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# REGIONAL GEOLOGY OF THE ARBUCKLE MOUNTAINS, OKLAHOMA

By

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**Guidebook for Field Trip No. 5**
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## PREFACE

The geologic provinces of southern Oklahoma have been of interest to geologists for many years, encompassing the Wichita Mountains to the southwest, the Arbuckle Mountains-Ardmore basin complex to the south, and the Ouachita Mountains to the southeast. Each of these structural uplifts contains vastly different rocks of unusual interest.

The Arbuckle Mountains area has been of special interest because of its fine outcrops of Precambrian, Lower Cambrian, and Middle Cambrian igneous rocks overlain by thousands of feet of well-exposed lower and middle Paleozoic carbonate rocks. It is an area suited for all types of geologic studies: igneous rocks are varied, sedimentary and stratigraphic problems are plentiful, and many units contain rich faunas that have been intensively studied. The structural geologist can find all types of folding and faulting in the mountains varying from simple to complex. Glass sand, sand and gravel, crushed stone for construction, chemical-grade carbonate, and building stone are all produced from rocks in the Arbuckle Mountains complex.

This part of Oklahoma has been intensively studied by many geologists over the years, but one in particular has contributed to the major portion of our detailed knowledge of the area, the late William E. Ham. Bill Ham's many years of work in the area have resulted in numerous publications, principal among which include *Geologic Map and Sections of the Arbuckle Mountains, Oklahoma* (with M. E. McKinley), in 1954, and *Basement Rocks and Structural Evolution of Southern Oklahoma* (with R. E. Denison and C. A. Merritt), in 1964. Both works were published by the Oklahoma Geological Survey. In addition, Bill wrote a number of less comprehensive reports concerning geologic problems and economic evaluation. Several field-conference guidebooks were written by Bill; the latest was in conjunction with the annual meeting of The American Association of Petroleum Geologists and the Society of Economic Paleontologists and Mineralogists in Oklahoma City in 1968, which resulted in publication of Oklahoma Geological Survey Guide Book XVII in 1969, *Regional Geology of the Arbuckle Mountains, Oklahoma.*

So, a field trip to the Arbuckle Mountains seemed appropriate for The Geological Society of America's annual meeting in Dallas in 1973. This guidebook represents an attempt to update and synthesize previous guidebooks of other field conferences, and most of the material has come from Oklahoma Geological Survey Guide Book XVII. New material not previously published covers Stop 3, written by T. W. Amsden. R. E. Denison has provided a summary of basement rocks and other new material for Stops 5, 6, and 7. Minor changes have been made in material taken from previous works.

Part I of this book contains an excellent introduction to the regional geology of southern Oklahoma by the late William E. Ham, modified by T. L. Rowland, as well as three other articles concerning various aspects of Arbuckle Mountains geology, which have been modified from Guide Book XVII. Part II of the book describes the stops of the 2-day trip.

**T. L. Rowland**

# REGIONAL GEOLOGY OF THE ARBUCKLE MOUNTAINS, OKLAHOMA

## PART I. REGIONAL GEOLOGY

**William E. Ham**

### INTRODUCTION

The geological province known as the Arbuckle Mountains consists of a huge inlier of folded and faulted Paleozoic and Precambrian rocks, covered on the east, north, and west by gently westward-dipping Pennsylvanian and Permian strata and on the south by gently southward-dipping Early Cretaceous sediments of the Gulf Coastal Plain.

This inlier is a roughly triangular area of nearly 1,000 square miles, almost in the center of the southern third of Oklahoma. The geology is characterized mostly by outcrops of carbonate rocks. Immediately to the east begins the 200-mile-long exposure of the Ouachita Mountains, principally a flysch sequence that is quite unlike the Arbuckles in stratigraphic and structural development; and 100 miles to the west are the Wichita Mountains, unlike either the Arbuckles or Ouachitas and characterized chiefly by extensive outcrops of Cambrian (not Precambrian) igneous rocks. Thus, the three uplifted segments of southern Oklahoma actually share little in common, despite their geographic proximity, and each has a profoundly different geologic emphasis.

The primary emphasis of Arbuckle Mountains geology lies in its early Paleozoic carbonates and late Paleozoic clastics, deposited partly upon a craton of Precambrian granites and partly in an adjoining geosynclinal basin, the whole welded by Pennsylvanian orogeny and epeirogeny into a single geographic unit. This geographic simplicity is misleading, as will be shown on following pages.

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

Whether plains or hill country, the Arbuckle Mountains region is of irresistible interest to geologists. Its 11,000 feet of fossiliferous Late Cambrian through Devonian strata constitute the best outcrops and greatest area of exposure of this sequence in all the Midcontinent region. Stratigraphic names taken from the Arbuckles, such as Arbuckle, Simpson, Viola, Sylvan, Hunton, and Woodford, have been widely applied in the subsurface as far away as West Texas, Illinois, and Nebraska. The 150-square-mile exposure of Precambrian granites in the eastern Arbuckle Mountains is the largest and best outcrop of such rocks in the central United States between the Llano area of Texas and the Black Hills of South Dakota. Finally, as much as 19,000 feet of Mississippian and Pennsylvanian clastics are present in the region, partly in synclinal grabens of the Arbuckle Mountains and to a much greater extent in the adjoining Ardmore basin. Fusulinids from thin Pennsylvanian limestones in this sequence are widely used as standards of reference.

The processes of strong uplift and deep erosion that have produced the Arbuckle Mountains of today have also resulted in the surface exposure of rocks that normally are deeply buried. Among the rocks are many that are commercially valuable, such as limestones from thick and widely distributed outcrops of the Arbuckle and Viola Formations that are extensively quarried as a source of crushed stone, high-purity silica sand from the Simpson Group for glass making and other industrial use, cement-making raw materials from the Viola Limestone and Sylvan Shale, high-purity dolomite from the Arbuckle Group, and building and monumental stone from Precambrian granite. Geologists are especially indebted to the stone industries for the magnificent exposures in these quarries.

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

### BASEMENT ROCKS

A geologic map of the United States strikingly illustrates the virtual absence of outcropping basement rocks in the vast central interior. Five major areas of relatively small outcrop are known, however, and each is important in representing the structural crest of a major uplift. In three of these areas—Black Hills of southwestern South Dakota, St. Francois Mountains of southeastern Missouri, and the Llano area of central Texas—Precambrian basement rocks are exposed at the crests of broad cratonic domes. In the fourth area, that of southern Oklahoma, the basement rocks are unique in that they are exposed along the margins of a profound intracratonic geosynclinal sag and consist mostly of igneous flows and intrusives of Cambrian, rather than Precambrian, age.

These young basement rocks of southern Oklahoma, isotopically dated at 500 to 550 million years, are exposed extensively in the Wichita Mountains of southwestern Oklahoma and in a much smaller area at the southwestern edge of the Arbuckle Mountains. Significantly, they are

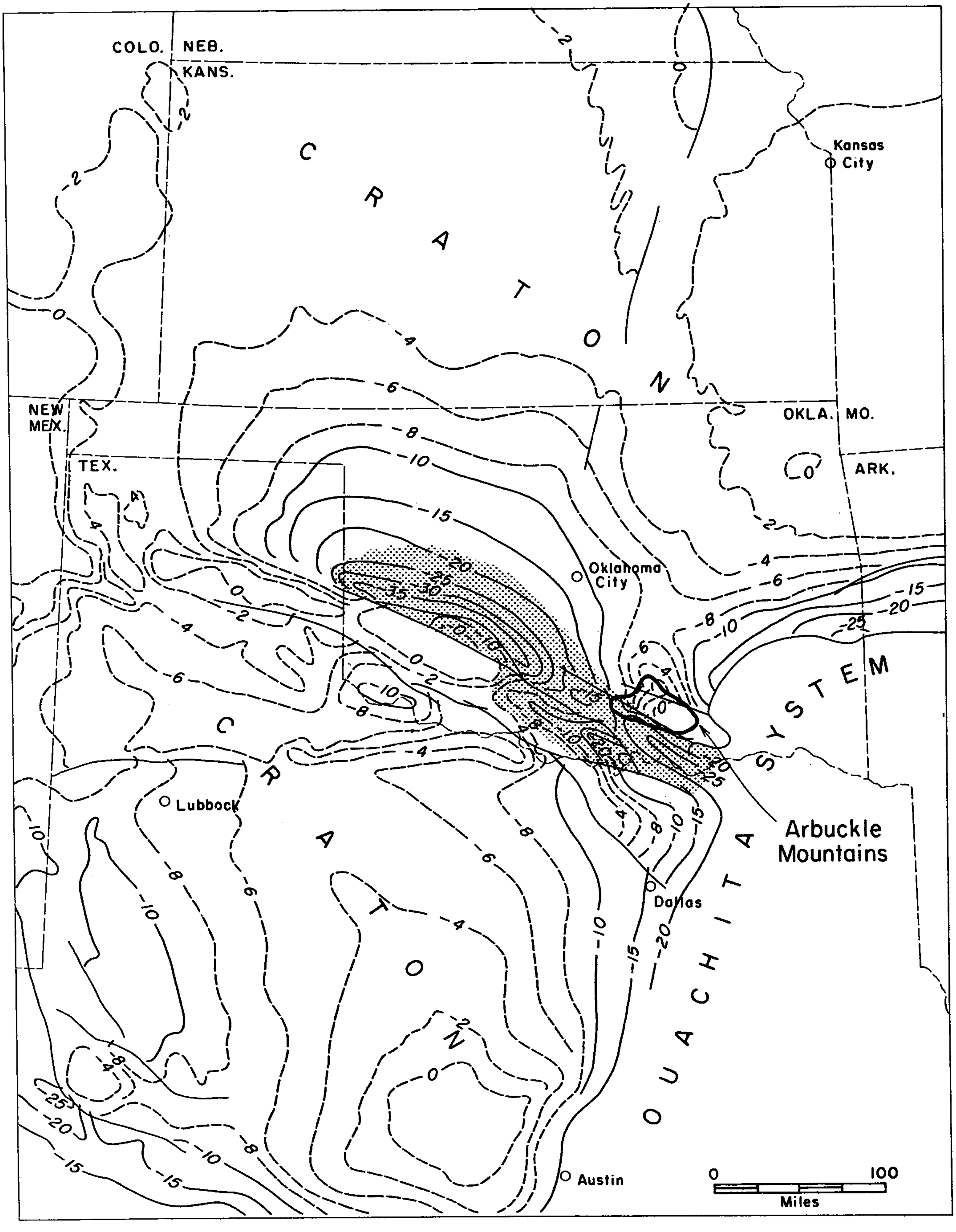


Figure 1. Basement Map of Oklahoma and Adjoining Areas
(See explanation, opposite page)

known from drilling data to continue in the subsurface between these uplifts and to underlie all or most of the intracratonic geosyncline.

At the top of the Cambrian basement-rock sequence are rhyolite flows and tuffs, called the Carlton Rhyolite Group, that attain a known thickness of nearly 5,000 feet, and these are underlain by spilitic basalts and tuffs with a maximum drilled thickness of 1,050 feet. A Cambrian basement floor of flows and tuffs, probably at least 7,500 feet thick, is not known elsewhere in the United States, and of even greater interest is the position of this sequence at the base of the outstanding deep basin, or geosyncline, of the North American craton. These two features cannot be related by mere coincidence; instead, the Cambrian flows and pyroclastics must represent the beginning stage of a transverse trough that persisted throughout Paleozoic time and was filled to a thickness of at least 45,000 feet. This trough has been named the Southern Oklahoma geosyncline.

Against this singular background, the Arbuckle Mountains play a further singular role in containing within their outcrop area the sharply defined contact between rocks of the Southern Oklahoma geosyncline and those of the adjoining cratonic shelf. Over the northern three-fourths of the Arbuckle Mountains, the basement rocks are Precambrian granites of the stable craton, extending from eastern Arbuckle Mountains outcrops northward through central Oklahoma into Kansas and beyond (fig. 1). At a fault contact, these rocks are separated from the southwestern segment of the Arbuckle Mountains, known as the Arbuckle anticline, in which the basement rocks are Cambrian rhyolites and the Paleozoic depositional and structural history is that of the geosyncline. The geosyncline includes the Arbuckle anticline and extends southward for about 50 miles, across the Ardmore basin and Marietta basin and terminating in the subsurface of northern Texas against the Precambrian cratonic rocks of that state (fig. 1).

Outcrops of basement rocks in the Arbuckle Mountains can be seen at two stops. In the Arbuckle anticline this rock is the 525-million-year-old Colbert Rhyolite, the equivalent of the Carlton Rhyolite Group but locally named for exposures along Colbert Creek in the West Timbered Hills. It is shown near the crest of the East Timbered Hills (fig. 2). The Colbert Rhyolite, with a drilled thickness of 4,500 feet on the southwest flank of the Arbuckle Anticline and encountered in at least six wells on the north flank, marks the northeasternmost occurrence of Cambrian basement rocks. All other structural segments of the Arbuckle Mountains are underlain by deeply eroded Precambrian mesozone granites, exposed as the Tishomingo Granite (Stop 6) and Troy Granite and encountered in many wells of the region. One of these wells penetrated nearly 11,000 feet of granites and diorites, isotopically dated at 1,200 m.y. to 1,350 m.y., and established a probable world-record penetration of basement rocks.

Details of basement-rock geology of southern Oklahoma, including petrology, distribution, and isotopic ages of the igneous rocks and their relation to the development of the Southern Oklahoma geosyncline, are contained in the comprehensive report by Ham and others (1964). An amplification of the geosynclinal concept is contained in the report by Ham and Wilson (1967).

## PALEOZOIC STRATIGRAPHY

Southern Oklahoma Paleozoic sediments, exclusive of the Ouachita Mountains, are divisible into four major lithostratigraphic units: (a) Late Cambrian-Early Devonian marine sediments, mostly carbonates; (b) Late Devonian and Mississippian dark shales; (c) Pennsylvanian dark shales, sandstones, thin marine limestones, and local conglomerates; and (d) Permian red shales, sandstones, and halite-gypsum evaporites. As shown in figure 3, the thickness of sediments in each of these Paleozoic units is greatest in the Southern Oklahoma geosyncline and least on the cratonic margins. The fullest representation is in the Anadarko basin, or western deep segment of the geosyncline, where Late Cambrian through Permian sediments are 38,000 feet thick and rest upon Middle Cambrian volcanic flows and tuffs, probably at least 7,000 feet thick. An essentially similar Paleozoic sequence is present in the eastern deep segment of the geosyncline, including the Ardmore basin and Arbuckle anticline, except that in this area the youngest Pennsylvanian and most of the Permian sediments are eroded. The sediments preserved–Late Cambrian through late Middle Pennsylvanian–are 34,000 feet thick, and they too rest upon a floor of Middle Cambrian volcanics. Beyond the geosyncline are elements of the stable craton, characterized by Paleozoic sediments about 10,000 feet thick, a thickness that is only about one-fourth that found within the geosyncline. In addition to the marked differences in thickness are the following notable differences in facies: the Late Cambrian-Early Ordovician Arbuckle Group is dominantly limestone in the geosyncline and dolomite upon the craton; Mississippian sediments are dark shales in the geosyncline and limestones upon the craton; and the Pennsylvanian sediments are chiefly dark shales and sandstones in the geosyncline, whereas on the craton they contain, relatively, much more limestone. The remaining rocks display few facies differences, but is is noteworthy that the three systems cited above account for approximately 70 percent of the geosynclinal filling.

The Late Cambrian-Mississippian sediments are better exposed and better known in the Arbuckle Mountains than in any other part of the southern Midcontinent region. Stratigraphic nomenclature and age assignments, as given in figure 4, provide outcrop comparisons between geosynclinal and cratonic sediments and also serve as a basis for stratigraphic work over a vast, oil-rich subsurface region.

Figure 1. Basement map of Oklahoma and adjoining areas, showing regional setting of Arbuckle Mountains. Configuration of basement surface given by contours drawn at 2,000-foot (dashed) and 5,000-foot (solid) intervals; sea-level datum. Modified from *Basement Map of North America* (Am. Assoc. Petroleum Geologists and U.S. Geological Survey, 1967). Cratonic elements of northern Texas, northern Oklahoma, and Kansas contain thin Paleozoic sedimentary rocks underlain by stable Precambrian rocks dated at 1,000-1,400 m.y. The great intracratonic sag of southern Oklahoma (stippled) is geosynclinal and contains 38,000 feet of Late Cambrian through Permian sedimentary rocks; it is underlain by thick volcanic flows and associated intrusive rocks dated at 525 m.y., probably of Middle Cambrian age. Arbuckle Mountains lie astride contact between cratonic province and geosynclinal province and thus manifest strongly contrasting features of each.

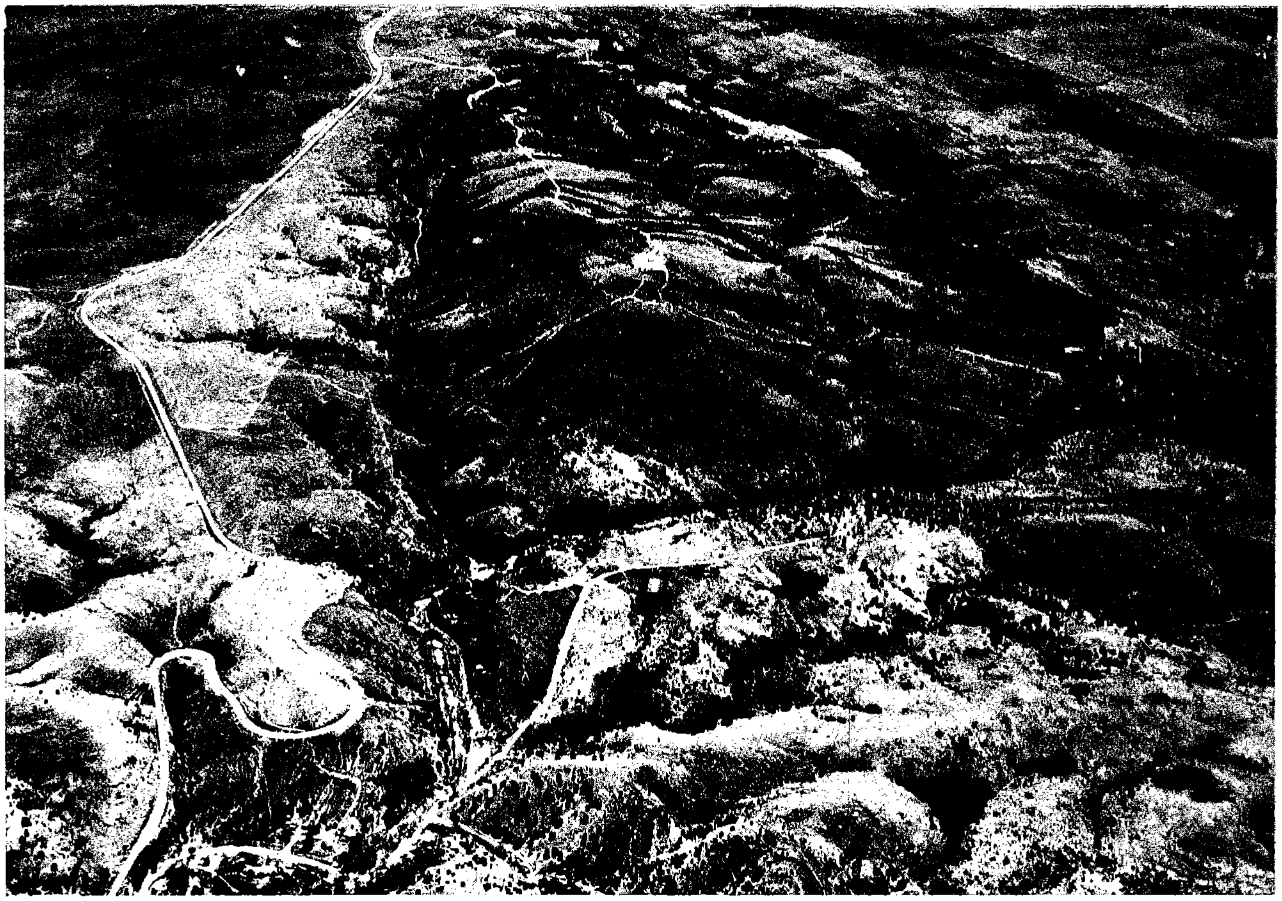

Figure 2. Oblique aerial photograph of East Timbered Hills in Arbuckle Mountains, looking southward along U.S. Highway 77. Rhyolite supporting hills is typical rock of Southern Oklahoma geosyncline beneath Late Cambrian sedimentary rocks, seen here in homoclinal succession at upper right.

(Photograph copyright F. A. Melton)

## Early Paleozoic Carbonates

Late Cambrian through Early Devonian sediments constitute about 90 percent of the Arbuckle Mountains outcrops and can be seen at many stops. In maximum development over the Arbuckle anticline the sequence is 11,000 feet thick and consists mostly of limestones (figs. 4, 5). Over the Hunton anticline the equivalent beds are 6,500 feet thick and also consist mostly of carbonates, although the Arbuckle Group, making up about two-thirds of the sequence, is dolomite rather than limestone. The stratigraphic units, listed in ascending order, are the Timbered Hills Group, Arbuckle Group, Simpson Group, Viola Limestone, Sylvan Shale, and Hunton Group. Details of distribution and stratigraphic relations of the major units are contained in other sections of the guidebook, at localities where representative strata are seen in the field. A condensed summary of outstanding regional characteristics is given below.

*Timbered Hills Group.*—Following the long-continued exposure of the Precambrian granites and the somewhat shorter exposure of the Cambrian geosynclinal volcanics, craton-wide submergence permitted the widespread deposition of transgressive Late Cambrian sandstones. In the Arbuckle Mountains they are known as the Reagan Sandstone, a feldspathic and normally glauconitic sequence of Franconian age. Owing to the irregularity of its depositional surface, the thickness of the Reagan ranges from 75 to 450 feet, and the formation is absent around local granite islands that stood in the Late Cambrian sea. The sandstone is succeeded upward by the Honey Creek Formation, consisting of a thin, trilobite-rich pelmatozoan limestone that is 100 feet thick in the Arbuckle anticline and grades into a sequence of fossiliferous sandy dolomites about 225 feet thick upon the craton.

*Arbuckle Group.*—Without stratigraphic discontinuity, the sediments continue upward as carbonates of the Arbuckle Group, which embraces late Franconian, Trempealeauan, and all of Canadian time. Of shallow-water marine deposition, the Arbuckle rocks are, in part, richly fossiliferous and contain trilobites, brachiopods, mollusks, pelmatozoans, sponges, and, well toward the top, graptolites. In the Arbuckle anticline the strata consist dominantly of interbedded thin carbonate mudstones, intraclast calcarenites, oolitic calcarenites, stromatolites, and laminated dolomites or dolomitic limestones. Upon the craton these strata consist of similar limestones that have been wholly dolomitized. Retained, however, are certain faunal elements that had been previously silicified, and, in this way, satisfactory interregional correlations have been established. The Arbuckle Group has a maximum thickness of 6,700 feet (column A, fig. 4), and thus it is one of the great carbonate sequences of the world. Because of this great thickness, outcrops of Arbuckle rocks dominate large segments of the Arbuckle Mountains.

*Simpson Group.*—Rocks of the Middle Ordovician Simpson Group represent a great change in depositional environment over that of the Arbuckle Group. Cleanly

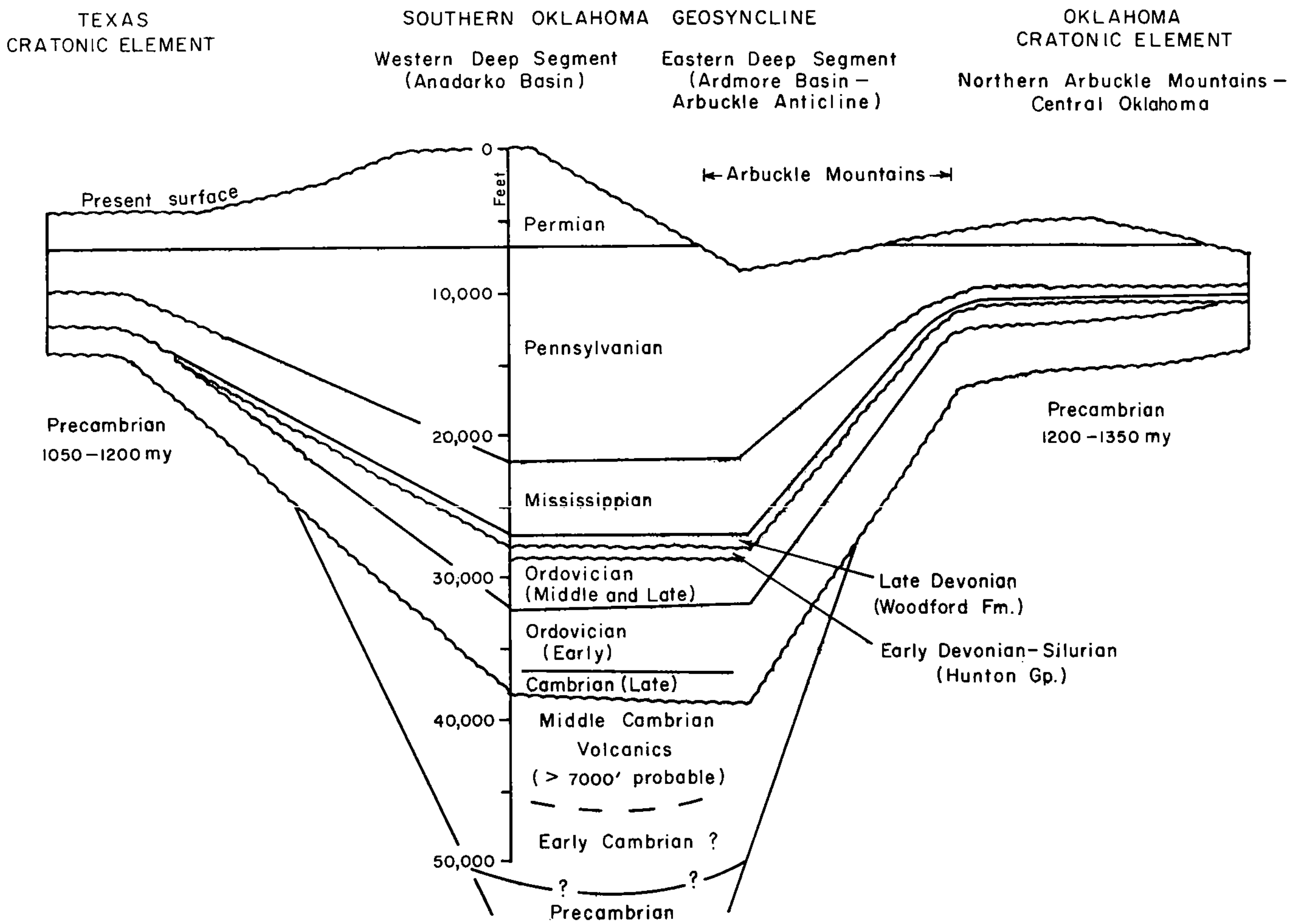


Figure 3. Regional stratigraphic section across Southern Oklahoma geosyncline. Length of section is 200 miles. Geosyncline extends transversely across southern Oklahoma and contains up to 38,000 feet of Late Cambrian through Permian sedimentary rocks deposited upon a floor of Middle Cambrian flows and tuffs at least 7,000 feet thick. Paleozoic filling of 45,000 feet contrasts with approximately 10,000 feet deposited upon stable cratonic elements of northern Texas and central Oklahoma.

washed sand is introduced in large volume for the first time, greenish-gray shale is present in well-defined beds, and many of the limestones are either skeletal calcarenites or algal-mat carbonates, of types that are decidedly rare in Early Ordovician rocks. Bryozoans make an abrupt and profuse appearance; cystoids are abundant and crinoids appear for the first time; brachiopods appear in new and much greater variety; and mollusks, sponges, and trilobites persist throughout. Conspicuously absent are (1) hemispheroidal stromatolites, which characterize the very shallow-water environment of the underlying Arbuckle Group, and (2) graptolites, which characterize the deeper water environment of the overlying Viola Limestone.

Division of the group, as originally made by Decker (Decker and Merritt, 1931), includes, at the base, the Joins Limestone, followed successively upward by the Oil Creek, McLish, Tulip Creek, and Bromide Formations. Each of the upper four formations contains a prominent basal sandstone, generally 50 to as much as 350 feet thick and consisting of well-sorted, rounded, and frosted quartz grains. In the subsurface these sandstone beds make excellent petroleum reservoirs, and on the outcrop they are mined as high-purity silica sands for the manufacture of glass and other industrial uses.

The Simpson Group embraces the post-Canadian and pre-Trentonian part of the Middle Ordovician Epoch and is assigned principally to the Chazy and Black River Stages, but it also includes the White Rock, Marmor, Ashby, Porterfield, and lower part of the Wilderness Stages of Cooper (1956). According to recent investigations by Derby (see pages 35-37), the base of the White Rock Stage in the Arbuckle Mountains is not at the base of the Joins, as previously believed, but nearly 100 feet below, in the upper part of the West Spring Creek Formation at the top of the Arbuckle Group. This faunal discontinuity is not accompanied by physical evidence for unconformity.

Maximum thickness of the Simpson Group is in the Arbuckle anticline (column A, fig. 4), where approximately 2,300 feet is normal for outcrops along the south flank. Skeletal calcarenites and skeletal carbonate mudstones are interbedded with shale and sandstone in approximately equal proportions, whereas in the shelf environment (column B, fig. 4), the much-reduced thickness of barely 1,000 feet consists mostly of limestones. Outstanding is the limestone of the McLish Formation, about 400 feet thick, which is chiefly an algal-mat or "birdseye" limestone that locally contains great concentrations of *Girvanella* oncolites.

*Viola Limestone.*—Above the Simpson Group is a widespread carbonate sequence named the Viola Limestone (fig. 6), shown by Glaser (1965) to be 600 to 900 feet thick in the Arbuckle anticline and 350 to 400 feet thick in the cratonic elements of the Arbuckle Mountains. The formation is divided into a basal unit of siliceous carbonate

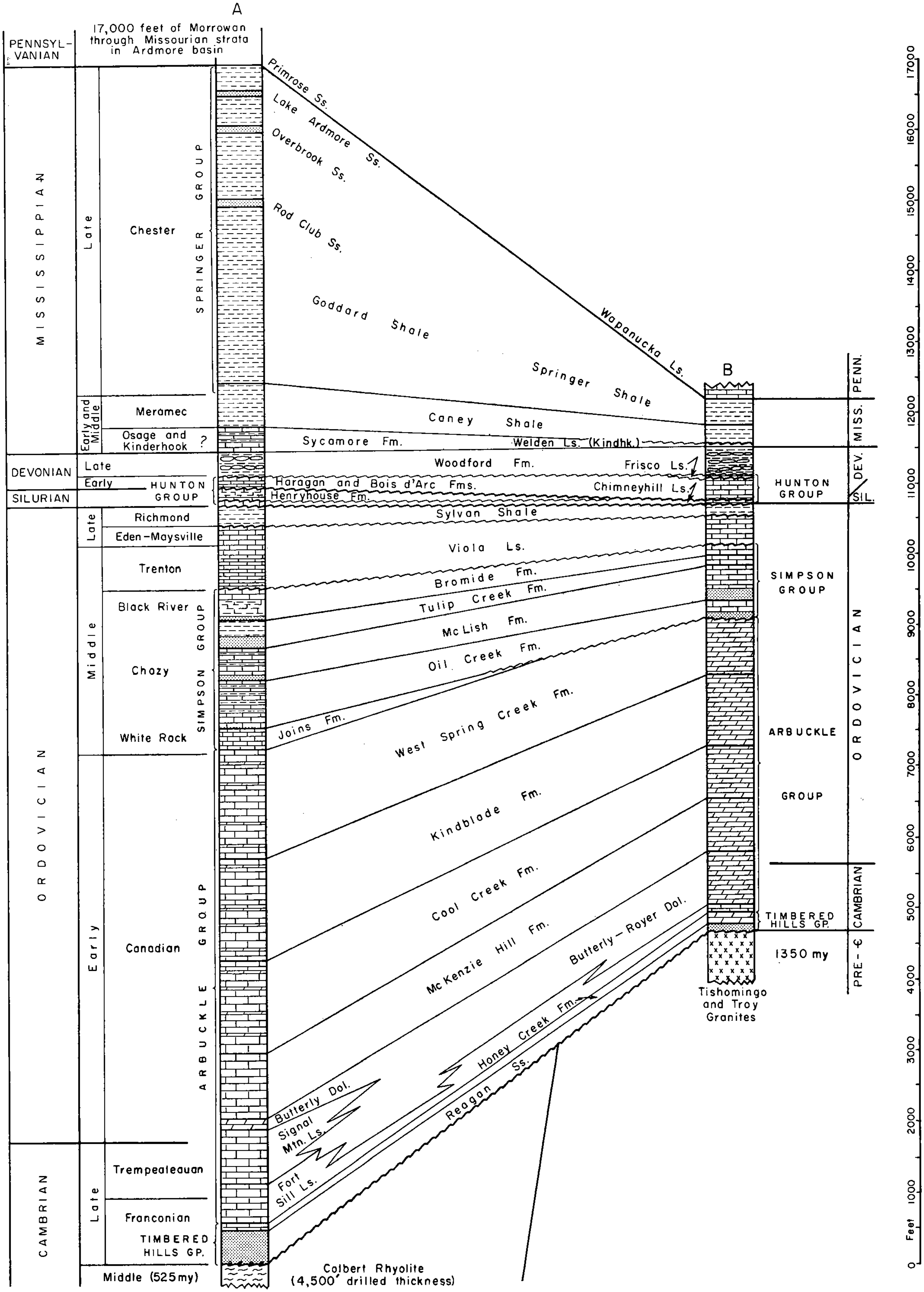


**Figure 4. Pre-Pennsylvanian Stratigraphic Columns in Principal Segments of Arbuckle Mountains**
**(See explanation, opposite page)**

laminites, a middle unit of burrowed skeletal mudstones, and a top unit of pelmatozoan calcarenite. Each unit is continuous throughout the region, although each shows substantial variation in thickness. In general, the laminites are thicker in the basin and the calcarenites are thicker where developed upon the shelf. The vertical disposition of the carbonate types indicates an upward decrease in water depth, from laminites to coarse calcarenites, and a corresponding increase in the energy of the depositional system. Graptolites occur with trilobites in the laminated and burrowed mudstones, whereas pelmatozoans, brachiopods, bryozoans, and mollusks are dominant in the calcarenites.

