THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

LITHOSTRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS OF THE PITKIN LIMESTONE (CHESTERIAN, MISSISSIPPIAN) IN PORTIONS OF CHEROKEE, MUSKOGEE, AND SEQUOYAH COUNTIES, OKLAHOMA

A THESIS

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

MASTER OF SCIENCE

By

A. LEE NAGEOTTE

Norman, Oklahoma

1981

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APPROVED FOR THE SCHOOL OF GEOLOGY AND GEOPHYSICS

By

[redacted]

ABSTRACT

This thesis provides a detailed lithostratigraphic analysis and interpretation of depositional environments of the pitkin limestone (Chesterian, Mississippian) in a portion of northeastern Oklahoma. The study area is located mostly in Cherokee County but also includes portions of Muskogee and Sequoyah Counties. Twenty-eight stratigraphic sections were measured and studied.

The Fayetteville Shale, which immediately underlies the Pitkin, was found to have a highly variable thickness in northeast Oklahoma. An adequate explanation of this feature is not possible at this time. The two formations are thought to have been at least in part deposited contemporaneously. Together they form a shoaling upward sequence.

Eleven facies were delineated in the study area: (1) Oolite Facies, (2) Oolitic Facies, (3) Bioclastic Facies, (4) Encrinite Facies, (5) Oncolitic Facies, (6) Nodular Limestone and Shale Facies, (7) Wackestone Facies, (8) Peloidal Facies, (9) Mudstone Facies, (10) Shale Facies, and (11) Mound Facies. Most of the Pitkin lithofacies were deposited in high energy shallow marine environments. The distribution of these facies and their inferred depositional environments suggest that the Pitkin was a platform carbonate.

An unconformity of regional extent separates Mississippian and Pennsylvanian strata on the Ozark Uplift and is easily recognized in the field because of the contrast between the light gray-weathering limestones of the Pitkin and the brown weathering sandy grainstones of the overlying Sausbee Formation (Lower Pennsylvanian). The Sausbee locally has at its base a cobble conglomerate of Pitkin Limestone clasts. A pre-Pennsylvanian north-south trending fluvial valley feature, with a regional relief of at least 60 feet, can be delineated in Cherokee and northern Sequoyah Counties by cross sections and isopach maps of the Pitkin. The Pitkin is locally removed within the study area with the Sausbee resting directly on the Fayetteville Shale.

The conformable Chesterian stratigraphic sequence of Hindsville-Fayetteville-Pitkin in the Oklahoma Ozark Region may represent a carbonate shelf cycle or mesothem. The Hindsville is interpreted as a transgressive unit, the Fayetteville as being both transgressive and regressive, and the Pitkin as a regressive carbonate unit. Depositional strike of the Pitkin Limestone shifts from northwest-southeast in Muskogee and Wagoner Counties, Oklahoma to northeast-southwest in Washington and Crawford Counties, Arkansas as a result of a positive topographic expression of the Ozark Uplift in Oklahoma.

ACKNOWLEDGEMENTS

The writer wishes to express gratitude to those people who made contributions in time and effort to this thesis. Dr. Patrick K. Sutherland, the thesis advisor, suggested the topic and provided assistance in the field and in the preparation of the manuscript. Dr. Walter Manger, University of Arkansas, and Dr. Charles Harper, University of Oklahoma, critically reviewed the manuscript and served on the thesis committee.

Steven H. Tennant assisted in the preparation of photographic plates and participated in many useful discussions about the thesis topic. John Groves and Bob Goldhammer assisted in thin section analysis. Bill Buchanan provided useful suggestions in the thin section lab and helped to acquire the equipment needed to complete this project.

Grateful acknowledgement is made for funds to defray field expenses, which came from the Oklahoma Geological Survey and from a Mobil Foundation Grant, to support carbonate studies, administered by Patrick K. Sutherland.

Special thanks go to David Clupper and April H. Orgren who worked on the Pitkin Limestone in adjacent areas of northeastern Oklahoma and made excellent suggestions on logistical procedure.

The writer wishes to acknowledge his parents, Alton and Betty Nageotte, for their encouragement over the years.

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CHAPTER I

INTRODUCTION

General Statement

The Pitkin Limestone of northeast Oklahoma and northwest Arkansas is a Chesterian (Mississippian) formation that crops out in a crescent shaped band along the southern flanks of the Ozark Uplift. The Pitkin is characterized by the common occurrence of the bryozoan Archimedes and by the lack of quartz grains. The predominant lithologies within the formation are skeletal and oolitic grainstones and packstones with less common wackestone, mudstones, and shale lenses. The recorded thicknesses of the Pitkin Limestone in the northeastern Oklahoma band of exposures range from 0 to 62 feet.

Nature of the Problem

This thesis is the third and last in a series of studies by masters' students at The University of Oklahoma that provide a detailed lithostratigraphic analysis of the Pitkin Limestone in northeastern

Oklahoma. The first study by David Clupper (1978) covered the southern part of Adair County. The second by April H. Orgren (1979) covered portions of Wagoner, Cherokee, and Muskogee Counties. These theses are part of a continuing project initiated by Dr. Patrick K. Sutherland on Mississippian and Lower Pennsylvanian regional stratigraphy of the Ozark Region (Fig. 1).

The main purpose of this thesis, like the earlier two, is to provide a detailed lithostratigraphic analysis and an interpretation of the depositional environments of the Pitkin Limestone in a specific area of Oklahoma. It is possible to add a regional synthesis of Pitkin stratigraphic relationships, including both northeastern Oklahoma and northwestern Arkansas, since this is the final thesis on the lithostratigraphy of the Pitkin.

The Pitkin is removed by pre-Pennsylvanian erosion within parts of the study area. A report is, therefore, included on the nature of the Mississippian-Pennsylvanian unconformity and its regional significance.

Preliminary observations on post-Boone/pre-Pitkin stratigraphy (Fig. 1) is included, with an emphasis on the Fayetteville Shale, which sets the stage for future studies of Mississippian strata in the area.

Location

The study area lies in northeastern Oklahoma on the southwest flank of Ozark Uplift (Fig. 2). It is mostly in Cherokee County but also includes portions of northeastern Muskogee and northern Sequoyah Counties (Fig. 3). The townships included are Ts. 13-15 N.,

SYSTEM	SERIES	GROUP / FORMATION	MEMBER / FORMATION
PENNSYLVANIAN	MORROWAN	MC CULLY FORMATION	
		SAUSBEE FORMATION	BREWER BEND MEMBER
			BRAGGS MEMBER
MISSISSIPPIAN	CHESTERIAN	PITKIN LIMESTONE	
		FAYETTEVILLE SHALE	
		HINDSVILLE FORMATION	
	MERAMECIAN	MOOREFIELD FORMATION	
	OSAGEAN	"BOONE" GROUP	KEOKUK FORMATION
			REEDS SPRING FORMATION
			ST. JOE FORMATION

Figure 1. Stratigraphy of the surface exposures in northeastern Oklahoma. The Pitkin Limestone is the youngest Chesterian unit. Adapted from A. Orgren (1979), Sutherland and Henry (1977), and Huffman (1958).

Rs. 21-23 E. with T. 13 N., R. 20 E. and T. 16 N., R. 23 E. each containing one measured section. The surface area is approximately 288 square miles. It includes the whole of the Tenkiller Ferry Lake area. The topography is moderate to steep. The area is cut by several northeast trending block faults which repeat sections of the Pitkin Limestone and associated strata. The surface is densely vegetated in most areas causing some difficulty in the location of good exposures. For this reason, field work was conducted in the spring months of March and April, 1980. Recent road cuts and natural bluff escarpments provide the best exposures.

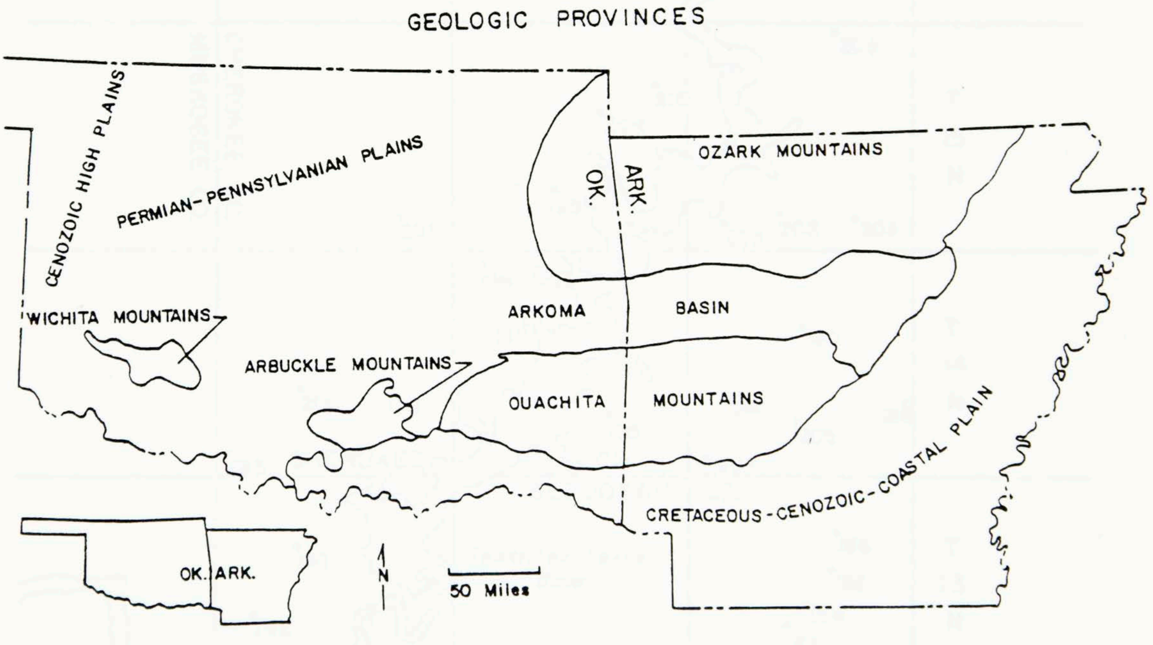


Figure 2. Geologic provinces of Oklahoma and Arkansas. From Sutherland and Manger (1979), Fig. 1, p. 1.

Methods of Investigation

In the early spring of 1980, an aerial photo analysis of the field area was conducted in a search for usable exposures of Chesterian

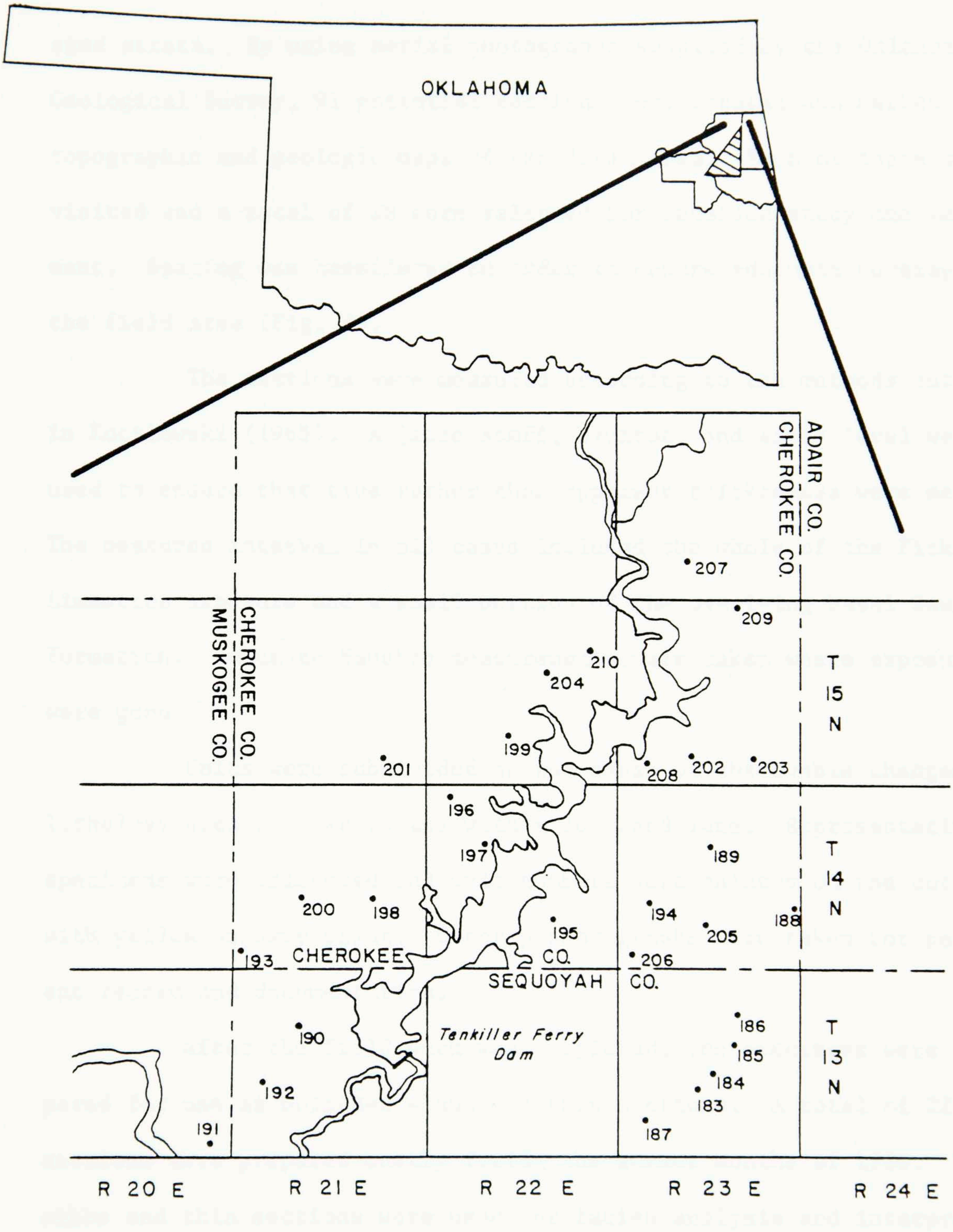


Figure 3. Location of the study area in northeastern Oklahoma and location of the measured sections within the study area.

aged strata. By using aerial photographs supplied by the Oklahoma Geological Survey, 91 potential sections were located and marked on topographic and geologic maps of the field area. Each of these were visited and a total of 28 were selected for detailed study and measurement. Spacing was considered in order to ensure adequate coverage of the field area (Fig. 3).

The sections were measured according to the methods outlined in Kottlowski (1965). A jacob staff, brunton, and abney level were used to ensure that true rather than apparent thicknesses were measured. The measured interval in all cases included the whole of the Pitkin Limestone exposure and a small portion of the overlying basal Sausbee Formation. Boone to Sausbee measurements were taken where exposures were good.

Units were subdivided on the basis of observable changes in lithology seen in outcrop and with a 10X hand lens. Representative specimens were collected and unit numbers were painted on the outcrop with yellow highway paint. Outcrop photographs were taken for permanent record and documentation.

After the field work was completed, the specimens were prepared for use as polished slabs and thin sections. A total of 221 thin sections were prepared mostly during the summer months of 1980. The slabs and thin sections were used for facies analysis and interpretations.

An attempt has been made in this study to reduce bias during thin section analysis by applying the statistical technique of point counting. The Glagalev-Chase method was used as outlined by Galehouse

(1971). Each thin section of the Pitkin and basal Sausbee was counted using a 1 millimeter grid of points (Fig. 4). The data were used to arrive at the percentage composition (see Appendix B). The assumption for this technique is that the area percentage values derived from point counting a thin section approximate the volume percentage composition of the rock. The results of the point counts were then placed on ternary diagrams (see Appendix C).

Figure 4. A grid of points is used to count constituent grains in thin sections by the Glagalev-Chase method. The result of this method is an estimate of the volume percent of the constituent grains (modified from Galehouse, 1971).

Figure 5 shows that 300 points are the optimum number to count for the maximum accuracy with minimum time investment. Probable error increases rapidly below 300 while decreasing slowly above it.

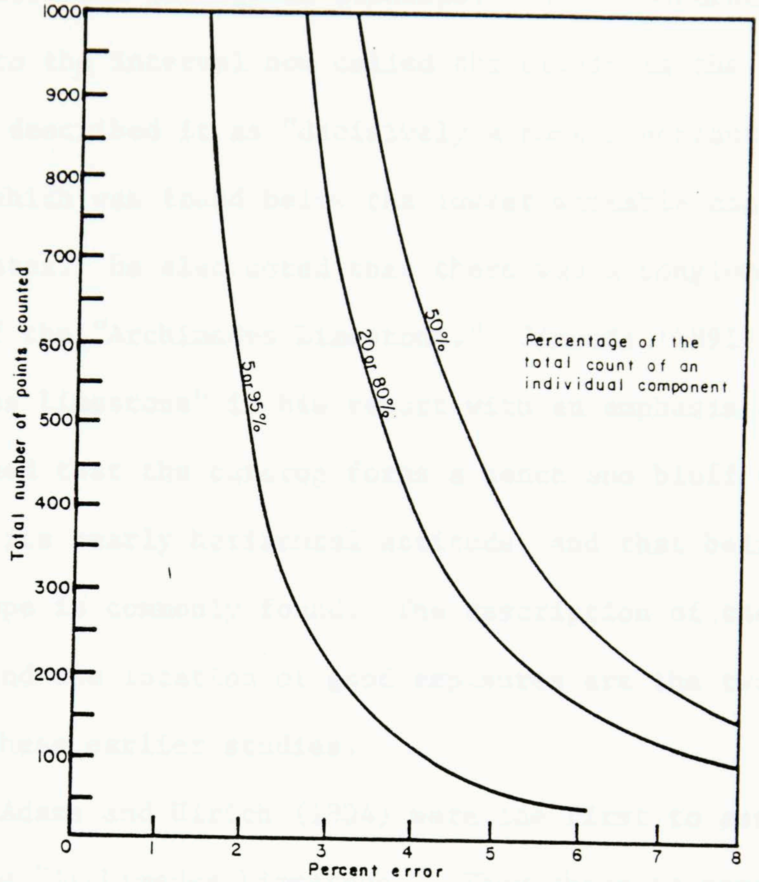


Figure 5. Probable error at 95.4 confidence level. Counting more than 300 points does not significantly increase the accuracy. Modified from Galehouse (1971), Fig. 5, p. 398.

A single ocular Zeiss petrographic microscope mounted with a mechanical stage and a James Swift and Son counter were the two pieces of equipment used for this part of the investigation. Horowitz and Potter (1971), Majewske (1969), and Scholle (1978) were consulted for problems with grain identification.

Previous Investigations

The first mention of Ozark Carboniferous stratigraphy is found in <u>The First Report of a Geological Reconnaissance of the Northern Counties of Arkansas</u>, by Owen (1857). It contains colored sketches of local scenery and geology in Arkansas. In Independence County, Owen referred to the interval now called the Pitkin as the Archimedes Limestone and described it as "decisively a most important geological horizon" which was found below the lowest workable coal in the western United States. He also noted that there was a conglomerate lying on the top of the "Archimedes Limestone." Simonds (1891) described the "Archimedes Limestone" in his report with an emphasis on paleontology. He mentioned that the outcrop forms a bench and bluff topography as a result of its nearly horizontal attitude, and that below the bluffs, a rubble slope is commonly found. The description of the general stratigraphy and the location of good exposures are the two main contributions of these earlier studies.

Adams and Ulrich (1904) were the first to assign a geographic name to the "Archimedes Limestone." They chose to name it after the town of Pitkin, in Washington County, Arkansas, because of the large bluff sections found east of that townsite. The town of Pitkin has since been renamed Woolsey and strata thought to be the type Pitkin turned out to be the Brentwood Member of the Morrowan Bloyd Formation (Easton, 1942). Adams and Ulrich (1904) were able to make faunal correlations between the Pitkin and other Mississippian strata in Illinois and Kentucky and they assigned a Chesterian age to the formation. They described the Fayetteville Shale underlying the Pitkin as being black, thinly laminated, and carbonaceous, containing carbonate lenses and a sandstone unit later named the Wedington Member. Their study was the first to mention the truncation, to the north, of the Pitkin by the basal Pennsylvanian unconformity.

The United States Department of the Interior published geologic atlases covering the areas of the Tahlequah and Muskogee quadrangles in 1904 and 1905, respectively. Taff was the author of the geographic and geologic sections of these works. He stated that the Pitkin Formation in these areas ranged in thickness from 0 to 70 feet and that the thickness increased to the southwest. He was the first to recognize oolites in the Pitkin and observed that granular and oolitic textures are the most common lithologies. He recognized the hiatus between the Chesterian and Morrowan strata by using biostratigraphy. Both of these geologic atlases are succinct and thorough, particularly considering the publication date. The geologic maps presented in these volumes differ little from more recent mapping efforts. Considering the logistical handicaps of that time, these atlases are commendable.

Snider produced three publications concerning the Mississippian strata of northeastern Oklahoma in 1914 and 1915. He proposed that the strata between the Boone and Fayetteville be called the Mayes Group. He also discussed the general trends associated with the Mississippian-Pennsylvanian unconformity and demonstrated that the Pitkin equivalent in the Arkoma Basin is the Caney Shale. A publication on Pitkin paleontology (Snider, 1915) is useful because of the numerous plates and lists of collecting localities.

Purdue and Miser (1916) authored the geologic atlas for the Eureka Springs and Harrison quadrangles (Arkansas). They discussed in detail the Pitkin-Fayetteville stratigraphic relationships and concluded that these formations are separated by an unconformity in

Arkansas. Buchanan (1927) pointed out the problems of correlating from the Ozark Region to the Arbuckle Mountains. He presented a table for Oklahoma Carboniferous stratigraphy and made comparisons to the Mississippi Valley sequence.

A series of faunal studies were conducted on the Pitkin in subsequent years. Roth (1929) presented biostratigraphic evidence indicating that the Fayetteville and Hindsville are both Chesterian in age and that the Hindsville in Oklahoma is correlative with the Batesville in Arkansas. L. R. Laudon (1941) studied the abundant and well preserved crinoid faunas of the Pitkin and Hale Formations. He proposed that the contact between the Fayetteville and the Pitkin in Oklahoma was conformable. Easton (1942, 1943) studied both the fauna and the stratigraphy of the Pitkin in Arkansas. Like Taff, he noted that the Pitkin is variable in lithic character but that granular and oolitic textures dominate. Easton proposed that ecologic barriers caused the coral fauna of the Pitkin to differ from the fauna of the Mississippi Valley type section.

In 1958, two significant studies were published which dealt with the regional stratigraphy of the Ozark Uplift and Arkoma Basin in Oklahoma (Fig. 2). Huffman's study of the flanks of the Ozark Uplift was a compilation of 26 masters' theses and it included detailed geologic maps and measured sections. These maps have greatly aided more recent field studies in the region. R. B. Laudon studied the shelf to basin transitional area south of the Chesterian outcrop band using primarily subsurface information.

Orgren (1961, 1968) analyzed the upper Mississippian rocks of northern Arkansas. Using a combination of measured sections and borehole data, he produced regional isopach maps of the Boone through Hale stratigraphic intervals in northern Arkansas. He recommended the adoption of the Mayes Group in the 1968 publication. In his doctoral dissertation, he conducted modal analyses of selected thin sections of the various units of his study.

Lane (1967) and Lane and Straka (1974) studied conodonts of the Chesterian and Morrowan Series in Arkansas and Oklahoma. The Pitkin was correlated to the Mississippi Valley and European Carboniferous sequences.

Jhen and Young (1976) published a short paper on Pitkin depositional environments. Their model included bioherms as the major rock accumulating mechanism.

Tehan (1976) and Warmath (1977) completed detailed lithostratigraphic studies of the Pitkin Limestone in northwestern Arkansas, immediately east of the Oklahoma State Line. Their studies concentrated on the occurrence of mud mounds within the Pitkin.

<u>Oklahoma Geological Survey Guidebook 18</u> (1977) and <u>19</u> (1979), edited by Sutherland and Manger, provide descriptions of the upper Mississippian and lower Pennsylvanian stratigraphy of the Ozark Region in Arkansas and Oklahoma. They contain summary articles covering the paleontology, biostratigraphy, and lithostratigraphy of the Pitkin Limestone.

Carbonate Classification

The Pitkin Limestone in northeast Oklahoma is predominately carbonate. No quartz grains were found in any of the thin sections examined for this study. However, there are thin shale lenses that may represent brief influxes of terrigenous material and subtle changes in the depositional environment. Volumetrically these lenses are of such minor importance that they will not be considered in this section of the thesis.

Dunham (1962) devised a carbonate rock classification based on depositional texture rather than constituent description. The classification placed emphasis on currents of removal as opposed to currents of delivery of fine-grained (clay-sized) sediment. He chose this emphasis because carbonate sediments are predominantly autochthonous (Wilson, 1975). The classification is based on four determinant characteristics of a given carbonate rock: (1) presence or absence of carbonate mud matrix, (2) grain support verus mud support, (3) binding during deposition, and (4) diagenetically altered crystalline texture. By observing these characteristics, a carbonate rock may be classified as a mudstone, wackestone, packstone, grainstone, boundstone, or crystalline carbonate (Table 1).

The carbonate classification used throughout this thesis is a modified version of Dunham's originally proposed by M. Orgren (1979). Dunham's definition of a grainstone is a rock that lacks mud and is grain-supported. Orgren redefines grainstone to include those rocks that have less than 10 percent carbonate mud matrix (Table 1). This definition has more application to this study of the Pitkin as a result of point counting.

Modifiers are used with Dunham's classification in order to identify the dominant grain type of a particular specimen. For example, a mixed oolitic and skeletal packstone denotes a carbonate rock that is composed of and supported by a mixture of both skeletal allochems and ooliths and has greater than 10 percent micrite between the grains.

<table>
<tr><td colspan="5">Depositional Texture recognizable</td><td rowspan="6">Depositional texture not recognizable

Crystalline carbonate

(Subdivide according to classifications designed to bear on physical texture or diagenesis.)</td></tr>
<tr><td colspan="4">Original components not bound together during depositions</td><td rowspan="4">Original components were bound together during deposition... as shown by intergrown skeletal matter, lamination contrary to gravity, or sediment-floored cavities that are roofed over by organic or questionably organic matter and are too large to be interstices.</td></tr>
<tr><td colspan="3">Contains mud (particles of clay and fine silt size)</td><td rowspan="3">Less than 10% mud and is grain-supported</td></tr>
<tr><td colspan="2">Mud-supported</td><td rowspan="2">Grain-supported</td></tr>
<tr><td>Less than 10% grains</td><td>More than 10% grains</td></tr>
<tr><td>Mudstone</td><td>Wackstone</td><td>Packstone</td><td>Grainstone</td><td>Boundstone</td></tr>
</table>

Table 1. Dunham's (1962) classification of carbonate rocks based on grain packing and the presence or absence of micrite, as modified by M. Orgren (1979).

CHAPTER II

PRE-PITKIN STRATIGRAPHIC RELATIONSHIPS

General Statement

In this chapter, the discussion will be centered on the formations that lie beneath the Pitkin Limestone and may influence its deposition. No detailed analyses have been made of this interval within the study area and it is not as yet fully understood precisely how the stratigraphy relates to the regional structural activity during the Late Mississippian.

The stratigraphic succession included here in ascending order is the Osagean-Lower Meramecian Boone Group, the Meramecian-Lower Chesterian Moorefield Formation, and the Chesterian Hindsville and Fayetteville Formations (Fig. 6). Special attention is given to the Fayetteville Shale because it may have a genetic relationship to both the Hindsville Formation and the Pitkin Limestone.

Structural Considerations

The southwest flank of the Ozark Uplift, where the study area is located (Fig. 2), was a positive tectonic element throughout most of the late Paleozoic Era (Huffman, 1958). A paleogeographic study conducted by Ham and Wilson (1967) demonstrated that the Ozark Uplift Region was topographically high as early as the Middle Ordovician.

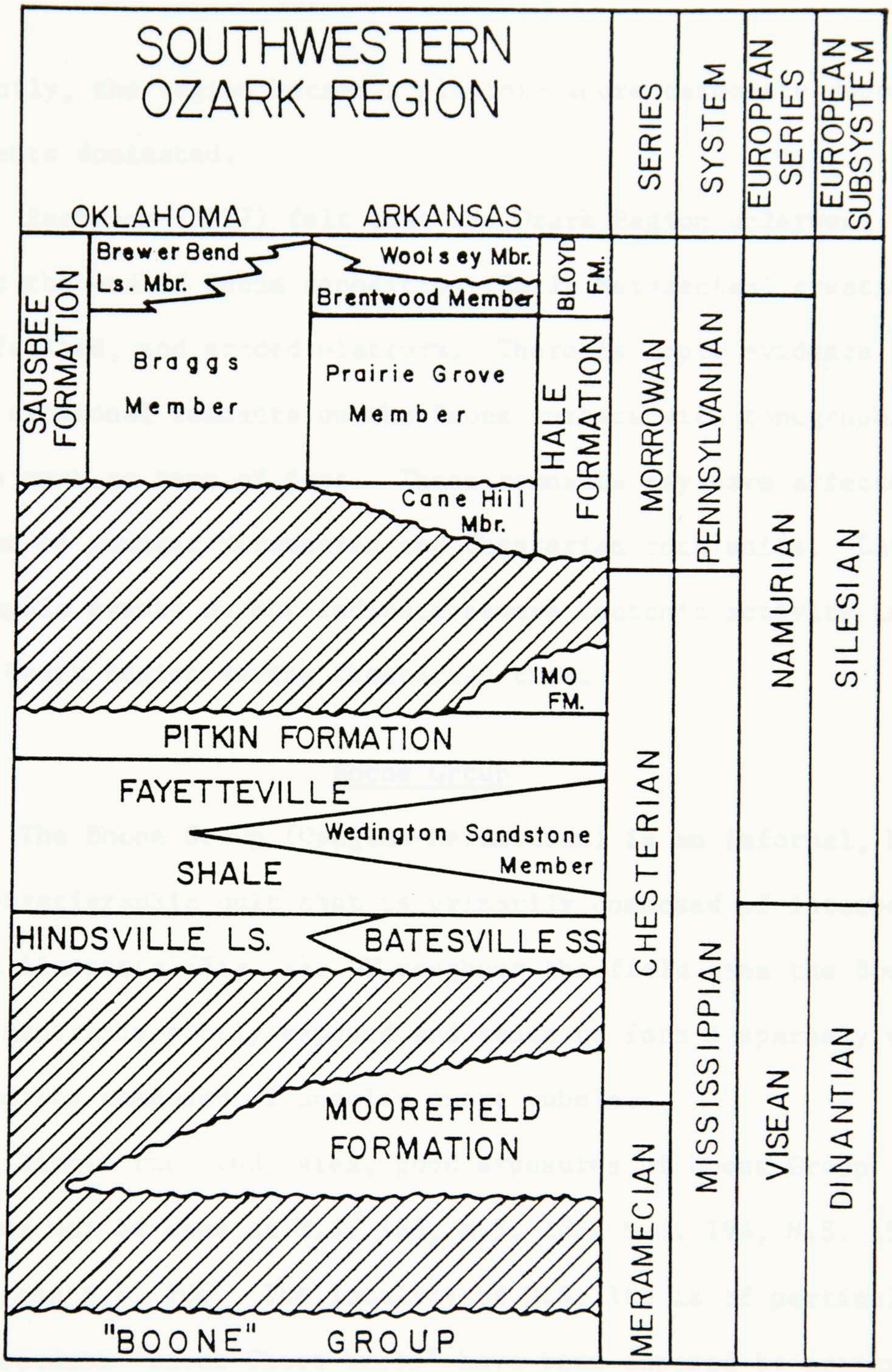


Figure 6. Upper Mississippian and Lower Pennsylvanian stratigraphy of the Ozark Region in northeastern Oklahoma and northwestern Arkansas. The relative duration of the unconformity events are depicted by the hashured areas (from Sutherland and Manger, 1979).

Subsequently, the region became a platform where carbonate depositional environments dominated.

Buchanan (1927) felt that the Ozark Region underwent tectonic uplift at the end of Boone deposition (Early Meramecian) creating a folded, faulted, and eroded platform. There is ample evidence in the field of erosional remnants on the Boone surface with topographic relief as much as tens of feet. These remnants may have affected the deposition of younger Meramecian and Chesterian rock units. Later stratigraphic events do not indicate severe tectonic activity in the Oklahoma Ozark Region during Chesterian time.

Boone Group

The Boone Group (Osagean-Meramecian) is an informal, but useful, stratigraphic unit that is primarily composed of interbedded chert and limestone (Fig. 1). Throughout the field area the Boone Group is generally poorly exposed and tends to form a sparsely vegetated regolith composed of angular chert rubble.

Within the study area, good exposures of Boone Group lithologies may be seen at M.S. 183, M.S. 188, M.S. 194, M.S. 197, M.S. 205, and M.S. 206. The locality of M.S. 183 is of particular interest because "Boone Chert knobs" have been exposed by present day erosion and appear to stand topographically above thin intervals of the Moorefield and Hindsville Formations (Plate 1-A).

Moorefield Formation

The Meramecian-Chesterian Moorefield Formation in Oklahoma has been subdivided by Huffman (1958) into four lithologically distinct members; (1) The Tahlequah Member--a glauconitic limestone, (2) the Bayou Manard Member--an argillaceous limestone, (3) the Lindsey Bridge Member--a chert pebble calcarenite, and (4) the Ordnance Plant Member--a siltstone and shale. These members are difficult to differentiate in the study area because of poor exposures.

A dark gray to blue gray, marly, crinoidal limestone is exposed at M.S. 203 (Plate 1-B). The same lithology can be seen in Adair County, Oklahoma, Washington County, Arkansas, and at M.S. 188 on the south flank of Beaver Mountain, but it cannot be precisely identified as Moorefield. A light gray, unfossiliferous marlstone crops out at M.S. 183 that has been tentatively identified as the Ordnance Plant Member.

Hindsville Formation

The Hindsville Formation is remarkably similar in character to the Pitkin both in outcrop and in thin section. It is a smooth weathering, commonly exfoliated, thick to massive bedded bluff former (Plate 1-C). It is also commonly crossbedded and in thin section contains ooliths, crinoids, brachiopods, abundant foraminifers, and bryozoans as the dominant allochemical constituents (Plate 1-D). The Hindsville generally represents higher energy depositional environments than the Pitkin, lacking mudstones and wackestones.

The Hindsville Formation ranges in thickness from 0 to 100 feet in the Oklahoma Ozark Region (Huffman, 1958), but is typically much thinner in the present study area. This may possibly be due to onlap over a combination of Boone and Moorefield erosional surfaces.

