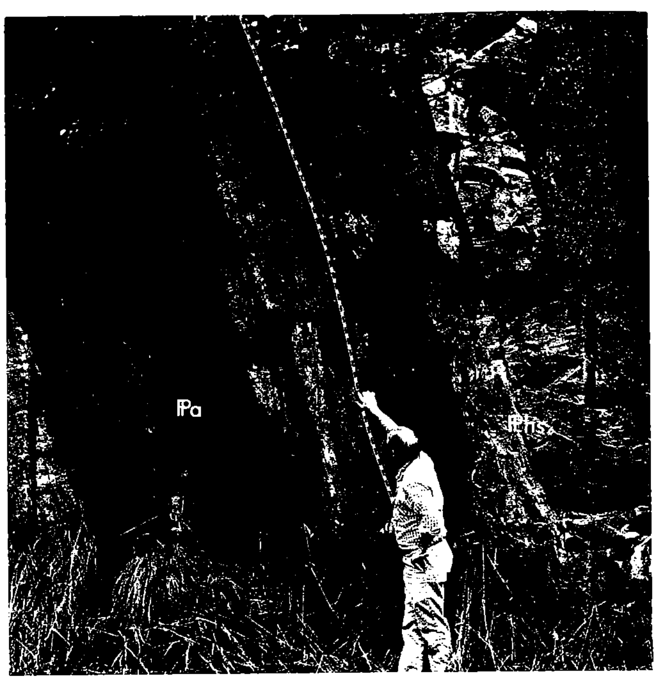


Figure 63. Contact between stream-channel deposits of Hartshorne Sandstone and prodelta deposits of Atoka Formation, looking west. Note shale-pebble conglomerate in lower part of channel to right of man. (Stop 19.)

Figure 64. Sequences of stream-channel deposits in Hartshorne Sandstone, looking west. (Stop 19.)

Figure 65. Stream-channel deposits of Hartshorne Sandstone and overlying delta-plain deposits of McAlester Formation, looking east. (Stop 19.)

Figure 66. Delicate flaser bedding in probable delta-plain (overbank) deposits in lower McAlester Formation, looking west. (Stop 19.)

with abundant bottom marks, scattered clay-ironstone concretions, and characterized by olistostromes. Along the north side of the Ouachita Mountains from the vicinity of Forester in western Arkansas to Atoka, Oklahoma (a distance of about 140 miles), erratic rocks ranging from fragments to immense masses and from Late Cambrian to Early Pennsylvanian age were derived from the miogeosynclinal and shelf facies of the Arbuckle and Ozark regions and redeposited in the Johns Valley Shale. The emplacement of these erratics has been the subject of many theories (see Shideler, 1970, for review). A recent interpretation by Stone and Haley (1978, p. 93-94) suggests that a series of normal faults, downthrown to the south, developed in Chesterian (Late Mississippian) time and continued to be active until early Atokan (Middle Pennsylvanian) time. Fragments from the formations exposed along the fault scarp and along submarine channels across the fault scarp fell into the mud, accumulating at the base of the scarp and then moving down slope as individual pieces, in conglomeratic masses, or as debris or turbidity flows. Nearly all the erratics in the Johns Valley Shale can be identified as belonging to existing formations north of their present site (fig. 68). The suite of erratics gradually changes from an Arbuckle type in the west to an Ozark type in the east, which is to be expected if the erratics all come from north of their depositional site. The amount of displacement across the normal fault, or faults, north of Boles, Arkansas, is unknown, but it would have to exceed 2,200 feet in order to provide the fragments of the Cotter Dolomite (Lower Ordovician) found in the Johns Valley Shale at Boles.

STOP 20—"Y" CITY

Location: Shale pit about 0.2 mile south of U.S. Highway 71 and approximately 1.6 miles west-southwest of "Y" City. NE¼ SE¼ sec. 20, T. 1 N., R. 29 W., Scott County, Arkansas.

This locality lies within the frontal Ouachita Mountains approximately 1 mile south of the surface trace of the northward-thrusted "Y" City Fault. This steeply southward-dipping sequence in the lower Johns Valley Shale is composed of gray clay shales with some thin sandstones and contains olistoliths of sandstone, limestone, dolomite, chert, and shale derived from the foreland facies to the north and northwest (fig. 67). Rocks ranging from Early Ordovician to Late Morrowan in age are present (fig. 68). Morrowan ammonoids of the *Branneroceras branneri* Zone and other fossils have been collected here by McFarland from indigenous small concretionary lenses and isolated concretions. These ammonoids indicate a middle Morrowan age for the Johns Valley Shale (Gordon and Stone, 1977). The thin sandstones in the Johns Valley are graded and commonly contain trace fossils (*Nereites* biofacies) indicative of deposition in a deep-water environment (Chamberlain and Basan, 1978). Small faults cut the sequence and generally exhibit slickensides coated with brownish-white dickite, a hydrothermal clay mineral.

In recent years the Johns Valley Shale has been delineated throughout the southern, central, and frontal Ouachita Mountains of Arkansas and Oklahoma. The Johns Valley is basically a clay shale containing some beds of sandstone generally

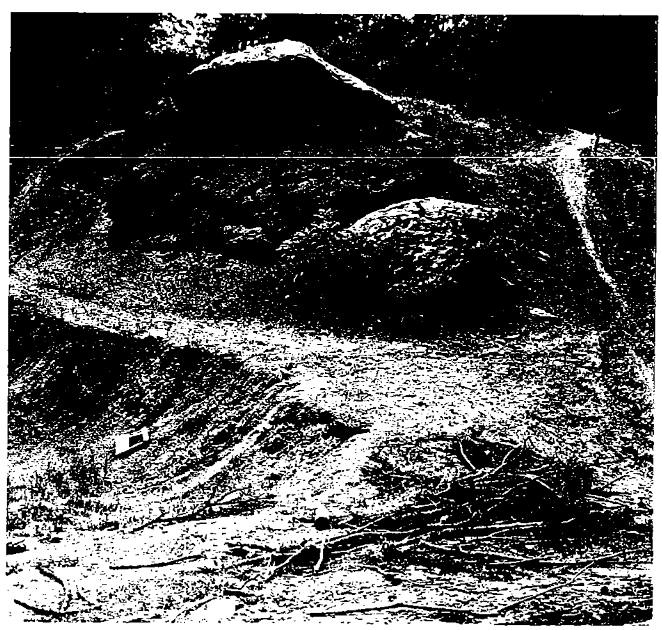


Figure 67. Olistoliths of sandstone (Prairie Grove Member) of Hale Formation, lower Morrowan Series) in shale of Johns Valley Shale, looking southwest. (Stop 20.)

	SERIES	ARBUCKLE FACIES	OUACHITA FACIES	OZARK FACIES
PENNSYLVANIAN	Atokan	Lake Murray-Atoka Fms.	Atoka Fm.	Atoka Fm.
	Morrowan	Golf Course-Wapanucka Fms. ● "Springer Fm."	Johns Valley Fm. Jackfork Gp.	Bloyd Fm. ● Hale Fm. ●
MISSISSIPPIAN	Chesterian	"Caney Sh." ●	Stanley Gp.	Pitkin Ls. Fayetteville Sh. Hindsville Ls.
	Meramecian			Moorefield Fm. ●
	Osagean	Sycamore Ls. ●	Arkansas Novaculite ●	Boone Fm.
	Kinderhookian	Woodford Fm. ●	Pinetop Chert ●	Chattanooga Fm.
DEVONIAN	Upper & Middle			
	Ulsterian	Hunton Gp.: Frisco Ls. Bois d'Arc Ls. ● Haragan Ls.	absent ?	Sallisaw Fm. ● Frisco Ls.
SILURIAN	Niagaran	Henryhouse Ls. ●	Missouri Mountain Fm.	St. Clair Ls.
	Alexandrian	Chimneyhill Ls. ●	Blaylock Ss.	absent ?
ORDOVICIAN	Cincinnatian	Sylvan Sh. Fernvale Ls. ●	Polk Creek Sh.	Sylvan Sh. Fernvale Ls.
	Trentonian	Viola Ls. ●	Bigfork Chert ●	Fite Ls. ●
	Blackriverian	Simpson Gp.: Bromide Fm. ● Tulip Creek Fm.	Womble Sh.	Tyner Fm. ●
	Chazyan	McLish Fm. ● Oil Creek Fm. ● Joins Fm. ●		Jasper Ls. ● Burgen Ss.
	Canadian	Arbuckle Gp.: West Spring Creek Fm. ● Kindblade Fm. ● Cool Creek Fm McKenzie Hill Fm.	Blakely Ss. Mazarn Sh. Crystal Mountain Ss. Collier Fm. Lukfata Ss.	Cotter Dol. ● Jefferson City Dol. Roubidoux Fm. Gasconade Dol.
CAMBRIAN	Croixan	Butterly Dol. Signal Mountain Fm. Royer Dol. Fort Sill Fm. ● Honey Creek Fm. Reagan Ss.	not exposed	Eminence Dol. Bonneterre Dol. Lamotte Ss.
PRECAMBRIAN		Granite & Rhyolite		Spavinaw Granite

Figure 68. Provenance of boulders identified with high confidence by Shideler (1970) with additions by the present authors from Johns Valley Shale in Ouachita province (modified from Shideler, 1970).

STOP 21—ACORN

Location: Road cut on U.S. Highway 71 about 0.3 mile northeast of junction of U.S. Highways 59 and 270 at Acorn. SE¼ SE¼ sec. 21, T. 1 S., R. 30 W., Polk County, Arkansas.

This rather complexly folded and faulted sequence of black shales, some thin graywackes, and isolated cone-in-cone silty iron carbonate concretions occurs near the middle of the Stanley Shale (Meramecian and Chesterian Series) (fig. 69). Thin, bottom-marked sandstones at this site are thought to represent lobe sequences of an outer submarine-fan or basinal-plain environment of deposition. The submarine-fan model and generalized turbidite sequences associated with the fan (Walker, 1978) are illustrated in figure 70A and B. It is likely that these sandstones were derived from sources to the

Figure 69. Deformed strata in middle Stanley Shale, looking north. (Stop 21.)

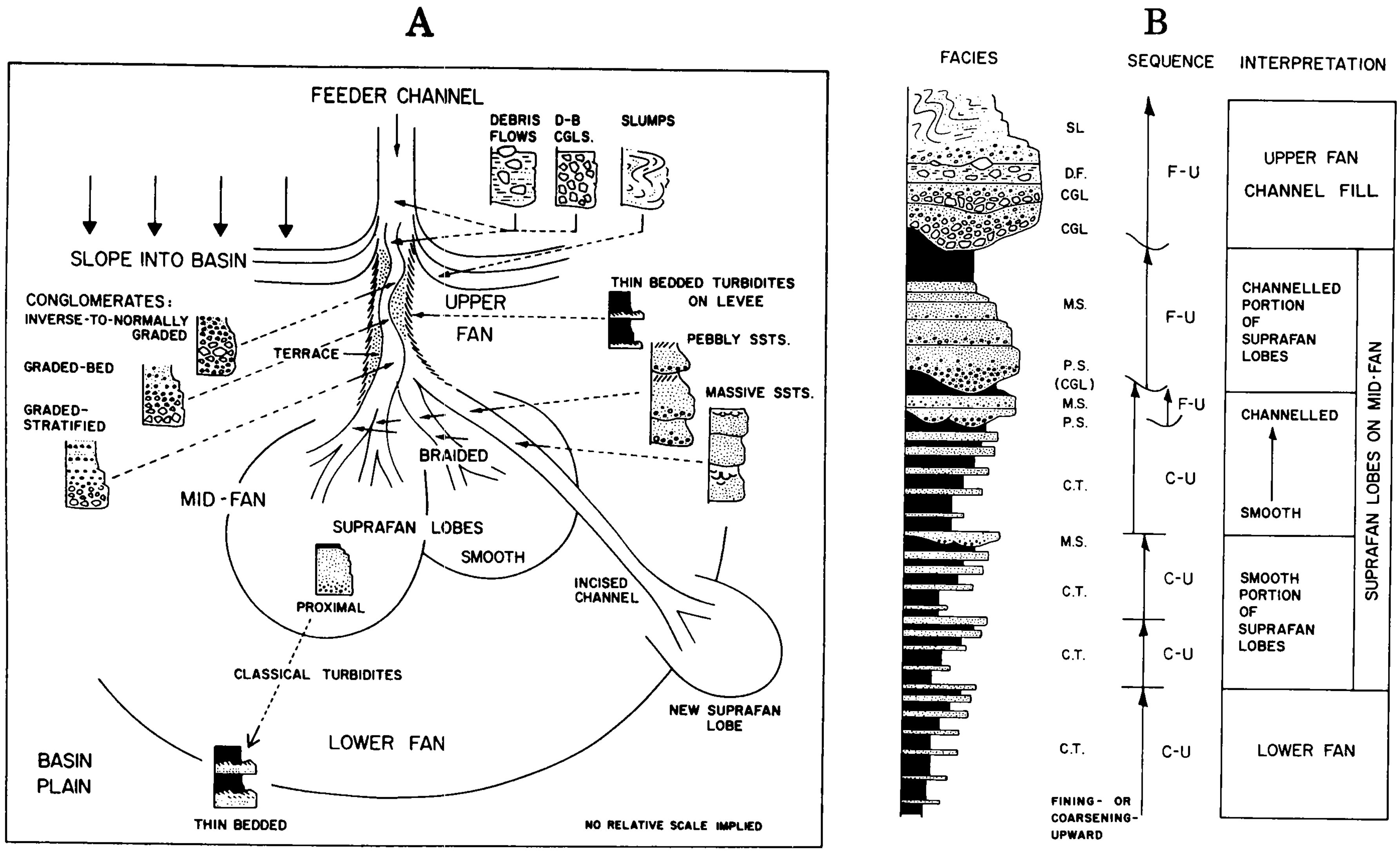


Figure 70. *A*, Submarine-fan model and associated turbidite facies of Walker (1978). *B*, Hypothetical stratigraphic sequence that could be developed during fan progradation; *C-U* represents thickening- and coarsening-upward sequence; *F-U* represents thinning- and fining-upward sequence; *C.T.*, classic turbidites; *M.S.*, massive sandstones; *P.S.*, pebbly sandstones; *CGL*, conglomerate; *D.F.*, debris flows; *SL*, slumps; from Walker (1978).

southeast. The sands were built out initially in large submarine fans toward the northwest and subsequently directed westward "down" the Ouachita trough.

The "sawdust" appearance of the shales at the east end of the exposure is typical of shales in close proximity to large thrust faults, several of which are present in this area. Small quantities of hydrothermal quartz, calcite, and dickite are present as small veinlets. Dickite is particularly common along the small slickenside surfaces. Close inspection of the sandstones shows both structural boudinage and sedimentary pull-aparts. Weathered Stanley shale is commonly greenish brown, as can be seen at the top of this exposure.

STOP 22—POTTER JUNCTION

Location: Road cut on U.S. Highway 71 about 1.8 miles south of Potter Junction. NE¼ NE¼ sec. 5, T. 3 S., R. 31 N., Polk County, Arkansas.

Exposed here are early trough (leptogeosynclinal) and flysch deposits of the Upper Division of the Arkansas Novaculite (Osagean and Meramecian) and the lower Stanley Shale including the Hot Springs Sandstone and Hatton Tuff Members (fig. 2). This sequence, in the western Caddo Mountain Range of the central Ouachita Mountains, shows the transition from the earlier thin trough deposits to the later thick flysch facies of the Ouachita Geosyncline. Along the south end of the road cut approximately 4 feet of novaculite at the top of the Upper Division of the Arkansas Novaculite is exposed in a small anticlinal fold. The overlying Stanley Shale can be divided into four intervals (fig. 71). The basal 50 feet of the Stanley is an unnamed, very thin interbedded siliceous shale, buff-maroon shale, and chert. The succeeding 20 feet of chert-bearing conglomerate with interbedded quartzitic sandstone and gray shales (figs. 72, 73) represents the Hot Springs Member of the basal Stanley Shale. The Hot Springs Member was derived by submarine slumps and slurries passing through submarine canyons and channels from scarps flanking the foreland side to the north of the Ouachita trough. An interval composed mostly of shale and generally covered follows. The next 315 feet of steeply dipping interbedded graywackes, siltstones, shales, and some tuffs (especially near the top of the unit) represents the Hatton Tuff Member of the Stanley Shale (fig. 74). The Hatton Tuff Member was formed by submarine fans

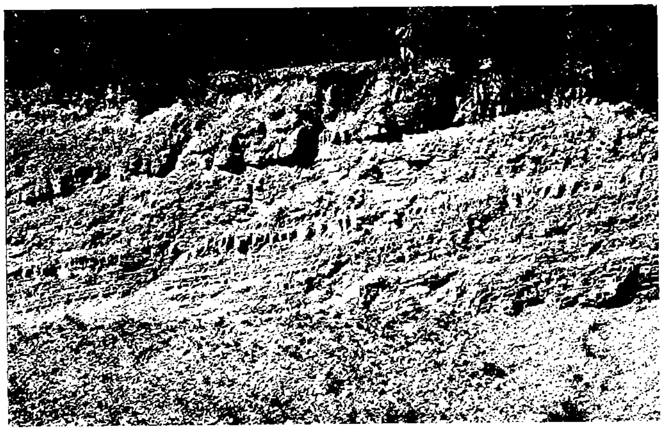


Figure 72. Beds of chert conglomerate, sandstone, siliceous shale, and shale in Hot Springs Sandstone Member of Stanley Shale, looking west. Contact with Upper Division of Arkansas Novaculite is exposed in road ditch to right of photo. (Stop 22.)

Figure 73. Chert conglomerate of Hot Springs Sandstone Member of Stanley Shale. (Stop 22.)

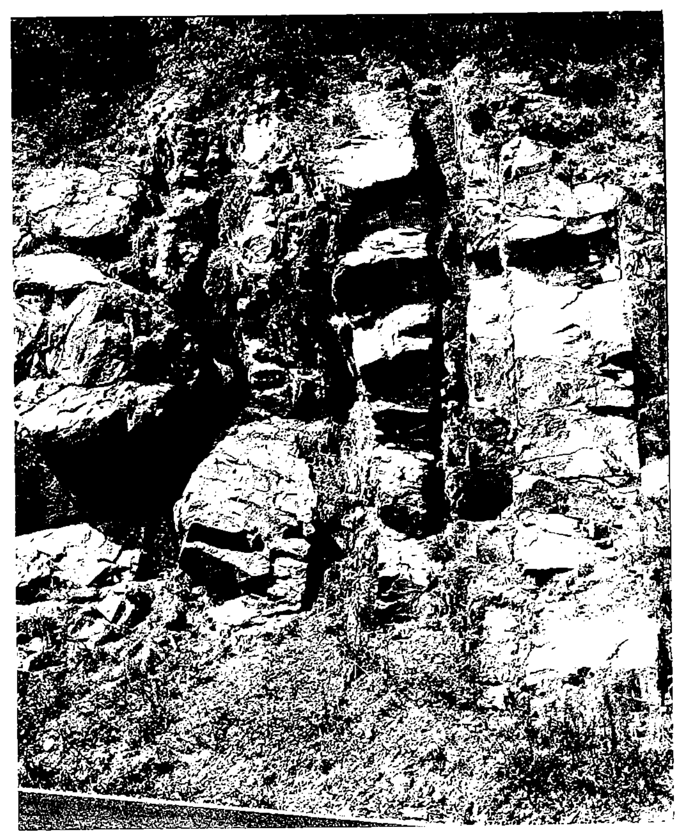


Figure 74. Steeply dipping (bottom to left) submarine-fan-channel sequence of graywacke and shale in Hatton Tuff Member of Stanley Shale, looking west. Note soft-sediment deformation. (Stop 22.)

