

**KANSAS GEOLOGICAL SURVEY  
OPEN-FILE REPORT 94-53**

**FACIES AND POROSITY RELATIONSHIPS OF ARBUCKLE STRATA:  
INITIAL OBSERVATIONS FROM TWO CORES,  
RICE AND RUSH COUNTIES, KANSAS**

by

Evan K. Franseen

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## **INTRODUCTION**

This paper reports on initial results from macroscopic and petrographic examination of Arbuckle strata from two cores located in Rush and Rice Counties, Kansas. Based on some additional reconnaissance of other cores housed at the core facility at the Kansas Geological Survey, the facies and features observed in the two studied cores appear to be representative of other cores that penetrate the Arbuckle in Kansas. The data reported here are the initial stages of a planned integrated study of the sedimentology, stratigraphy, structure, petrology, and geochemistry of Arbuckle rocks designed to improve reservoir classification relating porosity and permeability trends to depositional patterns, early diagenesis, structural controls, karst trends, and burial diagenesis.

### **Importance of Arbuckle Rocks in Kansas**

Arbuckle Group rocks (Cambrian and Lower Ordovician) represent an important record of sediment deposition in the history of the North American continent and they contain important accumulations of hydrocarbons (oil and gas) and base metal deposits. Despite their economic importance, the geologic history of these rocks in Kansas remains relatively poorly understood, both on a local and regional scale. A geologic study of rocks of the Arbuckle Group may open new avenues of applied research that could lead to improved economic development of an important resource.

Arbuckle strata account for about 40% of the volume of produced oil and known reserves in Kansas (Newell *et al.*, 1987). This represents a significant amount of revenue for the over 2 billion dollar Kansas oil and gas industry (Petroleum Independent, 1993). The Arbuckle and equivalent reservoirs in the Midcontinent are generally considered to have favorable reservoir qualities (i.e.

porosity and permeability) that are directly related to basement structural elements (e.g. fractures, regional uplifts, minor horst and graben features) and enhanced by karstic features (dissolution developed by prolonged subaerial exposure that began immediately after Arbuckle deposition and likely continued in some areas for over 200 million years, until the Pennsylvanian). The overwhelming acceptance of karst control on reservoir development in the Arbuckle has led to drilling practices that have focused on the upper Arbuckle surface and upper 30 feet or so of Arbuckle strata, virtually ignoring lower Arbuckle strata and any potential additional petroleum reservoirs within the Arbuckle.

The shallow drilling philosophy based on the fracture-controlled karst reservoir model has worked well in Kansas, but may be only scratching the surface of an important resource. Despite the prolific production history, Arbuckle strata in Kansas have remained virtually unstudied, apart from earlier general descriptive studies (e.g. McCracken, 1955; Jewitt, 1951, 1954; Walters, 1946, 1958; Merriam, 1963; Adler, 1971; Cole, 1975) and the level of detail known about the sedimentology, stratigraphy, and diagenesis of Arbuckle rocks in Kansas is much less than is known about age-equivalent strata (e.g. Knox and Ellenburger) that are producing significant petroleum in surrounding states.

Therefore, a detailed geologic study of the Arbuckle and the controls on porosity and permeability development in Kansas would be useful because: 1) The Arbuckle is the largest single producing horizon in Kansas, 2) Arbuckle strata are relatively understudied and poorly understood in Kansas, 3) The assumed influence of fracture-controlled karst on all Arbuckle reservoirs is not adequately tested and it may not apply to all Arbuckle reservoirs, and 4) There are extensive, readily available subsurface data on Arbuckle strata in Kansas. These strata are penetrated by hundreds of wells in Kansas thereby providing

an extensive geophysical log database. Over 115 cores of the Arbuckle interval from 35 counties in Kansas are housed in the Kansas Geological Survey core facility (Fig. 1). In addition, an extensive suite of Arbuckle cores (about 70,000 pounds) from the El Dorado field in Butler County was recently donated to the Kansas Geological Survey and is housed in the core facility.

## **GEOLOGIC BACKGROUND**

Kansas is characterized by broad basins and domes covering thousands of square kilometers. Prominent uplift and subsidence occurred episodically throughout the Phanerozoic, separated by periods of gradual deformation (Newell *et al.*, 1989). Two prominent structural uplifts that affect the Paleozoic rocks in Kansas, the Nemaha uplift and Central Kansas uplift (Fig. 2), represent significant Early Pennsylvanian deformation likely associated with similarly aged plate convergence along the Ouachita Mountains orogenic belt in Arkansas (Newell *et al.*, 1989). The crests of these uplifts in Kansas are sites of extensive erosion and truncation of the pre-Pennsylvanian strata. This uplift and erosion locally affected Arbuckle strata, especially on the Central Kansas uplift where Pennsylvanian strata directly overlie Arbuckle strata or basement rocks where Arbuckle strata are absent (Fig. 3).

### **Arbuckle Stratigraphic Framework**

Definitions of the Arbuckle Group in Kansas differ somewhat, but generally these rocks are thought to consist of Cambrian and Lower Ordovician rock units between the underlying Reagan or Lamotte Sandstone and overlying Simpson Group (Merriam, 1963; Zeller, 1968). Some authors include the Lamotte Sandstone, Bonneterre Formation, and Reagan Sandstone in the Arbuckle Group (e.g. Cole, 1975) (Fig. 4). With either definition the Arbuckle is

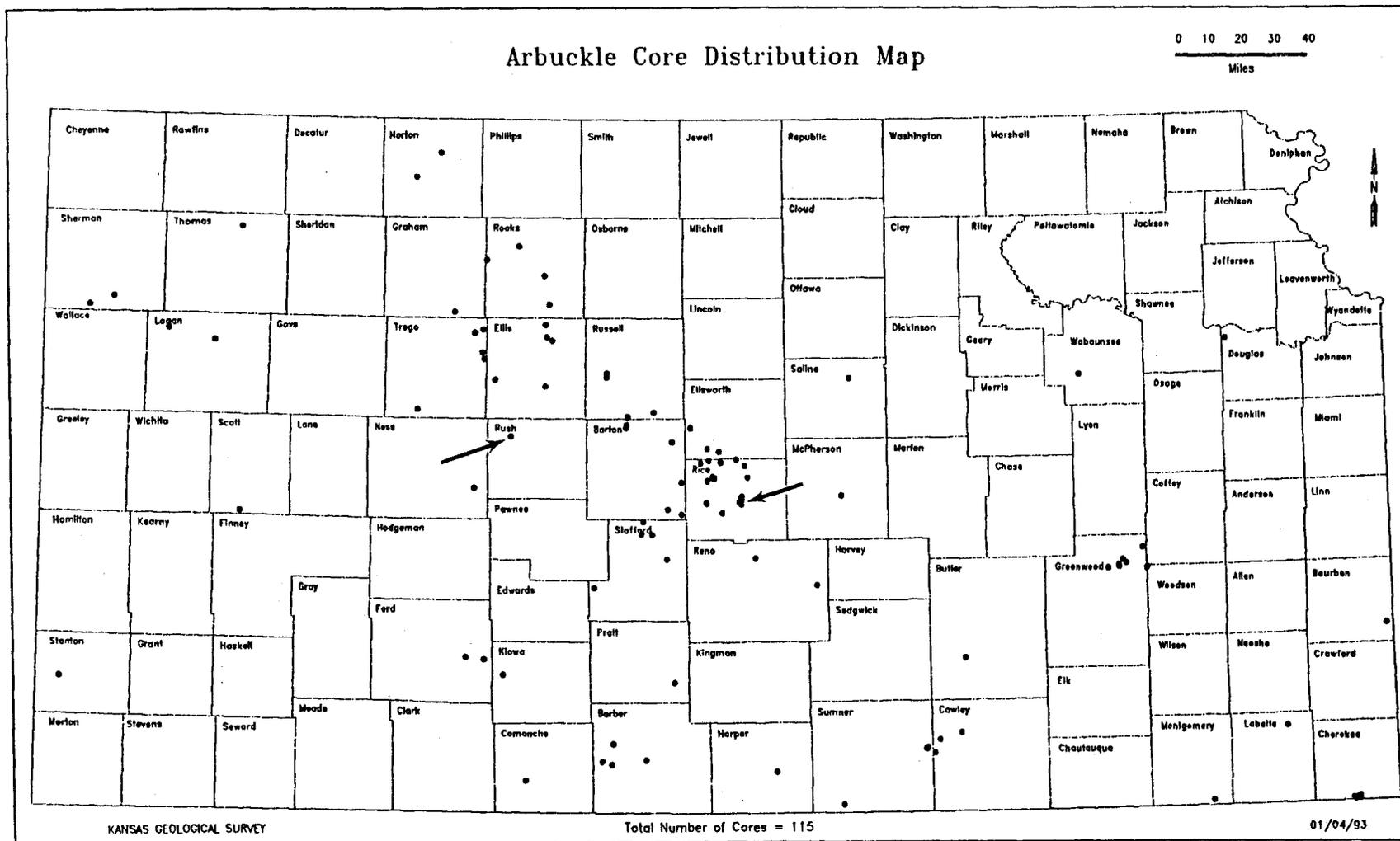


Figure 1: Map showing distribution of Arbuckle cores housed at the Kansas Geological Survey. Cores are available from over 115 wells scattered over 35 counties. This data does not include the recently donated 70,000 pounds of core from the El Dorado field in Butler County. Arrows show the locations of the two cores of this study.