PLATE 1

PRE-PITKIN STRATIGRAPHY

Figure A: Exposure of Boone Group erosional remnants. Two inliers can be seen, one in the foreground and one in the background. Both are topographically higher than local exposures of the Moorefield Formation. View to the east. (Below M.S. 183)

Figure B: Outcrop of Boone chert overlain by Moorefield limestone. Pick end of hammer rests against buff colored chert. A thin, fine grained chert conglomerate lies just above the hammer head. The painted number "2" can be seen on the overlying Moorefield Formation. (M.S. 203, units 1 and 2)

Figure C: Outcrop appearance of the Hindsville Formation. It generally forms a smooth weathering, rounded bluff or small bench beneath the Fayetteville Shale. This bed is 2 feet thick. (M.S. 194, unit 1)

Figure D: Thin section of the Hindsville Formation. Hindsville lithologies are generally similar to those of the Pitkin Limestone. Notice the abundance of bryozoan and crinoid skeletal fragments. The abrasion of the allochems, the tight packing, and the lack of carbonate mud all indicate a high energy depositional environment. Plane light. (M.S. 197, unit 2)

Figure E: Chesterian to lower Morrowan stratigraphic package of the Ozark Region. The Hindsville Formation, seen at the base of the photograph, is overlain by a covered interval of the Fayetteville Shale. The Pitkin is represented by a resistant gray weathering bluff. The Sausbee fills the upper 1/3 of the photograph. H=Hindsville, F=Fayetteville, P=Pitkin, and S=Sausbee. (M.S. 205)

Figure F: Outcrop appearance of the sharp, conformable contact between the Hindsville Formation and the Fayetteville Shale. Black arrow points to hammer for scale. (M.S. 207, units 1 and 2)

PLATE 1

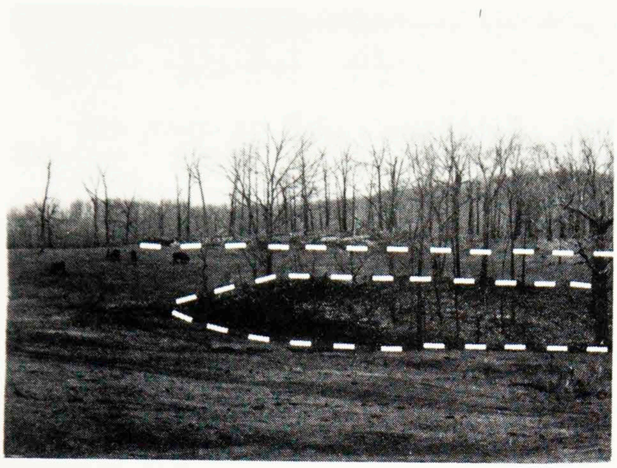


Figure A

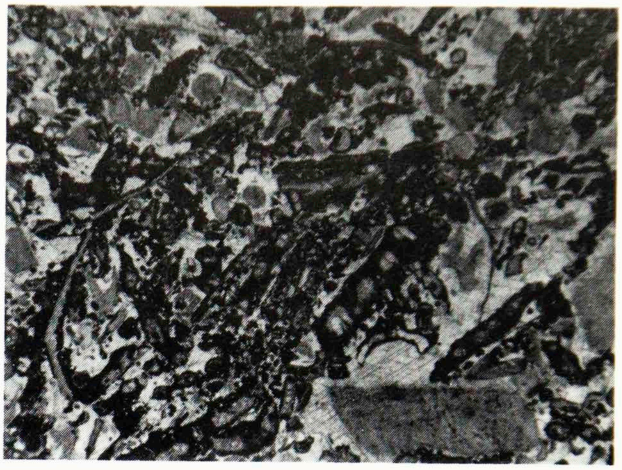


Figure D 1mm

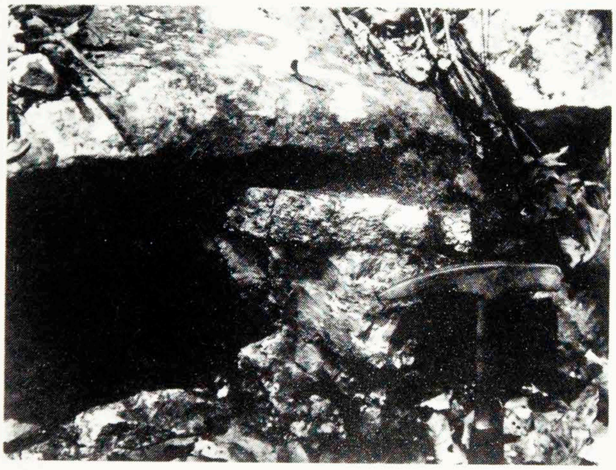


Figure B

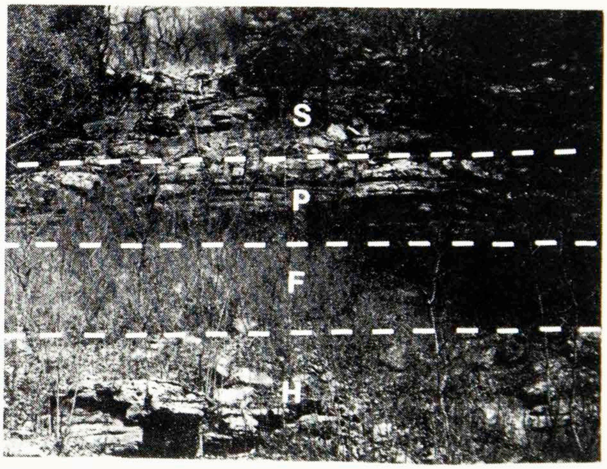


Figure E

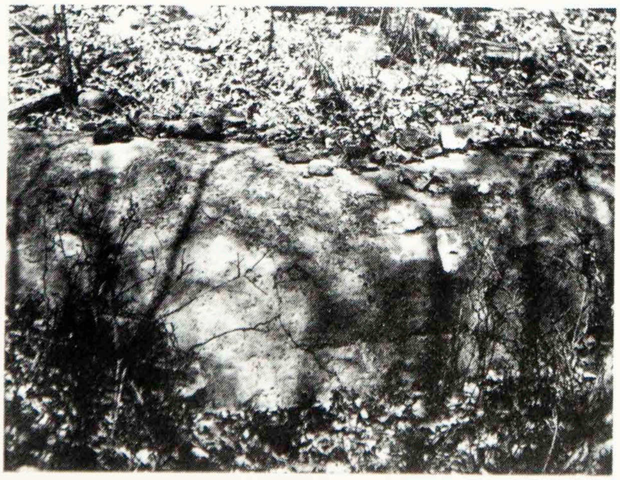


Figure C

Figure F

Thick bedded intervals are exposed at M.S. 185, M.S. 186, M.S. 188, M.S. 195, M.S. 203, M.S. 205, and M.S. 206. Much thinner exposures are seen at M.S. 183, M.S. 197, M.S. 199, M.S. 204, and M.S. 207.

The Hindsville marks the beginning of continuous deposition which characterizes the Chesterian stratigraphic package (Plate 1-E). The contact between it and the overlying Fayetteville is usually sharp in the study area (Plate 1-F). Outside the field area, the contact has been reported to be gradational (Huffman, 1958).

Fayetteville Shale

The Fayetteville Shale, throughout the study area, is commonly represented by a covered interval forming a gentle slope of Pitkin talus (Plate 1-E). It is difficult to pick the Fayetteville-Pitkin contact at most locations because of cover (Fig. 7; Plate 2-A). The best exposures of Fayetteville lithologies are observed at recent road cuts (Plate 2-B).

Black fissile shale is the dominant lithology (Plate 2-C). It is sparsely fossiliferous and commonly interrupted by beds of limestone that are less than one foot thick (Plate 2-D). These limestone units tend to weather into smooth rectangular blocks because of jointing. They appear to be fine-grained, falling into the wackestone or mudstone categories of Dunham's (1962) classification. Thin sections of the carbonates reveal silt-sized quartz grains, microbioclasts, and a mixture of abraded and unabraded invertebrate skeletal remains. Rarely are coarser grained (higher energy) lithologies encountered in the Fayetteville.

The most interesting feature of the Fayetteville in northeastern Oklahoma is its variation in thickness. Previous investigations have not seriously addressed the problem. Figure 8 is an isopachous map of the Fayetteville Shale in portions of northeastern Oklahoma. The control points are from Huffman (1958) and from the measured sections of this study. The contour interval is 20 feet. Thickness values range from 11 feet at M.S. 197 to 185 feet in eastern Adair County near the Arkansas border.

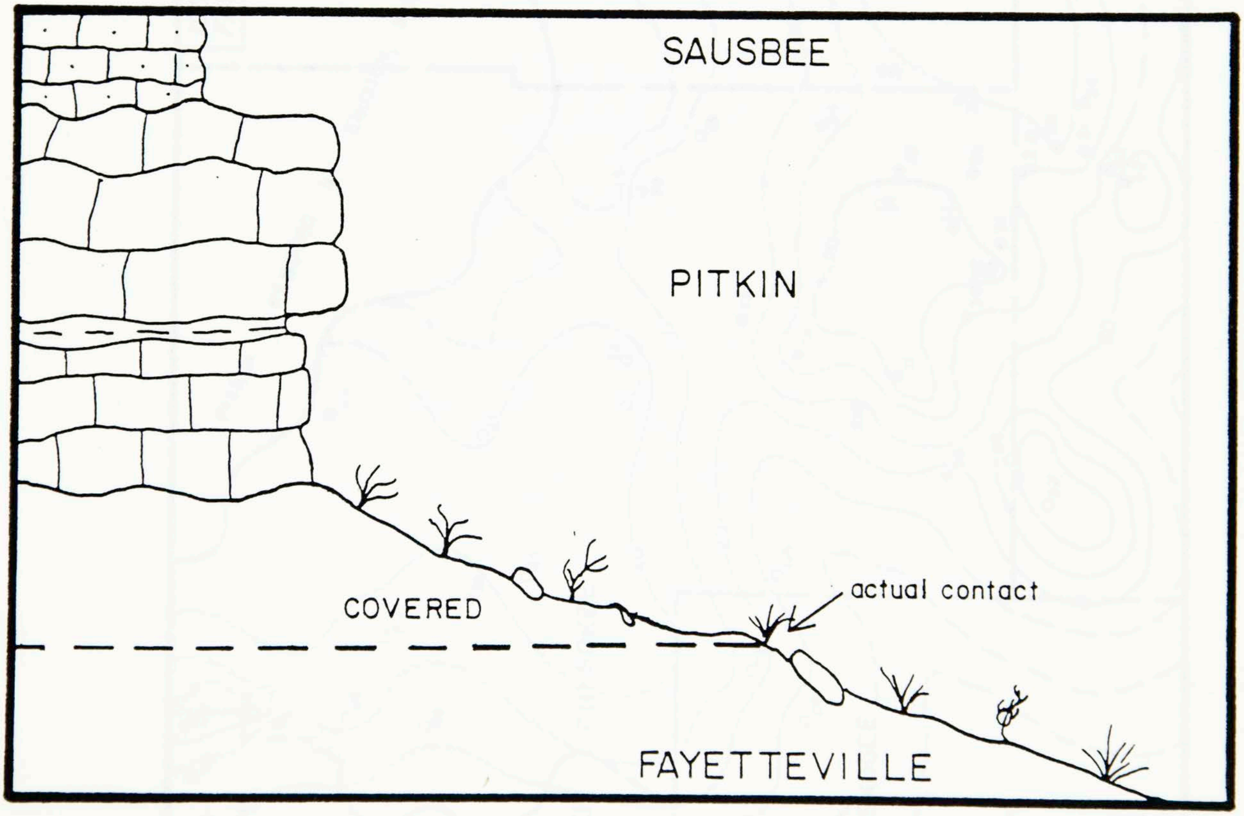


Figure 7. Typical field relationship of the upper Chesterian strata in northeastern Oklahoma. The Fayetteville Shale is commonly represented by a covered interval that obscures its contact with the Pitkin Limestone. The basal units of the Pitkin are also covered by talus and vegetation.

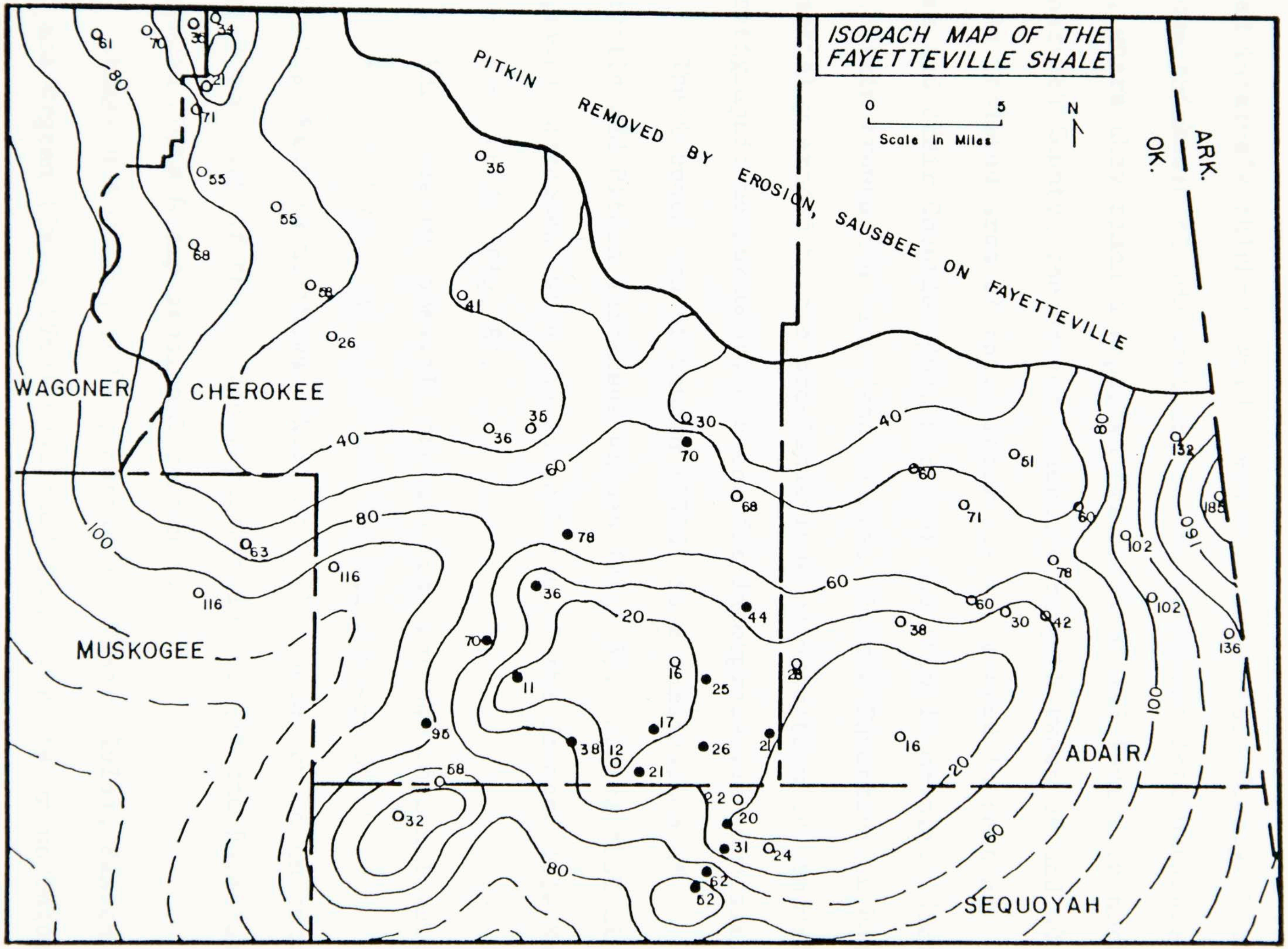


Figure 8. Isopachous map of the Fayetteville Shale in portions of northeastern Oklahoma. Solid circles are from sections measured in this study. Open circles are from sections measured in Huffman's (1958) study.

The thinnest intervals of Fayetteville are located in the central portion of the map area, in southern Cherokee County. The measured intervals thicken rapidly eastward into Adair County obtaining a maximum thickness of 185 feet and to the southwest into Muskogee County, where they reach a reported thickness of 116 feet. In northwest Cherokee County, the values generally range between 30 and 40 feet. An isolated area of thick intervals is located in central Cherokee and Adair Counties just north of the thin intervals. North of the Pitkin truncation line (see Chapter V), the Fayetteville has been partially eroded by the pre-Pennsylvanian unconformity rendering any stratigraphic measurements useless for interpretative purposes.

The isopach map of Laudon (1958) is a combination of Fayetteville and Pitkin thickness values (Fig. 9). Notice that it is in general agreement with the isopach map of the Fayetteville Shale in the present study (Fig. 8).

There are two possible explanations for the regional variations in the thickness and resultant isopach pattern of the Fayetteville Shale in northeast Oklahoma: (1) there may be an unconformity at the base or top of the Fayetteville, or (2) the Fayetteville thins around Boone Group erosional remnants.

Adams and Ulrich (1904), Purdue and Miser (1916), Easton (1942), and Orgren (1961, 1968) concluded that there is an unconformity at the top of the Fayetteville in Arkansas. They state that the formation can be divided in that area into three members: (1) a lower thick shale with carbonates at the base, (2) the Wedington Sandstone Member, and (3) an upper shale and carbonate unit. In Arkansas, the Pitkin seems to be lying on different members of the Fayetteville at different localities indicating the possible presence of an unconformity (Orgren, 1961).

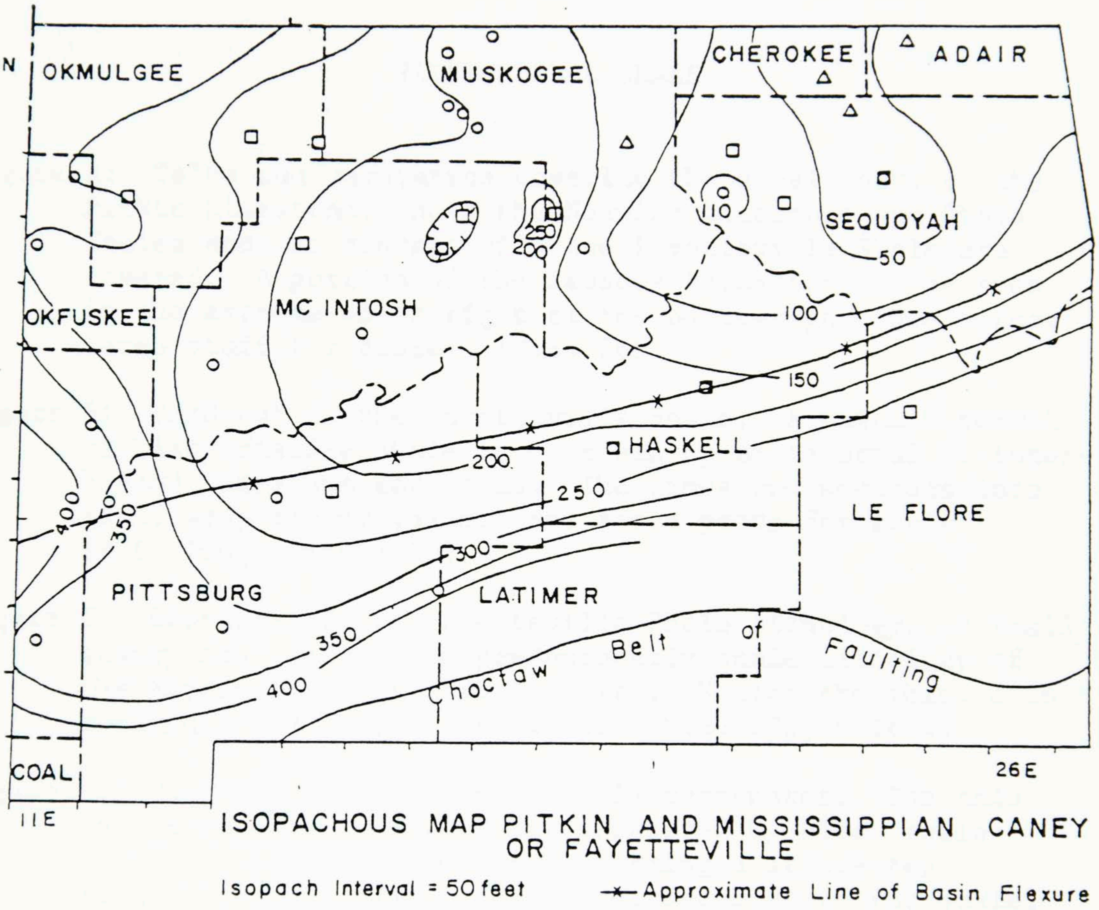


Figure 9. Isopachous map of upper Chesterian strata in northeastern Oklahoma. The stippled line represents the proposed line of basin flexure separating shallow shelf deposits from deep shelf to basin deposits (from Laudon, 1958, Fig. 4, p. 12).

There is no physical evidence for an unconformity at the top or base of the Fayetteville in the present study area. Absent are conglomerates, terrestrially derived sandstones, channel or scour surfaces, and relief on the contacts.

PLATE 2

FAYETTEVILLE SHALE

Figure A: Talus and vegetation covering the basal units of the Pitkin Limestone. Both the Nodular Limestone and Shale Facies and the contact with the Fayetteville Shale are covered. A portion of the Sausbee Formation can be seen in the extreme upper right of the photograph. See 5-foot Jacob staff for scale. (M.S. 205)

Figure B: Road cut of the Fayetteville Shale. A thick interval of black fissile shale is overlain by an interval of interbedded limestone and shale. The limestone weathers into light gray blocky talus. See fence posts for scale. (M.S. 196, units 8-12)

Figure C: Exposure of the Fayetteville Shale lithology. A small quarry has exposed the predominantly shale lithology of the Fayetteville at this locality. Notice the thin, even bedding. See hammer for scale. (M.S. 203, unit 4)

Figure D: Outcrop of upper Fayetteville carbonates. The thin to medium limestone beds are separated by black shale beds 0.5 to 1.5 inches thick, forming a stair-step pattern up the slope. See 5-foot Jacob staff for scale. (M.S. 183, unit 1-B)

PITKIN CROSSBEDS

Figure E: Outcrop of the Pitkin Limestone. The white arrows point to crossbeds exposed along the cliff face. This exposure of Pitkin is over 60 feet thick. (M.S. 193)

Figure F: Close up photograph of crossbeds within the Pitkin Limestone. See lense cap for scale. (M.S. 193, unit 8)

PLATE 2

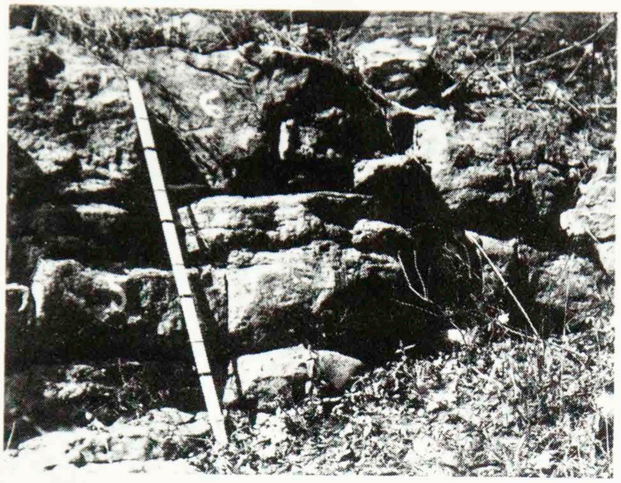


Figure A

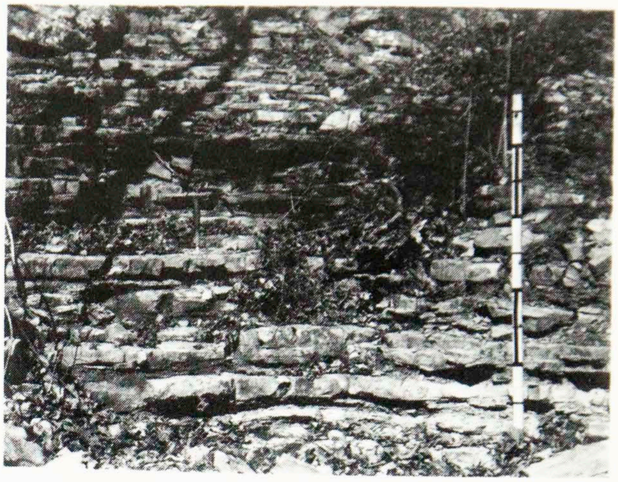


Figure D

Figure B

Figure E

Figure C

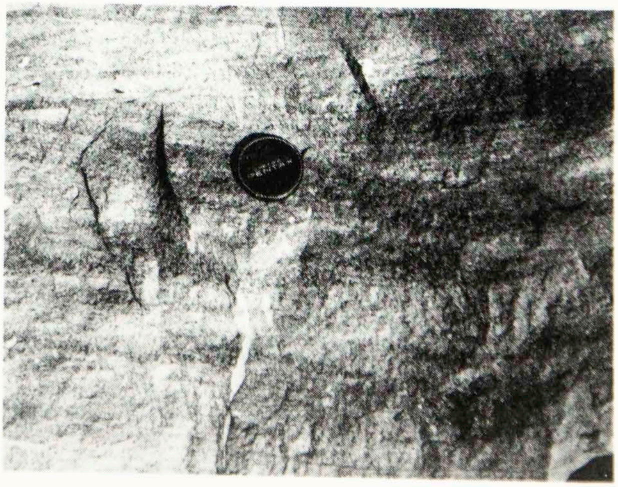


Figure F

The isopachous map of Figure 8 illustrates that the thin intervals of Fayetteville are confined mostly to Cherokee and western Adair Counties. Could this area be a Boone Group topographic high caused by Meramecian structural deformation which subsequently effected Fayetteville deposition?

In this study area the generally poor exposure and variable stratigraphic position of the carbonate units within the Fayetteville Shale inhibit their use for purposes of correlation. Also, Hindsville or Moorefield carbonates are present between the Boone and the Fayetteville in all other exposed sequences in the study area. This would suggest that the lower areas on the Boone surface had been filled in by those formations and that the Fayetteville was deposited on an essentially flat surface. Detailed information on the Hindsville-Moorefield interval where the Fayetteville Shale is anomalously thin or thick is not available at this time.

It can be concluded that our present state of knowledge of pre-Pitkin stratigraphy has not advanced to the point where the Fayetteville thickness variations can be adequately explained.

CHAPTER III

LITHOFACIES AND DEPOSITIONAL ENVIRONMENTS

> Bathurst (1971) has pointed out that the sea floor sediment represents but an insignificant remnant of the teeming variety of organisms and ecological systems that contribute to it. The unravelling of clues left in the residue of debris and sewage, for purposes of environmental reconstruction, is a fascinating and difficult chore (Wilson, 1975, p. 7).

Carbonate Depositional Environments

A sedimentary facies is a mass of sedimentary rock that can be defined and distinguished from others by its geometry, lithology, sedimentary structure, paleocurrent patterns, and fossil content. A particular facies is the product of a unique depositional environment. A depositional environment, on the other hand, is an area of the earth's surface that is physically, chemically, and biologically different from adjacent areas (Selley, 1978). It follows from these two interrelated definitions that a depositional environment is commonly expressed in the rock record by one or more sedimentary facies.

These two definitions need not be interrelated. A less rigid definition of facies is any rock unit that may be distinguished from another rock unit with no environmental inference. Examples of this type of facies definition are "the black shales facies," "the blue limestone facies," or the "red sandstone facies." In the following discussion this type of facies designation has been avoided. Each of the facies of the Pitkin in this study is assigned to a specific depositional environment or a set of genetically similar depositional environments on the basis of Wilson (1975, pp. 63-69) standard microfacies descriptions.

A basic premise of carbonate geology is the autochthonous origin of carbonate sediment. In recent studies of the Bahama Platform, biofacies have been found to coincide with, and generally influence the expression of, lithofacies (Newell and Rigby, 1957). This is a logical observation since most carbonate sediments are produced by organisms or organic activity. Direct relationships between biofacies and lithofacies allow for confidence when relating ancient facies to depositional environments and is applicable to large-scale studies of carbonate units. However, some investigators believe that the transport of carbonate sediment is sporadic and directly related to the roughness of the seas (Meany, 1973). Certainly a calcium carbonate grain will not survive the same amount of transport as will a terrestrial quartz grain. Limited transport of competent carbonate grains is believed to take place on a small geographic scale such as the one encompassed by the present study area.

Criteria used for establishing and defining the facies of the Pitkin in this study area are: (1) the texture of the rock, (2) allochem analysis based on point counts of thin sections, (3) outcrop characteristics, and (4) the comparison of the Pitkin to modern analogues described in the literature.

When analyzing the texture of an ancient limestone using Dunham's (1962) classification, some caution should be used. The amount of lime mud preserved in a limestone cannot invariably be related to the hydrologic environment at the time of deposition. The quantity of mud found in modern carbonate sediment seems to represent an equilibrium condition, between mud production and mud removal (Bathurst, 1971). For instance, the high energy coralgal facies of the Great Bahama Bank has as much as twice the mud by weight-percent as does the lower energy oolitic and grapestone facies (Bathurst, 1971). To overcome this limitation, more attention should be paid to the degree of sorting, abrasion, and coating found associated with carbonate grains. Textural observations combined with the close scrutiny of the transportation history of constituent grains can be used as a valuable interpretive tool.

When possible, the lithofacies are defined quantitatively. The results of the point counts of both Pitkin and Sausbee thin sections are presented in Appendix B. Appendix C is a series of ternary diagrams based on these point counts. Each point on a diagram represents one of the units described in the field then subsequently studied by thin section. The natural clustering of the points reveal the characteristics of the rock and may be used for interpretive purposes.

Again, caution should be used when comparing the relative abundance of carbonate grains in thin section. Observing Pitkin thin sections one can be overwhelmed by the amount of bryozoan and crinoidal skeletal fragments preserved in the rock. If it were possible to walk on the Pitkin sea floor, the thin sections give the impression that several bryozoan colonies would be crushed with each step. In a turbulent hydrologic environment delicate carbonate skeletons, such as those of bryozoans, are selectively destroyed and eventually reduced to mud or silt-sized particles (Chane, 1964). It would appear that robust skeletal fragments, like crinoids, would be preserved in ancient rock. However, this is not the case in recent sediments. The dominant sediment producer, whether robust or delicate, is selectively preserved. The codiacean alga Halimeda is a dominant carbonate producer in modern times, yet it makes up only 1 to 15 percent of the reef biota (Bathurst, 1971). Personal observations of the reef tract in Jamaica reinforce this statement. Nevertheless, biofacies and lithofacies do have a positive relationship that can be applied to the study of ancient carbonate rocks.

Outcrop descriptions are used to define and describe lithofacies qualitatively. Regardless of the type of allochems comprising crossbedded intervals, one can only assume that it was deposited in a turbulent environment (Plate 2-E, F). The Nodular Limestone and Shale Facies is defined solely on the basis of outcrop description and stratigraphic position. Most of the oolitic units are smooth weathering. The Wackestone Facies has faunal elements standing out in relief from the matrix on weathered surfaces. These and other field characteristics of Pitkin lithofacies were found to repeat themselves from section to section, thus allowing outcrop character to be used as a criterion for facies description.

Before establishing a facies as a legitimate indicator of a depositional environment, a search in the literature was made to find a modern analogue. It is believed that carbonate depositional environments have generally remained the same throughout geologic time with only subtle variations as a result of organic evolution (Wilson, 1975). One must assume that the physical and chemical processes involved in recent carbonate deposition were the same as those in the geologic past. Therefore, each facies has been assigned an analogue that best reflects the lithologic character of the rock unit in question.

It is evident from this discussion that each of the descriptive methods outlined above has inherent limitations, but when each are used to describe the units of the Pitkin, a group of reoccurring lithologies emerges. These are the lithofacies of the Pitkin Limestone.

Eleven facies were recognized in the Pitkin Limestone of the study area. They are: (1) Oolite Facies, (2) Oolitic Facies, (3) Bioclastic Facies, (4) Encrinite Facies, (5) Oncolite Facies, (6) Nodular Limestone and Shale Facies, (7) Wackestone Facies, (8) Peloidal Facies, (9) Mudstone Facies, (10) Shale Facies, and (11) Mound Facies. All of these facies may be defined either quantitatively and/or qualitatively and, with the exception of the Oolite Facies and the Mound Facies of Unit 193-5, were found to reoccur within the study area.

Oolite Facies

The word oolite, as defined in the Glossary of Geology, second edition, is "a sedimentary rock, usually a limestone, made up chiefly of ooliths cemented together." The same word was first used to name a facies of the carbonate sediments on the Great Bahama Bank by Imbrie and Purdy (1962). Their quantitative definition of the Oolite

Facies is any sediment that has a composition of greater than 80 percent ooliths. This is the definition used in the current study of Pitkin lithologies (Appendix C-V).

The single exposure of this facies produces a thick bedded, low-angle, crossbedded unit containing various small amounts of skeletal material (Plate 3-A). The dominant nuclei of Pitkin ooliths are peloids and abraded skeletal grains (Plate 3-B). Some of the ooliths are only superficially coated while others have several concentric lamellae (Plate 3-C). Most of the ooliths are normally packed but rare over-packed laminae are also present (Plate 3-D).

The Oolite Facies of the Pitkin was most likely deposited in a turbulent shallow water environment and might possibly represent an area of mobile carbonate sand, where ooliths were forming (Newell, Purdy, and Imbrie, 1960). This facies indicates a shoaling environment dominated by strong tidal currents and open marine waves that keep the grains in nearly constant motion. This interpretation is based on the texture and the low skeletal content, both indicating a high stress environment for filter feeding organisms (Purdy, 1964). Using the Bahama Banks as a modern analogue, the water depth at the time of deposition was probably less than 3 meters (Newell, Purdy, and Imbrie, 1960).

Overpacked ooliths in the Pitkin indicate a history of fluctuating environments where deposition occurred in a marine setting while lithification and cementation took place in a subaerial setting (Wilson, 1975). There are Recent examples of this phenomenon. The oolitic shoals near the Tongue of the Ocean and at Brown's Cay are

PLATE 3

OOLITHS AND THE OOLITE FACIES

Figure A: Outcrop of the Oolite Facies. The lithology and crossbeds in the exposure indicate a high energy depositional environment. See hammer for scale. (M.S. 202, unit 9)

Figure B: Thin section of the Oolite Facies. The oolitic coats surround peloids and skeletal grains. Notice the normal packing of the grains and compare to figures C and D. Plane light. (M.S. 202, unit 9)

Figure C: Thin section of tightly packed ooliths. The grains are in contact. Compare to figures B and D. Notice the variety of nuclei, concentric laminations, and radiating fabric in the individual ooliths. Plane light. (M.S. 185, unit 5)

Figure D: Thin section of overpacked ooliths. Overpacked ooliths in the Pitkin may indicate cementation during periods of subaerial exposure on shoals. Plane light. (M.S. 193, unit 4)

Figure E: Thin section of the Oolitic facies showing both normal and small sized ooliths. A bimodal size distribution of ooliths is common in oolitic and peloidal lithologies of the Pitkin. Plane light. (M.S. 192, unit 8)

Figure F: Polished slab of oolitic lithology. The percentage of ooliths in this specimen is not high enough to place it in the oolite category but their abundance may indicate deposition near an oolite shoal. Color variation is secondary. See penny for scale. (M.S. 191, unit 2)

PLATE 3

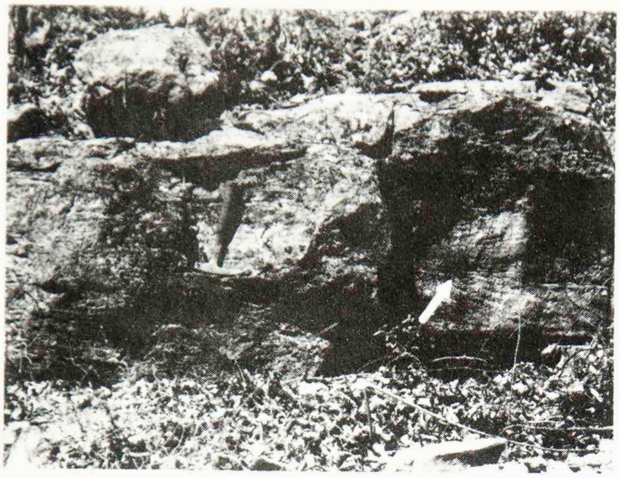


Figure A

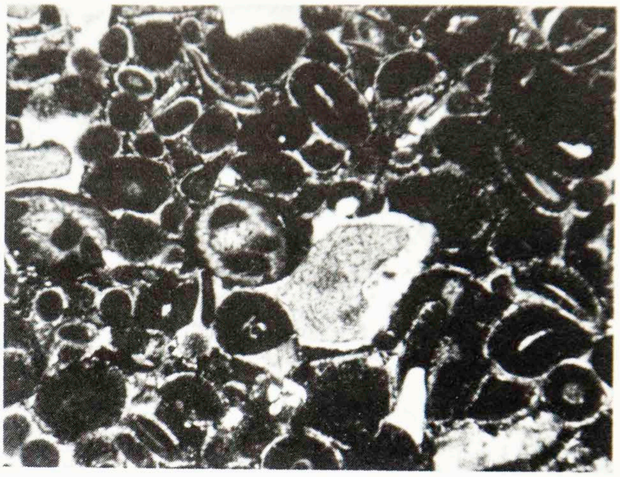


Figure D 1mm

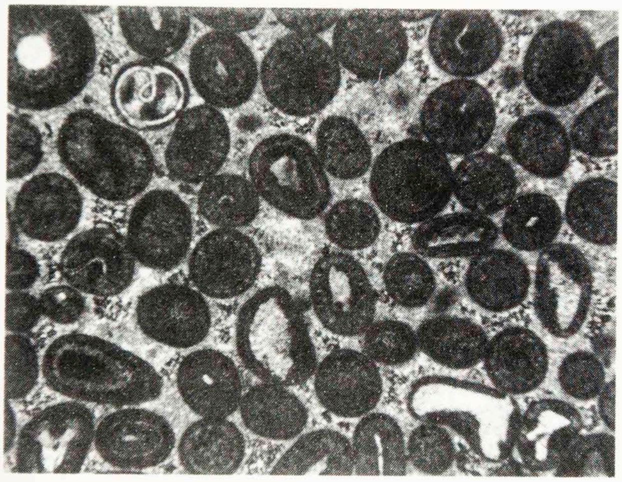


Figure B 1mm

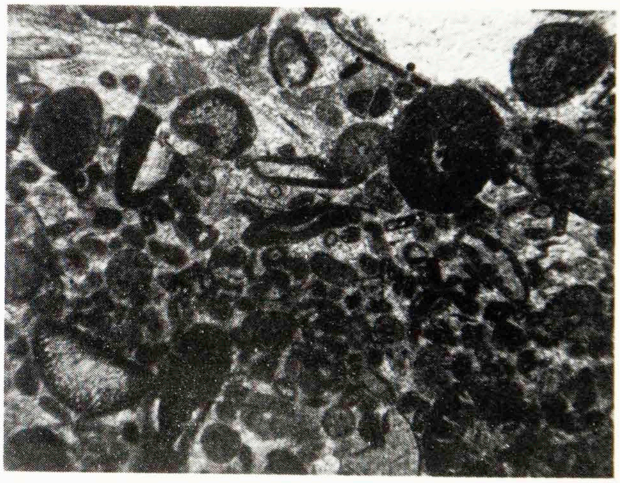


Figure E 1mm

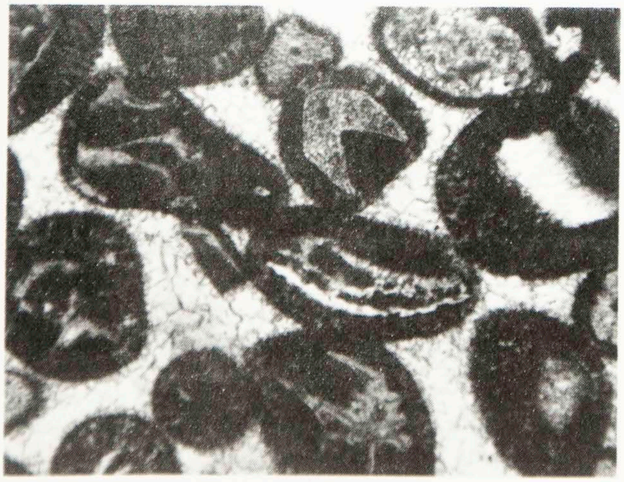


Figure C 1mm

Figure F

periodically exposed during low water, spring tides (Purdy, 1961).