From studies of graptolites (Ruedemann and Decker, 1934) and of brachiopods (Alberstadt, 1967), the stratigraphic age of the Viola is considered to range from the middle Trenton through the Eden-Maysville of the Cincinnati region and equivalent Utica-Lorraine strata of New York. No physical or faunal evidence of unconformity has been found within the Viola Limestone, but a prominent unconformity at its base probably represents all of early Trentonian time. Another unconformity, at the top of the Viola, presumably represents less time.

*Sylvan Shale.*—Dark, greenish-gray shale, well laminated and locally containing bedding surfaces that are crowded with graptolites, rests disconformably upon the top coarse calcarenites of the Viola Limestone. This unit is the Sylvan Shale, of Late Ordovician (Richmondian) age. Like the older formations, the Sylvan thins northeastward across the Arbuckle Mountains from a maximum of 325 feet in the basin to 150-175 feet on the shelf.

In addition to graptolites, the Sylvan contains a rich fauna of chitinozoans but generally lacks other fossils. These characteristics and the well-developed lamination suggest that the Sylvan was deposited in the deepest waters of all pre-Mississippian formations of the Arbuckle Mountains. Moreover, the Sylvan is the only shale unit of the older Paleozoic rocks that persists throughout the Southern Oklahoma geosyncline and extends beyond it over large areas of the craton. Its known distribution is from West Texas to Iowa, where the equivalent formation is the Maquoketa Shale.

*Hunton Group.*—The youngest rocks of the early Paleozoic carbonate sequence in southern Oklahoma are those of the Hunton Group (fig. 6), of Late Ordovician, Silurian, and Early Devonian age. Between 100 and 350 feet thick at most localities in the Arbuckle Mountains, the group is much thinner than the older sequences, partly because of numerous unconformities within and at the top of the Hunton Group. Without the reduction by erosion at unconformities, the Hunton Group would probably have a restored thickness of approximately 600 feet. Lithostratigraphic concepts and brachiopod paleontology of the group have been ably described by Amsden in numerous reports, chief of which are those published by the Oklahoma Geological Survey in 1958 and 1960. Other stratigraphic contributions deal with the distribution and thickness of beds of this age at the surface and in the subsurface throughout the State of Oklahoma (Amsden and Rowland, 1967a, 1967b).

Stratigraphic nomenclature and ages of Hunton units in the Arbuckle Mountains are given in Part II of the guidebook. The basal formation of the Hunton Group is the Keel (chiefly oolite) of Ordovician age, whereas the Silurian formations are, in ascending order, the Cochrane (chiefly glauconitic pelmatozoan calcarenite), Clarita (pelmatozoan calcarenite and skeletal mudstone), and Henryhouse (argillaceous skeletal mudstones with thin skeletal calcarenites). Overlying Devonian formations are the Bois d'Arc and Haragan (chiefly argillaceous skeletal mudstones), of Helderbergian age, and the Frisco (skeletal calcarenite), of Oriskanian or Deerparkian age. All of these formations produce petroleum at many localities in Oklahoma, although the Frisco Limestone and dolomitized Silurian beds have yielded the greatest reserves.

Depositional patterns of Silurian and Devonian strata are different from those of older and younger sequences of the Southern Oklahoma geosyncline. Neither the Hunton Group nor the overlying Woodford Formation are appreciably thicker in most parts of the geosyncline than upon the craton. Thickness of rocks of the Hunton Group is related more to the position of isolated cratonic basins and to the effectiveness of the several unconformities than to localization within a throughgoing trough. The maximum preserved thicknesses are 400 feet in Coal and Pontotoc Counties, just northeast of the Arbuckle Mountains, and 800 feet in the northern part of Caddo County, 75 miles northwest of the Arbuckle Mountains (Amsden and Rowland, 1967a). Both areas lie well within the craton. Similarly, the Woodford Formation's greatest thickness, 560 feet, lies upon cratonic elements in the eastern part of the Arbuckle Mountains and apparently increases toward the Ouachita Province.

These relationships clearly show that the Southern Oklahoma trough, thickly filled by rapid subsidence during the Cambrian and Ordovician, subsided at a much slower rate during the Silurian and Devonian. Rapid subsidence was renewed after this pause, however, and great thicknesses of Mississippian and Pennsylvanian sediments were deposited within the previously established trough (fig. 3).

## Late Devonian and Mississippian Dark Shales

With the close of Hunton sedimentation, the early Paleozoic phase, marked by dominance of carbonate rocks, was at an end. Later Paleozoic strata of southern Oklahoma are chiefly of clastic derivation, and the first sediments (Late Devonian and Mississippian) are overwhelmingly dominated by dark shales. The sharply defined change from long-continued, shallow-water marine environments to those of euxinic deeper waters marks one of the great

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Figure 4. Pre-Pennsylvanian stratigraphic columns in principal segments of Arbuckle Mountains. A—geosyncline, as illustrated by rocks of Arbuckle anticline and Ardmore basin. B—craton, as illustrated by rocks of Hunton anticline. Sequence begins with Late Cambrian transgressive sandstone and continues upward through dominantly shallow-water-marine carbonates to top of Early Devonian, embracing slightly more than 11,000 feet of strata in geosynclinal segment compared to 6,500 feet on cratonic segment. Regionally persistent unconformities characterize Late Ordovician, Silurian, and Early Devonian strata, and an especially widespread unconformity occurs at base of Woodford Formation of Late Devonian age. Rocks from base of Woodford to top of Mississippian are chiefly dark shales, about 5,800 feet thick in Ardmore basin compared to 1,000 feet in Hunton anticline. Thus, Late Cambrian through Mississippian strata are 17,000 feet thick in geosyncline and less than half that thick—7,500 feet—upon adjoining cratonic shelf. Pennsylvanian sedimentation in Arbuckle Mountains region continued this depositional pattern, yielding a total geosyncline/craton thickness ratio of about 3.5:1.


Figure 5. Vertical aerial photograph showing homoclinal early Paleozoic sedimentary rocks on south flank of Arbuckle anticline. Late Cambrian-Early Devonian sequence is dominated by carbonate rocks, primarily of Ordovician age, about 11,000 feet thick. In center, U.S. Highway 77 extends in northerly direction for nearly 2 miles.

divisions in the Paleozoic evolution of southern Oklahoma.

The earliest representative is the Late Devonian Woodford Formation. Consisting of bituminous shales and chert, it was deposited upon an unconformable surface of substantial relief and wide extent. Overlying Mississippian strata begin with the Sycamore Formation, composed of silty limestone interbedded with dark shale. It is succeeded upward by the Caney Formation and Springer Group, also consisting mostly of dark shales. Rocks of the Springer Group are characterized, in addition, by abundant thin siderite beds and plates.

This dark-shale sequence is 6,000 feet thick in the Southern Oklahoma geosyncline, of which slightly more than 5,500 feet is Mississippian. The Mississippian shales grade into carbonates well upon the craton, attaining a thickness of 2,500 feet in northern Texas and 500 feet in northern Oklahoma (fig. 3). Great contrasts in thickness are locally apparent within short distances along the craton margin, as for example in the Arbuckle Mountains, where the thickness of the Mississippian shales ranges from 5,500 feet in the geosyncline to only 650 feet upon the craton (fig. 4).

The Woodford Formation is like the Mississippian rocks in that it consists mostly of black shale, but it does not change abruptly in thickness and, except for the loss of chert outside southern Oklahoma, does not show a significant facies change. Its maximum thickness of 350 to 550 feet is attained in southern Oklahoma. From this area it thins gradually to 100 feet or less, persisting as nearly black shale over several hundred thousand square miles of the craton. The Chattanooga Shale of the central United States is equivalent to the Woodford in lithology and age.

*Woodford Formation.*—Over most of its outcrop area in the Arbuckle Mountains, the Woodford Formation is 350 to 400 feet thick and consists of dark, fissile shale, beds of vitreous chert, siliceous shale, and, in its upper part, concretionary nodules and plates of calcium phosphate. The formation covers the craton margin and geosyncline, with little change in thickness, but reaches its maximum thickness of 560 feet at the southeastern exposures of the Arbuckle Mountains, at a point barely 15 miles from the frontal belt of the Ouachita Mountains.

The Woodford dark shales are distinctive in being the oldest beds of southern Oklahoma that contain spores and forest trees, including silicified fragments of *Callixylon* that indicate an original trunk diameter of perhaps 4 feet. The shales also contain specimens of the alga *Tasmanites* that are sufficiently large and numerous to be seen with the naked eye.

In addition to plants, the Woodford contains conodonts, from a study of which it has been concluded by Hass and Huddle (1965) that the formation is mostly of Late Devonian age. Its range is from early Late Devonian (Frasnian) to Early Mississippian (Kinderhookian), all but the upper 1 to 10 feet being Late Devonian.

Stratigraphically and structurally, the Woodford Forma-

Figure 6. Oblique aerial view of Dougherty anticline and Vine's dome, showing broad, light band of Viola Limestone and narrower, but conspicuous, light band of Hunton limestone.
(Photograph copyright F. A. Melton)

tion has great significance for the Arbuckle Mountains and the southern Oklahoma region. The unconformity at its base is of craton-wide extent and is of such magnitude that all Devonian and Silurian strata below it have been removed by erosion over wide areas (fig. 7). This major time of uplift and folding closed the early Paleozoic episode of carbonate sedimentation in the Southern Oklahoma geosyncline and initiated the blanket deposition of dark shales.

*Sycamore Formation.*—Next above the Woodford Formation is a sequence of poorly fossiliferous, fine-grained, silty limestones interbedded with thin layers of dark-gray shale. Called the Sycamore Formation, it occurs only in the southwestern segments of the Arbuckle Mountains and in subsurface parts of the adjoining Southern Oklahoma geosyncline, where it ranges in thickness from 230 to 350 feet. Some of the impure limestone beds are thick and massive, and the formation generally crops out as a conspicuous ridge above the plain of the stratigraphically younger Caney Shale.

The age of the Sycamore has not been clearly established, owing primarily to the lack of distinctive fossils. However, as the lower contact at most localities is gradational with the top beds of the Woodford, the lower part of the Sycamore is undoubtedly of Kinderhookian (Early Mississippian) age. Similarly, the upper Sycamore grades into Caney Shale, the lower part of which is of Meramecian (Medial Mississippian) age (Elias, 1956, p. 70). Thus, by inference, the stratigraphic span of the Sycamore is principally Kinderhookian and Osagian and possibly earliest Meramecian.

From the central part of the Arbuckle Mountains (Mill Creek syncline) and northward upon the craton, the Sycamore Formation is not recognized. Its absence in the northern part of the Arbuckle Mountains is due to an unconformity at the base of the Caney, which rests upon the 5-foot Welden Limestone of Kinderhookian age. Rocks of Osagian age are absent, explaining in small part the extreme thinness of Mississippian rocks in this area.

*Caney Shale and Springer Formation.*—Dark-gray, fissile shales characterize the Caney Formation. Small phosphatic nodules and large calcareous septarian concretions are locally abundant, but limestone and sandstone are absent. Along the south flank of the Arbuckle anticline the shales are somewhat siliceous and weather to a much lighter color than is normal for the formation in all other parts of southern Oklahoma. The formation covers much of southern Oklahoma and ranges in thickness from 250 to 650 feet.

In appearance, the Caney Shale is much like the overlying Springer Formation (or Group). The boundary is drawn at the earliest appearance of siderite or clay-ironstone beds, which occur abundantly in and characterize the Springer sequence, even though the stratigraphic continuity of the boundary cannot be established. In the upper part of the Springer Shale in the Ardmore basin are prominent sandstones (fig. 4), locally of great economic importance as petroleum reservoir beds.

The Caney Formation of the Arbuckle Mountains is judged from its cephalopod fauna to be of Meramecian and Chesterian age (Elias, 1956, p. 56-71). The Springer Shale contains a greatly reduced cephalopod fauna and few additional marine invertebrates. It does contain, however, a great abundance of spores and pollen that have been investigated by Wilson (1966), who recognized some 200

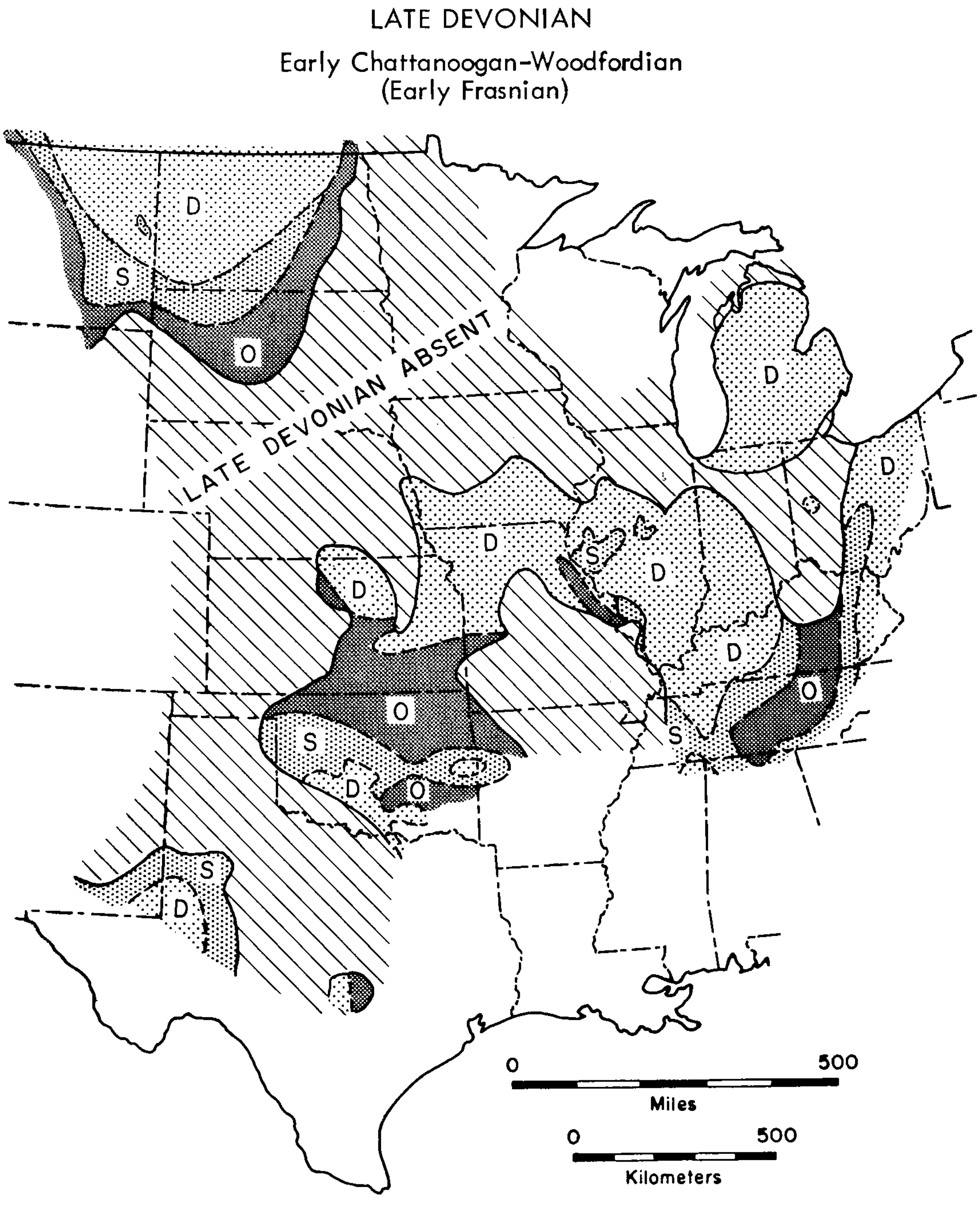



Figure 7. Pre-Late Devonian paleogeologic map of central United States (Ham and Wilson, 1967, p. 363). Subcrop beneath Woodford-Chattanooga and equivalents are Devonian (D), Silurian (S), and Ordovician (O) strata, showing influence and widespread extent of Late Devonian unconformity. Uplift and erosion were most pronounced in east (Nashville dome), north (margin of Williston basin), central (margins of Ozark dome), and southwest (Tobosa basin). Arbuckle Mountains and other parts of southern Oklahoma also were involved in pre-Late Devonian epeirogeny, with the result that Woodford shales locally rest upon Silurian and Ordovician beds over much more area than can be shown on this map. This regional folding and tectonic consolidation temporarily masked Southern Oklahoma geosyncline, closed its early stage of carbonate sedimentation, and began, with deposition of Woodford Formation, a new stratigraphic regime of dark shales.

species and concluded that the assemblage is of Late Mississippian (Chesterian) age.

The Springer Shale shows a marked increase in thickness from 350 feet in the Hunton anticline to 4,500 feet in the Ardmore basin, clearly reestablishing the Southern Oklahoma geosyncline as a major subsiding trough (fig. 4).

### Pennsylvanian Sediments and Regional Geology

Southern Oklahoma was again the site of abnormally thick sedimentation during the Pennsylvanian, the Southern Oklahoma geosyncline receiving locally as much as 15,000 to 17,000 feet of shales, sandstones, and generally thin limestones (fig. 3). Equivalent beds upon the craton are

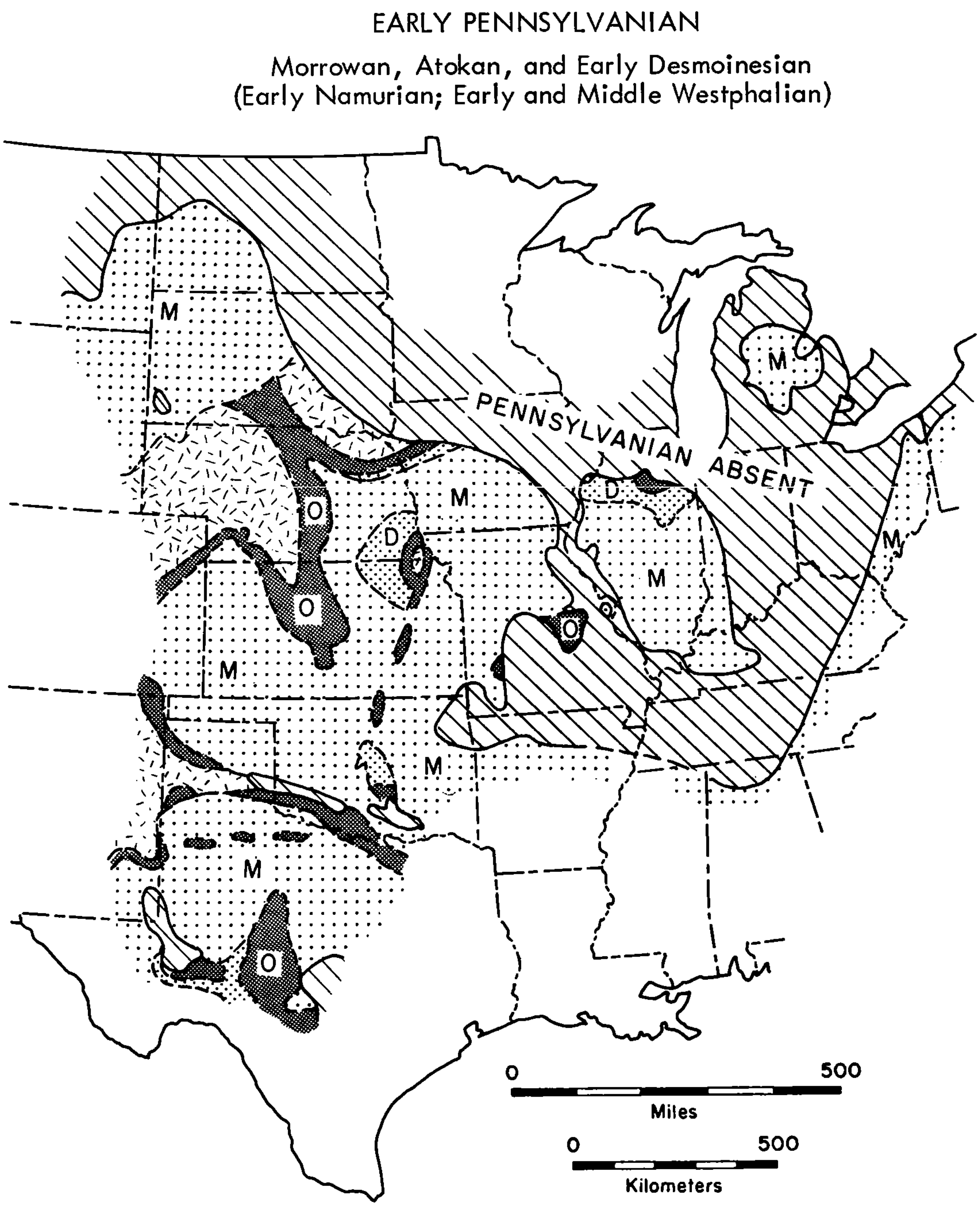



Figure 8. Pre-Pennsylvanian paleogeologic map of central United States (Ham and Wilson, 1967, p. 373). Subcropping rocks beneath Pennsylvanian strata are Precambrian (hachured), Late Cambrian through Ordovician (O), Silurian and Devonian (D), and Mississippian (M). Early Pennsylvanian episodes of folding, uplift, and erosion were greatest of Paleozoic time, affecting all parts of interior United States and uncovering, for first time, extensive areas of Precambrian granites.

about 3,000 feet thick and consist of shales and sandstones, with a much greater relative thickness of limestones.

The stratigraphic succession of Pennsylvanian beds in the Ardmore basin adjoining the Arbuckle anticline is 13,000 feet thick. In ascending order it comprises the Dornick Hills Group (3,000 feet: Morrowan and Atokan), Deese Group (6,000 feet: Desmoinesian), and Hoxbar Group (4,000 feet: Missourian). Early Virgilian beds presumably were deposited but have been eroded and are preserved nowhere in the Ardmore basin. The strata are mostly gray shales and sandstones interspersed with thin beds of limestone, many of which contain marine invertebrates, including fusulines. The fusulines have been described by Waddell (1966) and are of great value in establishing stratigraphic ages. In the upper part of the sequence, within the Hoxbar Group, are thin coal beds.

While Pennsylvanian sedimentation continued unabated in the central, rapidly subsiding parts of the Southern Oklahoma geosyncline, epeirogenic uplift was affecting much of the cratonic region of the central United States (fig. 8). Broad areas were uplifted, eroded, and covered unconformably by Early Pennsylvanian rocks at one of the most pronounced discontinuities of all Paleozoic time.

In Oklahoma the results were widespread and locally

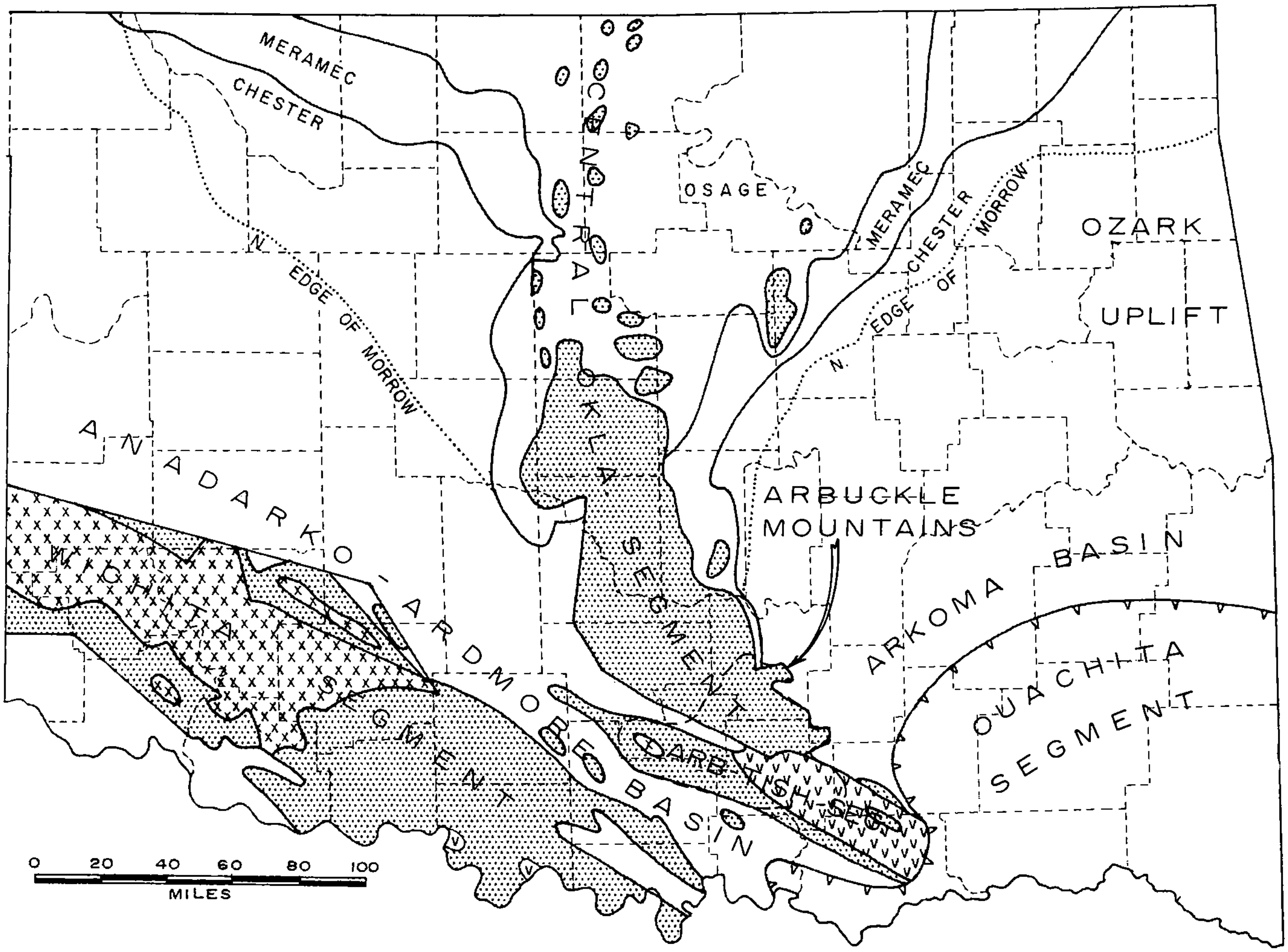



Figure 9. Pre-Pennsylvanian paleogeologic map of Oklahoma (exclusive of Panhandle), showing rocks below Pennsylvanian in subsurface and restored surface at close of Pennsylvanian time in areas where Pennsylvanian has been eroded (modified from Jordan and others, 1962). Stippled areas, Devonian through Late Cambrian (Woodford through Reagan); X pattern, Middle Cambrian intrusives and flows of Wichita province; V pattern, Precambrian granites.

Regions of greatest Pennsylvanian uplift are (1) northwest-trending Wichita segment, (2) *en echelon* Arbuckle-Tishomingo segment, (3) north-trending Central Oklahoma segment, and (4) linear fold-and-thrust belt of Ouachita segment. Interpretations of paleogeology at close of Pennsylvanian time in Ouachita segment are not well known and are not shown on map.

Sites of thick Pennsylvanian sedimentation were Arkoma basin (26,000 feet, Morrowan through early Desmoinesian) and Anadarko-Ardmore basin (15,000 feet, Morrowan through Virgilian). Arkoma basin was a Pennsylvanian foredeep of Ouachita segment in Oklahoma and Arkansas, whereas Pennsylvanian sediments of Anadarko-Ardmore basin were deposited in previously established intracratonic Southern Oklahoma geosyncline.

severe (fig. 9). Early Pennsylvanian (chiefly Atokan) uplift in the Wichita segment of southwestern Oklahoma was at least 15,000 feet, sufficient to denude the basement igneous rocks of the Wichita Mountains, which then contributed arkosic sediments to Desmoinesian beds of the Anadarko basin. Well toward the eastern end of the Wichita segment is the Criner Hills, at the southern margin of the Ardmore basin. It too was strongly elevated at this time, contributing the thick Bostwick conglomerates.

Across the Anadarko-Ardmore basin to the north, in central and northern Oklahoma, the principal Early Pennsylvanian folding resulted in the formation of a broad, north-trending arch, designated as the central Oklahoma segment. This uplift was wholly epeirogenic, although early Desmoinesian strata unconformably cover rocks that locally are as old as Early Ordovician. The southern anchor of the central Oklahoma segment is the Hunton anticline, which constitutes approximately the northern half of the Arbuckle Mountains.

At the time of Early Pennsylvanian folding, the Arbuckle anticline was not yet in existence and the Ardmore basin was still the site of thick sedimentation. These elements became structural fold belts during the Arbuckle orogeny of late Virgilian time.

## PENNSYLVANIAN CONGLOMERATES AND STRUCTURAL HISTORY OF THE ARBUCKLE MOUNTAINS

Rocks of Pennsylvanian age crop out around most of the Arbuckle Mountains and are preserved within them in the Mill Creek syncline, Wapanucka syncline, and Franks graben. Dornick Hills (Wapanucka and Atoka) strata within and adjoining the Arbuckle Mountains generally are non-conglomeratic, but the Desmoinesian and younger Pennsylvanian rocks are conglomerate-bearing and record the beginning and close of mountain-building in the Arbuckle Mountains region.

The four principal conglomerate sequences within and contiguous with the Arbuckle Mountains are "Franks," Deese, Collings Ranch, and Vanoss. All but the Vanoss, the youngest, are preserved in synclinal grabens and are moderately to strongly folded and faulted.

The "Franks" and Deese conglomerates are closely related; both were deposited at about the same time in marine sediments bordering the Hunton anticline, which began to emerge as a broad domal fold in McAlester (early Desmoinesian) time. The Hunton anticline remained emergent until late Virgilian time, when the western margin was covered by conglomerates and shales of the Vanoss Formation. Uplift of the Hunton anticline was accompanied by contribution of coarse clastics to the bordering marine areas of deposition, particularly in the northern area around Ada and in the present sites of the Franks graben and Mill Creek syncline. The conglomerates extended as far southward as the northern edge of the Ardmore basin, where they are present as thin beds in the Deese (Warren Ranch Conglomerate) and Hoxbar Groups.

In the Franks graben was deposited about 1,500 feet of conglomeratic strata, ranging in age from McAlester through Francis, or through much of Desmoinesian and part of Missourian time. These rocks have been called the Franks conglomerate, although the name can be applied only to the conglomeratic marginal facies of mid-Pennsylvanian strata and hence has little stratigraphic connotation.

Outside the Franks graben, younger conglomeratic strata, especially in the Ada Formation of middle Virgilian age, accumulated on the northern margin of the Arbuckle Mountains. The faults bordering the Franks graben and the steep dips within it were produced in post-Francis, pre-Ada time, as the main fault of the graben passes beneath the Ada Formation northwestward, in the north-central part of T. 2 N., R. 5 E. The time of faulting and folding is probably middle Virgilian and is believed to coincide with the beginning of strong folding in the Arbuckle anticline to the southwest. Both the "Franks" and Deese participated in this strong folding, whereas the Collings Ranch and Vanoss were deposited after the folding was accomplished and are in fact the products of that orogeny.

The Deese conglomerates in the Mill Creek syncline are similar in most respects to the "Franks." In the vicinity of Mill Creek, sec. 7, T. 2 S., R. 5 E., the Deese is about 1,950 feet thick (top eroded) and consists of pebble-cobble limestone conglomerates interstratified with red and gray shales and a few thin limestones. The conglomerate sequence rests disconformably upon the Atoka Formation. The oldest conglomerates, at the bottom of which the base of the Deese is placed, are made up largely of Woodford chert, the first resistant formation to be exposed by erosion of the Hunton anticline, whereas the conglomerates higher in the sequence are made up chiefly of Hunton and Viola limestones.

In the Buckhorn area, south of Sulphur, sec. 26, T. 1 S., R. 3 E., the Deese is at least 1,300 feet thick and also consists of conglomerates interbedded with marine shales and limestones. The top is eroded and is covered unconformably by the Vanoss Conglomerate. The youngest conglomerates exposed in the Deese sequence contain limestone pebbles and cobbles from the Oil Creek Formation and from the uppermost part of the Arbuckle Group. Fusulines from the fossiliferous limestones and shales have been identified by Dwight Waddell as of Deese (early Desmoinesian) age. In the Buckhorn area of the Mill Creek syncline, the Deese rests disconformably upon Springer Shale (Chesterian).

Deese rocks in the Mill Creek syncline of the central Arbuckle Mountains generally dip 30° to 70° but are overturned near major faults in the Buckhorn area. About 1 mile east of Mill Creek town, the Wapanucka Limestone is overturned on the north flank of the syncline and presumably the nearby Deese is overturned as well, although Deese outcrops are too poorly exposed for reliable measurement.

The westernmost outcrops assignable to Deese are in the Lake Classen area, secs. 2, 9, 10, T. 1 S., R. 1 E., on the northeast flank of the Arbuckle anticline. In a regional sense these outcrops are also on the south flank of the Mill Creek syncline and thus are related to the Buckhorn and Mill Creek areas. According to Dunham (1955), the sequence consists of shales, conglomerates, fossiliferous limestone, and sandstone totaling about 1,100 feet in thickness, the top being eroded and covered nonconformably by the Vanoss Conglomerate. An age assignment to upper Deese (Wetumka-Wewoka) was made from *Fusulina* contained in fossiliferous limestone 360 feet below the top at one locality, and the possibility was recognized that the beds above the occurrence of *Fusulina* are of early Missourian age. The conglomeratic Deese rocks in the Lake Classen area rest disconformably upon Caney Shale (Mississippian). They are steeply dipping to locally overturned and are structurally conformable with the older folded rocks of the Arbuckle anticline.