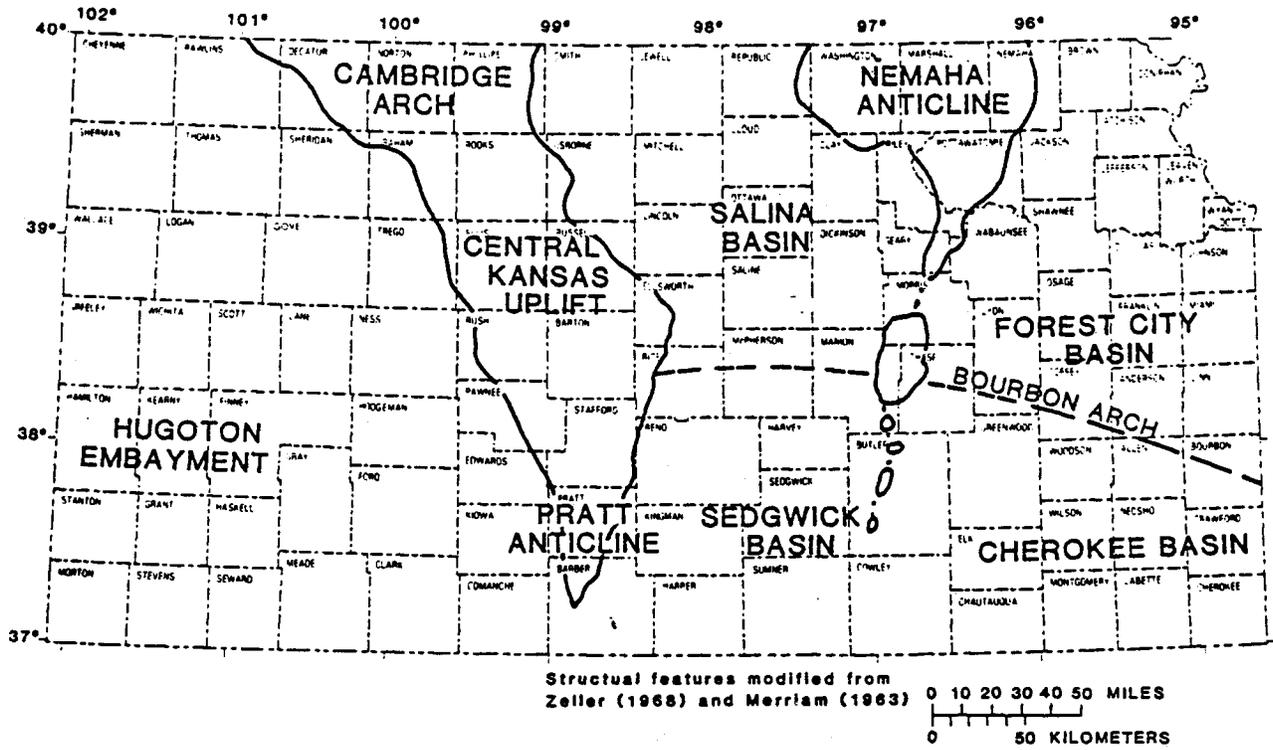


Figure 2: Map of major structural features in Kansas.



Time Stratigraphic Units		Rock-Stratigraphic Units		
SYS-TEM	Series	Based on correlation with surface sections (Kansas Geol. Survey Bull. 189)	Lithology	Based on common usage by Kansas petroleum geologists and used in this report
ORDOVICIAN	Upper	Maquoketa Shale		Maquoketa Shale
	Middle	Viola Limestone		Viola Limestone
		Simpson Group		Simpson Group
	Lower	Arbuckle Group		"Arbuckle" Group
CAMBRIAN	Upper	Bonneterre Dolomite		
		Lamotte Sandstone		
Precambrian		Precambrian		Precambrian

Figure 4: Stratigraphic column of Cambro-Ordovician units in Kansas showing two different (but similar) usages for Arbuckle Group strata in Kansas.

present in most of Kansas and is absent only in areas of northeastern and northwestern Kansas, and over ancient uplifts and buried Precambrian highs (Cole, 1962, 1975; Denison, 1966; Walters, 1946). The basal contact of the Arbuckle Group is an unconformity (sub-Sauk surface of Sloss, 1963) with basement rocks which in Kansas can range in age from Precambrian to Lower Ordovician (Cole, 1975). As throughout the craton of North America, the upper contact of the Arbuckle Group is also an unconformity (sub-Tippecanoe surface to sub-Absaroka surface of Sloss, 1963). The Arbuckle is thin to absent in parts of northeastern Kansas due to pre-Simpson uplift and erosion (Newell *et al.*, 1987). The Arbuckle is locally absent on the Nemaha uplift, Cambridge arch and Central Kansas uplift due to pre-Pennsylvanian erosion (Walters, 1946; Jewett, 1951, 1954; Merriam, 1963). The Arbuckle typically is unconformably overlain by Middle Ordovician Simpson sandstone and shale. However, reconnaissance work on the cores has identified cores where Arbuckle rocks are directly overlain by Viola Shale or Mississippian strata as well. In areas of greatest uplift since Ordovician time, such as the Central Kansas uplift, the Arbuckle Group may be unconformably overlain by beds as young as Pennsylvanian (Merriam, 1963; Cole, 1975) (Fig. 3).

Arbuckle Group rocks thicken from north to south and are thickest, up to 1390 feet, in the southeastern corner of Kansas (Cole, 1975). In Kansas the Arbuckle Group consists mainly of dolomite with scattered beds containing chert and sand (Merriam, 1963). Minor amounts of glauconite and pyrite occur throughout the Arbuckle (Merriam, 1963).

In earlier studies the Arbuckle had been subdivided and correlated with equivalent exposed strata in adjacent states by study of insoluble residues (McCracken, 1955) and various local subdivisions were proposed (e.g., Walters, 1946; 1991). Where the Arbuckle was eroded along the flanks of

uplifted areas, the dolomites and limestones were deeply weathered (Walters, 1958; Merriam, 1963). To date, the only stratigraphic studies that have attempted to subdivide and correlate Arbuckle strata in Kansas based on lithologic data were done by some early workers who used chert horizons and insoluble residues to correlate from the subsurface of Kansas to outcrops in Missouri (e.g. Ockerman, 1935; McCracken, 1955). Although the initial reconnaissance study of this report confirms the existence of subtidal to peritidal facies in Arbuckle cores from Kansas that, at least locally, occur in cyclic succession, no previous studies have documented these cycles or tried to correlate cycles within the context of a sequence stratigraphic framework in Kansas. Planned studies will utilize well logs and cores to further document the Arbuckle cycles and sequence stratigraphy, in combination with conodont analysis for age dating, to correlate and understand the genetic packaging of Arbuckle strata.

### **INITIAL CORE ANALYSIS**

Reconnaissance study to date of several cores reveals that the Arbuckle in Kansas consists of subtidal to peritidal facies with features similar to those described for Arbuckle-equivalent rocks outside of Kansas (e.g. Kerans, 1990; Lindsay and Koskelin, 1991; Montanez, 1992; Goldhammer et al., 1993).

One of the studied cores (#1 Littler) is from the Hampton field area in Rush County located on the Central Kansas Uplift (Figs. 1, 2). It extends down for about 50 feet from near the Arbuckle-Cherokee(?) contact. A more extensive core that has been studied in some detail comes from Rice County (#1 Caldwell, Lyons Field), a position situated on the southeastern flank of the Central Kansas uplift (Figs. 1, 2). This core extends into the Arbuckle for 133 feet from the Simpson-Arbuckle contact.

## **Depositional Facies**

The depositional facies in both of the cores consist predominantly of coarse-grained skeletal, intraclastic, oolitic, peloidal, dolograinstones/packstones and finer-grained dolowackestones/mudstones, thrombolites and digitate to LLH stromatolites, intraclastic conglomerate and breccia, and minor shale and siltstone. Silicified nodules and lenses are locally abundant and at least some likely represent replacement of original evaporite minerals. It appears that the facies, at least locally, are arranged in cyclic succession (shoaling upward cycles?) on the order of a meter to 5 meters or more. Scoured, erosional surfaces occur within the Arbuckle with mm-dm scale erosional relief. These surfaces are commonly overlain by intraclastic breccia and conglomerate.