STOP 22. POTTER JUNCTION

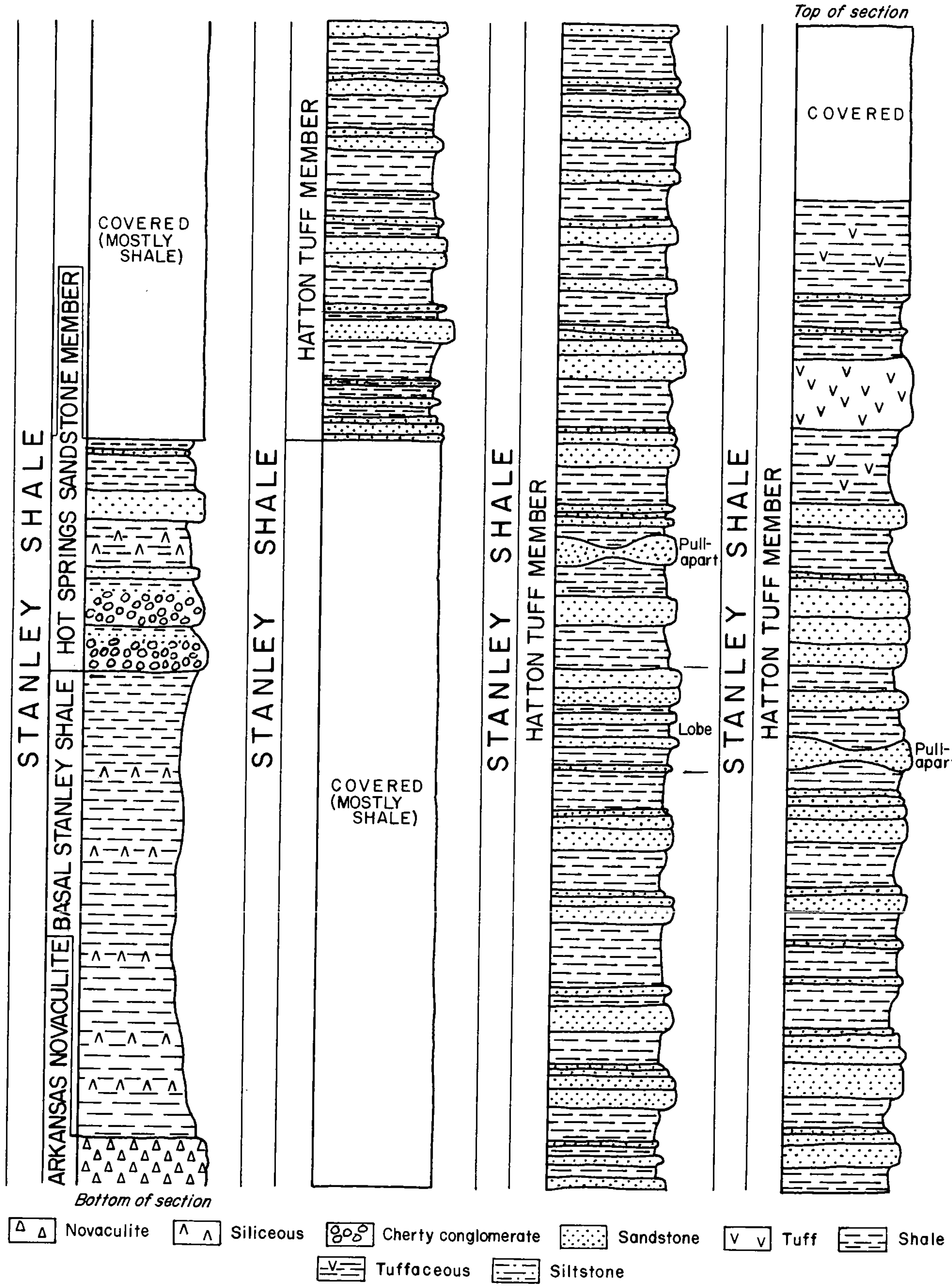


Figure 71. Graphic columnar section for Stop 22.

building out from the south and southeast, and at this locality the Hatton comprises mostly fan channels with some minor lobes in a middle to outer submarine-fan facies (fig. 70). This exposure is near the northern limit for the acidic volcaniclastic tuffs of the Hatton interval in the Ouachita Mountains. The tuff is a coarse-grained crystalline type, which is typically a poorly sorted, weakly stratified, graded, volcanic arenite composed of coarse euhedral plagioclase feldspar crystals in a shard-rich, greenish-gray matrix. Bottom marks indicating westward-flowing paleocurrents are prominent in the unit. Some rotated sedimentary slump structures are also present. Slickensides and small milky-quartz veins occur in the interval and mark small faults.

STOP 23—EAST RICH MOUNTAIN

Location: Road cut on Talimena Drive (Arkansas Scenic Highway 88) on east end of Rich Mountain, approximately 4.1 miles northwest of Mena (9.1 miles east of Queen Wilhelmina Lodge). NE¼ NE¼ sec. 36 and SE¼ SE¼ sec. 25, T. 1 S., R. 31 W., Polk County, Arkansas.

This exposure is on the north flank of the large Rich Mountain Syncline. Here, at least 100 feet of well-exposed, gently southward-dipping sandstones, siltstones, and shales of the lower Jackfork Sandstone (mostly early Morrowan) (figs. 75, 76) exhibit Bouma sequences (graded bedding, etc.), bottom marks, trace fossils, and other features that are indicative of deep-water flysch deposition (fig. 70). This series of six thickening-upward, fan-lobe sequences (figs. 70, 75) is in turn overlain by two thinning-upward, fan-channel sequences (figs. 70, 75). This thick package of turbidites represents a regressive interval deposited in the middle to outer submarine-fan environment. A zone (fig. 75, basal 10 feet) containing slumped sandstone masses, probably derived from the north, shows the instability present in the trough during deposition. Siltstone "blue" beds with carbonized plant fragments occur above many of the sandstones. Water-expulsion features are present at the top of some sandstone beds. Iron concretions and small chert masses also occur in some zones. Several high-angle reverse faults cut this section and contain veinlets of quartz and coatings of dickite on their slickensided surfaces (fig. 77).

STOP 24—INSCRIPTION ROCK

Location: Road cut and overlook on Talimena Drive (Arkansas Scenic Highway 88) approximately 7.1 miles west of Mena and 6.1 miles east of Queen Wilhelmina Lodge. SW¼ NE¼ sec. 22, T. 1 S., R. 31 W., Polk County, Arkansas.

This southward-dipping section of lower Jackfork Sandstone (mostly early Morrowan) occurs on the north flank of the Rich Mountain Syncline. The exposure has been inscribed often by visitors to the area. Carbonized plant fragments are preserved in a siltstone "blue" bed overlying a ripple-marked sandstone (fig. 78). Also present in the sequence are convolute bedding, load features, and small shale-siltstone sedimentary-deformed masses. Pyrite in the interval has been altered to melanterite (hydrous iron sulfate).

The overlook to the south provides a good view of the large, westward-plunging Rich Mountain Syncline and the various sequences of the more than 5,000-foot-thick Jackfork Sandstone. The Stanley Shale has been thrust over the south flank of the syncline by the Windingstair Fault.

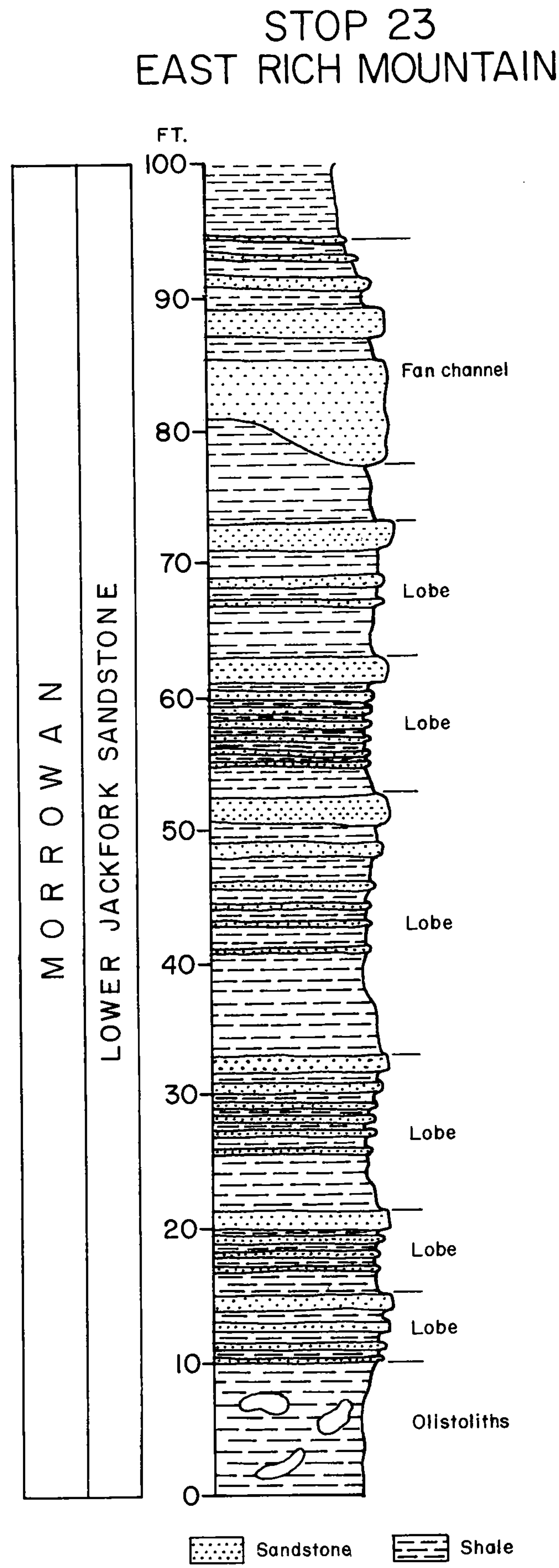


Figure 75. Graphic columnar section for Stop 23.

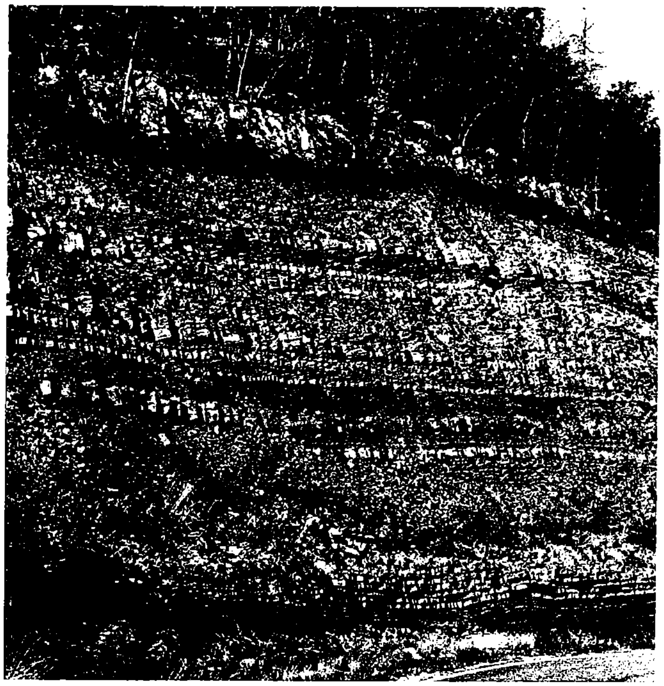


Figure 76. Series of submarine lobes overlain by fan-channel in lower Jackfork Sandstone, looking west. (Stop 23.)

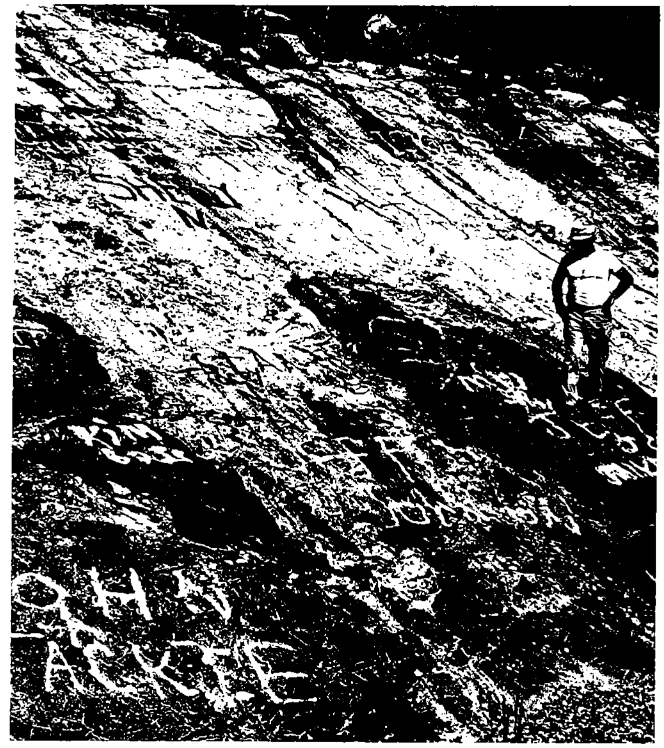


Figure 78. Inscribed sandstones and siltstones of lower Jackfork Sandstone, looking north. (Stop 24.)

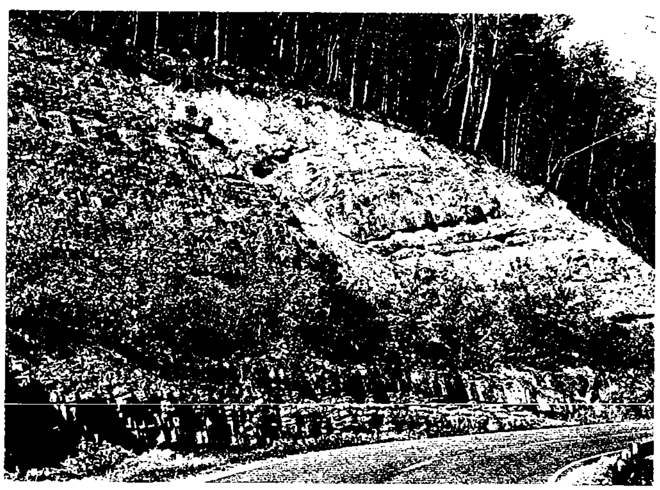


Figure 77. Reverse fault cutting turbidites of lower Jackfork Sandstone, looking west. (Stop 23.)

STOP DESCRIPTIONS—FOURTH DAY, MORNING

Charles G. Stone
Rufus J. LeBlanc, Sr.
Boyd R. Haley
John D. McFarland III

SUMMARY OF FOURTH DAY

The fourth day examines Carboniferous formations of the Ouachita facies in southeastern Oklahoma. The stops continue a study of this depositional province begun yesterday in Arkansas and again emphasize (1) the formations of Carboniferous age, (2) the rapid decrease in thickness in most Carboniferous formations to the north from an aggregate maximum thickness of more than 40,000 feet in the central Ouachita Mountains to about 15,000 feet in the southern Arkoma Basin, and (3) the sedimentary features that indicate the change from south to north of deep-water-marine (wildflysch and submarine-fan) to continental and (or) shallow-marine (deltaic) depositional environments.

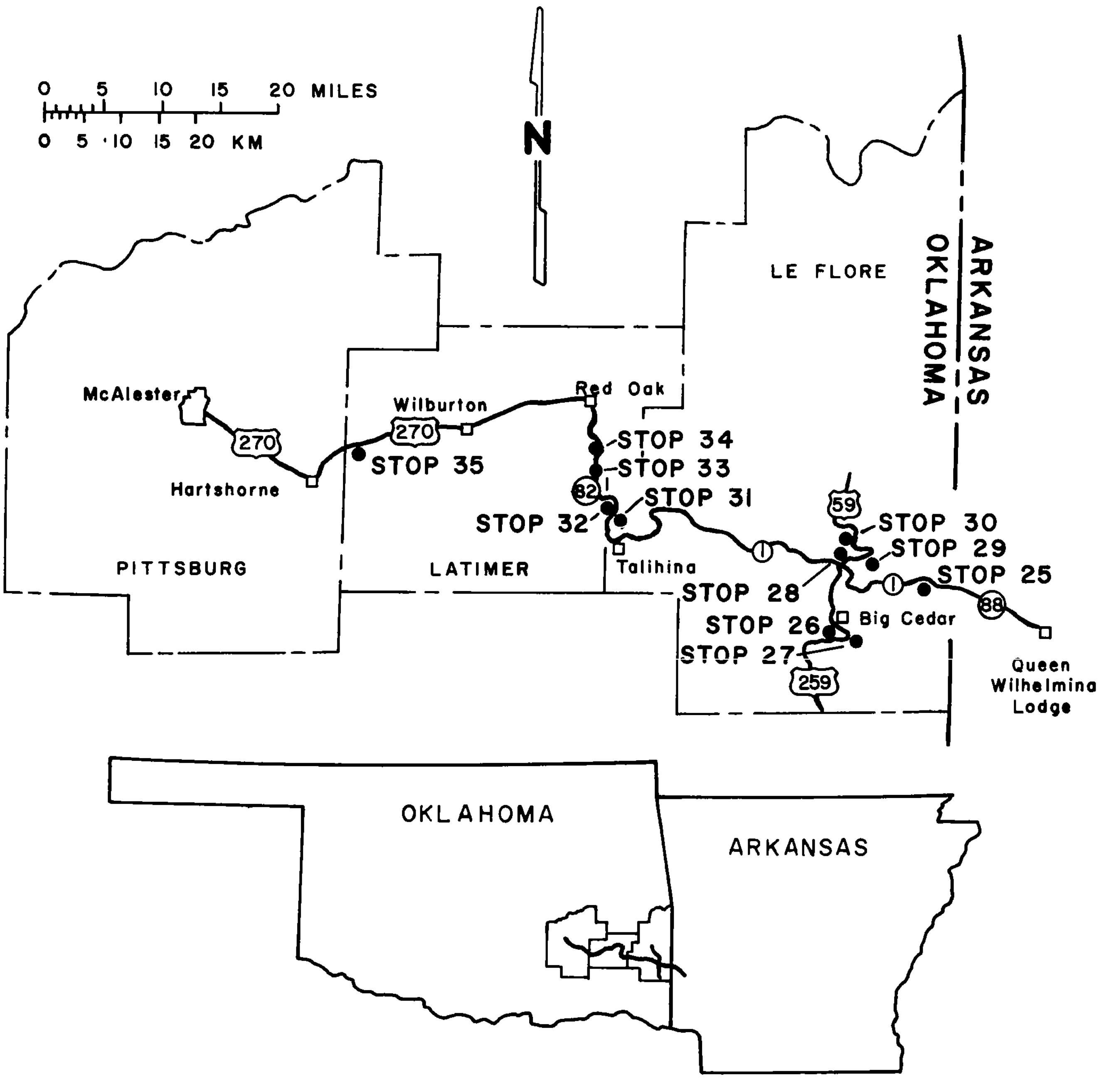


Figure 79. Locality and route map, fourth day.

STOP 25—WEST RICH MOUNTAIN

Location: Road cut on Talimena Drive (Oklahoma Highway 1) in Oklahoma about 10.4 miles west of Arkansas state line and 15.4 miles west of Queen Wilhelmina Lodge. SE¼ NE¼ sec. 1, T. 2 N., R. 25 E., Le Flore County, Oklahoma.

The tops of these southward-dipping, graded sandstones in the lower Jackfork Sandstone have numerous westward-directed asymmetrical ripple marks that are especially well developed in small depositional troughs or "valleys" (fig. 80). A network of small cross-cutting sandstone dikes is also visible. These dikes formed when water-saturated sand was injected upward along joints developed at the crests or "ridges" surrounding the troughs shortly after the deposition of the bed. Trails and burrows are also cut by these small dikes. The dikes appear to "die out" a few inches upward into the overlying thin shale. The bottoms of most of the sandstone beds have well-developed bottom marks (prods, flutes, grooves, and loads) that also indicate a westward-directed paleocurrent.

Figure 80. Ripple-marked sandstone in lower Jackfork Sandstone, looking northwest. (Stop 25.)

STOP 26—BIG CEDAR

Location: Road cut on U.S. Highway 259 approximately 2.4 miles south of Big Cedar on north slope of Kiamichi Mountain. NE¼ sec. 26, T. 2 N., R. 25 E., Le Flore County, Oklahoma.

This exposure represents the deep-water facies of the Chickasaw Creek Siliceous Shale Member of the upper Stanley Shale (upper Chesterian) and the lower Jackfork Sandstone (mostly lower Morrowan). The Chickasaw Creek is a dark-gray shale with some intervals of siliceous shale that become more cherty upon weathering (fig. 81). Some thin tuffaceous beds are also present. Small white siliceous globules occur in the "chert" and were reported by Cline (1968) to have nuclei of sponge spicules, diatoms, or radiolarians. Conodonts are also rather common in the shale and "chert." According to Gordon and Stone (1977) and Morris (1971), the Chickasaw Creek interval contains erratic boulders derived from the Ozark shelf facies (Pitkin Limestone and Fayetteville Shale of Chesterian age) in the frontal Ouachita Mountains of Arkansas.

Proceeding up the hill at this stop, the base of the first quartzose sandstone encountered (shown near the feet of the man in figure 82) represents the contact of the Stanley with the Wildhorse Mountain Member of the basal Jackfork Sandstone. The sandstones in the Jackfork have bottom marks, graded bedding, dish and pillow structures, convolute bedding, and many other features indicative of flysch deposition. Both lobes (thickening upward) and channels (thinning upward) in the sandstone sequences suggest lower-mid-fan and outer-submarine-fan deposition (fig. 70). A detailed description of the geology of these excellent exposures on Kiamichi Mountain is found in Cline and Moretti (1956).

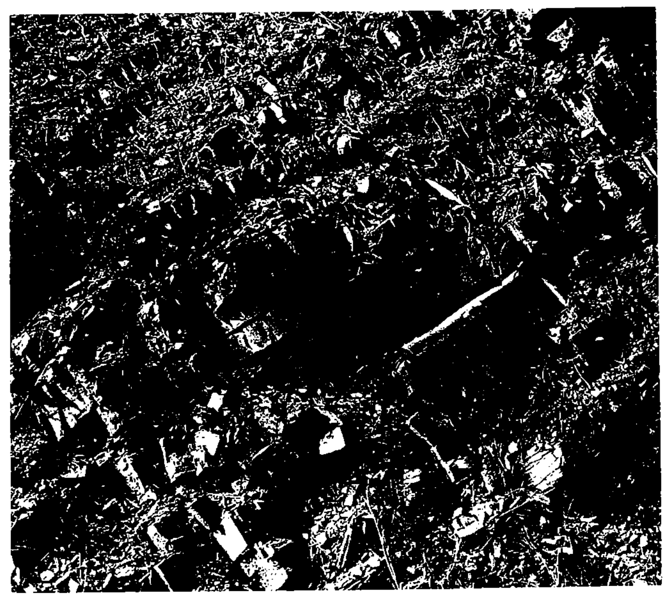


Figure 81. Thin-bedded chert and siliceous shale in Chickasaw Creek Siliceous Shale Member of upper Stanley Shale, looking west. (Stop 26.)