Because of the originally mobile nature of the Oolite Facies one would not expect it to be favored for preservation in the sedimentary record and, in fact, as defined in this study, it is only observed in M.S. 202, unit 9.

The Oolite and Oolitic Facies of the Pitkin are unusual because they contain ooliths approximately 0.06 mm in diameter as opposed to the normal size range of 0.25 mm to 0.5 mm. In thin section a bimodal distribution of these oolith sizes can be seen (Plate 3-E). The significance of these tiny ooliths has not been fully explained, yet they are common in the oolitic lithologies in the Pitkin.

Oolitic Facies

The Oolitic Facies was first named by Imbrie and Purdy (1962). The quantitative definition of the Oolitic Facies is any unit that has an allochem composition of between 30 and 80 percent ooliths (Appendix C-V; Plate 3-F). Other allochems seen in this facies are coated and uncoated skeletal grains, oncolites, and peloids (Plate 4-A, B). Exposures of this facies are resistant to weathering and generally form thick bedded to massive units (Plate 4-C). The rocks of this facies are commonly crossbedded, exhibiting minor grading and sorting. Texturally, this facies may fall into either the grainstone or packstone category.

Because of the increased skeletal allochem content of the rock an oolitic grainstone or packstone indicates a greater substrate stability than the Oolite Facies. Assuming that the skeletal grains represent indigenous faunas, the immobile nature of the oolitic sands may have allowed colonization by suspension feeders. Oolitic packstones usually contain a mixture of suspension and detritus feeders inferring that the sediment was deposited in less turbulent, more restricted marine conditions at or below wave base and remained immobile after deposition (Purdy, 1964).

Water depths at the time of deposition for this facies may have been less than 10 meters. The major transporting mechanisms for this facies were probably tidal currents and storm waves. The oolitic grainstones that are generally crossbedded may still represent shoaling environments, similar to those of the Oolite Facies. Oolitic packstones were probably deposited in local environments that were more restricted than those of the grainstones and may indicate intershoal areas.

Using the Bahamas as a modern analogue, mixed skeletal and oolitic carbonate sands at first appear to be mobile and are formed into subaqueous dunes or megaripples. Bathurst (1967) found that the carbonate sand that comprises these rather large sedimentary features is actually rendered immobile, except during storms, by the formation of a subtidal blue-green algal mat. The mat acts as a sediment stabilizer and the grains do not move in the normal day-to-day current regime. There is an abundance of the blue-green algae Girvanella preserved in Pitkin sediments. Perhaps this alga was the binding agent of Pitkin megaripples and dunes.

The depositional setting of the Oolitic Facies of the Pitkin Limestone was located in the proximity of oolite shoals. There is a

PLATE 4

OOLITIC FACIES

Figure A: Thin section of the Oolitic Facies. Even though ooliths are the dominant allochem in this specimen there is an abundance of coated and uncoated skeletal grains. Plane light. (M.S. 201, unit 9)

Figure B: Slab of the Oolitic Facies. Notice the abundant skeletal debris encased in an oolitic matrix. Cross-laminations indicate a shallow water, moderately high energy depositional environment. See penny for scale. (M.S. 201, unit 9)

Figure C: Outcrop of both the Oolitic and Bioclastic Facies. These facies tend to form thick bedded bluffs. The cliff above the Jacob staff grades upward from an oolitic to a purely bioclastic lithology. See 5-foot Jacobs staff for scale. (M.S. 193, units 3-8)

BIOCLASTIC FACIES

Figure D: Thin section of a bioclastic grainstone. The dominant allochem constituents are micrite-coated bryozoan and crinoid skeletal debris. Plane light. (M.S. 202, unit 4)

Figure E: Polished slab of a bioclastic packstone. The specimen is oriented with stratigraphic up at the top of the page. Notice the geopetal structure in the lower right portion of the photograph. The rock is composed of nearly equal proportions of crinoid, bryozoan, and brachiopod skeletal material. See penny for scale. (M.S. 201, unit 4)

Figure F: Outcrop of the Bioclastic Facies. It generally forms thick bedded bluffs and weathers rough. See 5-foot Jacob staff for scale. (M.S. 198, unit 5)

PLATE 4

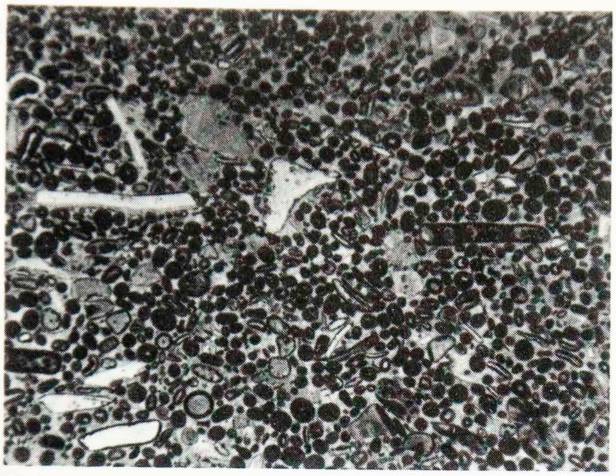


Figure A 1mm

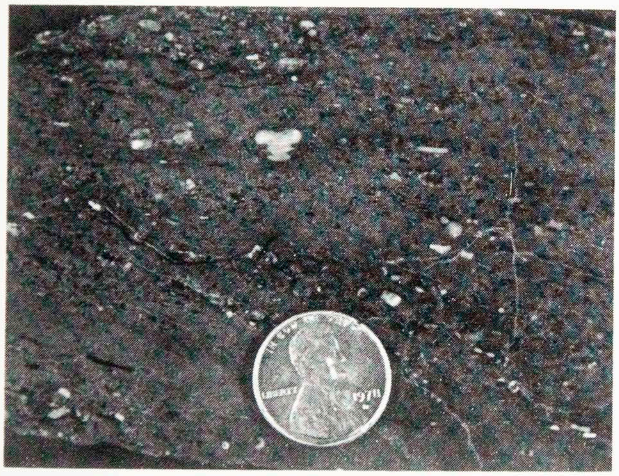


Figure B

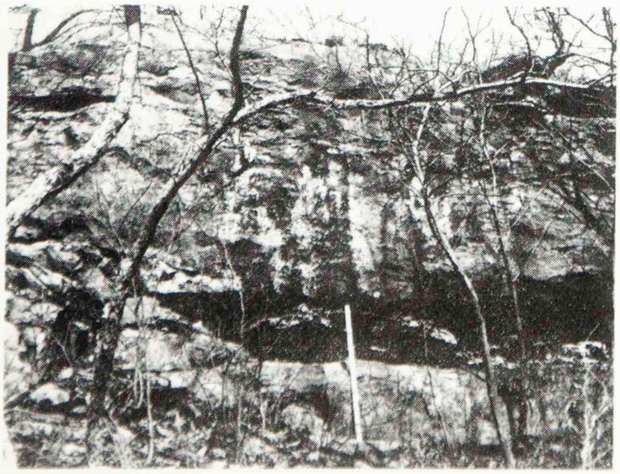


Figure C

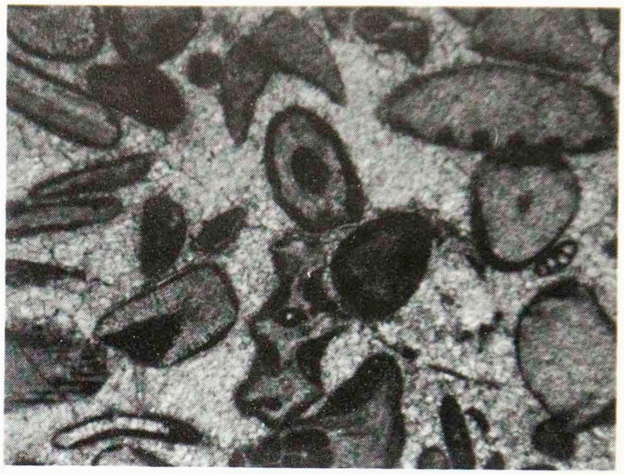


Figure D 1mm

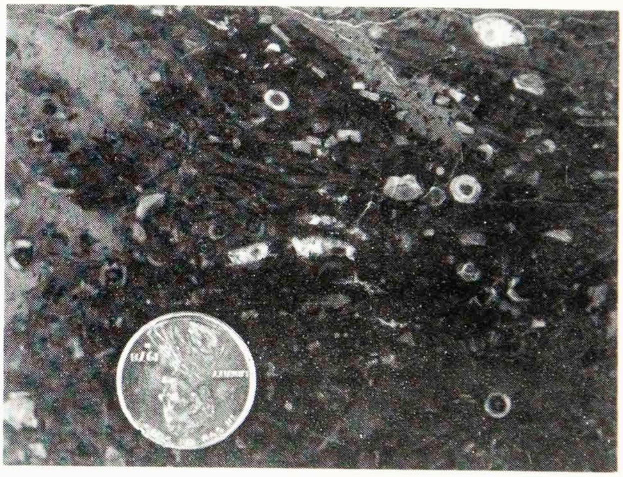


Figure E

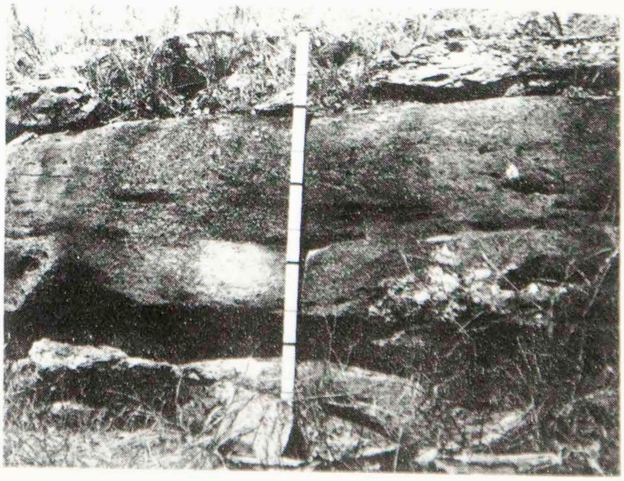


Figure F

higher content of ooliths in shelf lagoon sediments than in the fore-slope or outer platform deposits of modern carbonate sediment. Flood tides are stronger than ebb tides and tend to transport ooliths onto more restricted marine environments where they are deposited but not formed. Storm waves also contribute to this process (Newell, Purdy, and Imbrie, 1960). It may then be assumed that the Oolitic Facies of the Pitkin was deposited in local environments behind or landward from zones of oolite formation and may represent spillover lobes (Ball, 1967).

Bioclastic Facies

The quantitative definition of the Bioclastic Facies is any unit that has an allochem composition of greater than 80 percent skeletal debris and less than 30 percent ooliths (Plate 4-D). Qualitatively, this facies may be described as any grainstone or packstone containing primarily non-coated skeletal grains. In outcrop, this facies cannot be differentiated on the basis of bedding character from the Oolitic or Oncolitic Facies. It is commonly crossbedded, thick-bedded, and forms resistant cliffs or bluffs that weather light to medium gray (Plate 4-F). Fresh surfaces and polished slabs reveal minor sorting and grading of constituent grains (Plate 4-E).

The depositional environments described for this facies, in some respects, differ only slightly from those of the Oolitic Facies. Water depth for this facies, at the time of deposition, may have been less than 10 meters for grainstones and probably less than 30 meters for packstones. As in the Oolitic Facies, packstones may represent intershoal or partially restricted depositional environments, while crossbedded grainstones may indicate shoaling, above wave base depositional environments. The abundant crinoid and bryozoan faunas found in this facies may also indicate that it was deposited along the flanks of large dunes, shoals, or megaripples. This type of deposit has been described from the flanks of Mississippian bioherms in the Sacramento Mountains of New Mexico (Pray, 1958). Some of the grainstones have severely abraded allochems that are tightly packed and may represent lag deposits (Wilson, 1975). The units of the Bioclastic Facies may have also been deposited seaward from oolite shoals along the foreslope. Foreslope depositional environments are found both above and below wave base and, as a result, the lithologies formed in this environment have differing textures but are generally found to be packstones (Wilson, 1975).

A mixture of abraded or coated and non-abraded or non-coated skeletal grains in a specimen of the Bioclastic Facies may indicate textural inversion (Wilson, 1975). Loose non-abraded (whole fossils) skeletal debris may represent *in situ* preservation of indigenous faunas in partially restricted marine environments, whereas coated and abraded skeletal grains infer a transportation history in a turbulent environment prior to deposition (Heckle, 1972). This type of carbonate sediment is common in the Pitkin's Bioclastic Facies and may represent both hydrologic modification and *in situ* deposition of skeletal remains.

The Bioclastic Facies represents several depositional environments. Each unit and each thin section of this facies must be studied carefully, along with the vertical sequence where it occurs, in order to decide whether it originated in a foreslope environment or a shoaling, semi-restricted, platform environment.

The Bioclastic Facies may be analogous to the Coralgal Facies of the Great Bahama Bank (Purdy, 1963). The term "bioclastic" was originally used by Wilson (1975) to modify Dunham's (1962) classification. It refers to any rock that is predominantly composed of invertebrate skeletal material.

Encrinite Facies

This facies is quantitatively defined as any unit that contains over 30 percent total volume crinoidal skeletal debris (see Appendix B). Plate 5, figures A and B illustrate the crinoidal composition of the Encrinite Facies. In outcrop, it forms rubbly to rough-weathering units that are thin to medium-bedded (Plate 5-C). Typically, it is more poorly indurated than the previously described facies. The larger, crinoidal fragments are commonly found in discrete lenses that may indicate episodic storm activity. The Encrinite Facies of the Pitkin is texturally either a grainstone or a packstone.

The depositional environment of the Encrinite Facies is located bathymetrically at or below active wave base. Encrinites have been described by Wilson (1975) as being a special type of flank deposit found on slopes or shelf margins. The deposition of this facies requires constant water motion in the form of currents rather than waves (Wilson, 1975). Encrinites have been found surrounding banks, shoals, and bioherms. Pray (1958) discovered this facies flanking the large bryozoan bioherms of the Osagean Lake Valley Formation.

PLATE 5

ENCRINITE FACIES

Figure A: Thin section of the Encrinite Facies. This specimen is almost completely composed of crinoid debris. Notice the tight packing and microstylolites. Specimens of this facies are either grainstones or packstones. Plane light. (M.S. 185, unit 3)

Figure B: Polished slab of the Encrinite Facies. It is composed of abundant crinoid skeletal debris and a minor amount of bryozoan fragments. See penny for scale. (M.S. 193, unit 3)

Figure C: Outcrop of the Encrinite Facies. The crinoid fossils tend to "stand out" on a weathered surface. See lense cap for scale. (M.S. 193, unit 3)

ONCOLITIC FACIES

Figure D: Thin section of an oncolitic packstone. Micrite has been encrusted around bryozoan skeletal fragments by the activity of <u>Girvanella</u> to form small oncolites. Plane light. See also Plate 9-F. (M.S. 200, unit 6)

Figure E: Polished slab of an oncolitic packstone. These are the largest oncolites found in the study area. They require a mildly turbulent hydrologic environment for growth. Oncolites in a packstone indicate a transportation history from the environment of formation to the environment of deposition. See penny for scale. (M.S. 203, unit 6)

Figure F: Outcrop of the Oncolitic Facies. Exposures of the oncolitic facies generally form thick bedded, rounded units. See 5-foot Jacob staff for scale. (M.S. 202, units 6-8)

PLATE 5

Figure A 1mm

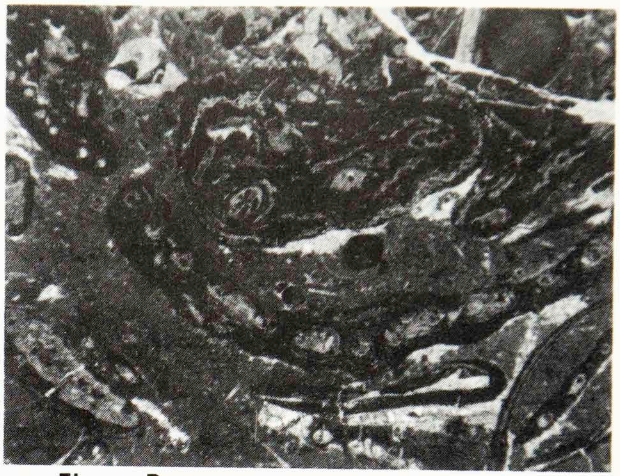


Figure D 1mm

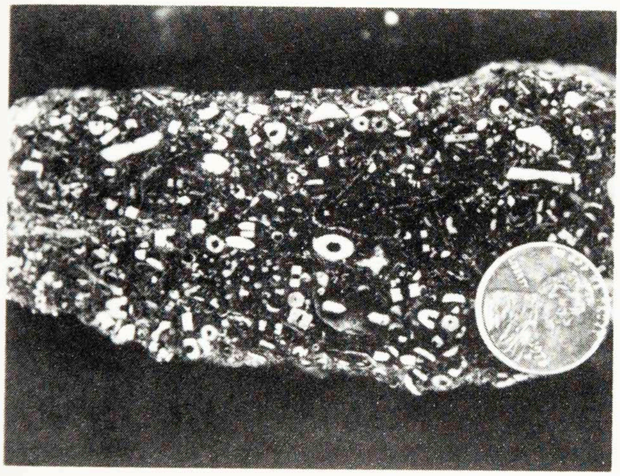


Figure B

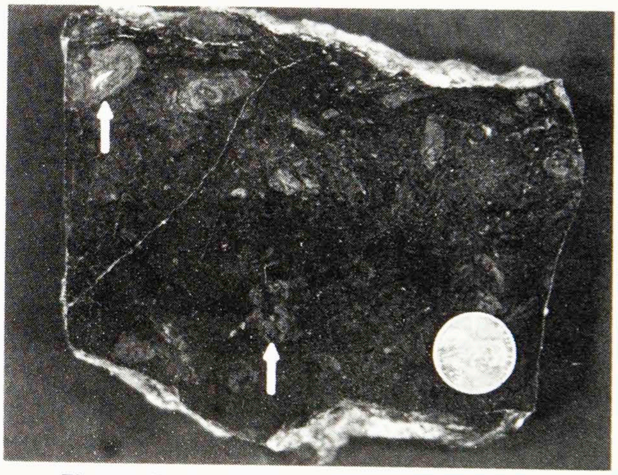


Figure E

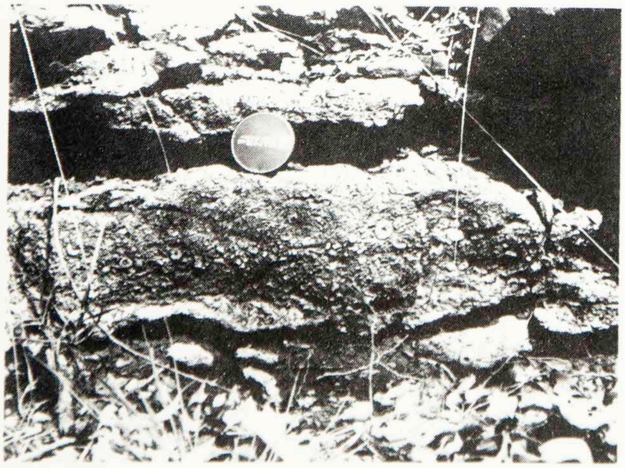


Figure C

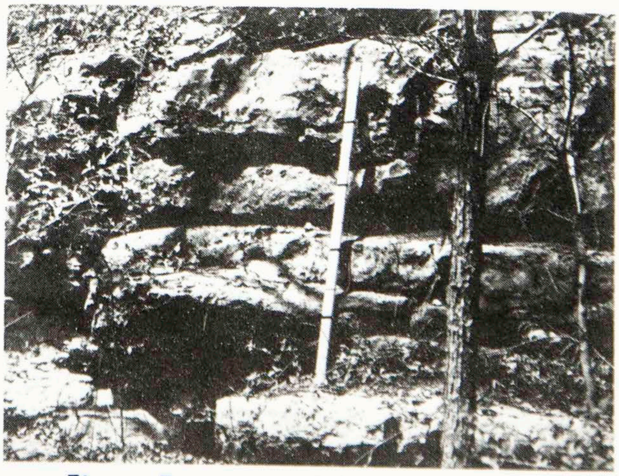


Figure F

Oncolitic Facies

Grain coats in the Pitkin consist of three types: (1) oolitic, (2) oncolitic, and (3) micritic. Oolitic coats originate from the interaction of sea water chemistry, hydrologic environment, and algal activity in shallow, marine waters but their exact nature is still controversial (Bathurst, 1971). Oncolitic coats originate from algal encrustations. The oncolitic coats of the Pitkin have been identified as being the algal-foraminiferal assemblage called Osagea (J. R. Groves, 1981, personal communication). Osagea is a genus level taxonomic classification for this assemblage (Henbest, 1963). The filamentous algal tubes of the blue-green algae Girvanella are the mechanism by which mud is trapped and bound to the grain (Plate 9-D). The newly-formed oncolite must be periodically disturbed by waves or currents in order for the grain to be completely encrusted (Kotila, 1973). Many of the oncolites seen in the Pitkin have preserved girvanellid tubes and microlaminations parallel to the curvature of the grain (Plate 5-D). Micrite envelopes or rinds are commonly much thinner than oncolitic coats and owe their origin to the activity of small boring or endolithic algae and the subsequent infilling of their tubes by mud. The micrite envelopes are not encrustations, they are replacements (Bathurst, 1966).

Both oncolitic-coated grains and micrite-coated grains are included in the coated grain category of the point count data (Appendix B).

The quantitative definition of the Oncolitic Facies is any unit that has greater than 50 percent coated allochems by volume

(Appendix C-VI). This definition requires a qualitative analysis of the coated grains in any particular thin section to see if the grain coats are of algal or diagenetic origin. The presence of megascopic oncolites are commonly revealed in polished slabs (Plate 5-E).

The dominant, allochem constituents of the Oncolitic Facies are algal encrusted bryozoan fragments. Bryozoans are preferentially encrusted by Girvanella as opposed to crinoid fragments which generally have micrite rinds (Appendix C-VII). Exposures of this facies are commonly medium bedded and darker in color than the Oolitic and Bioclastic Facies (Plate 5-F). The algal coatings are easily observed surrounding the grains with a 10X hand lens. These units may or may not be crossbedded and they texturally consist of both grainstones and packstones.

Since these oncolites are formed as a result of Girvanella encrustations and because of the present-day distribution of oncolites, the Oncolite Facies should be placed in a semi-restricted or back reef depositional environment (Kotila, 1973).

Oncolitic shoals are found in more gentle hydrologic conditions than those of oolite, oolitic, or bioclastic sediments. Water depths, at the time of deposition, may have been shallow, probably less than 2 meters but possibly as much as 5 meters. This facies, as a grainstone, is an above wave base, intertidal deposit. The dominant, transporting mechanism may have been waves and tidal currents with periodic storm activity modifying the shoal or bank.

Oncolitic packstones indicate textural inversion (Wilson, 1975). The oncolites were transported out of the shoaling environment where they originated, into quiet waters where the carbonate mud was not removed. These packstones may have been deposited in intershoal areas or on the flanks of shoals or buildups. Water depth may have ranged from 5 to 30 meters. Oncolites also tend to be deposited in tidal channels (Wilson, 1975).

Modern analogues of this facies can be observed at Rodgriquez Key and Tavernier Key in southern Florida (Bathurst, 1971).

Nodular Limestone and Shale Facies

As mentioned earlier, the Nodular Limestone and Shale Facies is defined by outcrop characteristics. The limestone nodules range in texture from pure mudstone to packstone with wackestone being dominant (Plate 6-A, B). In outcrop, this facies forms recessive intervals and is generally only partially exposed (Plate 6-C). M.S. 193 has the best exposure of this facies (Plate 6-D). The bedding, as the name implies, is wavy and nodular resulting from the differential compaction of carbonate sediments and shale. This phenomenon is called sedimentary boudinage (Wilson, 1975). It also contains thin limestone nodules approximately 2 to 5 centimeters in diameter called ball and flow structures (Plate 6-E). They result from argillaceous and calcareous sediments being deposited on slopes (Orgren, 1961). The mixing of shale and carbonate sediments may be due, in part, to bioturbation (Cook and Taylor, 1977). Evidence for bioturbation is the presence of pellets in carbonate thin sections of this facies.

The Nodular Limestone and Shale Facies are the best in the Pitkin for fossil collecting. The bryozoan Archimedes and well

PLATE 6

NODULAR LIMESTONE AND SHALE

Figure A: Thin section of the Nodular Limestone and Shale Facies. The texture is generally wackestone or less commonly mudstone. Notice the well preserved bryozoan skeletal microstructure in the lower left portion of the photograph. Plane light. (M.S. 183, unit 1-C)

Figure B: Polished slab of the Nodular Limestone and Shale Facies. Notice the well preserved bryozoan skeletal fragments in the center of the specimen. See penny for scale. (M.S. 193, unit 1)

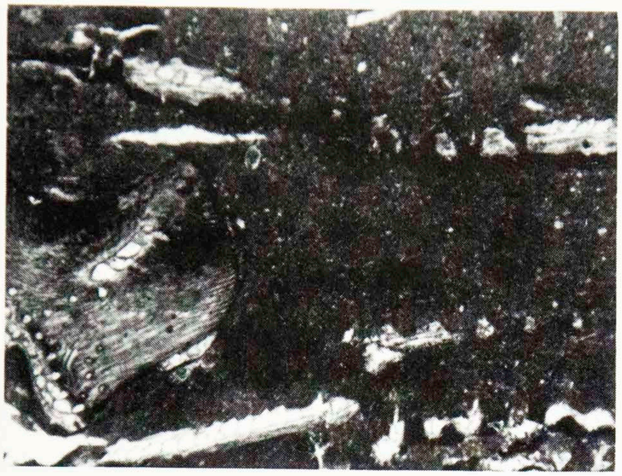
Figure C: Outcrop of the Pitkin Limestone. When exposed, the Nodular Limestone and Shale Facies typically weathers out to form a reentrant at the base of a bluff section. The units above the reentrant are expamples of the Oncolitic and Bioclastic Facies. (M.S. 185, units 1-6)

Figure D: Outcrop of the Nodular Limestone and Shale Facies. The limestone nodules are thicker and the shale is darker in color than in figure E. This exposure may be an example of sedimentary boudinage. See 5-foot Jacob staff for scale. (M.S. 193, unit 1)

Figure E: Outcrop of the Nodular Limestone and Shale Facies. Light gray rounded to elliptical limestone nodules are encased in a light gray to gray-green shale matrix. This exposure may be an example of the "ball and flow" structure. See hammer for scale. (M.S. 183, unit 1-C)

Figure F: Thin section of the Nodular Limestone and Shale Facies. This is a specimen of wackestone composed of abraded skeletal material, microbioclasts, and carbonate mud. Plane light. (M.S. 193, unit 1)

PLATE 6



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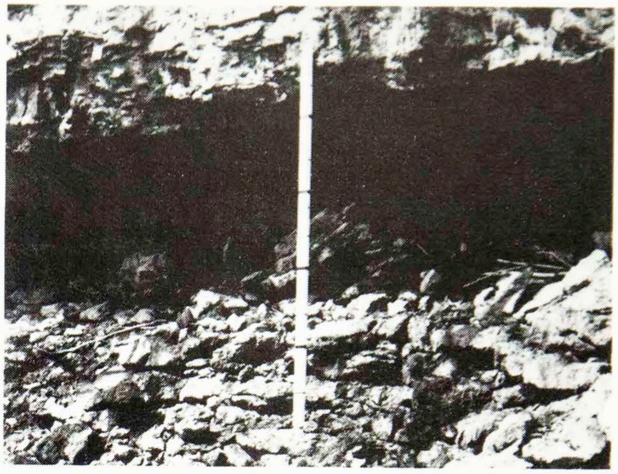


Figure D

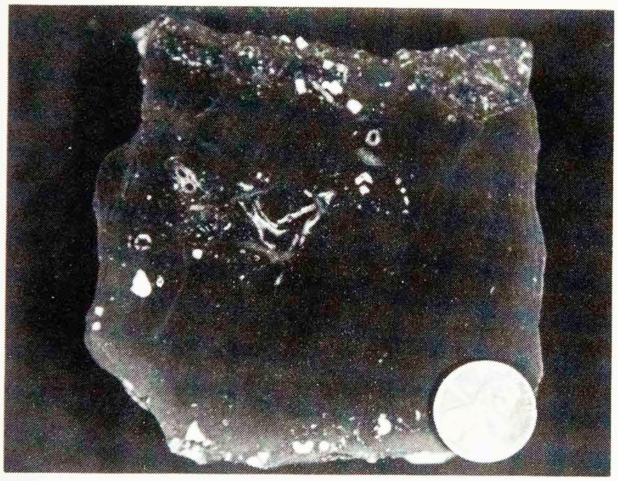


Figure B

Figure E

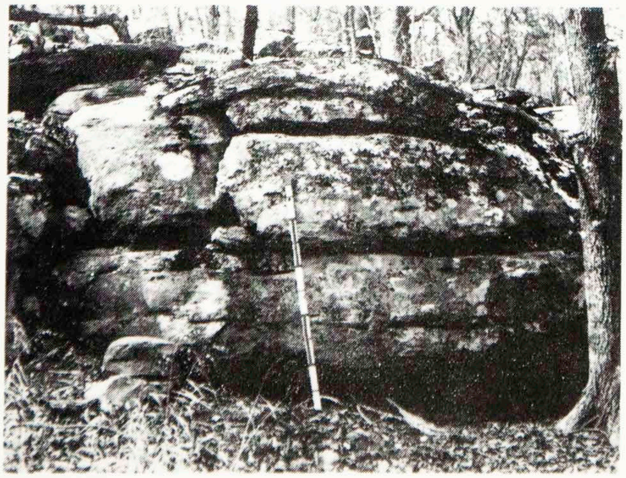


Figure C

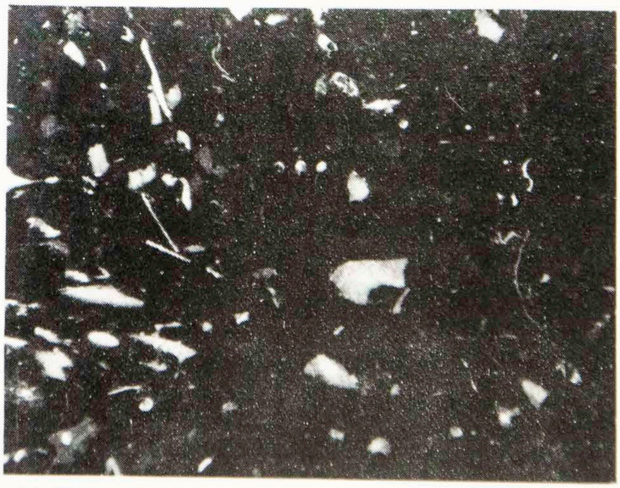


Figure F 1mm

preserved productid brachiopods can be recovered from the shale matrix. The shale generally weathers to a much lighter gray than the shales of the underlying Fayetteville Formation.

Thin sections of the carbonate portion of this facies contain unabraded, rarely coated bryozoans and brachiopods as the most common faunal elements. Recrystallized sponge spicules and other unidentifiable microbioclasts are also present in a carbonate mud matrix. As mentioned above, several specimens of this facies contain fecal pellets generally coalescing to form carbonate mud. Crinoid skeletal fragments are rare in this facies when compared to the other Pitkin lithologies. The crinoid fragments that are present are uncoated and severely abraded (Plate 6-F).

Of all the lithofacies of the Pitkin, the Nodular Limestone and Shale Facies is the most enigmatic. However, there are several lines of evidence that may indicate deposition in an open marine shelf located basinward or seaward from the main carbonate buildup of the Pitkin. The wackestone texture, the unabraded skeletal fragments, the coalescing of fecal pellets, and the fact that the carbonate portion of this facies is encased in shale, all tend to indicate a calm, hydrologic depositional environment. There are only minor algal encrustations around bryozoan fragments and absolutely no observable micrite rinds around the sparsely abundant crinoid fragments. The reduced presence of Girvanella, when compared to its common occurrence in the previously described facies, may indicate a "deeper" water environment beyond the optimum range in the photosynthetic spectrum for blue-green algae. Wilson (1975) places carbonates that exhibit nodular to wavey bedding, ball and flow structures, and sedimentary boudinage in his standard facies belt 2 which excludes the open marine shelf environment. Throughout the field area, this facies is normally found at the base of the Pitkin forming a gradational contact with the Fayetteville Shale. Based on stratigraphic position, the Nodular Limestone and Shale Facies may represent a transition from the "deep" mud deposition of the Fayetteville Shale to the "shallow" carbonate deposition of the Pitkin Limestone.

Water depth at the time of deposition for this facies may have ranged from 15 to 50 meters. No modern analogues of this facies were found in the literature.

Peloidal Facies

The term peloid is applied to carbonate grains that are composed of cryptocrystalline carbonate irrespective of origin (McKee and Gutshick, 1969). Some peloids are fecal in origin while others originate from altered (micritized) recrystallized ooliths and skeletal grains (Milliman, 1974). Peloids of fecal origin are elipsoidal, have a high organic content, and contain randomly distributed microbioclasts. Micritized grains are irregular in both size and shape and in some cases contain vague hints of the original skeletal structure. Under high magnification a micritized grain may show a type of nucleated structure and might be better placed in the coated grain category.

Detailed observation of the texture and composition of the rock encasing the peloids and vertical stratigraphic associations also yield information about their origin and depositional setting. When tightly packed, peloids that appear to have coalesced to form the flocculent structures seen in some mudstone lithologies are combined with rare whole fossil brachiopod fragments, that are neither coated nor abraded. In this setting, it could be concluded that the peloids are fecal in origin. Peloids associated with ooliths, coated and abraded skeletal grains, and oncolities probably originate from micritized skeletal grains.

The quantitative definition of the Peloidal Facies is any unit that has an allochem composition of greater than 20 percent peloids (Appendix C-4). In outcrop, the units are thin to medium bedded, well indurated, and form a smooth weathered surface. Other grains encased in a peloidal matrix are variable. The textures of the Peloidal Facies range from wackestone to grainstone (Plate 7-A, B). Depositional environments of fecally derived peloidal lithologies may range from open marine to restricted marine. The common replacement for the deposition of pellet muds is a calm hydrologic condition. Some thin sections show a transition from a peloidal packstone to an almost pure mudstone. Water depths at the time of deposition for this facies are variable.

Most of the peloids of the Pitkin are believed to have originated from the micritization process because they are associated with ooliths. In vertical sequence, applying Walther's Law, if the Peloidal Facies is found either above or below the oolitic facies, it might indicate a lateral association. The depositional environment may have been in shallow turbulent water probably less than 5 meters deep. Also, peloidal lithologies may be crossbedded (Plate 7-C).

PLATE 7

PELOIDAL FACIES

Figure A: Thin section of a peloidal packstone. There are a variety of shapes and sizes of peloids in this specimen. Notice how they tend to coalesce. Plane light. (M.S. 209, unit 3)

Figure B: Thin section of a peloidal grainstone. These peloids are presumed to be of diagenetic origin. They may have resulted from the micritization process acting on skeletal grains. They are also associated vertically with ooliths. Plane light. (M.S. 209, unit 6)

Figure C: Polished slab of the Peloidal Facies. The thin section of Figure B was made from a portion of this specimen. Notice the fine cross-laminations. The variation in color is due to weathering. See penny for scale. (M.S. 209, unit 6)

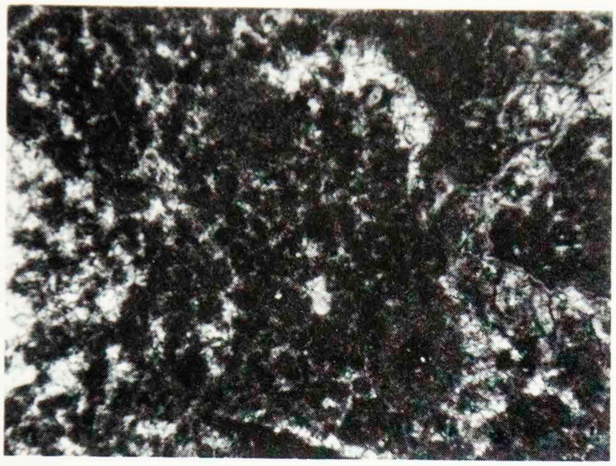
WACKESTONE FACIES

Figure D: Thin section of the Wackestone Facies. This specimen is composed of a mixture of abraded or unabraded, coated or uncoated skeletal fragments with abundant microbioclasts in a mud matrix. Plane light. (M.S. 189, unit 3)

Figure E: Polished slab of the Wackestone Facies. The crinoid rubble appears to be concentrated along one lamination near the base of the specimen. This may be due to a catastrophic event such as a storm. See penny for scale. (M.S. 187, unit 16).