### **Coarse-Grained Packstones/Grainstones**

This common facies is typically massive, or horizontally bedded to crossbedded (Fig. 5A) and commonly interbedded with fine-grained wackestone-packstone facies. Locally, burrow traces are distinguishable or the facies has a mottled texture that may be due to extensive burrowing. Grains include intraclasts (Fig. 5B), skeletal fragments, ooids, and peloids. This facies indicates high energy deposition in subtidal to peritidal settings. Fenestrae, keystone vugs, and vugs (Fig. 5C) occur locally indicating exposure. Locally, the coarse-grained packstone/grainstone facies is tightly cemented but more commonly contains significant intercrystalline, vuggy, local channel, local fenestral, moldic (Fig. 5D), and fracture porosity. This facies is also locally oil-stained.

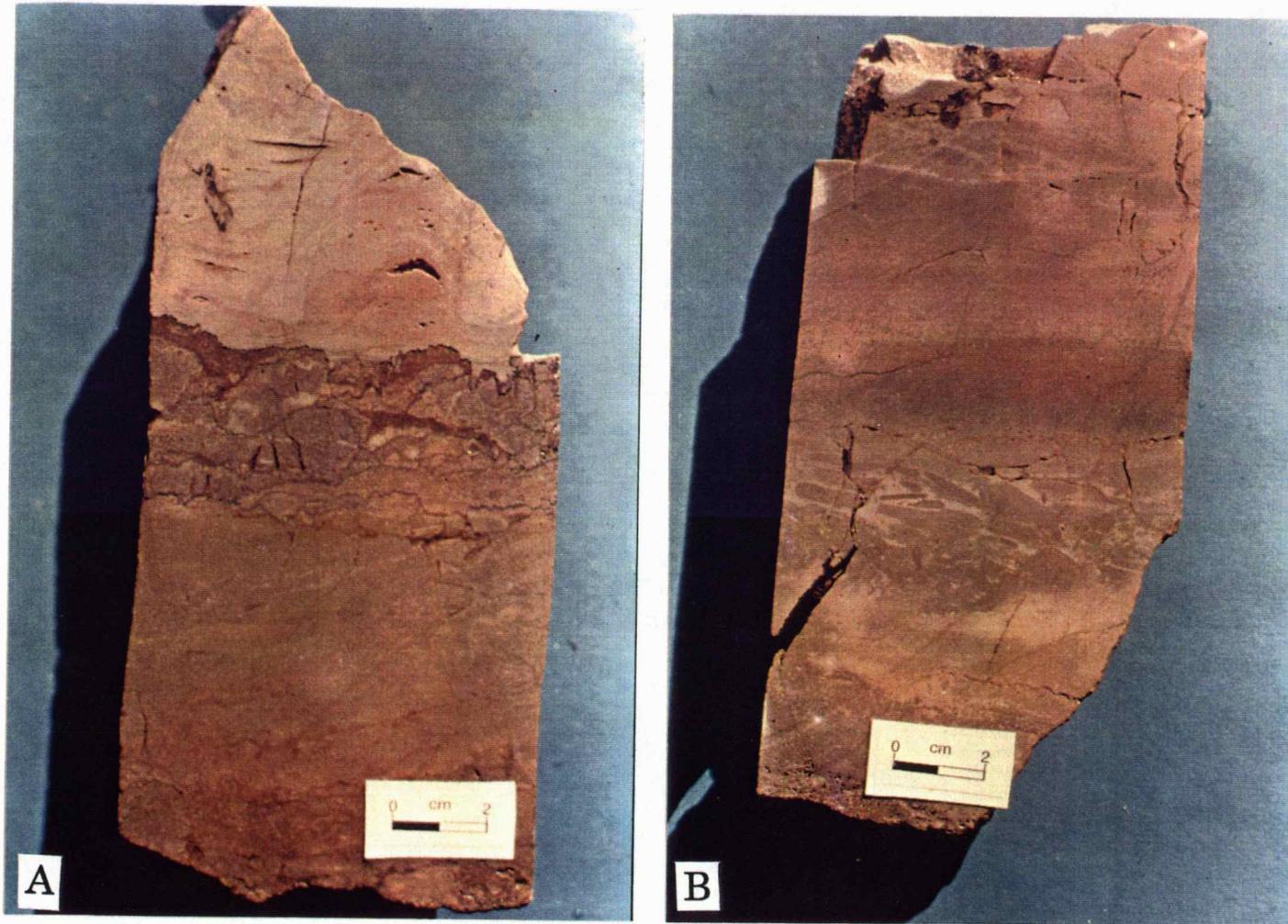
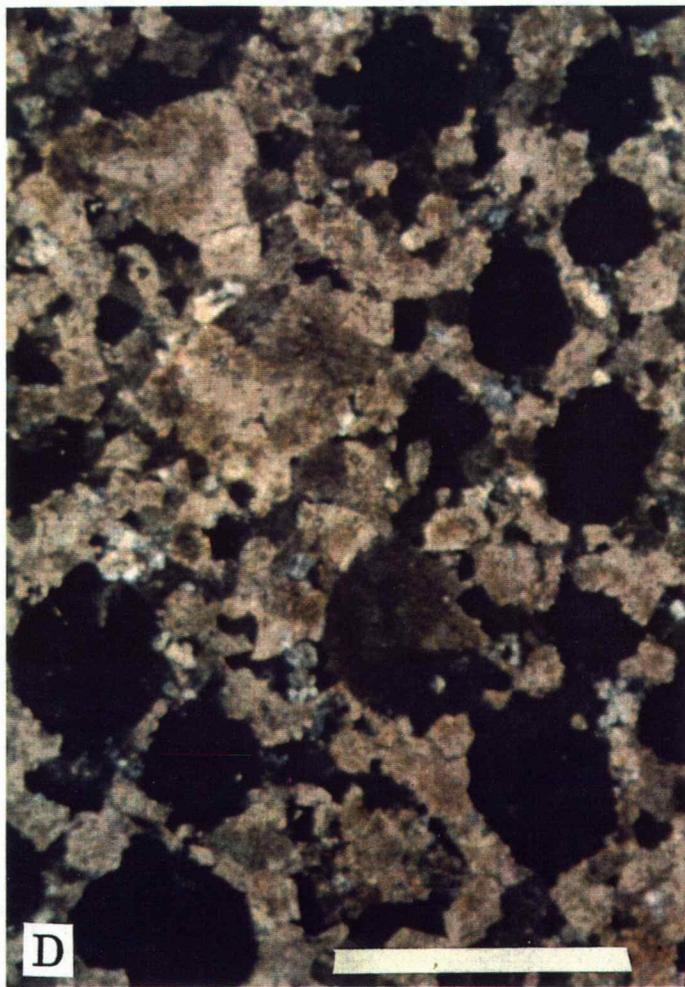


Figure 5:

- A) Oolitic grainstone (lower 2/3 of sample) and overlying stromatolitic facies (upper 1/3 of sample). #1 Littler, 3305'.
- B) Oolitic grainstone facies with local intraclastic conglomerate developed near center of sample. #1 Littler, 3306'.
- C) Cross bedded oolitic grainstone facies with vuggy/channel porosity (locally reduced by dolomite cement). #1 Littler, 3827'.
- D) Photomicrograph showing abundant oomoldic porosity in a clast of oolitic grainstone facies. Scale bar is 1 mm. #1 Caldwell, 3434.6'.



### **Fine-Grained Packstones/Mudstones**

This facies is typically massive to horizontally laminated and bedded, is commonly interbedded with coarser-grained carbonates (Fig. 6A), or locally contains wispy lenses of shale and interbedded shale layers. Burrow traces and mottling are common. Peloids are common and rare intraclasts and skeletal grains (e.g. gastropods) occur locally. Soft sediment deformation, dewatering or incipient teepee-like structures, mudcrack and desiccation cracks, and rip-up clasts are locally associated with this facies. The fine-grained packstone/mudstone facies represents deposition in relatively lower energy conditions in subtidal (massive and burrowed textures) to peritidal (mudcrack and desiccation cracks, incipient teepee-like structures, and rip-up layers and clasts) settings. This facies is typically tightly cemented, but locally contains some vuggy, intercrystalline, fracture and localized fenestral porosity.

### **Stromatolites - Thrombolites**

This facies consists of muddy, mottled to wavy laminated lithology interpreted to represent thrombolites (locally leopard rock texture), wavy algal laminites, brecciated stromatolitic horizons (Fig. 6B), and digitate to LLH stromatolites (Fig. 5A); locally these individual facies occur together in a vertical gradational sequence. Thrombolite-leopard rock texture is typically developed in mudstone-wackestone facies and locally contains some possible burrow mottling. It is usually tightly cemented but locally contains some vuggy and intercrystalline porosity, and more rarely some fenestral porosity. The thrombolite-leopard rock texture likely represents deposition in mostly a subtidal setting, but locally may reflect peritidal environments where fenestrae are developed. The wavy algal laminites occur in mudstone to packstone lithology. Locally, the laminations show evidence of current (ripple) modification.