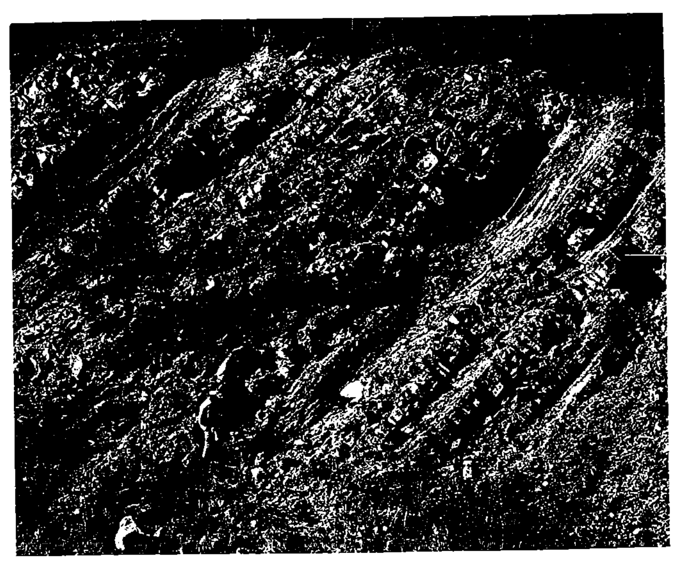


Figure 82. Contact between Stanley Shale and overlying Jackfork Sandstone, looking west. Rocks shown in figure 81 are to right of this photo. (Stop 26.)

STOP 27—KIAMICHI MOUNTAIN (NORTH)

Location: Road cut on U.S. Highway 259 approximately 3.6 miles south of Big Cedar and 1.2 miles south of stop 26 on north slope of Kiamichi Mountain. NW¼ SE¼ sec. 25, T. 2 N., R. 25 E., Le Flore County, Oklahoma.

A chaotic interval composed of irregularly shaped blocks and contorted masses of sandstone and shale with minor concretions characterizes the lower Jackfork Sandstone at this locality (fig. 83). This interval seems to represent a submarine sedimentary slurry deposit that was detached from some area upslope and moved by mass flow to its depositional site. Note the virtually undisturbed sandstone sequences above and below the interval. While a tectonic origin has been ascribed by some investigators, the notable lack of actual fault planes containing slickensides with hydrothermal dickite casts doubt on such an interpretation. Intervals of submarine slump are particularly common in many of the exposures of the middle and lower Jackfork Sandstone in both Oklahoma and Arkansas. It is our conclusion that these and other similar units associated with Carboniferous flysch deposits of the Ouachita Mountains reflect the highly unstable conditions that commonly prevailed within or adjacent to the Ouachita trough during this time. Some of these intervals likely represent localized detachments, but others that contain erratic materials were obviously derived from shelf regions outside the trough.

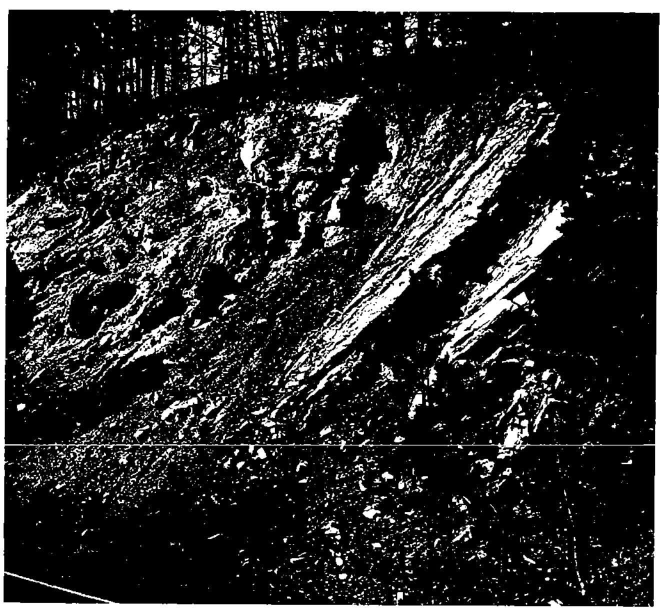


Figure 83. Olistostrome of sandstone and shale with minor concretions in shale interval of lower Jackfork Sandstone, looking west. (Stop 27.)

STOP 28—SPRING MOUNTAIN

Location: Road cut on U.S. Highway 259 about 1.5 miles north of junction with Talimena Drive and 6.7 miles north of Big Cedar. NE¼ sec. 24, T. 3 N., R. 25 E., Le Flore County, Oklahoma.

This alternating sequence of sandstone and shale is in the lower part of the Atoka Formation (fig. 84). There are many good examples of bottom marks, graded bedding, siltstone "blue" beds with some carbonized plant fragments, and trace fossils. Most of the units in the Bouma sequence (sharp basal contact followed by parallel laminations, current cross-laminations, and convolute laminations) can be recognized. This sequence exhibits sandstone intervals that thicken and coarsen upward, indicating that these beds were deposited as lobes in the lower-mid-fan and outer-submarine-fan environment (fig. 70).

The lower part of the Atoka Formation is about 18,000 feet thick in this vicinity and consists of shale, siltstone, and sandstone, all of which are thought to have been deposited in a deep-water environment. Stark (1966), in his study of approximately 5,500 feet of the lowermost lower Atoka across the central Ouachita belt of Oklahoma, reported a microfauna of siliceous foraminifers, radiolarians, and hexactinallid and monaxonid sponge spicules from the shales at this stop. Index foraminifers are *Ammobaculites, Spiroplectammina parva,* and *Trochammina rudis;* and Stark (1966) recognized three faunal zones in the lower Atoka in this area. By comparison of these Atoka faunas with faunas from Europe, Stark (1966) concluded that this facies of the lower Atoka was deposited in a bathyal part of the Ouachita geosyncline. Rufus J. LeBlanc, in his research with turbidites, separates deep-water sediments into three general types: (1) submarine-canyon deposits consisting of channel scour and fill and slumping down the side of the continental slope; (2) submarine-fan deposits consisting of distributary channel cut and fill, and lobe deposits (interchannel) at the base of the continental slope; and (3) basinal-plain deposits (fig. 70). Using this classification, practically all of the rocks in the Stanley, Jackfork, and Atoka Formations in this part of the Ouachitas represent submarine-fan or basinal-plain deposits. The wildflysch facies in the Johns Valley Shale appears to represent submarine-canyon deposits.

Figure 84. Outer-submarine-fan deposits in lower Atoka Formation, looking west. A sparse mold fauna is present in lower part of thicker sandstone. Note small low-angle fault. (Stop 28.)

STOP 29—SPRING MOUNTAIN (NORTH)

Location: Road cut on U.S. Highway 259 about 1.5 miles north of Stop 28 and 0.5 mile south of junction of U.S. Highways 59 and 270. NW¼ SE¼ sec. 17, T. 3 N., R. 26 E., Le Flore County, Oklahoma.

This 350 feet of alternating sandstone, siltstone, and shale is in the lower Atoka Formation. The section consists mostly of several fan-lobe sequences each of which thickens upward with very thin (shallow) fan-channel sequences above the lobes (fig. 85), indicating progradation of the fan. These interbedded shallow channel and lobe sequences indicate lower-mid-fan and outer-submarine-fan depositional environments (fig. 70). Graded bedding, bottom marks, Bouma sequences, trace fossils, and other deep-water indicators are present. Seely (1963) placed these beds approximately 5,000 feet above the base of the Atoka Formation.

Bottom marks generally indicate an east-to-west paleocurrent direction in the lower Atoka (fig. 86). However, lithology and other data suggest that the sediments were derived from delta systems to the north, northeast, and east-southeast and were carried by turbidity currents through a series of complex coalescing submarine-fan systems into the rapidly subsiding Ouachita trough during early Atoka time.

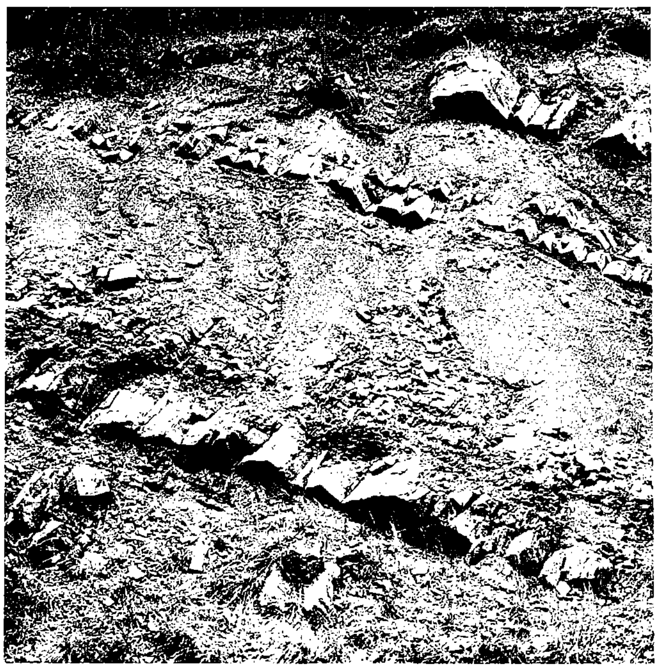


Figure 85. Outer submarine-fan channel and some lobe deposits in lower Atoka Formation, looking southwest. (Stop 29.)

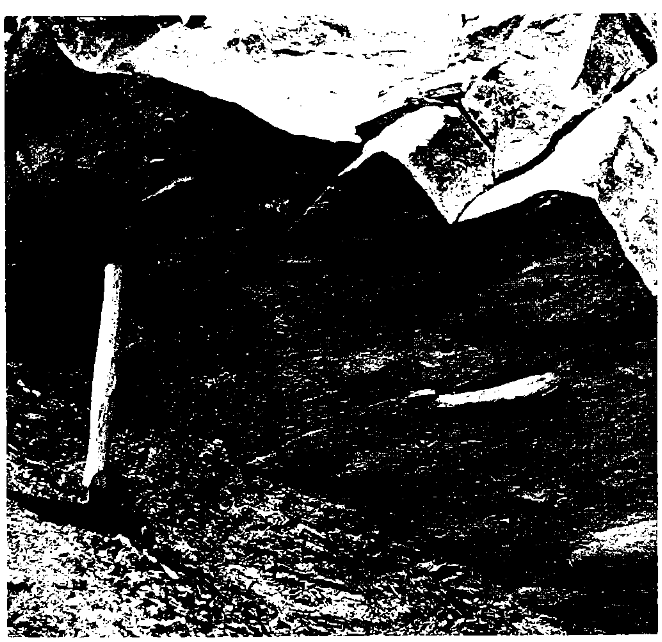


Figure 86. Flute casts and bottom marks on bottom (to left) of "second" sandstone shown in figure 85. (Stop 29.)

STOP 30—STAPP

Location: Road cut on U.S. Highways 59 and 270 about 0.6 mile south of Stapp. NW¼ SE¼ and SW¼ NE¼ sec. 12, T. 3 N., R. 25 E., Le Flore County, Oklahoma.

This is a well-known locality in the wildflysch facies of the Johns Valley Shale (see also Stop 20). In recent years the Johns Valley Shale has been delineated in the southern, central, and frontal Ouachita Mountains of Oklahoma and Arkansas. The Johns Valley is typically a clay shale containing some beds of sandstone generally with abundant bottom marks and some clay-ironstone concretions and small olistostromes. Rocks ranging from Late Cambrian to Early Pennsylvanian in age were derived from the miogeosynclinal and shelf facies of the Arbuckle and Ozark regions and redeposited in the Johns Valley Shale (fig. 68). The erratics in the shale at this locality include limestone, dolomite, sandstone, and other lithologic types and are moderately well rounded (fig. 87). Some conglomerate masses are present, which have clasts ranging from subangular to well rounded (figs. 88, 89). Bottom marks and graded bedding are well exhibited by the submarine-fan channel sandstones at the south end of the exposure and indicate that the bottoms of the beds face to the south (fig. 90). Small faults cut the sequence and generally have slickensides coated with brownish-white dickite.

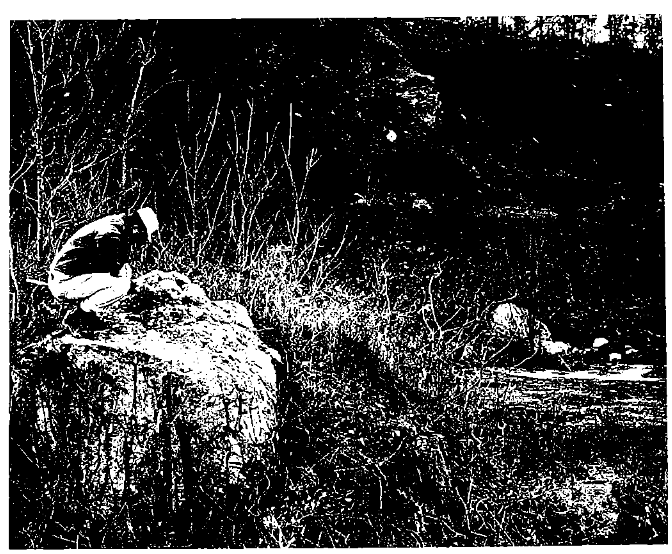


Figure 87. Olistostrome composed mostly of limestone and dolomite quarried from shale in Johns Valley Shale, looking south. (Stop 30.)

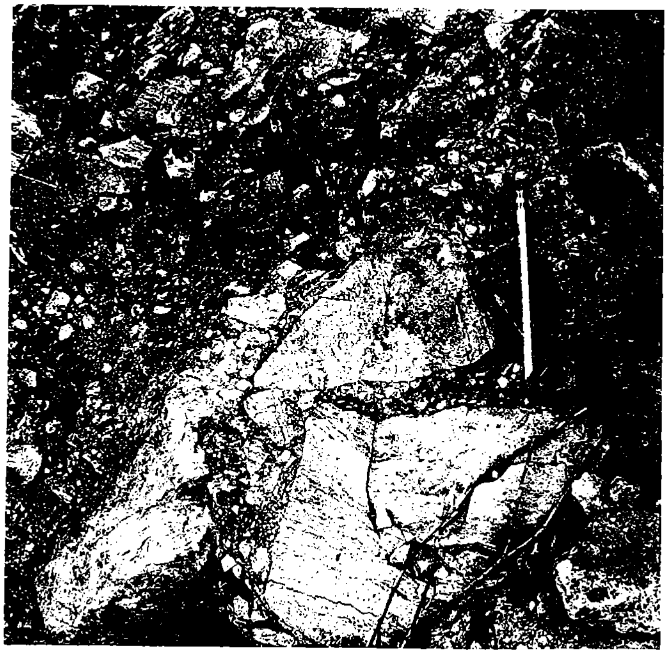


Figure 88. Olistoliths in olistostrome shown in figure 87. (Stop 30.)

Figure 89. Limestone olistostromes and olistoliths in shale of Johns Valley Shale, looking west. (Stop 30.)

Figure 90. Submarine-fan channel deposits in Johns Valley Shale, looking west. Beds are overturned, and bottom is to left in photo. (Stop 30.)

STOP DESCRIPTIONS—FOURTH DAY, AFTERNOON

Patrick K. Sutherland

STOP 31—WINDINGSTAIR MOUNTAIN

Location: Road cut on east side of Oklahoma Highway 82, on road from Talihina to Bengal, 3.8 miles north of junction with Oklahoma Highway 1, just west of Talihina. Highway 82 runs generally north-south, staying within 1 mile of Le Flore-Latimer County line, between Talihina and Bengal. SW¼ SE¼ sec. 24, T. 4 N., R. 21 E., Le Flore County, Oklahoma.

The road north from Talihina to Bengal to Red Oak crosses the northern part of the central Ouachitas, the narrow belt of the frontal Ouachitas, and the southernmost margin of the Arkoma Basin. The boundary between the central Ouachita facies and the frontal Ouachita facies is marked by the Ti Valley thrust fault, located about 5 miles north of Talihina and less than 1 mile south of the small village of Bengal. The Ti Valley Fault marks the northern limit of exposures of the deeper water Stanley-Jackfork-Johns Valley sequence and the southern limit of the shallower water "Caney"-"Springer"-Wapanucka sequence. Only the overlying Atoka Formation occurs in both areas.

Figure 91 is a cross section by Fellows (1964, pl. 1, sec. D-D') that approximately follows Highway 82 from Talihina to Bengal and crosses the east-west-trending Windingstair Range. Note on the cross section the different formational terminology north of the Ti Valley Fault.

The highest ridges in the Windingstair Range are mostly formed by resistant sandstones in the lower Atoka Formation, as seen at Stop 31. The top of the Atoka Formation in this area is eroded. Fellows (1964) estimated the maximum preserved thickness of the Atoka Formation in the Windingstair Mountain area to be 6,000 to 7,000 feet.

At Stop 31 (fig. 92) the basal 200 feet of the Atoka Formation is well exposed and in contact with about 20 feet of the underlying Johns Valley Shale. The upper Johns Valley Shale, poorly exposed at the northeast end of the road cut, contains a few scattered limestone erratics up to 0.7 foot in diameter. The lower Atoka Formation at this locality consists of interbedded turbidite sandstones and shales. The basal 70 feet is predominantly shale with classic turbidite layers, using the Bouma model (Walker, 1978; this report, fig. 96A). Sole markings are exceptionally well developed (fig. 93; front cover).

Figure 92. Lower Atoka Formation. (Stop 31.)

Figure 93. Well-developed sole markings on bottom of 1.5-foot classic turbidite sandstone layer, lower Atoka Formation (same subject as front cover). (Stop 31.)

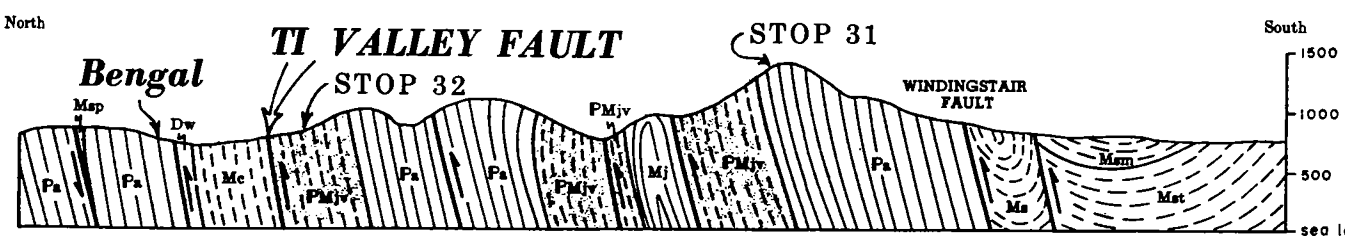


Figure 91. North-south cross section extending along Le Flore-Latimer County line, approximately from Talihina (south) to Bengal (north). Terminology south of Ti Valley Fault: *Mst*, Tenmile Creek Formation; *Msm*, Moyers Formation; *Ms*, Stanley Group (undivided); *Mj*, Jackfork Group (undivided); *IPmjv*, Johns Valley Shale; *IPa*, Atoka Formation. Terminology north of Ti Valley Fault: *Dw*, Woodford Formation; *Mc*, "Caney" Shale; *Msp*, "Springer" Formation; *IPa*, Atoka Formation. (From Fellows, 1964, pl. 1, sec. D-D'. Contrary to this report, Fellows assigned the Jackfork to the Mississippian and the Johns Valley to both the Mississippian and Pennsylvanian.)

The basal shaly interval is overlain by a massive sandstone layer, about 25 feet thick, that shows almost no internal bedding features. It appears to be fine grained throughout. This unit is overlain by an additional 25 feet that is predominantly sandstone, but this interval is made up of about 10 modified classic turbidite flows in which shale interbeds make up no more than 10 percent of the overall interval (fig. 92, center). These turbidites have well-developed bottom-transport features. Directions of transport recorded within this 25-foot interval vary from S. 5° W. to S. 72° W. These appear to be at variance with the more nearly westerly direction (parallel to present strike) illustrated for this general area by Briggs and Cline (1967, fig. 4).

The 50-foot interval composed predominantly of sandstone, just described, possibly represents some part of a submarine-fan deposit, but these sandstones are fine grained throughout and the beds show little or no lateral variation in thickness within the extent of the outcrop.

STOP 32—BENGAL SOUTH

Location: Road cut on south side of Oklahoma Highway 82, 5.3 miles north of junction with Oklahoma Highway 1, just west of Talihina and 1.6 miles southeast of Bengal. NW¼ SE¼ sec. 13, T. 4 N., R. 21 E., Le Flore County, Oklahoma.

The upper Johns Valley Shale seen at this locality (fig. 94) differs from the exposure at Stapp (Stop 30) in that the erratic limestone and sandstone boulders are much smaller in size and the shale shows no distortion either by sediment transport or by subsequent structural movement. One can see the depositional relationship of the erratics to the shale. At this locality the shale is very evenly bedded, and the small erratics appear as suspended "plums in a pudding." There are numerous small ironstone concretions.