Figure F: Exposure of Pitkin Limestone in Stratton Hollow. Units 4 and 5 are both composed of wackestone. They are more resistant to weathering than the Nodular Limestone and Shale Facies below or the basal Sausbee above. Note also the darker color and crossbedding of the overlying Sausbee Formation. A small bench is formed on top of the Pitkin wackestone. See 5-foot Jacob staff for scale. (M.S. 194, units 3-6)

PLATE 7



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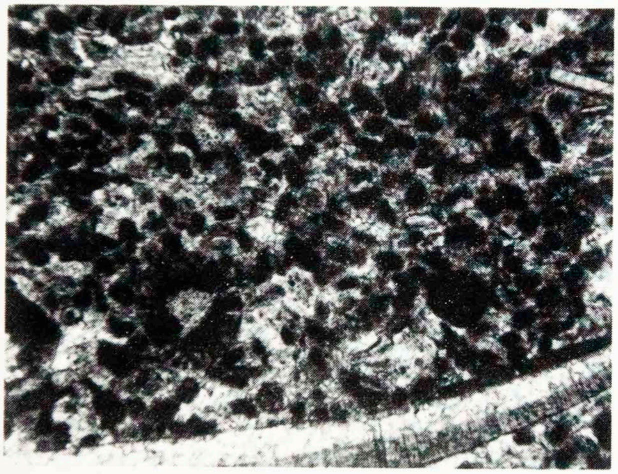


Figure B 1mm

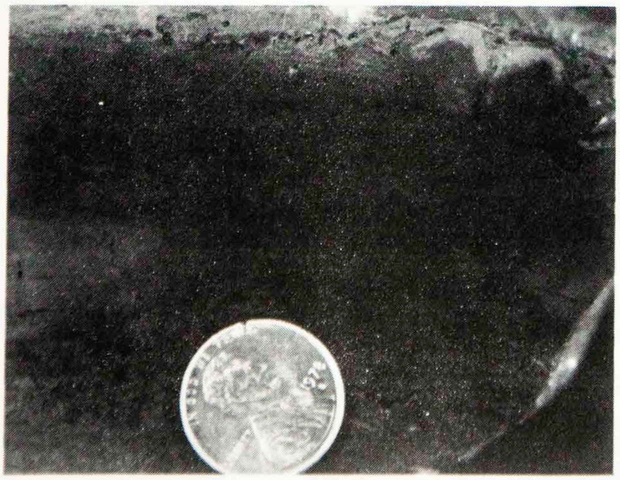


Figure C

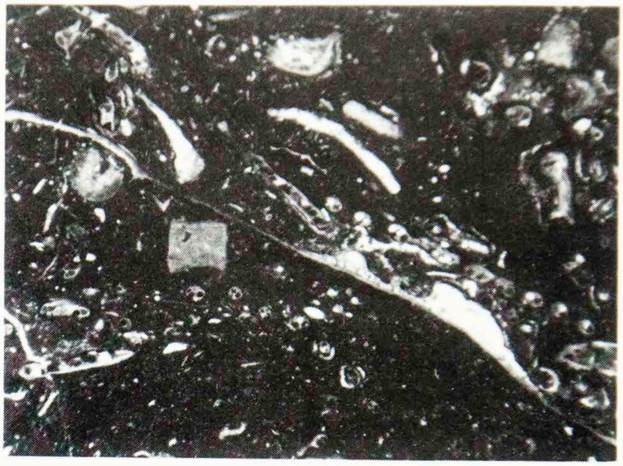


Figure D 1mm

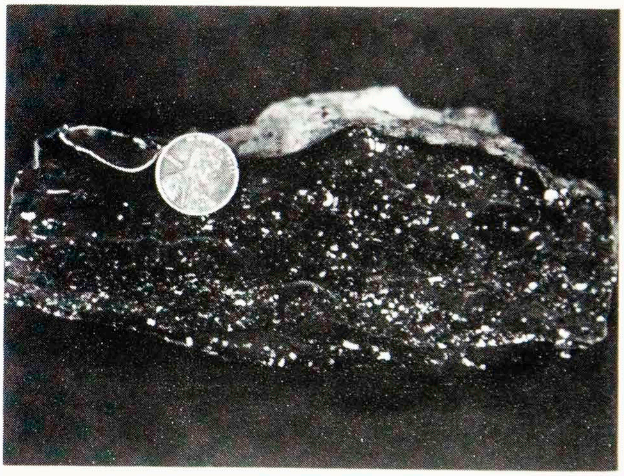


Figure E

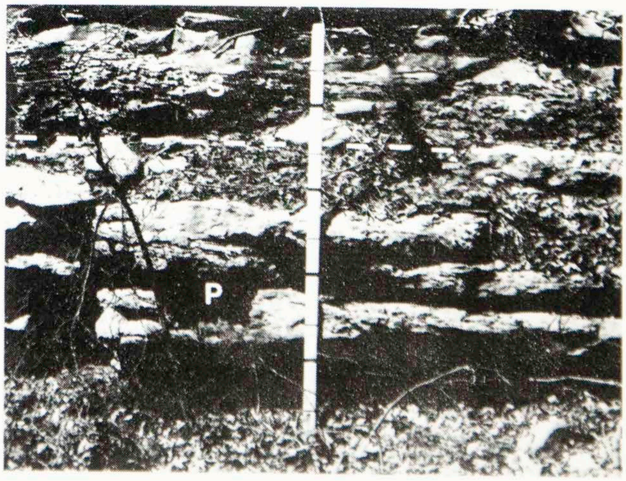


Figure F

Peloids are found in lesser abundance in other facies and must be studied carefully to see if they are derived fecally from indigenous fauna or are a result of the micritization process. Wilson (1975) assigns peloidal lithologies to restricted marine shoals and restricted marine shelf lagoons. Modern analogues for this facies are found on the interior of the Bahama Platform (Purdy, 1963) and near Tavernier Key in Florida Bay (Bathurst, 1971).

Wackestone Facies

The Wackestone Facies is assigned to any unit or thin section that has a volume of greater than 10 percent allochems, but yet is mud supported (Dunham, 1962). The dominant allochems of this facies are unabraded bryozoans, brachiopods, and mollusks with minor amounts of peloids and crinoidal debris (Plate 7-D). The mud matrix contains microbioclasts and ostracod fragments (Plate 7-E). Exposures of this facies display variable bedding and usually form dense, resistant units with fossils standing out on weathered surfaces (Plate 7-F).

The Wackestone Facies found in the lower units of the Pitkin in this study area may contain recrystallized spicules that are indicative of an open marine environment. However, positive identification of sponge spicules in this facies is tenuous because of the recrystallization process. Whole fossil preservation indicates *in situ* deposition; a homogenized wackestone with a random distribution of skeletal allochems indicates bioturbation (Wilson, 1975). The wackestones of the Pitkin generally have their allochems distributed along discrete laminae which may have formed quickly as a result of storm activity.

Storm debris are periodically swept into restricted marine areas in recent carbonate environments. In either case, whether shallow shelf, open marine or restricted marine, these rocks were deposited below active wave base in a flow regime that allowed the deposition of carbonate mud.

Wackestones in Mississippian rocks are commonly found in the core of bryozoan bioherms (Pray, 1958), or Waulsortian Mounds (Wilson, 1975), but the Pitkin in this field area is predominantly composed of shoal deposits and it might be more appropriate to assume that the Wackestone Facies represent either deep foreslope or intershoal depositional environments. Water depth would probably be greater than 10 meters.

Mudstone Facies

Carbonate mud originates in one of five different ways: (1) from the breakdown of calcareous algae, (2) inorganic precipitation, (3) the mechanical breakdown of invertebrate skeletons, (4) the biological breakdown of invertebrate skeletons, and (5) the compaction of fecal pellets (Bathurst, 1971). In deeper marine environments calcareous microplankton settle at abyssal depths to form carbonate ooze (Wilson, 1975). The different explanations for the origin of carbonate mud are probably all functioning at different degrees in different depositional systems. Regardless of the origin of carbonate mud, a low energy environment is required to prevent the mud from being winnowed away.

The Mudstone Facies, as defined by Dunham (1962) is any rock that contains less than 10 percent volume allochem composition. Mudstones from the Pitkin contain numerous microbioclasts (Plate 8-A) with rare whole skeletal fragments lacking coats. In outcrop these units are generally thick bedded and may be smooth or rough depending on the degree of weathering (Plate 8-C).

Carbonate mud is deposited in areas of restricted marine circulation (Ginsburg, 1956) and represents periods of in situ deposition with little or no modification of the sediment by currents or waves (Bathurst, 1971). Carbonate muds exhibit plastic or fluid properties and are sought out by deposit feeders because of their high organic content (Walker, 1974). The random arrangement of skeletal fragments within the mud matrix may have been caused by the bioturbation of the sediment by deposit feeders.

The Pitkin Mudstone Facies probably were deposited in shallow restricted marine environments with little or no hydrologic influence. Along with packstones and wackestones, mudstones may represent intershoal areas. In vertical section, if the Mudstone Facies is sandwiched between shoaling facies, one would expect it to have been deposited adjacent to shoaling facies and represent an intershoal depositional environment according to Walther's Law. The Mudstone Facies is illustrated in Plate 8-A, B).

Modern analogues for the Mudstone Facies are found in Florida Bay and on the Bahama Bank (Bathurst, 1971).

PLATE 8

MUDSTONE FACIES

Figure A: Thin section of the Mudstone Facies. This specimen contains numerous unidentifiable microbioclasts. Plane light. (M.S. 189, unit 3-B)

Figure B: Polished slab of the Mudstone Facies. No allochems can be seen with the naked eye. This specimen is smooth and resistant to weathering. See penny for scale. (M.S. 189, unit 3-B)

Figure C: Outcrop of the Mudstone Facies. The Mudstone Facies commonly weathers rough and angular. Arrow points to lense cap for scale. (M.S. 202, unit 2)

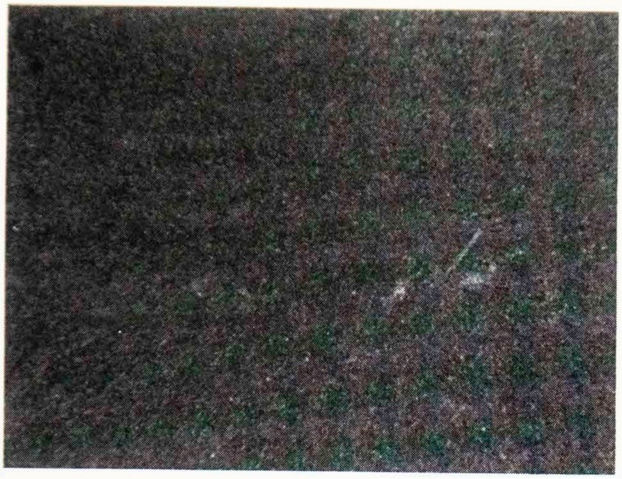
MOUND FACIES

Figure D: Thin section of the Mound Facies. The allochems in this specimen are not coated and show little, if any, abrasion. Plane light. (M.S. 193, unit 5)

Figure E: Polished slab of the Mound Facies. This facies is composed of bryozoan and brachiopod fragments in a lime mud matrix. The fenestrate bryozoans may have trapped carbonate mud in a manner similar to that of the Pennsylvanian phylloid algae. See penny for scale. (M.S. 195, unit 5)

Figure F: Mud mound in M.S. 193, unit 5. This small mud mound was found to be encased in an argillaceous unit of the Oncolitic Facies. There are two additional smaller mounds located just behind the one seen in the photograph. See hammer for scale. (M.S. 193, unit 5)

PLATE 8



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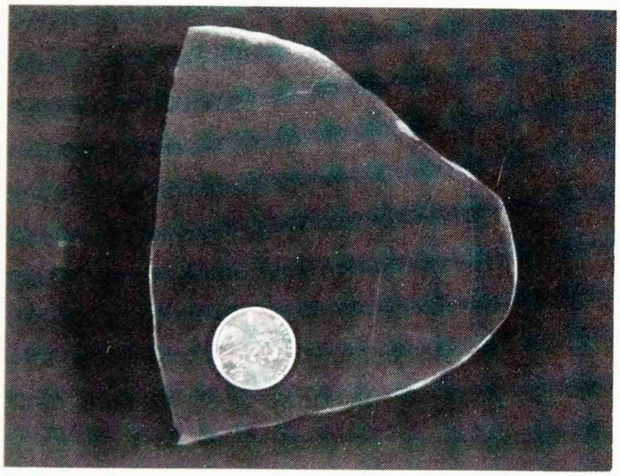

Figure B

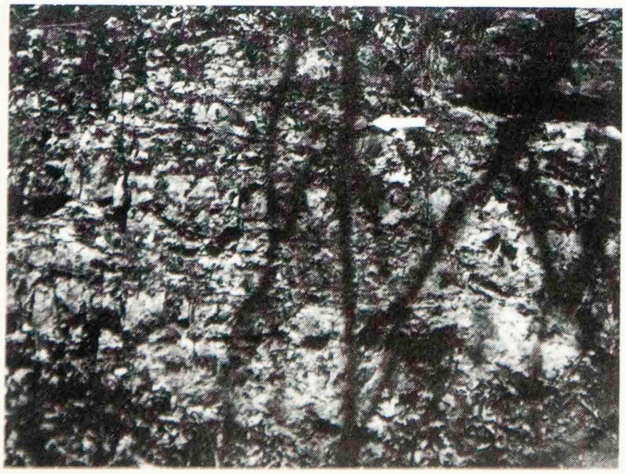

Figure C

Figure D 1mm

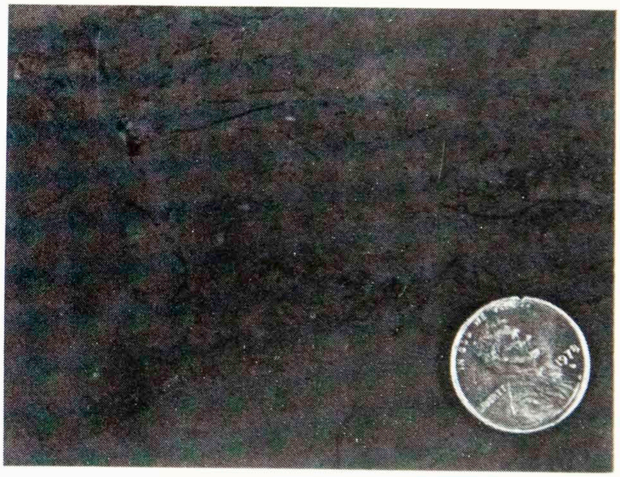

Figure E

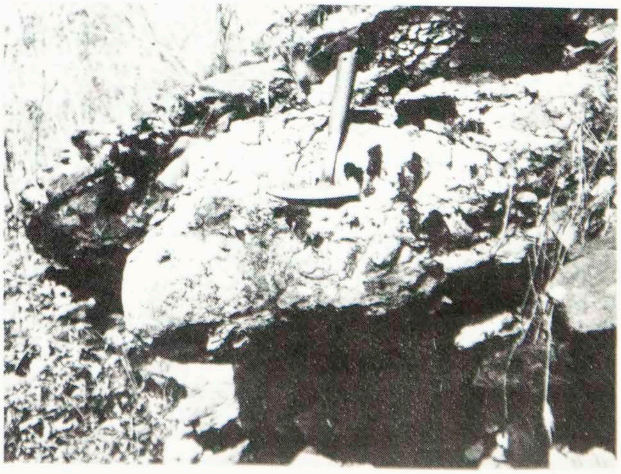

Figure F

Shale Facies

The Shale Facies of the Pitkin are thin and tend to form recessive intervals. They are generally fossiliferous containing the bryozoan Archimedes, brachiopod shells, and crinoid stems. They are also lighter and less fissile than Fayetteville shale lithologies, resembling the shaly portion of the Nodular Limestone and Shale Facies.

These thin shale units may represent brief influx of fine-grained terrigenous material that was deposited in calm water. This type of deposit might be found in semi-restricted marine environments. When the Nodular Limestone and Shale Facies is located between higher energy facies in vertical sequence, clastic influx could be used as an explanation. Water depths for this facies are variable but calm water is the essential requirement for deposition. The Shale Facies may be responsible for the covered intervals seen in the Pitkin (Orgren, 1979).

Mud Mounds of Unit 193-5

Unit 193-5 is an oncolitic packstone that contains three adjacent small lime mud mounds along the same horizon. The largest of the three is 1.5 feet high and 3.5 feet wide (Plate 8-F). The allochem constituents of the mounds do not differ from those found in other Pitkin facies but peloids are notably absent. Bryozoans and crinoids are the dominant faunal elements with minor brachiopods, pelecypods, and a few foraminifera (Plate 8-D, E). The mounds are of a much lighter color than any of the other mud dominated lithologies of the Pitkin. Mounds like these occur in shallow marine water on shelves or on the gentle slopes of shelf margins (Wilson, 1975, p. 79).

Depositional Environments of the Fayetteville Shale

The carbonate lithologies of the Fayetteville Shale were deposited in open marine waters possibly tens to hundreds of meters deep. The dark (almost black) color of Fayetteville limestones indicates deeper water deposition than the Pitkin in, perhaps, anoxic conditions (Wilson, 1974). This interpretation is based on stratigraphic position, field description, and thin section analysis of Fayetteville carbonate units.

The upper carbonate-rich intervals are commonly less than one-foot thick and alternate with thin beds of black fissile shale (Plate 9-C). This may represent carbonate flych-bedded deposits which are indicative of slope to basin transition (Wilson, 1975, p. 75). Thin-section analysis of these carbonates show that the dominant textures are wackestone and mudstone. Several packstone lithologies are also observed. In this case the fossil fragments are abraded but not coated, showing possible evidence of downslope transport. The packstones and wackestones contain small unabraded molluscan grains that might also indicate open marine conditions and <u>in situ</u> deposition. There are rare fecal pellets that contain quartz grains and microbioclasts. These pellets show glauconitic coats when observed under reflected light further suggesting fecal origin (Goldhammer, 1981, personal communication). Two thin sections contained silt-sized quartz grains concentrated along microlaminations resembling Bouma sequences, further reinforcing the interpretation of an open marine depositional environment for the upper Fayetteville carbonate lenses (Plate 9-A, B).

PLATE 9

FAYETTEVILLE CARBONATES

Figure A: Thin section of a Fayetteville carbonate. This rock is composed of micrite and silt sized quartz grains sorted into discrete microlaminations. On the right half of the photograph, the laminations may have been disrupted by bioturbation. Plane light. (M.S. 187, unit 7)

Figure B: Polished slab of a Fayetteville carbonate. Most Fayetteville limestones appear to be mudstones to the naked eye but are wackestones in thin section. They are commonly dark blue gray to black but tend to weather light gray. See penny for scale. (M.S. 187, unit 7)

Figure C: Interbedded Fayetteville shale and carbonate lithologies. See hammer for scale. (This photograph was taken at a road cut near M.S. 197).

CALCAREOUS ALGAE

Figure D: Thin section showing a well preserved fragment of the green alga, Dasycladaceae. The algal fragment is identifiable by the radiating perforate wall about a central cavity. Notice also that the wall microstructure is poorly preserved. Plane light. (M.S. 205, unit 5)

Figure E: Thin section showing the green alga, Dasycladaceae. This is an oblique longitudinal section through the wall of a branch or stalk. The grain is coated. Notice the recrystallization and the perforations on the left side of the specimen. Plane light. (M.S. 206, unit 4)

Figure F: Thin section showing well preserved tubes of the blue-green alga, Girvanella. The presence of Girvanella indicates shallow marine waters. Plane light. (M.S. 206, unit 4)

PLATE 9

Figure A 1mm

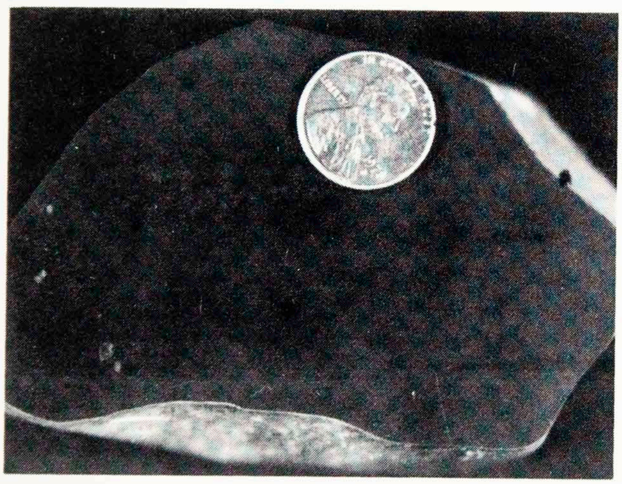

Figure B

Figure C

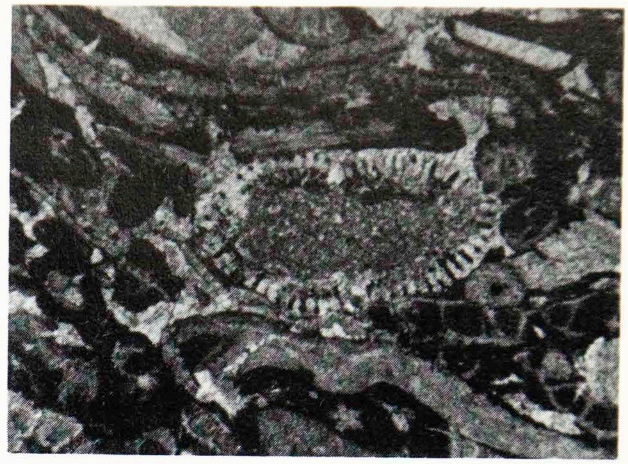

Figure D 1mm

Figure E 1mm

Figure F 1mm

Summary

The Oolite Facies represents shoals where ooliths were forming. The Oolitic, Bioclastic, Oncolitic, and Peloidal facies all represent shoaling, above wave base, high-energy depositional environments when they are texturally classified as grainstones. The same facies represent intershoal, blanket sand, foreslope, or flanking deposits when they are seen as packstones. The Encrinite Facies represents a type of flank deposit.

The Wackestone, Mudstone, and Peloidal facies generally suggest calm, partially restricted, marine depositional environments found in very shallow water. They may be analogous to the core facies of the fenestrate bryozoan bioherms of Pray (1958) but field evidence is inconclusive. They may also be found in intershoal areas. The Shale Facies is deposited in the same type of environment as those mentioned above during intervals of clastic influx in low-energy depositional environments.

The Mound Facies is unique in the field area and forms in association with algae on slopes in shallow marine environments (Wilson, 1975, p. 79). The Nodular Limestone and Shale Facies of the basal Pitkin was deposited in open marine water probably tens of meters deep. This facies is deposited in lower foreslope environments and is transitional, lying between the Fayetteville Shale and Pitkin Limestone.

Fayetteville carbonate rocks lack the algae that indicate shallow marine environments. They were deposited in deeper open marine conditions at depths of tens to hundreds of meters.

Figure 10 summarizes the vertical distribution of the Pitkin lithofacies.

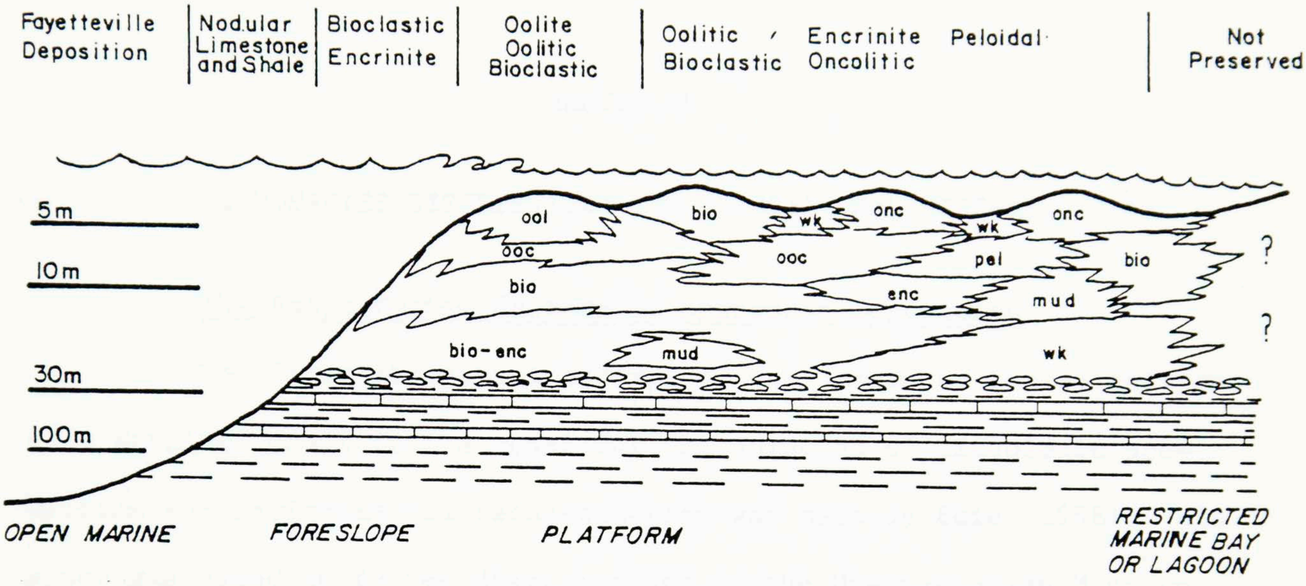

Figure 10. This diagram is a hypothetical illustration of the vertical distribution of the Pitkin lithofacies and major depositional environments. Note the vertical exaggeration. The lithofacies abbreviations are: ool for oolite, ooc for oolitic, bio for bioclastic, enc for encrinite, wk for wackestone, and mud for mudstone.

CHAPTER IV

LITHOFACIES DISTRIBUTION AND DEPOSITIONAL HISTORY

The Basic Facies Pattern of Carbonate Deposition

The first successful attempt to put carbonate facies patterns of a marginal shelf into a model for the purposes of lithologic prediction and environmental reconstruction was made by Edie (1958). His study was based on facies distributions in the Mississippian Mission Canyon Limestone in Saskatchewan, Canada. Modifications in this original model applied to epeiric seas were made by Shaw (1964) and Irwin (1965).

In each of these two models marine carbonate environments are divided into three zones based on water depth, turbulence and biota (Fig. 11). The first zone (Irwin's X) is open marine. The sea floor lies well below normal wave base and represents a calm water or low-energy depositional environment. The second zone (Irwin's Y) is that of high energy, above wave base, turbulent water depositional environments. This zone is characterized by oolitic and bioclastic shoal water facies. The most landward of the three zones (Irwin's Z) represents restricted marine environments where the substrate is not subjected to high-energy hydrologic processes. Fine-grained carbonates and evaporitic deposits are found in this zone.

These models represent epeiric deposition of carbonate rock types in laterally extensive shallow cratonic seas. The width of the sedimentation bands or zones is directly related to the slope of the shelf margin (Irwin, 1965). In epeiric seas Irwin's (1965) zones are tens to hundreds of miles wide while in marginal seas they are only miles to tens of miles wide (Wilson, 1975). The width and expression of the basic facies patterns may also be modified by tectonic and eustatic processes.

Wilson (1975) combined the study of both modern and ancient carbonate deposits with the ideas of Edie, Irwin, and Shaw to derive a basic facies model for the interpretation of carbonate rocks of any geologic age (Fig. 12) that can be applied to shelf margin carbonates that are deposited around the edges of continents.

Pitkin Limestone in the General Model of Carbonate Deposition

Most of the Pitkin lithofacies described in Chapter III, with the exception of the Nodular Limestone and Shale Facies, fall within Wilson's standard facies belt 6 (Figs. 11 and 12). Others fall within Wilson's standard facies belt 7 representing shelf lagoon or partially restricted marine sediments. The assignment of Pitkin lithologies to Wilson's facies belts 6 and 7 has been explained in Chapter III sedimentologically. These assignments may also be explained paleoecologically.

In conjunction with the sedimentary features mentioned in Chapter III, Paleozoic algae may be used as paleoenvironmental indicators (Wray, 1977). The Pitkin contains the chlorophytic alga

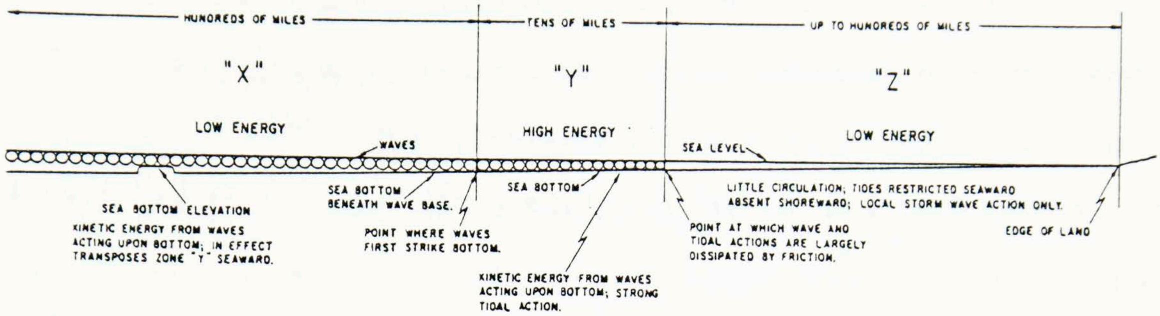

Figure 11. The Irwin model of epeiric clear water sedimentation (from Irwin, 1965, fig. 3, p. 450).

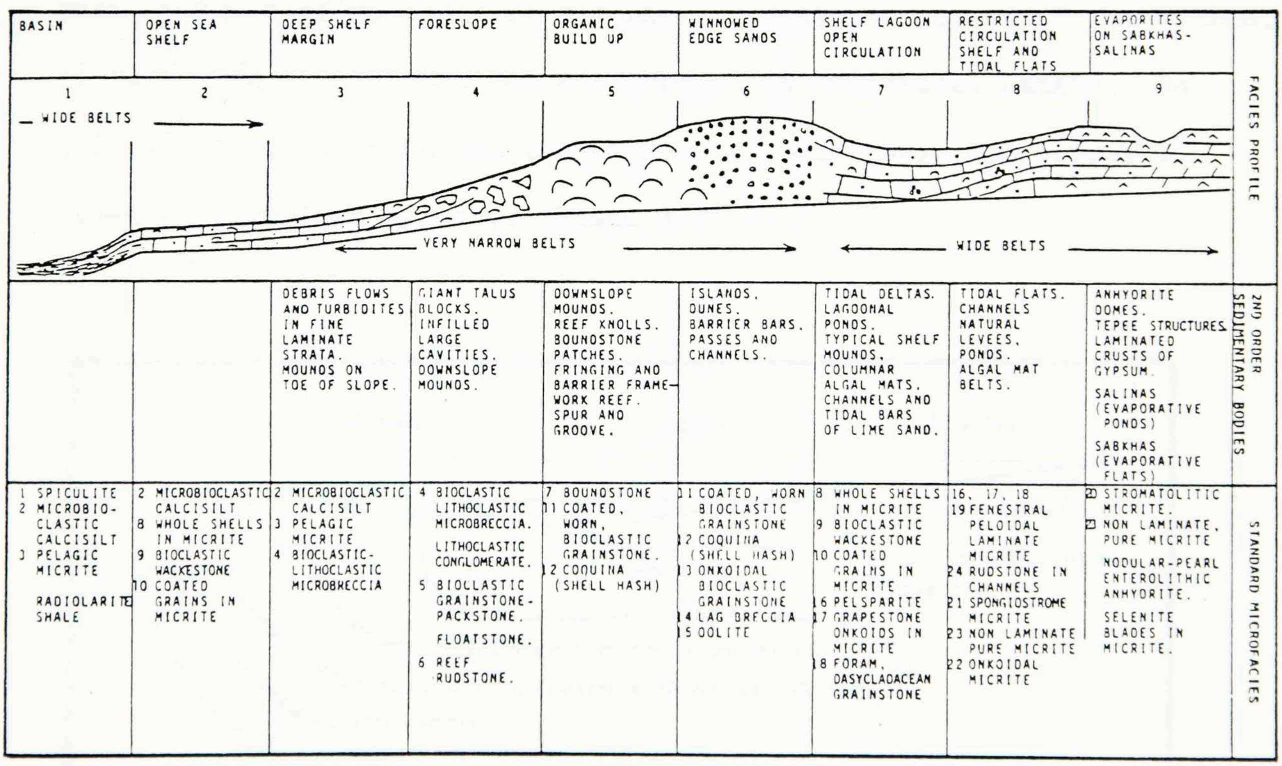

Figure 12. The basic facies pattern of Wilson (1975, fig. XII, p. 351). This model is applicable to shelf margin carbonates.

Dasycladaceae and the cyanophytic alga Girvanella. Dasycladacean algae have perforate, ramose, calcareous skeletons (Plate 9-D, E). They grow on both sandy and muddy bottoms in shallow protected back reef environments (Wray, 1969). They generally indicate water depths ranging from 0 to 30 meters but are most prolific at depths of 0 to 5 meters. They obtain optimum rates of photosynthesis in the red spectrum of light which is preferentially absorbed with increasing water depth (Wray, 1977). The presence of Girvanella as Osagea in carbonate rocks probably indicates shallow water (Kotila, 1973)(Fig. 13). When it is seen as the binding agent of oncolites, as is the case with the Pitkin, it indicates a mild shoaling environment in intertidal waters. In thin section, it is formed into masses of very small nonperforate tubes of a uniform diameter (Plate 9-F).

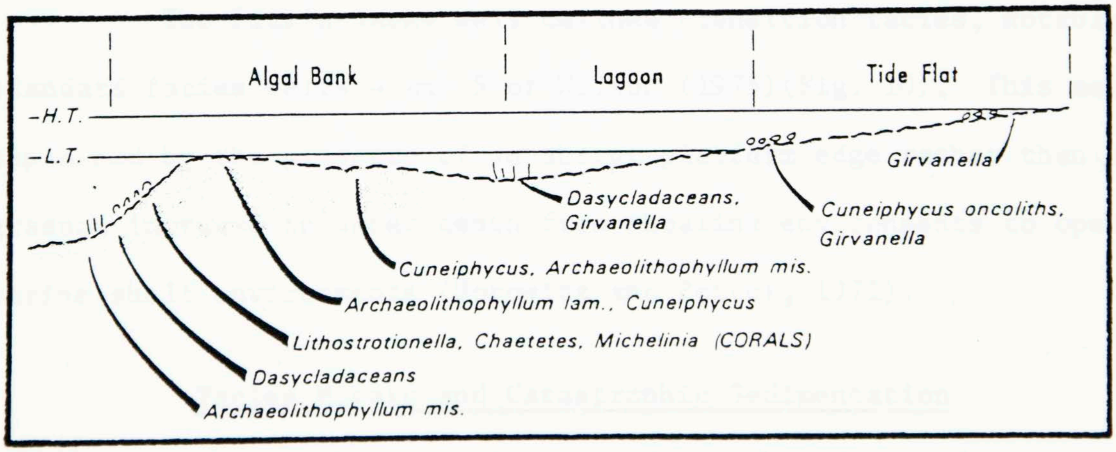

Figure 13. Algal ecology profile from the Morrowan of northeastern Oklahoma. From Wray (1977, fig. 148, p. 135; after Kotila, 1973, fig. 4, p. 99).

Depositional History of the Pitkin

In vertical sequence, the combination of open marine Fayetteville carbonates and shales overlain by the predominantly shallow water facies of the Pitkin represents a shoaling upward sequence that typifies the progradation of carbonates on a shelf (Smith, 1977). This relationship is illustrated in Figure 14.

On top of the Fayetteville, the Nodular Limestone and Shale Facies represents deposition in water depths probably less than 50 meters yet still retains some open marine characteristics. This facies is capped by a bioclastic packstone which is a foreslope deposit. Above this packstone, in vertical sequence, is a bioclastic grainstone, an oncolitic grainstone, and an oolitic grainstone, all of which were deposited in shallow water shoaling depositional environments.

The Pitkin lacks well defined transition facies, notably standard facies belts 4 and 5 of Wilson (1975)(Fig. 10). This may be explained by the presence of an abrupt platform edge rather than a gradual increase in water depth from shoaling environments to open marine shelf environments (Horowitz and Potter, 1971).