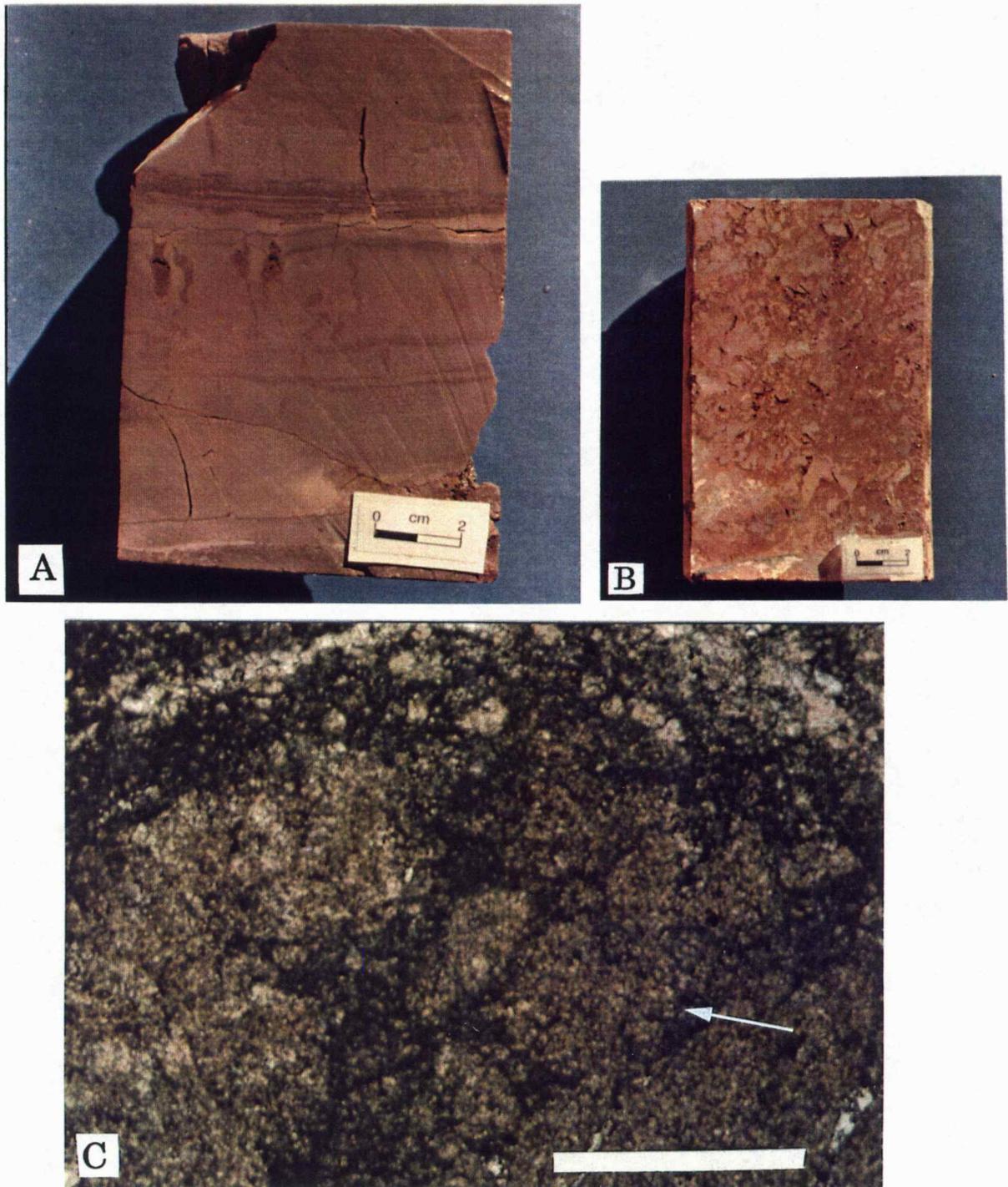


Figure 6:

- A) Laminated and burrowed finer-grained packstone interbedded with oolitic grainstone facies. #1 Littler, 3807'.
- B) Brecciated stromatolitic facies containing abundant intercrystalline and some vuggy porosity. #1 Caldwell, 3421'.
- C) Photomicrograph of fracturing and autobrecciation (arrow) likely forming from desiccation and wetting associated with a period of intra-Arbuckle subaerial exposure. Both host material and overlying and infilling material is dolomitic. Scale bar is 1 mm. #1 Caldwell, 3353.5'.

Typically the laminites are tightly cemented. The algal laminite facies most likely represents a peritidal depositional setting. The brecciated stromatolite and stromatolite facies occurs in mudstone to packstone lithology. Typically brecciated stromatolite texture grades upwards to non-brecciated, in-place stromatolites. The stromatolites locally are tightly cemented but more commonly contain abundant and distinctive differentially developed intercrystalline, fenestral, keystone vug and solution enlarged vuggy porosity that closely follow laminations. The stromatolite to brecciated stromatolite facies likely represents local subtidal to mostly peritidal environments. This facies is locally oil-stained.

### **Intraclastic Conglomerate and Breccia**

Many of the conglomerates or breccias consist of rip-up clasts derived from underlying lithologies whereas other horizons show a mixture of clast lithologies. Textures range from clast- to matrix-support. Conglomerates and breccias are commonly associated with desiccation and mud cracks, dewatering structures, and incipient teepee structures. Although the intraclastic conglomerates and breccias commonly overlie a sharp erosional surface, some conglomerates and breccias are associated with an upwards gradation from undisrupted beds to deformed and fractured beds, to ripped-up conglomerate and brecciated textures. Local autoclastic breccia textures (Fig. 6C) indicate subaerial exposure of some Arbuckle horizons. A variety of mechanisms (including storms, tides, and relative sea level fluctuations) are plausible for conglomerate and breccia development in subtidal to peritidal settings. A peritidal setting is indicated where the conglomerates and breccias are closely associated with desiccation and mud cracks, incipient teepee structure development, and autoclastic breccia textures. Some collapse breccia textures may have resulted from dissolution of evaporites. The conglomerate and

breccia facies commonly has differentially developed porosity. The matrix is typically grainy with abundant intercrystalline, and vuggy (locally fracture) porosity whereas the clasts (e.g. mudstones to wackestones) are relatively tightly cemented. Locally, where there is a mixture of packstone-grainstone clasts and mudstone-wackestone clasts, the grainstone-packstone clasts are locally porous as well.

## **Shale**

Green shale occurs throughout the core as thin depositional layers and as later fracture filling sediment (Fig. 7A). Shale is commonly associated with stylolite development. Locally, as shown in thin section, fracture fill contains fragments of dolomite rhombs (Fig. 7B) and subangular to rounded silt-size to coarse-grained detrital quartz grains (Fig. 7B). Several horizons consist of wavy horizontal to horizontally interbedded shale and carbonate mudstone-wackestone. Several shale layers contain silicified nodules and lenses that may have replaced evaporites (Fig. 8). The shale layers likely represent relatively low energy subtidal to peritidal conditions. Supratidal conditions may be indicated for some horizons where silicified nodules apparently represent replacement of original evaporite minerals.

## **Secondary Features**

Secondary features affecting the original depositional facies include several complex events of later fracturing and brecciation, silicification, local mineralization and various other early and late diagenetic processes including pervasive but mostly non-fabric destructive dolomitization(s). Later brecciation and fracturing occurs with various textures ranging from incipient fracturing, and brecciation with a "fitted" clast texture and little clast rotation to

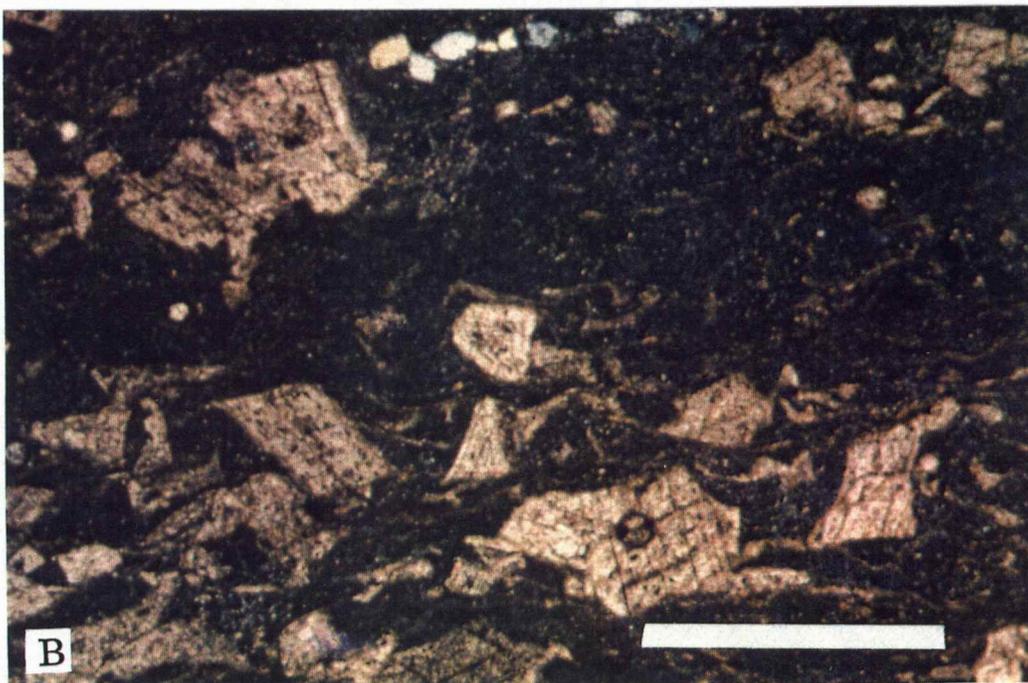


Figure 7:

- A) Stromatolite facies overprinted by later fracturing and sediment fill. Note local vuggy porosity generally following laminations in the stromatolite. Fractured area contains several different types of sediment fill including light green shale. #1 Caldwell, 3446'.
- B) Photomicrograph of dark green shale, fragmented dolomite rhombs, and silt to very fine-grained detrital quartz grains filling in a fracture near the Arbuckle-Simpson contact. Scale bar is 1 mm. #1 Caldwell, 3350.7'.