Fellows (1964) estimated the thickness of the Johns Valley in this region to be 500 to 700 feet. About 70 feet is exposed in this road cut, and these strata are apparently in the upper part of the formation.

The Johns Valley is exposed in the railroad cuts of Compton Cut, described and illustrated by Harlton (1934), 1.5 miles to the southeast from Stop 32. A few large erratics occur at that locality, but there has been much structural disturbance. There is no access road to Compton Cut. It can be reached on foot by walking about 2 miles along the tracks southeast from Bengal.

The Ti Valley Fault lies in the valley only 0.5 mile north of Stop 32, and the village of Bengal is located 1.6 miles to the northwest, along Oklahoma Highway 82. About 0.7 mile west of Bengal, and directly north of the Ti Valley Fault, Fellows (1964, p. 20) described an exposure in a creek bed of the upper 36 feet of the Woodford Chert and the lower 45 feet of the overlying "Caney" Shale. These rocks are part of the frontal Ouachita facies.

STOP 33—BENGAL NORTH

Location: Long double road cuts on Oklahoma Highway 82, 4.0 miles north of Bengal and 8.1 miles south of Red Oak. SE¼ NE¼ sec. 34, T. 5 N., R. 21 E., Latimer County, Oklahoma.

Seen at this locality are long double road cuts exposing an estimated 700 feet of the Atoka Formation (fig. 95). This sequence consists predominantly of shale, with an estimate of only 15 to 20 percent sandstone present. A limited number of these layers exceed 1 foot in thickness (the maximum seen is about 4 feet thick), and these have the features of classic turbidites (figs. 96A, 97). They are unusual in that the bottom surfaces are characterized mainly by casts of well-developed trails and burrows (fig. 98), and transport grooves may be lacking (as in fig. 98) or faintly superimposed on the trail and burrow marks, the scouring at the time of transport not having completely destroyed the trails and burrows. Most of the transport grooves present are too indistinct to give convincing evidence as to direction of transport.

Most sandstone layers at this locality range in thickness from 0.3 to 0.9 foot thick and have features that suggest in-

Figure 94. Johns Valley Shale. Note even-bedded shale and small size of erratic boulders. (Stop 32.)

Figure 95. Lower Atoka Formation. Interbedded, incomplete, and complete classic turbidites. Compare with figures 96A, B. (Stop 33.)

complete Bouma sequences (fig. 96B). Some of these layers have thin horizontal bedding in the lower part (see fig. 96B, middle figure). Some show basal tracks and burrows, but few show transport features.

This sequence is believed to represent basin-plain, complete and incomplete classic turbidites, deposited far from their source.

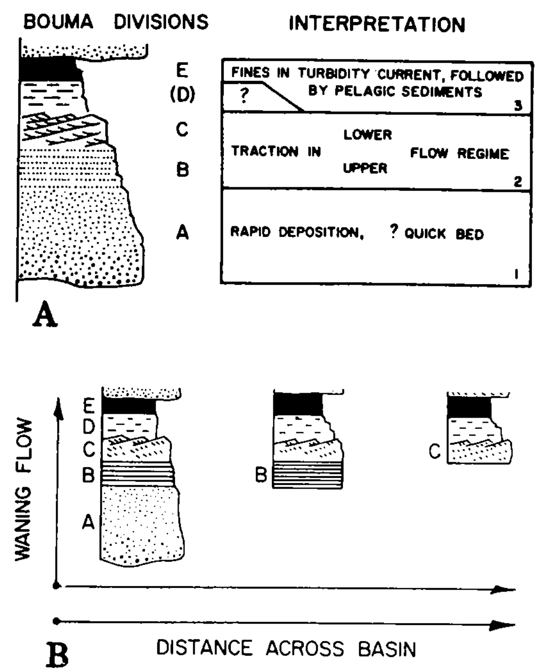


Figure 96. *A*, Bouma model for classic turbidites; division *A* is massive or graded, *B* is parallel laminated, *C* is rippled, *D* consists of faint laminations of silt and mud, and *E* is pelitic; after Walker (1978). *B*, interpretation of Bouma sequence in terms of waning flow suggests that groups of turbidites beginning with divisions *B* and *C* represent deposition from progressively slower flows, presumably related to distance from source; after Walker (1978).

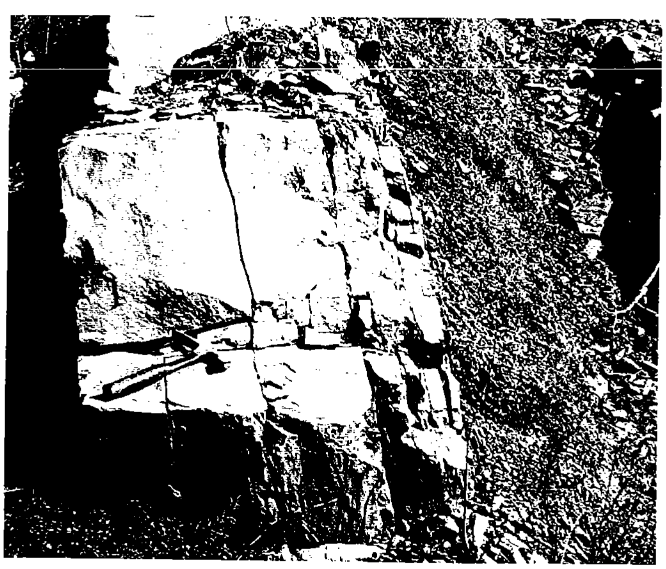


Figure 97. A single classic turbidite sandstone layer (compare with fig. 96A), with sharp base at left. (Stop 33.)

Figure 98. Bottom surface of classic turbidite sandstone layer, showing filling of burrows and trails. Note lack of transport features. (Stop 33.)

STOP 34A—RED OAK SOUTH (WAPANUCKA SECTION 11)

Location: Road cut on west side of Oklahoma Highway 82, 6.0 miles north of Bengal and 6.1 miles south of Red Oak. SW¼ SW¼ sec. 23, T. 5 N., R. 21 E., Latimer County, Oklahoma.

This is the easternmost known exposure of the Wapanucka Limestone in the frontal Ouachita belt (figs. 99, 100). Exposed is the upper part of the middle shale member and the upper sandstone/limestone member (see fig. 104 and discussion of Wapanucka stratigraphy at beginning of fifth day by Robert C. Grayson, Jr.). The Wapanucka sequence at this locality has a strike of N. 76° E. and a dip of 81° SE (overturned).

The upper sandstone/limestone member is interpreted by Grayson as having been deposited in a shallow-water marine environment. At this locality this member consists mostly of sandstone with some carbonate mudstone, oolite, and thin layers of shale and siltstone.

Conodonts of the lower Atokan *Streptognathodus elegantulus* Zone have been recovered from bed 6 (fig. 99).

STOP 34B—RED OAK SOUTH, ATOKA

Location: Road cut on west side of Oklahoma Highway 82, 6.2 miles north of Bengal, 5.9 miles south of Red Oak, and 0.2 mile north of Stop 34A. NW¼ SW¼ sec. 23, T. 5 N., R. 21 E., Latimer County, Oklahoma.

The Atoka sequence at this locality is composed of evenly bedded thin sandstones and thicker shale intervals. The sandstone layers represent primarily incomplete classic turbidite intervals (see fig. 96B), but they are unusual in having rather sharp top as well as bottom surfaces. Most show no bottom-transport features, only filled burrows and trails. These sandstones are very fine grained and typically 0.1 to 0.6 foot thick. This interval is interpreted as a distal classic turbidite sequence.

The Atoka strata at this stop are structurally disturbed in

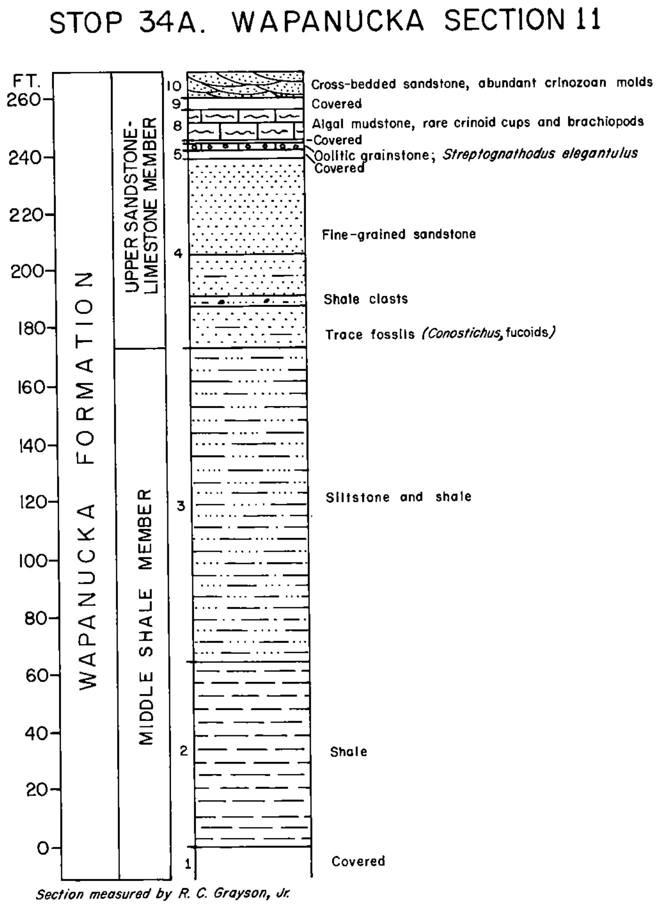


Figure 99. Graphic columnar section for Stop 34A. See figure 104 for location of section in relation to other Wapanucka localities.

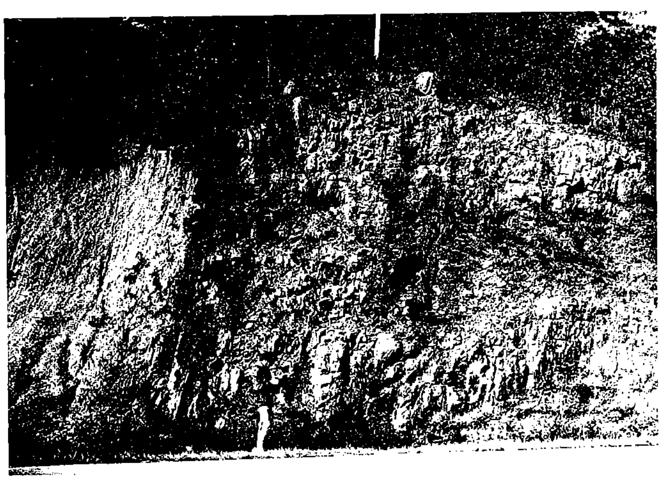


Figure 100. Overturned middle shale and upper sand-stone/limestone member of Wapanucka Formation. (Stop 34A.)

the southern part of the exposure, but the faulting appears to be minor. The top of the sequence is to the northwest, with a strike of about N. 50° E. and a dip of 77° S. (overturned). It is possible that this interval is in normal sequence with the Wapanucka Formation at Stop 34A, 0.2 mile to the south, where the overturned strata dip in approximately the same direction. However, the alternative possibility cannot be ruled out that major faulting separates the two exposures.

Robert C. Grayson, Jr. (personal communication), reports that this is the only locality observed by him in his recent comprehensive study of the Wapanucka Formation in the Frontal Ouachitas where an Atoka flysch facies is found in fairly close proximity above the Wapanucka Formation in the first range or so south of the Choctaw Fault in the frontal Ouachitas. If the two localities are in normal sequence, the relationship would be unusual in that the underlying upper sandstone/limestone member of the Wapanucka Formation exhibits features that suggest shallow-water deposition (see discussion of Wapanucka stratigraphy at beginning of fifth day).

The Choctaw thrust fault, which marks the northern margin of the Ouachita Mountains, lies covered in the broad valley about 0.8 mile north of Stop 34B. About 0.7 mile north of the Choctaw Fault, 2.9 miles north of Stop 34B by road, and 3.0 miles south of Red Oak, Oklahoma Highway 82 crosses a low sandstone ridge (strike N. 64° E., dip 30° N.). This ridge is made up of Atoka sandstone, which displays, in a small quarry just east of the road at the crest of the hill, typical shallow-water depositional features. The sandstone layers are heavily bioturbated, and the top surfaces of layers are covered with well-developed ripple marks.

One mile farther north, and 2.0 miles south of Red Oak, Oklahoma Highway 82 crosses the high Hartshorne Sandstone ridge. This unit also displays many shallow-water depositional features, including flaser and laminated bedding, in what appear in part to be tidal-flat deposits.

STOP 35—GAINES CREEK

Location: Road cut on southwest side of U.S. Highway 270, 8.4 miles west of junction with Oklahoma Highway 2 (to south) in Wilburton and 1.4 miles southwest of bridge over Gaines Creek. SE¼ NE¼ sec. 24, T. 5 N., R. 17 E., Latimer County, Oklahoma.

This road-cut exposure is in the upper part of the Atoka Formation (fig. 101) and lies no more than 100 feet below the base of the Hartshorne Sandstone, which caps the high bluff. This part of the Atoka Formation is composed mostly of shale in-

Figure 101. Flat-lying upper Atoka Formation, with sandstone dike (next to figure). (Stop 35.)

terbedded with a few fine-grained, thin-bedded sandstone layers. The shales are gray and micaceous, and plant fragments are common on some bedding planes. The environment of deposition is presumed to be shallow water marine to nonmarine transitional, possibly deltaic. The strata strike N. 65° W. and dip 3° to 4° to the southwest. The locality is in the Arkoma Basin, about 4 miles northwest of the Choctaw Fault.

An unusual feature at this locality is the presence of discontinuous sandstone dikes. They possibly should be called discontinuous "plugs" instead of dikes, since they are not continuous either vertically or horizontally. There are three different such masses in this exposure. The best preserved (next to the man in fig. 101) is about 2.5 feet in diameter, has vertical sides, and is at least 8 feet in height (its base is not exposed). There is irregular horizontal bedding within this plug (fig. 102), and the grains are medium and well sorted in comparison to the fine-grained layers of sandstone in the surrounding Atoka.

Figure 102. Sandstone dike in upper Atoka Formation. (Stop 35.)

STOP DESCRIPTIONS—FIFTH DAY

Robert C. Grayson, Jr.

SUMMARY

This portion of the excursion (fig. 103) will be used to examine lithofacies and facies changes in the Wapanucka Formation (Morrowan-Atokan) of the frontal Ouachita Mountains of Oklahoma. Lithologically, the formation contrasts markedly with stable-shelf equivalents that have been examined in the southwestern Ozark region (fig. 2). Five stops are scheduled that will provide an opportunity to examine some features of particular interest: (1) lithostratigraphic subdivision of the Wapanucka; (2) complex and abrupt facies changes in the marine-shoal deposits characterizing the lower limestone member; (3) character of the Chickachoc Chert Member, which is the basinal, deeper water time equivalent of the lower limestone member; (4) offshore bar and inter-bar facies, characterizing the upper sandstone/limestone member; and (5) conodont biostratigraphic subdivisions of the Wapanucka Formation (Morrowan-Atokan).

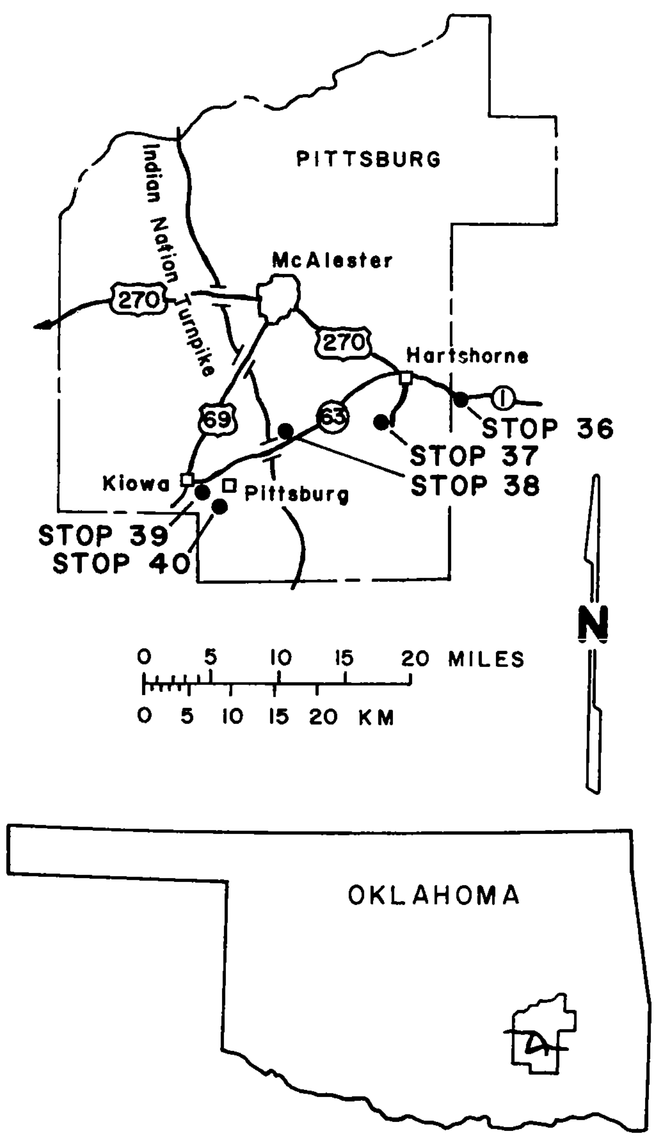


Figure 103. Locality and route map, fifth day.

WAPANUCKA STRATIGRAPHY

The Wapanucka Formation (Morrowan-Atokan) is exposed in a series of arcuate thrust-fault blocks in the frontal Ouachita Mountains of Oklahoma. The formation is repeated by faults as many as five times in a distance of approximately 2 miles. These fault-block exposures range from less than 1 mile to nearly 50 miles in linear extent. Thirty-three measured sections spaced along this narrow outcrop belt (fig. 104) provide control for stratigraphic study and subdivision of the Wapanucka. The formation is herein subdivided informally into four members that contain part or all of four newly recognized conodont zones (fig. 105). These zones are defined by the lowest occurrences of time-sensitive conodont platform elements. The biostratigraphic framework provided by the conodonts is an invaluable tool in local correlation because of abrupt facies changes and structural complexities. Conodonts also provide a basis for correlation with the type Morrowan sequence in northwestern Arkansas and northeastern Oklahoma (Grayson 1978).

The four informal members (fig. 105) of the Wapanucka Formation are, in ascending order, (1) the Chickachoc Chert Member, (2) the lower limestone member, (3) the middle shale member, and (4) the upper sandstone/limestone member. The Chickachoc Chert and lower limestone members are laterally equivalent for the most part, so only three members are recognized at most localities. The lower limestone includes a variety of marine-shoal facies. It is a complex lithologic association consisting of varying proportions of micritic and spiculiferous limestone, oolite and bioclastic calcarenite, limestone-pebble conglomerate, and shale interbeds. Based on conodonts, the shoal lithologies of the lower limestone are the time equivalents of the much thicker basinal facies comprising the Chickachoc Chert Member (fig. 105).

The Chickachoc Chert was proposed by Taff (1901) for cherty beds that he thought formed a lens in the basal Atoka Formation. In contrast, Hendricks and others (1947) argued that the Chickachoc was a formation that was the basinward equivalent of the whole of the Wapanucka Formation. Detailed field study and correlations based on conodonts, however, indicate that the Chickachoc Chert Member is equivalent only to the lower limestone member and not to the whole of the Wapanucka (fig. 105). The Chickachoc, in contrast to the lower limestone, consists of a few persistent and particularly distinctive lithologies: shale, flaser-bedded spiculite, spiculiferous limestone, and rare thin interbeds of cross-bedded bioclastic calcarenite. Shale and flaser-bedded spiculites are the dominant lithologies; spiculiferous limestone, thin cross-bedded bioclastic calcarenite, and sandstone constitute only a small fraction of the unit. Flaser-bedded spiculite consists of interbedded current-aligned spicules and shale drapes in a complex pattern of laminated, wavy, lenticular, and flaser bedding. The spicules are not indigenous. They are thought to have been transported basinward from shoal environments by episodic current activity. This current system may have been tidal in origin, but longer periodicity currents cannot be ruled out. The dark color of flaser-bedded spiculite suggests a reducing environment. The common occurrence of feeding traces assigned to the *Zoophycus* Ichnofacies of Sielacher (1967), in conjunction with the dark flaser-bedded spiculite, indicates deposition in an outer-shelf environment in moderate water depths. In contrast to flaser-bedded spiculite, spiculiferous limestone is thought to represent an essentially *in-situ* accumulation of loose spicules. Presumably, these spiculiferous limestones indicate a more open, well-circulated marine environment possibly higher on the shelf. The thin bioclastic calcarenites are products of catastrophic events. They invariably exhibit sharp basal contacts and low-angle planar cross-bedding that dips in a basinward direction. These calcarenites are thought to represent basinward transport of shoal bioclasts by major storm-generated currents.

The lower limestone and Chickachoc Chert members were deposited on a basinward-sloping substrate. The middle shale member is a fine-grained clastic wedge that thickens toward the basin. It represents a basin-fill stage of sedimentation. To a considerable extent, this clastic influx diminished the basinward-sloping bathymetric profile that had existed previously. Subsequently, deposition of carbonate and quartz sand, recognized as the upper sandstone/limestone member, began in shallow water on a more nearly horizontal substrate. Bioclastic calcarenite and quartz sand accumulated as a linear system of offshore bars. Inter-bar facies include micritic and spiculiferous limestone as well as shale.