Facies Mosaic and Catastrophic Sedimentation

When a carbonate unit progrades or builds out from cratonic margins large scale platforms or ramps result. The irregular facies distribution, observed in Plates 11 and 12, suggest that the Pitkin Limestone in this study area was deposited on a platform rather than a ramp during the progradation process. The cross sections display

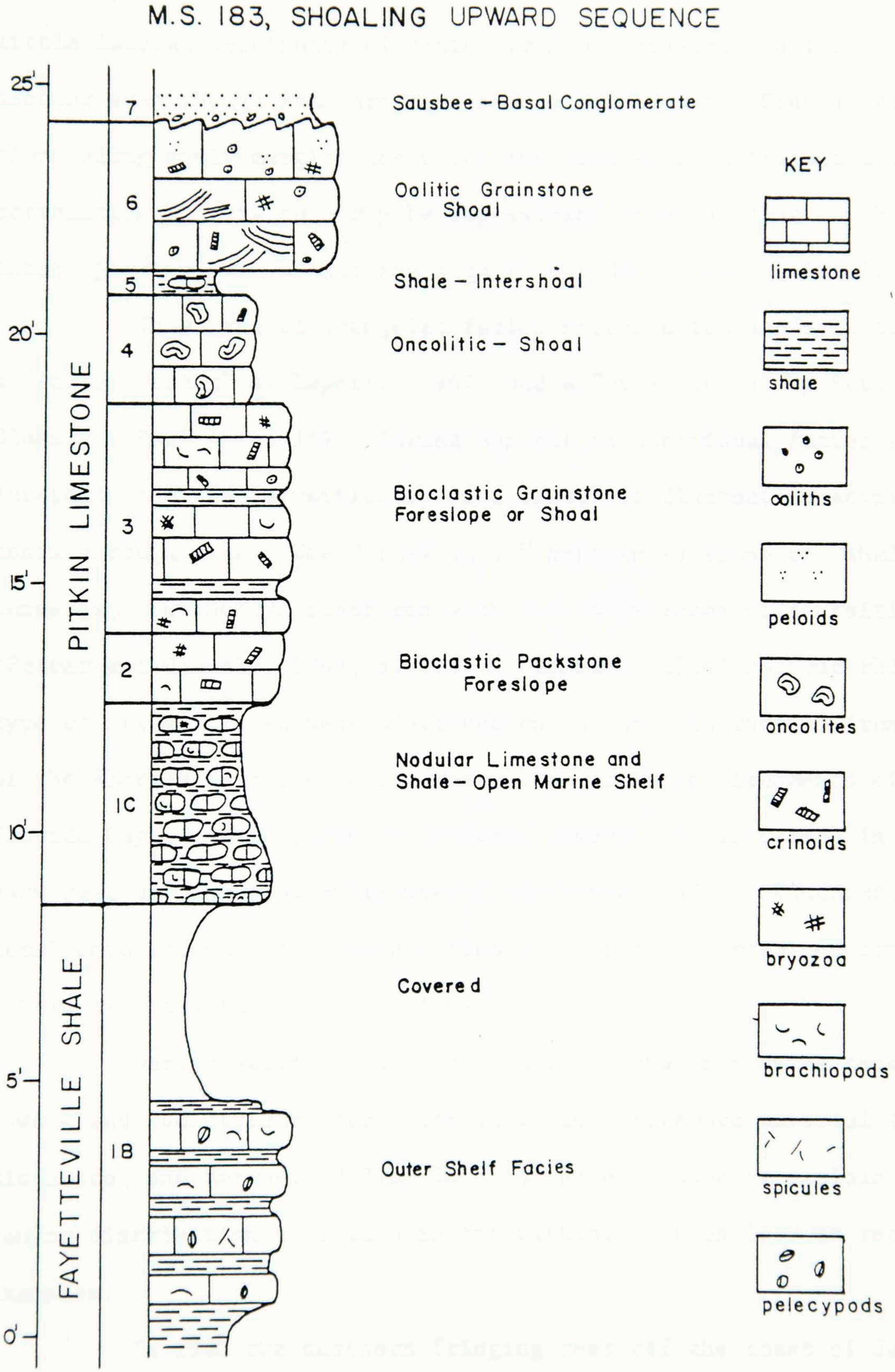

Figure 14. M.S. 183 best illustrates the shoaling upward sequence seen in the Fayetteville-Pitkin stratigraphic relationship.

little lateral continuity of facies from one measured section to another even though some are less than a mile apart. Precise correlations along shelf margins and platforms tend to be difficult and facies correlation in this case may be impossible. Even bedding may be interrupted by both shoals and organic buildups (Wilson, 1975).

This type of irregular facies distribution has been termed a "facies mosaic" by Laporte (1967) and a "crazy quilt" by Potter and Blakely (1968) (Fig. 15). During deposition individual facies shift laterally and change vertically as a result of fluctuating environments through time. The "crazy quilt" pattern is found on "shallowly submerged continental platforms with very slow rates of deposition" (Potter and Blakely, 1968, p. 162). Ginsburg (1956) noticed this same type of irregular sediment distribution in the back reef environments of the Florida Keys and in the restricted marine environments of Florida Bay. A wide range of textural composition is common in modern back reef and lagoonal environments (Milliman, 1974). Fluctuations of local depositional environments tend to complicate broad and commonly subtle regional facies transitions.

During storms catastrophic depositional processes tend to rework and redistribute carbonate sands and framework material (Blatt, Middleton, and Murray, 1972). This may also be used to explain the random distribution of facies in the Pitkin. Let us look at recent examples.

In 1980 the northern fringing reef off the coast of Jamaica was devastated by Hurricane Allen. The upper 20 feet of the reef crest was removed than redeposited down slope as coralgal sand (R. M. Bonem,

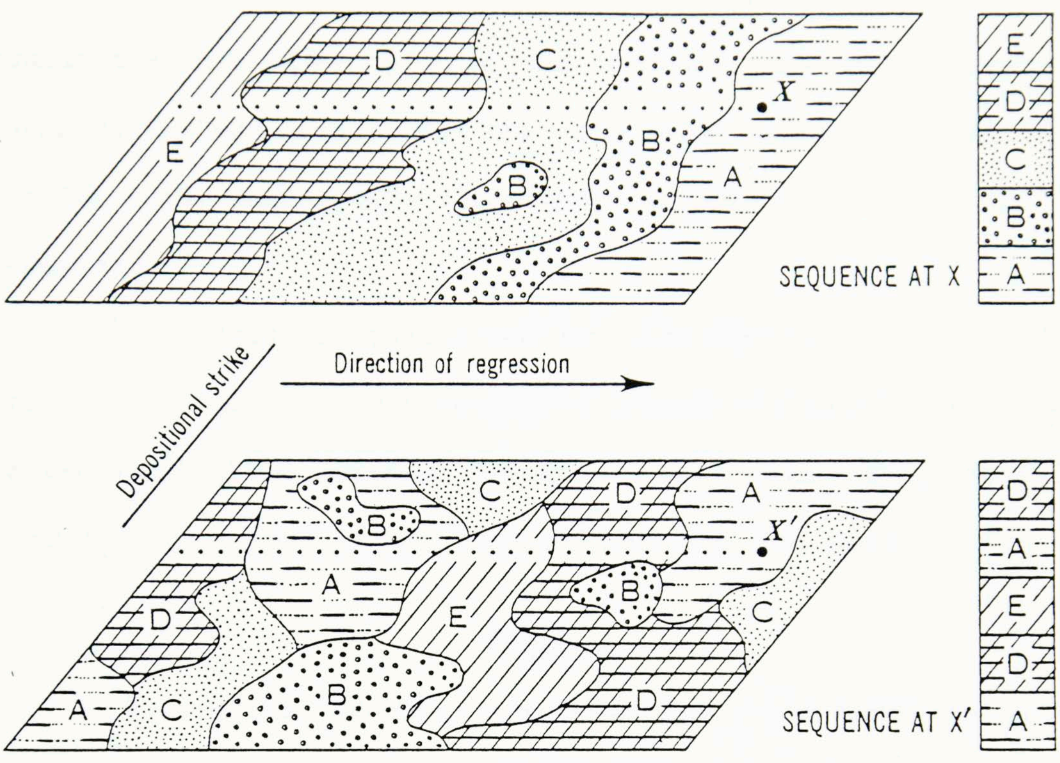

Figure 15. The upper portion of this figure shows an orderly progression of carbonate facies aligned parallel to depositional strike. This pattern would be developed as a result of regression on a gently sloping shelf. The lower portion of this figure shows a "facies mosaic" or "crazy quilt" pattern which is generally developed on a carbonate platform. From Potter and Blakely (1968, fig. 2, p. 159).

1981, personal communication). Similar effects were observed in Puerto Rico caused by the same hurricane (J. R. Bloch, 1981, personal communication). In the Gulf of Mexico, there is a 95 percent probability that a hurricane will pass over a particular point at least once every 3,000 years disrupting normal sedimentary processes and modifying the local depositional environments (Ager, 1973). Every point on the surface of the Bahama Platform is affected by a hurricane at least once every 100 years (Newell and Rigby, 1957). Bathurst

(1967) has observed that these large-scale sedimentary events are probably the only means by which the subtidal algal mat is destroyed. As long as the mat is present, the back shoal carbonate sands remain immobile. Only during storms are these sediments reworked and redeposited.

From this discussion one may conclude that catastrophic processes such as hurricanes modify carbonate sedimentary environments in a series of short duration events and the results are eventually preserved in the rock record (Ball, Shinn, and Stockman, 1967).

Summary

In vertical sequence the transition from Fayetteville deep water mixed terrigenous and carbonate facies to the pure shallow water carbonate facies of the Pitkin represents a shoaling upward sequence associated with the basinward progradation of a platform carbonate. Most of the Pitkin facies may be placed in Wilson's standard facies belt 6 which reflects very shallow shoal water environments. This assignment is based on both sedimentary information and paleoecologic inferences provided by green and blue-green algae. The complex, almost random, distribution of facies within the Pitkin form a facies mosaic or crazy quilt pattern that is common to platform carbonate buildouts. Occasional catastrophic processes probably contributed to the redistribution of depositional environments and their resultant lithofacies.

Two problems have inhibited observations of Pitkin lithologies in this study area. The first is mediocre exposure of the Pitkin in the Oklahoma Ozark Region. Most exposres are partially covered laterally by vegetation and slumping. Less competent lithologies are seen only as talus slopes.

The second problem is caused by the truncation of Pitkin lithologies by the Mississippian-Pennsylvanian unconformity. The cross sections in Plate 11 and 12 are oriented along southwest-northeast and south-north lines in order to include the thickest sections for facies analysis. A detailed analysis of the unconformity is the subject of Chapter V.

CHAPTER V

NATURE OF THE MISSISSIPPIAN-PENNSYLVANIAN UNCONFORMITY

General Statement

The predominantly carbonate lithologies of the Chesterian-Morrowan sequence in the Ozark Uplift area are punctuated by the occurrence of several regional unconformities, which divide the section into sedimentary packages (Fig. 6). Unconformities are observed at the base of the Meramecian, base of the Chesterian, Chesterian-Morrowan boundary, and at the Morrowan-Atokan boundary (Sutherland and Manger, 1979). This chapter will deal specifically with the Mississippian-Pennsylvanian (Chesterian-Morrowan) unconformity and the effects of erosion on the Pitkin Limestone during the hiatus.

Biostratigraphy

Many authors have presented biostratigraphic evidence for a hiatus separating Mississippian and Pennsylvanian strata in northeast Oklahoma and northwest Arkansas using both megafauna and microfauna. In chronological order the most important works have been done by Snider (1915), Roth (1941), Laudon (1941), Easton (1943), Lane (1967), Saunders, Manger, and Gordon (1977), and Manger and Sutherland (unpublished manuscript, 1981). Saunders, Manger, and Gordon (1977) used ammonoid assemblages to demonstrate that the H_1 and H_2 ammonoid zones, which define the Chokierian and Alportian Stages of the Namurian Series in Europe, are missing in the Ozark Region of Arkansas.

Local Field Characteristics

The contact between the Chesterian Pitkin and the Morrowan Sausbee is variable within the present study area. The two formations may be differentiated by the presence of quartz sand in the Sausbee and the lack of it in the Pitkin. In this area local relief on the unconformity is low, usually less than 1 foot at any given exposure. The maximum local relief is seen at M.S. 205 where the contact drops approximately 2 feet over a lateral distance of 50 feet.

The Pitkin is generally dense, gray weathering, and forms resistant bluffs (Plate 2-A) while the Sausbee is medium to dark gray, brown weathering, generally conglomeratic at its base, and exhibits differential weathering along crossbeds (Plate 10-A). The Sausbee is less resistant than the Pitkin and a bench is commonly formed at their unconformable contact (M.S. 184, M.S. 188, M.S. 193, M.S. 196, M.S. 198, M.S. 203, M.S. 205, and M.S. 206 (Plate 7-F). Karst features are present, but rare (Plate 10-B).

Pitkin Truncation

Truncation of the Pitkin is the most obvious feature of the unconformity. The thickness of the Pitkin ranges from 0 to over 60 feet within the present study area with a maximum thickness of 80 feet reported in the Oklahoma Ozark region by Huffman (1958). The thickest section in the field area is M.S. 193, Greenleaf Lake, which measures 61.9 feet (Plate 2-F). The thinnest is M.S. 195, Buckhorn Mountain,

PLATE 10

MISSISSIPPIAN-PENNSYLVANIAN UNCONFORMITY

Figure A: The unconformable Pitkin-Sausbee contact. The gray weathering Nodular Limestone and Shale Facies of the Pitkin is directly overlain by the brown weathering conglomeratic sandstone of the basal Sausbee. (P=Pitkin and S=Sausbee). See lense cap for scale. (M.S. 195, units 3 and 4).

Figure B: A remnant of a possible karst feature. The hammer rests on a small block of sandstone that is cemented firmly onto the Pitkin well below the unconformity surface. See hammer for scale. (M.S. 199, unit 6)

Figure C: Truncation of the Pitkin. Units 6, 7, and 8 of M.S. 209 are shown in this photograph. Unit 7 is being truncated by the unconformity from left to right. On the right side of the photograph unit 6 of the Pitkin is directly overlain by unit 8 (Sausbee). The white arrow points to pebbles found at the base of the Sausbee. See hammer for scale. (M.S. 209)

BASAL SAUSBEE CONGLOMERATE

Figure D: Polished slab of a basal Sausbee conglomerate. This specimen contains pebble to cobble sized clasts of predominantly fine grained Pitkin lithologies along with reworked Mississippian rugose corals. See penny for scale. (M.S. 210-A, unit 4)

Figure E: Field shot of a basal Sausbee conglomerate. This exposure contains abundant cobble sized clasts, probably of the Pitkin, in a sandy matrix. See hammer for scale. (M.S. 210-A, unit 4)

BASAL SAUSBEE LITHOLOGY

Figure F: Thin section of the basal Sausbee Formation. The most common lithology at the base of the Sausbee is a sandy limestone. Notice the mixture of carbonate and quartz grains. Note the gastropod filled in with silt and sand. Plane light. (M.S. 200, unit 9)

PLATE 10

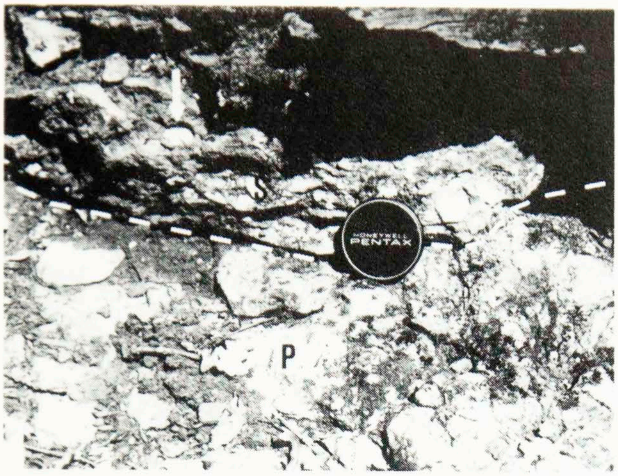

Figure A

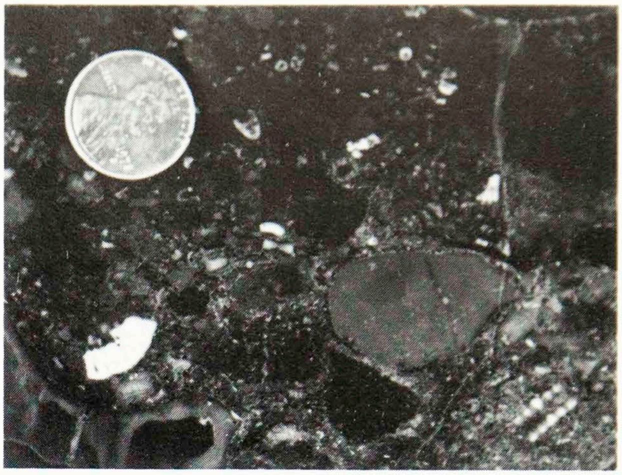

Figure D

Figure B

Figure E

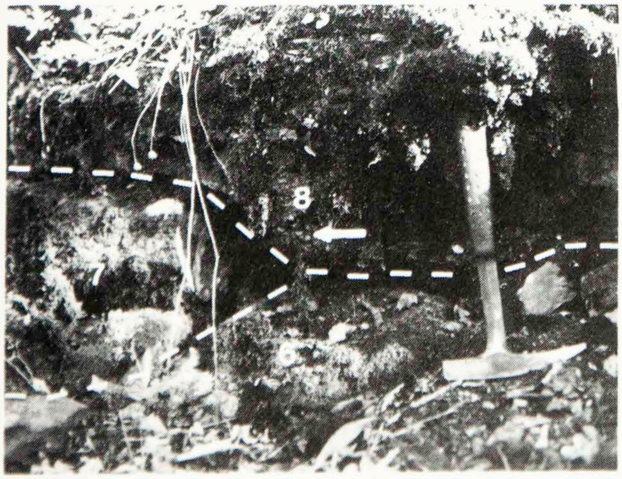

Figure C

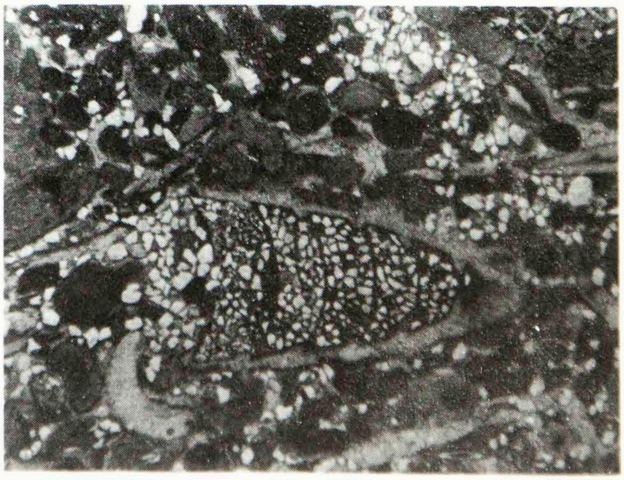

Figure F

1mm

which is 1.5 feet thick. The unconformity can clearly be seen truncating upper Pitkin units at M.S. 205 and M.S. 209 (Plate 10-C). At M.S. 194, M.S. 195, M.S. 208, M.S. 210A, and M.S. 210B, the unconformity truncates all Pitkin lithologies except the basal Nodular Limestone and Shale Facies. At M.S. 79 of Sutherland and Henry (1977A), the Pitkin has been completely removed by pre-Pennsylvanian erosion and the Sausbee rests directly on the Fayetteville Shale.

Figure 16 is an isopachous map of the Pitkin Limestone based on thickness values obtained from the measured sections. Five additional points are from Orgren's (1979) study. A ten-foot contour interval is used. The thickest measured sections are on the margins of the field area. Over 60 feet of Pitkin strata are preserved on the west side. Moving east, the Pitkin is less than 10 feet thick over the central part of the field area. The small area enclosed by the dashed 0-foot isopach contour is where Sutherland and Henry's (1977A) M.S. 79 is located. On the east side of the study area between 30 and 40 feet of Pitkin are preserved (M.S. 202). The 0-foot isopachous contour to the northeast is the limit of Pitkin preservation.

The isopachous map leads to a possible interpretation of fluvial activity causing the truncation, leaving a broad topographic valley prior to the marine transgression that deposited Morrowan-aged strata. This interpretation is substantiated by west to east cross sections A-A' and B-B' (Figs. 17 and 18). Note the various lithologies at the base of the Sausbee. Basal conglomerates are contained within the valley feature and, except for M.S. 201 in the east-central portion of the study area, and M.S. 187 in the southeastern portion of

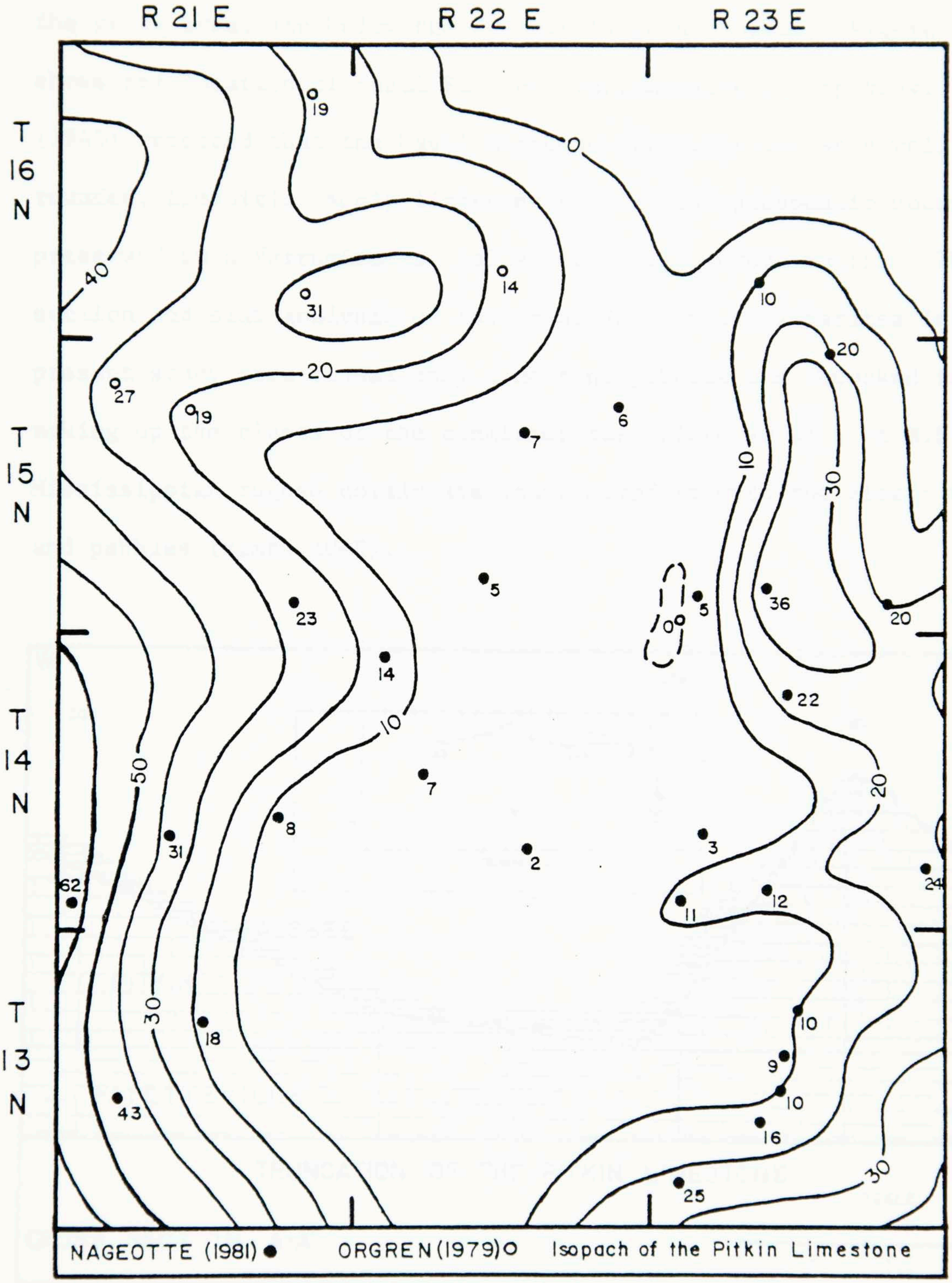

Figure 16. Isopachous map of the Pitkin Limestone in portions of Cherokee, Muskogee, and Sequoyah Counties in northeastern Oklahoma. A 10 foot contour interval is used. Solid circles are from sections measured in this study, open circles are from Orgren (1979).

the study area, lie below the 20-foot isopach contour. Figure 19 shows the location of basal Sausbee conglomerates in map view. Moore (1940) reported that the basal Morrowan conglomerates were well rounded, limonitic, shaly limestone pebbles and phosphatic nodules preserved in a ferruginuous, calcareous yellow-brown matrix. Thin section and slab analysis of the basal Sausbee conglomerates in the present study area reveal only limestone pebbles and reworked fossils making up the clasts of the conglomerates (Plate 10-D). At M.S. 210A, Mississippian rugose corals are found mixed in with the Pitkin cobbles and pebbles (Plate 10-E).

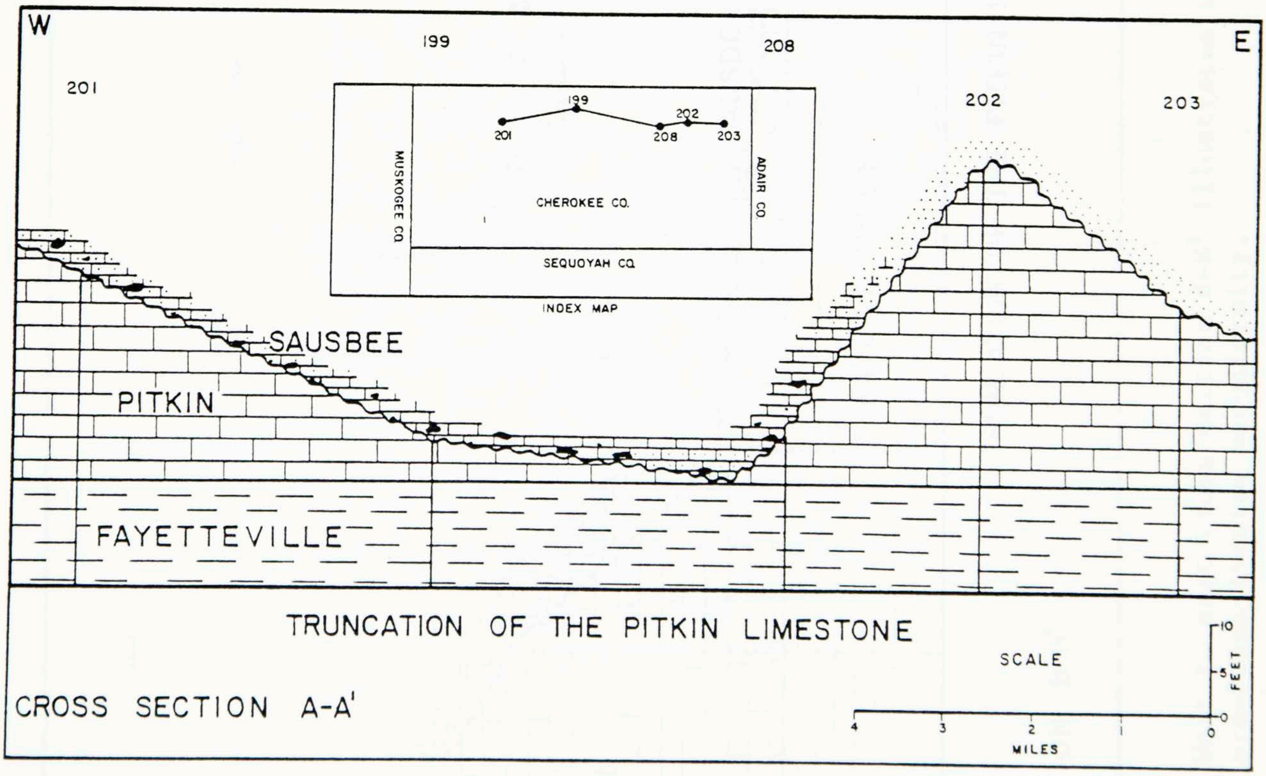

Figure 17. West-east cross section A-A' illustrates the truncation of the Pitkin Limestone by the pre-Pennsylvanian unconformity.

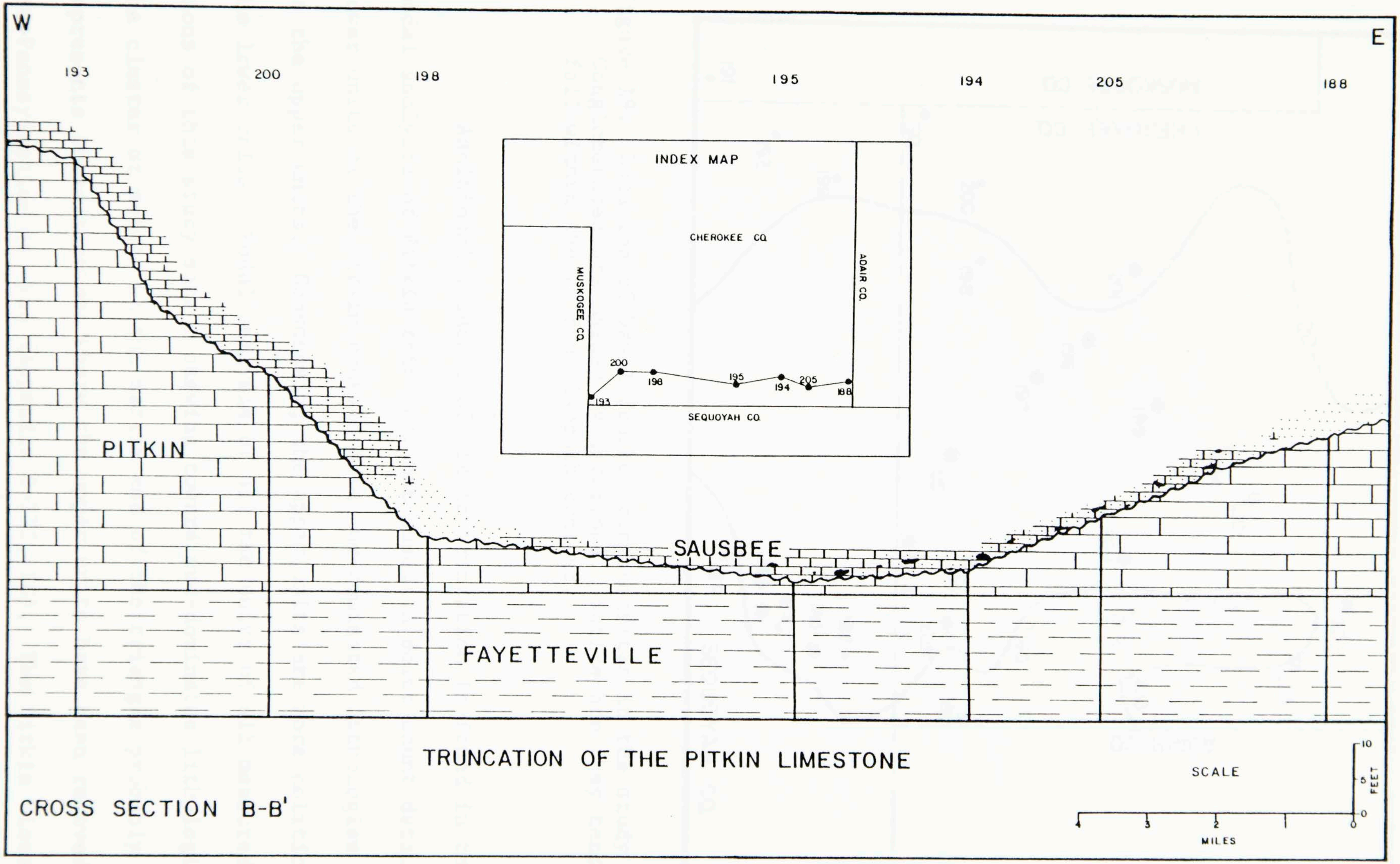

Figure 18. West to east cross section B-B' illustrates the truncation of the Pitkin Limestone by the pre-Pennsylvanian unconformity.

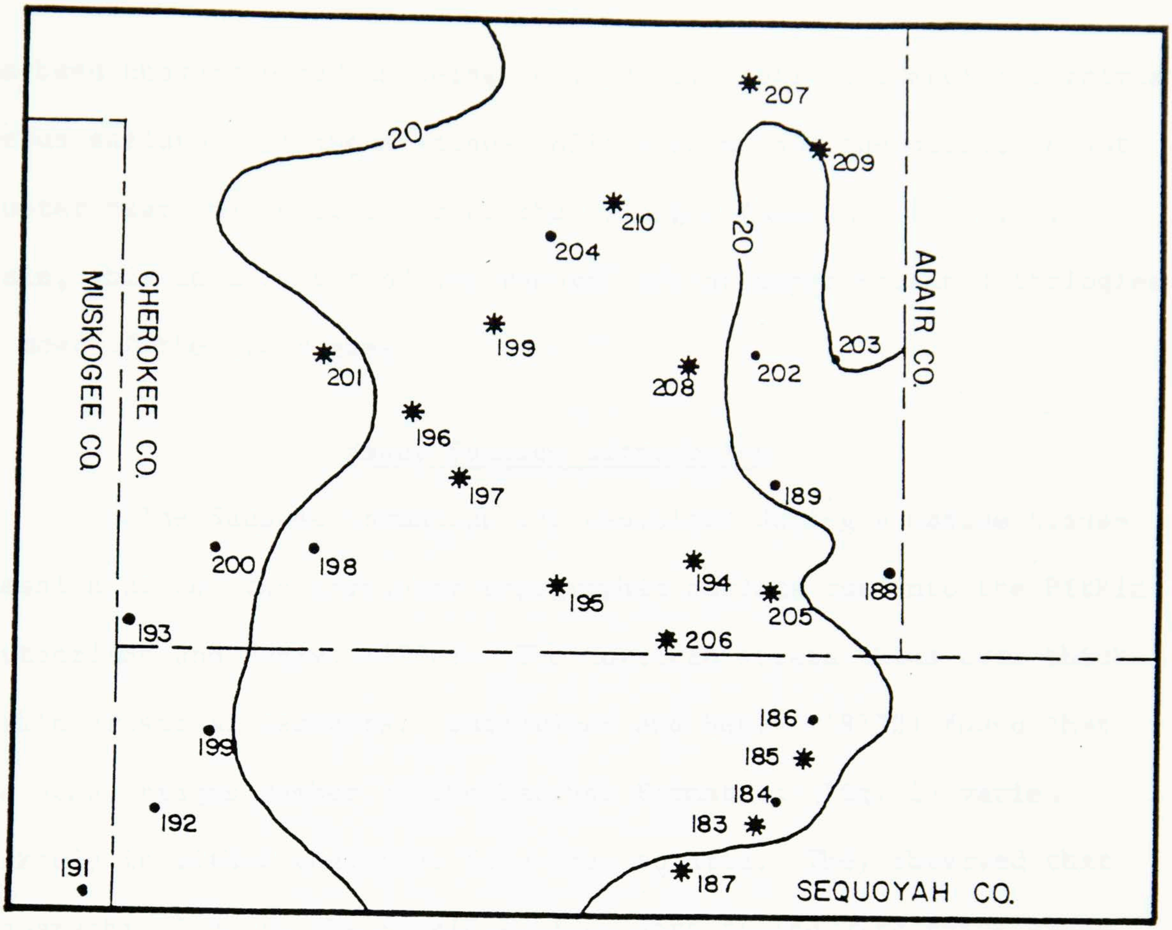

Figure 19. Location of basal Sausbee conglomerates in the study area. Conglomerates are marked by asterisks. Notice how they tend to fall within the 20 foot isopach contour.

Additional evidence of Pitkin truncation is found in the modal analysis of Pitkin thin sections based on point count data. The lower units of the Pitkin contain more mud-dominated lithologies than do the upper units. Conversely, the upper units are more oolitic than the lower units. Modal analysis of all the units of all measured sections of this study show a skewing toward mud-dominated lithologies. The cluster of points at the matrix end of the triangle probably represents those sections where the upper units have been removed by pre-Pennsylvanian erosion (Appendix C-III, IC). The Pitkin Limestone has been characterized as being oolitic but plots of cement and matrix versus skeletal allochems versus ooliths show that the points do not cluster near the ooliths end of the triangle (Appendix C-I, II). Again, this is a result of the removal of the upper Pitkin lithologies in most of the field area.

Basal Sausbee Lithologies

The Sausbee Formation was deposited during a marine transgression across the irregular topographic surface cut into the Pitkin (Sutherland and Henry, 1977A). The Morrowan strata thins over thick Pitkin erosional remnants. Sutherland and Henry (1977B) found that the basal Braggs Member of the Sausbee Formation (Fig. 1) varied markedly in lithic character from area to area. They observed that topographic lows in the Pitkin surface were filled with thick sandstones while topographic highs were overlain directly by pure non-sandy carbonates.

Point counts of basal Sausbee thin sections were used for modal analysis. The results show that there is a spectrum of lithologies within the basal 2 feet of the Sausbee. The lithologies range from pure quartz sandstones in a calcareous matrix to pure limestones with no terrigenous material (Appendix C-VIII). The pure carbonates were differentiated from the Pitkin in the field by presence of basal conglomerates. The main cluster of points on the ternary diagram, near the base of the triangle, shows that the dominant lithology in this field area is a sandy carbonate (Plate 10-F). Possible sources of quartz sand in the Sausbee Formation are the Ordovician Burgen

Sandstone, the Sycamore Sandstone Member of the Devonian Chattanooga Formation, and the Wedington Sandstone Member of the Chesterian Fayetteville Shale.

M.S. 191, M.S. 192, M.S. 193, and M.S. 201 are some of the thicker Pitkin sections in this study area and, as already mentioned, lie on the west side of the field area. This group of thick measured sections are oriented in a north-south trend and coincide with the Gore-Braggs Mountain High of Sutherland and Henry (1977A) (Fig. 20). From that study, they were able to demonstrate that this area of thick Pitkin intervals was a topographic high during Morrowan time based on the thickness and lithology of the overlying Sausbee Formation. The Gore-Braggs Mountain High is most easily observed on the regional isopach map of the Pitkin Limestone (Plate 13).