Clearly the Deese and "Franks" contain erosional products derived from the first great period of uplift in the Arbuckle Mountains, which began as broad domal folding of the Hunton anticline in early Desmoinesian (early Deese) time. It also is clear that these conglomerates were closely folded, locally overturned, and faulted by later Pennsylvanian orogeny. This later deformation, to which the name Arbuckle orogeny has long been applied, produced the structurally complex Arbuckle anticline and the major folds of the Ardmore basin and was certainly the most intense deformation to affect the Arbuckle Mountains region. The folding can be dated from the evidence seen in the Ardmore basin as post-Hoxbar, from the Mill Creek syncline and Lake Classen area as post-Deese (and possibly post-Hoxbar), and from the Franks graben as post-Francis (middle Missourian). From a comparison with widely distributed marine rocks north of the mountains, the date of the Arbuckle orogeny can be correlated with the unconformity at the base of the Ada Formation, in the middle part of the Virgil Series. Conglomerates of the Ada Formation consist dominantly of limestone pebbles from the Arbuckle Group and have been derived almost exclusively by erosion of the Arbuckle anticline. No other conglomerates of comparable character are known in the region. Moreover, rocks of the Ada conglomerate are exactly like those of the Collings Ranch Conglomerate at its type locality in the Arbuckle Mountains, where it is unconformable upon vertically dipping beds of the Arbuckle anticline. The major conclusions are that the Collings Ranch and Ada conglomerates are equivalents and that the strongest pulse of Arbuckle orogeny was mid-Virgilian.

The Collings Ranch and Vanoss Conglomerates rest with pronounced angular unconformity on older rocks that were steeply folded during culmination of the Arbuckle orogeny. These conglomerates, resulting from this uplift and deposited peripheral to the Arbuckle Mountains, are exposed now only around the Arbuckle anticline and northward into the Sulphur area. Most of these coarse clastic sediments were derived from the Arbuckle and Tishomingo anticlines.

The Collings Ranch was the first, thickest, and coarsest orogenic deposit following this folding. Undoubtedly, it was spread over a wide area in irregular sites of deposition, but the mountain system was still actively rising. Thus, most of the conglomerate was uplifted, eroded, and lost. The only area where the conglomerate has been extensively preserved is in the synclinal graben near Turner Falls on U.S. Highway 77 (fig. 10).

Figure 10. Collings Ranch Conglomerate in roadcut along U.S. Highway 77. It is principally a boulder conglomerate derived from carbonate rocks of Arbuckle Mountains and is principal depositional product of Arbuckle orogeny.

A late phase of Arbuckle orogeny, chiefly faulting and uplift without strong folding, came in the last stage of deposition of the Collings Ranch Conglomerate. At this time the conglomerate was folded and faulted into a graben. Some of the faults bordering the graben extend northwestward to the edge of the mountains, where they pass underneath the Vànoss Conglomerate, thereby showing the Vanoss to be younger than the Collings Ranch.

The Vanoss Formation in the vicinity of the Arbuckle Mountains consists of a lower conglomerate member and an upper shale member. Their combined maximum thickness is about 1,550 feet. The conglomerate member has a maximum thickness of 650 feet and is restricted to the northern edge of the mountains in the area between Sulphur and Hennepin. Northward from Sulphur the conglomerate member disappears by gradation into the shale member, whereas westward and southward around the Arbuckle anticline it is overlapped by the shale member. Both members locally contain abundant feldspar and granite fragments, although lenses and beds of arkose, in particular, characterize the shale member. At most places the rocks have gentle dips and are not faulted, yet in a few areas they dip as much as 40° and are cut by small faults, the displacements of which die out upward in the conglomerate sequence. Such post-Vanoss local deformation was produced by the dying pulse of the Arbuckle orogeny.

In summary (fig. 11), the principal conglomerates in the Arbuckle Mountains region are readily divisible into two general groups, an older, consisting of the "Franks" and Deese, and a younger, consisting of the Collings Ranch and Vanoss. Each group is characterized by specific derivation that in turn is reflected in the composition of pebbles and cobbles in the conglomerates. The "Franks" and Deese contain rocks chiefly from Hunton through uppermost Arbuckle, derived almost exclusively by epeirogenic uplift of the Hunton anticline. The Collings Ranch and Vanoss Conglomerates are orogenic products of middle and late

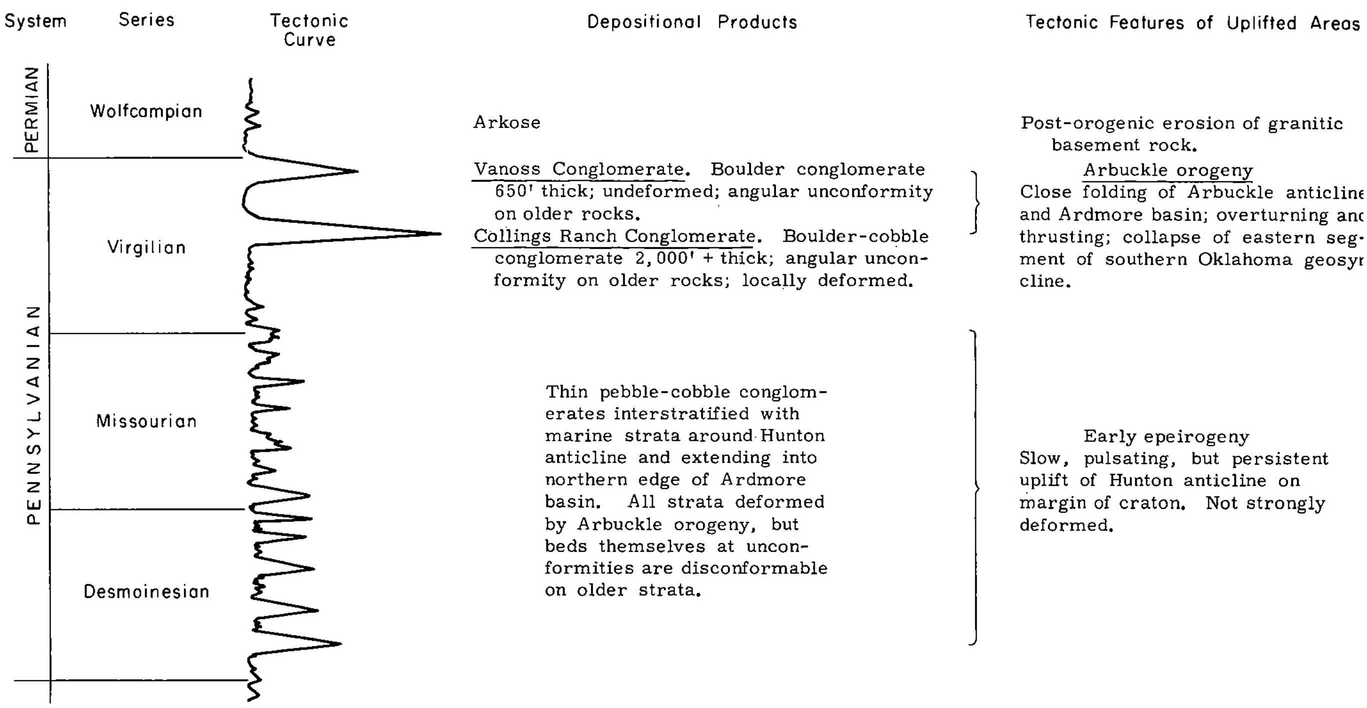



Figure 11. Summary of Pennsylvanian tectonism in Arbuckle Mountains.

Virgilian uplifts, respectively, which together constitute the Arbuckle orogeny. The Collings Ranch, being younger, contains mostly upper and middle Arbuckle rocks; and the Vanoss, being youngest, contains granite, feldspar, and vein quartz from Precambrian granites that were exposed only after the highest uplift and deepest erosion of the Arbuckle Mountains.

### Summary of Depositional and Structural Evolution of the Arbuckle Mountains

With the close of the Arbuckle orogeny, the building of the Arbuckle Mountains was at an end. A geosynclinal margin had been welded to the margin of the craton, and a total structural relief of about 7 miles had been achieved. The long-continued evolutionary series began with Cambrian volcanics, continued with sedimentation throughout most of Paleozoic time, and culminated in a Late Pennsylvanian orogeny. Major steps in the evolution are illustrated in figure 12 and are summarized as follows.

A. Pre-Pennsylvanian stage of sedimentation, yielding 17,000 feet of Late Cambrian through Mississippian strata in the geosynclinal segment, compared with 6,500 feet on the adjoining craton. Beneath geosynclinal sediments are Middle Cambrian flows and tuffs probably at least 7,500 feet thick, representing an earlier phase of geosynclinal filling. Sediments of the craton are underlain by massive Precambrian granites dated at 1,350 m.y. and slightly downflexed at craton margin. Exposed at present in the Arbuckle Mountains are elements of both geosyncline and craton, each with contrasting stratigraphic and structural features genetically related to its depositional province.

B. Early Pennsylvanian stage of continued thick sedimentation in geosyncline and thinner sedimentation on craton, with first emergence of Hunton anticline in early Desmoinesian time. Resulting conglomerates are preserved in bordering Desmoinesian strata but did not extend into present site of Ardmore basin, with exception of Warren Ranch Conglomerate in Deese Group. Epeirogenic rise of Hunton anticline is localized near border of craton.

C. Missourian through mid-Virgilian sedimentation, with development of thin conglomerates marginal to the continually rising Hunton anticline. Virgilian sediments are eroded from the Ardmore basin but are preserved on the central Oklahoma shelf. The distinction between geosyncline and craton has persisted to this closing stage of sedimentation. Accumulated in the geosyncline was approximately 30,000 feet of Late Cambrian through Pennsylvanian sediments, deposited principally as carbonates during the Ordovician (8,800 feet) and as clastics during the Mississippian (5,500 feet) and Pennsylvanian (13,000 feet). The thin pre-Pennsylvanian sediments of the craton margin were further reduced in thickness by erosion accompanying Pennsylvanian epeirogenic uplift of the Hunton anticline. The basement-granite surface of the craton was now standing at least 6 miles above the floor of the geosyncline.

D. Same as C, simplified and without vertical exaggeration, showing the Arbuckle Mountains region immediately preceding the late Virgilian Arbuckle orogeny. All uplift in the Arbuckle Mountains until this time was epeirogenic, and structural discordance, even at the early Desmoinesian unconformity, was slight.

E. Late Virgilian Arbuckle orogeny, resulting in close folding and high-angle thrust faulting of thick geosynclinal sediments. The Arbuckle anticline and Ardmore basin were folded at this time by compression of the thick prism of sediments against the cratonic buttress. The strongly folded Mill Creek synclinal graben was formed along the previously downflexed craton margin, but the Hunton anticline and other elements of the craton were only slightly affected. Two orogenic pulses yielded two orogenic conglomerates, derived chiefly from pre-Pennsylvanian limestones of the Arbuckle anticline; the older is the mid-Virgilian Collings Ranch Conglomerate and the younger is the late Virgilian Vanoss Conglomerate. Slight additional folding persisted into Early Permian time.

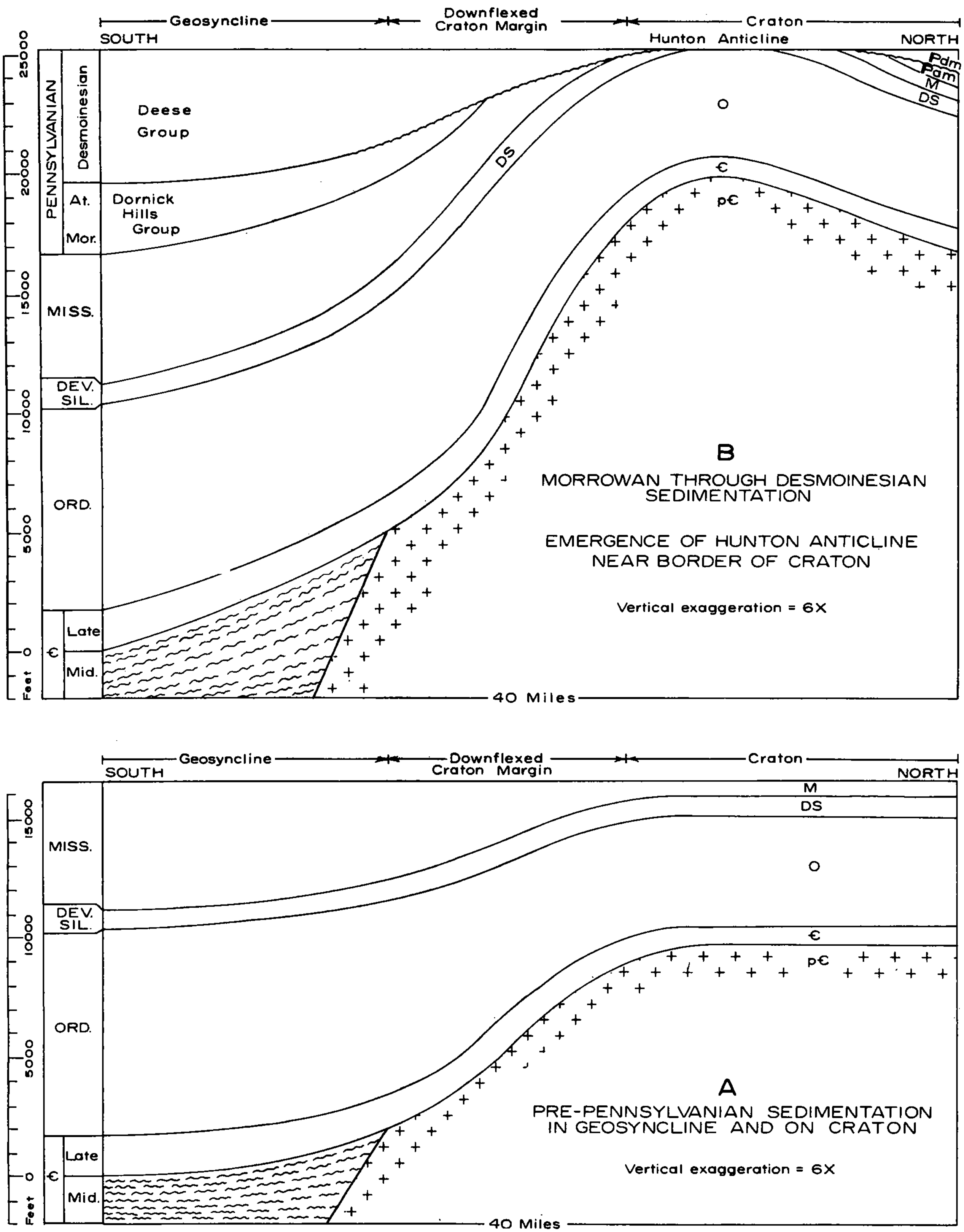
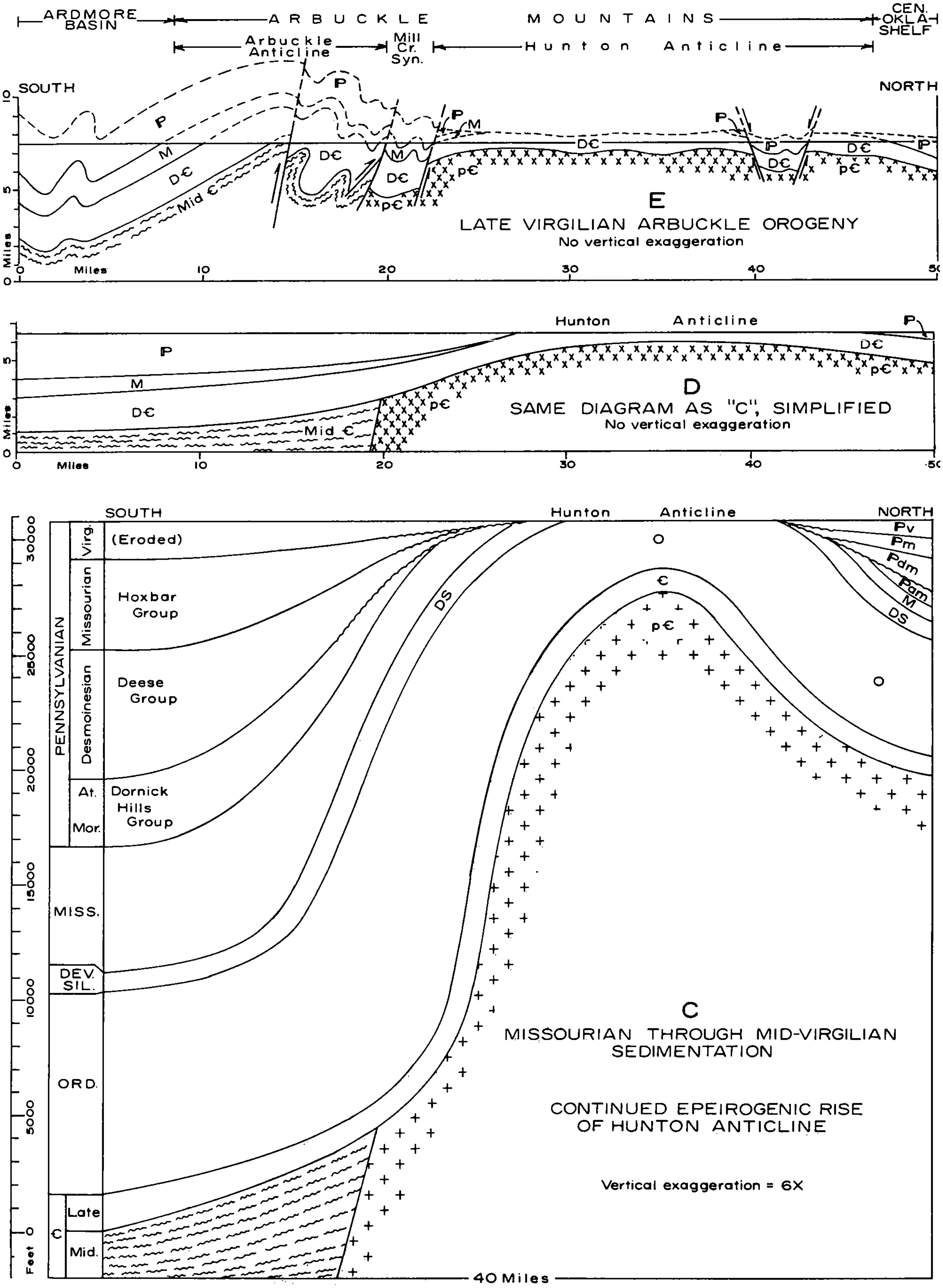



Figure 12. Major elements in depositional and structural evolution of Arbuckle Mountains. For explanation, see text.


ARDMORE BASIN
ARBUCKLE MOUNTAINS
CEN. OKLA. SHELF
Arbuckle Anticline
Mill Cr. Syn.
Hunton Anticline
SOUTH
NORTH
P
M
DЄ
Mid Є
pЄ
E
LATE VIRGILIAN ARBUCKLE OROGENY
No vertical exaggeration
Miles
0 10 20 30 40 50
Hunton Anticline
D
SAME DIAGRAM AS "C", SIMPLIFIED
No vertical exaggeration
SOUTH
Hunton Anticline
NORTH
(Eroded)
Hoxbar Group
Deese Group
Dornick Hills Group
PENNSYLVANIAN
Virg.
Missourian
Desmoinesian
At.
Mor.
MISS.
DEV. SIL.
ORD.
Late
Mid.
Є
O
DS
pЄ
Pv
Pm
Pdm
Pam
M
Feet
0 5000 10000 15000 20000 25000 30000
C
MISSOURIAN THROUGH MID-VIRGILIAN SEDIMENTATION
CONTINUED EPEIROGENIC RISE OF HUNTON ANTICLINE
Vertical exaggeration = 6X
40 Miles

# PART II. DESCRIPTIONS OF LOCAL GEOLOGY

## BIOSTRATIGRAPHY AND DEPOSITIONAL HISTORY OF THE TIMBERED HILLS AND LOWER ARBUCKLE GROUPS, WESTERN ARBUCKLE MOUNTAINS, OKLAHOMA

James H. Stitt

### Introduction

Ham (1955; also fig. 13) clearly delineated the complex limestone-dolomite facies relationships that exist in the Late Cambrian and Early Ordovician rocks in the Arbuckle Mountains. The moderately fossiliferous limestones in the western end of the Arbuckle Mountains were subsequently re-collected in detail, and the trilobites from these collections have been described (Stitt, 1971). This present summary has been abstracted from these two sources and includes some additional unpublished data of mine.

The stratigraphic ranges for the common trilobite taxa are given in figure 14. Most of this information was obtained from collections from the Joins Ranch section at the westernmost end of the Arbuckle Mountains. In that section the Fort Sill and Signal Mountain Limestones are thickest, the unfossiliferous Royer Dolomite is not present, and the unfossiliferous Butterly Dolomite is thinnest (see fig. 13). The U.S. Highway 77 section (see fig. 13) was also collected from and faunal information from that section added to make the combined range chart (fig. 14). The latter section is located a few hundred yards west of Interstate Highway 35, just south of Turner Falls.

The thickness measurements for formations and trilobite zones given at the bottom of figure 14 are cumulative thicknesses above the base of the Honey Creek Limestone. They have been drawn to scale for the Joins Ranch section only. Thickness data given for the U.S. Highway 77 section show the positions of the trilobite zones within the formations and also the eastward thickening of the Royer and Butterly Dolomites, but these thicknesses are not drawn to scale.

### Cambrian and Ordovician Nomenclature

The Croixan Series of Late Cambrian age consists of the Dresbachian, Franconian, and Trempealeauan Stages. Trilobites of the *Elvinia, Taenicephalus,* and *Saratogia* Zones of the Franconian Stage occur in the Timbered Hills and lower Arbuckle Groups as well as trilobites of the *Saukia* Zone (with four subzones) of the Trempealeauan Stage (fig. 14). No Dresbachian fossils have been found.

No stage nomenclature is presently in use for the Canadian Series of Early Ordovician age. Trilobites of the basal Ordovician *Missisquoia* and *Symphysurina* Zones occur in the upper part of the Signal Mountain Limestone and at the base of the McKenzie Hill Limestone (fig. 14).

### Timbered Hills Group

The Timbered Hills Group consists of the basal Reagan Sandstone and the overlying Honey Creek Limestone. The Reagan is mostly a medium- to fine-grained, reddish-brown to white, glauconitic arkose. Fragments of the unconformably underlying rhyolites and granites occur at the base of the Reagan. No identifiable fossils have been recovered from the base of the Reagan, but trilobites of the *Elvinia* Zone occur in the upper part of the Reagan in the Joins Ranch section and in the middle and upper parts of the Reagan in the Wichita Mountains. This suggests that the Reagan was deposited as a basal sandstone during the transgression of the Franconian seas, and that the Oklahoma area was probably an emergent land mass during the preceding Dresbachian inundation of the Midcontinent.

The Honey Creek Limestone is typically a medium-gray, glauconitic biosparite or biomicrite with abundant trilobites, brachiopods, and pelmatozoan fragments; it is easily the most fossiliferous Cambrian formation. Trilobites of the *Elvinia, Taenicephalus,* and lowermost *Saratogia* Zones succeed each other in ascending order within the Honey Creek (fig. 14). The faunal change at the top of the *Elvinia* Zone is particularly sharp, and only one species (an agnostid trilobite) survived into the overlying *Taenicephalus* Zone, which is populated by trilobites unrelated at the family level to those of the underlying *Elvinia* Zone. A similar sharp faunal change occurs at this zonal boundary throughout the North American craton. There is, however, no lithologic change within the Honey Creek at this horizon.

Palmer (1969) and Lochman-Balk (1971) have documented the presence of a concentric lithofacies pattern that existed during the Late Cambrian in North America. The interior landmass was surrounded by an inner detrital belt of sandstones and siltstones that graded seaward into a broader belt of limestones and dolomites. Seaward of this broad carbonate shelf, and probably accumulating in deeper water, was an outer detrital belt of dark, thin-bedded siltstones and fine-grained limestones. During the Franconian transgression, the Reagan Sandstone was deposited as part of the inner detrital belt. As the transgression proceeded northwestward, carbonate deposition began with the Honey Creek and continued uninterrupted until just after the start of the Middle Ordovician.

The rocks of both the inner detrital belt and the carbonate belt accumulated predominantly in shallow-water environments, as suggested by the common occurrence of crossbedding and generally good sorting in the sandstones and siltstones and by the presence of oolites, sparry-cemented calcarenites, sporadic oncolites and stromatolites, and a moderately abundant and diverse invertebrate fauna (trilobites, brachiopods, gastropods, sponges, conodonts) in the carbonate belt. As might be expected over this broad area of generally similar depositional conditions, contemporaneous trilobite faunas show a great deal of similarity. Thus for the *Elvinia, Taenicephalus,* and *Saratogia* Zones, similar trilobites at both the generic and specific level have

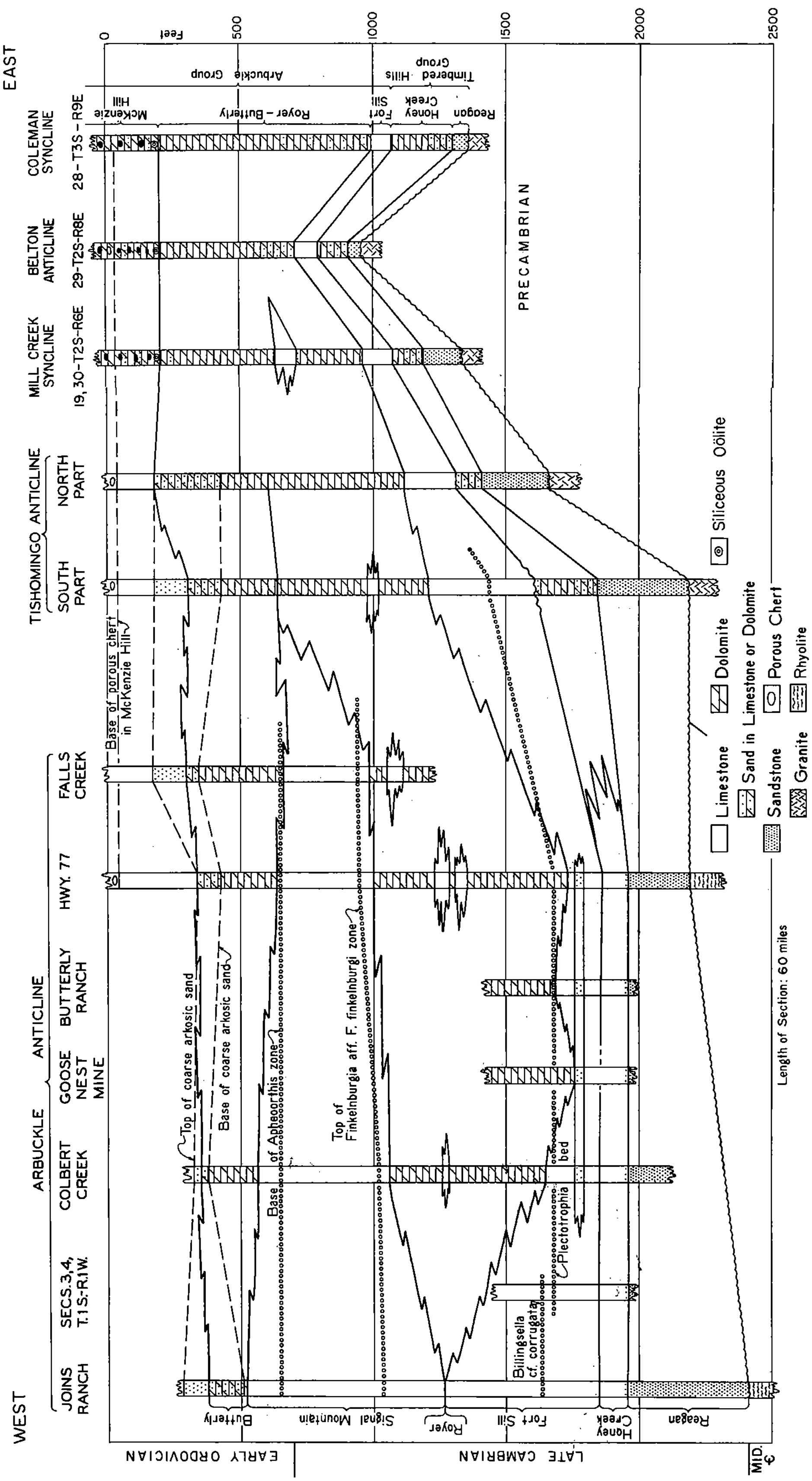



Figure 13. Regional stratigraphic section of Timbered Hills Group and lower part of Arbuckle Group (modified from Ham, 1955).

been reported from the central Appalachians, the type Croixan of the Upper Mississippi Valley, southeastern Missouri, central Texas, the Great Basin, Wyoming, Montana, and parts of the Canadian Rocky Mountains (Stitt, 1971). The minor differences between the faunas in these areas probably reflect local depositional or environmental conditions that favored the genera and species best adapted for those particular conditions. For example, the most striking difference between contemporaneous trilobite faunas of the type Croixan area and the Arbuckle Mountains is the abundance of the Franconian genera *Conaspis, Ptychaspis,* and *Prosaukia* in the inner detrital belt of sandstone exposed in Minnesota and Wisconsin and their relative scarcity in the contemporaneous carbonate rocks in the Arbuckle Mountains.

## Arbuckle Group

The Fort Sill Limestone, Royer Dolomite (unfossiliferous), Signal Mountain Limestone, Butterly Dolomite (unfossiliferous), and basal McKenzie Hill Limestone have been sampled in detail thus far.

The Fort Sill is usually a light-gray, very sparsely fossiliferous biomicrite that grades laterally into the Royer Dolomite from west to east in the Arbuckle Mountains (fig. 13). The upper 50-100 feet of this thick formation is characterized by well-developed stromatolitic algal heads that occur abundantly throughout this interval. Fossils are scarce in the Fort Sill, but enough trilobites have been recovered to allow recognition of several subzones in the latest Franconian *Saratogia* Zone and in the Trempealeauan *Saukia* Zone (fig. 14). Several silicified brachiopod zones were traced through the Arbuckle mountains during field mapping by Ham (fig. 13), and they helped to document the interfingering of the Fort Sill and Royer.

The Royer Dolomite is predominantly brownish, medium- to very coarsely crystalline dolomite. No fossils were recovered from the Royer. Comparison of trilobite zonal boundaries that occur immediately below and above the Royer suggests that the upper 36 feet of the Fort Sill and 752 feet of the Royer accumulated in the vicinity of Interstate Highway 35, whereas only 544 feet of the Fort Sill and Signal Mountain accumulated in the Joins Ranch section just 9 miles west.

The Signal Mountain Limestone is composed of a variety of types of limestone, with trilobite biomicrite and intrasparite being most common. The Signal Mountain is more fossiliferous than the Fort Sill, and the upper three subzones of the Trempealeauan *Saukia* Zone occur in the lower two-thirds of the formation (fig. 14).

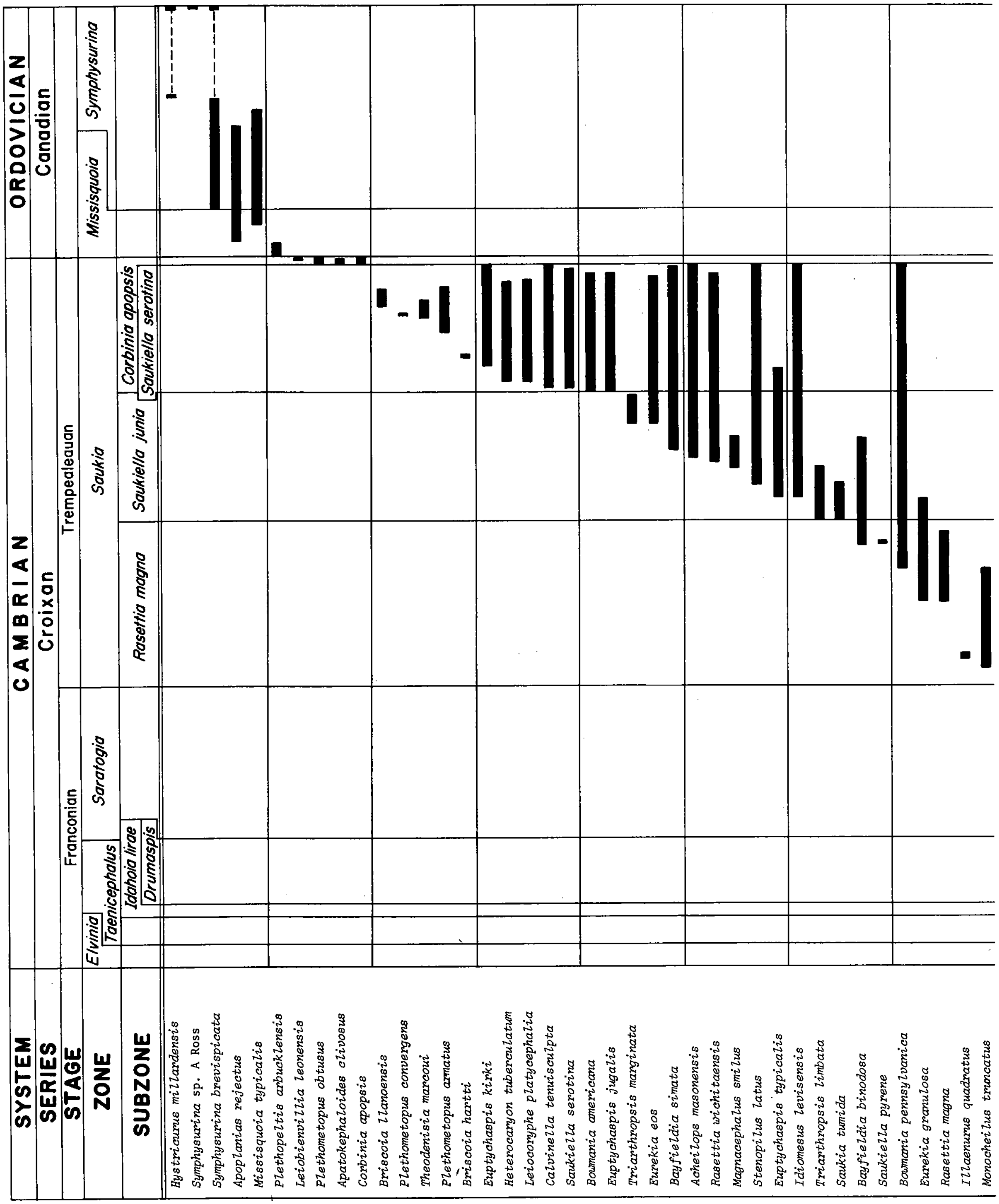
With no accompanying lithologic change, the Cambrian trilobites abruptly become extinct within the upper part of the Signal Mountain and are replaced by an unrelated group of Ordovician trilobites assigned to the *Missisquoia* Zone (fig. 14). Derby and others (1972) and Taylor (1973) documented the widespread nature of this abrupt faunal change from the Alberta Rocky Mountains to the Great Basin to central Texas to eastern New York. In all these areas on the craton, the change from the Cambrian to the Ordovician was apparently a non-event sedimentologically and a rough jolt "trilobitologically"!