The four conodont zones in the Wapanucka Formation (fig. 105) can be characterized as follows. The *Idiognathodus convexus Zone* (Lane, 1977) indicates equivalence to the Kessler Limestone Member of the type Morrowan Series. The succeeding *Neognathodus kanumai-Idiognathoides ouachitensis* and *Diplognathodus orphanus* Zones are new zones represented by an erosional gap between the Kessler and overlying Trace Creek Shale (Grayson and Sutherland, 1977; Sutherland and others, 1978) in the type Morrowan Series in northwestern Arkansas. The *Streptognathodus elegantulus* Zone is the youngest biostratigraphic unit present in the Wapanucka. This zone is also present in the Trace Creek Shale Member of the Atoka Formation in northwestern Arkansas and northeastern Oklahoma (Sutherland and Grayson, 1978). Its occurrence is thought to indicate an earliest Atokan age.

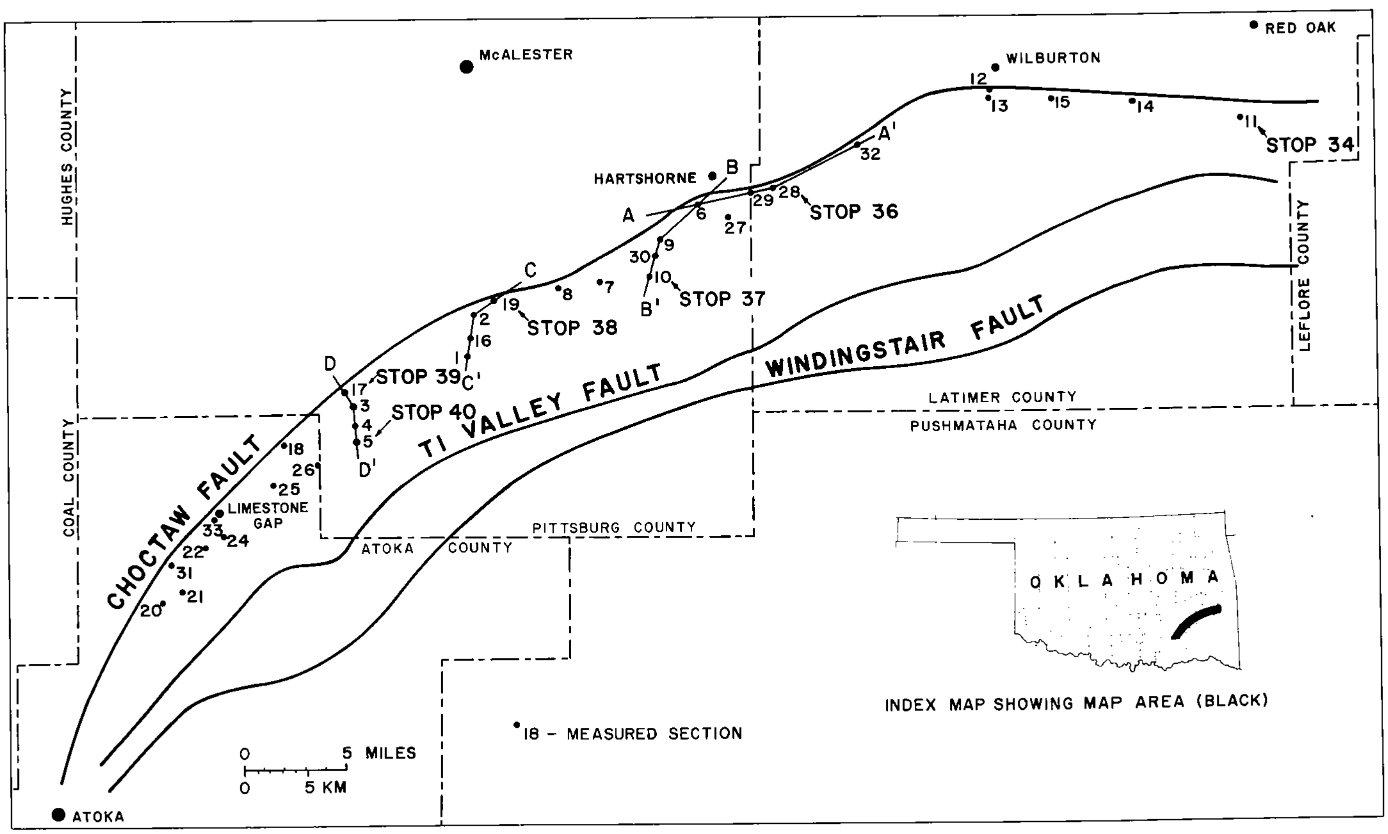


Figure 104. Generalized locality map for measured sections by Robert C. Grayson, Jr., in Wapanucka Formation. Note locations of cross sections A-A', B-B', C-C', and D-D' (figs. 106, 109, 111, and 115, respectively); north-to-south distances between measured sections arbitrarily expanded by a factor of 2 to 3.

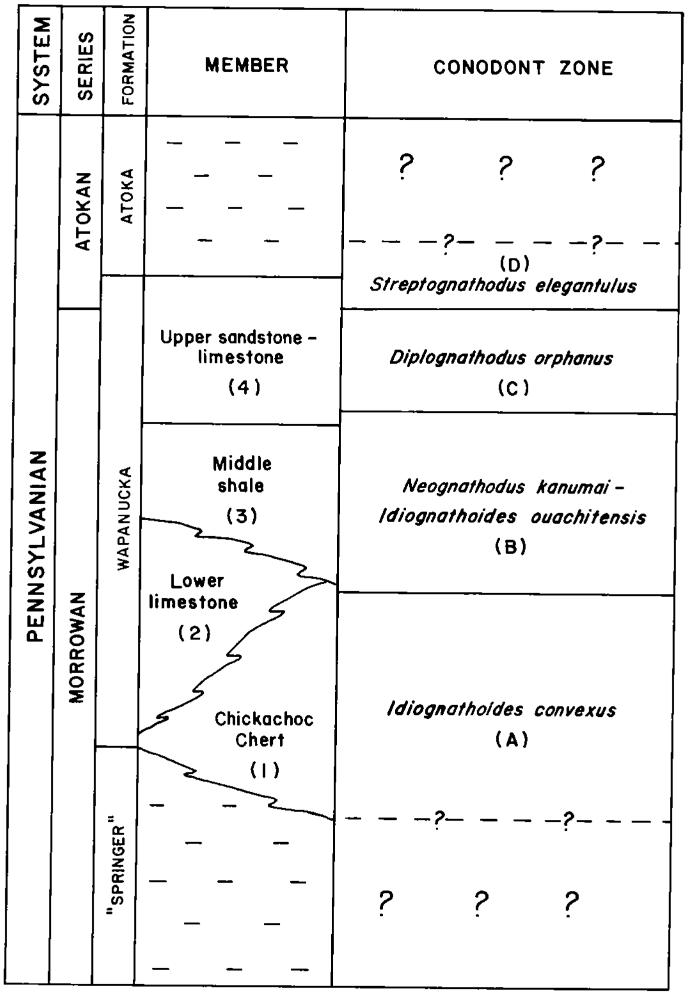


Figure 105. Summary of lithostratigraphic and biostratigraphic subdivisions of Wapanucka Formation, Ouachita Mountains, Oklahoma.

STOP 36—LATIMER-PITTSBURG COUNTY LINE (WAPANUCKA SECTION 28)

Location: Road cut on northeast side of Oklahoma Highway 1, 3.0 miles southeast of intersection of Oklahoma Highway 1 with U.S. Highway 270 at eastern limit of Hartshorne, and 0.2 mile east of Latimer-Pittsburg County line. SE¼ SW¼ sec. 28 and SW¼ SE¼ sec. 28, T. 4 N., R. 17 E., Latimer County, Oklahoma.

The lower limestone member of the Wapanucka Formation is well exposed at this locality on both sides of Oklahoma Highway 1. Unfortunately, contacts with adjacent members are not exposed. The measured section (fig. 106, sec. 28) on the northern side of the highway totals 190 feet. The lower limestone member (fig. 107) makes up 126 feet of the total measured thickness but is capped by a covered interval. Spiculiferous limestone is volumetrically the most important lithology. In hand sample and thin section, spiculiferous limestone can be seen to consist of unoriented spicules in an organic-rich, muddy matrix. Secondary silicification is pervasive. Comminuted plant debris and plant fossils (fig. 106, sec. 28, unit 14) are locally abundant, while a calcareous biota is rare or absent. Ham and Rowland (1971) suggested that these spiculites were continental-slope deposits that accumulated at water depths exceeding 600 feet. This conclusion is at variance with the present interpretation: the spiculiferous limestones in the lower limestone member are thought to indicate low-energy but well-circulated shallow-water lagoonal environments. The locally abundant plant fossils and comminuted organic debris suggest proximity to a marsh or brackish-water swamp.

Micritic limestone is not an important lithology at this locality but does occur as an interbed (fig. 106, sec. 28, unit 9) with spiculiferous limestone in the lowermost part of the section (units 8-10). Laterally along the strike of Limestone Ridge (fig. 106) the volumetric importance of micritic and spiculiferous limestone is generally related in an inverse manner. At sections where micritic limestone is volumetrically important (fig. 106, secs. 6, 32), spiculiferous limestone is relatively less important. In contrast, at sections where spiculiferous limestone interbeds are volumetrically important (fig. 106, secs. 29, 28), the section invariably contains few interbeds of micritic limestone. This intertonguing gradational change in lithology suggests that the depositional environments of micritic and spiculiferous limestone were closely related but dissimilar regimes that existed adjacent to one another. By analogy to recent carbonate-mud accumulations, micritic limestone probably represents deposition in low-energy, poorly circulated lagoonal environments. As previously suggested, spiculiferous limestone may have accumulated in low-energy but better circulated lagoonal environments.

Calcarenites punctuate deposits of micritic and spiculiferous limestone along the strike of Limestone Ridge (fig. 106). These calcarenites include three closely related but distinct lithologies: oolite, bioclastic calcarenite, and limestone-pebble conglomerate. Calcarenitic lithologies intertongue and grade laterally from one to another along the strike of Limestone Ridge (fig. 106). At least two zones of persistent calcarenites can be distinguished between section 6 (units 6, 15-17, fig. 106), section 29 (units 3-5, 10, fig. 106), section 28 (units 7, 13, fig. 106), and section 32 (units 2-8, top of unit 10, fig. 106).

A locally persistent limestone-pebble conglomerate is found in sections 6, 29, 28, and 32. It is represented in section 28 by unit 13 (fig. 108). At this locality the pebbles range in diameter from tenths of inches to approximately 3 inches. The pebbles are well rounded and consist of spiculiferous, micritic, and calcarenitic limestone derived from lithologies within the lower limestone member. Unit 13 also marks the local boundary between the *Idiognathoides convexus* Zone and the *Neognathodus kanumai-Idiognathoides ouachitensis* Zone (fig. 106).

The character of bioclastic calcarenite is exemplified by unit 7 in section 28 (fig. 106). The dominant constituents are abraded crinozoan and ramose bryozoan fragments. Oolite does not occur in the lower limestone here, although it is present in adjacent sections (fig. 106). An opportunity to examine similar oolitic calcarenites is provided at Stop 38. Limestone-pebble conglomerate, oolite, and bioclastic calcarenite record a transition from subaerial exposure through intertidal conditions to a shallow, agitated subtidal environment.

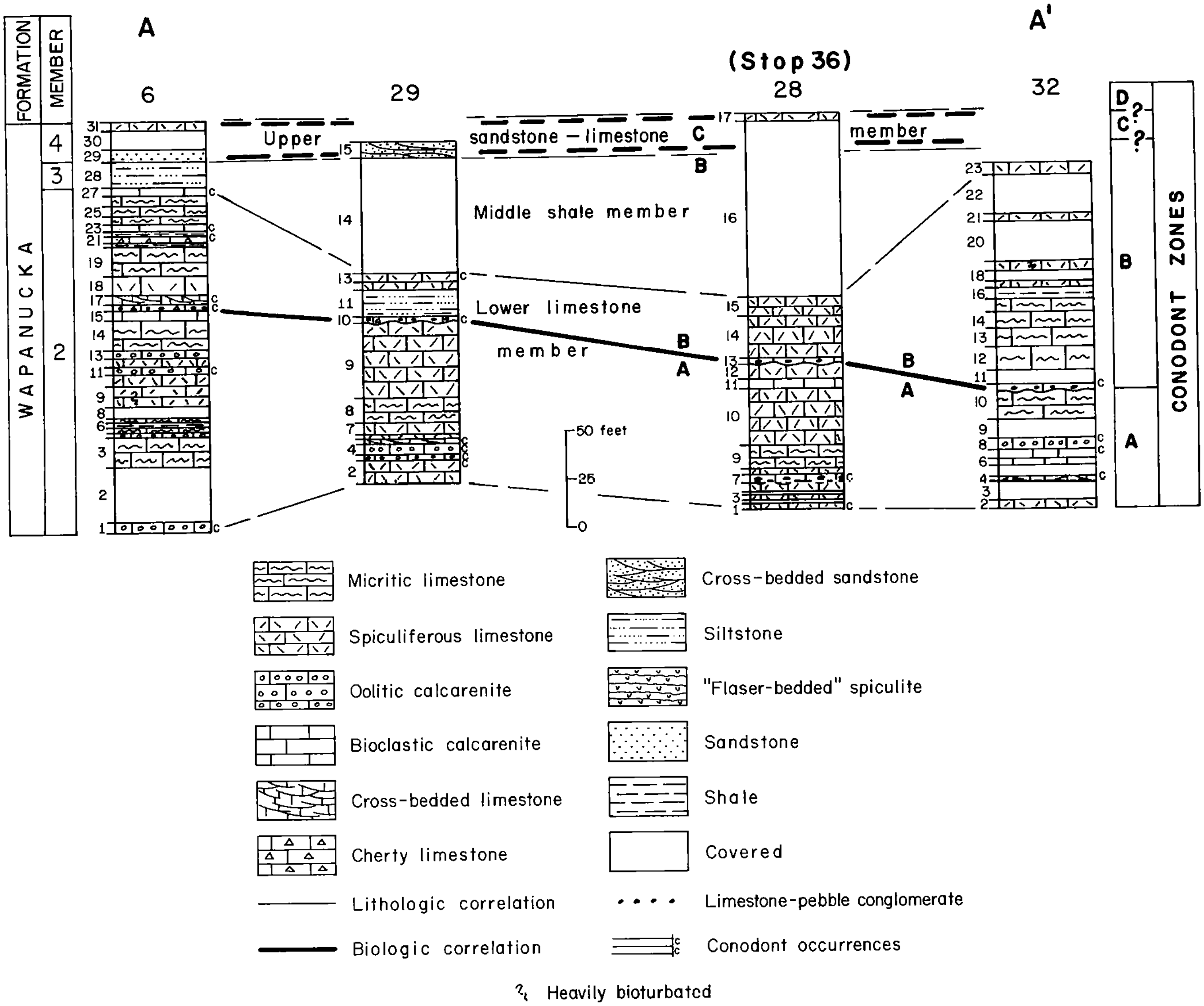


Figure 106. Lithostratigraphic and biostratigraphic correlation of selected measured sections along strike of Limestone Ridge in Hartshorne area. Note highly variable lithologies making up lower limestone member. (Stop 36.)

Figure 107. Wapanucka Formation, lower limestone member. Stop 36, north roadside.

Figure 108. Limestone-pebble conglomerate (section 28, unit 13) in lower limestone member of Wapanucka Formation. (Stop 36.)

STOP 37—NEW STATE MOUNTAIN (WAPANUCKA SECTION 10)

Location: Natural exposure about 250 feet east of main Blue Valley Ranch house and 0.8 mile south down gravel road from main country road that begins as 7th Street in Hartshorne. NE¼ SW¼ sec. 34, T. 4 N., R. 16 E., Pittsburg County, Oklahoma.

The basinal Chickachoc Chert facies of the Wapanucka Formation does not crop out on the basinward fault blocks from Limestone Ridge in the Hartshorne area. However, the Wapanucka does exhibit other basinward changes (fig. 109). The total thickness of the formation increases from about 200 feet (fig. 109, sec. 6) to slightly more than 500 feet (fig. 109, sec. 9). This increased thickness results principally from a thickened middle shale and upper sandstone/limestone interval. The lower limestone, although maintaining a nearly constant thickness, exhibits striking basinward changes in lithologic composition and complexity. Basinward (fig. 109), oolite and limestone-pebble conglomerate disappear entirely, bioclastic calcarenite is much reduced in importance, and shale interbeds become increasingly more important, nearly replacing micritic and spiculiferous limestone.

This exposure is important because it documents the occurrence of shallow-water lithologies deep in the frontal Ouachita Mountains. The lower limestone member (fig. 109, sec. 10, units 1-3) totals 186 feet in thickness. Almost all of the interval is assumed to be shale (unit 2), but a thin sequence of interbedded spiculiferous limestone (unit 1) and micritic limestone (unit 3) occurs. The middle shale is not exposed but is presumed to be represented by a thin (11.4 feet) covered interval (fig. 109, sec. 10, unit 4). The unusual thinness of the middle shale member is difficult to explain, but structural complexities are a possibility. The feature of greatest interest is the thick (50+ feet) exposures of the upper sand-

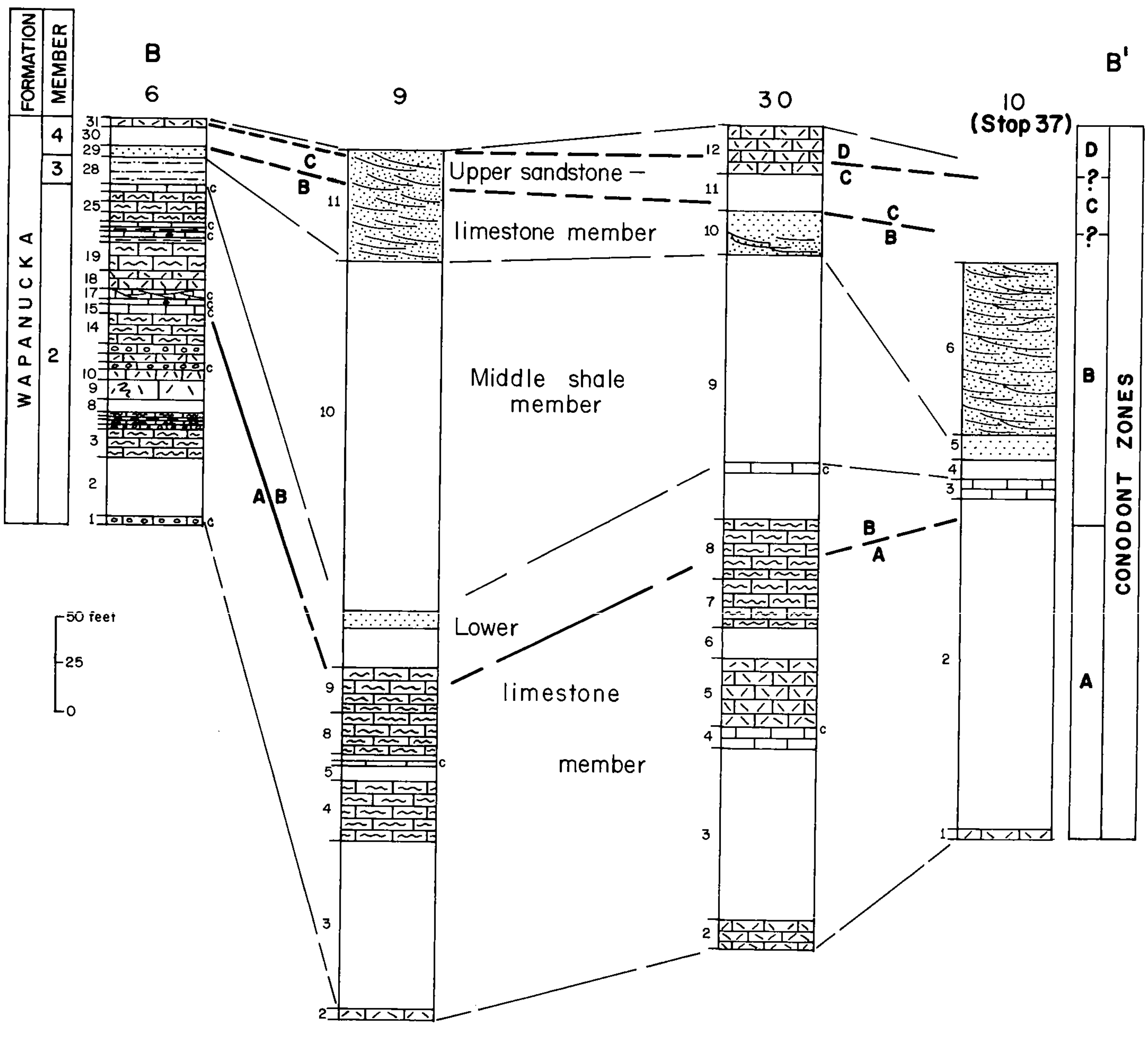


Figure 109. Measured sections illustrating basinward facies changes in Wapanucka Formation in area south of Hartshorne. (Stop 37.)

stone/limestone member (fig. 109, sec. 10, units 5, 6). Here, the member is exposed in a chain of isolated elephantine blocks (fig. 110). Consequently, it is possible to examine the character of the unit in greater detail than is generally possible in road-cut or quarry exposures. The member consists of fine- to medium-grained mature quartzarenite. Two subfacies are recognized, based on the presence or absence of tabular cross-bedding. The tabular cross-bedded subfacies (fig. 109, sec. 10, unit 6) is particularly well exposed. It consists of several sets of cross-beds, each set marked by a sharp base and ranging in thickness from about 2.0 to 4.0 feet. The cross-beds invariably show a strong basinward inclination. This subfacies is interpreted as quartz-sand accumulations formed by migrating sand waves at the crests of offshore bars. The quartzarenite subfacies, lacking tabular cross-bedding (fig. 109, sec. 10, unit 5), probably accumulated at the margin of an offshore bar, perhaps in slightly deeper, less turbulent water.