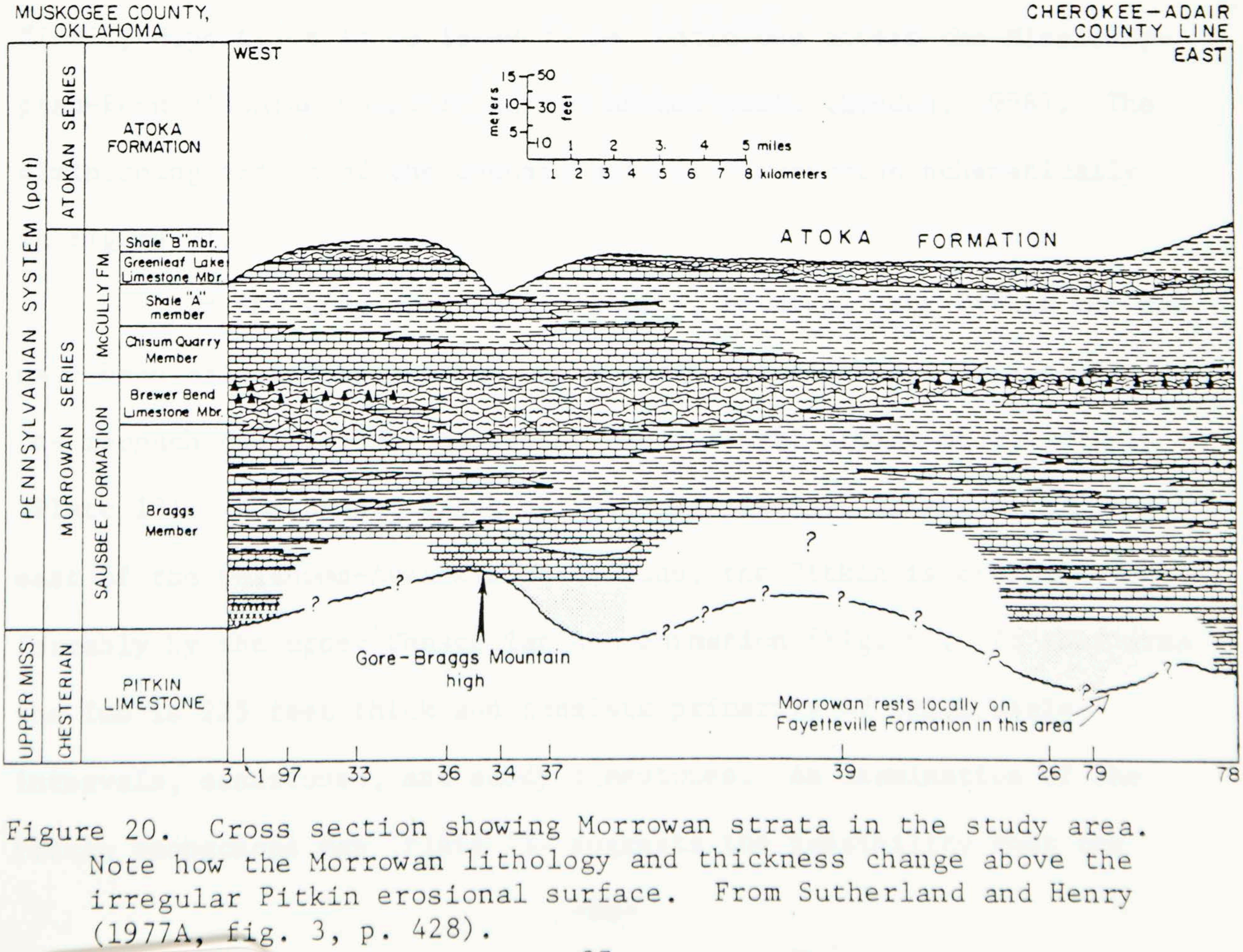

Figure 20. Cross section showing Morrowan strata in the study area. Note how the Morrowan lithology and thickness change above the irregular Pitkin erosional surface. From Sutherland and Henry (1977A, fig. 3, p. 428).

Regional Effects of the Unconformity

The thickness values obtained for the regional isopach map of the Pitkin Limestone in northeast Oklahoma and northwest Arkansas (Plate 13) were obtained mostly from previous field studies with a few subsurface control points to the southeast. A ten-foot contour interval was used. The Pitkin thickness values within this map are a range from 0 in Cherokee County, Oklahoma to 220 feet in the subsurface of Franklin County, Arkansas.

The isopachous contours show erosion and truncation to the north, caused by fluvial systems, giving way to a more ordered pattern to the southeast, where there was less intense erosion. As the unconformity is traced from the platform area southward onto the shelf, then into the Arkoma Basin, the hiatus diminishes in magnitude until finally deposition is believed to be continuous across the Mississippian-Pennsylvanian boundary in the Arkoma Basin (Laudon, 1958). The diminishing effect of the unconformity is illustrated schematically in Figure 21.

In the area of Crawford County, Arkansas, the Pitkin may not have been affected by erosion. The northeast-southwest orientation of the isopach contours may represent depositional strike of the Pitkin (Plate 13). Northeast, along strike, near Leslie, Arkansas, 120 miles east of the Oklahoma-Arkansas state line, the Pitkin is overlain conformably by the upper Chesterian Imo Formation (Fig. 6). In that area the Imo is 225 feet thick and consists primarily of thick shale intervals, sandstones, and sandy limestones. An examination of the Pitkin isopachous map (Plate 13) suggests the possibility that the

Pitkin is overlain by the Imo or a correlative unit in the subsurface in Crawford and southern Washington Counties, Arkansas, and has not been affected by pre-Pennsylvanian erosion. A detailed subsurface analysis of the Pitkin might possibly answer this question, but the Imo has the same well log characteristics as the Cane Hill Member of the lower Morrowan Hale Formation (Doy Zachry, 1981, personal communication) (Fig. 6).

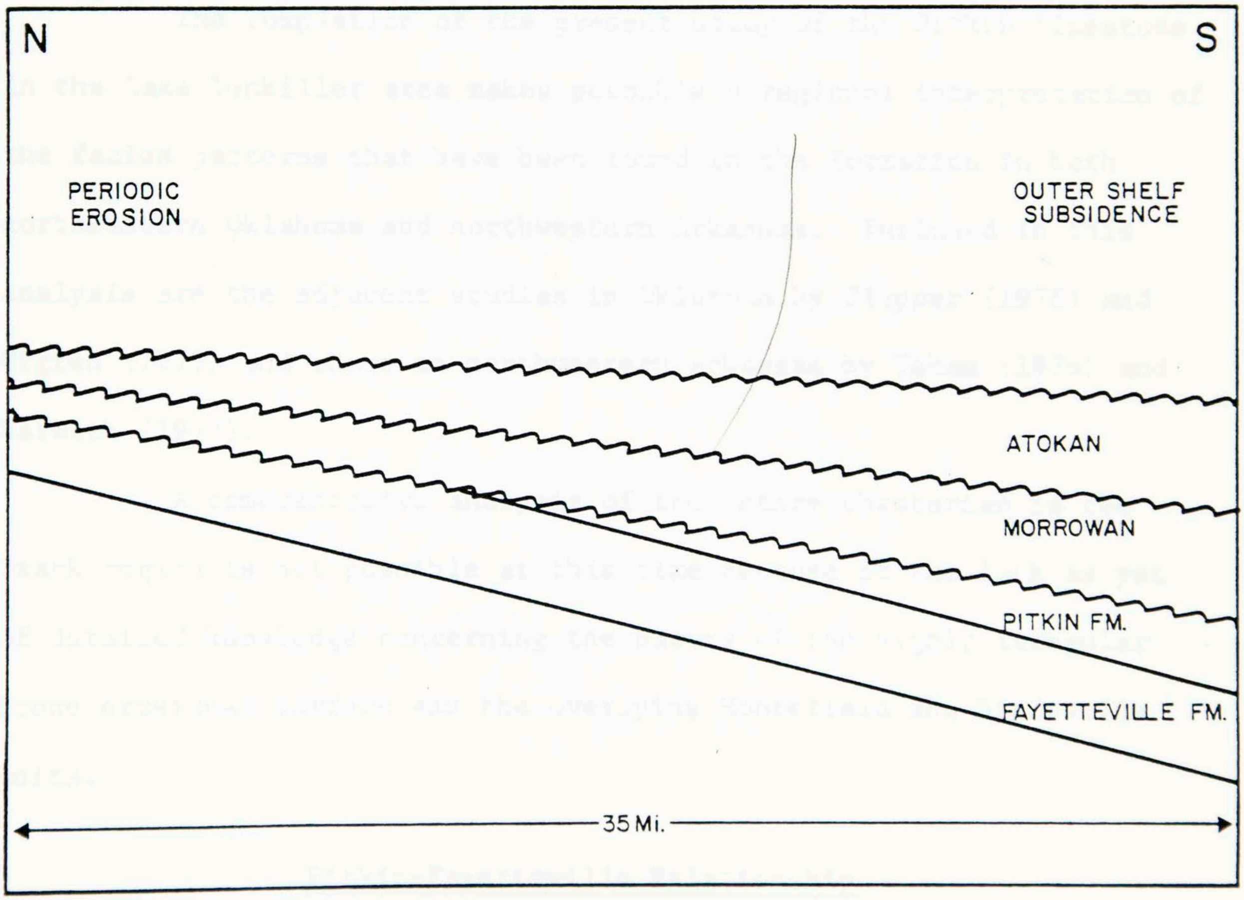

Figure 21. Schematic diagram illustrating the diminishing effect of the pre-Pennsylvanian unconformity on the thickness of the Pitkin Limestone from the inner shelf-platform to the outer shelf on the southern flank of the Ozark Uplift. See also Figure 23.

CHAPTER VI

REGIONAL SYNTHESIS

General Statement

The completion of the present study of the Pitkin Limestone in the Lake Tenkiller area makes possible a regional interpretation of the facies patterns that have been found in the formation in both northeastern Oklahoma and northwestern Arkansas. Included in this analysis are the adjacent studies in Oklahoma by Clupper (1978) and Orgren (1979) and those in northwestern Arkansas by Tehan (1976) and Warmath (1977).

A comprehensive analysis of the entire Chesterian in the Ozark region is not possible at this time because of the lack as yet of detailed knowledge concerning the nature of the highly irregular Boone erosional surface and the overlying Moorefield and Hindsville units.

Pitkin-Fayetteville Relationship

The key to understanding the genesis of the Pitkin Limestone is found in its relationship with the underlying Fayetteville Shale. Jhen and Young (1976) recognized this problem and combined the two formations into a "genetic rock unit." They believed that the Pitkin and the Fayetteville were deposited in a set of similar environments, possibly belonging to the same depositional cycle, but they did not expound on this idea. Orgren (1979) presented two models that were interpretations of this relationship: the environmental replacement model and the transgression model.

The environmental replacement model is the one most often cited by previous investigators to explain the change from predominantly shale deposition of the Fayetteville to the predominantly carbonate deposition of the Pitkin. In this model, the carbonate deposition of the Hindsville was drowned out by the influx of fine-grained, terrigenously derived, clastic material. A large amount of clay-sized material settled on the inner shelf and eventually formed a shale platform. The Wedington Sandstone Member of the Fayetteville, present in Arkansas and eastern Adair County, Oklahoma, may have prograded onto the inner shelf as a deltaic complex during a period of increased coarse-grained clastic influx (McNully and Jackson, 1974). It was eventually inundated by the interbedded shales and limestones of the upper Fayetteville. The ocean bottom was subsequently raised to the photic zone by rapid sedimentation allowing Pitkin carbonates to accumulate during a period of slow marine transgression and reduced clastic influx (Fig. 22-A).

The transgressive model is based on Irwin's (1965) interpretation of epeiric clear water deposition. The Fayetteville represents a lagoonal or backreef deposit of terrigenous clastics that maintained both temporal and stratigraphic relationships to the Pitkin as a result of transgression (Fig. 22-B). The relationship described above would be expressed in continental or epeiric seas where facies

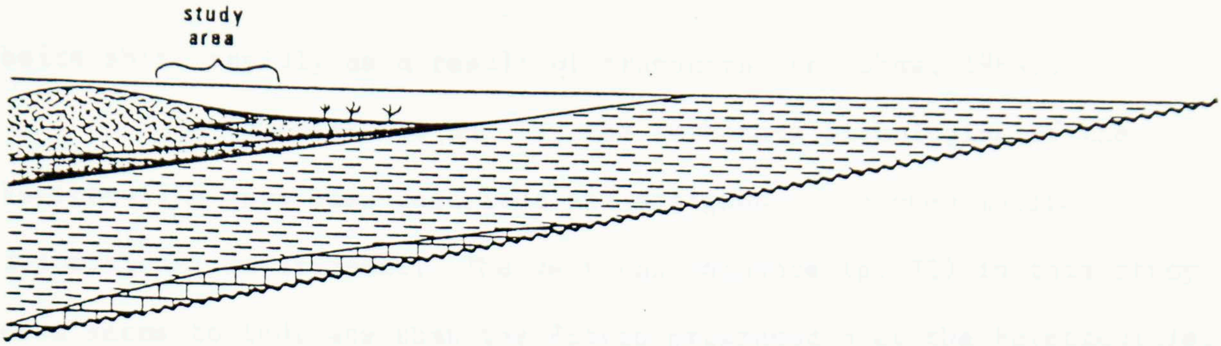

Figure 22-A. The final stage of the environmental replacement model of Orgren (1979). "Lower energy" Fayetteville muds are replaced by "higher energy" Pitkin carbonates. From Orgren (1979, fig. 8, p. 61).

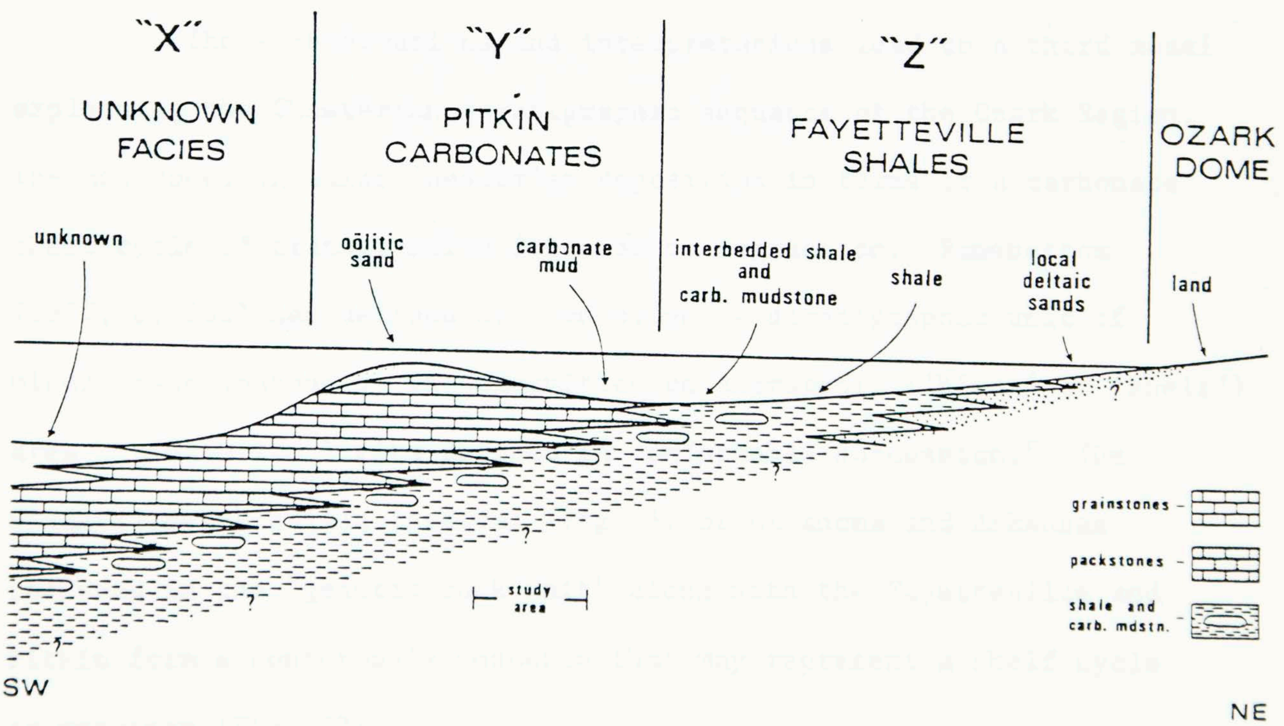

Figure 22-B. The transgressive model of Orgren (1979). The Fayetteville Shale is interpreted as being a lagoonal deposit. From Orgren (1979, fig. 10, p. 64).

belts shift rapidly as a result of transgression (Shaw, 1964).

In Chapters III and IV, the carbonate lithologies of the Fayetteville have been described and assigned to an open marine depositional environment. The vertical sequence (p. 72) in this study area seems to indicate that the Pitkin prograded over the Fayetteville, thus preserving the temporal and lithologic relationships at any measured section within the Ozark Region. With this in mind, it may be speculated that the Fayetteville-Pitkin contact is diachronous as a result of Pitkin progradation and that the deposition of the upper Fayetteville on the open marine shelf was simultaneous with the deposition of the Pitkin on the Ozark carbonate platform.

These observations and interpretations lead to a third model explaining the Chesterian stratigraphic sequence of the Ozark Region. The new model explains Chesterian deposition in terms of a carbonate shelf cycle of transgression followed by regression. Ramsbottom (1977, p. 282) has defined as a mesothem "a stratigraphic unit of middle rank bounded by unconformities on a cratonic ('block' or 'shelf') area but with its limits defined in conformable succession." The Hindsville-Batesville interval (Fig. 6) of Oklahoma and Arkansas included in the "genetic rock unit" along with the Fayetteville and Pitkin form a conformable sequence that may represent a shelf cycle or mesothem (Fig. 23).

The Hindsville and Batesville Formations were deposited in nearshore, shallow marine depositional environments (Grayson, 1969) as a result of transgression (Garner, 1967). In Arkansas, the Batesville is a sandstone that interfingers with the Hindsville and

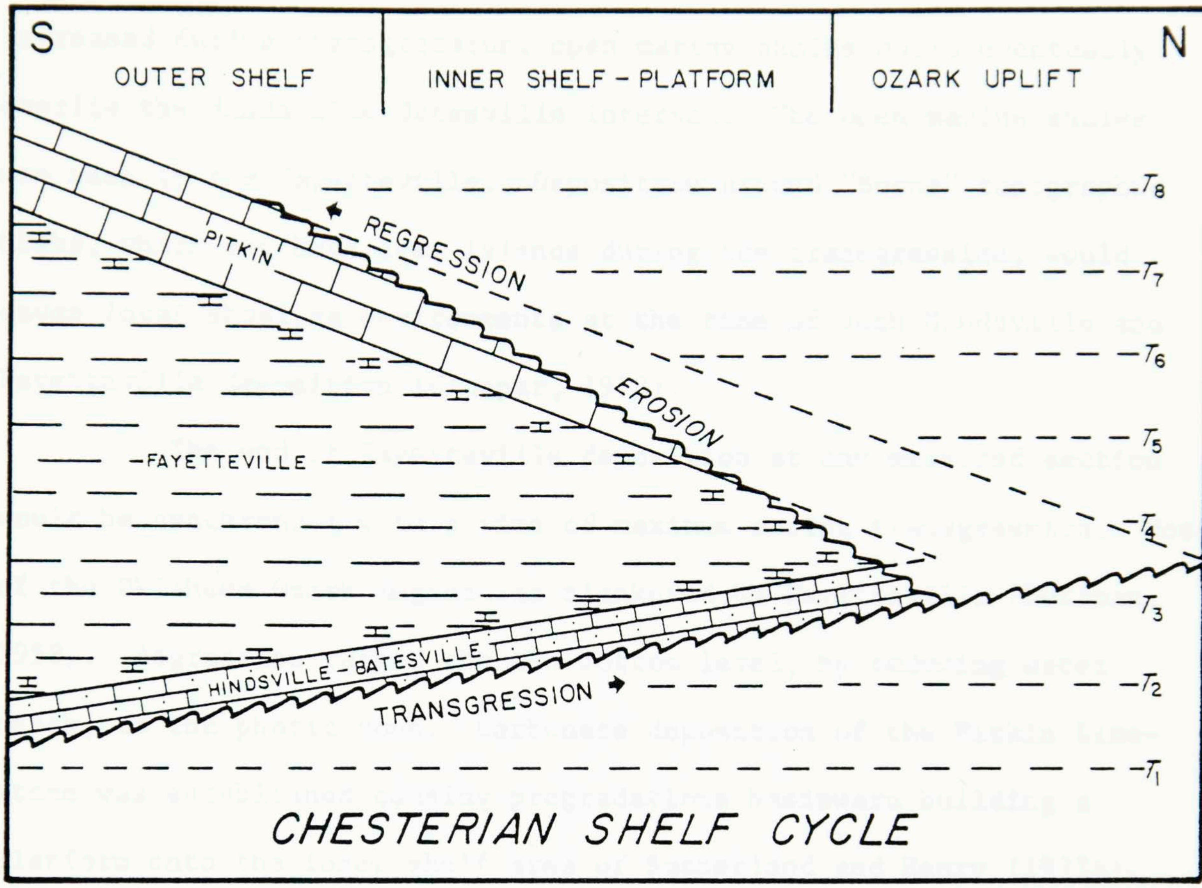

Figure 23. The Chesterian carbonate shelf cycle (mesothem) on the southern flanks of the Ozark Uplift. This interpretation explains the temporal and lithostratigraphic relationships of the region for this time interval.

may represent close to source transgressive strandline deposition. In the present study area the Hindsville is predominantly a grainstone, with ooliths, coated grains, dasycladacean algae, and cross laminations all of which indicate depositional environments in Wilson's standard facies belt 6. The Hindsville thin sections also contain numerous quartz grains. The reason carbonates are prevalent in this interval in Oklahoma is because they were away from the sources of clastic material in northeastern Arkansas (Orgren, 1961). As water depths increased during transgression, open marine shales would eventually overlie the Hindsville-Batesville interval. The open marine shales are seen in the fayetteville. Deposition around "Boone" topographic highs, which may have been islands during the transgression, would cause local shoaling environments at the time of both Hindsville and Fayetteville deposition (Clupper, 1978).

The end of Fayetteville deposition at any measured section would be synchronous with a time of maximum marine transgression. Most of the Oklahoma Ozark Region was blanketed by Fayetteville (Huffman, 1958). Regression raised the sea-bottom level, by reducing water depth, to the photic zone. Carbonate deposition of the Pitkin Limestone was established causing progradations basinward building a platform onto the inner shelf area of Sutherland and Henry (1977A).

The most appealing aspects of this model are: (1) the temporal relationships are maintained throughout the Ozark region, (2) the regressive carbonate shoaling up sequence is common in the geologic record and is seen in other North American carbonate units of Mississippian age, (3) all of the Chesterian strata included in the proposed cycle have conformable contacts fitting the definition of a mesothem, and (4) subsidence, tectonics, or wildly fluctuating sea level changes are not needed to explain the lithologic changes from one unit to another. Cyclic sedimentation is a succession of ordered and predictable depositional environments through time.

A weakness of this model is the lack of an explanation for the presence of the Imo Formation which conformably overlies the Pitkin in Van Buren County, Arkansas. The only way the Imo can fit into the top of a regressive sequence is by clastic influx drowning out carbonate deposition. Perhaps Imo sediments owe their origin to the erosion of higher standing areas located landward (north) of the marine shelf. The erosion may have occurred during the same regression that caused the Pitkin to prograde over the Fayetteville.

Regional Geometry of the Pitkin Limestone

Whether the Pitkin prograded over the Fayetteville as a result of slow transgression, sea level stillstand, or regression has little effect on the depositional environments interpreted from the facies analysis of this and previous studies. Almost all authors agree that the Pitkin carbonates were deposited in shoaling and partially restricted marine waters. The progradation of these facies, in Oklahoma, built a platform that contains a mosaic of shallow water facies.

Depositional strike, from west to east, around the platform can be inferred from changes in the distribution of facies, isopach map patterns, and the orientation of mud mounds in Arkansas. The cross sections from Orgren's (1979) study show that grain-dominated lithologies are more prevalent to the northeast. This may indicate that depositional strike in her study area was northwest to southeast. Depositional strike is difficult to demonstrate in the present study because of the random distribution of facies in cross section (Plates 11 and 12). However, grainstones are dominant in both the south and southeast portion of the field area possibly indicating east-west depositional strike. In Adair County, Clupper's (1978) north-south cross section shows that grainstones dominate in the southern part of his field area while mustone and wackestone are more common to the north. He also measured the attitude of crossbeds and found that they tended to orient themselves in a northwest-southeast fashion. Depositional strike was probably east-west on the west shelf of Adair County and northeast-southwest on the east half. The isopachous map (Plate 13) indicates a northeast-southwest depositional strike for the Pitkin in Washington and Crawford Counties, Arkansas.

By coincidence, the mud mounds reported by Tehan and Warmath (1977) are aligned along this same northeast-southwest trend. The isopachous maps of Orgren (1961, 1968) show the same strike orientation in the upper Mississippian units of northwest Arkansas. Additional information in support of a northeast-southwest depositional strike in Adair County, Oklahoma, and Washington and Crawford Counties, Arkansas, can be found in Snider (1915), Moore (1940), Glick (1975), Zimbrick (1978), Price (1981) and Foshee and Zachry (1981). From this information, it may be concluded that the direction of marine encroachment and withdrawal during Chesterian and Morrowan time, in Arkansas and Adair County, Oklahoma, was from southeast to northwest.

The Fayetteville isopachous maps (Figs. 8 and 9) may indicate that there was deeper water surrounding the platform area in Oklahoma. This information, combined with lithofacies distribution of both Clupper (1978) and Orgren (1979), tends to suggest that carbonate deposition of the Pitkin was ultimately influenced by the positive topographic expression of the Ozark Uplift. The "halo effect" is commonly a result of the progradation of a carbonate buildup during times of regression or sea level stillstand (Wilson, 1975). The geographic center of the Pitkin "halo" was located in south-central Delaware County, Oklahoma (Fig. 23).

Missing Units

Two lithologies that comprise Wilson's (1975) standard facies belts 8 and 9 or Irwin's (1965) Y zone have not been observed in this study of the Pitkin or reported in previous investigations. These missing lithologies are flaser bedded tidal flat deposits and evaporitic/dolomitic sequences. The assignment of the Pitkin lithofacies to the basic model of carbonate deposition has been one of the main themes of this thesis. Why are these facies not seen in the Ozark Region?

In the present study, it cannot be demonstrated that finer grained lithologies are found to the north because of the truncation of Pitkin lithologies by the pre-Pennsylvanian unconformity. Evidence may lie in an analysis of basal Sausbee conglomerates. Most of the limestone clasts that comprise the basal Sausbee conglomerate in the northern portion of the present study area are fine-grained. Using the principle of stratigraphic inversion, one would expect lithologies found higher in the sedimentary column to be transported into topographic depressions during erosion events. Because mudstone and wackestone cobbles are found in the basal Sausbee it may be inferred that the Pitkin lithologies higher in the section to the north may have been fine grained.

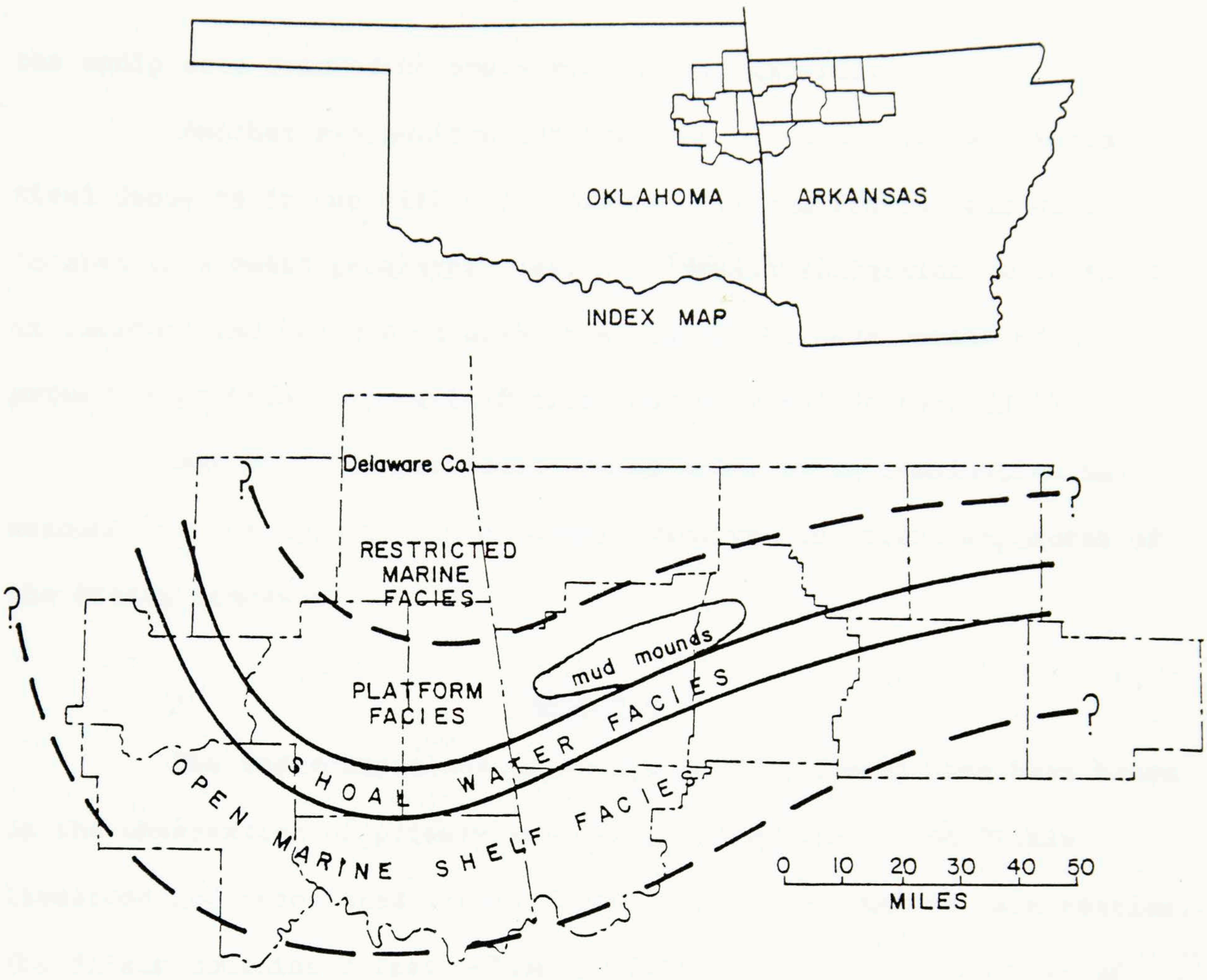

Figure 24. The regional geometry and major facies distribution of the Pitkin Limestone reflects the control of carbonate deposition by the positive topographic expression of the Ozark Uplift. Most of the restricted marine facies have been removed by pre-Pennsylvanian erosion.

If the Pitkin were a transgressive rather than regressive carbonate unit, these lithologies would have traveled shoreward and eventually been covered by open marine deposits. This is clearly not the case. The lack of preserved nearshore carbonates adds more weight to the regressive model of Pitkin deposition. Also, more nearshore deposits in the Pitkin, whatever their nature, would be located in the updip area removed by post-depositional erosion.

Another explanation for the lack of intertidal and supratidal deposits in the Pitkin is climate. If the Pitkin seas were located in a humid geographic region, brackish salinities would exist in lagoonal and restricted areas preventing the development of a primary supratidal dolomitic facies (Horowitz and Potter, 1971).

Any of these processes acting alone or in combination may account for the lack of these facies preserved in recent exposures of the Pitkin Limestone.

Diagenesis

The interpretations presented in this thesis have been based on the observation of primary sedimentary features of the Pitkin Limestone and associated strata, both in the field and in thin section. The Pitkin contains a fascinating variety of diagenetic features as well. Aggrading neomorphism is seen sporadically in the finer-grained thin sections. Many of the coarser-grained lithologies have both marine and phreatic cements revealing a complex post-depositional history. Now that the best exposures of the Pitkin have been located, measured, and described, a detailed analysis of the cementation history is possible.

CONCLUSIONS

1. Eleven lithofacies of the Pitkin Limestone have been defined both qualitatively and quantitatively and most of them are found to reoccur throughout the field area. They are: Oolite Facies, Oolitic Facies, Bioclastic Facies, Encrinite Facies, Oncolite Facies, Nodular Limestone and Shale Facies, Peloidal Facies, Wackestone Facies, Mudstone Facies, Mound Facies, and Shale Facies.

2. These facies were deposited mostly in shallow, shoal water, marine environments. The grainstone textures represent shoal and shallow carbonate sands, while packstone, wackestone and mudstone textures represent intershoals or flanks. Some of these facies may possibly represent foreslope deposits.

3. In vertical section and in cross section, the Pitkin facies are randomly distributed in the central and eastern portion of the field area forming a facies mosaic. The mosaic may have resulted from storm activity.

4. The abundance of shallow, high energy, lithologies, combined with the mosaic facies pattern and a shallow water algal flora, suggests that the Pitkin Limestone of the study area was a platform carbonate.

5. The relationship of the Pitkin to the Fayetteville is a shoaling upward sequence indicating that the Pitkin Limestone prograded

over the Fayetteville Shale. The two formations were deposited contemporaneously during the regressive phase of the proposed Chesterian mesothem and their contact is diachronous.

6. The Pitkin Limestone was regionally truncated by fluvial activity during the Mississippian-Pennsylvanian unconformity leaving a surface with several tens of feet of relief. The lithologies of the succeeding Morrowan strata and isopachous maps reflect the irregular nature of the erosional surface.

7. The Chesterian stratigraphic package on the southern and southwestern flanks on the Ozark Uplift may be interpreted as a carbonate shelf cycle or mesothem. The Hindsville is a transgressive unit, the Fayetteville is both transgressive and regressive, and the Pitkin is a regressive unit.

8. Depositional strike of the Pitkin Limestone, as evidenced by the facies transitions in adjacent study areas, isopachous map patterns, and the alignment of mud mounds, was ultimately controlled by the positive topographic expression of the Ozark Uplift in both northeast Oklahoma and northwest Arkansas.

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APPENDIX A

MEASURED SECTIONS

This appendix contains the descriptions of the 28 stratigraphic sections measured in this study. The sections are numbered from 183 to 210, in sequence with other studies in the northeastern Oklahoma Ozark Region that are concerned with upper Mississippian and lower Pennsylvanian strata directed by Dr. P. K. Sutherland at the University of Oklahoma.

Each measured section is subdivided into units based on lithologic character observed in outcrop. The units are grouped by formation. The descriptions are based solely on field observations with a 10X hand lens. Thin section analyses of collected Pitkin and Sausbee units are given in Appendix B.

The general format for each description is as follows: (1) Dunham's (1962) classification, (2) color fresh, (3) color weathered, (4) grain size, (5) grain sorting, (6) composition, (7) accessory minerals, (8) sedimentary structures, (9) fossils, (10) bedding according to Ingram's (1954) classification, (11) persistency, (12) weathered appearance, (13) additional pertinent comments, and (14) basal contact description. Some items on this list are omitted when not applicable. The distance above the base of the unit is included in parentheses indicating where specimens were collected.

The thickness of each unit and each formation are expressed in feet. Formation tallies are labeled "partial thickness" when either the base or the top of the formation is covered by slumping, talus, or vegetation.

Measured Section 79 of Sutherland and Henry (1977) is included in this study. It is located in the north-central portion of the field area. The Pitkin is completely removed by pre-Pennsylvanian erosion at this locality and the Sausbee Formation rests directly on the Fayetteville Shale.

Measured Section 183: Smith Ranch

Location: $SW\frac{1}{4}$ $SE\frac{1}{4}$ sec. 21, T. 13 N., R. 23 E., Sequoyah County, Oklahoma.

Drive 1.5 miles northwest from the railroad tracks in Marble City to a gravel road just north of Pettit Methodist Church and turn west (left). Continue driving 1.2 miles northwest, then turn southwest (left) onto a smaller gravel road. Drive 1.3 miles to a gate. The land owner lives in a small house visible from the gate. Enter and obtain permission to drive across the pasture beyond the house. Drive about 0.5 mile southwest through the pasture to the end of the cleared land. The section is located on a bluff about 75 yards to the north of the northwest corner of the pasture in a gully which forms the head of a stream.