The lowest occurrence of the familiar Ordovician genus *Symphysurina* serves to define the base of the *Symphysurina* Zone, which overlies the *Missisquoia* Zone in the uppermost part of the Signal Mountain. Although no fossils have been recovered from the brown, sandy, finely to coarsely crystalline Butterly Dolomite, species of *Symphysurina* and *Hystricurus* occur near the base of the overlying McKenzie Hill (fig. 14), indicating that the top of the *Symphysurina* Zone lies higher in the section, probably in the McKenzie Hill.

Trilobites of the Trempealeauan Stage and the Canadian Series found thus far in the Arbuckle Group are similar to contemporaneous trilobite faunas reported from the carbonate belt in the southwestern and western United States and Canada. Most of this interval is dolomitized along the eastern part of North America, and is thus only sparingly fossiliferous. In the type Croixan area in the inner detrital belt, genera such as *Osceolia, Dikelocephalus, Saukia*, and *Saukiella* are abundant, but these genera are scarce in the Arbuckle Mountains, thus creating some problems in correlation from the carbonate belt to the inner detrital belt.

## Ptychaspid Biomere

The biostratigraphic interval of the *Taenicephalus, Saratogia*, and *Saukia* Zones, bounded below and above by nonevolutionary changes in the trilobites, forms an evolutionary package called the Ptychaspid Biomere (Longacre, 1970). Within this interval most of the abundant trilobites are members of two families (the Ptychaspididae and the Parabolinoididae), species of which appeared at the base of the biomere (just after the abrupt extinction of the *Elvinia* Zone fauna) and evolved and diversified rapidly upsection. These families and others that later moved into the area during the *Saukia* Zone appear to have been thriving and well adapted when they were abruptly extinguished at the close of the Cambrian. The cause of these abrupt extinctions is unknown at present but may be related to a rapid climatic change that cooled the cratonic sea water enough to kill the North American Cambrian cratonic trilobites used to warm, tropical or subtropical temperatures and that simultaneously triggered a replacement migration by unrelated open-ocean trilobites used to cooler polar water.


SYSTEM
SERIES
STAGE
ZONE
SUBZONE
ORDOVICIAN
CAMBRIAN
Canadian
Croixan
Trempealeauan
Franconian
Symphysurina
Missisquoia
Saukia
Saratogia
Taenicephalus
Elvinia
Corbinia apopsis
Saukiella serotina
Saukiella junia
Rasettia magna
Idahoia lirae
Drumaspis
Hystricurus millardensis
Symphysurina sp. A Ross
Symphysurina brevispicata
Apoplanias rejectus
Missisquoia typicalis
Plethopeltis arbucklensis
Leiobienvillia leonensis
Plethometopus obtusus
Apatokephaloides clivosus
Corbinia apopsis
Briscoia llanoensis
Plethometopus convergens
Theodenisia marcoui
Plethometopus armatus
Briscoia hartti
Euptychaspis kirki
Heterocaryon tuberculatum
Leiocoryphe platycephalia
Calvinella tenuisculpta
Saukiella serotina
Bowmania americana
Euptychaspis jugalis
Triarthropsis marginata
Eurekia eos
Bayfieldia simata
Acheilops masonensis
Rasettia wichitaensis
Magnacephalus smilus
Stenopilus latus
Euptychaspis typicalis
Idiomesus levisensis
Triarthropsis limbata
Saukia tumida
Bayfieldia binodosa
Saukiella pyrene
Bowmania pennsylvanica
Eurekia granulosa
Rasettia magna
Illaenurus quadratus
Monocheilus truncatus

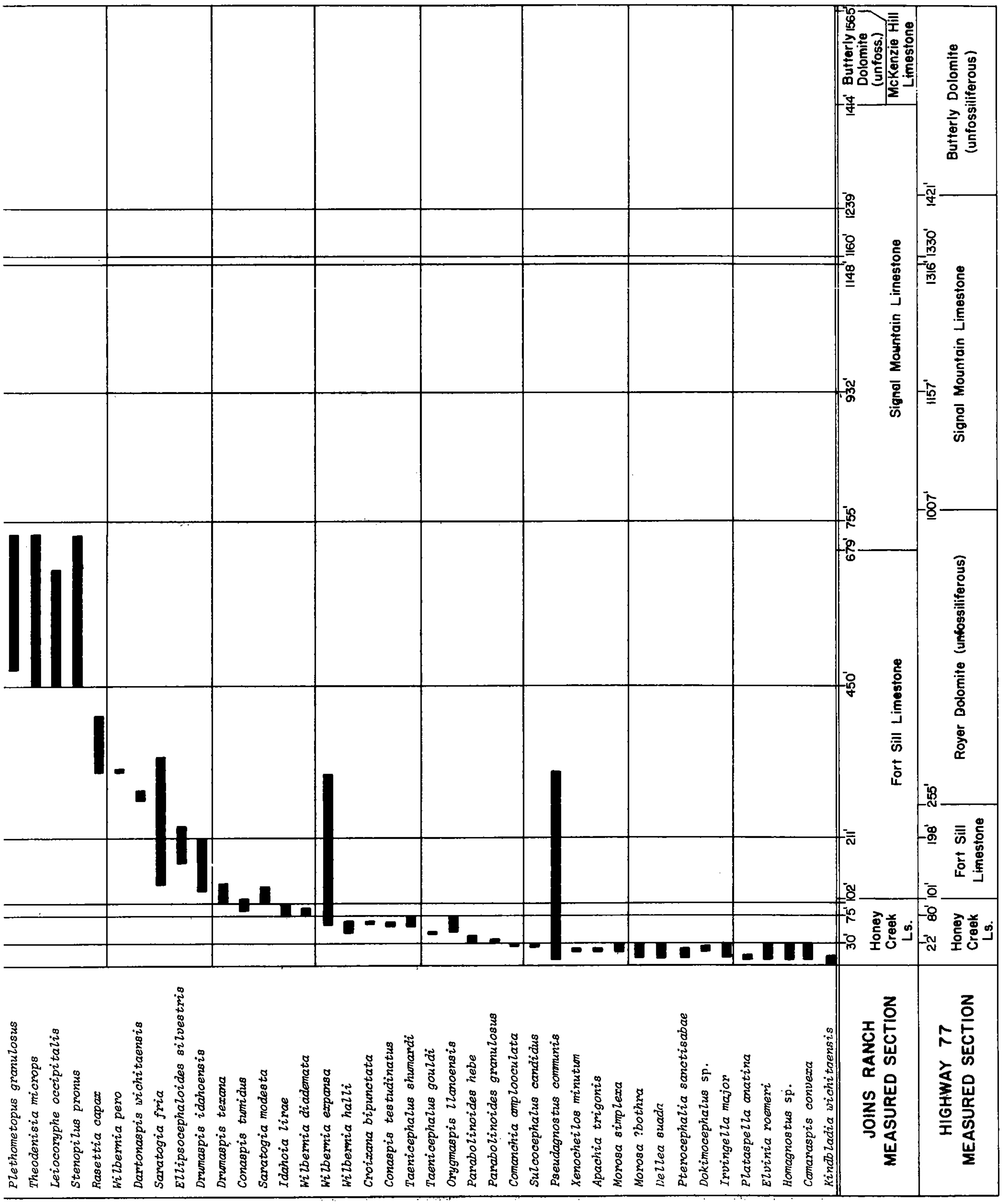



Figure 14. Ranges of trilobite species in Honey Creek Limestone and lower part of Arbuckle Group in Arbuckle anticline.

# LOWER ORDOVICIAN-MIDDLE ORDOVICIAN BOUNDARY IN WESTERN ARBUCKLE MOUNTAINS, OKLAHOMA

**James R. Derby**

## Introduction

In 1969 I published (Derby, 1969) a short note revising the position of the Middle Ordovician-Lower Ordovician time-stratigraphic boundary in the western Arbuckle Mountains. The essential conclusion of that paper remains unmodified, i.e., that the time-stratigraphic boundary between the Lower and Middle Ordovician Series falls *within* the West Spring Creek Formation of the Arbuckle Group, in the interval 90 to 100 feet below the top of the Arbuckle rather than at the Arbuckle-Simpson lithologic contact. New information from other areas permits more precise correlations and suggests that a disconformity may be present within the West Spring Creek Formation at the series boundary.

The initial study of the Arbuckle-Simpson faunas was conducted with the able assistance of my former colleagues at Pan American Petroleum Corporation (now Amoco), W. B. Creath[1] and Gilbert Klapper,[2] who studied the ostracode and conodont faunas, respectively. Subsequent studies have been greatly aided by discussions and exchange of information with F. C. Shaw, Herbert H. Lehman College, Bronx, New York; R. L. Ethington, University of Missouri, Columbia; and R. J. Ross, Jr., U.S. Geological Survey, Denver.

## Previous Work

Earlier workers believed that the contact between the West Spring Creek Formation (Arbuckle Group) and the Joins Formation (Simpson Group) coincided with the Lower Ordovician-Middle Ordovician series boundary. This was a reasonable assumption insofar as the faunas were known. The West Spring Creek Formation was known to contain a brachiopod-gastropod-graptolite fauna that all workers agree is Early Ordovician (Ulrich and Cooper, 1938; Decker, 1939, 1941; Cooper, 1952; Yochelson and Bridge, 1957). Similarly the Joins Formation was known to contain a brachiopod-ostracode-graptolite fauna of Middle Ordovician age, earlier assigned to the Chazyan (e.g., Decker and Merritt, 1931; Harris, 1957; Schramm, 1965) but now assigned to the basal Middle Ordovician Whiterockian Stage (Cooper, 1956; Berry, 1960).

## Early Ordovician Fauna

Detailed collecting throughout the West Spring Creek Formation at the well-known U.S. Highway 77 section and on the west branch of West Spring Creek (westernmost Arbuckle Mountains) revealed that the Lower Ordovician fauna occurs no higher than 100 feet below the top of the Arbuckle Group (100 feet at West Spring Creek, 155 feet at Highway 77). Although my study of the entire fauna remains incomplete, the West Spring Creek fauna of Early Ordovician age can be subdivided into at least two faunal units. The lower part of the West Spring Creek contains a fauna characterized by *Ceratopea ankylosa* (replaced by *C. buttsi* in the middle of the formation), *Goniotelina subrectus* (Bradley, 1925), *Isoteloides flexus* Hintze, 1951, undetermined (possibly new) species of *Bolbocephalus* and *Diparelasma*, and a species of *Ischyrotoma* [=*Dimeropygiella*] close to *I. ovata* (Hintze, 1951). This fauna suggests a correlation with Zone H or I of the Ross-Hintze trilobite zones in Utah and Nevada (fig. 15).

The upper half of the West Spring Creek Formation, below 100 feet below the top, contains the following fauna:

| | |
|---|---|
| Brachiopods: | *Syntrophopsis magna* Ulrich and Cooper, 1936 |
| | *Diparelasma typicum* Ulrich and Cooper, 1936 |
| | *Diparelasma rowelli* Ross, 1968 |
| | *Pomatotrema oklahomense* Ulrich and Cooper, 1936 |
| | *Tritoechia planodorsata* Ulrich and Cooper, 1938 |
| | *Polytoechia subrotunda* Ulrich and Cooper, 1938 |
| Gastropod: | *Ceratopea unguis* Yochelson and Bridge, 1957 |
| Trilobites: | *Aponileus latus* Hu, 1963 |
| | *Goniotelina* aff. *G. brevus* (Hintze, 1951) |
| | *Isoteloides* aff. *I. polaris* Poulsen, 1927 |
| | *Kawina* aff. *K. arnoldi* Whittington, 1963 |
| Graptolite: | *Didymograptus protobifidus* Elles, 1933 |
| Ostracodes: | Ostracodes described in unpublished work, Creath, pers. comm., 1968: |
| | *Isochilina* n. sp. A (large lateral processes) |
| | *Isochilina* n. sp. B |
| | *Ceratoleperditia* n. sp. |
| | *Leperditella* (3 species) |
| Conodonts: | Lower Ordovician fauna (see note by Klapper in section, Conodont Evidence) |
| Echinoderms: | Camerate crinoid plates |

This fauna represents the youngest Early Ordovician fauna in North America. On the basis of both brachiopods and trilobites, it would appear to correlate with Zones J and K in the Great Basin (fig. 15). The absence of *Hesperonomia* and *Hesperonomiella* may indicate that this unit is older than Zone K. However, the correlative Smithville and Black Rock Formations in Arkansas contain *Hesperonomia* and *Hesperonomiella* in association with an otherwise identical fauna (Derby, 1973). Their absence here is probably due to ecologic conditions. Similar faunas have been reported from the top of the Lower Ordovician of Maryland (Sando, 1957, 1958) and Utah and Nevada (Ross, 1951, 1968; Hintze, 1952; Jensen, 1967). The critical elements in this fauna are the brachiopod, trilobite, and gastropod species. Most of these species (and six of the genera) occur only in upper Lower Ordovician strata. A single, atypical, species of *Syntrophopsis* ranges into the Middle Ordovician (Ross, 1968, fig. 2), but species of the *S. magna* type are known to occur only with Lower Ordovician taxa.

Recently Ross (1968, p. H4; 1970, p. 52-53) has argued that the earliest Middle Ordovician *Orthidiella* zone is time equivalent to the latest Early Ordovician. This argument stems largely from the suggestion by Sando (1957, 1958) that the *Syntrophopsis-Clelandoceras* fauna in the Beekmantown of Maryland may be equivalent to Middle Ordovician (Whiterockian) faunas, a suggestion that is not accepted here. Sando combined two distinctly different

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[1]Environmental Sciences Corporation, Tulsa, Oklahoma.

[2]The University of Iowa, Iowa City, Iowa.

faunas into one "zone." The lower fauna consists of *Syntrophopsis minor* and *Ceratopea unguis* (Sando, 1957, pl. 4; Yochelson and Bridge, 1957, fig. 103), which are equivalent in age to the fauna 100 feet to about 300 feet below the top of the West Spring Creek Formation and to the fauna of the Smithville-Black Rock. The higher fauna in the "*Syntrophopsis-Clelandoceras* fauna" contains *Clelandoceras* and the brachiopod *Anomalorthis*? *vermontensis*, which Ross (1968, p. H4) suggested may indicate equivalence to Zone L (*Orthidiella* Zone), and *Notorthis pennsylvanica*, which would suggest correlation with Zone K. However, Ross (1968, p. H4) suggested that Zone K "may not warrant designation as a separate zone," except as modified by Hintze (1952, p. 19) to indicate a monospecific coquina of *Hesperonomiella minor*.

The youngest Early Ordovician faunas appear to be characterized by the following genera and species:

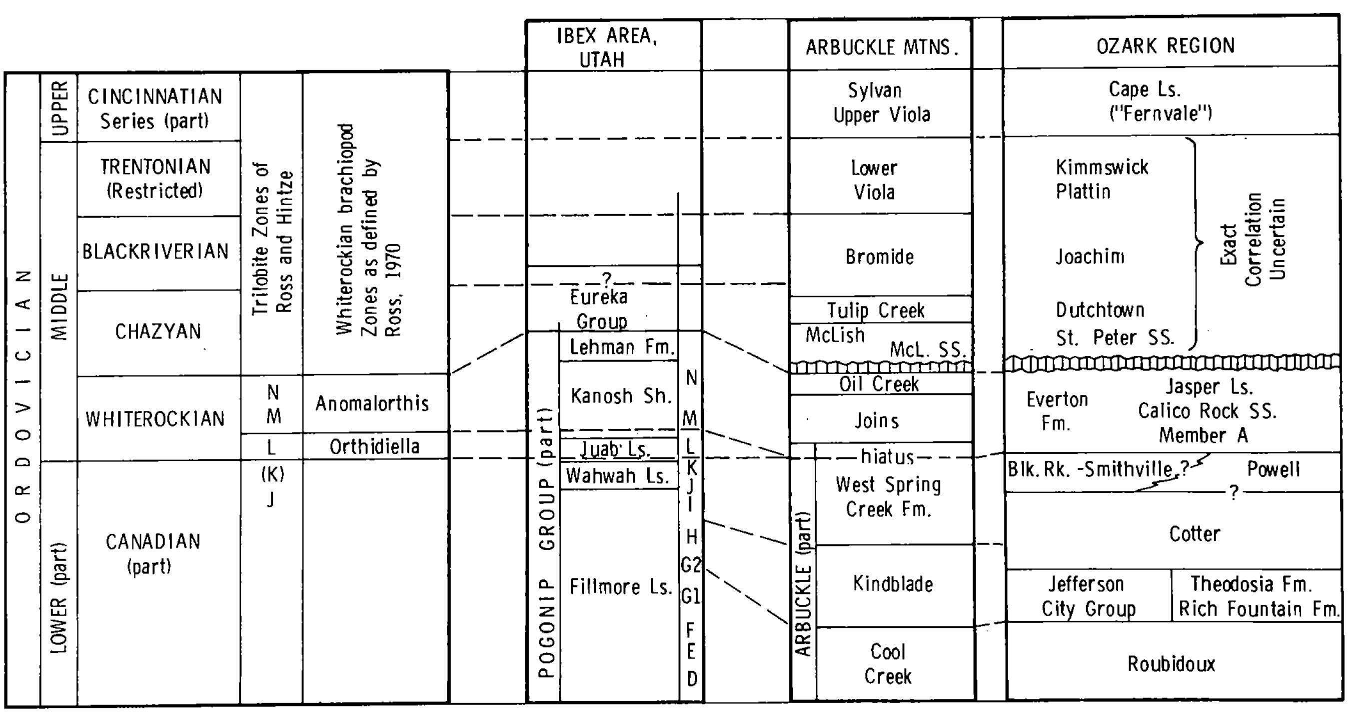
*Ceratopea unguis*
*Syntrophopsis magna* and allied species
*Diparelasma* spp., especially *D. typicum*
*Tritoechia* spp.
*Polytoechia* spp.
*Hesperonomia* spp.
*Hesperonomiella* spp.
Trilobites of Zone J of Ross (1951) and Hintze (1952)

As indicated previously, this fauna is present in the West Spring Creek Formation and also in the Smithville *and* Blackrock Formations of Arkansas, in Zone J (and K) of the upper Fillmore, Wahwah, and basal few feet of the Juab Formations in western Utah (Jensen, 1967), and in the *Diparelasma* and basal *Syntrophopsis* faunal zones of the Beekmantown of Maryland. In the Ibex area of western Utah (Hintze, 1952; Jensen, 1967), this fauna is succeeded by a quite different assemblage of brachiopods fully typical of the (Whiterockian) *Orthidiella* Zone, which is identical with Zone L in much of Utah and Nevada (Ross, pers. comm., 1973), i.e., *Orthidiella* spp., *Anomalorthis* spp. with low cardinal area, *Orthambonites* spp., *Idiostrophia*. Therefore, the youngest Early Ordovician fauna appears to be distinct from and consistently subjacent to faunas that have been considered to be Middle Ordovician; Ross (pers. comm., 1973) now concurs with this opinion.

## Middle Ordovician Fauna

In the West Spring Creek Formation of Oklahoma, from the top of the formation down to 90 feet below the top at both sections, a Middle Ordovician fauna is found. At both localities studied this fauna is separated from the subjacent Lower Ordovician fauna by a significant interval of barren thin-bedded argillaceous dolomite. Part of the fauna from the uppermost West Spring Creek has already been reported by Harris (1960), Harris and Harris (1965), and Creath (1966). This fauna includes the following:

| | |
|---|---|
| Brachiopod: | *Desmorthis nevadensis* Ulrich and Cooper, 1936 |
| Ostracodes: | *Ceratoleperditia arbucklensis* Harris, 1960 |
| | *Isochilina kamara* Creath, 1966 |
| | *Leperditella* (4 species) |
| | *Tallinnella* n. sp. |
| | *Paraschmidtella* n. sp. |
| | *Euprimitia*(?) n. sp. |
| | 2 undescribed species with affinity to Middle Ordovician Baltic forms (Creath, pers. comm., 1967) |
| Conodonts: | Middle Ordovician fauna described in part by Harris and Harris (1965) (see note by Klapper in section, Conodont Evidence) |




NOTE: DOTTED LINES INDICATE TIME LINES
SOLID LINES ARE FORMATION BOUNDARIES

Figure 15. Correlation of Lower and Middle Ordovician strata in Utah, Arbuckle Mountains, and Ozark region.

Prior to my note in the previous guidebook (Derby, 1969), *Desmorthis nevadensis* had not been reported from the West Spring Creek Formation. Previously, the species was known in the Arbuckle Mountains only from the Joins Formation (Cooper, 1956, p. 118) and was reported as *Orthis costalis* by early workers (e.g., Decker and Merritt, 1931, p. 15). *Desmorthis nevadensis* has never been found in association with Early Ordovician faunas, nor in the basal Whiterockian *Orthidiella* Zone (Zone L). Rather, the genus *Desmorthis* ranges throughout the *Anomalorthis* Zone; the "*Desmorthis* Zone" is synonymous with the *Anomalorthis* Zone, which is essentially synonymous with trilobite zones M and N (Ross, 1970, p. 48). *Desmorthis nevadensis* in the upper 90 feet of the West Spring Creek indicates, therefore, that this rock interval is equivalent in age to the Middle Ordovician *Anomalorthis* Zone. This, in turn, suggests that strata representing the time of deposition of the *Orthidiella* (L) Zone is either missing by nondeposition or is represented by a mere 10 feet of barren strata at the West Spring Creek locality and possibly 65 feet of barren strata at U.S. Highway 77.

In contrast to the faunal discontinuity within the West Spring Creek Formation, the *Anomalorthis* Zone fauna continues upward across the lithologic boundary with the overlying Joins Formation (fig. 15). *Desmorthis nevadensis* is present throughout the Joins, as is an unidentified species of *Anomalorthis*. In the Oil Creek Formation, *Anomalorthis oklahomensis* and two species of *Orthambonites* are present (Cooper, 1956, p. 119). Correlation of the Joins-Oil Creek with the *Anomalorthis* Zone is supported by conodont evidence (R. L. Ethington, pers. comm., 1973) and by the presence of *Pseudoolenoides acicaudus* Hintze, a Zone N trilobite, in the upper Joins and lower Oil Creek (Derby, unpub.; F. C. Shaw, in press). One trilobite species in the middle Joins, *Carolinites angustagena* Ross, suggests correlation with the *Orthidiella* Zone; but the bulk of the evidence indicates that the uppermost West Spring Creek, Joins, and Oil Creek Formations are biostratigraphically equivalent to the *Anomalorthis* Zone in the west.

## Conodont Evidence

The correlations of the Arbuckle Mountains section based on megafossils are also supported by conodont evidence. In both sections a dramatic change in the conodont fauna coincides with the megafaunal changes. Gilbert Klapper, who made the original study of our conodont faunas, commented as follows (Klapper, pers. comm., 1967):

> The conodont fauna from the upper 90 feet of the West Spring Creek Formation at U.S. Highway 77 is Middle Ordovician (Whiterock) in age. The fauna is dominated by several forms of *Multioistodus* Cullison, *Erismodus* Branson and Mehl, and *Coleodus* Branson and Mehl, all of which preclude a Lower Ordovician assignment. Some of the *Multioistodus* from this fauna were illustrated by Harris and Harris (1965). The upper West Spring Creek conodont fauna shows affinities with that of the overlying Joins and Oil Creek, and not at all with the subjacent faunas.
>
> The conodont fauna from as high as 160 feet below the top of the West Spring Creek at Highway 77, as well as from lower horizons in the formation, is Early Ordovician in age and is dominated by *Acodus* Pander and *Paltodus* Pander.

R. L. Ethington, who has studied Lower and Middle Ordovician conodonts in the western United States and now has our collections for additional study, concurs with Klapper's conclusions (Ethington, pers. comm., 1973). Sweet and Bergström (1973) correlated the Joins and Oil Creek with the Whiterock, and the overlying McLish, Tulip Creek, and lower Bromide with the Chazy. Based partly on conodont evidence from Oklahoma and Arkansas, I (Derby, 1973) recently suggested that the Everton Formation in Arkansas and Missouri is equivalent to the Whiterockian uppermost West Spring Creek, Joins, and Oil Creek Formations in Oklahoma.

## Conclusions

The time-stratigraphic boundary between the Lower Ordovician and Middle Ordovician Series is placed at a position approximately 100 feet below the top of the West Spring Creek Formation at two sections in the western Arbuckle Mountains (fig. 15). Below 100 feet below the top, the West Spring Creek is youngest Early Ordovician (latest Canadian). From 90 feet below the top upward, the West Spring Creek contains a fauna correlative with the *Anomalorthis* Zone of the Whiterockian Stage of Middle Ordovician age. The basal Whiterockian *Orthidiella* Zone is not represented in the Arbuckle section, suggesting an unrecognized hiatus within the West Spring Creek Formation.

The faunal change across the West Spring Creek-Joins formational boundary is relatively minor, despite the major lithologic change, suggesting that there is no significant hiatus at this boundary. Perhaps the sub-Simpson unconformity recognized in the eastern Arbuckle Mountains (Ham, 1955, 1969) is traceable into an obscure disconformity or paraconformity within the West Spring Creek Formation.

Finally, in terms of stratigraphic sequences (Sloss, 1963), the Whiterockian interval in the Arbuckle Mountains appears to be a small independent sequence bounded above and below by unconformities. By correlation to the west and to the (pre-St. Peter) Everton Formation, the Whiterockian West Spring Creek, Joins, and Oil Creek Formations are best classified with the Sauk sequence rather than with the Tippecanoe.

# BROMIDE FORMATION ON TULIP CREEK AND IN THE ARBUCKLE MOUNTAINS REGION

**Robert O. Fay** and **A. Allen Graffham**

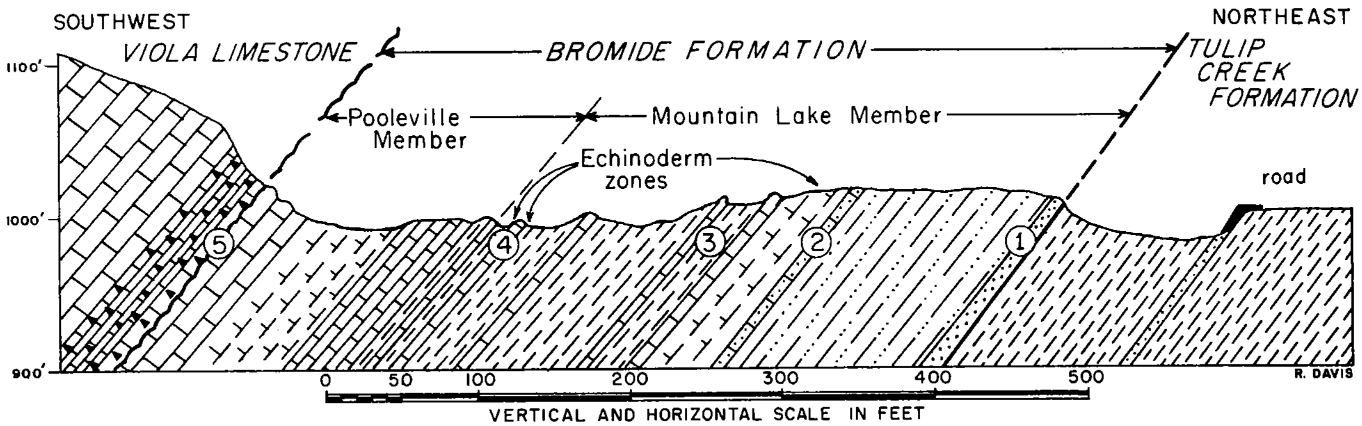



Figure 16. Stratigraphic section of Bromide Formation on Tulip Creek, NW¼NW¼NE¼ sec. 25, T. 2 S., R. 1 E., Carter County. Strike, N. 60° W., dip, 56° SW.

The Bromide Formation is the uppermost of five formations of the Simpson Group. A generalized measured section of the Bromide at Tulip Creek (fig. 16) is as follows.

**Pooleville Member** (120 feet thick):

| | | |
|---|---|---|
| 1. | Limestone, gray, fine-grained, dense, massive; eroding into a ledge (bed 5, fig. 16) | 14.0 |
| 2. | Limestone, gray to tan, fine-grained, dense, thin-bedded; eroding into a ledge | 16.0 |
| 3. | Limestone, gray, fine-grained, dense, medium-bedded; eroding into a ledge | 9.5 |
| 4. | Limestone, gray to tan, medium-granular, medium-bedded, fossiliferous | 7.0 |
| 5. | Limestone, gray to tan, with interbedded shale, very fossiliferous | 22.0 |
| 6. | Limestone, gray, fine-grained, dense, massive; eroding into a ledge | 1.0 |
| 7. | Limestone, gray to tan, argillaceous, thin-bedded to medium-bedded, fossiliferous; with interbedded shale | 43.5 |
| 8. | Shale and limestone, tan, thin-bedded, very fossiliferous | 7.0 |
| 9. | Limestone, tan, medium-granular, thin-bedded, very fossiliferous; eroding into a ledge | 4.0 |

**Mountain Lake Member** (300 feet thick):

| | | |
|---|---|---|
| 10. | Shale, tan, with interbedded limestone, thin-bedded, very fossiliferous; *Amygdalocystites* 1 foot below top (upper echinoderm zone) | 4.0 |
| 11. | Limestone, tan, fine-grained, massive, fossiliferous; eroding into a ledge (bed 4, fig. 16) | 1.25 |
| 12. | Shale, tan, with interbedded limestone, thin-bedded, very fossiliferous; *Amygdalocystites, Sinclairocystis, Glyptocystites* (upper echinoderm zone) | 7.0 |
| 13. | Shale, greenish-gray; with medium-granular, thin-bedded limestone | 30.0 |
| 14. | Limestone, gray to tan, fine-grained to medium-granular, thin-bedded; eroding into a ledge | 7.0 |
| 15. | Shale, greenish-gray, blocky; with a 1-foot fossiliferous limestone 20 feet below the top with abundant *Sowerbyella* | 70.0 |
| 16. | Limestone, tan, fine-grained to medium-granular, thin-bedded; with interbedded greenish-gray shale; eroding into a ledge | 11.0 |
| 17. | Shale, greenish-gray, blocky (bed 3, fig. 16) | 20.0 |
| 18. | Limestone, gray to tan, fine-grained to medium-granular, thin-bedded, fossiliferous; with interbedded greenish-gray shale and lower echinoderm zone about 22 feet above the base | 48.0 |
| 19. | Limestone, brown to gray, medium-granular, arenaceous, echinodermal, massive; gradational into a sandstone; eroding into a ledge (bed 2, fig. 16) | 1.5 |
| 20. | Shale, greenish-gray, with some interbedded medium-granular limestone and fine-grained to medium-grained sandstone; mostly covered | 70.0 |
| 21. | Sandstone, brown, fine-grained to medium-grained, quartzose, massive, well-indurated; eroding into a ledge | 4.0 |
| 22. | Shale, greenish-gray, with interbedded sandstone | 12.0 |
| 23. | Sandstone, light-tan, fine-grained to medium-grained, thin-bedded to medium-bedded, quartzose; eroding into a prominent ledge (bed 1, fig. 16) | 14.0 |

**Tulip Creek Formation** (only 86 feet described):

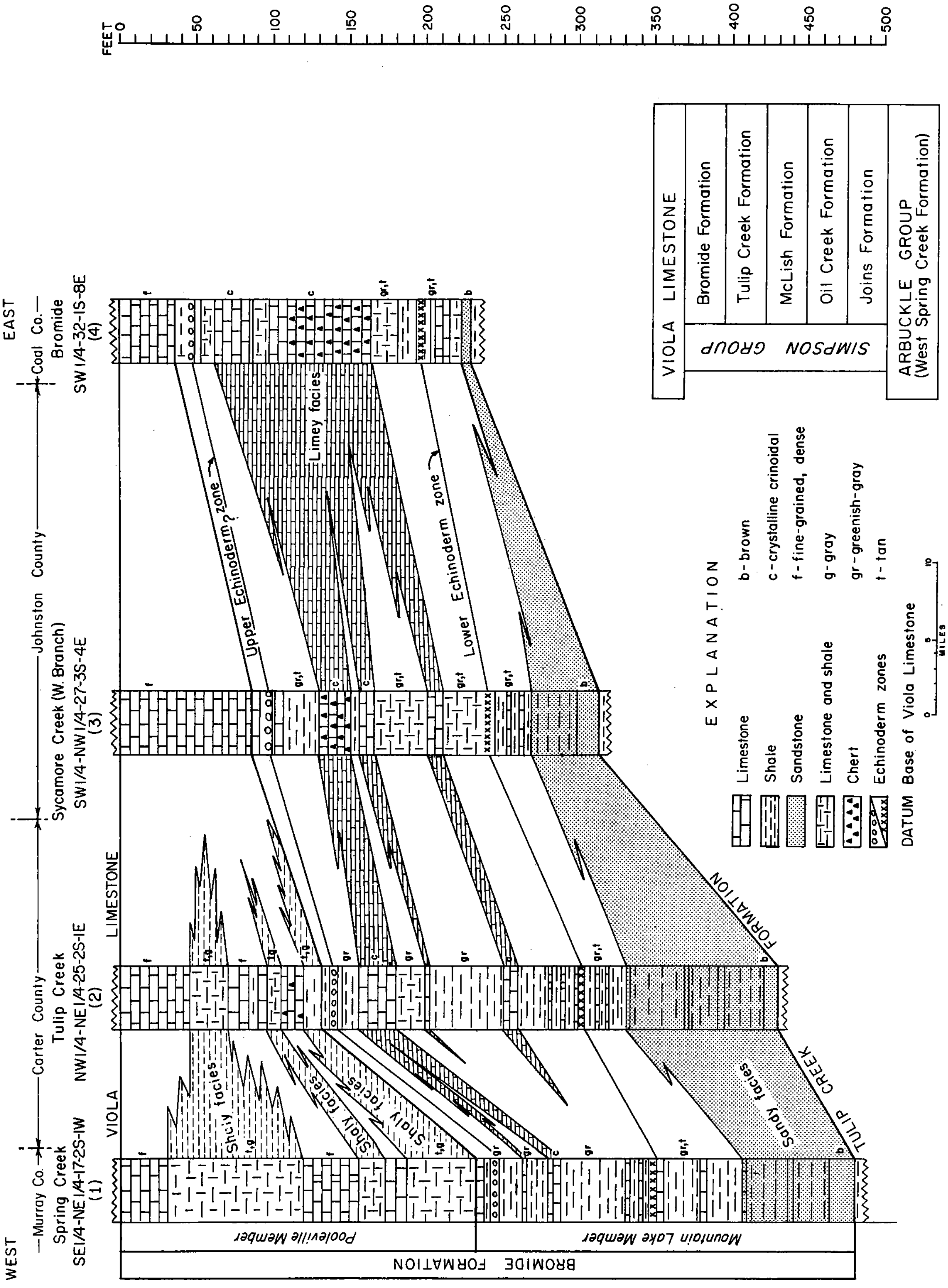
| | | |
|---|---|---|
| 1. | Shale, greenish-gray, blocky, weakly indurated; with some interbedded limestone and sandstone | 76.0 |
| 2. | Sandstone, brown, fine-grained to medium-grained, quartzose, medium-bedded; eroding into a ledge just south of the road | 10.0 |

At this locality (fig. 16), the Bromide Formation is about 420 feet thick, cropping out in a bench below the scarp face of Viola Limestone in the high ridge to the south. The Viola-Bromide contact is well defined.