Figure 110. Upper sandstone/limestone member of Wapanucka Formation (section 10, unit 6), showing unusual elephantine-block exposure at Stop 37.

STOP 38—BLANCO EAST (WAPANUCKA SECTION 19)

Location: Section measured along western side of quarry 200 yards north of section-line road, 2.8 miles east of intersection of section-line road with Oklahoma Highway 63 in Blanco. SW¼ SW¼ SW¼ sec. 9, T. 3 N., R. 15 E., Pittsburg County, Oklahoma.

Basinward facies changes in the Wapanucka were originally documented by Sutherland and Grayson (1976, 1977). Their reports were based on detailed lithologic and conodont biostratigraphic analyses of two measured sections (fig. 111, secs. 1, 2) south of McAlester, Oklahoma, on the Indian Nation Turnpike. Subsequently, Grayson located and measured two additional exposures (figs. 104, 111, secs. 16, 19) that, combined with the Turnpike sections, constitute an important reference sequence for the Wapanucka. Sections 1, 2, and 16, however, have now been mostly covered by rock, rubble, and soil as a result of recent efforts by the Oklahoma Turnpike Authority to establish grass on those exposures. Figures 112 and 113 show section 1 before and in the process of being covered. This has destroyed some of the usefulness of this important sequence of reference sections (fig. 111), and it has covered a stratigraphically important goniatite locality (fig. 112). This goniatite fauna was found in unit 19 of section 1 (fig. 111). Gordon and Sutherland (1975) assigned the fauna to the *Diaboloceras neumeieri* Zone, which, they said, suggested a correlation with the Trace Creek Shale Member now referred to the Atoka Formation in northwestern Arkansas (Sutherland and Grayson, 1978). This correlation, however, disagrees with that indicated by conodonts. The conodonts suggest a correlation with the upper part of the Kessler Limestone Member of the Bloyd Formation (Morrowan Series) and (or) the erosional gap separating the Kessler from the overlying Trace Creek (Grayson and Sutherland, 1977).

The lower limestone member (fig. 111, sec. 19, units 1-22) is exceptionally well exposed at this locality. The quarry exposure is on a small fault block that lies north of the regionally continuous Limestone Ridge. Several interesting features are present the most striking of which is the occurrence of spiculiferous limestone interbedded with oolitic calcarenites (fig. 111, sec. 19, units 5-20). These oolites appear to be *in situ*. The association of spiculiferous limestone with oolite-shoal deposits is unequivocal evidence for a shallow-water origin for these spiculites. One of these spiculiferous limestone units (fig. 111, sec. 19, unit 13) must have accumulated during episodes of sedimentation alternating with periods of nondeposition. The surfaces of nondeposition are marked by submarine hardgrounds, which are readily distinguishable by their elaborate system of vertical to subvertical tube-shaped burrows associated with dominantly horizontal feeding traces (fig. 114). Another feature unique to this locality is the abundant occurrence of *Chaetetes* (unit 22). *Chaetetes* is common in Morrowan rocks in northern Oklahoma and Arkansas (Sutherland and Henry, 1977a) but is unknown from the Wapanucka with this exception.

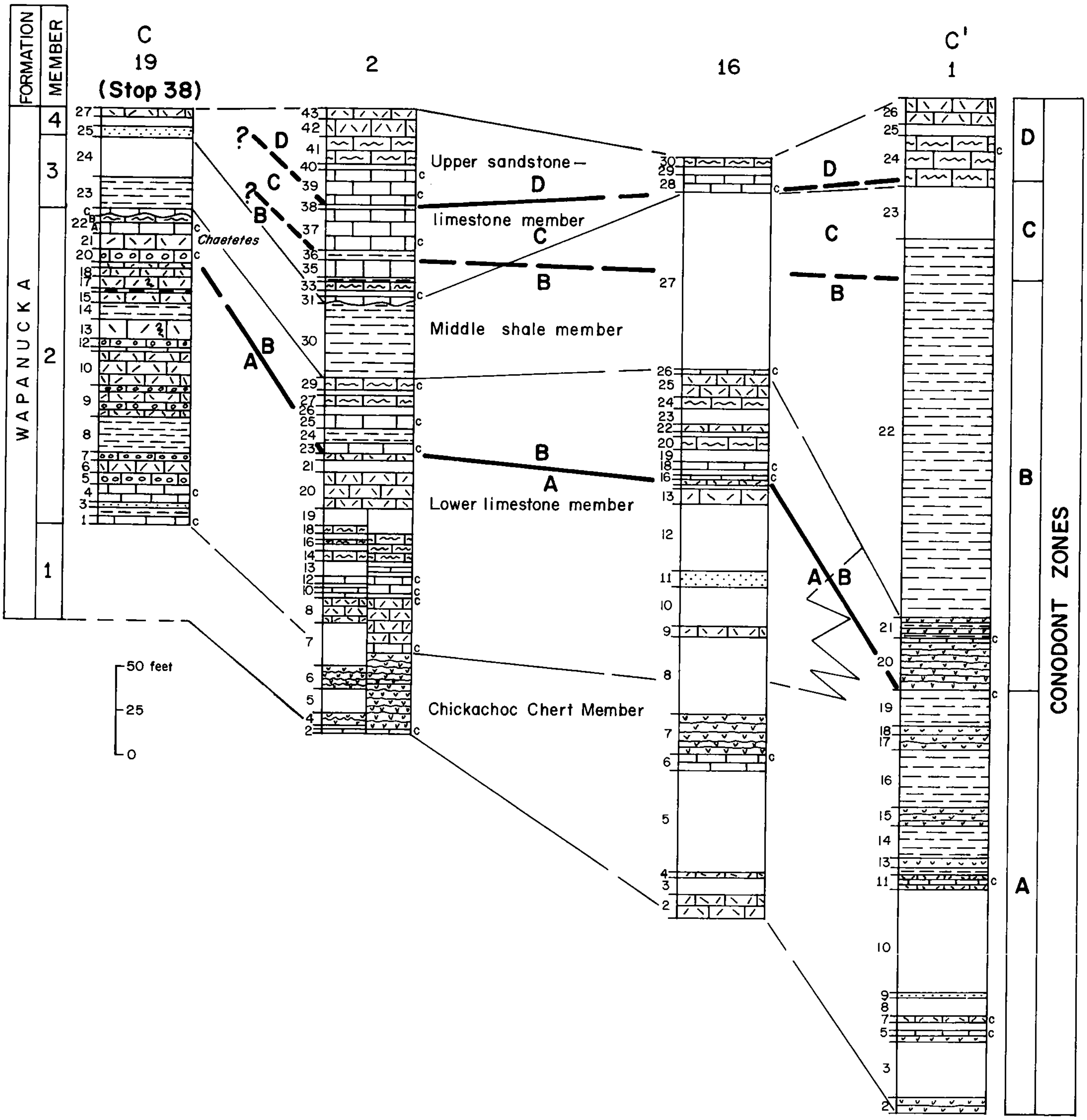


Figure 111. Basinward facies changes in Wapanucka Formation adjacent to Indian Nation Turnpike south of McAlester. (Stop 38.)

Figure 112. Chickachoc Chert Member, Wapanucka Formation. Section 1, unit 19 and base of unit 20; unit 19 contains *Diaboloceras neumeieri* goniatite zone. (Stop 38.)

Figure 113. Chickachoc Chert Member, Wapanucka Formation. Section 1, in the process of being covered with truckloads of soil in 1978. (Stop 38.)

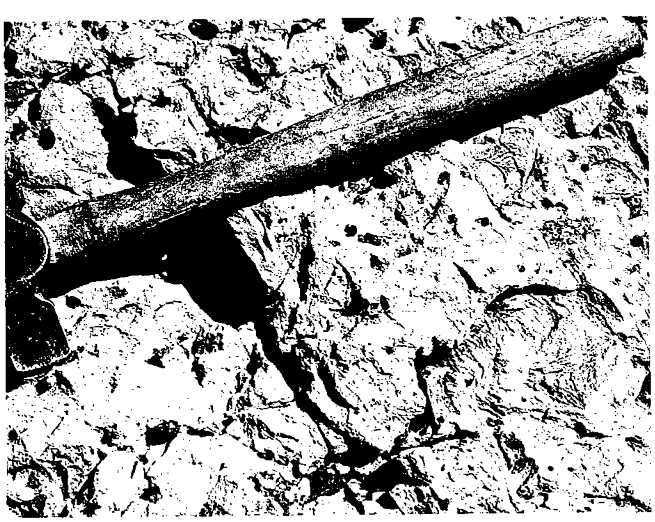


Figure 114. Bioturbation surface marking a presumed submarine hardground in lower limestone member of Wapanucka Formation. Near top of unit 13 at Stop 38.

STOP 39—KIOWA EAST (WAPANUCKA SECTION 17)

Location: Section measured along northeastern side of quarry in Limestone Ridge west of section-line road approximately 1.1 miles south of Oklahoma Highway 63. Section-line road intersects Oklahoma Highway 63 1.0 mile east of intersection of Oklahoma Highway 63 with U.S. Highway 69 in Kiowa. SW¼ NE¼ NE¼ sec. 36, T. 3 N., R. 13 E., Pittsburg County, Oklahoma.

At this locality the typical character of the carbonate portion of the upper sandstone/limestone member of the Wapanucka Formation can be examined (fig. 115). The member consists essentially of lithologies similar to those present in the lower limestone member. The two units differ, however, by the absence of oolite and by the greater importance of quartz sandstone and micritic limestone in the upper sandstone/limestone member. Additionally, lithologic units in this member exhibit greater lateral persistence than those of the lower member. One of the most persistent lithologies is a distinctive carbonate mudstone (fig. 115, sec. 17, unit 19) that generally marks the top of the Wapanucka.

The upper sandstone/limestone is interpreted to represent deposition in shallow-water offshore-bar and inter-bar environments. The inter-bar facies consists of low-energy accumulations of micritic and spiculiferous limestone, interbedded with shale. The higher energy bar facies consists of either bioclastic calcarenite or mature quartzarenite. Two subfacies of calcarenite or quartzarenite are distinguished by the presence or absence of tabular cross-bedding. Tabular cross-bedded units are thought to indicate shoaling conditions at the bar crest. The bar-margin facies does not exhibit tabular cross-bedding. At this locality both bar subfacies consist of bioclastic calcarenite (fig. 116). The bar-crest facies consists of tabular cross-bedded, coarse- to fine-grained crinozoan grainstone (fig. 115, sec. 17, top of unit 10, unit 11). Bioclastic calcarenite interpreted as bar-margin facies is found in unit 10 (fig. 115, sec. 17). These calcarenites are coarse-grained crinozoan packstone and grainstone. Intraclasts and abundant carbonized plant debris characterize the lower and middle part of this interval. Goniatites identified as *Pseudoparalogoceras kesslerense* and *Pseudopronorites arkansiensis* also occur abundantly. This goniatite-bearing zone falls within the new *Diplognathodus orphanus* conodont zone of latest Morrowan age. This zone correlates to the erosional gap separating the Kessler Limestone Member of the Bloyd Formation and the Trace Creek Shale Member of the Atoka Formation in northwestern Arkansas. The highest part of the upper sandstone/limestone member at this locality correlates with the Atokan Trace Creek Shale, based on the occurrence of *Streptognathodus elegantulus* in unit 17 (fig. 115, sec. 17).

Basinward from this locality the upper sandstone/limestone member exhibits changes in thickness and lithologic character (fig. 115). The bar facies passes from bioclastic calcarenite into quartzarenite. Inter-bar facies of micritic and spiculiferous limestone, however, persist into the area of quartz-sand accumulation.

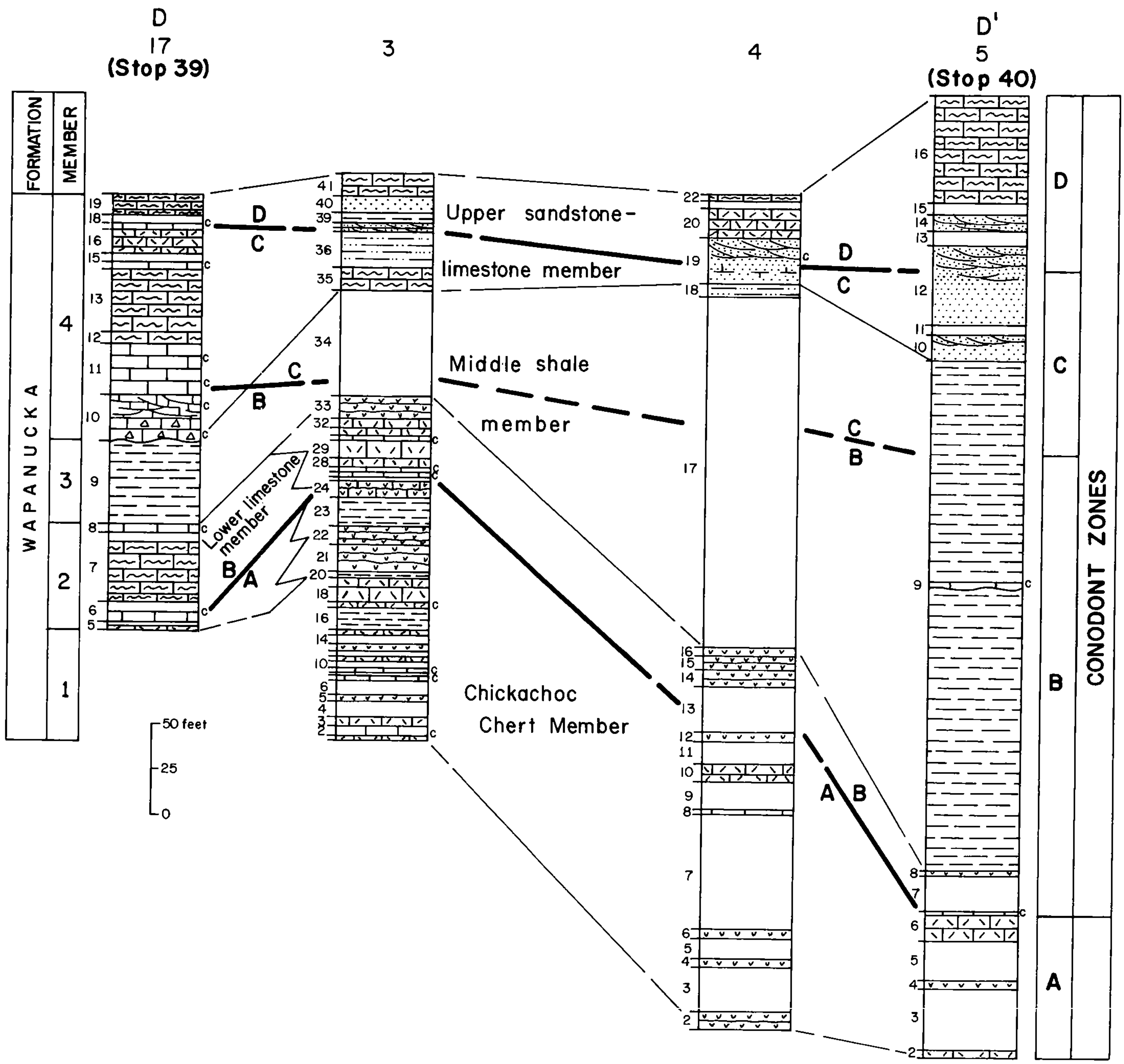


Figure 115. Measured sections showing basinward facies changes in Wapanucka Formation in area near Kiowa, Oklahoma. (Stops 39 and 40.)

Figure 116. Offshore-bar-crest facies consisting of tabular cross-bedded bioclastic calcarenite in upper sandstone/limestone member of Wapanucka Formation (section 17, units 10 and 11). (Stop 39.)

STOP 40—PITTSBURG SOUTH (WAPANUCKA SECTION 3)

Location: Road cut on east side of section-line road except for lowest exposed beds. Exposure is 3.1 miles south on section-line road from intersection with Oklahoma Highway 63, 0.6 mile west of Pittsburg. NW¼ NW¼ NW¼ sec. 5, T. 2 N., R. 14 E., Pittsburg County, Oklahoma.

The Chickachoc Chert, middle shale, and upper sandstone/limestone members of the Wapanucka Formation are exposed on the east and west sides of this section-line road. The typical basinal facies that constitute the Chickachoc Chert Member (fig. 115, sec. 3) are poorly exposed. Sufficient exposure exists, however, to demonstrate the marked contrast of this member with the time-equivalent shoal deposits of the lower limestone member. The Chickachoc is mostly poorly exposed shale (fig. 115, sec. 5, units 3, 5, 7), although spiculiferous limestone (unit 6) and flaser-bedded spiculite (units 2, 4, 8) are an equally important constituent. Only a single thin bioclastic calcarenite (top of unit 6) is present. This calcarenite produces a conodont fauna that belongs within the *Neognathodus kanumai-Idiognathoides ouachitensis* conodont zone.

A thick section (288 feet) of the middle shale member is exposed in the drainage ditch on the west side of the road. The shale is monotonous in character. It is platy to fissile, blue-gray clay shale that contains no obvious megafossils. A concretionary bioclastic calcarenite interbed containing productid brachiopods, crinozoan fragments, and rare goniatites occurs within the middle shale about 140 feet above the base of the unit (fig. 115, sec. 5, unit 9).

The upper sandstone/limestone member consists of several exposed sandstone interbeds (fig. 115, sec. 5, units 10, 12, 13) overlain by a distinctive carbonate mudstone (unit 16). The solitary rugose coral *Koninckophyllum* occurs abundantly in this unit, commonly in presumed life position. This carbonate mudstone (fig. 115, sec. 5, unit 16) is one of the few units that can be correlated lithologically basinward between fault-block exposures (fig. 115). At some exposures (compare with fig. 111) this high limestone is overlain by an equally distinctive black, cherty, spiculiferous limestone.

REFERENCES

Adams, G. I. (assisted by Purdue, A. H., and Burchard, E. F.), 1904, Zinc and lead deposits of northern Arkansas: U.S. Geological Survey Professional Paper 24, p. 1-89.

Arkansas Geological Survey, 1929, Geologic map of Arkansas: scale 1:500,000.

Beckwith, C. G., Jr., 1950, The geology of the Fort Gibson area, Cherokee and Muskogee Counties, Oklahoma: University of Oklahoma unpublished M.S. thesis, 74 p.

Berry, R. M., and **Trumbly, W. D.**, 1968, Wilburton gas field, Arkoma basin, Oklahoma, *in* Cline, L. M., editor, A guidebook to the geology of the western Arkoma basin and Ouachita Mountains, Oklahoma: Oklahoma City Geological Society Guidebook for AAPG-SEPM Annual Meeting, p. 86-103.

Blythe, J. G., 1959,, Atoka formation on the north side of the McAlester basin: Oklahoma Geological Survey Circular 47, 74 p.

Bonem, R. M., 1977, Stratigraphic setting, carbonate lithofacies, and development of Lower Pennsylvanian bioherms of northeastern Oklahoma, *in* Sutherland, P. K., and Manger, W. L., editors, Upper Chesterian-Morrowan stratigraphy and the Mississippian-Pennsylvanian boundary in northeastern Oklahoma and northwestern Arkansas: Oklahoma Geological Survey Guidebook 18, p. 55-59.

Bouma, A. H., 1962, Sedimentology of some flysch deposits: a graphic approach to facies interpretation: Elsevier, Amsterdam, 168 p.

Brenckle, Paul, 1977, Foraminifers and other calcareous microfossils from late Chesterian (Mississippian) strata of northern Arkansas, *in* Sutherland, P. K., and Manger, W. L., editors, Upper Chesterian-Morrowan stratigraphy and the Mississippian-Pennsylvanian boundary in northeastern Oklahoma and northwestern Arkansas: Oklahoma Geological Survey Guidebook 18, p. 73-88, 4 pls.

Brenckle, Paul, Lane, H. R., Manger, W. L., and **Saunders, W. B.**, 1977, The Mississippian-Pennsylvanian boundary as an intercontinental biostratigraphic datum: Newsletters on Stratigraphy, v. 6, p. 106-116.

Briggs, Garrett, 1973, Geology of the eastern part of the Lynn Mountain syncline, Le Flore County, Oklahoma: Oklahoma Geological Survey Circular 75, 34 p.