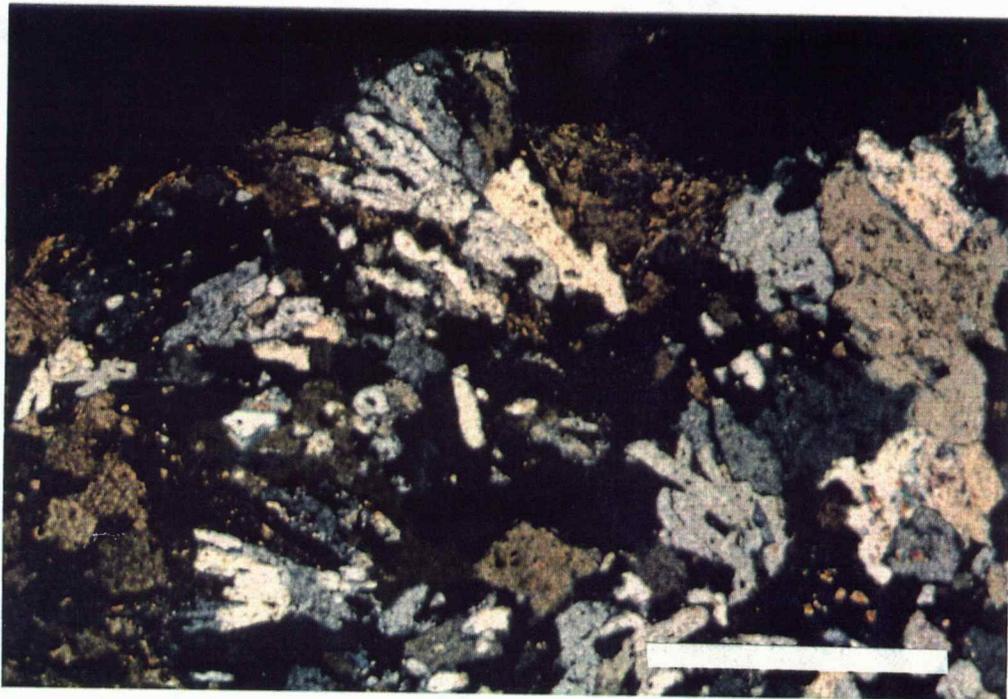


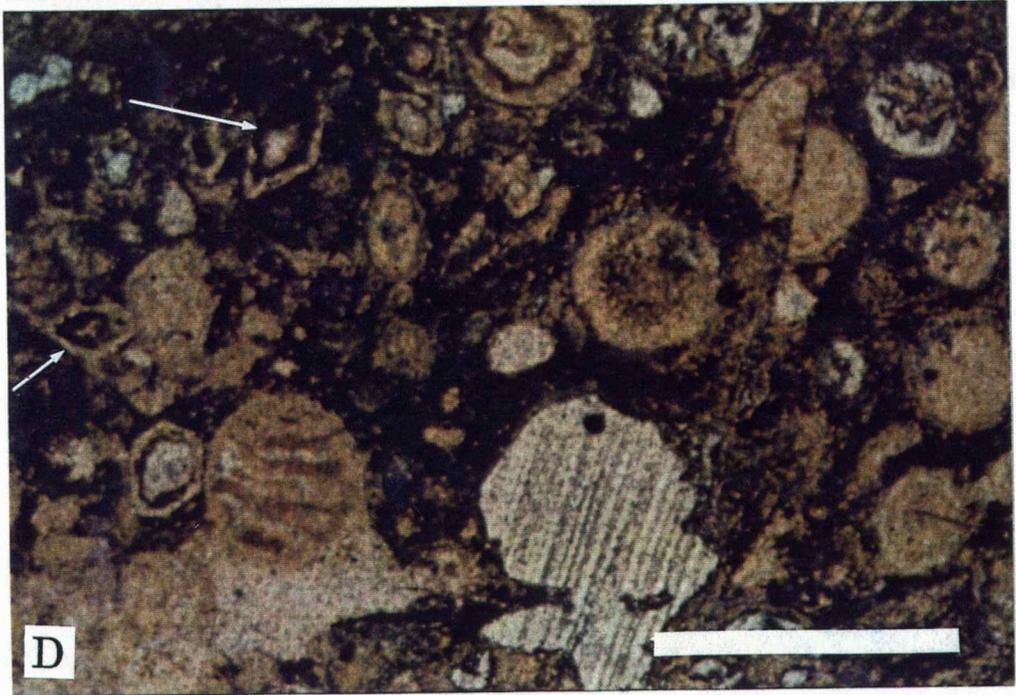
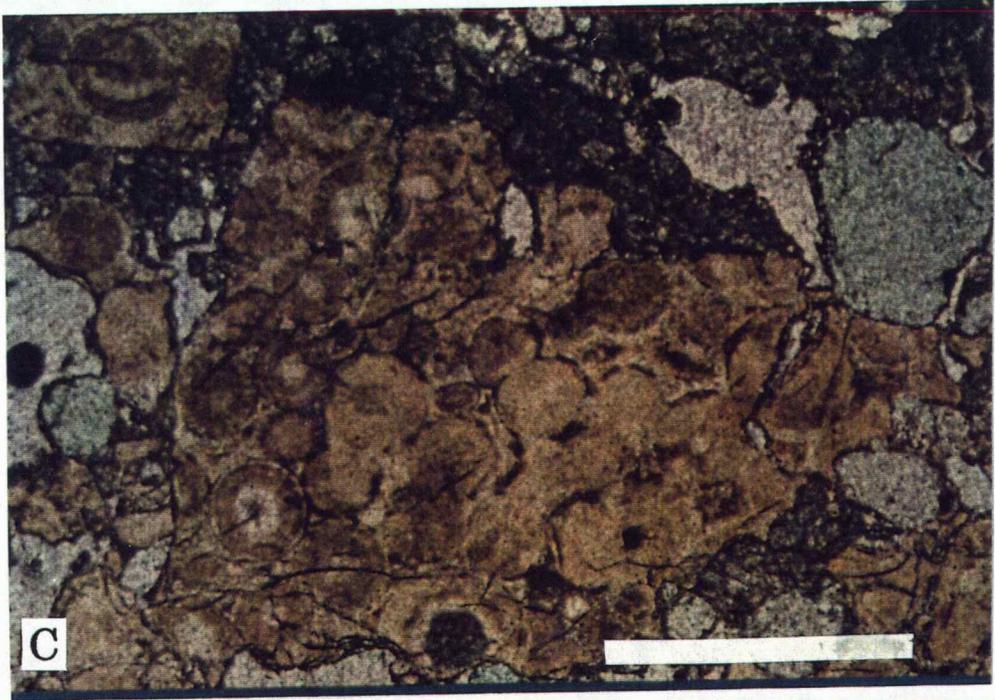
Figure 8: Photomicrograph of a silicified nodule and some dolomite rhombs. Note the bladed and radiating bladed morphology of some the crystals that likely indicate replacement of an original evaporite mineral such as gypsum or anhydrite. Scale bar is 1 mm. #1 Caldwell, 3370.1'.

extreme fracturing and brecciation with chaotically oriented clasts of various lithologies (Fig. 9A-G). This later stage fracturing and brecciation is also characterized by various types of sediment fill and locally by cements. Many of these late-stage fractures are only partially filled, or in some cases completely open, and represent significant effective secondary porosity. Some of these features are similar to those described by Kerans (1988) in the Ellenburger that he attributed to karsting associated with the pre-Simpson Group (Middle Ordovician) subaerial exposure event. Several horizons in the cores of this study show an upward transition of chaotic clast-supported or matrix-supported breccia texture (e.g. Fig. 9F) to a fitted, fracture breccia texture with little to no clast rotation (e.g. Fig. 9G) which may represent a transition from cave collapse zone upward to cave roof facies possibly developed during the post-Sauk subaerial exposure event. Elsewhere, fractures appear to have a preferred orientation that likely reflect a tectonic influence. In addition to the open fractures, other late-stage porosity development includes vuggy, channel, and interparticle porosity, much of which is likely related to the post-Arbuckle exposure event.