The Bromide is subdivided into two members, the Pooleville Limestone (upper 120 feet) and Mountain Lake Shale (lower 300 feet), with much sandstone in the lower 100 feet (beds 1 and 2, fig. 16).

The Mountain Lake is mostly greenish-gray shale and crinoidal limestone (bed 3, fig. 16). A lower 3-foot echinoderm zone, about 170 feet below the top, or about 22 feet above bed 2 (fig. 16), is sparsely fossiliferous and not well developed. *Platycystites* (a paracrinoid) and *Hybocrinus* (a crinoid) commonly occur in this zone, along with the brachiopod *Mimella extensa* and many bryozoans. Near the top of the Mountain Lake is a 10-foot upper echinoderm zone (bed 4, fig. 16). It is characterized by *Amygdalocystites* and *Sinclairocystis* (paracrinoids), which are rare here, along with *Prasopora fritzae* and other bryozoans and brachiopods.

The Pooleville is mostly a gray, fine-grained, dense limestone, or argillaceous limestone, with some fossiliferous


WEST
EAST
Murray Co.
Carter County
Johnston County
Coal Co.
Spring Creek
SE1/4-NE1/4-17-2S-1W
(1)
Tulip Creek
NW1/4-NE1/4-25-2S-1E
(2)
Sycamore Creek (W. Branch)
SW1/4-NW1/4-27-3S-4E
(3)
Bromide
SW1/4-32-1S-8E
(4)
VIOLA LIMESTONE
Shaly facies
Limey facies
Sandy facies
Upper Echinoderm zone
Lower Echinoderm zone
TULIP CREEK FORMATION
Poolesville Member
Mountain Lake Member
BROMIDE FORMATION
FEET
0
50
100
150
200
250
300
350
400
450
500
EXPLANATION
Limestone
Shale
Sandstone
Limestone and shale
Chert
Echinoderm zones
DATUM Base of Viola Limestone
b - brown
c - crystalline crinoidal
f - fine-grained, dense
g - gray
gr - greenish-gray
t - tan
MILES
0
5
10
VIOLA LIMESTONE
Bromide Formation
Tulip Creek Formation
McLish Formation
Oil Creek Formation
Joins Formation
SIMPSON GROUP
ARBUCKLE GROUP
(West Spring Creek Formation)

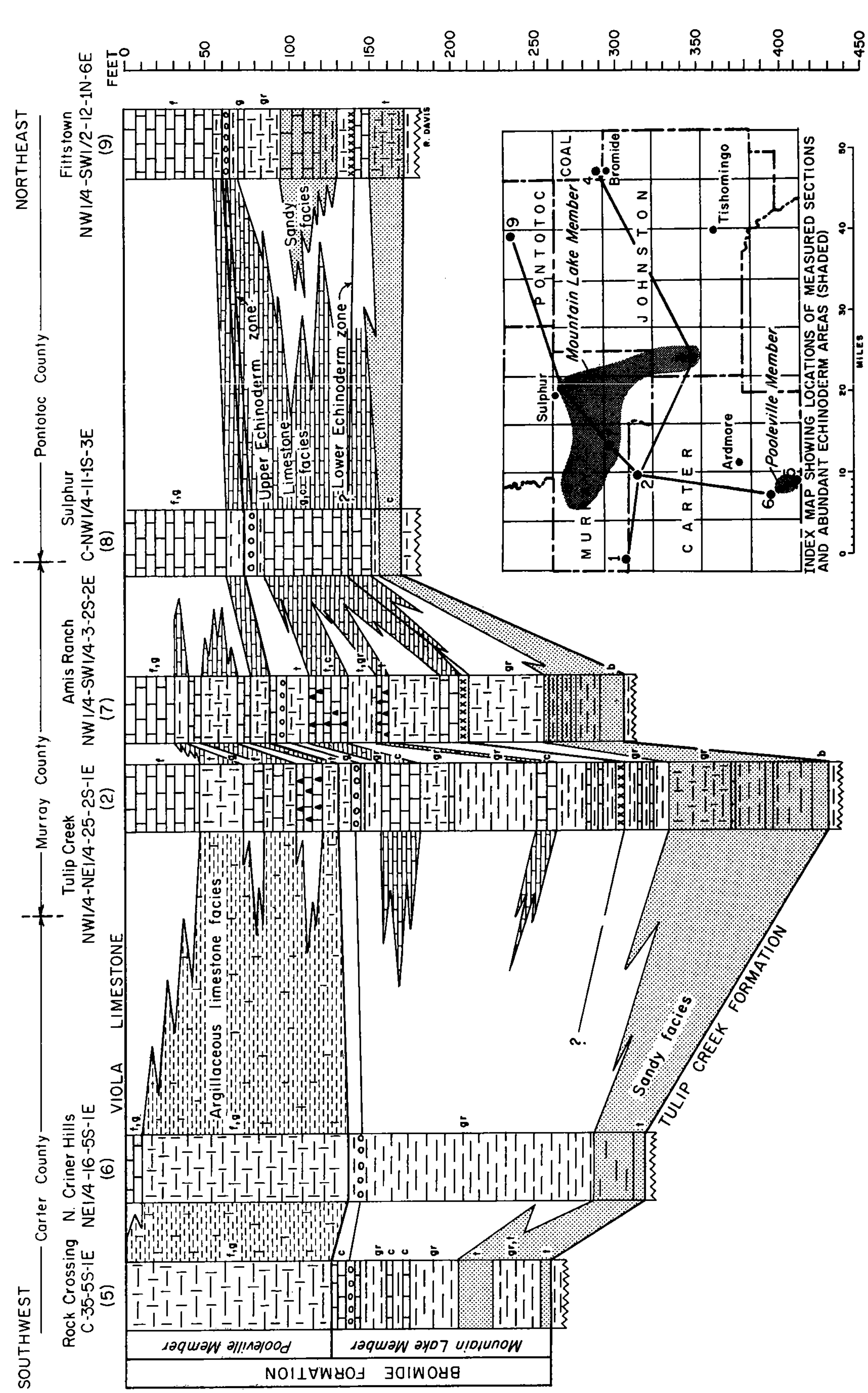



**Figure 17. Regional stratigraphic sections of Bromide Formation in Arbuckle Mountains and Criner Hills.**

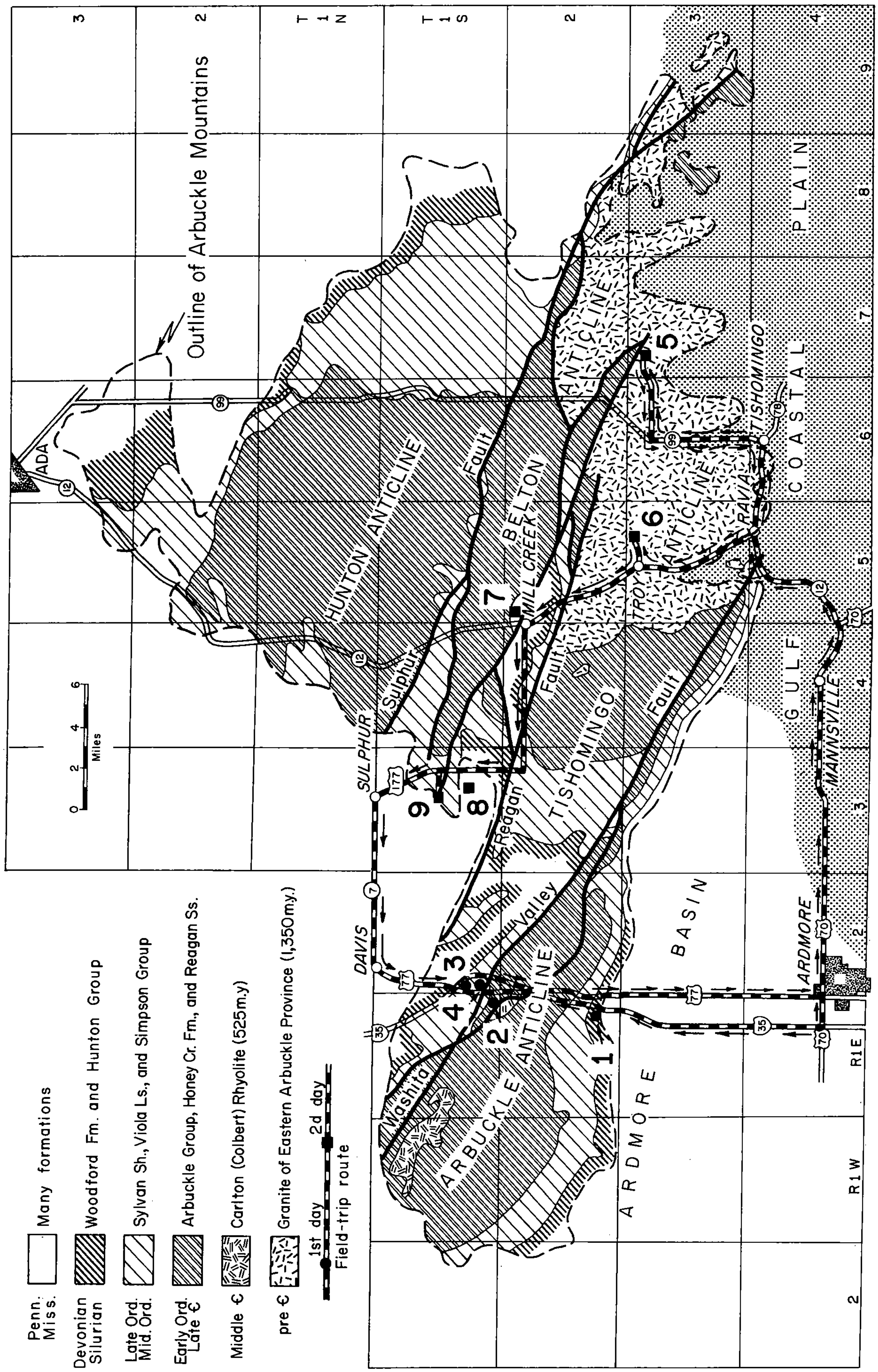



Figure 18. Geologic map of Arbuckle Mountains showing field-trip route.

shale at the base and near the middle. At the top is about 14 feet of massive limestone, in contact with the overlying thin-bedded, dark, cherty, lithographic Viola Limestone, with a thin, greenish-gray shale at the contact (bed 5, fig. 16).

Regionally, the Bromide has much sandstone to the north, shale to the west and south, and limestone to the east (fig. 17). The Bromide is thinner eastward and northeastward, along with other formations of the Simpson Group, and appears to be thinner southward in the Criner Hills. Much of the eastward thinning appears to be within the Pooleville Member, and the southward thinning is mostly within the Mountain Lake Member. The echinoderms occur abundantly in areas where shale and limestone are about equally developed, especially along edges of bryozoan bioherms. The Pooleville echinoderms have been found almost exclusively in the Criner Hills, and the Mountain Lake echinoderms have been found almost exclusively in the Arbuckle Mountains, being abundant in the Camp Classen, Dougherty, Sulphur, and Sycamore Creek areas (shaded area, fig. 17).

## STOP 1. Arbuckle anticline along Interstate Highway 35

*Robert O. Fay*

In 1970 the Oklahoma Department of Highways completed construction of Interstate Highway 35 through the Arbuckle Mountains. About 4 million yards of rock was removed, and the project cost about $4 million.

Beginning on the west side of the west lane, and proceeding northward, we will study the rocks on the south flank of the Arbuckle anticline (figs. 19-23). The first outcrop is the Sycamore Limestone (Mississippian), and the last outcrop to be seen at the turnout is the Kindblade Limestone (Lower Ordovician). The walk is about 2 miles long.

The rocks on the north flank (figs. 24-27) are complexly folded and faulted along the Washita Valley fault zone, with one thrust (Chapman Ranch fault) having a displacement of 7,000 feet or more and some normal faults having displacements of 700 to 2,000 feet or more. The faults occur in four stages, all being Virgilian in age (Late

Figure 19. South flank of Arbuckle anticline on Interstate 35, looking west. Upper Sycamore Limestone (48 feet), underlain by 72 feet of dark-gray shale, resting upon middle Sycamore Limestone. Strike, N. 60° W.; dip, 45° SW. Upper contact of Sycamore with overlying Delaware Creek Shale is at station 2323 + 25 feet, just off left margin of photograph. Lower shale contact is at station 2324 + 18 feet, at right side of photograph.

Figure 20. South flank of Arbuckle anticline on Interstate 35, looking northwest. Middle (120 feet) and lower (125 feet) Sycamore Limestone, resting upon Woodford Shale (290 feet), with Fay standing at contact near right side of photograph (station 2329 + 52 feet). Strike, N. 60° W.; dip, 45° SW. Lower contact of middle Sycamore is at station 2327 + 33 feet.

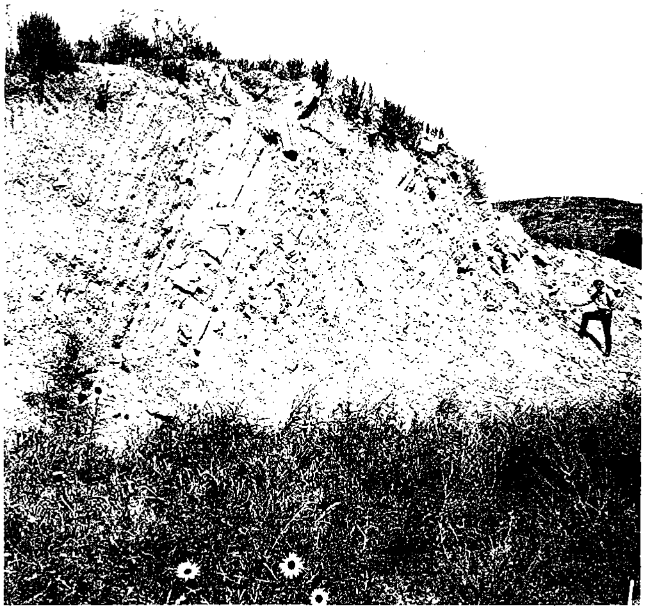


Figure 21. South flank of Arbuckle anticline on Interstate 35, looking northwest. Lower Woodford Shale, resting upon massive Bois d'Arc Limestone (8.8 feet; station 2333 + 83 feet), underlain by Haragan Limestone (26 feet) and Henryhouse shale and limestone (191 feet). Fay is pointing to Haragan-Henryhouse contact at station 2334 + 40 feet. Strike, N. 60° W.; dip, 46° SW.

Figure 22. Oil seep in Viola Limestone, 201 feet below top, on east side of southbound lane of Interstate 35 at station 2345 + 20 feet. Strike, N. 60° W.; dip, 53° SW. South flank of Arbuckle anticline.

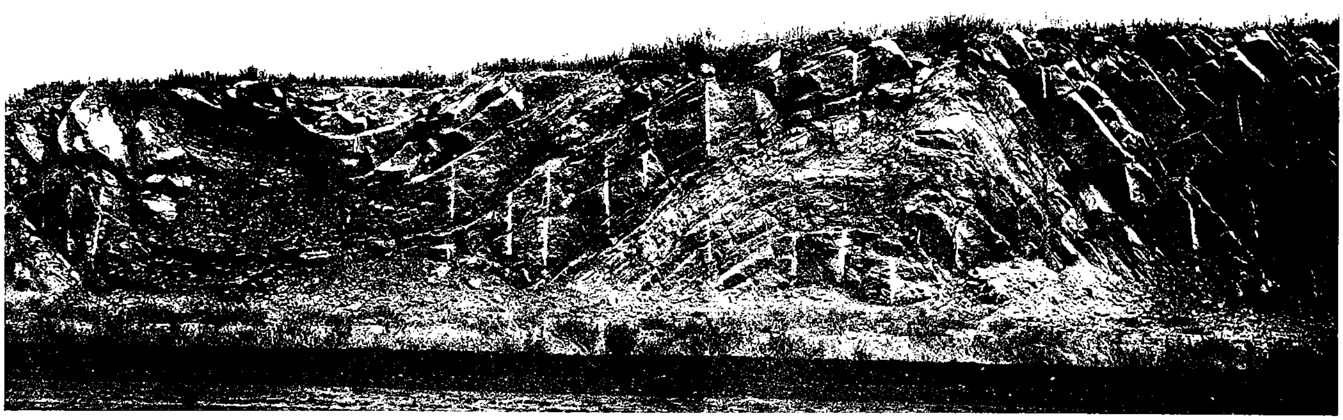


Figure 23. Syncline and anticline in lower Kindblade Limestone about 110 feet above base. East side of northbound lane of Interstate 35 at station 2423 + 15 feet (at anticlinal axis). Structures represent small flexure on downdropped side of normal fault that strikes east-west, off left margin of photograph. Rocks on south side of fault dropped about 100 feet.

Pennsylvanian) or slightly younger. The Chapman Ranch is a bedding-plane fault, thrust from southwest to northeast, which steepens to almost vertical attitude with depth. This fault is cut by normal or tension faults at right angles. These tension faults are cut by the Collings Ranch graben, subparallel to the Chapman Ranch fault. The Collings Ranch Conglomerate of Late Pennsylvanian age, in the graben, is slightly folded and faulted.

The Oklahoma Department of Highways designates station numbers as a means of reference to any point along the Interstate project. Station numbers have been set up at hundred-foot intervals along the median, beginning with zero at the south bank of the Red River and proceeding northward. For instance, station 1 is 100 feet north of the south bank of the Red River. With reference to photographs or measured sections, a station number is given for each contact between formations or zones, measured at the base of the cliff face, at right angles to the center line of the median. Thus, the Delaware Creek-Sycamore contact is at station 2323 + 25 feet, or 232,325 feet north of the south bank of the Red River, measured at the base of the cliff on the west side of the west lane at a right angle to the center-line tangent.

For safety reasons, please do not walk on shoulders, and please do not run back and forth across the highway. Also, be careful of falling rock. The deepest cut is 156 feet high, and many cuts are 50 to 60 feet high.

Figure 28 summarizes the stratigraphic sequence exposed along Interstate 35. Figure 29 is a regional section of the middle and upper part of the Arbuckle Group, and figure 30 shows photomicrographs of typical Arbuckle Group limestones.

Figure 24. View, looking southwest on Interstate 35, of Collings Ranch Conglomerate unconformably overlying upturned and slightly overturned (dip, 61° SW.) edges of Pooleville Limestone Member of Bromide Formation and Viola Limestone (at right). At left is edge of graben (station 2629 feet), with 3,000 feet of Collings Ranch filling graben. Fay is pointing to Pooleville-Viola contact at station 2630 + 50 feet. Graben formed first by almost vertical bedding-plane faulting; then the Collings Ranch sediments washed in, filling graben and spilling over upturned Ordovician rocks.

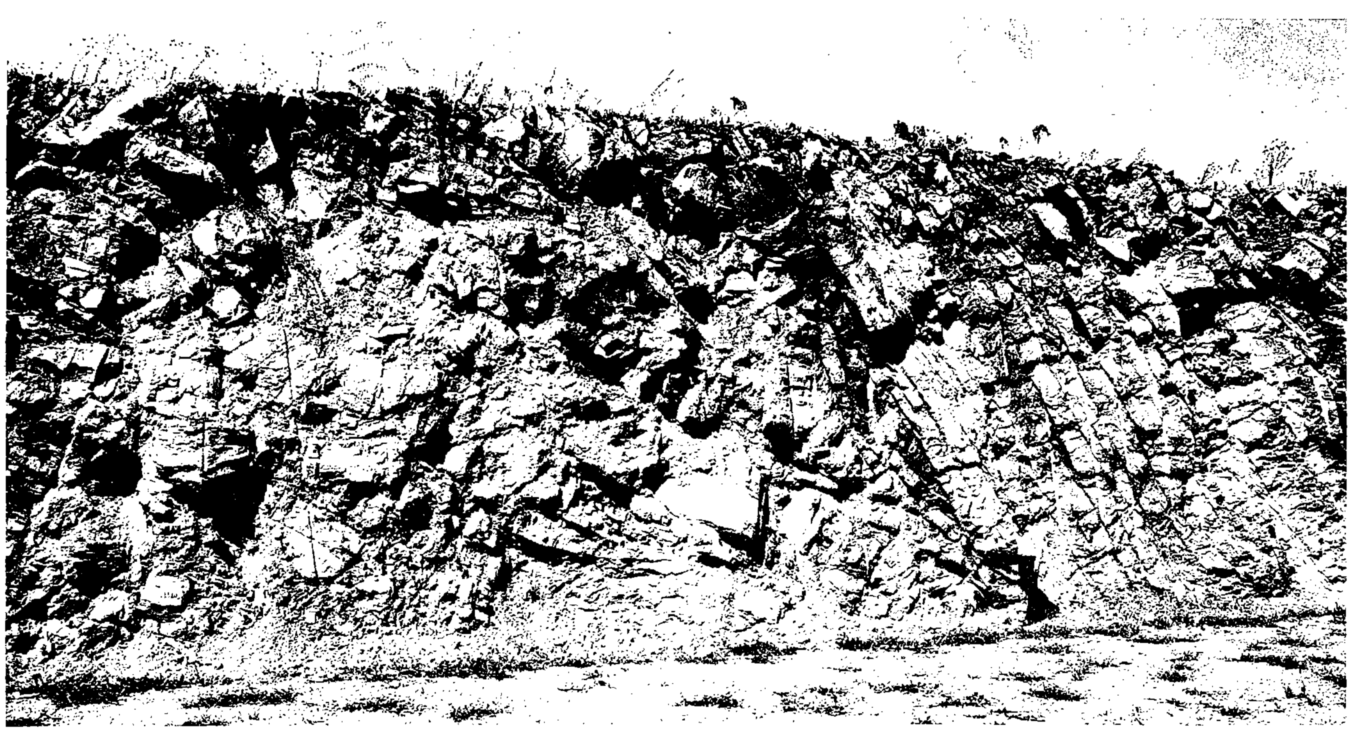


Figure 25. North flank of Arbuckle anticline, looking west on Interstate 35. Tectonic breccia in upper Kindblade Limestone. Undisturbed Kindblade at right; strike, N. 70° W.; dip, 56° NE. Fay is pointing to contact with breccia at station 2598 + 50 feet. Following overthrusting, closely spaced tension faults, striking northeastward, cut some Ordovician-Cambrian formations into brecciated blocks.

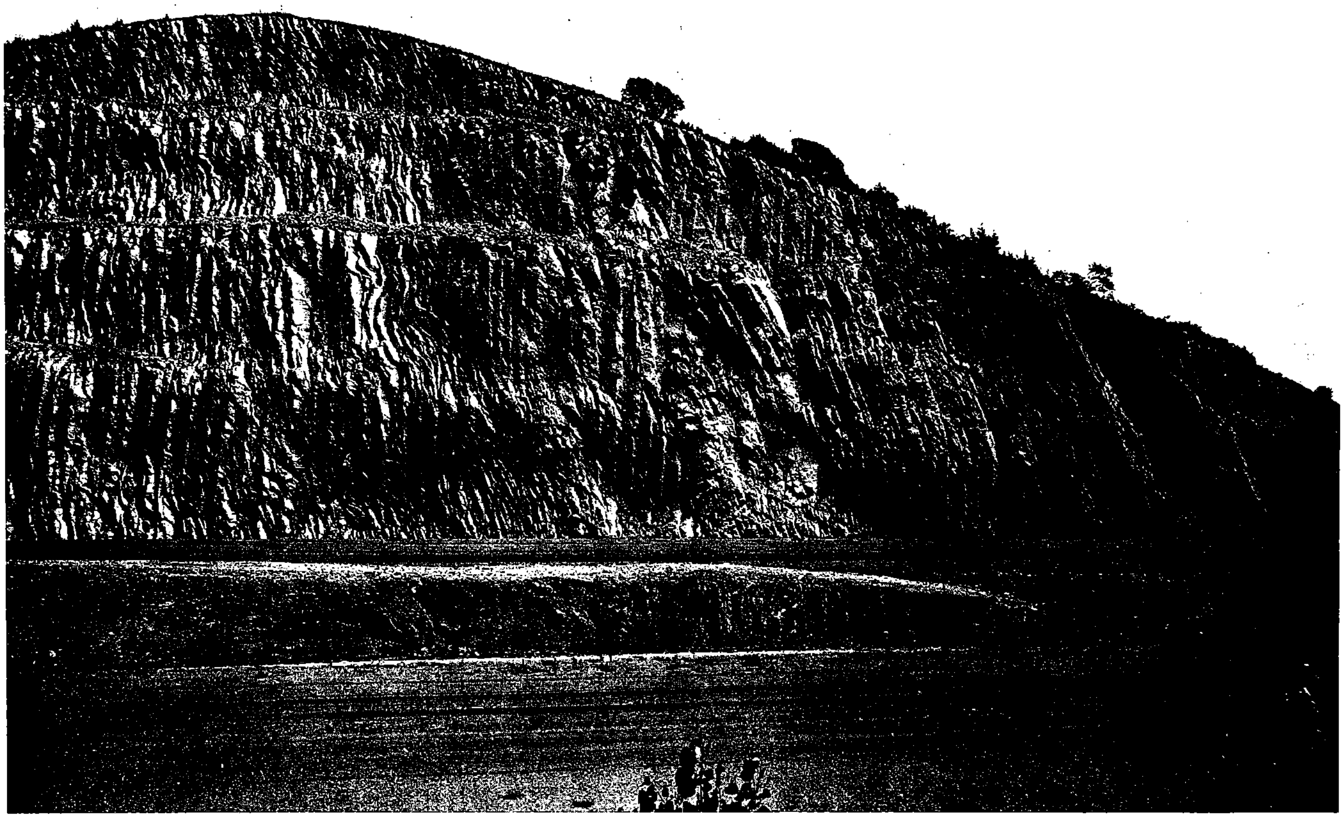


Figure 26. North flank of Arbuckle anticline, looking east on Interstate 35. Viola Limestone overturned above Bromide Formation; contact at station 2658 + 60 feet. Strike, N. 55° W.; dip, 75° SW. Contact between Pooleville Limestone Member and Mountain Lake Member (at right) of Bromide Formation is at station 2657 + 40 feet. This cut is deepest in Arbuckle Mountains, with a vertical span of 156 feet.

Figure 27. Sycamore Limestone, 221 feet thick, on north flank of Arbuckle anticline, looking northeast on Interstate 35. Strike, N. 73° W.; dip, 78° SW., overturned. Upper limestone, 46 feet thick, partly shown on left, followed by 19 feet of underlying shale and 88 feet of main limestone ridge in center (station 2681 + 45 feet at base); 68 feet of transition zone of shales and 4 limestone beds to right. Just off photograph to right, at base of fourth limestone, is greenish-gray glauconitic contact with underlying Woodford Shale (station 2679 + 52 feet).

PENNSYLVANIAN

Collings Ranch Conglomerate (3,000 feet)
(Erosional unconformity at base)

MISSISSIPPIAN

Goddard Shale (2,500 feet plus, not exposed)
Delaware Creek Shale (425 feet south side)
Sycamore Limestone (370 feet south side, 221 feet north side)

DEVONIAN

*Upper*
Woodford Shale (290 feet south side, 274 feet north side)
(Disconformity at base)
*Lower*
Hunton Group (229 feet south side, 132 feet north side)
Bois d'Arc Limestone (8 feet south side, 0-19 feet north side)
Haragan Marlstone (26 feet south side, 16-48 feet north side)

SILURIAN

*Upper*
Henryhouse Marlstone (190 feet south side, 17-78 feet north side)
*Middle*
Clarita Limestone (12 feet south side, 13 feet north side)
*Lower*
Cochrane Limestone (13 feet south side, 6 feet plus, north side)

ORDOVICIAN

*Upper*
Keel Limestone (oolite) (0-1 foot south side, 3-7 feet north side)
Sylvan Shale (305 feet south side, 275 feet north side)
*Middle*
Viola Limestone (684 feet south side, 710 feet north side)
Simpson Group
Bromide Formation
Pooleville Limestone Member (120 feet south side, 80 feet north side)
Mountain Lake Member (300 feet south side, 266 feet north side)
Tulip Creek Formation (395 feet south side, 297 feet north side)
McLish Formation (475 feet south side, 450 feet north side)
Oil Creek Formation (747 feet south side)
Joins Limestone (294 feet south side)
*Lower*
Arbuckle Group
West Spring Creek Formation (1,528 feet south side)
Kindblade Formation (1,440 feet south side)
Cool Creek Formation (1,300 feet south side)
McKenzie Hill Formation (900 feet south side)
Butterly Dolomite (297 feet south side)

CAMBRIAN

*Upper*
Arbuckle Group (cont.)
Signal Mountain Formation (415 feet south side)
Royer Dolomite (717 feet south side)
Fort Sill Limestone (155 feet south side)
Timbered Hills Group
Honey Creek Limestone (105 feet south side)
Reagan Sandstone (240 feet south side)
(Erosional unconformity at base)
*Middle*
Colbert Rhyolite Porphyry (4,500 feet drilled thickness; 7,500 feet estimated thickness)

**Figure 28. Stratigraphic succession of units exposed on Interstate 35.**

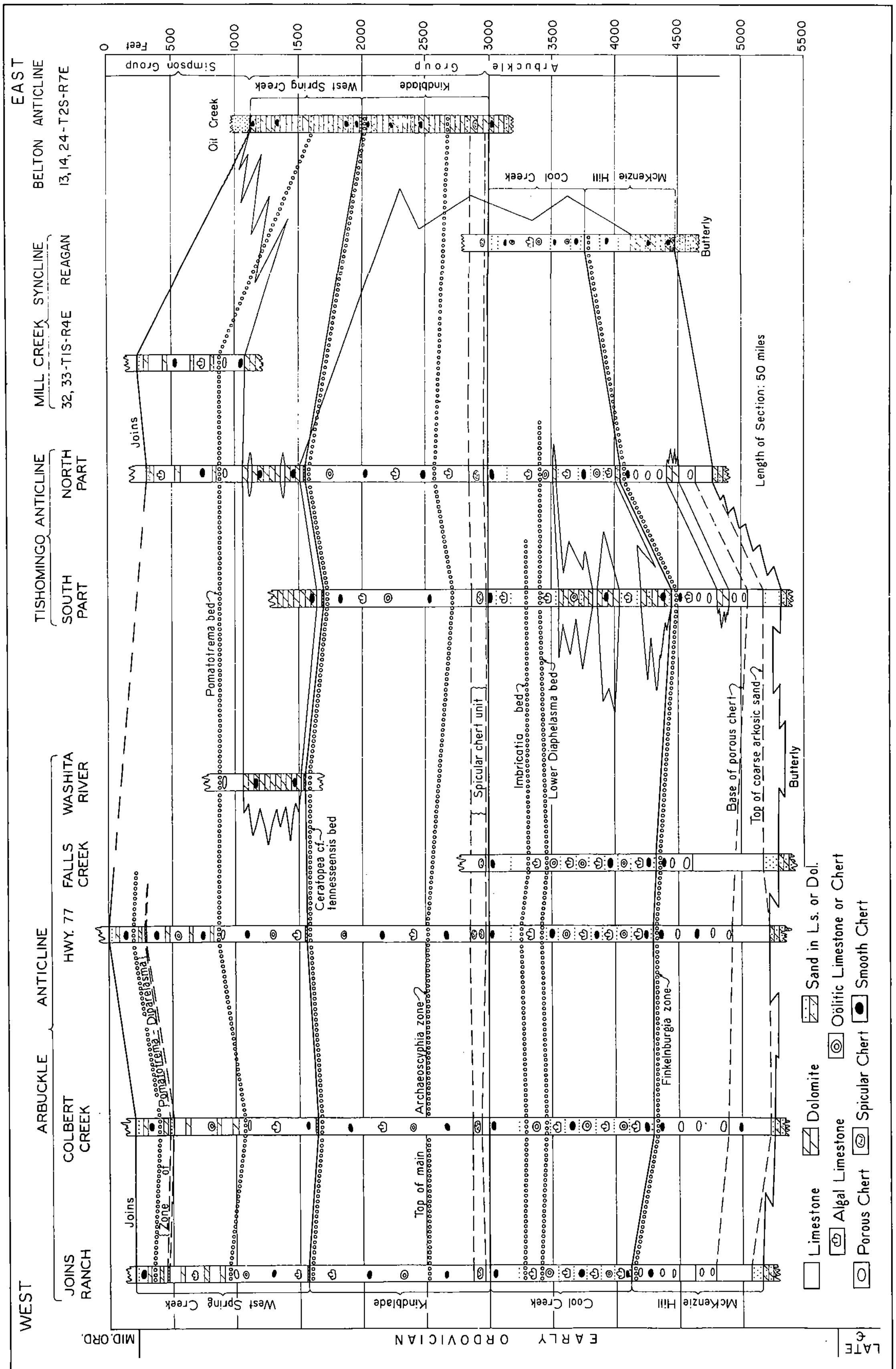



Figure 29. Regional stratigraphic section of middle and upper part of Arbuckle Group (modified from Ham, 1955).