——1974, Carboniferous depositional environments in the Ouachita Mountains-Arkoma basin area of southeastern Oklahoma, *in* Briggs, Garrett, editor, Carboniferous of the southeastern United States: Geological Society of America Special Paper 148, p. 225-239.

Briggs, Garrett, and **Cline, L. M.**, 1967, Paleocurrents and source areas of late Paleozoic sediments of the Ouachita Mountains, southeastern Oklahoma: Journal of Sedimentary Petrology, v. 37, p. 985-1000.

Briggs, Garrett, McBride, E. F., and **Moiola, R. J.**, leaders, 1975, A guidebook to the sedimentology of Paleozoic flysch and associated deposits, Ouachita Mountains-Arkoma basin, Oklahoma: Dallas Geological Society Guidebook for AAPG-SEPM Annual Meeting, 128 p.

Buchanan, R. S., and **Johnson, F. K.**, 1968, Bonanza gas field—a model for Arkoma basin growth faulting, *in* Cline, L. M., editor, A guidebook to the geology of the western Arkoma basin and Ouachita Mountains, Oklahoma: Oklahoma City Geological Society Guidebook for AAPG-SEPM Annual Meeting, p. 75-85.

Burdick, D. W., and **Strimple, H. L.**, 1973, New Late Mississippian crinoids from northern Arkansas: Journal of Paleontology, v. 47, p. 231-243, 2 pls.

Bush, W. V., and others, 1978, A guidebook to the Atoka Formation in Arkansas: Arkansas Geological Commission Miscellaneous Publication, 62 p.

Campbell, M. D., 1976, Paleoenvironmental and diagenetic implications of selected siderite zones and associated sediments in the upper Atoka Formation, Arkoma Basin, Oklahoma-Arkansas: Rice University unpublished M.S. thesis, 124 p.

Caplan, W. M., 1957, Subsurface geology of northwestern Arkansas: Arkansas Geological Commission Information Circular 19, 14 p.

Chamberlain, C. K., 1971, Bathymetry and paleoecology of Ouachita geosyncline of southeastern Oklahoma as determined from trace fossils: American Association of Petroleum Geologists Bulletin, v. 55, p. 34-50.

——1975, Biogenic sedimentary structures—trace fossils—of the Ouachitas, *in* Briggs, Garrett, McBride, E. F., and Moiola, R. J., leaders, 1975, A guidebook to the sedimentology of Paleozoic flysch and associated deposits, Ouachita Mountains-Arkoma basin, Oklahoma: Dallas Geological Society Guidebook for AAPG-SEPM Annual Meeting, p. 51-68.

Chamberlain, C. K., and **Basan, P. B.**, 1978, Field guide to the trace fossils and paleoecology of the Ouachita Geosyncline, *in* Chamberlain, C. K., editor, Trace fossils and paleoecology of the Ouachita Geosyncline: Society of Economic Paleontologists and Mineralogists Guidebook for AAPG-SEPM Annual Meeting, p. 38-68.

Chandler, P. P., 1950, The geology of the McBride area, Cherokee and Wagoner Counties, Oklahoma: University of Oklahoma unpublished M.S. thesis, 69 p.

Cline, L. M., 1960, Stratigraphy of the late Paleozoic rocks of the Ouachita Mountains, Oklahoma: Oklahoma Geological Survey Bulletin 85, 113 p.

——1968, Comparison of main geologic features of Arkoma basin and Ouachita Mountains, southeastern Oklahoma, *in* Cline, L.M., editor, A guidebook to the geology of the western Arkoma basin and Ouachita Mountains, Oklahoma: Oklahoma City Geological Society Guidebook for AAPG-SEPM Annual Meeting, p. 63-74.

Cline, L. M., editor, 1968, A guidebook to the geology of the western Arkoma basin and Ouachita Mountains, Oklahoma: Oklahoma City Geological Society Guidebook for AAPG-SEPM Annual Meeting, 126 p.

Cline, L. M., and **Moretti, Frank**, 1956, Description and correlation of two complete stratigraphic sections of the Jackfork sandstone in Kiamichi Mountains, central Ouachita Mountains, Oklahoma: Oklahoma Geological Survey Circular 41, 20 p.

Cline, L. M., and **Shelburne, O. B.**, 1959, Late Mississippian-Early Pennsylvanian stratigraphy of the Ouachita Mountains, Oklahoma, *in* Cline, L. M., Hilseweck, W. J., and Feray, D. E., editors, The geology of the Ouachita Mountains—a symposium: Dallas Geological Society and Ardmore Geological Society, p. 175-207.

Collinson, Charles, Rexroad, C. B., and **Thompson, T. L.**, 1971, Conodont zonation of the North American Mississippian: Geological Society of America Memoir 127, p. 353-394.

Copeland, M. J., 1967, A new species of *Dithyocaris* (Phyllocarida) from the Imo Formation, Upper Mississippian of Arkansas: Journal of Paleontology, v. 41, p. 1195-1196, pl. 62.

Croneis, C. G., 1930, Geology of the Arkansas Paleozoic area with especial reference to oil and gas possibilities: Arkansas Geological Survey Bulletin 3, 457 p., 45 pls.

Denison, R. E., Burke, W. H., Otto, J. B., and **Hetherington, E. A.**, 1977, Age of igneous and metamorphic activity affecting the Ouachita foldbelt, *in* Symposium on the geology of the Ouachita Mountains: Arkansas Geological Commission, v. 1, p. 25-40.

Easton, W. H., 1942, Pitkin limestone of northern Arkansas: Arkansas Geological Survey Bulletin 8, 115 p., 12 pls.

——1943, The fauna of the Pitkin formation of Arkansas: Journal of Paleontology, v. 17, p. 125-154, pls. 21-24.

Engel, A. E. J., 1952, Quartz crystal deposits of western Arkansas: U.S. Geological Survey Bulletin 973-E, p. 168-260.

Fellows, L. D., 1964, Geology of the western part of Winding Stair Range, Latimer and Le Flore Counties, Oklahoma: Oklahoma Geological Survey Circular 65, 102 p.

Flawn, P. T., Goldstein, August, Jr., King, P. B., and **Weaver, C. E.**, 1961,The Ouachita system: University of Texas Publication 6120, 401 p.

Frezon, S. E., and **Glick, E. E.**, 1959, Pre-Atoka rocks of northern Arkansas: U.S. Geological Survey Professional Paper 314-H, p. 171-189.

Furnish, W. M., Quinn, J. H., and **McCaleb, J. A.**, 1964, The Upper Mississippian ammonoid *Delepinoceras* in North America: Paleontology, v. 7, p. 173-180, pl. 30.

Garner, H. F., 1967, Moorefield-Batesville stratigraphy and sedimentation in Arkansas: Geological Society of America Bulletin, v. 78, p. 1233-1246.

Glick, E. E., 1975, Paleotectonic investigations of the Pennsylvanian System in the United States; Chapter 9, Arkansas and northern Louisiana: U.S. Geological Survey Professional Paper 853, p. 157-175.

Glick, E. E., Frezon, S. E., and **Gordon, Mackenzie, Jr.**, 1964, Witts Springs Formation of Morrow age in the Snowball quadrangle, north-central Arkansas: U.S. Geological Survey Bulletin 1194-D, 16 p.

Goldstein, August, Jr., 1959, Petrography of the Paleozoic sandstones from the Ouachita Mountains of Oklahoma and Arkansas, *in* Cline, L. M., Hilseweck, W. J., and Feray, D. E., editors, The geology of the Ouachita Mountains—a symposium: Dallas Geological Society and Ardmore Geological Society, p. 97-116.

Goldstein, August, Jr., and **Hendricks, T. A.**, 1962, Late Mississippian and Pennsylvanian sediments of Ouachita facies, Oklahoma, Texas, and Arkansas, *in* Branson, C. C., editor, Pennsylvanian System in the United States—a symposium: American Association of Petroleum Geologists, p. 385-430.

Gordon, Mackenzie, Jr., 1965, Carboniferous cephalopods of Arkansas: U.S. Geological Survey Professional Paper 460, 322 p., 30 pls.

——1969, An early *Reticuloceras* zone fauna from the Hale Formation in northwestern Arkansas: U.S. Geological Survey Professional Paper 613-A, 21 p., 2 pls.

——1970, Carboniferous ammonoid zones of the south-central and western United States: 6^e Compte Rendu, 6^e Congrès International de Stratigraphie et de Géologie du Carbonifère, Sheffield, 1967, v. 2, p. 817-826.

——1974, The Mississippian-Pennsylvanian boundary in the United States: 7^e Compte Rendu, 7^e Congrès International de Stratigraphie et de Géologie du Carbonifère, Krefeld, 1971, v. 3, p. 129-141.

Gordon, Mackenzie, Jr., and **Stone, C. G.**, 1977, Correlation of the Carboniferous rocks of the Ouachita trough with those of the adjacent foreland, *in* Symposium on the geology of the Ouachita Mountains: Arkansas Geological Commission, v. 1, p. 70-91.

Gordon, Mackenzie, Jr., and **Sutherland, P. K.**, 1975, Ammonoids of the upper Wapanucka Limestone and their bearing on the Morrowan-Atokan boundary in Oklahoma [abstract]: American Association of Petroleum Geologists and Society of Economic Paleontologists and Mineralogists Annual Meetings Abstracts, v. 2, p. 30.

Grayson, R. C., Jr., 1974, Petrography and biostratigraphy of the Hindsville Limestone (Mississippian) in its type area, northwest Arkansas: Arkansas Academy of Science Proceedings, v. 28, p. 19-21.

——1975, Lithostratigraphy and conodont biostratigraphy of the Hindsville Limestone (Mississippian), northwest Arkansas [abstract]: Geological Society of America Abstracts with Programs, v. 7, p. 169-170.

——1976, Lithostratigraphy and conodont biostratigraphy of the Hindsville Formation, northwest Arkansas: University of Arkansas unpublished M.S. thesis, 139 p.

——1978, Depositional environments and conodont biostratigraphy of the Wapanucka Formation (Pennsylvanian), frontal Ouachita Mountains, Oklahoma [abstract]: American Association of Petroleum Geologists Bulletin, v. 62, p. 518.

Grayson, R. C., Jr., and **Sutherland, P. K.**, 1977, Conodont evidence for unconformity within Trace Creek Shale Member of Bloyd Formation (Lower Pennsylvanian) in northwestern Arkansas and northeastern Oklahoma, *in* Sutherland, P. K., and Manger, W. L., editors, Upper Chesterian-Morrowan stratigraphy and the Mississippian-Pennsylvanian boundary in northeastern Oklahoma and northwestern Arkansas: Oklahoma Geological Survey Guidebook 18, p. 181-185.

Haley, B. R., 1966, Geology of the Barber quadrangle, Sebastian County and vicinity, Arkansas: Arkansas Geological Commission Information Circular 20C, 76 p.

——1976, Geologic map of Arkansas: Arkansas Geological Commission and U.S. Geological Survey, scale 1:500,000.

——1978, Low-volatile bituminous coal and semianthracite in the Arkansas Valley Coal Field: Arkansas Geological Commission Information Circular 20K, 26 p.

Haley, B. R., and **Frezon, S. E.**, 1965, Geologic formations penetrated by the Shell Oil Company No. 1 Western Coal and Mining Company well on the Backbone anticline, Sebastian County, Arkansas: Arkansas Geological Commission Information Circular 20D, 17 p.

Haley, B. R., and **Hendricks, T. A.**, 1968, Geology of the Greenwood quadrangle, Arkansas-Oklahoma: Arkansas Geological Commission Information Circular 20F, 15 p.

Ham, W. E., 1961, Correlation of pre-Stanley strata in the Arbuckle-Ouachita Mountain regions: Oklahoma Geology Notes, v. 21, p. 204-224.

Ham, W. E., and **Rowland, T. L.**, 1971, Burial cementation in the Wapanucka Limestone (Pennsylvanian) of Oklahoma, *in* Bricker, O. P., editor, Carbonate cements: Johns Hopkins University Studies in Geology 19, p. 198-204.

Harlton, B. H., 1934, Carboniferous stratigraphy of the Ouachitas with special study of the Bendian: American Association of Petroleum Geologists Bulletin, v. 18, p. 1018-1049.

——1938, Stratigraphy of the Bendian of the Oklahoma salient of the Ouachita Mountains: American Association of Petroleum Geologists Bulletin, v. 22, p. 852-914.

Hart, D. L., Jr., 1974, Reconnaissance of the water resources of the Ardmore and Sherman quadrangles, southern Oklahoma: Oklahoma Geological Survey Hydrologic Atlas 3, scale 1:250,000, 4 sheets.

Hart, O. D., 1963, Geology of the eastern part of Winding Stair Range, Le Flore County, Oklahoma: Oklahoma Geological Survey Bulletin 103, 87 p.

Hass, W. H., 1950, Age of lower part of Stanley shale: American Association of Petroleum Geologists Bulletin, v. 34, p. 1578-1588.

——1951, Age of Arkansas novaculite: American Association of Petroleum Geologists Bulletin, v. 35, p. 2526-2541.

——1956, Age and correlation of the Chattanooga shale and the Maury formation: U.S. Geological Survey Professional Paper 286, 47 p.

Hass, W. H., and **Huddle, J. W.**, 1965, Late Devonian and Early Mississippian age of the Woodford Shale in Oklahoma, as determined from conodonts, *in* Geological Survey research. 1965: U.S. Geological Survey Professional Paper 525-D, p. D125-D132.

Henbest, L. G., 1953, Morrow group and lower Atoka formation of Arkansas: American Association of Petroleum Geologists Bulletin, v. 37, p. 1935-1953.

——1962a, Type sections for the Morrow Series of Pennsylvanian age, and adjacent beds, Washington County, Arkansas: U.S. Geological Survey Professional Paper 450-D, p. D38-D41.

——1962b, New members of the Bloyd Formation of Pennsylvanian age, Washington County, Arkansas: U.S. Geological Survey Professional Paper 450-D, p. D42-D44.

Hendricks, T. A., 1959, Structure of the frontal belt of the Ouachita Mountains, *in* Cline, L. M., Hilseweck, W. J., and Feray, D. E., editors, The geology of the Ouachita Mountains—a symposium: Dallas Geological Society and Ardmore Geological Society, p. 44-56.

Hendricks, T. A., **Gardner, L. S.**, **Knechtel, M. M.**, and **Averitt, Paul**, 1947, Geology of the western part of the Ouachita Mountains of Oklahoma: U.S. Geological Survey Oil and Gas Investigations Preliminary Map 66, scale 1:42,240, 3 sheets.

Henry, T. W., and **Sutherland, P. K.**, 1977, Brachiopod biostratigraphy of Morrowan Series (Pennsylvanian) in northwestern Arkansas and northeastern Oklahoma, *in* Sutherland, P. K., and Manger, W. L., editors, Upper Chesterian-Morrowan stratigraphy and the Mississippian-Pennsylvanian boundary in northeastern Oklahoma and northwestern Arkansas: Oklahoma Geological Survey Guidebook 18, p. 107-116, 2 pls.

Hill, J. G., 1966, Petrology and provenance of sandstones of the Stanley Group (Mississippian), southern Ouachita Mountains, Oklahoma, *in* Field conference on flysch facies and structure of the Ouachita Mountains: Kansas Geological Society Guidebook, v. 29, p. 112-124.

Hoffman, Paul, **Dewey, J. F.**, and **Burke, Kevin**, 1974, Aulacogens and their genetic relation to geosynclines, with a Proterozoic example from Great Slave Lake, Canada, *in* Dott, R. H., Jr., and Shaver, R. H., editors, Modern and ancient geosynclinal sedimentation: Society of Economic Paleontologists and Mineralogists Special Publication 19, p. 38-55.

Honess, C. W., 1924, Geology of southern Le Flore and northwestern McCurtain Counties, Oklahoma: Bureau of Geology, Norman, Oklahoma, Circular 3, 23 p.

Horowitz, A. S., and **Macurda, D. B., Jr.**, 1977, Late Mississippian and Early Pennsylvanian blastoids from northeastern Oklahoma and northwestern Arkansas, *in* Sutherland, P. K., and Manger, W. L., editors, Upper Chesterian-Morrowan stratigraphy and the Mississippian-Pennsylvanian boundary in northeastern Oklahoma and northwestern Arkansas: Oklahoma Geological Survey Guidebook 18, p. 169-170.

Huffman, G. G., 1958, Geology of the flanks of the Ozark uplift, northeastern Oklahoma: Oklahoma Geological Survey Bulletin 77, 281 p.

Johnson, K. E., 1968, Sedimentary environment of the Stanley Group of the Ouachita Mountains of Oklahoma: Journal of Sedimentary Petrology, v. 38, p. 723-733.

Katz, S. G., and **Sprinkle, James**, 1977, Morrowan (Lower Pennsylvanian) *Pentremites* in Oklahoma and Arkansas, *in* Sutherland, P. K., and Manger, W. L., editors, Upper Chesterian-Morrowan stratigraphy and the Mississippian-Pennsylvanian boundary in northeastern Oklahoma and northwestern Arkansas: Oklahoma Geological Survey Guidebook 18, p. 161-167, 1 pl.

King, P. B., 1975, The Ouachita and Appalachian orogenic belts, *in* Stehli, F. G., and Nairn, Alan, editors, Gulf of Mexico and Caribbean, *v. 3 of* The ocean basins and margins: Plenum Publishing Corp., New York.

Kotila, D. A., 1973, Algae and paleoecology of algal and related facies, Morrow Formation, northeastern Oklahoma: University of Oklahoma unpublished Ph.D. dissertation, 231 p.

Lane, H. R., 1967, Uppermost Mississippian and Lower Pennsylvanian conodonts from the type Morrowan region, Arkansas: Journal of Paleontology, v. 41, p. 920-942, pls. 119-123.

——1977, Morrowan (Early Pennsylvanian) conodonts of northwestern Arkansas and northeastern Oklahoma, *in* Sutherland, P. K., and Manger, W. L., editors, Upper Chesterian-Morrowan stratigraphy and the Mississippian-Pennsylvanian boundary in northeastern Oklahoma and northwestern Arkansas: Oklahoma Geological Survey Guidebook 18, p. 177-180.

Lane, H. R., and **Straka, J. J.**, 1974, Late Mississippian and Early Pennsylvanian conodonts, Arkansas and Oklahoma: Geological Society of America Special Paper 152, 144 p.

Laudon, R. B., 1958, Chesterian and Morrowan rocks in the McAlester basin of Oklahoma: Oklahoma Geological Survey Circular 46, 30 p.

LeBlanc, R. J., 1975, Significant studies of modern and ancient deltaic sediments, *in* Broussard, M. L., editor, Deltas, models for exploration: Houston Geological Society, p. 13-85.

——1977, Distribution and continuity of sandstone reservoirs—parts 1 and 2: Journal of Petroleum Technology, v. 29, p. 776-804.

Lumsden, D. N., **Pittman, E. D.**, and **Buchanan, R. S.**, 1971, Sedimentation and petrology of Spiro and Foster Sands (Pennsylvanian), McAlester basin, Oklahoma: American Association of Petroleum Geologists Bulletin, v. 55, p. 254-266.

McBride, E. F., 1975, The Ouachita trough sequence: Marathon region and Ouachita Mountains, *in* Briggs, Garrett, McBride, E. F., and Moiola, R. J., leaders, A guidebook to the sedimentology of Paleozoic flysch and associated deposits, Ouachita Mountains-Arkoma basin, Oklahoma: Dallas Geological Society Guidebook for AAPG-SEPM Annual Meeting, p. 23-41.

McCaleb, J. A., 1964, Two new genera of Lower Pennsylvanian ammonoids from northern Arkansas: Oklahoma Geology Notes, v. 24, p. 233-237.

——1968, Lower Pennsylvanian ammonoids from the Bloyd Formation of Arkansas and Oklahoma: Geological Society of America Special Paper 96, 91 p., 12 pls.

McCaleb, J. A., **Quinn, J. H.**, and **Furnish, W. M.**, 1964, The ammonoid family Girtyoceratidae in the southern Midcontinent: Oklahoma Geological Survey Circular 67, 41 p., 4 pls.

Manger, W. L., and **Quinn, J. H.**, 1972, Carboniferous dimorphoceratid ammonoids from northern Arkansas: Journal of Paleontology, v. 46, p. 303-314, 2 pls.

Manger, W. L., and **Shanks, J. L.**, 1976, Lower Mississippian lithostratigraphy, northern Arkansas: Arkansas Academy of Science Proceedings, v. 30, p. 78-80.

Merewether, E. A., 1961, Thickening of the Atoka Formation in the central part of the Arkansas Valley, northwestern Arkansas: U.S. Geological Survey Professional Paper 424-C, p. C85-C87.

Miser, H. D., 1934, Carboniferous rocks of Ouachita Mountains:

American Association of Petroleum Geologists Bulletin, v. 18, p. 971-1009.

——1954, Geologic map of Oklahoma: U.S. Geological Survey and Oklahoma Geological Survey, scale 1:500,000.

——1959, Structure and vein quartz of the Ouachita Mountains of Oklahoma and Arkansas, *in* Cline, L. M., Hilseweck, W. J., and Feray, D. E., editors, The geology of the Ouachita Mountains—a symposium: Dallas Geological Society and Ardmore Geological Society, p. 30-43.

Miser, H. D., and **Honess, C. W.**, 1927, Age relations of the Carboniferous rocks of the Ouachita Mountains of Oklahoma and Arkansas: Oklahoma Geological Survey Bulletin 44, 28 p.