This section was measured on March 4 and 5, 1980. It is of particular interest because of the partial exposure of Boone Group erosional remnants in the pasture. There is also a thick interval of Fayetteville carbonates exposed below the prominent Pitkin bluffs.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
7	Calcareous sandstone. Buff to light brown. Weathers gray brown with ironstain. Medium to coarse grained. Poorly sorted. Composed of mixed quartz and carbonate grains. Medium bedded. Friable. Basal contact welded. (0.1 foot above base)	1.0
PITKIN LIMESTONE		15.6

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
6	Grainstone. Medium to dark gray brown. Weathers medium gray. Coarse grained. Well sorted. Coated skeletal grains and ooliths. Low-angle crossbedding. Rare graded bedding. Dominant faunal elements are bryozoans, crinoids, and brachiopods. Medium to thick bedded. Lateral facies become increasingly oolitic. Unit forms resistant cliff. Weathers along cross-beds. Supports abundant lichens. Basal contact undulating. (1.5 feet above base)	3.0
5	Wackestone and shale. Medium to dark gray brown. Weathers light gray brown. Coarse skeletal grains in mud matrix. No sorting. Composed of carbonate mud, skeletal grains, and rare ooliths. Thin nodular bedding. Becomes a recessive shale unit laterally. Basal contact sharp. (0.2 foot above base)	0.4
Offset 12 feet west on top of unit 4.		
4	Packstone. Medium gray brown. Weathers light gray brown. Coarse grained. Poorly sorted. Composed of coated skeletal grains. Thick bedded. Laterally persistent but forms a reentrant. Basal contact welded. (2.2 feet above base)	2.2
3	Wackestone and packstone. Dark blue gray. Weathers light to medium gray brown. Medium grained. Poorly sorted. Composed of skeletal grains with minor ooliths. Medium bedded with shale partings. Changes facies laterally. Forms a resistant rough weathering unit. Petroliferous. Basal contact undulating but sharp. (4.0 feet above base)	4.5
2	Wackestone. Medium to dark gray. Weathers light to medium gray. Fine to coarse grained. Poorly sorted. Composed of skeletal grains. Spiculiferous. Medium bedded. Forms a resistant ledge. Petroliferous. Basal contact undulating. (0.5 foot above base)	1.5

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
1-C	Mudstone and shale. Dark blue gray. Weathers light gray to gray brown. Coarse skeletal inclusions. Unit is composed of limestone and dark gray fissile shale. Contains abundant Archimedes bryozoa and a variety of crinoids. Thin to nodular bedded. Forms recessive interval where exposed. Petroliferous. Basal contact covered. (2.0 feet above base)	4.0
FAYETTEVILLE SHALE		52.0
1-B	Shale and covered. A stair-step pattern of interbedded mudstone and shale may be seen in the stream below the Pitkin bluff with rare exposures of black ironstained shale. This unit is covered laterally. (6.0 feet above base)	
HINDSVILLE FORMATION - partial thickness		
1-A	Grainstone. Medium to dark gray brown. Weathers light to medium gray. Medium to coarse grained. Poorly sorted. Coated skeletal grains. Medium to thick bedded. Poorly exposed. Forms rough weathering outcrop. Basal contact covered. (0.75 foot above base)	

Measured Section 184: Smith Hollow

Location: SE¼ NE¼ sec. 21, T. 13 N., R. 23 E., Sequoyah County, Oklahoma.

Drive 1.5 miles northwest from the railroad tracks in Marble City on a paved county road to a gravel road just north of Pettit Methodist Church and turn west (left). Continue driving 1.2 miles northwest, then turn southwest (left) onto a smaller gravel road. Drive 1.0 mile, then turn north (right) onto a ranch road cut into the bluff. Drive or hike about 100 yards to a gully on the west side of the road. The section is located about 50 yards west of the ranch road in the gully.

This section was measured on March 5, 1980. Cut-and-fill structures can be seen on the top of the Pitkin. Small rivulets are filled with presumably Morrowan age sandstone.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
6	Sandstone. Light gray to pink. Weathers rust brown. Medium to coarse grained. Poorly sorted. Subangular. Friable. Crossbedded. Medium bedded. Basal contact welded in part. (sampled at base)	1.0
PITKIN LIMESTONE		10.0
5	Grainstone. Medium gray brown. Weathers light gray brown. Medium grained. Poorly sorted. Composed of coated skeletal grains and ooliths. Minor crossbedding. Thick bedded. Sausbee sandstone can be seen filling in rivulets on the top of this unit. Basal contact undulating. (1.5 feet above base)	2.0
4	Grainstone. Blue gray to gray. Weathers medium gray to gray brown. Ironstained. Medium grained. Poorly sorted. Abundant crinoid rubble. Skeletal grains are coated. Medium bedded. Forms a recessive interval. Exfoliated. Basal contact sharp. (2.2 feet above base)	4.5
3	Mudstone and shale. Blue gray. Weathers light gray brown. Fossiliferous. Shale is dark gray and subfissile. Thin bedded. Forms a small reentrant. Basal contact sharp and undulating. (0.2 feet above base)	0.5
2	Packstone. Medium gray. Weathers light gray brown. Coarse grained. Well sorted. Composed of abraded skeletal grains. Minor crossbedding. Medium bedded. Rough weathering. Petroliferous. Basal contact sharp. (1.2 feet above base)	2.5

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
1-B	Wackestone and shale. Light to medium gray brown. Weathers light gray brown. Coarse grained. Poorly sorted. Thin to medium bedded. Forms a resistant unit. Shale forms a reentrant. Basal contact covered. (sampled at base)	0.15
FAYETTEVILLE SHALE - partial thickness		65.0
1-A	Covered interval. Limited exposures of black shale and limestone are found in the stream bed.	

Measured Section 185: Jackson Mountain Road Section

Location: NW¼ SW¼ sec. 15, T. 13 N., R. 23 E., Sequoyah County, Oklahoma.

Drive 1.5 miles northwest from the railroad tracks in Marble City on a paved county road to a gravel road just north of Pettit Methodist Church and turn west (left). Drive 2.2 miles past a dump and park. The Pitkin bluff should be observable on the southwest side of the road in the winter and early spring. Walk to the bluff from the road. Follow the bluff south about 25 yards to the painted unit numbers.

This section was measured on March 6, 1980. It is the thinnest Pitkin interval in the Marble City area. The units are laterally persistent along the bluff face. A crossbedded basal Sausbee sandstone overlies the Pitkin at this locality.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
6	Calcareous sandstone. Light brown to white. Weathers rust brown. Medium to coarse grained. Well sorted. Subangular quartz grains. Friable to firm. Sparsely fossiliferous. Crossbedded. Basal contact undulating. (sampled at base)	1.0
PITKIN LIMESTONE		9.1
5	Grainstone. Medium gray brown. Weathers light gray brown. Fine to medium grained. Well sorted. Contains ooliths and coated skeletal grains. Thin bedded. Forms a slightly recessive interval. Weathers smooth and rounded. Basal contact varies from sharp to gradational. (0.5 foot above base)	1.0
4	Grainstone. Medium gray brown. Weathers light gray brown. Medium grained. Poorly sorted. Composed of abraded skeletal grains and ooliths. Thin bedded. Smooth weathering. Basal contact gradational. (0.4 foot above base)	0.8
3	Packstone. Medium gray brown. Weathers light gray. Medium to coarse grained. Poorly sorted. Crinoidal. Medium bedded. Laterally persistent with a reentrant at the base. Weathers rounded and rough. Basal contact sharp. (1.5 feet above base)	3.0
2	Grainstone. Medium blue gray. Weathers medium gray brown. Coarse grained. Poorly sorted. Thick bedded. Forms a resistant ledge. Weathers with a honeycomb appearance. Basal contact gradational. (1.5 feet above base)	2.8
1-C	Limestone and shale. Dark blue gray. Weathers light gray. Shale is black and fissile. Sparsely fossiliferous. Thin bedded. Forms a recessive unit. Basal contact covered. (0.8 foot above base)	1.5

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UNIT NO.	LITHOLOGY	THICKNESS (FEET)
FAYETTEVILLE SHALE		31.0
1-B	Covered interval. Talus slope contains typical blocky mudstone rubble with intermittent exposures of black fissile shale. (no sample)	31.0
HINDSVILLE FORMATION - partial thickness		2.2
1-A	Packstone. Dark gray. Weathers medium gray. Predominantly coarse grained. Poorly sorted. Composed of brachiopodal and crinoidal skeletal debris. Minor crossbedding. Thick bedded. Poorly exposed. Resistant. Smooth weathering. Basal contact covered. (2.0 feet above base)	2.2

Measured Section 186: Jackson Mountain Saddle Section

Location: NW¼ SW¼ sec. 10, T. 13 N., R. 23 E., Sequoyah County, Oklahoma.

Drive 1.5 miles northwest from the railroad tracks in Marble City on a paved county road just north of Pettit Methodist Church and turn west (left). Continue driving 3.7 miles to an intersection at the top of Jackson Mountain and park. The section is located 0.25 mile east of the intersection in a deeply cut valley on a northeast facing bluff.

The easiest way to locate the section is to walk down the valley until Boone Group lithologies are encountered. Then carefully proceed up section past a covered Fayetteville interval to well exposed Pitkin bluffs.

This section was measured on March 6, 1980. A thick, well exposed section of the Boone to Pitkin stratigraphic interval is present at this locality. The units of the Pitkin are variable laterally.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
7	Calcareous sandstone. Light gray. Weathers light brown. Very coarse grained. Poorly sorted. Composed of quartz and carbonate grains. Medium bedded. Friable. Basal contact sharp. (sampled at base)	1.0
PITKIN FORMATION		10.3
6	Packstone and wackestone. Medium gray. Weathers buff to tan. Fine grained. Poorly sorted. Predominantly composed of coated skeletal grains with minor ooliths. Medium bedded. Forms a slight reentrant. Basal contact gradational. (1.0 foot above base)	1.0
5	Grainstone. Medium to dark blue gray. Weathers medium gray brown. Coarse grained. Well sorted. Graded bedding. Forms single rounded, thick bed. Weathers rough and pitted. Basal contact sharp and undulating. (1.0 foot above base)	6.0
4	Limestone and shale. Blue gray. Weathers light gray brown. Mudstone in part. Thin, wavy bedding. Changes thickness laterally. Forms a reentrant. Basal contact covered. (1.0 foot above base)	1.0
3	Covered interval.	0.5
2	Grainstone. Medium to dark blue gray. Weathers medium gray brown. Coarse grained. Poorly sorted. Composed of coated bryozoan and crinoidal skeletal debris. Medium bedded. Forms a resistant ledge. Smooth weathering. Basal contact covered. (0.8 foot above base)	0.8
1-B	Packstone. Medium gray brown. Weathers light gray brown. Fine to medium grained. Well sorted. Composed of coated bryozoan skeletal grains and ooliths. Medium to thick bedded. Forms a resistant unit. Petroliferous. Basal contact covered. (1.0 foot above base)	1.0

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
FAYETTEVILLE SHALE		20.0
1-A	Covered interval. Forms a talus slope between the Pitkin and the Hindsville. (no sample)	20.0

Measured Section 187: Circle A Ranch

Location: NE¼ NW¼ sec. 31, T. 13 N., R. 23 E., Sequoyah County, Oklahoma.

From Pinhook Corners, northeast of Vian, drive north on a gravel road 2.5 miles to a gate on the west (left) side of the road. The landowner, Mr. G. Smith, lives in a small house visible from the gate. Obtain permission to cross his land. Hike on the trail to the west behind the house for a distance of about 1.0 mile, to Little Vian Creek. Continue north along the creek (upstream) 75 yards. If the creek is dry, the Fayetteville should be exposed in the creek bed. Turn east at the first small tributary encountered. The Pitkin section is located on a bluff about 150 yards upstream from the mouth of the tributary.

This section was measured on March 8, 1980. It is the southernmost exposure of Pitkin Limestone in the western half of the study area. It contains a thick interval of mudstone and wackestone. An unusually thick interval of Morrowan strata composed mostly of carbonate lithologies is present above the Pitkin.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
20	Conglomerate. Light to medium gray. Weathers light gray. Ironstained. Very coarse grained. Poorly sorted. Minor crossbedding. Thick bedded. Forms a slightly recessive interval. Rough weathering. Basal contact sharp. (sampled at base)	1.0
PITKIN LIMESTONE		25.1
19	Grainstone. Medium blue gray to gray brown. Weathers light to medium gray. Medium to coarse grained. Well sorted. Composed of skeletal grains and ooliths. Thick bedded. Forms rounded outcrop. Basal contact welded. (1.5 feet above base)	3.5
18	Grainstone. Light blue gray. Weathers light gray to gray brown. Very coarse grained. Poorly sorted. Medium bedded. Forms a recessive interval between two massive units. Basal contact welded. (0.6 foot above base)	0.7
17	Grainstone. Medium blue gray to brown. Weathers white to light gray brown. Medium grained. Well sorted. Composed of ooliths and abraded skeletal grains. Thin bedded. Weathers rough and pitted. Basal contact welded. (0.8 foot above base)	0.8
16	Wackestone. Dark blue gray. Weathers light gray brown. Contains crinoids, brachiopods, and bryozoans. Forms smooth, rounded outcrop on the south facing slope and rubbly outcrop on the north facing slope. Basal contact gradational. (sampled at base)	2.2
15	Mudstone. Blue gray. Weathers light gray brown to buff. Contains a packstone lense 0.2 foot above the base. Forms smooth, rounded outcrop on south facing slope and rubbly outcrop on north facing slope. Grades upward into unit 16. Basal contact covered. (5.0 feet above base)	5.5

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
14	Covered interval.	2.5
13	Packstone. Medium to dark blue gray. Weathers light gray to rust brown. Medium grained. Well sorted. Oolitic. Medium bedded. Forms smooth, rounded outcrop. Poorly exposed. Moss covered. Forms two resistant units in a stair-step fashion. Basal contact covered. (3.0 feet above base)	3.5
12	Covered interval.	1.5
11	Wackestone. Medium to dark gray. Weathers light gray brown. Sparsely fossiliferous. Medium bedded. Forms a small ledge. Weathers smooth with fossils standing out. Basal contact welded. (sampled at base)	1.5
10	Grainstone. Medium blue gray. Weathers gray brown. Coarse grained. Poorly sorted. Minor cross-laminations. Medium to thick bedded. Forms laterally persistent unit. Smooth weathering with fossils standing out. Moss covered in part. Petroliferous. Basal contact gradational. (2.2 feet above base)	2.9
9	Limestone and shale. Dark blue gray. Weathers light brown. Shales are dark gray and fissile. Carbonates are in thin, nodular beds. Petroliferous. Exposed by digging. Basal contact covered. (0.5 foot above base)	0.5
FAYETTEVILLE SHALE - partial thickness		38.0
8	Covered interval.	10.5
7	Mudstone and shale. Three shale intervals are each capped by a 0.5 foot carbonate mudstone. Unit can be followed upstream and is exposed in a stair-step fashion. Blue gray. Weathers light gray brown. Fine grained. Medium bedded. Petroliferous. Basal contact covered. (3.0 feet above base)	3.2
6	Covered interval.	3.0

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
5	Interbedded mudstone and shale. Dark blue gray. Weathers light gray with traces of ironstain. Found in the tributary of Little Vian Creek. (no sample)	10.5
	Offset 150 feet north on top of unit 4 along east side of the creek.	
4	Mudstone. Dark blue gray. Weathers light gray. Forms a smooth, rounded outcrop. Exposed beneath stream terrace. Top 0.5 foot of unit is recrystallized. Basal contact sharp but covered laterally. (no sample)	3.5
3	Wackestone. Medium to dark gray. Weathers medium gray brown. Fine grained. Contains well preserved brachiopods. Forms a resistant unit. Basal contact undulating. (no sample)	2.0
2	Mudstone and shale. Shale is black. Weathers light gray. Thin bedded. Fissile. Mudstone is blue gray. The two lithologies are interbedded in intervals less than 1.0 foot thick. Medium bedded. Basal contact gradational. (no sample)	5.3
1	Mudstone. Medium to dark blue gray. Weathers light gray brown. Forms flagstones in stream bed. Basal contact covered. (no sample)	0.2

<u>Measured Section 188: South Beaver Mountain</u>

Location: C sec. 25, T. 14 N., R. 23 E., Cherokee County, Oklahoma.

Drive north from the railroad tracks in Marble City on a paved county road 3.5 miles to a small school located next to a fork in the road. Take the west (left) branch of the ford and proceed north an additional 2.7 miles to the sign marked "Beaver Tower Trail". Turn east (right) onto the trail and drive up the mountain 1.1 miles to a power line. Park and walk east to the well exposed Pitkin bluffs. The exposed bluffs curve north at the head of a large valley (see Huffman's

1958 map). Follow the bluff east about 150 yards to the painted unit numbers.

This section was measured on March 11, 1980. The Pitkin Limestone is well exposed on all flanks of Beaver Mountain (Clupper, 1978). The high topographic relief provides good exposures of older Mississippian strata. The most interesting feature of the Pitkin at this locality is the presence of siliceous concretions in unit 7. The units of this section have almost no lateral continuity, and can be seen to change facies in a distance of 100 feet.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
12	Sandstone. Light gray to pink. Weathers rust brown. Medium to coarse grained. Poorly sorted. Sub-angular quartz grains. Friable. Crossbedded. Thin to medium bedded. Weathers along crossbeds. Calcareous. Basal contact undulating. (0.5 foot above base)	5.0
PITKIN LIMESTONE - partial thickness		23.7
11	Grainstone. Medium gray. Weathers medium gray. Fine to medium grained. Well sorted. Oolitic. Cross-laminated. Thick bedded. Forms a smooth, rounded outcrop. Grades upward to a coarse skeletal grainstone. Slightly exfoliated. Basal contact covered. (0.5 foot above base)	1.5
10	Covered interval.	1.3
9	Grainstone. Medium to dark gray. Weathers medium gray brown. Find to medium grained. Well sorted. Composed of skeletal grains and ooliths. Thick bedded. Intermittently exposed. Smooth weathering. Basal contact covered. (3.0 feet above base)	3.2

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
8	Covered interval.	2.0
7	Grainstone. Medium to dark gray. Weathers light gray. Fine to medium grained. Poorly sorted. Oolitic with skeletal debris. Thick bedded. Facies are variable within unit and thickness is variable laterally. Forms a jointed, angular weathering outcrop. Thin mudstone seen at base. Siliceous concretions. Basal contact undulating. (3.0 feet above base)	4.0
6	Grainstone. Medium gray. Weathers light gray. Medium to coarse grained. Poorly sorted. Friable to firm. Thick bedded. Pinches out laterally. Forms a rough weathering, rounded outcrop. Exfoliated. Basal contact slightly undulating. (0.7 foot above base)	1.7
5	Grainstone. Medium gray. Weathers light gray brown. Fine grained. Becomes poorly sorted upward. Low angle cross-laminations. Thin to medium bedded. Smooth weathering, rounded outcrop. Basal contact covered. (1.0 foot above base)	2.2
4	Covered interval.	5.5
3	Packstone. Medium gray brown. Weathers light brown. Coarse grained. Poorly sorted. Composed of crinoid and bryozoan skeletal debris. Medium bedded. Covered laterally. Jointed. Rough weathering. Petroliferous. Basal contact undulating. (0.5 foot above base)	0.5
2	Mudstone. Blue gray. Weathers light gray brown. Thick bedded. Forms a resistant unit at the base of the bluff. Rough weathering. Thin, nodular bedding. Grades upward into a resistant wackestone. Minor shale partings. Petroliferous. Recrystallized fossils. Basal contact covered. (0.2 foot above base)	1.8

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
FAYETTEVILLE SHALE		22.0
1	Covered interval with shale and interbedded mudstone. The shale is black and fissile. The mudstone is dark blue gray weathering to light gray. Forms a pronounced break in slope. Basal contact with the Hindsville Formation is sharp. (no sample)	22.0

Measured Section 189: Ford's Corner

Location: NW¼ NE¼ sec. 16, T. 14 N., R. 23 E., Cherokee County, Oklahoma.

From Cookson, drive south 0.3 mile on Route 82 then turn east (left) onto a paved county road. Proceed 3.6 miles to an intersection with a gravel road to the north (left). Park and obtain permission to enter the land from Mr. Ford, who lies in a house on the northwest corner of the intersection. The section starts 50 yards east of the house on the east side of the driveway.

This section was measured on March 13, 1980. The lower 14.5 feet of the Pitkin is composed of mudstone and wackestone. The Boone, Moorefield, and Hindsville are well exposed in the stream bed at this locality.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
8	Conglomerate. Light gray. Weathers light gray. Coarse grained. Poorly sorted. Medium bedded. Forms rounded outcrop. Slumped. Basal contact undulating. (0.2 foot above base)	0.5

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
PITKIN LIMESTONE		22.1
7	Packstone. Light gray. Weathers gray brown. Medium grained. Well sorted. Oolitic. Thick bedded. Poorly exposed. Forms a smooth outcrop. Basal contact sharp. (0.5 foot above base)	2.5
6	Grainstone. Medium gray. Weathers light gray brown. Coarse grained. Poorly sorted. Skeletal debris. Medium bedded. Forms rounded outcrop. Rough weathering. Jointed. Basal contact undulating. (2.0 feet above base)	2.2
5	Limestone and shale. Medium to dark brown. Medium grained. Poorly sorted. Oolitic. Thin to medium nodular bedding. Forms a partially covered recessive interval. Basal contact undulating. (0.2 foot above base)	0.5
4	Grainstone. Medium gray brown. Weathers light gray. Medium to coarse grained. Moderately sorted. Mixed coated skeletal grains and ooliths. Medium to thick bedded. Poorly exposed. Weathers rounded. Basal contact undulating. (1.0 foot above base)	2.0
3	Mudstone. Dark blue gray. Weathers light gray. Thin bedded. Poorly exposed. Forms a break in slope. Petroliferous. Basal contact undulating. (B-5.0 feet above base) (A-sampled at base)	11.0
Offset 60 feet southwest on top of unit 2.		
2	Mudstone. Medium to dark blue gray. Weathers light gray. Brachiopod and crinoid skeletal inclusions. Thick bedded. Forms single laterally persistent bluff. Weathers jointed and angular. Contains wackestone lenses. Petroliferous. Basal contact covered. (0.5 foot above base)	3.5
FAYETTEVILLE SHALE		25.0

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
1	Mudstone, shale, and covered. Mudstone and shale are exposed intermittently throughout the interval. (no sample)	25.0

Measured Section 190: Boy's Ranch

Location: SE¼ SE¼ sec. 9, T. 13 N., R. 21 E., Cherokee County, Oklahoma.

From the intersection of Route 10 and Route 100 in Gore, drive east 6.1 miles on Route 100 then turn northwest onto Route 10-A. Continue driving 1.3 miles to a sharp curve and park. Locate an east-west fence line, just south of the sharp north curve in the road, which marks the northern border of the Methodist Boy's Ranch. Cross the fence to the south side and walk south about 30 feet along the west-facing Pitkin bluff to the painted unit numbers.

This section was measured on March 15, 1980. It was well exposed and has a thick basal Nodular Limestone and Shale Facies. The upper units of this section are composed mostly of mixed skeletal and oolitic lithologies.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
9	Calcareous sandstone. Light gray to pink. Weathers rust brown to medium brown. Coarse grained. Poorly sorted. Composed of abraded carbonate grains. Crossbedded. Medium bedded. Forms a reentrant on top of the Pitkin. Friable. Basal contact covered. (1.0 foot above base)	1.0

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
PITKIN LIMESTONE		17.5
8	Grainstone. Buff. Weathers light gray. Fine to medium grained. Poorly sorted. Oolitic with crinoid skeletal fragments. Medium bedded. Poorly exposed. Smooth weathering. Basal contact undulating. (1.5 feet above base)	3.5
7	Grainstone. Medium gray. Weathers medium gray. Medium to very coarse grained. Poorly sorted. Oolitic with skeletal fragments. Graded bedding. Thick bedded to massive. Forms a laterally persistent bluff. Rough weathering. Partially exfoliated. Basal contact undulating. (sampled at base)	4.0
6	Grainstone. Medium gray. Weathers light gray brown. Very fine grained. Well sorted. Medium bedded. Covered laterally. Smooth weathering. Basal contact covered. (0.2 foot above base)	0.7
5	Limestone and shale. Dark gray. Weathers light gray. Thin bedded. Intermittently exposed. Forms a break in slope. Angular weathering. Basal contact covered. (0.5 foot above base)	1.0
Offset 200 feet north along the bluff face on the top of unit 4.		
4	Grainstone. Dark gray. Weathers medium gray brown. Coarse grained. Poorly sorted. Skeletal. Medium bedded. Poorly exposed but persistent laterally. Friable. Basal contact sharp. (0.4 foot above base)	0.4
3	Grainstone. Medium to dark gray. Weathers light to medium gray. Medium grained. Poorly sorted. Oolitic with minor coated skeletal grains. Forms single massive unit. Laterally persistent. Weathers to a smooth, rounded outcrop. Petroliferous. Basal contact undulating. (3.0 feet above base)	3.4

Offset 50 feet north on the top of unit 2.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
2	Grainstone. Dark gray brown. Weathers medium gray. Coarse grained. Poorly sorted. Graded bedding. Forms a single thick bed. Weathers to a smooth, friable outcrop. Basal contact undulating. (1.5 feet above base)	1.5
1	Limestone and shale. Dark blue gray. Weathers light gray. Predominantly mudstone. Contains abundant brachiopods. Medium bedded. Shale weathered out forming a stair-step pattern. Partially covered. Petroliferous. Basal contact gradational with the Fayetteville Shale. (1.0 foot above base)	3.0
FAYETTEVILLE SHALE		
	Covered interval. Mudstone float in the area confirms the presence of the formation below the Pitkin.	

Measured Section 191: South Cedar Creek

Location: E½ NW¼ sec. 36, T. 13 N., R. 20 E., Muskogee County, Oklahoma.

From the intersection of Route 10 and Route 100 in Gore, drive north 3.0 miles on Route 10 then turn west (left) onto a gravel road. Continue driving west 0.3 mile to a north-south fence line. Permission to enter the land must first be obtained from the landowner who lives in a house on the north side of the gravel road, 0.5 mile west of the fence line. Return to the fence line and proceed on foot 200 feet south up a steep hill along the west side of the fence to a poorly exposed Pitkin bluff. Follow the bluff west 100 feet to the painted unit numbers.

This section was measured on March 17, 1980. It is the southernmost section in the western portion of the study area. It is poorly exposed even in the early spring when the vegetation is least pronounced. The Pitkin is composed of skeletal and oolitic lithologies.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
8	Covered interval. Calcarenite talus confirms presence of the formation. (float sample)	1.0
PITKIN LIMESTONE - partial thickness		37.1
7	Covered and grainstone. Talus slope has packstone and oolitic grainstone which are believed to be Pitkin lithologies. Poor exposure of the unit prevents the precise placement of the Pitkin-Sausbee contact. (15.0 feet above base, float sample)	16.00
6	Grainstone. Medium to dark gray. Weathers light gray to gray brown. Medium grained. Very well sorted. Oolitic. Sparsely fossiliferous. Poorly exposed. Smooth weathering. Basal contact sharp. (2.0 feet above base)	4.9
5	Grainstone. Light gray to buff. Weathers light gray. Fine to medium grained. Poorly sorted. Mixed skeletal and oolitic. Minor crossbedding. Medium bedded. Smooth weathering. Basal contact undulating. (1.0 foot above base)	2.5
4	Grainstone. Medium gray. Weathers light gray. Predominantly coarse grained with fine grained lenses. Poorly sorted. Skeletal debris are mostly bryozoans and crinoids. Medium bedded. Forms a well exposed bluff. Basal contact sharp. (1.0 foot above base)	5.5
Offset 30 feet west along the bluff face on the top of unit 3.		
3	Grainstone. Medium gray brown. Weathers light gray. Very fine grained. Well sorted. Medium bedded. Angular weathering. Poorly exposed. Basal contact sharp. (sampled at base)	3.2

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
2	Grainstone. Medium gray brown. Weathers medium gray. Medium grained. Well sorted. Oolitic with minor skeletal fragments. Crossbedded. Thick bedded. Covered and slumped laterally. Basal contact covered. (1.0 foot above base)	3.0
1	Covered and blocky mudstone. (float sample)	2.0

Measured Section 192: Radio Tower

Location: NW¼ NW¼ sec. 20, T. 13 N., R. 20 E., Cherokee County, Oklahoma.

From the intersection of Route 100 and Route 10 in Gore, drive 6.1 miles east on Route 100, then take Route 10-A north 4.8 miles to a gravel road. Turn south (left) and proceed 1.2 miles to a cleared trail on the left (east), just before reaching the radio tower road. Park and walk east down the trail. It is bounded by fences on both sides. A locked gate will be encountered about 0.5 mile down the trail. Continue past the gate 150 yards east to the foot of the slope marked by an open pasture. Turn north (left) and walk along the west edge of the pasture 0.5 mile, then turn west (left) and proceed about 50 yards up the wooded slope until Pitkin bluffs are encountered. Follow the bluffs south 100 feet to the painted unit numbers.

This section was measured on March 19, 1980. Although the mudstone talus of the Fayetteville is present, the Nodular Limestone and Shale Facies is not exposed at the base of the Pitkin at this locality. Unit 10 is covered with blocky mudstone talus possibly indicating the presence of a substantial shale interval in the Pitkin.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
14	Grainstone. Light gray. Weathers medium gray. Very coarse grained. Poorly sorted. Slightly sandy. Crossbedded. Medium bedded. Poorly exposed. Weathers along crossbeds. Basal contact undulating. (1.0 foot above base)	2.2
PITKIN LIMESTONE - partial thickness		41.1
13	Mudstone and covered. Dark blue gray. Weathers light gray. Thin to medium bedded. Forms a talus slope. Basal contact covered. (float sample)	2.0
12	Wackestone. Light gray. Weathers light gray brown. Medium to coarse grained. Poorly sorted. Medium bedded. Poorly exposed. Rough weathering. Basal contact sharp. (0.4 foot above base)	0.6
11	Grainstone. Light gray. Weathers medium gray. Fine grained. Poorly sorted. Composed of skeletal and oolitic grains. Thick bedded. Well exposed forming a prominant bluff. Smooth weathering. Basal contact covered. (1.0 foot above base)	3.7
10	Covered interval. Block mudstone talus. (float sample)	12.5
Offset 100 feet south on top of unit 9.		
9	Grainstone. Light gray. Weathers medium gray to yellow. Medium grained with coarse grained lenses. Well sorted. Oolitic with minor skeletal fragments. Cross-laminations. Medium bedded. Basal contact undulating. (1.0 foot above base)	3.5
8	Grainstone. Light to medium gray. Weathers medium gray. Medium to coarse grained. Poorly sorted. Friable. Composed of ooliths and skeletal fragments. Thin to medium bedded. Slumped laterally. Forms a small bluff. Basal contact gradational. (2.0 feet above base)	4.0

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
7	Grainstone. Light gray brown. Weathers light brown. Very fine grained. Well sorted. Sparsely fossiliferous. Thin to medium bedded. Forms a reentrant. Poorly exposed laterally. Basal contact welded. (1.0 foot above base)	1.5
6	Grainstone. Light gray brown. Weathers medium gray. Medium to coarse grained. Poorly sorted. Oolitic with bryozoan and crinoidal skeletal debris. Thick bedded. Covered laterally. Smooth weathering. Basal contact covered. (1.0 foot above base)	1.2
5	Covered interval.	1.2
4	Wackestone and packstone. Medium blue gray. Weathers light gray brown. Coarse grained. Poorly sorted. Predominantly crinoid debris. Medium to thick bedded. Laterally persistent. Smooth weathering. Wackestone at base grades upward into packstone. Basal contact gradational, undulating laterally. (samples at base)	2.2
3	Grainstone. Light to medium gray. Weathers light gray to buff. Fine to coarse grained. Moderately well sorted. Fines upward. Oolitic with coated skeletal grains. Thin bedded. Persistent laterally. Jointed. Basal contact gradational. (0.4 foot above base)	1.2
2	Grainstone. Medium gray. Weathers light gray. Coarse to very coarse grained. Poorly sorted. Crinoids, bryozoans, brachiopods, and gastropods with minor ooliths. Cross-laminated. Thick bedded. Forms a single massive unit. Weathers rounded and rough. Basal contact covered. (1.5 feet above base)	6.5
FAYETTEVILLE SHALE		
1	Covered interval. Forms gentle talus slope. No shale exposed. Measurement not possible.	

Measured Section 193: Greenleaf Lake

Location: SW¼ NW¼ sec. 31, T. 14 N., R. 21 E., Cherokee County, Oklahoma.

Before attempting to reach this section, it is recommended that the Braggs Quadrangle 7.5 minute series topographic map be consulted.

From the intersection of Route 100 and Route 10 in Gore, drive 13.8 miles north on Route 10 to the entrance of the Gruber Public Hunting area. Proceed east 3.4 miles on the main gravel road, then turn south (right) and continue 0.9 mile. Turn east (left) at a fork in the road marked by a large white rock, and drive east an additional 1.7 miles to the gate that marks the entrance to the Gruber State Game Management Area. A four-wheel drive vehicle is recommended from this point. From the gate, proceed south 1.0 mile on a well marked trail. Take the east (left) fork in the trail and continue south 0.2 mile to a side road that goes east to the game reserve fence located about 0.2 mile from the main trail. Walk south about 0.25 mile along the fence on the east side. Greenleaf Lake should be clearly visible to the west. At the break in slope, veer off to the fence line in a southeast direction and walk about 100 yards to the Pitkin cliffs. Painted unit numbers should be easily observable on the cliff face. Offset about 150 feet northeast to the beginning of the section.

This section was measured on March 26, 1980. It is the thickest and best exposed section in the entire study area. It has the distinction of possessing small mud mounds in unit 5. The well exposed cliffs are excellent for studying the various sedimentary structures found in the Pitkin. The Nodular Limestone and Shale Facies at the base is the thickest measured in the study area.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
10	Conglomeratic grainstone. Medium gray. Weathers rust brown. Very coarse grained. Poorly sorted. Friable. Slightly sandy. Composed of reworked skeletal grains. Medium bedded. Partially covered. Basal contact covered. (1.0 foot above base)	1.0
PITKIN LIMESTONE		61.9
9	Covered interval. Abundant oolitic talus indicated Pitkin Limestone. The top of this unit forms a distinct bench which may be the top of the Pitkin. Sample collected from single, in place bed. (5.5 feet above base)	13.5
Offset 150 feet northwest on top of unit 8.		
8	Grainstone. Medium to dark gray. Weathers dark gray. Very coarse grained. Poorly sorted. Dominant faunal elements are crinoids with minor bryozoans. Crossbedded. Massive cliff forming unit. Laterally persistent. Rough weathering. Basal contact sharp to gradational. (7.5 feet above base)	9.0
7	Grainstone. Light to medium gray. Weathers medium gray. Medium grained. Well sorted. Oolitic with coated skeletal grains at the base. Crossbedded. Thick bedded. Basal contact gradational to undulating. (4.5 feet above base)	6.0
6	Grainstone. Medium to dark gray brown. Weathers medium gray brown. Very coarse grained. Poorly sorted. Skeletal at base. Grades upward into an oolitic grainstone. Crossbedded. Thick bedded. Weathers rounded with grains standing out. Basal contact undulating. (4.0 feet above base)	6.7

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
5	Wackestone to grainstone. Medium to gray brown. Weathers light gray brown. Very coarse grained. Poorly sorted. Contains well preserved faunal elements. Thin to medium nodular bedding. Unit forms a reentrant. Covered laterally. Rough weathering. Contains numerous springs and three small mud mounds 200 feet northeast of measured interval (see Chapter Three for a full treatment and description). Basal contact sharp. (1.5 feet above base)	3.5
4	Packstone. Medium gray to gray brown. Weathers medium gray. Fine grained. Poorly sorted. Oolitic with coarse skeletal inclusions. Cross-bedded. Thick bedded. Laterally persistent. Weathers rough and rounded. Basal contact undulating. (2.0 feet above base)	6.5
Offset southwest, toward Greenleaf Lake, 150 feet on top of unit 3.		
3	Grainstone. Medium gray. Weathers medium gray. Very coarse grained. Poorly sorted. Composed of crinoid debris. Thin, nodular bedding. Forms a reentrant. Covered laterally. Interbedded with thin shale laminae. Basal contact undulating. (0.5 foot above base)	1.7
2	Grainstone. Dark gray. Weathers medium gray brown. Ironstained. Medium grained. Well sorted. Composed of ooliths and coated skeletal grains. Crossbedded. Thick bedded. Forms a resistant ledge. Smooth weathering. Basal contact undulating. (1.0 foot above base)	2.5
1	Limestone and shale. Dark blue gray to gray brown. Weathers light gray. Coarse grained. Well sorted. Contains recrystallized productid and spiriferid brachiopods, crinoids, and Archimedes bryozoa. Thin to medium nodular bedding. Covered laterally, but well exposed where measured. Forms a steep slope. Basal contact covered. (5.0 feet above base)	12.5

UNIT NO.	LITHOLOGY	THICKNESS (FEET)

FAYETTEVILLE SHALE

Covered interval. Can be observed laterally from the cliff to the lake. Mudstone confirms presence of formation beneath the Pitkin cliffs. No measurement attempted.

Measured Section 194: Stratton Hollow

Location: C NE¼ sec. 30, T. 14 N., R. 23 E., Cherokee County, Oklahoma.

From Cookson, drive south 2.1 miles on Route 82 to the entrance of the Sixshooter Camping Area. Permission to enter the land must be obtained from either Mr. or Mrs. Howard Stratton, who live in the first house on the left as one drives 1.4 miles west into the camping area. Drive east 1.8 miles on the gravel road opposite the Sixshooter entrance to a gate numbered 14. Park and follow the Hindsville-Fayetteville contact in a northeasterly direction for about 0.25 mile. Large cliffs of Sausbee will appear on the left as you walk up the valley. Look for a painted number "1" on the upper surface on the Hindsville which marks the first unit in the measured section.