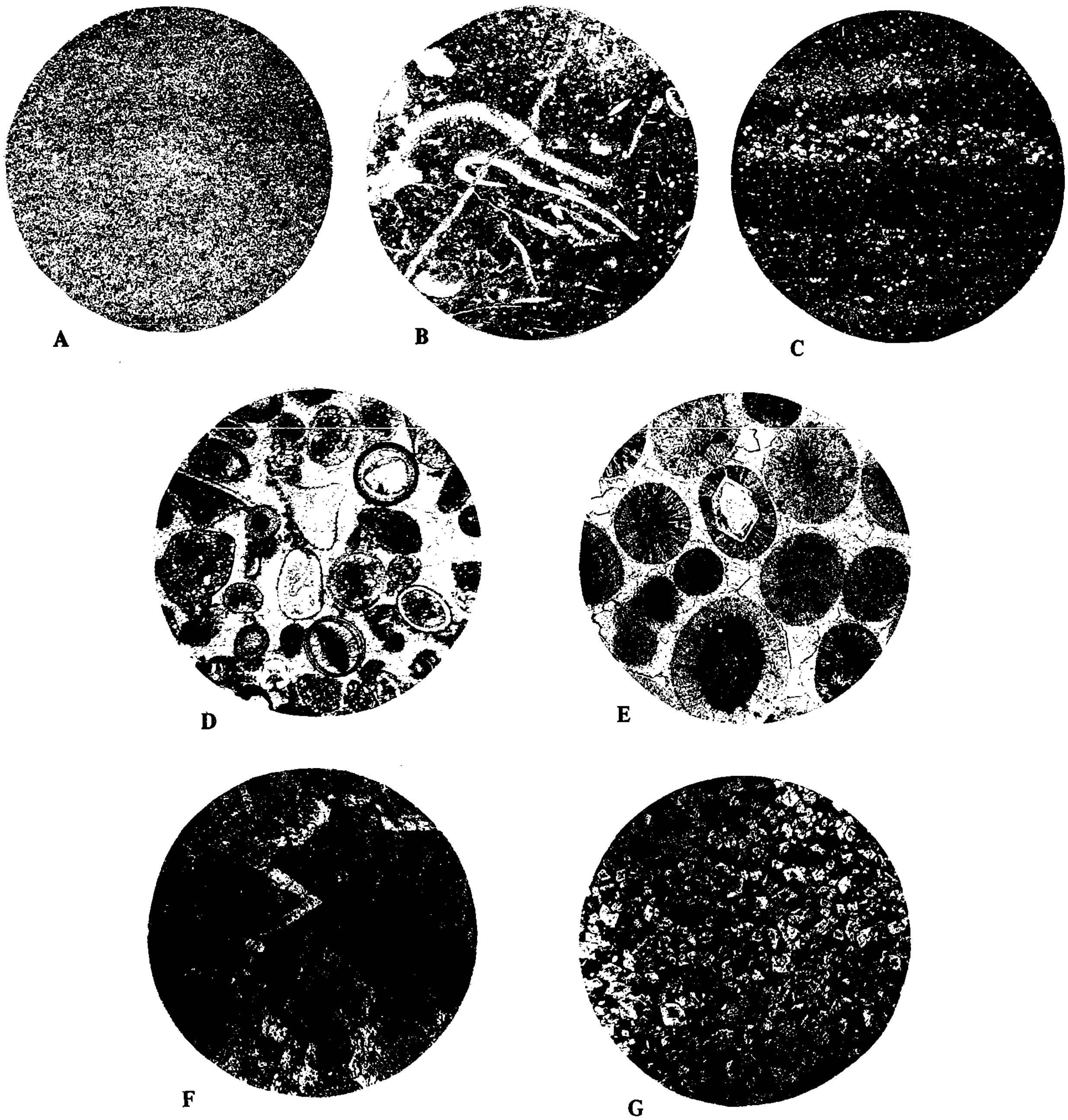



Figure 30. Photomicrographs of typical Arbuckle Group limestones in Arbuckle Mountains.

A. Calcilutite or carbonate mudstone, faintly banded but otherwise homogeneous. Kindblade Limestone, ×12.5.

B. Burrowed skeletal calcilutite. Skeletal elements are trilobites, pelmatozoans, and a few sponge spicules; filled burrow of clacisiltite at top. Fort Sill Limestone, ×12.5.

C. Laminated dolomitic calcilutite. Lamination results from layered concentration of silt-sized dolomite rhombohedrons. West Spring Creek Formation, ×28.

D. Intraclast-skeletal-ooid calcarenite cemented with sparry calcite. Most grains are coated by thin micritic envelope. Signal Mountain Limestone, ×12.5.

E. Oolitic calcarenite, cemented with void-filling sparry calcite. Nuclei are intraclasts and quartz sand grains; note one euhedral quartz crystal regenerated from rounded nucleus. Cool Creek Limestone, ×28.

F. Partly dolomitized calcilutite. Incomplete dolomite rhombs are invading and replacing carbonate mudstone. From limestone lens in Royer Dolomite, ×28.

G. Dolomitic calcilutite. Euhedral dolomite rhombs about 60 microns in diameter have uniformly replaced fine-grained limestone. West Spring Creek Formation, ×28.

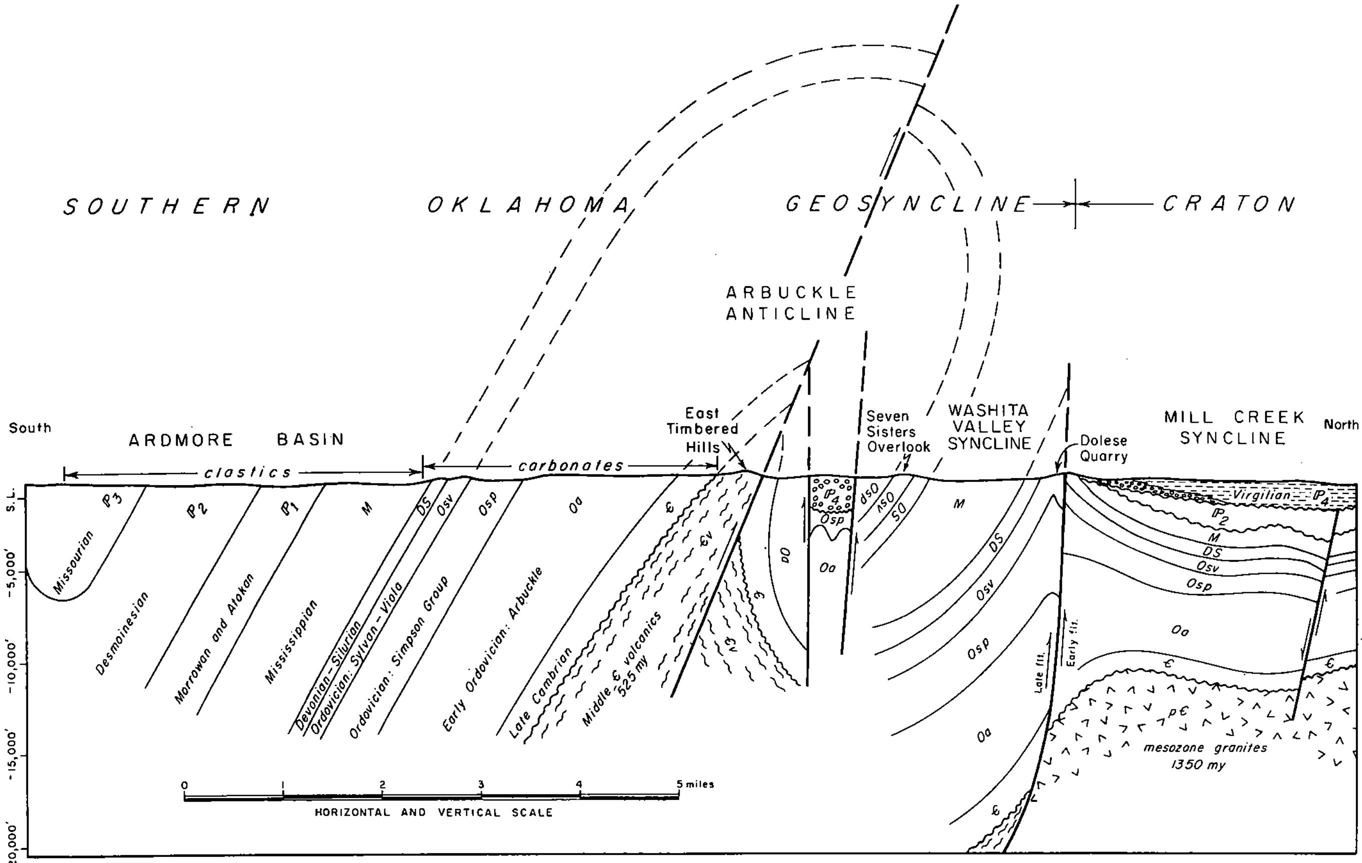



Figure 31. Stop 2. Structure section of Arbuckle Mountains in vicinity of U.S. Highway 77. In this area Arbuckle Mountains consist chiefly of Arbuckle anticline, which displays sedimentational and structural features of Southern Oklahoma geosyncline.

## STOP 2. Turner Falls overlook, SW¼ SE ¼ NE¼ sec. 36, T. 1 S., R. 1 E., Murray County

*William E. Ham*

All streams flowing across the limestone beds of the Arbuckle Mountains dissolve calcium carbonate, carrying much of it away in solution. But at Turner Falls on Honey Creek, an edifice of calcium carbonate has been deposited from the stream waters (fig. 32). The deposit consists of spongy-textured travertine. The thickness of the travertine gradually increased with the passage of water over it, until the falls reached a maximum height of 150 feet. Then, probably during middle Pleistocene time, increased rainfall caused Honey Creek to cut a chasm into the depositional platform it had just built, and the waterfall was reduced to half its former height. This beautiful waterfall is now in a stage when it is maintaining a steady state, receiving about as much calcium carbonate in the form of stream-floor deposits as is mechanically abraded during floods. Blue-green algae assist in precipitating the calcium carbonate.

Unlike the typical waterfall, which results from the exhumation of a preexisting resistant rock layer by stream erosion, Turner Falls is a subsequent creation of Honey Creek. The creek itself provided the materials to construct the precipice over which it falls.

Behind the falls, as a scenic background, are the East Timbered Hills, composed of Carlton Rhyolite. Between the rhyolite and the overlook are complexly folded and

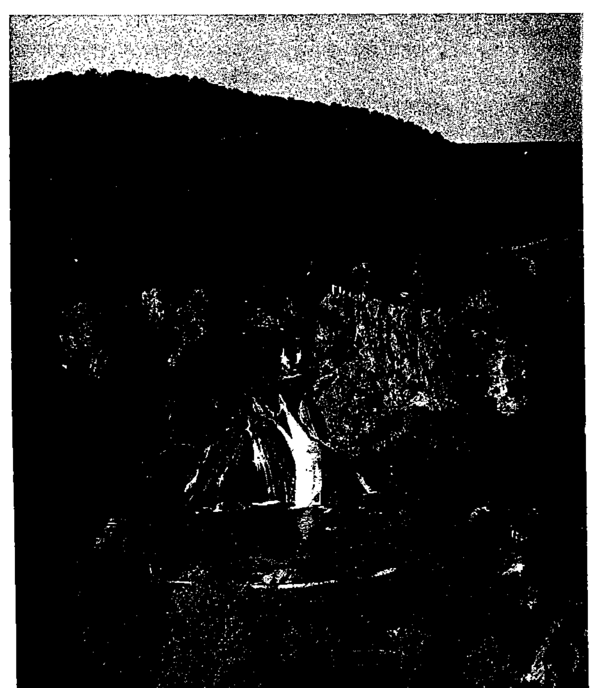


Figure 32. Turner Falls, viewed from scenic overlook (Stop 2) on U.S. Highway 77.

faulted Late Cambrian and Early Ordovician rocks on the north limb of the Arbuckle anticline. A fault trace parallels the valley of Honey Creek, separating Cool Creek Limestone at the overlook from McKenzie Hill Limestone, well exposed downstream and across the valley in a bold cliff face. Above the cliff and barely behind it is a small lateral valley, occupied by a few deciduous trees, which marks the trace of the Washita Valley fault. Beyond the fault is the Collings Ranch Conglomerate.

The Cool Creek Limestone, upon which the overlook is situated, is of middle Canadian age and is about 3,300 feet stratigraphically below the top of the Arbuckle Group. The extreme shallowness of the Arbuckle depositional environment is displayed by the common types of Cool Creek strata (fig. 33) that crop out here, including hemispheroidal algal stromatolites, edgewise conglomerates, and mudcracked calcilutites.

Figure 33. Algal stromatolite beds in Cool Creek Limestone at Turner Falls overlook.

## Stop 3. Late Ordovician, Silurian, and Early Devonian strata

*Thomas W. Amsden*

*Arbuckle Mountains and Criner Hills region.*—Strata of very Late Ordovician, Silurian, and Early Devonian age make up an incomplete sequence of rocks referred to the Hunton Group (fig. 34). These strata are widely distributed and well exposed in this region. They are almost exclusively low-magnesium limestones, mainly marlstone and organo-detrital limestone, commonly with the Keel Oolite at the base. Their maximum thickness in the outcrop area is about 450 feet, but in most places it is substantially less because of thinning produced by post-Hunton, pre-Woodford erosion as well as by erosion that occurred during Hunton time. Most Hunton strata are richly fossiliferous, and numerous faunal groups are represented, including brachiopods, ostracodes, corals, trilobites, crinoids, graptolites, conodonts, and foraminifers; but very little algal material is present. No reefs or boundstones have been observed in Oklahoma, and, for the most part, these strata represent sheets of organic debris spread out on the sea floor. Their lithostratigraphic and biostratigraphic character indicates that they are a part of the shallow-water carbonate deposition that was widespread in the continental interior during much of middle Paleozoic time. (A more detailed description is given in Amsden, 1960.)

*Outcrop at Stop 3.*—This outcrop is a new roadcut on the west side of Interstate Highway 35 interchange and presents a nearly complete exposure of strata from the Sylvan Shale through Silurian and Early Devonian strata into the lower part of the Woodford Shale (fig. 35). The upper Sylvan, Chimneyhill, Henryhouse, and lower Haragan Formations are completely exposed; however, the upper Haragan and the Woodford are rather poorly exposed, and this part of the section can be observed to better advantage in a roadcut on Highway 77A a few hundred feet east of Stop 3. Approximately 200 feet of Hunton strata is present, with only the Bois d'Arc and Frisco Formations of Early Devonian age absent (fig. 34). The Frisco, which is a well-defined organo-detrital limestone of middle Early Devonian age (Deerparkian; Siegenian), has been removed by post-Hunton, pre-Woodford erosion and is absent through this part of the Arbuckle Mountains. However, the Bois d'Arc Formation is a cherty and calcarenitic facies of the Haragan marlstone, and its absence is due to the local merging of these two lithofacies.

The Chimneyhill Subgroup includes, from oldest to youngest, the Keel, Cochrane, and Clarita Formations, a group of organo-detrital limestones that can be distinguished from the underlying Sylvan Shale and overlying Henryhouse Formation because these units are relatively low in insoluble clay and silt-size detritus (Amsden, 1967). They constitute an incomplete sequence ranging in age from Late Ordovician (late Ashgillian) to early Late Silurian (Wenlockian), with the individual formations separated by periods of erosion and at least local truncation (Amsden, 1963). Within the Arbuckle Mountains-Criner Hills outcrop area each of these formations is readily identifiable, so that lumping them into a subgroup might seem to serve little purpose. However, the Chimneyhill Subgroup has proved to be a useful stratigraphic division in the subsurface, where data are commonly inadequate to distinguish the individual formations.

The oldest Hunton formation is the Keel, a fossiliferous oolite, partly cemented by spar and partly by micrite. At Stop 4 this unit is approximately 4 feet thick and exhibits well-defined upper and lower contacts. Brachiopods from the Keel are similar to those from the lower Edgewood Formation of eastern Missouri and western Illinois and to the *Hirnantia* fauna of Europe, suggesting an age of very latest Ordovician (late Ashgillian). The Keel is separated from the overlying Cochrane by a time interval spanning a considerable part of the Early Silurian (early and middle Llandoverian), during which time there was at least local erosion and truncation of the Keel (Amsden, 1960, 1963).

The Cochrane Formation is about 6 feet thick at Stop 3 and comprises organo-detrital limestones with substantial glauconite. Brachiopods from this formation indicate a late Early Silurian (late Llandoverian) age and point to a correlation with the Blackgum Formation of eastern Oklahoma and the Sexton Creek Formation of southeastern Illinois.

The Clarita Formation is about 14 feet thick and is completely exposed. This formation is divided into a lower Prices Falls Member, which is a thin but persistent shaly or marly bed that can be recognized over most of the outcrop area, and an upper Fitzhugh Member, which is an organo-detrital limestone with varying amounts of insoluble detritus. At Stop 3 the lower 10 feet of this upper member is the typical, biomicrite lithology (average 6.9 percent HCl insolubles, mostly silt- and clay-size detritus); however, the upper few feet is quite shaly (average 27.9 percent HCl insolubles) and resembles the overlying Henryhouse Formation. Nonetheless, the Clarita-Henryhouse contact is lithologically well defined at this exposure, the base of the Henryhouse being marked by a sharp increase in insoluble detritus (the basal Henryhouse beds average about 47 percent HCl insolubles). There is also a change in the concentration of microfossils: the uppermost Clarita strata carry a rich fauna of arenaceous Foraminifera, whereas in the basal Henryhouse beds these fossils are much less numerous. Throughout most of the Arbuckle Mountains region, the Clarita-Henryhouse boundary is a reasonably well-defined, mappable contact, but there are some places, such as the exposures in the region centering around Stop 3, where difficulties have been encountered in distinguishing the upper Clarita from the Henryhouse with

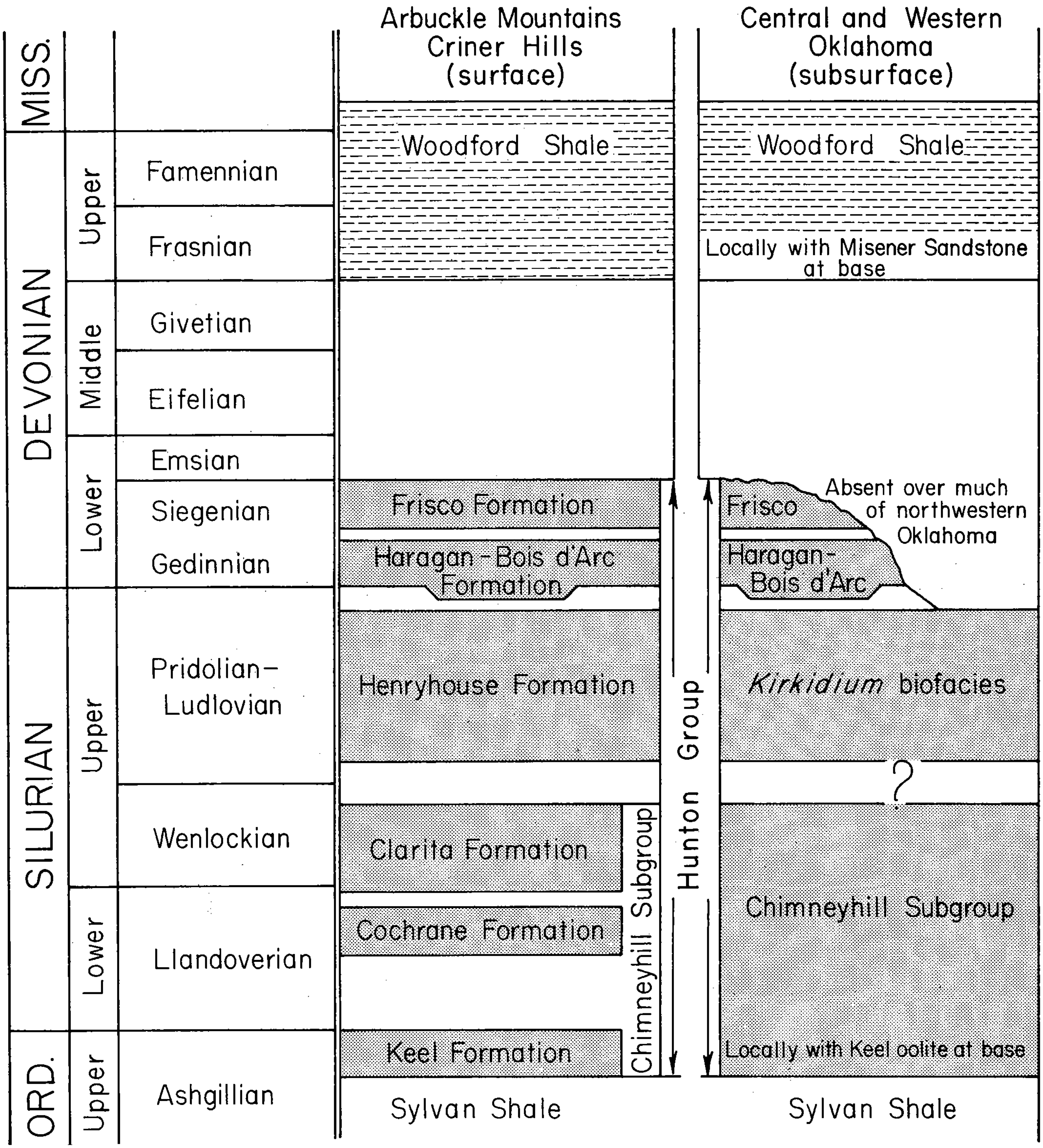



Figure 34. Chart showing stratigraphic divisions of uppermost Ordovician, Silurian, and Devonian recognized on outcrop in Arbuckle Mountains and Criner Hills of south-central Oklahoma and in subsurface of central and western Oklahoma.

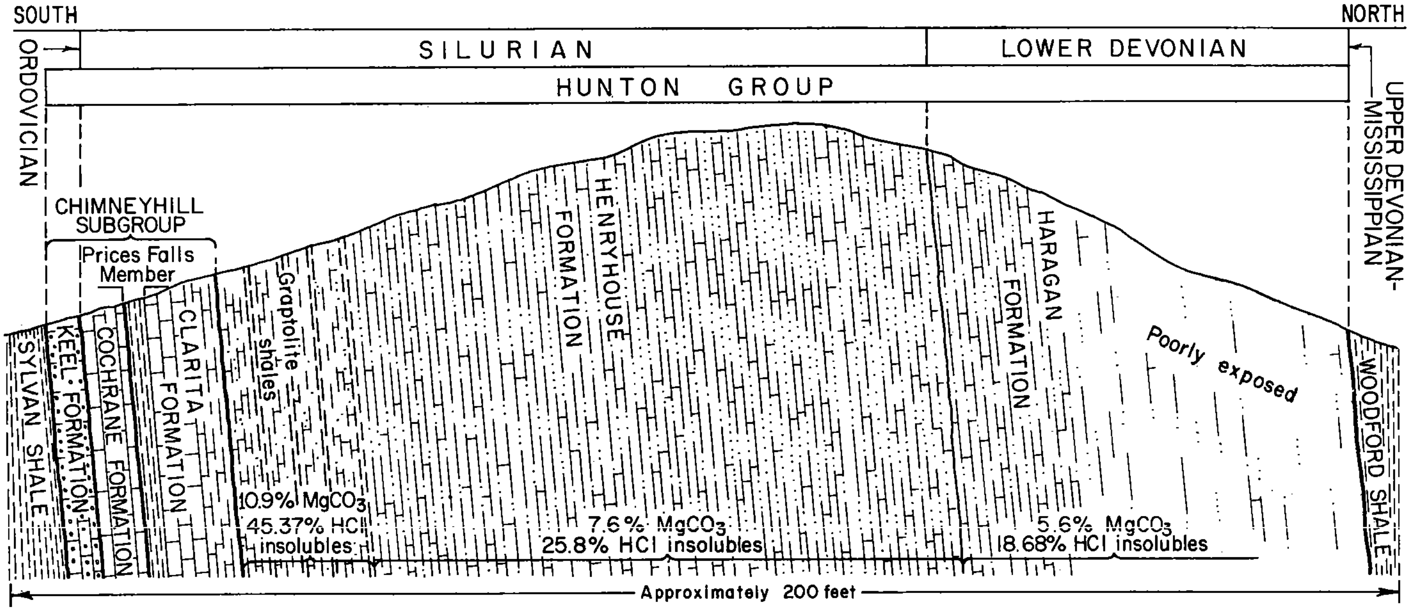



Figure 35. Stop 3. Outcrops of Sylvan Shale, Hunton Group, and Woodford Shale. West side of Interstate Highway 35 interchange, NW¼ sec. 30, T. 1 S., R. 2 E., Murray County. (Cut is near stratigraphic section M17 of Amsden, 1960.) Here, Henryhouse-Haragan contact is poorly defined lithologically, but elsewhere in Arbuckle Mountains Silurian-Devonian boundary marks substantial erosional unconformity. Pre-Woodford erosion has removed all of Frisco Formation and part of Haragan-Bois d'Arc Formations.

precision (Amsden, 1960, p. 61). The recent study of this new, fresh exposure, plus a reexamination of some of the older sections in this area (e.g., Amsden, 1960, sections M2, Ca2, M8), shows a persistent lithologic break at this stratigraphic position, although the relationship of the megafaunas to the lithologic contact is not entirely clear because of a paucity of fossils in the upper Clarita and lower Henryhouse strata.

The Prices Falls Member bears a conodont fauna, which Dr. Gilbert Klapper of The University of Iowa assigns to the late Llandoverian (Amsden, 1967, p. 944). The Fitzhugh Member carries an early Late Silurian (Wenlockian) brachiopod fauna similar to the one in the St. Clair Limestone of Arkansas (Amsden, 1968).

The Henryhouse Formation is approximately 100 feet thick at Stop 3 and is mostly marlstone with a few thin calcareous shale beds in the lower part. The marlstone is composed typically of finely divided carbonate mixed with clay- and silt-size insoluble detritus. The carbonate is mostly calcite with only scattered dolomite crystals (at Stop 3 the Henryhouse averages 9.9 percent $MgCO_3$). Fossils are scattered throughout the matrix in varying concentrations, but the matrix probably has a mud-supported fabric. The lower 18 feet of the Henryhouse is high in terrigenous detritus (averaging 45.3 percent HCl insolubles) and includes 4 thin, graptolite-bearing shale bands. The detrital content in the upper part of the formation is reduced (averaging 25.8 percent HCl insolubles), but is still well above the average of 20 percent for the formation throughout the outcrop area.

The Henryhouse-Haragan contact here is, as elsewhere in the Arbuckle Mountains region, poorly defined lithologically. However, this contact is biostratigraphically well defined and can be mapped on this basis throughout the outcrop area. On the average, the Haragan has a slightly lower insoluble-detrital content (regional average, 16 percent HCl insolubles), and this is also the case at Stop 3 (the lower Haragan averages 18.6 percent HCl insolubles). However, this difference is too small to serve as a useful distinction at the outcrop, in hand specimen or in thin section. Despite this obscure lithostratigraphic break, the Haragan-Bois d'Arc fauna (Helderbergian) is separated from the underlying Silurian strata by an unconformity of some magnitude. In fact, over a large area in the southeastern part of the Arbuckle Mountains region, Haragan-Bois d'Arc strata bearing numerous Early Devonian fossils rest on the Cochrane Formation of Early Silurian age, or locally on the Ordovician.

The Henryhouse bears a large, well-preserved invertebrate fauna, and several faunal groups have been described: brachiopods, by Amsden (1951); corals, by Sutherland (1965); trilobites, by Campbell (1967); ostracodes, by Lundin (1965); crinoids, by Strimple (1963). These authors assign the Henryhouse to the Upper Silurian, although its exact position within this series has generally not been specified. The present outcrop is of special interest because it is one of the three localities from which C. E. Decker (1935) reported graptolites (Stop 3 is near Decker's Honey Creek locality). The graptolites are from the lower 18 feet of the Henryhouse at all three localities, and Decker assigned them an early Ludlovian age; however, Jaeger recently (1967) restudied the Decker collections, indicating that at least one of the collections (Cool Creek) is of late rather than early Ludlovian age. Whether this age assignment holds true for all the graptolite beds at all localities, or whether the graptolites span a considerable part of Ludlovian time, is uncertain at present. In any event, the graptolite beds present a distinctive Henryhouse facies which is unusually high in detrital quartz and mica (see following section on regional distribution).

The Haragan Formation is approximately 60 feet thick. However, the upper part is poorly exposed, and there is some evidence of structural disturbance in the lower part of the Woodford Shale. The exposed beds have a characteristic marlstone texture, similar to that described previously for the Henryhouse. The Haragan strata average 18.6 percent

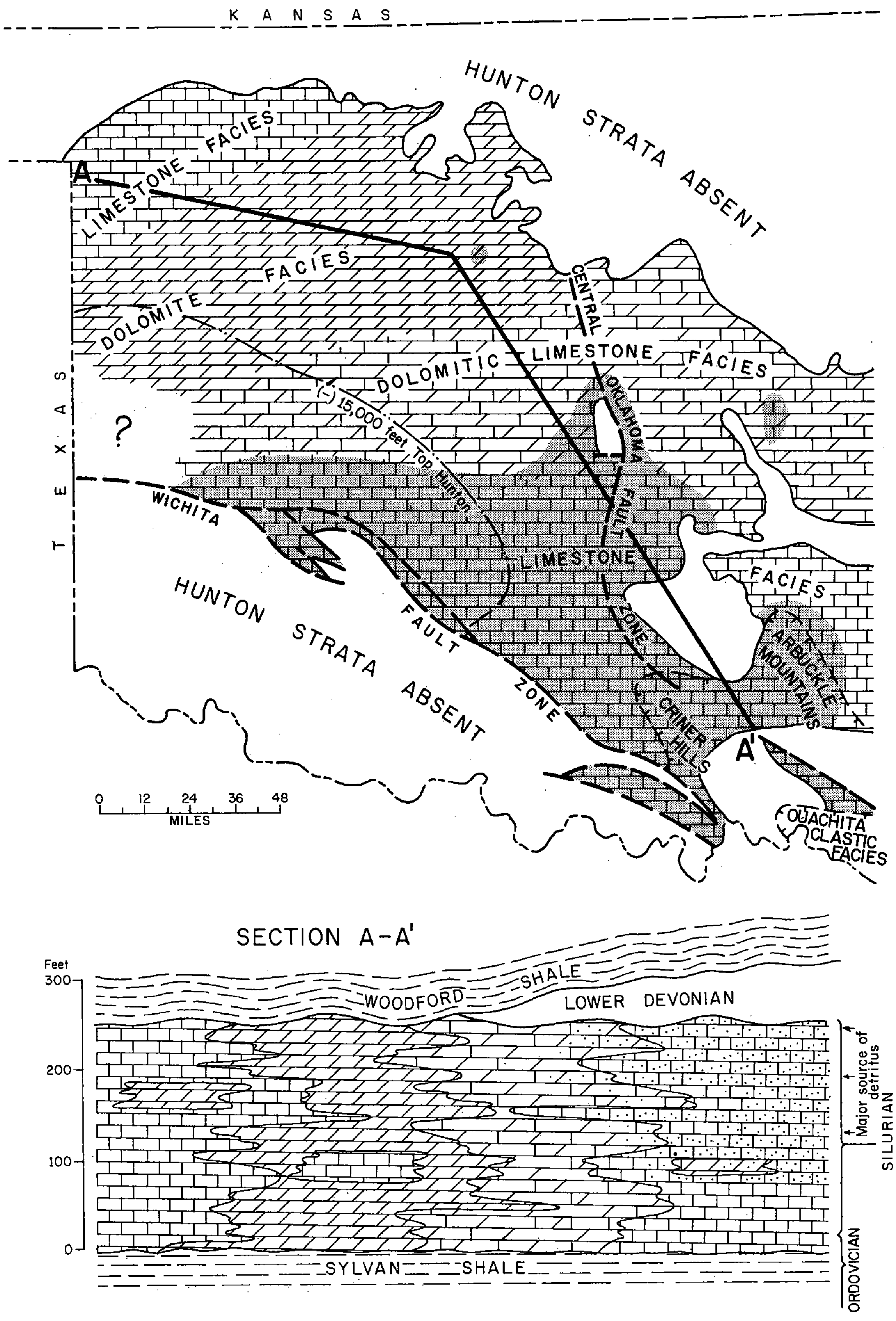



Figure 36. Simplified lithofacies map showing limestone-dolomite distribution in Silurian rocks of western Oklahoma. Distribution of terrigenous detritus is included in cross section but not on map, as Chimneyhill strata are generally low in insoluble detritus. Map represents pre-Woodford subcrop, and blank areas indicate removal of Hunton strata by post-Early Devonian erosion. Areas where Silurian rocks are overlain by Lower Devonian strata (Haragan-Bois d'Arc and/or Frisco Formations) are indicated by stippled pattern. (Information on Devonian rocks in deep part of Anadarko basin based entirely on lithostratigraphic data.)