Miser, H. D., and **Purdue, A. H.**, 1929, Geology of the DeQueen and Caddo Gap quadrangles, Arkansas: U.S. Geological Survey Bulletin 808, 195 p.

Moiola, R. J., and **McBride, E. F.**, 1975, Sedimentology of Ouachita turbidites, southeastern Oklahoma: a summary, *in* Briggs, Garrett, McBride, E. F., and Moiola, R. J., leaders, A guidebook to the sedimentology of Paleozoic flysch and associated deposits, Ouachita Mountains-Arkoma basin, Oklahoma: Dallas Geological Society Guidebook for AAPG-SEPM Annual Meeting, p. 42-50.

Moore, R. C., and **Strimple, H. L.**, Lower Pennsylvanian (Morrowan) crinoids from Arkansas, Oklahoma, and Texas: University of Kansas Paleontological Contributions, Article 60 (Echinodermata 12), 84 p., 23 pls.

Morris, R. C., 1971, Stratigraphy and sedimentology of Jackfork Group, Arkansas: American Association of Petroleum Geologists Bulletin, v. 55, p. 387-402.

——1974a, Carboniferous rocks of the Ouachita Mountains, Arkansas: a study of facies patterns along the unstable slope and axis of a flysch trough, *in* Briggs, Garrett, editor, Carboniferous of the southeastern United States: Geological Society of America Special Paper 148, p. 241-279.

——1974b, Sedimentary and tectonic history of the Ouachita Mountains, *in* Dickinson, W. R., editor, Tectonics and sedimentation: Society of Economic Paleontologists and Mineralogists Special Publication 22, p. 120-142.

Mutti, E., and **Ricci Lucchi, F.**, 1978, Turbidites of the northern Appennines: American Geological Institute Reprint Series 3. [Reprinted from International Geology Review, v. 20, p. 125-166. Translated by T. H. Nielson from 1972 paper.]

Niem, A. R., 1977, Mississippian pyroclastic flow and ash-fall deposits in the deep-marine Ouachita flysch basin, Oklahoma and Arkansas: Geological Society of America Bulletin, v. 88, p. 49-61.

Orgren, D. E., 1968, Stratigraphy of Upper Mississippian rocks of northern Arkansas: American Association of Petroleum Geologists Bulletin, v. 52, p. 282-294.

Owen, D. D., 1858, First report of a geological reconnaissance of the northern counties of Arkansas made during the years 1857 and 1858: Arkansas Geological Survey, 256 p.

Picha, Frantisek, and **Niem, A. R.**, 1974, Distribution and extent of beds in flysch deposits, Ouachita Mountains, Arkansas and Oklahoma: Journal of Sedimentary Petrology, v. 44, p. 328-335.

Purdue, A. H., 1907, Description of the Winslow quadrangle [Arkansas-Indian Territory]: U.S. Geological Survey Geologic Atlas, Folio 154, 6 p.

Purdue, A. H., and **Miser, H. D.**, 1916, Description of the Eureka Springs and Harrison quadrangles, Arkansas-Missouri: U.S. Geological Survey Geologic Atlas, Folio 202, 22 p.

Quinn, J. H., 1966, The Pitkin and superjacent formations in northern Arkansas: Shale Shaker, v. 17, p. 2-12.

Quinn, J. H., and **Saunders, W. B.**, 1968, The ammonoids *Hudsonoceras* and *Baschkirites* in the Morrowan Series of Arkansas: Journal of Paleontology, v. 42, p. 397-402, pl. 57.

Reinemund, J. A., and **Danilchik, Walter**, 1957, Preliminary geologic maps of the Waldron quadrangle and adjacent areas, Scott County, Arkansas: U.S. Geological Survey Oil and Gas Investigations Map OM 192, scale 1:48,000.

Saunders, W. B., 1966, New goniatite ammonoid from the Late Mississippian of Arkansas: Oklahoma Geology Notes, v. 26, p. 43-48, 1 pl.

——1973, Upper Mississippian ammonoids from Arkansas and Oklahoma: Geological Society of America Special Paper 145, 110 p., 8 pls.

——1975, The Upper Mississippian *Eumorphoceras richardsoni-Cravenoceras friscoense* ammonoid assemblage, North American Midcontinent: 7ᵉ Compte Rendu, 7ᵉ Congrès International de Stratigraphie et de Géologie du Carbonifère, Krefeld, 1971, v. 4, p. 201-207.

Saunders, W. B., **Manger, W. L.**, and **Gordon, Mackenzie, Jr.**, 1977, Upper Mississippian and Lower and Middle Pennsylvanian ammonoid biostratigraphy of northern Arkansas, *in* Sutherland, P. K., and Manger, W. L., editors, Upper Chesterian-Morrowan stratigraphy and the Mississippian-Pennsylvanian boundary in northeastern Oklahoma and northwestern Arkansas: Oklahoma Geological Survey Guidebook 18, p. 117-137, 6 pls.

Seely, D. R., 1963, Structure and stratigraphy of the Rich Mountain area, Oklahoma and Arkansas: Oklahoma Geological Survey Bulletin 101, 173 p.

Sellars, R. T., Jr., 1966, Geology of the Mena-Board Camp quadrangles, Polk County Arkansas: Tulane Studies in Geology, v. 4, p. 141-172.

Shelburne, O. B., Jr., 1960, Geology of the Boktukola syncline, southeastern Oklahoma: Oklahoma Geological Survey Bulletin 88, 84 p.

Shideler, G. L., 1970, Provenance of Johns Valley boulders in late Paleozoic facies, southeastern Oklahoma and southwestern Arkansas: American Association of Petroleum Geologists Bulletin, v. 54, p. 789-806.

Seilacher, Adolf, 1967, Bathymetry of trace fossils: Marine Geology, v. 5, p 413-428.

Stark, P. H., 1966, Stratigraphy and environment of deposition of the Atoka Formation in the central Ouachita Mountains, Oklahoma, *in* Field conference on flysch facies and structure of the Ouachita Mountains: Kansas Geological Society Guidebook, v. 29, p. 164-176.

Stone, C. G., 1968, The Atoka Formation in north-central Arkansas: Arkansas Geological Commission Miscellaneous Publication, 24 p.

——1978, Road log for second day of field trip from the vicinity of Heavener to near Broken Bow, Oklahoma, *in* Field guide to structure and stratigraphy of the Ouachita Mountains and the Arkoma Basin: Oklahoma City Geological Society Guidebook for AAPG-SEPM Annual Meeting, p. 84-140.

Stone, C. G., **Haley, B. R.**, and **Viele, G. W.**, 1973, A guidebook to the geology of the Ouachita Mountains, Arkansas: Arkansas Geological Commission, 113 p.

Straka, J. J., 1972, Conodont evidence of age of Goddard and Springer Formations, Ardmore basin, Oklahoma: American Association of Petroleum Geologists Bulletin, v. 56, p. 1087-1099.

Strimple, H. L., 1977, Chesterian (Upper Mississippian) and Morrowan (Lower Pennsylvanian) crinoids of northeastern Oklahoma and northwestern Arkansas, *in* Sutherland, P. K., and Manger, W. L., editors, Upper Chesterian-Morrowan stratigraphy and the Mississippian-Pennsylvanian boundary in northeastern Oklahoma and northwestern Arkansas: Oklahoma Geological Survey Guidebook 18, p. 171-176.

Sullivan, H. J., and **Mischell, D. R.**, 1971, The Mississippian-Pennsylvanian boundary and its correlation with Europe: 6[e] Compte Rendu, 6[e] Congrès International de Stratigraphie et de Géologie du Carbonifère, Sheffield, 1967, v. 4, p. 1533-1540.

Sutherland, P. K., 1977, Analysis of the Middle Carboniferous rugose coral genus *Petalaxis* and its stratigraphic significance: Second International Symposium on Corals and Fossil Coral Reefs, Paris, September, 1975: Mémoires du Bureau de Recherches Géologiques et Minières, no. 89, p. 185-189.

Sutherland, P. K., and **Grayson, R. C., Jr.**, 1976, Basinward facies changes in the Wapanucka Limestone (Lower Pennsylvanian), Indian Nation Turnpike, Ouachita Mountains, Oklahoma [abstract]: American Association of Petroleum Geologists Bulletin, v. 60, p. 727.

——1977, Basinward facies changes in the Wapanucka Formation (Lower Pennsylvanian), Indian Nation Turnpike, Ouachita Mountains, Oklahoma: Oklahoma Geology Notes, v. 37, p. 39-44.

——1978, Redefinition of the Morrowan Series (Lower Pennsylvanian) in its type area, northwestern Arkansas [abstract]: Geological Society of America Abstracts with Programs, v. 10, p. 501.

Sutherland, P. K., Grayson, R. C., Jr., and **Zimbrick, G. D.**, 1978, Reevaluation of Morrowan-Atokan Series boundary in northwestern Arkansas and northeastern Oklahoma [abstract]: American Association of Petroleum Geologists Bulletin, v. 62, p. 566.

Sutherland, P. K., and **Henry, T. W.**, 1977a, Carbonate platform facies and new stratigraphic nomenclature of the Morrowan Series (Lower and Middle Pennsylvanian), northeastern Oklahoma: Geological Society of America Bulletin, v. 88, p. 425-440.

——1977b, Stratigraphy of uppermost Mississippian and Lower Pennsylvanian strata in northeastern Oklahoma, *in* Sutherland, P. K., and Manger, W. L., editors, Upper Chesterian-Morrowan stratigraphy and the Mississippian-Pennsylvanian boundary in northeastern Oklahoma and northwestern Arkansas: Oklahoma Geological Survey Guidebook 18, p. 41-48.

Sutherland, P. K., and **Manger, W. L.**, editors, 1977, Upper Chesterian-Morrowan stratigraphy and the Mississippian-Pennsylvanian boundary in northeastern Oklahoma and northwestern Arkansas: Oklahoma Geological Survey Guidebook 18, 183 p.

Taff, J. A., 1901, Description of the Coalgate quadrangle [Indian Territory]: U.S. Geological Survey Geologic Atlas, Folio 74, 6 p.

——1902, Description of the Atoka quadrangle [Indian Territory]: U.S. Geological Survey Geologic Atlas, Folio 79, 8 p.

——1905, Description of the Tahlequah quadrangle [Indian Territory-Arkansas]: U.S. Geological Survey Geologic Atlas, Folio 122, 7 p.

Taylor, T. N., and **Eggert, D. A.**, 1967, Petrified plants from the Upper Mississippian (Chesterian Series) of Arkansas: American Microscopical Society Transactions, v. 84, p. 412-416.

Tehan, R. E., and **Warmath, A. T.**, 1977, Lime-mud mounds of the Pitkin Formation (Chesterian), northwestern Arkansas, *in* Sutherland, P. K., and Manger, W. L., editors, Upper Chesterian-Morrowan stratigraphy and the Mississippian-Pennsylvanian boundary in northeastern Oklahoma and northwestern Arkansas: Oklahoma Geological Survey Guidebook 18, p. 49-54.

Thomas, W. A., 1977, Structural and stratigraphic continuity of the Ouachita and Appalachian Mountains, *in* Symposium on the geology of the Ouachita Mountains: Arkansas Geological Commission, v. 1, p. 9-24.

Thomson, Alan, and **LeBlanc, R. J.**, 1975, Carboniferous deep-sea fan facies of Arkansas and Oklahoma [abstract]: Geological Society of America Abstracts with Programs, v. 7, p. 1298-1299.

Ulrich, E. O., 1904, Determination and correlation of formations, *in* Adams, G. I. (assisted by Purdue, A. H., and Burchard, E. F.), Zinc and lead deposits of northern Arkansas: U.S. Geological Survey Professional Paper 24, p. 90-113.

——1927, Fossiliferous boulders in the Ouachita "Caney" shale and the age of the shale containing them: Oklahoma Geological Survey Bulletin 45, 48 p.

Viele, G. W., 1973, Structure and tectonic history of the Ouachita Mountains, Arkansas, *in* DeJong, K. A., and Scholten, Robert, editors, Gravity and tectonics: Wiley-Interscience, New York, p. 361-377.

Walker, R. G., 1978, Deep-water sandstone facies and ancient submarine fans: models for exploration for stratigraphic traps: American Association of Petroleum Geologists Bulletin, v. 62, p. 932-966.

Walker, R. G., and **Mutti, E.**, 1973, Turbidite facies and facies associations, *in* Turbidites and deep-water sedimentation: Society of Economic Paleontologists and Mineralogists, Pacific Section, Short Course, p. 119-157.

Waterschoot van der Gracht, W. A. J. M. van, 1931, Permo-Carboniferous orogeny in south-central United States: American Association of Petroleum Geologists Bulletin, v. 15, p. 991-1057.

White, David, 1934, Age of Jackfork and Stanley formations of Ouachita geosyncline, Arkansas and Oklahoma, as indicated by plants: American Association of Petroleum Geologists Bulletin, v. 18, p. 1010-1017.

——1937, Fossil plants from the Stanley shale and Jackfork sandstone in southeastern Oklahoma and western Arkansas: U.S. Geological Survey Professional Paper 186-C, p. 42-67, pls. 10-14.

Wickham, John, 1978, The Ouachita foldbelt: a Paleozoic continental margin, *in* Field guide to structure and stratigraphy of the Ouachita Mountains and the Arkoma Basin: Oklahoma City Geological Society Guidebook for AAPG-SEPM Annual Meeting, p. 36-52.

Wickham, John, Roeder, Dietrich, and **Briggs, Garrett**, 1976, Plate tectonic models for the Ouachita foldbelt: Geology, v. 4, no. 3, p. 173-176.

Wilson, C. W., Jr., 1935, Age and correlation of Pennsylvanian surface formations and of oil and gas sands of Muskogee County, Oklahoma: American Association of Petroleum Geologists Bulletin, v. 19, p. 503-520.

Zachry, D. L., Jr., 1975, Early Pennsylvanian fluvial sedimentation in northwestern Arkansas [abstract]: American Association of Petroleum Geologists and Society of Economic Paleontologists and Mineralogists Annual Meetings Abstracts, v. 2, p. 84-85.

——1977, Stratigraphy of middle and upper Bloyd strata (Pennsylvanian, Morrowan), northwestern Arkansas, *in* Sutherland, P. K., and Manger, W. L., editors, Upper Chesterian-Morrowan stratigraphy and the Mississippian-Pennsylvanian boundary in northeastern Oklahoma and northwestern Arkansas: Oklahoma Geological Survey Guidebook 18, p. 61-66.

Zachry, D. L., and **Haley, B. R.**, 1975, Stratigraphic relationships between the Bloyd and Atoka Formations (Pennsylvanian) of northern Arkansas, *in* Contributions to the geology of the Arkansas Ozarks: Arkansas Geological Commission, p. 96-106.

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NINTH INTERNATIONAL CONGRESS OF CARBONIFEROUS STRATIGRAPHY AND GEOLOGY

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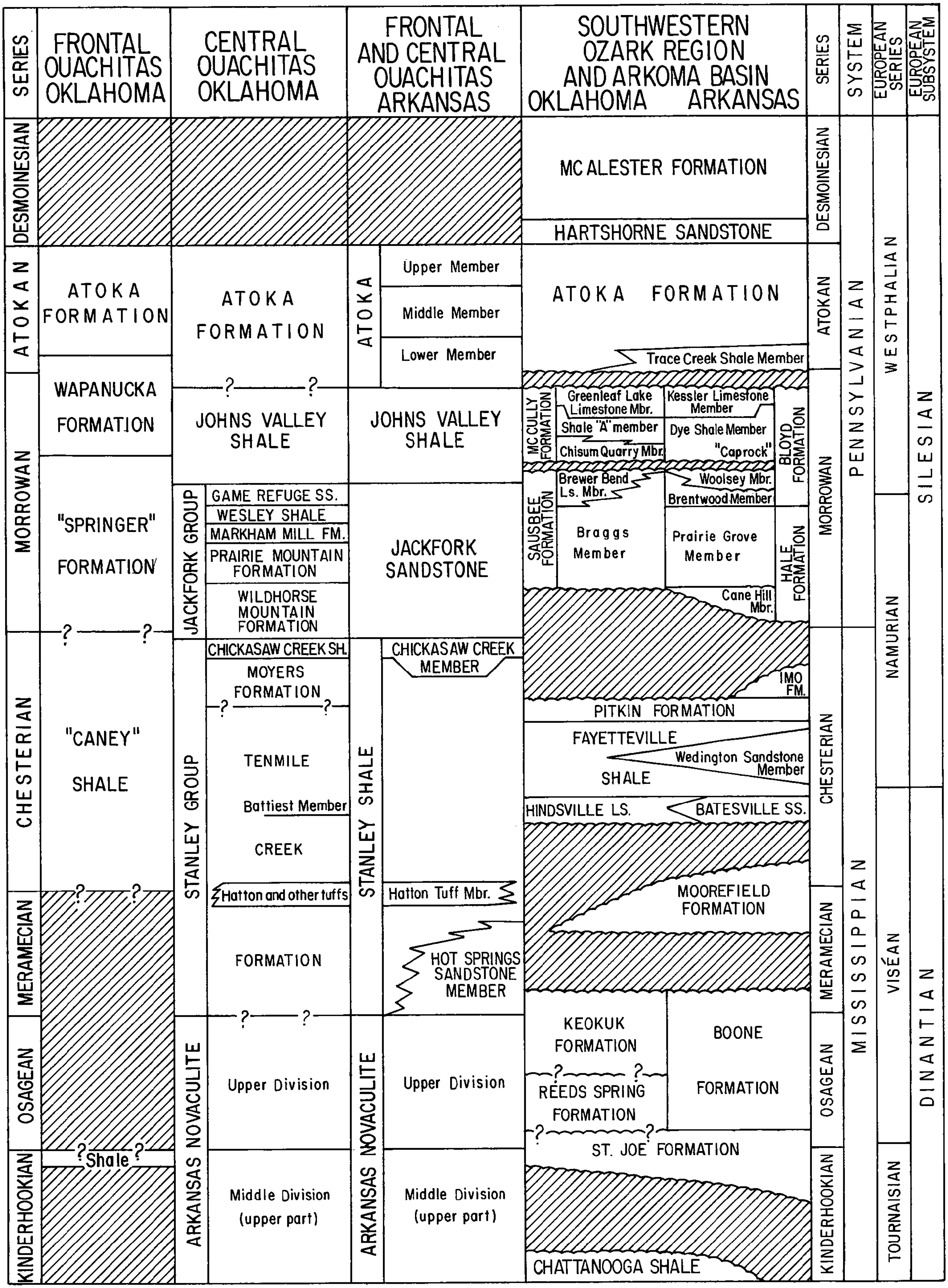
SERIES
FRONTAL OUACHITAS OKLAHOMA
CENTRAL OUACHITAS OKLAHOMA
FRONTAL AND CENTRAL OUACHITAS ARKANSAS
SOUTHWESTERN OZARK REGION AND ARKOMA BASIN OKLAHOMA ARKANSAS
SERIES
SYSTEM
EUROPEAN SERIES
EUROPEAN SUBSYSTEM
DESMOINESIAN
MC ALESTER FORMATION
HARTSHORNE SANDSTONE
ATOKAN
ATOKA FORMATION
ATOKA FORMATION
ATOKA
Upper Member
Middle Member
Lower Member
ATOKA FORMATION
Trace Creek Shale Member
MORROWAN
WAPANUCKA FORMATION
JOHNS VALLEY SHALE
JOHNS VALLEY SHALE
MC CULLY FORMATION
Greenleaf Lake Limestone Mbr.
Shale "A" member
Chisum Quarry Mbr.
Kessler Limestone Member
Dye Shale Member
"Caprock"
BLOYD FORMATION
Brewer Bend Ls. Mbr.
Woolsey Mbr.
Brentwood Member
SAUSBEE FORMATION
Braggs Member
Prairie Grove Member
HALE FORMATION
Cane Hill Mbr.
"SPRINGER" FORMATION
JACKFORK GROUP
GAME REFUGE SS.
WESLEY SHALE
MARKHAM MILL FM.
PRAIRIE MOUNTAIN FORMATION
WILDHORSE MOUNTAIN FORMATION
JACKFORK SANDSTONE
CHESTERIAN
"CANEY" SHALE
STANLEY GROUP
CHICKASAW CREEK SH.
MOYERS FORMATION
TENMILE
Battiest Member
CREEK
Hatton and other tuffs
FORMATION
STANLEY SHALE
CHICKASAW CREEK MEMBER
Hatton Tuff Mbr.
HOT SPRINGS SANDSTONE MEMBER
IMO FM.
PITKIN FORMATION
FAYETTEVILLE
Wedington Sandstone Member
SHALE
HINDSVILLE LS.
BATESVILLE SS.
MERAMECIAN
MOOREFIELD FORMATION
OSAGEAN
ARKANSAS NOVACULITE
Upper Division
Upper Division
KEOKUK FORMATION
BOONE FORMATION
REEDS SPRING FORMATION
ST. JOE FORMATION
KINDERHOOKIAN
Shale
Middle Division (upper part)
Middle Division (upper part)
CHATTANOOGA SHALE
PENNSYLVANIAN
MISSISSIPPIAN
WESTPHALIAN
NAMURIAN
VISÉAN
TOURNAISIAN
SILESIAN
DINANTIAN