The striking feature in the cores, however, is the abundance and apparent importance of "matrix" porosity (intercrystalline, moldic, fenestral, vuggy) throughout the entire lengths of the cores that is related to depositional facies, early diagenesis, and dolomitization and not necessarily related to the upper post-Sauk subaerial exposure surface. Initial observations indicate that more than 50% of the preserved porosity are these types of "matrix" porosity. Figures 10A-F show various types of Arbuckle dolomite textures and variations in porosity. Much of the matrix porosity-rich intervals are associated with coarse-grained, laminated to bedded facies that are

Figure 9:

- A) Simpson-Arbuckle contact. Simpson consists of dark green shale. Note fracturing and collapse breccia in Arbuckle with sediment infill that includes coarse-grained carbonate and green shale similar to Simpson lithology. Dark area near bottom of sample is pyritic. #1 Caldwell, 3349'.
- B) Original wavy-laminated (algal?) facies, with some original fenestral and vuggy porosity, affected by late-stage fracturing and brecciation near the Arbuckle-Simpson contact. Fractures are filled or partially filled with several different sediment types, including green shale. Open fractures may connect some of the vugs and fenestral pores making more effective porosity and permeability. #1 Caldwell, 3352'.
- C) Photomicrograph of fracture-fill near the Arbuckle-Simpson contact containing silicified ooid clasts, dolomitic sediment, mud, and very fine-grained to coarse-grained detrital quartz. Scale bar is 1 mm. #1 Caldwell, 3353.3'.
- D) Photomicrograph of fracture-fill near the Arbuckle-Simpson contact containing silicified ooid clasts, dolomitic sediment, mud, and very fine-grained to coarse-grained detrital quartz. Note the ooid clasts also contain some silicified dolomite rhombs (arrows). Scale bar is 1 mm. #1 Caldwell, 3353.3'.
- E) Fracturing and brecciation with some clast rotation of original tight mudstone-wackestone facies. The fractures are only partially filled with coarse-grained material. #1 Caldwell, 3399-3400'.
- F) Chaotic breccia. Chaotically oriented clasts consist of mudstone-wackestone, oolitic packstone-grainstone facies, and chert in a coarse-grained carbonate-dominated matrix. #1 Littler, 3821'.
- G) Highly fractured, "fitted" breccia texture (clasts show little to no rotation) in originally tight wavy laminated mudstone-wackestone facies. Most fractures remain open whereas others are partially filled with green clay material. #1 Littler, 3843'.