HCl-insoluble residue, mostly clay- and silt-size detritus, and 5.6 percent $MgCO_3$. The Henryhouse-Haragan contact is poorly defined lithologically (see previous discussion) and must be determined by means of fossils. The basal Haragan bed has numerous *Scyphocrinus (Camarocrinus)* bulbs, but this is of no biostratigraphic significance as these crinoids also occur in the Henryhouse.

The Bois d'Arc is not represented at this locality, although this formation is fairly well developed in nearby outcrops. The Haragan and Bois d'Arc represent facies of one another, and there is a complete gradation from the typical Haragan marlstone into the low-detrital biosparites (commonly with chert) of the Bois d'Arc. A minor faunal difference exists between the two lithofacies, but this is thought to be because of environmental changes rather than a time difference (Amsden, 1958a).

The Haragan bears a large, well-preserved invertebrate fauna, dominated by brachiopods (Amsden, 1958a) and containing many ostracodes (Lundin, 1968), trilobites, corals, and bryozoans. It is assigned an Early Devonian (Helderbergian, Gedinnian) age.

*Regional distribution.*—Hunton rocks are widely distributed in the subsurface of western Oklahoma and the Texas Panhandle. This area is occupied largely by the Anadarko basin, where Hunton strata reach a depth of more than 26,000 feet below sea level and a thickness of nearly 1,800 feet.

As I am now completing a biostratigraphic and lithostratigraphic study of the Hunton rocks in this region, a brief outline of this study may be helpful. Three sources of data have been used in the study: cores, well cuttings, and mechanical logs. Numerous cores are available in the shallower parts of the basin, extending down to about −14,000 feet, and these cores furnish fossils in addition to detailed lithostratigraphic evidence. On the basis of brachiopods recovered from cores, it has been possible to recognize the major units present at the surface, and, in particular, to separate Silurian from Early Devonian carbonates. Below −14,000 feet it is necessary to rely on well cuttings, which are of no value in studying the megafossils but which do provide excellent lithostratigraphic data, especially when thin sections are prepared. It should be kept in mind that all correlations into the deep part of the Anadarko basin are based on lithostratigraphy. Mechanical logs are useful in locating the Woodford-Hunton and Hunton-Sylvan contacts.

Early Devonian rocks in Oklahoma belong entirely to a carbonate lithofacies and have a somewhat restricted distribution (fig. 36). In the subsurface of central Oklahoma, both the Frisco Formation and the Haragan-Bois d'Arc Formations can be identified by fossils from cores. The Frisco Formation, which is separated from older strata by an unconformity of some magnitude, truncates the underlying Haragan-Bois d'Arc beds and extends a short distance into the central part of the State, where it rests directly on the Silurian *Kirkidium* biofacies. North and west of this point Lower Devonian beds have been largely removed by pre-Woodford erosion, so that over most of northwestern Oklahoma the Woodford rests directly on the Silurian or older strata. In the deep part of the Anadarko basin, no biostratigraphic data are available, but the lithostratigraphic sequence suggests that Early Devonian rocks are present, as shown in figure 36.

Two major lithostratigraphic and biostratigraphic divisions are recognized in Silurian rocks of western Oklahoma: an upper *Kirkidium* biofacies, considered to be the approximate equivalent of the Henryhouse Formation, and a lower Chimneyhill Subgroup (fig. 36). Both lithostratigraphic and biostratigraphic data support this correlation in the shallower parts of the basin, but in the deep part the correlation depends entirely on lithostratigraphy.

The *Kirkidium* biofacies and the Chimneyhill Subgroup become increasingly dolomitic toward the northwest and finally grade into a largely crystalline-dolomite lithology (more than 28 percent $MgCO_3$). This is illustrated in the photomicrographs shown in figure 37, which show the changes from low-magnesium Henryhouse limestone to crystalline dolomite, and from low-magnesium oolite to a completely dolomitized oolite. Still farther west, these strata, especially the *Kirkidium* biofacies, grade back into low-magnesium limestone. Over this same area the insoluble detritus irregularly but progressively decreases, this change being especially noticeable in the Henryhouse-*Kirkidium* beds. In contrast to the northwestern facies changes, the limestone facies of the Arbuckle Mountains-Criner Hills region extends with little change westward along the deep axis of the Anadarko basin. In fact, the lithostratigraphic sequence in some of the recently drilled deep wells is remarkably similar to the sequence observed in the northeastern part of the Arbuckle Mountains, where the Hunton section consists of Lower Devonian organo-detrital sparites, Henryhouse-Haragan marlstones, and Chimneyhill organo-detrital limestones including a basal oolite.

A discussion of the Silurian dolomites of western Oklahoma is beyond the scope of this report, but a few general remarks are in order. These strata appear to represent a dolomitized (here interpreted as an early-stage, penecontemporaneous replacement) organo-detrital limestone. The fauna is mainly benthonic and consists of large brachiopods, crinoids, and some corals and includes little or no algal material. There is virtually no anhydrite or salt associated with the dolomite, and there is no evidence that it represents deposition in a tidal zone. In fact, no evidence exists for an ancient shoreline in this region, and the distribution of terrigenous detritus in the Silurian rocks indicates a principal southerly source.

## BASEMENT ROCKS IN THE ARBUCKLE MOUNTAINS

**Rodger E. Denison**

The basement rocks in the Arbuckle Mountains can be divided into the Colbert Rhyolite Group of Cambrian age in the western mountains and the massive Precambrian granitic rocks in the eastern mountains.

The Carlton Rhyolite Group is the most widespread of the Cambrian basement rocks. The rhyolites are inferred or can be demonstrated to have underlain over 15,000 square miles, but this original distribution has been considerably diminished by Cambrian and later Paleozoic erosion. The thickness of rhyolites beneath younger Cambrian rocks ranges from about 2,600 to more than 3,600 feet.

The rhyolites crop out in the East and West Timbered

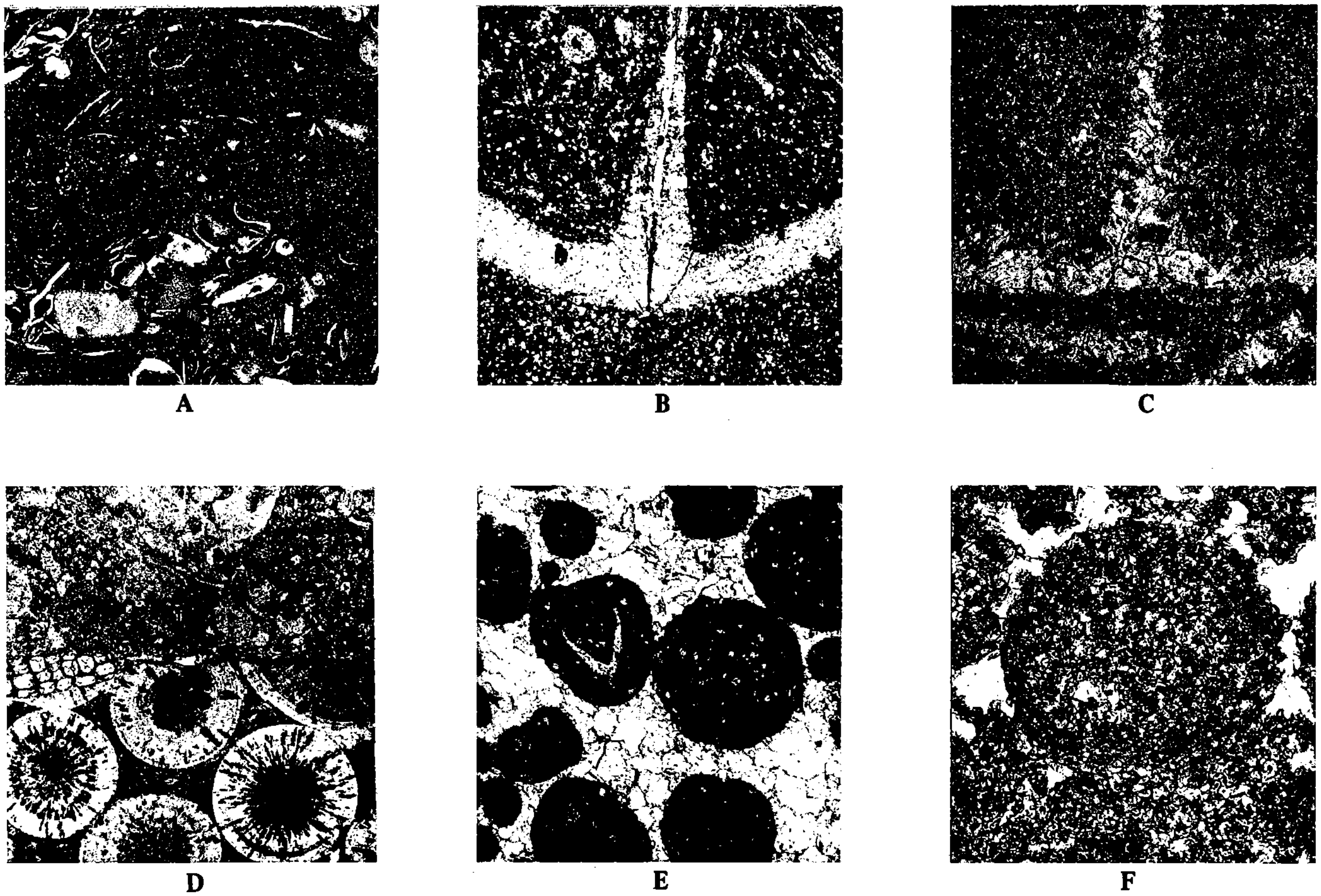



Figure 37. Photomicrographs of Hunton Group rocks. A through C and D through F show increasing dolomitization from left to right.

A. Henryhouse Formation, showing typical marlstone texture ($MgCO_3$, 5.5 percent; HCl insolubles, 19.5 percent). From outcrop at stratigraphic section M17 of Amsden (1960), near Stop 3 of this trip. ×6.

B. Dolomitic limestone facies of *Kirkidium* biofacies ($MgCO_3$, 18.3 percent; HCl insolubles, 9.8 percent). Note cross section of pedicle valve of *Kirkidium* sp. From Calvert No. 1 Bertie core, depth 8,351 feet; C NE¼NW¼ sec. 35, T. 19 N., R. 9 W., Kingfisher County. ×10.

C. Crystalline dolomite facies of *Kirkidium* biofacies ($MgCO_3$, 38.7 percent; HCl insolubles, 4.4 percent). Note cross section of pedicle valve of *Kirkidium* sp., completely replaced by dolospar. From Sunray-DX No. 1 Franz core, depth 14,522 feet; C SW¼NE¼ sec. 3, T. 15 N., R. 16 W., Custer County. ×15.

D. Keel Oolite overlain by Cochrane Formation, both undolomitized. From outcrop at Prices Falls, SW¼NW¼ sec. 33, T. 1 S., R. 2 E., Murray County. ×20.

E. Slightly dolomitized oolite ($MgCO_3$, 11.9 percent; HCl insolubles, 3.6 percent). From Getty No. 1 Luetkemeyer core, depth 9,245 feet; C NW¼NW¼ sec. 24, T. 19 N., R. 10 W., Blaine County. ×20.

F. Single oolite completely replaced by crystalline dolomite ($MgCO_3$, 43.1 percent; HCl insolubles, 0.98 percent). From Cleary No. 1-24 Kramp Cobb core, depth 8,512 feet; C W¼NW¼ sec. 24, T. 19 N., R. 10 W., Blaine County. ×20.

Hills at the crest of the Arbuckle anticline. Here, the rhyolites are overlain by the Reagan Sandstone of Late Cambrian age. The rhyolites are not well exposed, however, but surface information as well as deep drilling outlines the character of the unit. The Frankfort No. 1 Sparks, drilled on the south flank of the Arbuckle anticline, penetrated about 4,500 feet of rhyolite flows of various sorts before being abandoned after drilling an additional 530 feet of micrographic granite.

The rhyolite sequence contains many individual units that show their extrusive character. Most samples do not show any diagnostic petrographic character. The rhyolites generally carry phenocrysts of perthite, plagioclase, and lesser quartz and iron ores. These are set in a generally felsophyric groundmass composed mostly of quartz-feldspar and lesser iron ores and chlorite. No original femic minerals remain, and most chlorite appears to be deuteric in the groundmass rather than pseudomorphic. Spherulites, perlites, delicate flow bands, and relict eutaxitic structures are well defined locally.

The massive Precambrian granitic rocks in the Tishomingo-Belton anticlines (fig. 38) contrast strongly with the Cambrian volcanic rocks. The relief in the Precambrian part of the Arbuckle Mountains is also mild by comparison. The principal topographic surface is Cretaceous in age, which has been modified by erosion along streams. Virtually all the worthwhile outcrops are adjacent to the major streams.

The eastern Arbuckle Mountains contain four main Precambrian rock units. At the western end of the Tishomingo anticline the Troy Granite and an unnamed granodiorite are the principal units. The Troy can be seen to cut the granodiorite in widely separated localities along creeks, the Troy having been only slightly chilled at the contact. The Tishomingo Granite intrudes the Troy Granite and the granodiorite. The Tishomingo has been chilled for a distance of about 200 meters away from the contact with the older rocks. To the east the Tishomingo Granite intrudes a gneiss referred to here, informally, as the Blue River gneiss. Here the contact has not been chilled. The relationship of the Troy Granite and the granodiorite to the gneiss is not known because of the intervening intrusion of the Tishomingo Granite. It is possible that the gneiss represents metamorphosed Troy Granite and the unnamed granodiorite because the bulk compositions are similar.

It appears that the Tishomingo Granite probably acted as a metamorphic agent in contributing to the present texture of the Blue River gneiss. Foliations in the Blue River are strike-parallel to the Tishomingo contact. Near the center of sec. 8, T. 3 S., R. 7 E., the Tishomingo can be seen to intrude the Blue River gneiss. The exposures at this location are spotty, but the Blue River and the Tishomingo appear to be intimately mixed over a zone of about 400 meters. Near the contact the Tishomingo is slightly finer grained than normal but retains its porphyritic character. South and east of Reagan large mappable xenolithic masses of gneiss are clearly cut by the Tishomingo. These, based on poor exposures, crop out apparently continuously over an area of 1 square mile or less and probably represent roof pendants.

Isotopic dating of the granitic units has not led to clear-cut distinctions. All the units appear to fall into the range 1,260-1,360 m.y. (47 b.y. half-life), with rather high analytical errors on the individual isochrons. Mineral ages are very close to the whole-rock isochrons except for the Blue River gneiss; this age range indicates that the rocks are the oldest known in Oklahoma.

Four main types of dikes cut the massive granitic rocks. Diabases are most common and cut all units. Fine equigranular granite dikes also cut all units. Pale-pink microgranite porphyry dikes are found only in the Troy Granite and the unnamed granodiorite. Brick-red rhyolite porphyry dikes cut all units. The rhyolite dikes are petrographically related to the Colbert Rhyolite Group and yield Cambrian ages. Diabase can be seen to cut a rhyolite dike in at least one locality. Dating of the diabases has not been completely successful, apparently because of excess argon in some samples, but there is strong evidence that some diabases are Precambrian in age, close to the age of the granitic rocks, whereas others are Cambrian. Both the granite and microgranite dikes yield ages in the range of the massive granitic rocks.

The preferred strike direction for all dikes is about N. 60° W. This is also the late Paleozoic structural direction.

## STOP 4. Collings Ranch Conglomerate (middle Virgilian), NE¼ SE¼ NE¼ sec. 36, T. 1 S., R. 1 E., Murray County

*William E. Ham*

Exposed in the roadcut on the east side of the highway are magnificent outcrops of the Collings Ranch Conglomer-

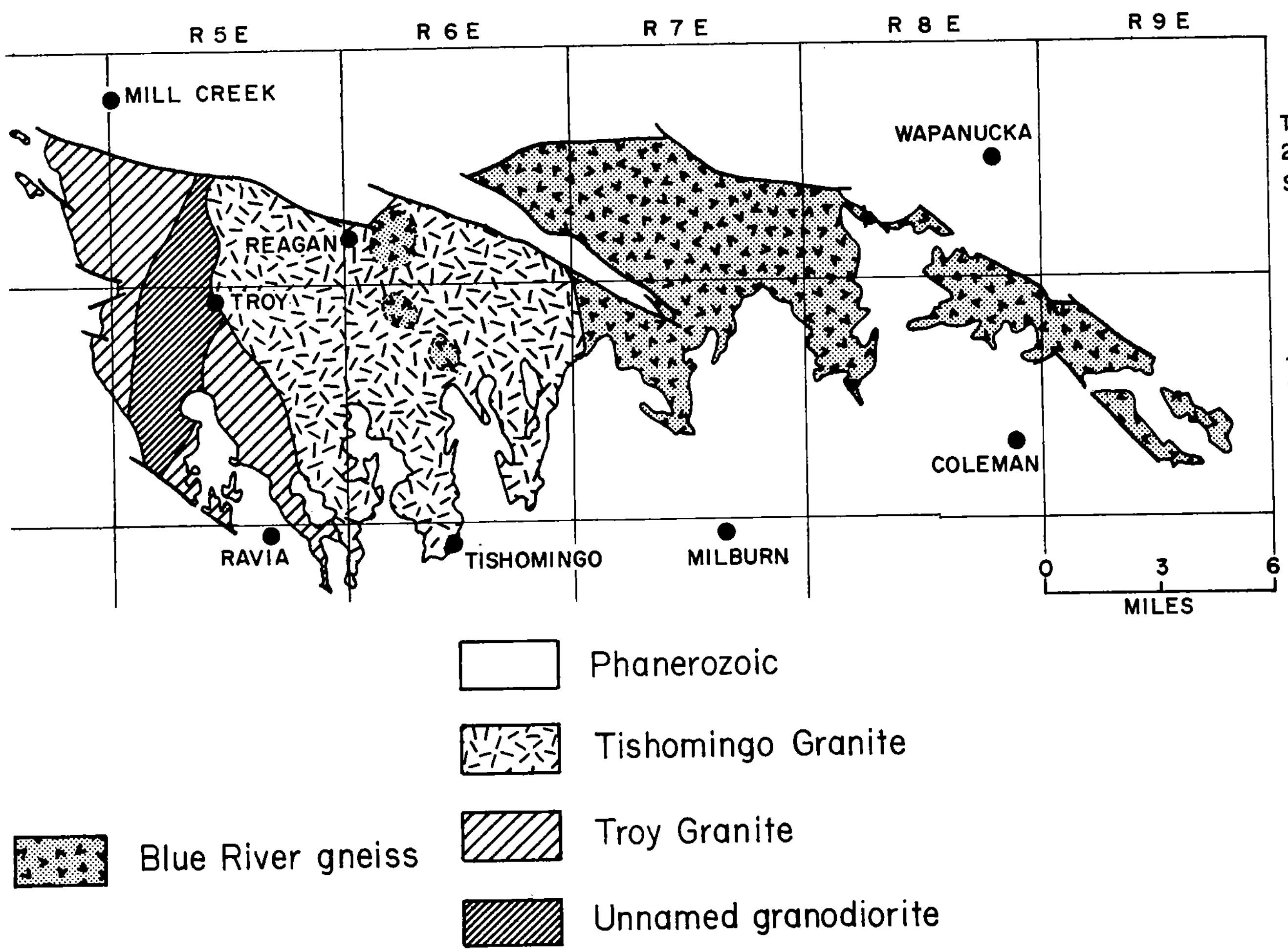



Figure 38. Preliminary map of Precambrian rocks in eastern Arbuckle Mountains.

ate (fig. 10), which occurs principally as a synclinal fold within a graben 0.5 to 1 mile wide. U.S. Highway 77 crosses the approximate middle of the outcrop belt. Consisting of limestone boulders and cobbles derived from the upturned beds upon which they lie with marked angular unconformity, the Collings Ranch Conglomerate is the first and thickest orogenic deposit of the Arbuckle anticline. It has a measurable thickness of 2,000 feet, but the top is eroded and the original thickness may have been as much as 3,000 feet. Most of the fragments have been derived from the thick Arbuckle Group, and the oldest so far found is a single cobble of Reagan sandstone. No feldspar, granite, or rhyolite is present to suggest that the basement rocks had been exposed by Collings Ranch time.

The unconformable contact of the conglomerate is particularly well displayed about 1 mile west of U.S. Highway 77 and on the hill directly south of the Methodist Assembly Grounds, where gently dipping conglomerate beds cap vertically dipping Viola Limestone beds. In normal relations, all underlying beds dip 70° or more.

Faulting is conspicuous at the north and south boundaries of the graben in which the Collings Ranch beds are contained. The north fault probably is continuous along the graben but is concealed for about 0.5 mile east of U.S. Highway 77 by a cover of young conglomerate beds that extend into the graben from the north, near the Methodist Assembly Grounds. This occurrence indicates that most, but not all, of the Collings Ranch was deposited before faulting ceased at this locality. The south fault of the graben is one of the principal throughgoing faults of the Arbuckle Mountains (Washita Valley fault). It has nearly vertical dip, is well exposed in three cuts on the hairpin curve, and continues westward to the edge of the Arbuckle Mountains. Here it passes beneath the Vanoss Conglomerate, thereby showing the Vanoss to be younger than the Collings Ranch.

As discussed in Part I, the age of the Collings Ranch Conglomerate, and thus the time of formation of the Arbuckle anticline, is considered to be Late Pennsylvanian (mid-Virgilian).

### STOP 5. Blue River gneiss, SW¼ sec. 5, T. 3 S., R. 7 E.

*Rodger E. Denison*

This area along the Blue River is underlain by granitic rocks showing a variety of metamorphic features. Taylor (1915) mapped the rocks in the eastern Tishomingo-Belton anticlines as Troy Granite. Although the rocks mapped by Taylor bear a very close resemblance to the Troy in many outcrops, there are distinct petrographic differences between these rocks and those in the western Tishomingo anticline near the town of Troy. Thus, the name "Blue River" has been applied informally to these gneissic rocks.

At only a few outcrops, such as this one, is the gneissic character of the Blue River well defined (see figs. 39-42). I believe this is mostly because the percentage of femic minerals (generally less than 5 percent) is low, which might otherwise make the gneissic character more apparent. The fabric of the rock in thin section is clearly different from the Troy Granite to the west. The gneissic rocks have a hypidiomorphic-granular texture and carry slightly perthitic microcline as the potash feldspar. The Troy Granite has a regular hypidiomorphic texture and carries microcline perthite. The average bulk mineral composition of the two units overlaps.

In most outcrops the gneiss is fairly homogeneous and generally fine grained with sparse, erratically occurring phenocrysts of pink potash feldspar. The major minerals are intermediate oligoclase, quartz, and slightly perthitic microcline, with biotite, muscovite, iron oxides, sphene, apatite, and zircon as common and widespread accessory minerals. Plagioclase averages about 45 percent, quartz 30 percent, and microcline 20 percent. The color index averages less than 4 percent. Thus it is not a true granite in average bulk composition, but an adamellite or quartz monzonite. This is also true of the other "granites" in the Arbuckle Mountains.

The amphibolite dike seen near the large parking area is composed of plagioclase, hornblende, and biotite, with lesser quartz, iron oxides, sphene, and traces of apatite. The dike strikes generally north-south. The bulk composition is similar to apparently unmetamorphosed quartz-bearing diorite dikes that cut the gneiss elsewhere. The granite gneiss host for the amphibolite is fine grained and shows rude preferred orientation of biotite in the plane of the amphibolite foliation.

The gneiss outcrop approximately 300 meters south of the amphibolite on an unnamed creek (fig. 39) is perhaps the most unusual basement-rock outcrop in Oklahoma. While it must look rather ordinary to those used to Precambrian geology in the Rockies or Canadian Shield areas, there is no other like it in Oklahoma. The rude banding is caused by alternate tonalitic to granodioritic gray gneiss and pink granitic gneiss. Fine-grained and coarse-grained phases of both compositions are present. There is a hint of foliation in the more femic-rich portions. This compositional layering is cut by aplitic, pegmatitic, and amphibolitic dikelets (figs. 41, 42).

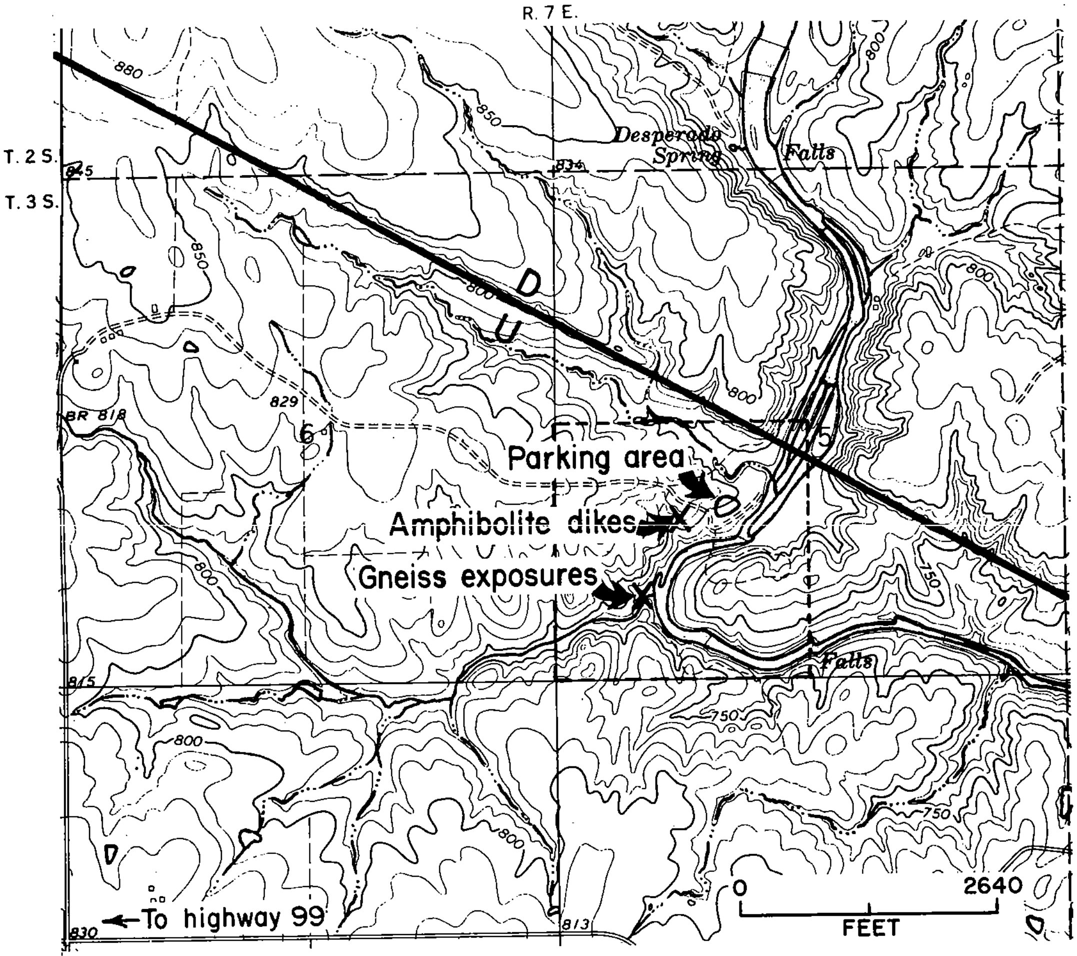
The banding and foliation of the gneiss strike generally north-south. The regional contact of the Tishomingo Granite-Blue River gneiss is also north-south. So the unusually well-developed gneissic character is probably due to the proximity of the intrusive Tishomingo Granite and the contrast of bulk composition within a small area.

The rather scoured and polished appearance of the gneiss outcrop is typical of its outcrop along the smaller creeks. These creeks carry a large sand load during torrential rains, whereas the Blue River does not carry a large sand load. The small waterfalls or rapids along the river are caused by the growth of travertine evidently over original bedrock outcrops. The headwaters of the Blue are in the Hunton anticline, which is underlain by carbonates of the Arbuckle Group. The carbonate is taken into solution there and is precipitated when passing over a natural rapids. Honey Creek in the western Arbuckles, particularly notable at Turner Falls, has an analogous travertine buildup. No other creek flowing through the Precambrian shows this feature.

### STOP 6. Capitol quarry at Ten Acre Rock, C NE¼ sec. 3, T. 3 S., R. 5 E.

*Rodger E. Denison and William E. Ham*

The largest area of exposure of Precambrian rocks in Oklahoma is in the eastern part of the Arbuckle Mountains, within the Tishomingo and Belton uplifts. Ten Acre Rock, probably the best known locality for these rocks, is a low bare hill of coarse-grained Tishomingo Granite that rises above Rock Creek near Troy (fig. 43). In early days of settlement it served as a prominent landmark for the region,



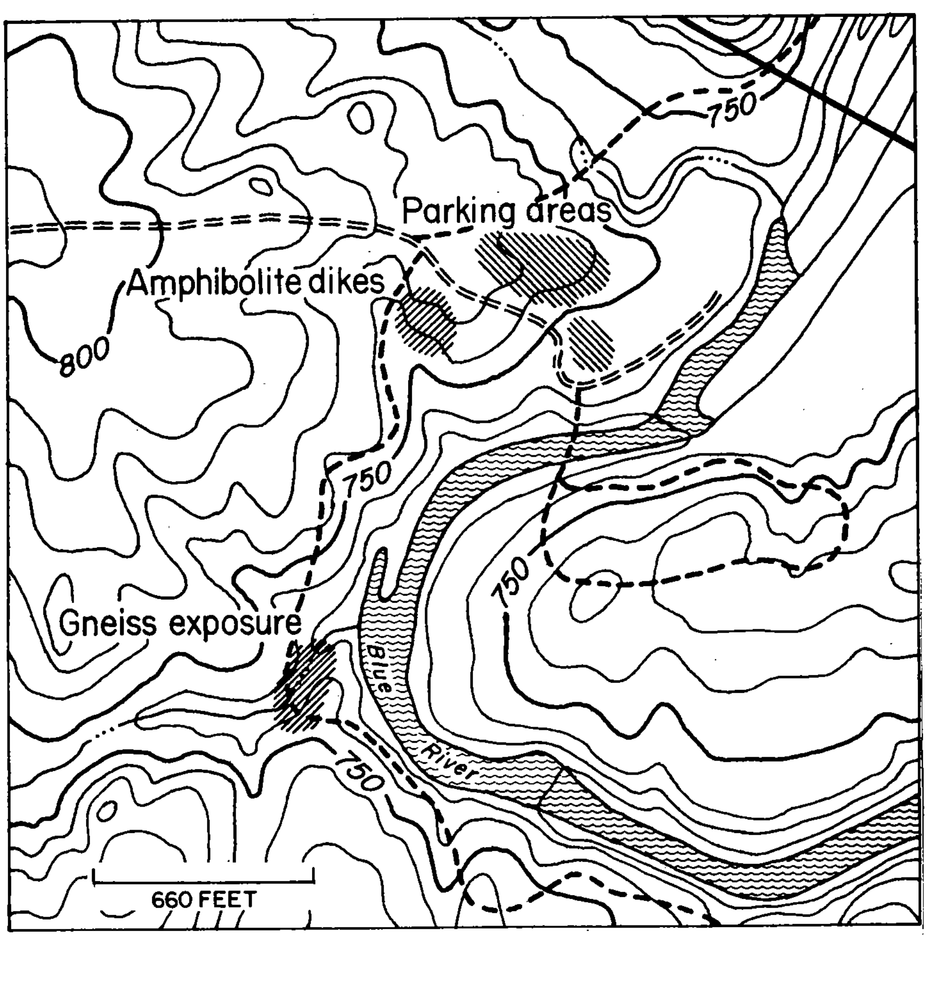




Figure 39. Stop 5. Top: Portion of topographic map of Connerville SE 7½-minute quadrangle. Bottom: Enlargement of central portion of topographic map, showing approximate exposures of Blue River gneiss.

Figure 40. Stop 5. Homogeneous, fine-grained Blue River gneiss (light) cut by amphibolite dike (dark, foreground).

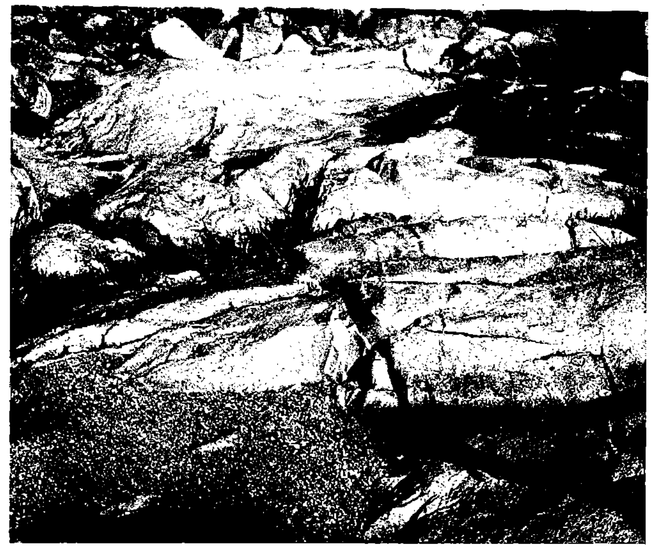


Figure 41. Stop 5. Well-exposed, banded and foliated Blue River gneiss on a tributary of Blue River. Note thin amphibolite dike (dark) cutting across foliation.