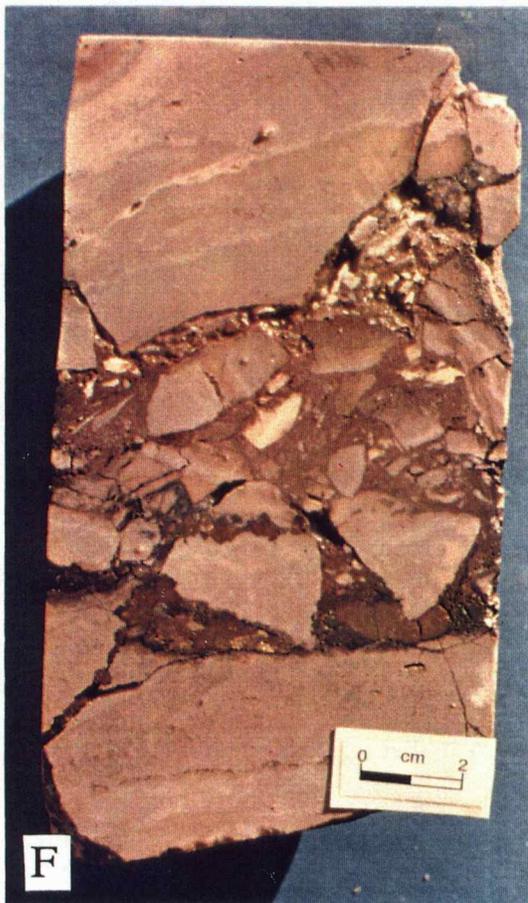
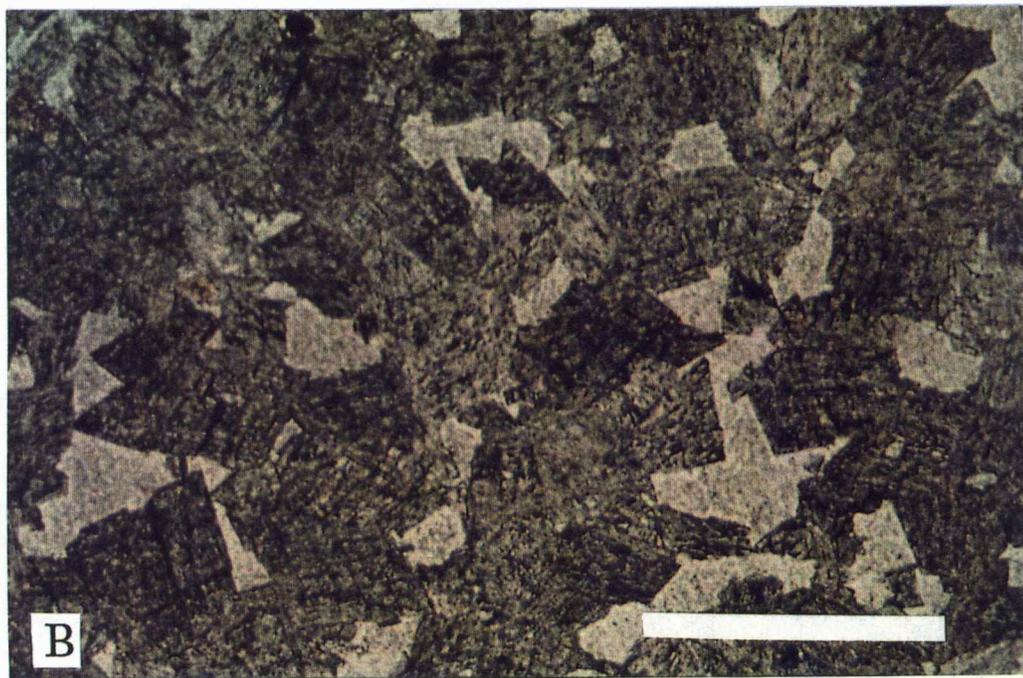
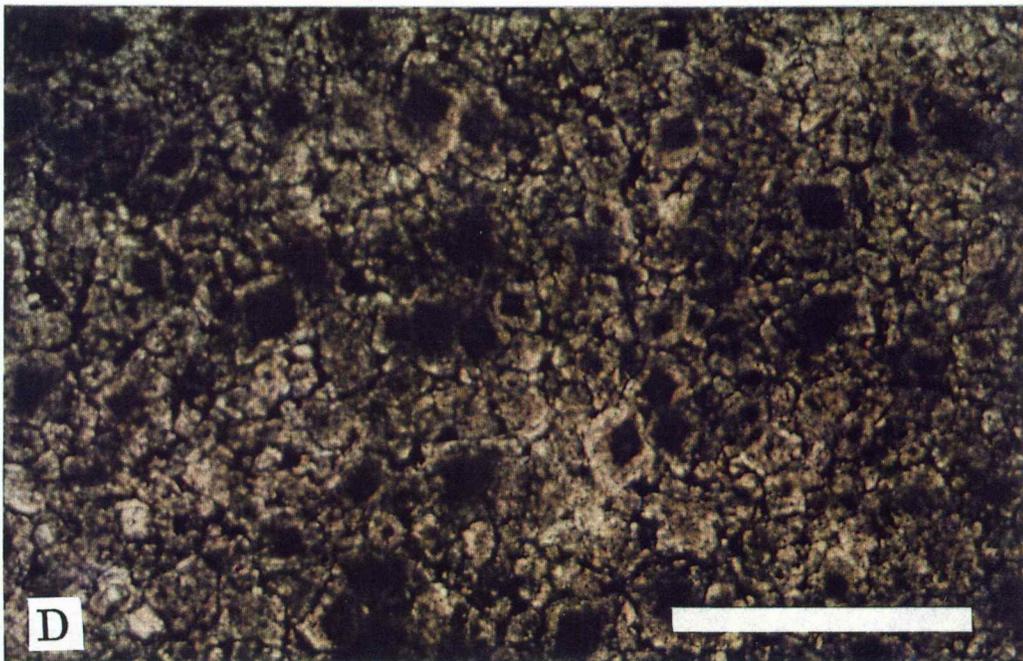
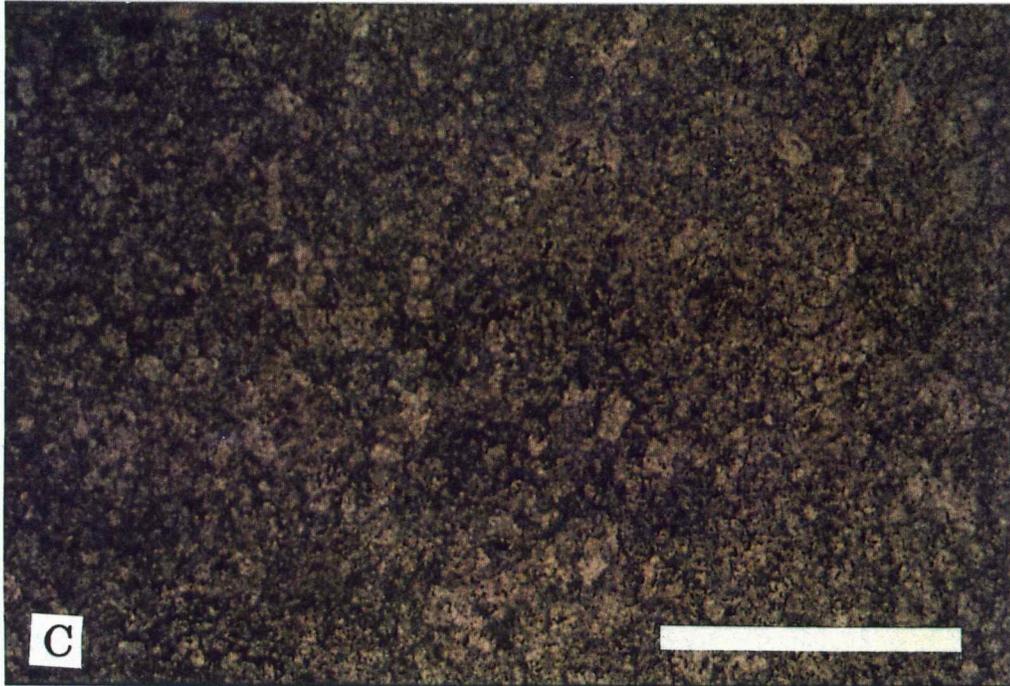
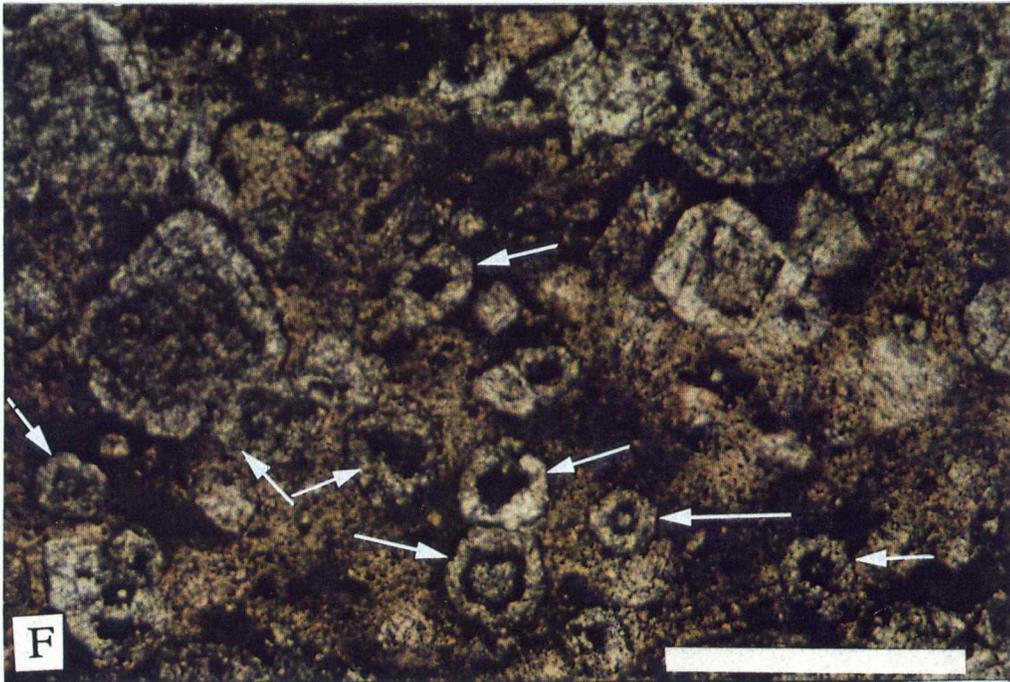
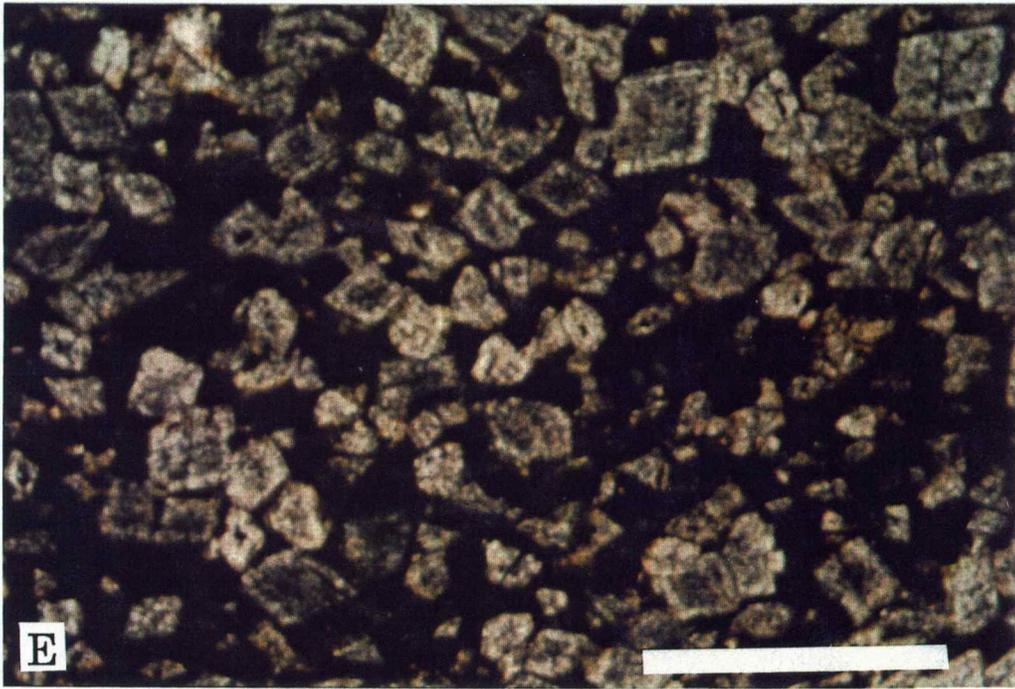


Figure 10:

- A) Photomicrograph of coarsely to very coarsely crystalline zoned dolomite. Note clear rims on some dolomite rhombs and intercrystalline porosity (dark) at bottom of the photo. Scale bar is 1 mm. #1 Caldwell, 3350.7'.
- B) Photomicrograph of dolomite with abundant intercrystalline porosity (lighter areas). Scale bar is 1 mm. #1 Caldwell, 3350.7'.
- C) Photomicrograph of tightly cemented dolomite. Scale bar is 1 mm. #1 Caldwell, 3350.7'.
- D) Photomicrograph of dolomite rhombs with turbid cores. Despite the relatively tightly cemented appearance, there is significant micro-intercrystalline porosity. Scale bar is 1 mm. #1 Caldwell, 3355.5'.
- E) Photomicrograph of zoned dolomite rhombs "floating" in shale matrix. This sample is tightly cemented. Scale bar is 1 mm. #1 Caldwell, 3366.9'.
- F) Photomicrograph illustrating unusual spheroidal to polyhedral dolomite crystal morphologies (some are indicated by the arrows). Note some of these crystals have rhombic centers whereas others have spheroidal centers. The spheroidal - polyhedral dolomite crystal morphology is typically indicative of fluids with elevated salinities which may also be supported by the occurrence of silicified nodules in the same sample that have a bladed and radiating bladed crystal morphology likely indicating replacement of an original evaporite mineral (See Fig. 8). Scale bar is 0.4 mm. #1 Caldwell, 3370.1'.