Figure 42. Stop 5. Closeup of exposure shown in figure 41. Amphibolite (dark) and aplite (light) dikes cutting foliation and banding of Blue River gneiss.

Figure 43. Stop 6. Capitol quarry at Ten Acre Rock. Photograph was taken in 1916, when Tishomingo Granite of Precambrian age was being quarried as a source of dimension stone for use in construction of state capitol at Oklahoma City. Quarry appears much the same today, not having been actively worked in the intervening years, except that original equipment has been removed.

and it achieved some fame when in 1915 a quarry was opened on its north slope for the production of dimensional granite for constructing the ground floors of the state capitol at Oklahoma City. Since that time it has been known as the Capitol quarry, although the quarry face itself has not been actively worked in succeeding years.

The Tishomingo Granite is the youngest massive igneous rock in the Tishomingo-Belton anticlines. It intrudes the Troy Granite to the west and the Blue River gneiss to the east. Only diabase, granite, and rhyolite dikes are younger than the Tishomingo. This outcrop is typical of the Tishomingo throughout the area.

Conspicuous phenocrysts of pink microcline perthite are set in a rather coarse matrix of pink microcline perthite, whitish plagioclase, and clear quartz. The plagioclase is intermediate oligoclase and typically contains fine sericitic alterations as well as small iron-poor epidote granules. The potash feldspars are fresh. The quartz contains very fine needles of rutile in abundance. Partly chloritized biotite is the characteristic femic mineral. Hornblende is sparse to absent. Sphene is a prominent mineral in resinous red wedges.

Opaque minerals account for less than 1 percent of the rock volume and are represented by relatively pure magnetite and lesser pyrite. Apatite and zircon are widespread and common accessory minerals. Muscovite is a sparse, erratically distributed mineral, which is rarely identifiable in hand specimen.

The rock locally is cut by pegmatite dikes and veinlets of epidote. In the central parts of some pegmatites are open spaces lined with euhedral microcline and quartz. Dark-purple fluorite also occurs but is decidedly uncommon.

The texture is hypidiomorphic and shows no significant signs of modification after crystallization. The grain boundaries are straight and smooth except near some larger dikes, where the granite is partially melted.

In the Capitol quarry the granite contains about 33 percent microcline perthite, 26 percent plagioclase, and 30 percent quartz. Nearly 5 percent feldspar alterations after plagioclase are present, so that the original plagioclase and potash feldspar must have been very nearly equal. There is about 3 percent biotite and 1 percent sphene, with other minerals present in amounts less than 1 percent. Granite in the small quarry directly across from Ten Acre Rock carries about 40 percent potash feldspar, 20 percent plagioclase, 34 percent quartz with 4 percent feldspar alteration, only about 1 percent biotite, and all other minerals less than 1 percent. This variation represents the most potash feldspar-rich and leucocratic of all the Tishomingo Granite samples examined.

The granite is about 1,270 m.y. (47 b.y. half-life) old, based on Rb/Sr whole-rock determinations. K/Ar ages on biotite are identical, within analytical error. The initial ratio of .7024 ± .0008 suggests that contamination by radiogenic sialic material was negligible. The granite, unlike most in the southern continental interior, has a generally poor ratio of rubidium to strontium. This unfavorable ratio, together with only a small variation in the ratio of rubidium to strontium and difficulty in obtaining suitably fresh samples for whole-rock analysis, has made age determination a very challenging problem.

A diabase dike is exposed at the bridge over Rock Creek just west of Ten Acre Rock. This diabase is somewhat unusual in having melted the granite adjacent to the dike. Most dikes show no contact effects, but several dikes scattered through all the granitic units have partially melted and contaminated the granites for a distance of a meter or so from the contact. An olivine-bearing diabase dike just south of Ten Acre Rock is clearly different from the one exposed on Rock Creek. The contact is not exposed, and its location and strike are marked by a line of residual boulders, a common expression of diabase occurrence in this rather poorly exposed province. The strike of these diabase dikes is about N. 60° W., which is the preferred statistical strike direction of all dikes in the Arbuckle Mountains.

Another diabase dike is exposed about 200 meters upstream from the bridge. At this locality the diabase was worked for gold in pre-Statehood days. No gold was recovered, and none has been found in any rock of the region, but the diabase itself is of interest geologically as the second most common type in the Eastern Arbuckle province. The diabase consists of small laths of plagioclase (labradorite) set ophitically in pyroxene, accompanied by abundant magnetite and a little biotite. The exceptional abundance of diabase cutting granite of this province is shown by cuttings of the Honeymon No. 1 Townsend, SE SE NW sec. 30, T. 5 S., R. 8 E., Bryan County, which penetrated 3,653 feet of granite and diabase basement rock. Of this penetration, 2,630 feet is granite and 1,023 feet, or 28 percent, is diabase. The diabase occurs in the form of dikes and sill-like bodies, some of them having a drilled thickness of 150 to 200 feet.

**STOP 7. Oil Creek Sandstone (Middle Ordovician) in quarry of Pennsylvania Glass Sand Corp., SW¼NE¼ sec. 6, T. 2 S., R. 5 E., Johnston County. Dip 10-15° S.**

*Rodger E. Denison and William E. Ham*

Silica sand, primarily for glass manufacture, has been produced at this locality for 50 years (figs. 44, 45). Thick deposits of high-purity, loosely consolidated sandstone have been worked in five principal pits over an area of about 200 acres, all in a gently plunging syncline that is sharply cut off at the south by the Mill Creek fault.

**Figure 44. Stop 7. East and south faces of Pennsylvania Glass Sand Corporation quarry, where Oil Creek Sandstone is worked as a source of high-purity silica sand for glass manufacture.**

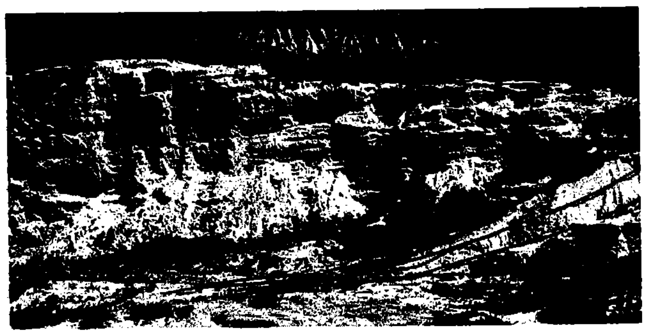


**Figure 45. Stop 7. South face of Pennsylvania Glass Sand Corporation quarry. Note thick, well-bedded nature of Oil Creek Sandstone.**

The sandstone member of the Oil Creek Formation in the syncline is 350 feet thick, the thickest of all Simpson Group sands in the Arbuckle Mountains. North of the plant are outcrops of the underlying West Spring Creek Formation, consisting of laminated fine-grained dolomites. Overlying the sandstone, and exposed near the top of the south walls of the southern pits, are skeletal calcarenites typical of the upper, or limestone, member of the Oil Creek Formation.

Cleanly washed, well-sorted sands of the Oil Creek, McLish, Tulip Creek, and Bromide Formations are widely distributed in southern Oklahoma, where they locally are prolific oil-producing reservoirs.

Crude sand from the quarry contains 99.57 percent $SiO_2$. After being shot from the face, pumped to the plant, washed, and dried, the sand contains 99.87 percent $SiO_2$ and 0.02 percent or less $Fe_2O_3$. It is widely sold in the United States and as far south as Mexico as melting sand in glass-making, as foundry sand, as a source of silica in making sodium silicate, and, in ground form (silica flour), as an abrasive, potters flint, or inert filler. About 69 percent of the washed product is fine sand (1/2 to 1/8 mm) and 26 percent is very fine sand (1/8 to 1/16 mm).

Thin sections cut from the impregnated sandstone show a very well-rounded and sorted sand-size fraction. The sand

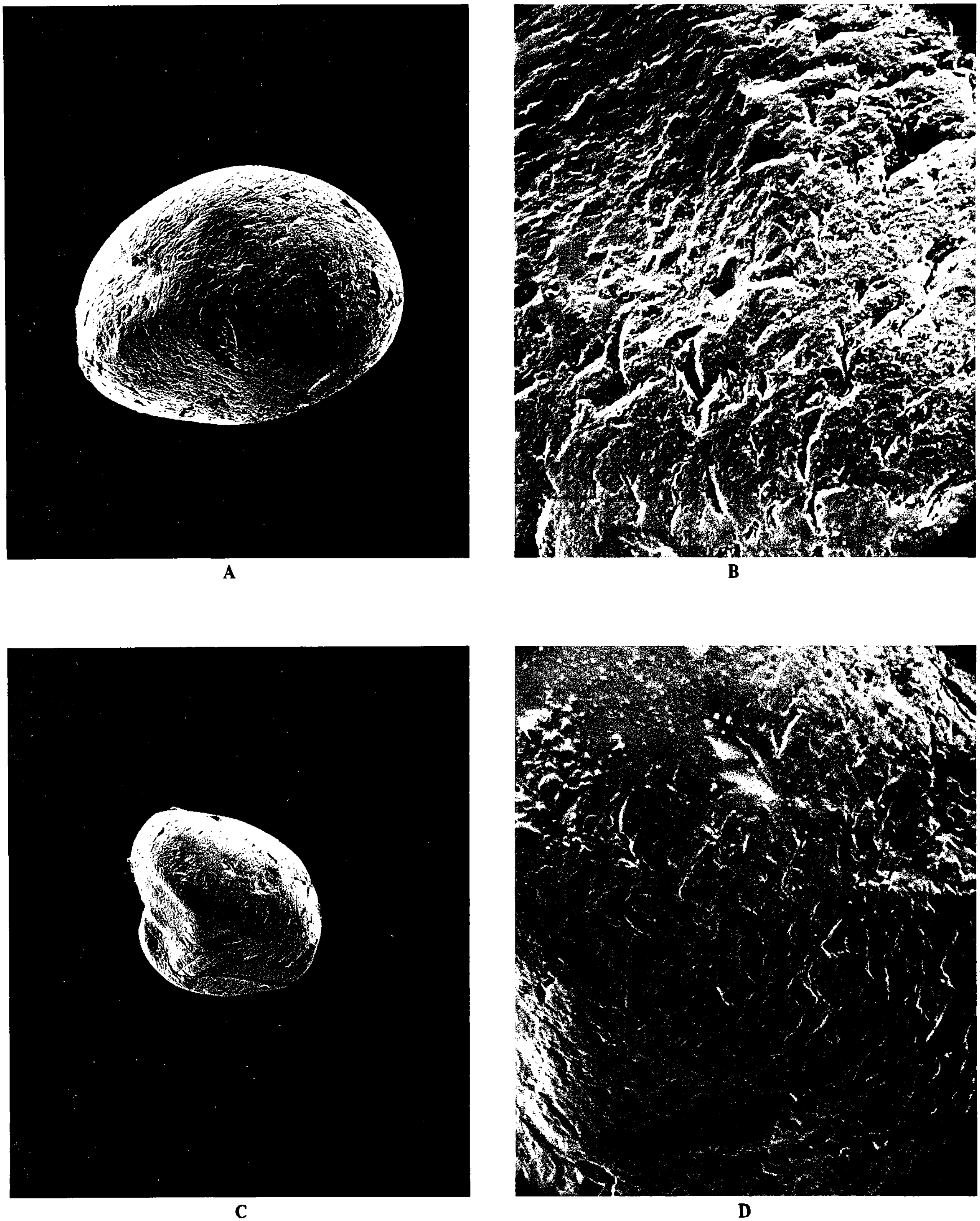



Figure 46. Scanning-electron photomicrographs of Oil Creek Sandstone from Pennsylvania Glass Sand quarry (Stop 7).
A. Very well-rounded sand grain, showing mild pressure-solution depressions and scalloped indentations. ×200.
B. Enlargement of sand grain shown in A. Small crystal faces of secondary quartz have formed within indentations. ×1,000.
C. More irregularly shaped sand grain, with healed fracture and dislocation near base. ×200.
D. Enlarged view of typical surface texture of sand grain shown in C. ×1,000.
(Photomicrographs by J. J. Porter, Mobil Research and Development Company, Dallas, Texas)

grains are coated by a thin rim of poorly crystalline illite. This rim is only about 2-3 microns wide and generally surrounds each grain completely. There is only scattered petrographic evidence of pressure solution, and the illite seems to separate most of the grains at contacts. The scanning electron microscope shows (fig. 46) mild, concave features that are probably pressure-solution phenomena. No quartz overgrowths can be seen. A few grains of microcline are present in the thin sections examined, but these are rare. Virtually all the quartz grains are single unstrained crystals. A few strained grains are present. What is normally thought of as polycrystalline quartz is lacking. The quartz grains are mostly clear, but a few contain bubble trains. Others contain various inclusions, mostly of rutile needles, but biotite flakes, tourmaline, zircon, apatite, and epidote can also be identified. The heavy minerals represent a minuscule percentage of the total volume of the sandstone. They are composed mainly of diverse well-rounded tourmaline, with lesser zircon and opaque minerals. A very small percentage of other heavy minerals is present; they are difficult to identify because they occur so sparsely. A number of the tourmalines show fractures along which breakage has occurred. These fractures are believed to have been formed during diagenesis, with the breakage having occurred during disaggregation.

The sandstone disaggregates in water; on placing a sample in a beaker of water the specimen soon becomes loose sand grains. A milky-clay fraction is held in suspension. This is the key to obtaining a clean glass sand.

There are dumps of well-cemented sandstone cobbles in the quarry that have been culled during processing. These are unusual in that they are composed of a distinctly bimodal, silica-cemented sandstone containing larger well-rounded "typical" sand grains set in a fine, poorly sorted and angular sand matrix. A number of the larger grains have been fractured and brecciated. These cobbles are from fracture zones that can be seen at several locations in the quarry.

The environment of deposition, as well as the source of the quartz in the Oil Creek Formation (and other sandstones in the Simpson Group), is not clear. The problem is simply that the underlying rocks of the Arbuckle Group and their equivalents extend an enormous distance in all known directions away from the Arbuckle Mountains, which could not have been the source of the quartz sand. But in Middle Ordovician time glass sands appeared in Oklahoma, Arkansas, Missouri, and northward into Minnesota. The sand came either from a far-distant source area or from a closer, unknown source area, e.g., an area now hidden beneath the Ouachita thrusts to the southeast. The formation here lacks the critical sedimentary structures that might indicate an environment of deposition. The very lack of diagnostic structures in such a clean sand is puzzling.

The illite coating of the sand grains is almost certainly secondary. The green waxy appearance of the clays is typical of shales of the Simpson Group. The clay was probably brought in by migrating fluids after deposition.

Scanning electron microscopy shows the surface of the sand grains to be characterized by finely scalloped indentations and a generally etched appearance (fig. 46). The pressure-solution depressions are a common but mild feature. Evidence of overgrowths are sparse, but a few crystal faces can be seen growing locally on some sand grains. The frosted appearance of the grains in hand specimen has resulted from the original appearance modified by transportation processes. The abundant secondary silica cement that is found where the sand grains are broken indicates that the illite coating formed early in the diagenetic process and has served to protect the grains from secondary effects.

**STOP 8. Deese (Desmoinesian) strata on Dry Branch of Buckhorn Creek, north-central part of sec. 26, T. 1 S., R. 3 E., Murray County. Strike mostly N. 60° E., dip 32° NW.**

*T. L. Rowland, William E. Ham, and Richard L. Squires*

This area is of classic importance because its excellent outcrops afford documentation for major geologic concepts in the building of the Arbuckle Mountains. A homoclinal sequence of Desmoinesian strata, stratigraphically dated by fusulinids, disconformably overlies the Late Mississippian Springer Shale. Morrowan and Atokan sediments have been eroded as a result of epeirogenic uplift of the craton. The Hunton anticline in the northern part of the Arbuckle Mountains was undergoing uplift and erosion throughout Desmoinesian time and was intermittently contributing pebble-cobble conglomerates to the shallow marginal basins.

On Dry Branch the lower Desmoinesian conglomerates consist mostly of debris from limestones of the Hunton Group, whereas the middle Desmoinesian conglomerates consist mostly of fragments from the Viola Limestone, thus representing a stratigraphic inversion resulting from progressive uplift of the source area.

Desmoinesian and older beds were then folded during the mid-Virgilian Arbuckle orogeny, and the strata were nonconformably covered by a gently dipping blanket of late Virgilian Vanoss Conglomerate. The Vanoss in this area consists chiefly of boulders and cobbles from the Arbuckle Group, together with all other rocks of the Arbuckle Mountains down to and including Precambrian granite. The low dip of the Vanoss Conglomerate may be seen in the field and inferred from the outcrop pattern of figure 47.

Investigations of fusulinids from the Dry Branch section by Dwight W. Waddell, Shell Oil Company, Midland, Texas, have been especially helpful in ascertaining stratigraphic ages and correlations. The principal fusulinid-bearing limestones are indicated in figure 47 as beds I, II, III, and IV, which range through a stratigraphic thickness of 1,000 feet. The oldest is bed I, about 50 feet above the base of the sequence, containing *Fusulinella* of Waddell's zone III of the Ardmore basin (Waddell, 1966). It is of early Desmoinesian age, approximately equivalent to the Pumpkin Creek Limestone of the Ardmore basin and to the Savanna Formation of the Oklahoma coal basin. In beds II (fig. 48), III, and IV are species of *Fusulina* and *Wedekindellina*, belonging to Waddell's zone IV of the Ardmore basin, of early middle Desmoinesian age and including the lower-middle part of the Deese Group as well as the Boggy-Sonora of the Oklahoma coal basin.

An item of special interest is the Buckhorn asphaltic-limestone quarry in the SW¼ SE¼ sec. 23, T. 1 S., R. 3 E., about one-fourth mile north of the Defratus ranch house. Middle Desmoinesian (Arnold-Boggy) fossiliferous limestones are impregnated with asphalt, evidently introduced as petroleum shortly after deposition of the Vanoss Conglomerate. As a result, the molluscan shells of the limestone retain their original aragonite mineralogy, and the cephalopods retain, in addition, their original iridescence.

Additional information concerning the shell mineralogy and chemistry has been obtained from a Ph.D. dissertation

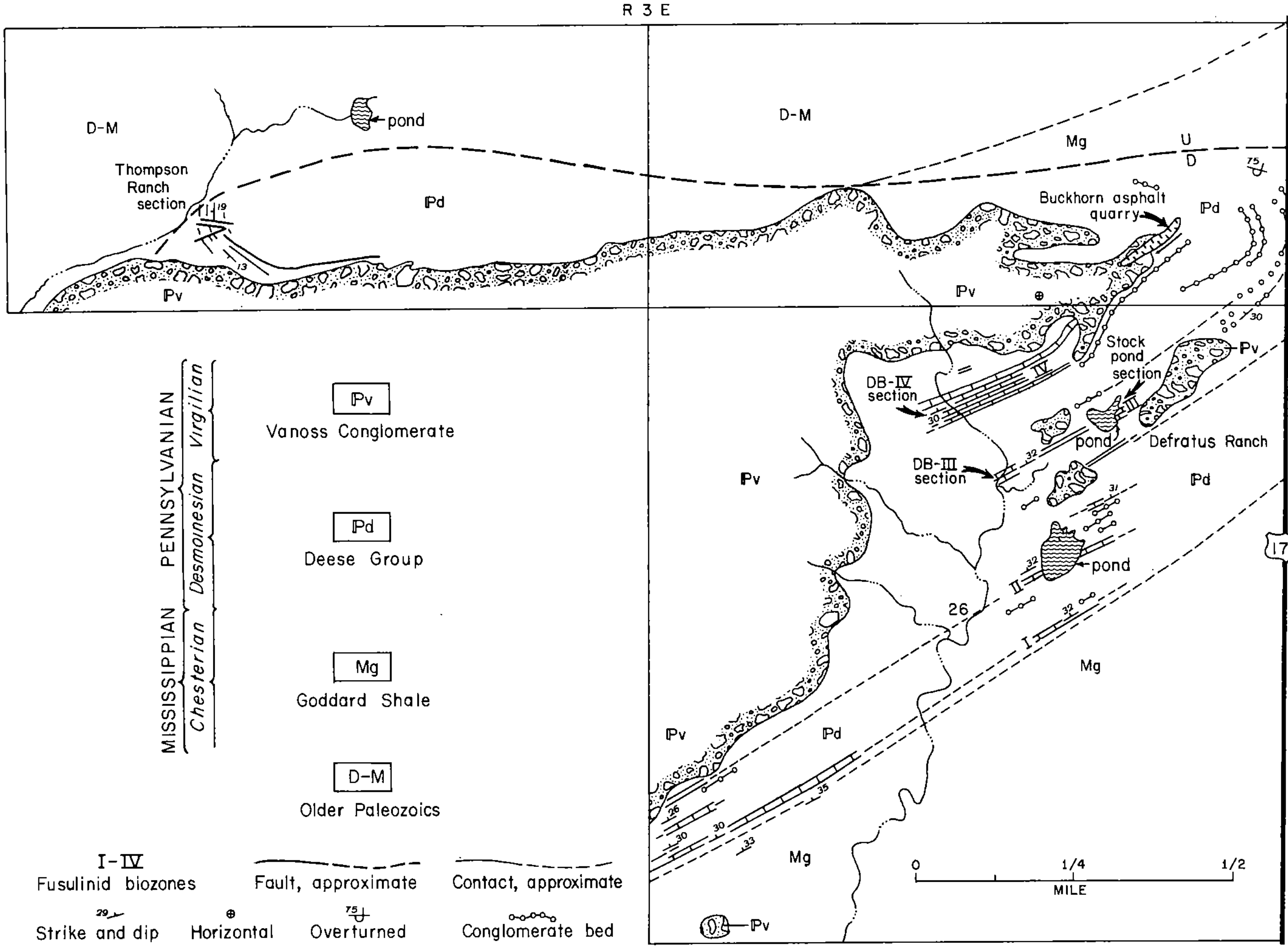



Figure 47. Stop 8. Geologic map of Buckhorn asphalt quarry region. Early Pennsylvanian epeirogeny is demonstrated by disconformable relations of early Desmoinesian Deese beds on Springer Shale of Late Mississippian age and by occurrence of numerous conglomerate beds within Deese. Modified from Ham (1969, fig. 40) and Squires (1973, fig. 5).

Figure 48. Fusulinid calcilutite from limestone bed II of Buckhorn area (Stop 8). Micrite matrix is partly recrystallized into microgranular calcite. ×12.5.

by Richard L. Squires, prepared when he was a student at the California Institute of Technology. Squires studied the area in detail, especially the quarry. Figure 49 is a lithologic section of the quarry; it also identifies the floral and faunal constituents of the asphalt beds.

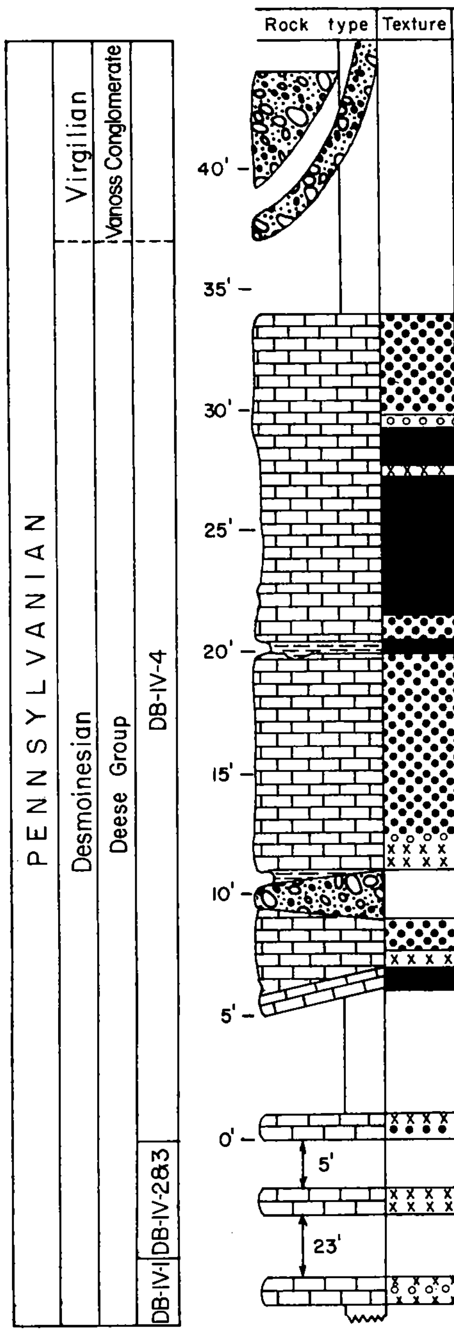
Some of the major points that resulted from Squires' work are summarized as follows.

1. Early sealing of the quarry beds by oil preserved the microarchitecture and mineralogy of various skeletal carbonates. The oil prevented the grain-supported limestones from becoming well cemented and allowed them to become compacted during the Arbuckle orogeny.

2. Most of the fossils occur as fragments in several skeletal-debris grainstones, which are inferred to be shallow, turbulent-water channel deposits. Underlying calcareous, skeletal mudstones and wackestones were deposited in less turbulent-water environments. The original mineralogy of skeletal carbonates was established for the first time in many specimens; some of these consisted entirely of aragonite, some of outer-layer calcite and inner-layer aragonite, and some entirely of calcite.

3. Diagenetic effects were detected in skeletal carbonates. The amount of replacement calcite and degree of obliteration of shell microarchitecture in the skeletal aragonites increase with decreasing asphalt content. Asphalt-impregnated skeletal calcites contain more Mg and usually less Sr than corresponding nonasphalt-impregnated specimens.

4. Data on the Mg and Sr concentrations of the best




| Unit | Lithologic description | Floral and faunal constituents |
|---|---|---|
| 15 | Ls cobble conglomerate: nonasphaltic, poorly sorted and moderately well-rounded medium-size pebbles to small-size cobbles. | |
| | Local unconformity. | |
| | Covered section: clayey shale. | |
| 14 | Chert and ls pebble conglomerate: nonasphaltic, poorly sorted and well-rounded small-size pebbles to small-size cobbles. | |
| | Unconformity. | |
| | Covered section: clayey shale? | |
| 13 | Foraminifera-cephalopod grainstones: mudstones and packstones in lower foot, asphaltic (avg. 20% by wt.), insoluble residue = 13% in lower part, minor amount fine-silt to medium-sand-size detrital chert and qtz, with 2-3% granule to medium-pebble-size chert and nonasphaltic ls clasts in upper 2 feet; microchannels and crossbedding in lower foot. | Plant fragments, small Foraminifera, *Wedekindellina?* sp., *Chaetetes* cf. *C. favosus* fragments, *Penniretepora?* sp., *Streblotrypa?* sp., *Anthracospirifer opimus*, brachiopod spines, gastropods, *Plagioglypta?* sp., nautiloids, bivalves, *Bairdia* sp. A., *Cavellina* sp., and echinoderm frags. |
| 12 | Bivalve mudstones: partly asphaltic to nonasphaltic, insoluble residue = 7% in lower foot, small amount of medium- to coarse-silt-size detrital chert and qtz; minor amount of replacement dolomite in lower part. Channel in upper part. Microchannels, crossbedding and laminated bedding in lower and upper foot. | Plant fragments, small Foraminifera (includ. *Globivalvulina* sp.), *Anthracospirifer opimus*, *Prothyris* sp., *Acanthopecten?* sp., and echinoderm fragments. Coiled nautiloid fragments and *Proparaparchites* sp. in channel. |
| 11 | Mollusk-ostracode mudstones: gastropod-ostracode coquina in lower part, slightly asphaltic, insoluble residue = 40%, trace amount well-rounded qtz; some silicification and replacement dolomite. | *Wedekindellina?* sp., *Chaetetes* aff. *C. favosus*, *Anthracospirifer opimus*, gastropods, *Pseudorthoceras knoxense*, *Prothyris?* sp., *Hypotetragena* sp., *Proparaparchites* sp., and echinoderm frags. |
| 10 | Coal(?) bed: gilsonitized zone with emanating dikes. | Plant fragments and *Proparaparchites* sp. |
| 9 | Foraminifera-mollusk grainstones: wackestones and packstones in lower foot, Foraminifera-cephalopod coquina in upper part, asphaltic (avg. 12% by wt.), local zones of gilsonite, insoluble residue = 33% in lower part, 13% in upper part; minor coarse-silt- to medium-sand-size clasts; microchannels in lower foot and middle of unit, crossbedding(?) in lower foot. | Plant fragments, small Foraminifera, *Wedekindellina?* sp., *Chaetetes* sp. fragments, bryozoans, brachiopod spines, *Naticopsis* sp., *Trachydomia whitei*, *Pseudorthoceras knoxense*, "*Orthoceras*" *unicamera*, *Metacoceras cornutum*, *Domatoceras* sp., *Pseudoparalegoceras* sp., *Wellerites mohri?*, unidentified cephalopod fragments, *Chaenocardia ovata*, *Bairdia* sp., *Proparaparchites* sp., and *Archaeocidaris megastyla?* spines. |
| 8 | Calcareous sh: 5% small- to large-size pebbles. | Bivalves. |
| 7 | Chert peb. congl: asphaltic, poor sort., mod-well rnd, 40-50% granules to v. lge pebs; intbd. lamin. grainstones; microchannels. | Silicified logs, *Chaetetes* sp. frags., and nautiloids. Small forams and echinoderm fragments in interbedded grainstones. |
| 6 | Foram packstones and grainstones: wackestones and packstones at base, asphaltic, clasts and plants incr. in content upwds; microchannels. | *Calamites?*, sm. forams, *Wedekindellina?* sp., *Straparolus (Euomphalus)* sp., nautiloids, *Bairdia* sp., *Proparaparchites* sp., and echinoderm frags. |
| 5 | Chaetitid mudstone: asphaltic, minor amount coarse-silt-size qtz; some large *in situ Chaetetes* cf. *C. favosus* colonies. | *Chaetetes* cf. *C. favosus* and *Straparolus (Euomphalus)* sp. |
| | Covered section. | |
| 4 | Foram wackestone and grainstone: asphaltic, insol. res. = 30% tr. silt-size clasts, 2% med-silt- to v.f.-sand-size clasts in up. pt. | Small Foraminifera, *Trochammina* sp., *Climmacammina* sp., *Fusulina* sp., gastropods, *Glyptopleura* sp., *Bairdia* sp., and echinoderm fragments. |
| | Covered section. | |
| 3 | Wackestone: some asphalt. | Small forams, bryozoans, spiriferid brachiopods, gastropods, bivalves, and *Bairdia* sp. |
| | Covered section. | |
| 2 | Fusulinid wackestone with interbedded packstone: nonasphaltic, trace medium- to very fine-silt-size detrital chert and qtz. | *Trochammina* sp., *Fusulina* sp., calcareous sponge spicules, productid brachiopods, ostracodes, and echinoderm fragments. |

Grainstone — Packstone — Wackestone — Mudstone

Figure 49. Stratigraphic section of rocks exposed in Buckhorn asphalt quarry (Stop 8). Modified from Squires (1973, fig. 6).

preserved specimens indicate the following: The Sr/Ca ratio for the coiled nautiloids is similar to that for the modern-day *Nautilus* sp.; the Mg contents in the calcites of the Foraminifera, bivalves, and ostracodes are similar to those in related Holocene forms; the shell walls of the extinct orthocone nautiloids have lower Sr contents relative to the cameral deposits. These large differences are apparently due to the "vital effect" of the organism.

## STOP 9. Asphaltic sand of Oil Creek Formation (Middle Ordovician) in abandoned workings, N½ SW¼ SE¼ sec. 15, T. 1 S., R. 3 E. Dip 15° SE.

*William E. Ham*

In a broad sense, all the rock-asphalt deposits about 3 miles south of Sulphur are referred to as the Buckhorn asphalt district. Bedrock strata of various ages and rock types under or near the unconformable cover of Vanoss Conglomerate contain asphalt locally and many quarries have been opened since mining began in 1890. The asphaltic rocks were eagerly sought in earlier days and extensively used for road surfacing. Mining was particularly active before refiner's asphalt was available in quantity, but even as late as 1943 the district produced slightly more than 100,000 short tons of asphaltic rock per year. Total cumulative production exceeded 1 million tons before mining ceased in 1962.

Although the range in age of asphaltic rock in the Buckhorn district is from Middle Ordovician to Middle Pennsylvanian, virtually all production has been obtained from the Oil Creek Sandstone of Middle Ordovician age. With a thickness of 350 feet and a bitumen content of approximately 8 percent, it has been the richest asphaltic rock of the area. It was blended with Viola Limestone, quarried near Dougherty and containing 3 percent bitumen, in a proportion of about two-thirds limestone and one-third sand and sold for road patching and surfacing.

Asphaltic rocks occur locally beneath the Vanoss Conglomerate on the northern margin of the Arbuckle Mountains along a distance of approximately 25 miles. The asphalt occurs without regard to structural traps but rather is sealed by the overlying conglomerate. This situation seems to indicate that oil migrated from nearby basins into the localities presently seen, there decomposing into asphalt through loss of the volatile fractions.

A superlative example of unconformity is seen along the north wall of the pit (fig. 50). Oil Creek Sandstone of early Middle Ordovician age is unconformably overlain by the Vanoss Conglomerate of Late Pennsylvanian age. Fragments of the sandstone are mixed in the conglomerate with other rocks of the Arbuckle Mountains, including Precambrian granite, all derived by folding and uplift accompanying the mid-Virgilian Arbuckle orogeny.

Figure 50. Stop 9. North face of abandoned quarry in Oil Creek Sandstone. Note truncation and channeling of Oil Creek by overlying Vanoss Conglomerate.

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