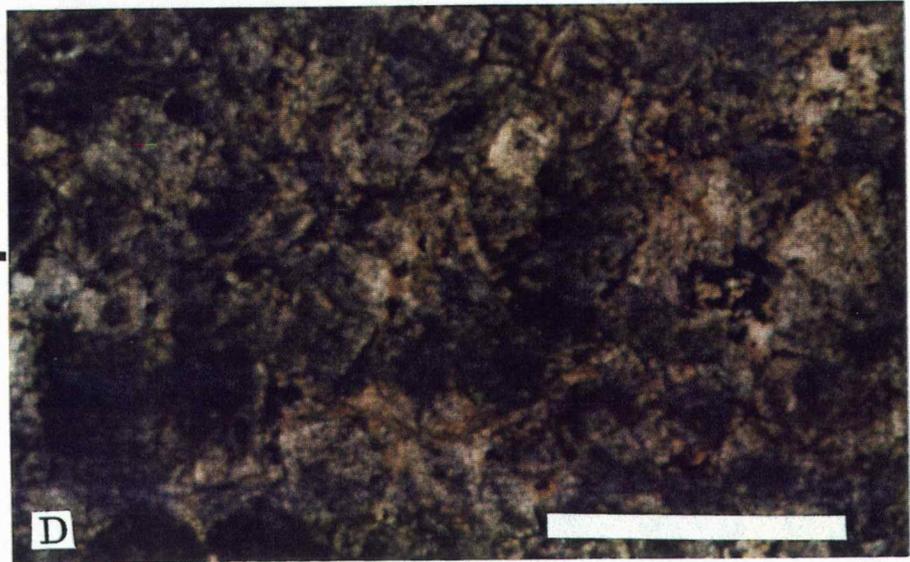
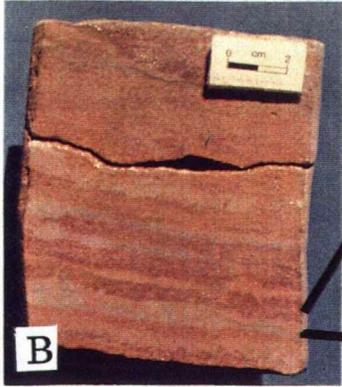
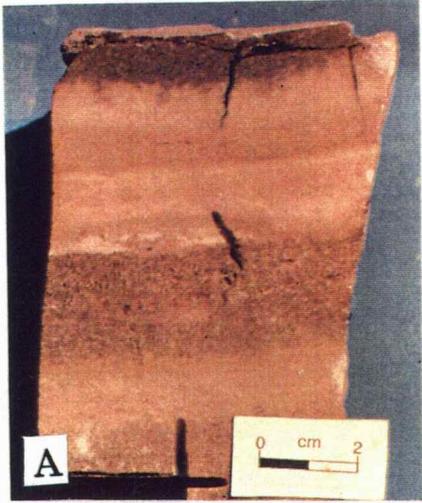
differentially cemented (Fig. 11A-D) or with stromatolitic intervals (Fig. 12A-B) that show differential porosity development likely due to differences in original texture (e.g. mud content) and early diagenesis (e.g. development of fenestral and vuggy porosity during early subaerial exposure events). Several of the coarse-grained and stromatolite intervals in the cores are heavily stained with oil. It is apparent that these intervals are significant in their potential for storage of fluids and deserve increased attention in exploration/production strategies. Just as striking in the cores is the subtleness and relative lack of macroscopic exposure features and porosity associated with the upper subaerial exposure event, especially near the upper contact. However, the later fracture and breccia associated porosity that is present, and likely due to the post-Arbuckle karsting, serves to create more effective porosity and may affect the producibility of the matrix-dominated porosity zones.

### **Discussion and Summary**

Most of the present oil and gas zones in the Arbuckle are contained in the top 25 ft, some are 25-50 ft within the Arbuckle (Adler, 1971). Although most production is from the top of the Arbuckle, Bloesch (1964) concluded that the Arbuckle cannot be considered fully tested until Precambrian rocks are reached. Over the years several authors have described deeper productive petroleum zones within the Arbuckle in Kansas and Oklahoma (e.g. Bloesch, 1964; Mullins and Ireland, 1967; Ramondetta, 1990) that illustrate the Arbuckle is not a simple homogeneous reservoir, that complex vertical and lateral heterogeneities exist including both non-porous and porous horizons in the formation, and that high probability exists of finding additional oil with improved

**Figure 11:**

- A) Horizontally bedded to crossbedded coarse-grained (oolitic?) packstone-grainstone with alternating tight and porous (intercrystalline, vuggy) layers. #1 Littler, 3837'.**
- B) Horizontally bedded to low-angle crossbedded packstone-grainstone with alternating tight and porous zones. Differential porosity likely relates to subtle differences in original textures (e.g. mud content). #1 Caldwell, 3363'.**
- C) Photomicrograph of layer with abundant intercrystalline porosity (light areas). Note the clotted and peloidal textures in the dolomite rhombs. Scale bar is 1 mm. #1 Caldwell, 3363.1'.**
- D) Photomicrograph of tightly cemented layer. Note the clotted and peloidal textures in the dolomite rhombs. Scale bar is 1 mm. #1 Caldwell, 3363.1'.**



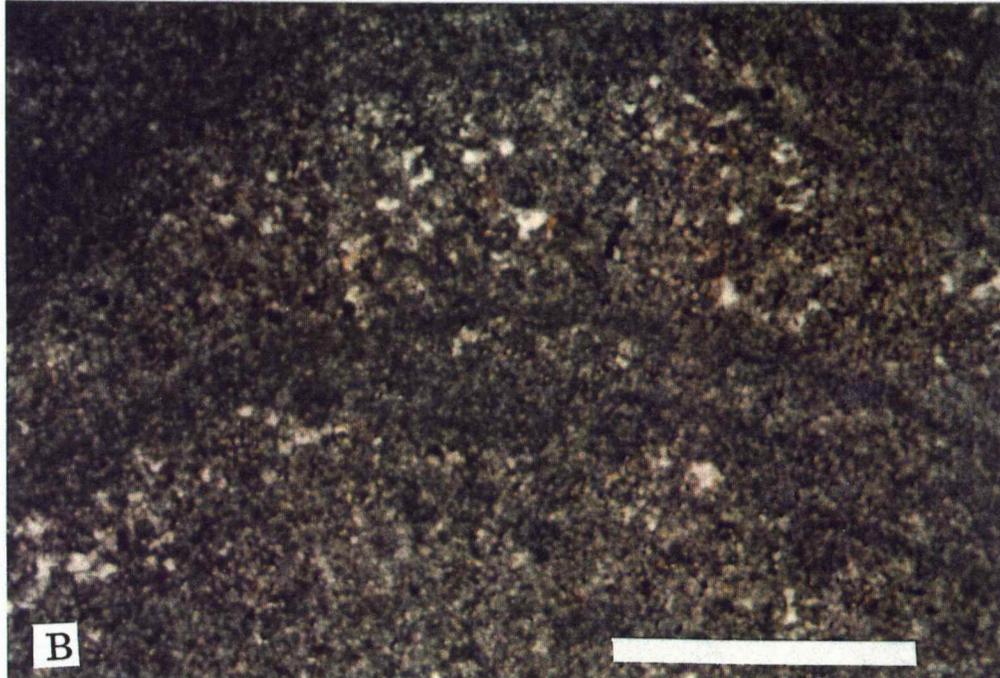
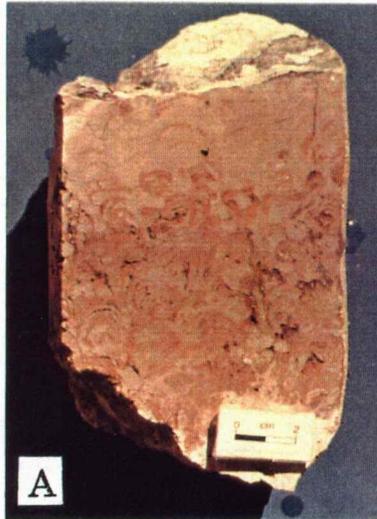


Figure 12:

- A) Stromatolite facies with differential porosity developed between laminations. Note the top of the sample is relatively tightly cemented and the bottom is relatively porous. Intercrystalline, fenestral and vuggy porosity create significant porous zones in this common facies in cores observed to date. #1 Caldwell, 3421'.
- B) Photomicrograph of stromatolite facies showing the differentially developed fenestral and vuggy porosity (light areas) between laminations. Scale bar is 1 mm. #1 Caldwell, 3421'.

reservoir characterization. The deeper productive zones may be controlled by several factors such as depositional facies, dolomitization, or intra-formational exposure events (e.g. Walters, 1958; Montanez, 1992; Ramondetta, 1990). The initial study of cores of Arbuckle rocks in Kansas reported herein confirms significant deeper porous/permeable zones within the Arbuckle, as well as tight dolomite facies, shale, and chert layers that could provide seals on local and regional scales. A significant amount of porosity in the cores is controlled by depositional facies and dolomitization with relatively minor porosity, at least in the cores studied to date, related to late stage brecciation and fracturing that resulted from structural controls or karst. The results of the other drilling studies and the reconnaissance observations of Kansas cores reported here indicate the importance for evaluating the potential for significant porosity/permeability (reservoirs) deeper in the Arbuckle of Kansas and for geologically classifying porosity/permeability patterns relating to structural setting, karst surface geomorphology, and other possible controlling factors on porosity/permeability development that could result in better exploration and production strategies in the Arbuckle.

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