This section was measured on March 31, 1980. Only the Nodular Limestone and Shale Facies is present in this exposure of Pitkin. Other units have been removed by pre-Pennsylvanian erosion.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)

SAUSBEE FORMATION

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
6	Conglomerate. Medium to gray brown. Weathers rust brown. Fine to coarse grained. Poorly sorted. Mixed quartz and carbonate grains. Pebble inclusions. Thick bedded. Basal contact undulating. (0.2 foot above base)	1.5
PITKIN LIMESTONE		3.3
5	Wackestone. Dark blue gray. Weathers light to medium gray. Sparse, poorly sorted, skeletal debris. Large crinoid stems. Grainstone lenses. Thin to medium bedded. Covered laterally. Rough weathering. Basal contact gradational. (0.5 foot above base)	1.5
4	Packstone. Dark blue gray. Weathers light gray. Medium grained. Poorly sorted. Contains skeletal grains and ooliths. Thin to medium bedded. Well exposed. Forms a resistant ledge. Rough weathering. Basal contact undulating. (0.2 foot above base)	1.0
3	Limestone and shale. Dark blue gray. Weathers light gray. Fine grained with coarse skeletal inclusions. Contains crinoids and <u>Archimedes</u> bryozoa. Thin, nodular to wavy bedding. Shale partings are 1 to 3 centimeters thick. Basal contact covered. (0.2 foot above base)	0.8
FAYETTEVILLE SHALE		17.7
2	Covered interval. Forms a gentle talus slope. Thickness is consistent laterally. (float sample)	17.7
HINDSVILLE FORMATION - partial thickness		3.3
1	Grainstone. Medium gray. Weathers light gray. Fine to medium grained. Well sorted. Contains ooliths and coated skeletal grains. Minor graded bedding. Predominantly thick bedded. Well exposed locally. Weathers smooth and rounded. Basal contact covered. (1.0 foot above base)	3.3

Measured Section 195: Buckhorn Mountain

Location: E½ NE¼ sec. 27, T. 14 N., R. 22 E., Cherokee County, Oklahoma.

From Cookson, drive south 3.5 miles on Route 82 to the scenic view parking area on the west flank of Buckhorn Mountain. Park and walk down the slope until Sausbee bluffs are encountered. The Pitkin-Sausbee contact may be recognized by a distinct break in slope. Turn north and follow the contact about 200 feet to the painted unit numbers. This section will most likely be obscured by vegetation during the late spring and summer months.

This section was measured on April 1, 1980. The Pitkin is intermittently exposed in this area and laterally it is completely removed by pre-Pennsylvanian erosion. The basal Sausbee is variable at this locality and is interesting to observe following the exposure south from the measured section.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
4	Conglomerate. Dark gray brown. Weathers rust brown. Medium grained with coarse pebble inclusions. Poorly sorted. Crossbedded. Thin bedded. Basal contact undulating with 0.5 foot of relief on the unconformity. (sampled at base)	2.5
PITKIN LIMESTONE		1.5
3	Limestone and shale. Dark blue gray. Weathers light gray. Contains recrystallized brachiopod fragments. Thin, wavy bedding. Covered laterally. Variable thickness. Basal contact covered. (sampled at base)	1.5

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
FAYETTEVILLE SHALE		38.0
2	Covered interval. Forms a gentle talus slope and supports abundant vegetation. (float sample)	38.0
HINDSVILLE FORMATION		
1	Grainstone. Dark gray brown. Weathers light gray. Very fine grained. Well sorted. Composed of coated skeletal grains. Minor cross-laminations. Medium to thick bedded. Poorly exposed. Weathers smooth and rounded. Basal contact covered. (1.0 foot above base)	1.0

Measured Section 196-A: Seller's Mountain

Location: $W\frac{1}{2}$ $SW\frac{1}{4}$ sec. 5, T. 14 N., R. 22 E., Cherokee County, Oklahoma.

From the intersection of Route 82 and Route 62 west of Tahlequah, drive south 4.9 miles on Route 82 to a paved county road across from the Gateway Grocery. Turn southwest (right) and proceed 6.5 miles to a well exposed Fayetteville road cut. Park and walk northeast down a stream valley northeast of the road cut about .25 mile to a point where the Hindsville Formation forms a flat bottom in the stream bed. The section begins here and continues upstream to the top of the road cut.

This section was measured on April 2, 1980. The Fayetteville Shale is thick and well exposed at this locality.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
FAYETTEVILLE FORMATION - estimated thickness		69.0

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
12	Mudstone and shale. Dark blue gray. Weathers rust brown. Medium bedded. Thin bedded shale partings. Well exposed at road cut. Basal contact gradational. (no sample)	4.0
11	Limestone and shale. Medium gray brown. Weathers rust brown. Medium bedded. Very fine grained. Well sorted. Covered laterally. Basal contact sharp. (no sample)	3.5
10	Mudstone and shale. Black fissile shale. Medium gray brown. Weathers light gray. Fine grained. Well sorted. Basal contact sharp. (no sample)	5.4
9	Mudstone and shale. Dark blue gray. Weathers rust brown. Lenses of mudstone in shale are variable in thickness laterally. Basal contact sharp. (no sample)	3.5
Offset south along road cut face 100 feet on top of unit 8.		
8	Shale. Black. Weathers blue gray. Firm. Fissile. Slightly calcareous. Basal contact covered. (no sample)	9.8
7	Covered interval.	4.0
6	Wackestone, packstone, and shale. Dark blue gray. Weathers light blue gray. Medium to coarse grained. Poorly sorted. Composed of skeletal grains. Contains well preserved spiriferid brachiopods. Thick bedded. Basal contact covered. (10.0 feet above base)	10.5
5	Covered interval.	17.3
4	Limestone. Medium gray. Weathers light gray brown. Fine grained. Well sorted. Minor coarse skeletal inclusions. Medium to thick bedded. Poorly exposed. Basal contact sharp. (no sample)	2.5

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
3	Limestone and shale. Shale is dark gray and fissile. Limestone is medium gray. Weathers medium gray. Fine grained. Well sorted. Thin bedded. Basal contact covered. (no sample)	2.5
2	Covered interval.	6.0
HINDSVILLE FORMATION - partial thickness		3.0
1	Packstone. Medium to dark gray. Weathers light gray brown. Medium to coarse grained. Poorly sorted. Predominantly composed of crinoid and brachiopod debris. Thin to medium bedded. Exposed only in stream bed. Smooth weathering. Basal contact covered.	

Measured Section 196-B: Seller's Mountain

Location: E½ SE¼ sec. 6, T. 14 n., R. 22 E., Cherokee County, Oklahoma.

From the intersection of Route 82 and Route 62 west of Tahlequah, drive south 4.9 miles on Route 82 to a paved county road across from the Gateway Grocery. Turn southwest (right) and proceed 6.5 miles to a well exposed Fayetteville road cut. Park and walk about 400 feet west from the road cut across a valley and a ranch road to the prominant Pitkin bluff. Follow the bluff southeast for a distance of 50 feet to the painted unit numbers.

This section was measured on April 2, 1980. The units of the Pitkin exhibit little lateral continuity. An interesting conglomerate talus is present at the base of the Sausbee.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
21	Covered interval. Forms a distinct bench on the top of the Pitkin. Conglomerate talus is scattered laterally along the bench. (float sample)	2.0
PITKIN LIMESTONE		
20	Grainstone. Medium gray. Weathers light gray to gray brown. Well sorted. Oolitic with crinoid skeletal debris. Minor crossbedding. Poorly exposed. Forms a reentrant above the bluff. Smooth weathering. Basal contact sharp. (1.2 feet above base)	2.5
19	Grainstone. Light gray. Weathers medium gray. Medium to coarse grained. Poorly sorted. Contains coated skeletal grains. Medium bedded. Smooth weathering with fossils standing out. Partially covered. Exposed by digging. Basal contact undulating. (0.5 foot above base)	1.9
Offset 10 feet northwest along bluff face on the top of unit 18.		
18	Grainstone. Medium gray to gray brown. Weathers medium to dark gray. Medium grained. Poorly sorted. Oolitic with coated skeletal grains. Contains preserved brachiopods, bryozoans, and crinoids. Minor crossbedding. Thick bedded. Thin bedded reentrant at base. Rough weathering. Basal contact gradational. (2.0 feet above base)	2.0
17	Wackestone to grainstone. Light gray brown. Weathers light gray. Very fine grained with coarse skeletal inclusions. Poorly sorted. Minor cross-laminations. Forms a resistant cliff. Rough weathering. Becomes oolitic upward. Basal contact undulating. (2.0 feet above base)	2.5
16	Packstone. Medium to dark gray. Weathers light gray brown. Coarse grained. Poorly sorted. Thin bedded. Forms a reentrant. Basal contact undulating. (no sample)	0.5

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
15	Grainstone. Medium gray brown. Weathers light gray. Medium to coarse grained. Poorly sorted. Composed of coated skeletal debris. Contains well preserved brachiopods. Medium to thick bedded. Forms a thin resistant ledge. Rough weathering. Basal contact undulating. (sampled at base)	1.2
14	Limestone and shale. Dark blue gray. Weathers light gray. Contains brachiopods, bryozoans, and crinoids. Packstone lenses throughout. Thin to wavy nodular bedding. Covered laterally. Smooth weathering. Basal contact covered. (4.0 feet above base)	4.2
FAYETTEVILLE SHALE - partial thickness		22.0
13	Covered interval. Blocky mudstone talus indicated presence of formation. (no sample)	22.0

<u>Measured Section 197: Pine Hollow</u>

Location: NW¼ NE¼ sec. 17, T. 14 N., R. 22 E., Cherokee County, Oklahoma.

From the intersection of Route 82 and Route 62 west of Tahlequah, drive south 4.9 miles on Route 82 to a paved county road across from the Gateway Grocery. Turn southwest (right) and continue 9.1 miles to a paved road across from the Seller's Mission sign. Drive east 1.3 miles, then turn north (left) onto a gravel road and proceed 0.2 mile. Turn north (left) and drive northeast a final 1.6 miles to a well exposed Fayetteville road cut. The section begins across the road (east) from the exposed Fayetteville in a stream bed on the top of the Boone Group.

This section was measured on April 3, 1980. The Pitkin facies at this locality are laterally variable. Oolitic lithologies are not present in this section, but may be seen in the same stratigraphic interval less than a mile away. The Nodular Limestone and Shale Facies of the basal Pitkin is not present in this section. The Fayetteville is directly overlain by a dense, thick bedded wackestone.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
13	Grainstone. Medium gray. Weathers dark gray brown. Coarse grained. Poorly sorted. Conglomeratic. Crossbedded. Thick bedded. Well exposed. Rough weathering. Basal contact covered. (1.5 feet above base)	3.0
PITKIN LIMESTONE		6.8
12	Covered interval. Blocky mudstone talus. (float sample)	1.8
11	Packstone. Dark blue gray. Weathers medium blue gray. Coarse grained. Poorly sorted. Abundant recrystallized brachiopods. Thin bedded. Poorly exposed. Covered laterally. Basal contact undulating. (sampled at base)	0.5
Offset east 75 feet on top of unit 10.		
10	Grainstone. Medium gray. Weathers gray brown. Coarse grained. Well sorted. Contains crinoid skeletal debris. Minor cross-laminations. Well exposed laterally. Weathers smooth and rounded. Basal contact undulating. (1.0 foot above base)	1.4
9	Wackestone and shale. Dark blue gray. Weathers light brown to buff. Coarse grained. Poorly sorted. Contains coated skeletal grains. Thin bedded. Unit forms a reentrant with shale weathered out. Basal contact sharp. (0.4 foot above base)	0.7

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
8	Wackestone. Medium gray. Weathers medium gray. Medium to coarse grained. Poorly sorted. Bryozoan and brachiopod coated skeletal inclusions. Thick bedded. Covered laterally. Packstone lenses at base. Basal contact gradational. (1.2 feet above base)	2.4
FAYETTEVILLE SHALE		10.5
7	Shale and limestone. Limestone is medium gray weathering rust brown. Very fine grained. Well sorted. Thin bedded. Shale is black and fissile. Basal contact covered. (0.5 foot above base)	0.5
6	Covered interval.	2.3
5	Wackestone. Dark blue gray. Weathers medium blue gray. Coarse skeletal inclusions. Poorly sorted. Abundant brachiopods. Thick bedded. Laterally persistent. Smooth weathering with fossils standing out. Basal contact sharp. (1.0 foot above base)	1.7
4	Shale and mudstone. The shale is black, fissile, and weathers medium gray. The mudstone is dark blue gray weathering rust brown. Basal contact covered. (2.2 feet above base)	5.0
3	Covered interval.	1.0
HINDSVILLE FORMATION		4.0
2	Grainstone. Light gray brown. Weathers medium gray brown. Ironstained. Medium grained. Well sorted. Composed of skeletal debris. Thin bedded. Poorly exposed laterally. Basal contact welded and undulating. (3.5 feet above base)	4.0
BOONE GROUP		
1	Chert and limestone. Medium gray. Weathers dark gray. Chert is black to buff. Forms a resistant unit in stream bed. Thickness not measured.	

Measured Section 198: Upper Dogwood Creek

Location: SW¼ SE¼ sec. 23, T. 4 N., R. 21 E., Cherokee County, Oklahoma.

The directions to this section are complex; therefore, it is recommended that the Qualls Quadrangle 7.5 minute topographic map be consulted before attempting to locate this section.

From the intersection of Route 82 and Route 62 west of Tahlequah, drive west 7.7 miles on Route 62 to the Zeb entrance of the Gruber State Game Management Area. Permission to enter the game reserve must first be obtained from Monte M. Dodson, the area manager (918-457-4575). From the Zeb entrance, drive south 3.4 miles to the reserve headquarters. A key must be obtained from John Martin, the reserve caretaker. Continue driving south 5.6 miles and take the west (right) fork in the road. Proceed south 1.0 mile to a locked gate. Enter the reserve and drive south an additional 2.7 miles to a side road on the left. Turn east (left), take the north (left) branch of this road, and drive 0.5 mile. Park in an open field on the south side of the road and walk 200 yards in a southeasterly direction to the Pitkin bluffs. This section begins at the bottom of a grassy slope in a stream bed.

This section was measured on April 4, 1980. The Fayetteville interval is thick at this locality and the Pitkin appears to be anomalously thin. The lower portion of the Pitkin is probably covered, but the facies that are exposed are consistent laterally. The Pitkin-Sausbee contact is predominantly covered.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
7	Covered interval. Forms a distinct bench covered with sandstone. No reliable in place exposure.	
PITKIN LIMESTONE - partial thickness		8.0
6	Packstone. Medium blue gray. Weathers medium gray. Fine to coarse grained. Poorly sorted. Contains skeletal debris with minor ooliths. Abundant brachiopods. Thick bedded. Moss covered. Basal contact welded. (1.0 foot above base)	1.3
5	Grainstone. Medium to gray brown. Weathers light gray. Coarse grained. Poorly sorted. Composed of coated skeletal debris, crinoid rubble, and minor ooliths. Crossbedded. Medium bedded. Poorly exposed. Rough weathering. Basal contact covered. (4.0 feet above base)	4.4
4	Covered interval.	1.5
3	Grainstone. Light to medium gray brown. Weathers medium gray. Medium to coarse grained. Poorly sorted. Composed of coated skeletal grains. Contains crinoids, bryozoans, and brachiopods. Thick bedded. Poorly exposed. Smooth weathering. Basal contact covered. (0.8 foot above base)	0.8
FAYETTEVILLE SHALE - estimated thickness		95.0
2	Covered interval. Forms a steep, grassy slope with rare mudstone talus.	95.0
HINDSVILLE FORMATION - partial thickness		2.0
1	Limestone. Medium blue gray. Weathers light gray. Very fine grained. Well sorted. Contains spiriferid brachiopods. Thick bedded. Exposed in stream bed. Covered laterally. Smooth weathering. Basal contact covered. (2.0 feet above base)	2.0

Measured Section 199: North Gum Creek

Location: W½ SE¼ sec. 28, T. 15 N., R. 22 E., Cherokee County, Oklahoma.

From the intersection of Route 82 and Route 62 west of Tahlequah, drive south 4.9 miles on Route 82 to a paved county road across from the Gateway Grocery. Turn southwest (right) and continue 4.2 miles to a Fayetteville road cut on the east side of the road. The section begins on the top of the Hindsville at the foot of a slope near road level.

This section was measured on April 8, 1980. It has a well exposed Fayetteville interval and a thin, poorly exposed Pitkin. The basal Pitkin units are partially covered. A karst feature may be observed within the Pitkin at this section.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
8	Packstone. Medium gray. Weathers light gray to rust brown. Coarse grained. Poorly sorted. Conglomeratic. Contains reworked skeletal debris. Medium bedded. Covered laterally. Slightly sandy. Basal contact welded. (sampled at base)	0.5
PITKIN LIMESTONE - partial thickness		4.9
7	Grainstone. Medium gray. Weathers light gray. Medium to coarse grained. Poorly sorted. Composed of skeletal debris. Medium bedded. Well exposed. Slumped laterally. Rough weathering. Basal contact undulating. (1.0 foot above base)	2.5

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
6	Packstone and shale. Medium gray. Weathers light gray. Fine to coarse grained. Poorly sorted. Composed of skeletal debris. Abundant bryozoans. Thin to medium nodular bedding. Forms a re-entrant. Contains thin grainstone lenses. Basal contact undulating. (sampled at base)	1.0
5	Packstone. Dark blue gray. Weathers light gray brown. Coarse grained. Poorly sorted. Contains bryozoan and crinoid skeletal debris with minor brachiopods. Medium bedded. Poorly exposed. Basal contact covered. (1.0 foot above base)	1.4
FAYETTEVILLE SHALE		35.7
4	Covered interval.	1.5
3	Mudstone and shale. Dark blue gray. Weathers light gray. Minor fossils. Basal contact gradational. (2.0 feet above base)	20.2
2	Shale. Black. Weathers black. Ironstained. Fissile. Basal contact sharp where exposed. (no sample)	14.0
HINDSVILLE FORMATION - partial thickness		
1	Grainstone. Medium gray brown. Weathers medium brown. Coarse grained. Poorly sorted. Composed of skeletal debris. Abundant crinoids. Thick bedded. Poorly exposed. Basal contact covered. (0.2 foot above base)	0.2

Measured Section 200: South Game Reserve

Location: SE¼ SW¼ sec. 21, T. 14 N., R. 21 E., Cherokee County, Oklahoma.

The directions to this section are complex and it is recommended that the Qualls Quadrangle 7.5 minute topographic map be consulted before attempting to locate this section.

From the intersection of Route 82 and Route 26 west of Tahlequah, drive west 7.7 miles on Route 62 to the Zeb entrance of the Gruber State Game Management Area. Permission to enter the game reserve must first be obtained from Monte M. Dodson, the area manager (918-457-4575). From the Zeb entrance, drive south 3.4 miles to the reserve headquarters. A key may be obtained from John Martin, the reserve caretaker. Continue driving south 5.6 miles and take the west (right) fork in the road. Proceed south 1.0 mile to a locked gate. Enter the reserve and drive an additional 5.1 miles to an open field on the north (right) side of the road. Park and walk north along the western edge of the field to the northwest corner. Find the head of a small stream and follow it north for 0.25 mile to Sausbee and Pitkin bluffs. Painted unit numbers should be seen on the west facing bluff.

This section was measured on April 9, 1980. It is moderately well exposed even though some problems were encountered making accurate offsets. The units are laterally consistent within the Pitkin. The Pitkin-Sausbee contact is difficult to place because of the absence of abundant quartz grains and conglomeratic lithologies in the basal Sausbee.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
9	Grainstone. Medium gray brown. Weathers medium gray. Ironstained. Very coarse grained. Poorly sorted. Contains quartz and skeletal grains. Poorly exposed. Friable. Rough weathering. Relief on the unconformity is less than 0.5 foot. Basal contact undulating. (sampled at base)	1.0

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
PITKIN LIMESTONE - partial thickness		31.2
8	Grainstone. Medium gray. Weathers light gray brown. Very coarse grained. Poorly sorted. Contains skeletal debris with minor ooliths. Thick bedded to massive. Well exposed locally. Covered and slumped laterally. Weathers rough and rounded. Basal contact covered. (5.0 feet above base)	12.2
7	Covered interval	2.8
Offset southwest 50 feet to the north facing bluff on top of unit 6.		
6	Packstone and grainstone. Medium to dark gray. Weathers medium gray brown. Coarse grained. Poorly sorted. Composed of crinoid, bryozoan, and brachiopod skeletal debris with minor ooliths. Rare shale partings. Thin to medium nodular bedding. Well exposed. Petroliferous. Basal contact undulating. (2.2 feet above base)	4.5
5	Grainstone. Medium gray. Weathers light gray brown. Medium grained. Well sorted. Skeletal grains are coated. Grades upward into a pure oolite. Medium bedded to massive. Smooth weathering. Basal contact undulating. (2.5 feet above base)	8.2
4	Grainstone. Medium gray. Weathers light gray brown. Fine grained. Well sorted. Composed of skeletal debris. Medium bedded. Well exposed. Smooth weathering. Basal contact undulating. (0.5 foot above base)	0.8
3	Grainstone. Medium to dark gray. Weathers light gray brown. Very coarse grained. Poorly sorted crinoid debris. Thin bedded. Forms a reentrant. Weathers rough. Basal contact gradational. (no sample)	0.5
2	Packstone. Medium gray. Weathers light gray. Coarse to very coarse grained. Poorly sorted. Contains brachiopod, bryozoan, and crinoidal debris. Thick bedded. Well exposed. Rough weathering. Basal contact covered. (1.2 feet above base)	2.2

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
FAYETTEVILLE SHALE		
1	Covered interval. Gentle slope below Pitkin bluffs is assumed to be Fayetteville. No measurement attempted.	

Measured Section 201: Northwest Qualls

Location: W½ NE¼ sec. 35, T. 15 N., R. 21 E., Cherokee County, Oklahoma.

From the intersection of Route 82 and Route 62 west of Tahlequah, drive west 7.7 miles on Route 62 to the Zeb entrance of the Gruber State Game Management Area. No permission is necessary to get to this section because it is located on public land. Drive south 7.5 miles than turn east (left) onto a side road and proceed 0.3 mile to the bottom of a stream valley. Walk north (upstream) about 200 feet to painted unit numbers on the west (left) bank.

This section was measured on April 10, 1980. This exposure has the distinction of forming no steep bluffs. The beds are exposed in a series of stair-steps along the stream. An interesting conglomerate can be seen at the base of the Sausbee Formation.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
12	Sandstone. Medium gray. Weathers rust brown. Predominantly coarse grained. Conglomeratic. Poorly sorted. Friable to firm. Angular to subangular quartz grains. Thin to medium bedded. Basal contact undulating. (B - 1.0 foot above base) (A - sampled at base)	1.5

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
PITKIN LIMESTONE		22.8
11	Grainstone. Medium gray brown to buff. Weathers medium gray brown. Fine to medium grained. Well sorted. Contains ooliths and coated skeletal grains. Thick bedded, weathering thin bedded. Poorly exposed. Covered laterally. Basal contact covered. (3.0 feet above base)	6.5
10	Covered interval.	0.8
9	Grainstone. Medium gray. Weathers medium gray brown. Fine to coarse grained. Variable sorting. Contains skeletal debris with oolitic lenses. Crossbedded. Thin bedded. Well exposed. Rough weathering. Capped by a thin mudstone. Basal contact covered. (1.8 feet above base)	4.2
8	Covered interval.	0.5
7	Mudstone. Dark blue gray. Weathers light to medium gray. Sparsely fossiliferous. Thin packstone and wackestone lenses. Thin to medium bedded. Moderately well exposed. Basal contact covered. (2.6 feet above base)	3.6
6	Covered interval.	2.5
5	Grainstone. Light gray. Weathers medium gray brown. Fine to medium grained. Moderately well sorted. Oolitic with minor coated skeletal grains. Cross-laminated. Well exposed. Thick bedded. Weathers rough and angular. Fossils stand out from weathered surface. Basal contact undulating. (1.0 foot above base)	2.0
4	Grainstone. Medium gray. Weathers medium gray brown. Coarse grained. Poorly sorted. Predominantly composed of crinoid skeletal debris. Minor coated grains. Cross-laminated. Thin bedded. Poorly exposed. Rough weathering. Basal contact undulating. (0.5 foot above base)	1.0
3	Covered interval.	0.3
2	Mudstone. Dark blue gray. Weathers light gray. Thin to medium nodular bedding. Sparsely fossiliferous. Covered laterally. Basal contact covered. (0.4 foot above base)	1.4

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
FAYETTEVILLE SHALE - partial thickness		15.0
1	Covered interval.	15.0

Measured Section 202: Hopper Flat

Location: NW¼ NE¼ sec. 33, T. 15 N., R. 23 E., Cherokee County, Oklahoma.

From the intersection of Route 100 and Route 82 north of Cookson, drive east 4.0 miles on Route 100 then turn south (right) onto a gravel road. Proceed 2.2 miles southeast then turn south (left) and cross a bridge. Continue driving south 2.5 miles to a smaller gravel road. Turn west (right) and drive 1.5 miles to a gate. Enter and continue driving west on an abandoned ranch road 0.25 mile to the end of a field. Cross a north-south fence line on foot and proceed northwest about 150 yards obliquely down a steep north facing slope to a stream valley. Walk down the stream about 100 yards to the Pitkin exposure.

This section was measured on April 16, 1980. The Pitkin section is thicker in this area than adjacent localities in the eastern half of the field area. The section is also fairly well exposed. Relief on the Pitkin-Sausbee contact is less than 1.0 foot.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
12	Sandstone. Light brown. Weathers rust brown. Fine grained. Well sorted. Subangular to subrounded quartz grains. Well cemented. Pebble inclusions. Basal contact welded. (sampled at base)	0.5

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
PITKIN LIMESTONE - partial thickness		35.9
11	Grainstone. Light to medium gray. Weathers medium gray. Fine to medium grained. Well sorted. Fines upward. Sparsely fossiliferous. Oolitic. Packstone lenses. Thick bedded. Moderately well exposed. Smooth weathering. Basal contact covered. (3.0 feet above base)	4.0
10	Covered interval.	5.5
9	Grainstone. Light to medium gray. Weathers light gray brown. Medium grained. Well sorted. Oolitic with minor skeletal grains. Minor cross-laminations. Medium bedded. Smooth weathering. Capped by a thin mudstone. Basal contact sharp. (1.0 foot above base)	2.3
8	Grainstone. Medium gray. Weathers light gray. Fine grained with coarse skeletal inclusions. Poorly sorted. Minor crossbedding. Thick bedded. Well exposed. Smooth weathering. Basal contact undulating. (3.0 feet above base)	4.5
7	Wackestone and shale. Medium blue gray. Weathers light gray. Fine to medium grained. Poorly sorted. Fossiliferous containing abundant brachiopods. Thin, nodular bedding. Forms a reentrant with shale weathering out. Thickness variable laterally. Basal contact sharp. (0.5 foot above base)	1.0
Offset 12 feet southwest on top of unit 6.		
6	Wackestone. Dark gray brown. Weathers light to medium gray. Very coarse grained. Poorly sorted. Contains crinoids, bryozoans, brachiopods, and gastropods. Grades upward into a packstone. Medium bedded. Laterally persistent. Rough weathering. Well exposed. Basal contact covered. (1.0 foot above base)	2.0
5	Covered interval.	9.5

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
4	Grainstone. Light to medium gray. Weathers light gray brown. Coarse grained. Poorly sorted. Fossiliferous containing abundant crinoid stems. Minor cross-laminations. Medium bedded. Covered laterally. Smooth weathering. Basal contact covered. (0.5 foot above base)	1.5
3	Covered interval.	1.2
2	Mudstone. Medium to dark gray brown. Weathers medium gray. Ironstained. Sparsely fossiliferous. Abundant brachiopods. Thick bedded. Laterally persistent forming a distinct bluff. Weathers rough and angular. Petroliferous. Basal contact covered. (1.5 feet above base)	4.0
FAYETTEVILLE SHALE - partial thickness		7.7
1	Covered interval. Talus indicates possible Fayetteville-Pitkin contact.	7.7

<u>Measured Section 203: Owl Mountain</u>

Location SE¼ NE¼ sec. 35, T. 15 N., R. 23 E., Cherokee County, Oklahoma.

From the intersection of Route 100 and Route 82 north of Cookson, drive east 4.0 miles on Route 100 then turn south (right) onto a gravel road. Proceed 1.6 miles and cross Dry Creek at a ford. Continue driving south 0.4 mile to a small yellow house. Obtain permission to enter from the landowner and drive south 0.2 mile on a ranch road to an open pasture. Park and walk east from the main ranch road on a smaller side road about 100 yards to a Fayetteville Shale quarry cut into the hillside on the south (right) side of the road. Pitkin bluffs are located approximately 150 feet south (upslope) from the quarry. Boone, Moorefield, and Hindsville exposures are located in a small stream valley 100 feet north of the quarry.

This section was measured on April 17 and 18, 1980. The Pitkin interval is well exposed but slumping requires several offsets. The Basal Sausbee can be seen as a sandstone infilling rivulets on the top of the Pitkin. The Nodular Limestone and Shale Facies is well exposed where the section is measured but is covered laterally. Carbonate rocks, which may either be Moorefield or Hindsville, are intermittently exposed beneath the Fayetteville.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
14	Sandstone. Light rust brown. Weathers dark brown. Medium grained. Well sorted. Subangular to subrounded quartz grains. Friable to firm. Found on upper Pitkin surface filling in rivulets. (sampled at base)	0.1
PITKIN LIMESTONE		19.5
13	Grainstone. Medium gray brown. Weathers light brown. Medium to coarse grained. Poorly sorted. Mixed skeletal and oolitic composition. Thin bedded. Forms a resistant cap on unit 12. Basal contact welded. (0.5 foot above base)	0.8
12	Limestone. Light gray. Weathers light gray. Very fine grained. Well sorted. Sparsely fossiliferous with minor crinoids. Thick bedded. Forms a small bluff. Rough weathering. Petroliferous. Basal contact sharp. (1.5 feet above base)	2.0

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
11	Packstone and grainstone. Medium gray brown. Weathers light to medium gray. Medium to coarse grained. Skeletal inclusions. Mudstone lenses. Rare oncolites. Abundant brachiopods. Medium to thin nodular bedding. Poorly exposed. Shale weathers out. Covered laterally. Measured by offsetting north along bedding planes. Basal contact undulating. (3.0 feet above base)	4.5
10	Mudstone and wackestone. Medium to dark gray. Weathers light to medium gray. Very fine grained with coarse skeletal inclusions. Minor bryozoans, brachiopods, crinoids, and gastropods. Medium bedded. Poorly exposed. Smooth weathering. Basal contact covered. (1.0 foot above base)	1.5
9	Covered interval.	1.8
Offset 200 feet northeast on top of unit 7.		
8	Packstone and grainstone. Medium gray. Weathers medium gray. Medium to coarse grained. Poorly sorted. Skeletal grains are coated. Minor ooliths. Becomes coarser upward. Thick bedded. Slumped. Well exposed laterally. Basal contact gradational. (2.7 feet above base)	3.5
7	Mudstone. Medium gray brown. Weathers medium gray. Abundant brachiopods. Thin to medium bedded. Well exposed. Weathers rough and angular. Forms a small cliff. Basal contact gradational. (3.6 feet above base)	4.2
6	Mudstone and shale. Medium gray brown. Weathers light gray. Sparsely fossiliferous containing productid brachiopods. Thin to medium nodular bedding. Shale weathers out. Forms a reentrant beneath unit 7. Covered laterally. Basal contact covered. (0.5 foot above base)	1.2
FAYETTEVILLE SHALE		44.0

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
5	Covered interval.	34.5
4	Shale. Black. Fissile. Very thin bedded. Well exposed in a small quarry along ranch road. Basal contact sharp.	9.5
HINDSVILLE FORMATION		14.8
3	Grainstone. Medium gray brown. Weathers medium gray. Medium to coarse grained. Poorly sorted. Coarse skeletal inclusions. Crinoids, bryozoans, brachiopods, and minor gastropods. Medium bedded. Basal contact sharp. (14 feet above base)	14.8
MOOREFIELD FORMATION		7.4
2	Wackestone. Dark blue gray to black. Weathers gray brown. Fine grained with coarse crinoid skeletal inclusions. Poorly sorted. Medium bedded. Basal contact sharp. (4.0 feet above base)	7.4
BOONE GROUP		
1	Chert. White to light gray. Weathers gray brown. Capped by a fine grained chert pebble conglomerate. No measurement attempted. (1.0 foot below top)	

Measured Section 204: Carter's Ranch

Location: SE¼ NE¼ sec 15, T. 15 N., R. 22 E., Cherokee County, Oklahoma.

From the intersection of Route 82 and Route 62 west of Tahlequah, drive south 4.8 miles then turn west onto a private driveway that leads to the home of the landowner, Mr. Levi Carter. Obtain permission to enter the land and drive or walk west on the main ranch road about 1.0 mile to a north-south fence line. Follow the fence line south for approximately 75 yards then turn east and walk 25 yards upslope to a small Pitkin bluff. The section starts at the top of the Hindsville Formation just east of the fence line.

This section was measured on April 19, 1980. The section appears to be located near a fault causing the beds to dip to the east between 10° and 20°. The exposed Pitkin at this locality looks like Sausbee. It is a rough weathering grainstone. The basal Sausbee is a rust brown, friable, quartz sandstone.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION - partial thickness		3.7
9	Covered interval.	3.5
8	Sandstone. Gray brown. Weathers rust brown. Medium grained. Well sorted. Subrounded. Pebble inclusions. Firm to hard. Thin bedded. Crossbedded. Calcareous. Basal contact welded locally, undulating laterally. (sampled at base)	0.2
PITKIN LIMESTONE		7.3
7	Mudstone. Dark blue gray. Weathers light gray. Dense. Sparsely fossiliferous. Covered laterally. Basal contact covered. (sampled at base)	0.1
6	Covered interval.	2.8
5	Packstone. Medium gray brown. Weathers medium gray. Medium to coarse grained. Poorly sorted. Composed of crinoid and bryozoan debris with minor brachiopods. Forms a small bluff. Weathers rough and angular. Basal contact undulating. (2.0 feet above base)	2.8

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
4	Limestone and shale. Medium gray. Weathers light gray. Coarse grained. Poorly sorted. Composed perdominantly of crinoid debris. Medium nodular to wavy bedding. Weathers rough and rounded with fossils standing out. Shale weathers out. Slumped in part. Unit forms a reentrant. Basal contact covered. (sampled at base)	1.6
FAYETTEVILLE SHALE - estimated thickness		78.0
3	Covered interval. Blocky mudstone to wackestone talus. (float sample)	18.0
2	Covered interval.	60.0
HINDSVILLE FORMATION - estimated thickness		10.0
1	Grainstone. Medium gray. Weathers gray brown. Medium to coarse grained. Well sorted. Contains coated skeletal grains. Rare brachiopods. Medium bedded. Partially covered. Sparsely weathering. Forms low, flat exposure. Basal contact covered. (sampled at base)	10.0

Measured Section 205: East Terrapin Creek

Location: E½ NW¼ sec. 33, T. 14 N., R. 23 E., Cherokee County, Oklahoma.

From Cookson, drive south 2.1 miles on Route 82 to a gravel road across from the Sixshooter Camping Area entrance. Turn east (left) and proceed 3.7 miles to a gate. Obtain permission to enter from the ranch foreman who lives in a small brown house next to the gate on the north side of the road. Continue driving east on the ranch road 0.8 mile to a cattle feeder. Park and walk 0.25 mile east (upstream) along the north bank of Terrapin Creek to the painted unit numbers. The section starts on the top of the Hindsville Formation.

This section was measured on April 20, 1980. When compared to M.S. 194, it can be seen that the Pitkin becomes thicker east of Tenkiller Lake. The Fayetteville is completely covered as well as 2 to 5 feet of basal Pitkin. Further to the east, more Pitkin is exposed but the Hindsville-Fayetteville contact is covered. This exposure was chosen for measuring because it is the best in the area for observing the Chesterian and lower Morrowan stratigraphic package.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
7	Conglomerate. Dark gray brown. Mottled. Weathers rust brown. Fine to very coarse grained. Poorly sorted. Limestone pebble inclusions. Mixed quartz and carbonate sand matrix. Medium bedded. Basal contact welded, covered laterally. (2.0 feet above base)	2.3
PITKIN LIMESTONE - partial thickness		
6	Grainstone. Medium gray. Weathers medium gray. Medium grained. Well sorted. Oolitic with skeletal grains. Minor crossbedding. Thick bedded. Smooth weathering. Basal contact sharp. (1.3 feet above base)	2.5
5	Grainstone. Medium gray. Weathers medium gray. Coarse grained. Poorly sorted. Composed of skeletal debris. Medium to thick bedded. Well exposed. Forms a laterally persistent cliff. Smooth weathering. Basal contact gradational. (2.0 feet above base)	4.0

Offset 15 feet east on top of unit 4.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
4	Packstone and shale. Medium gray. Weathers medium gray. Medium to coarse grained. Poorly sorted. Contains coated skeletal grains. Abundant bryozoans and crinoids with minor gastropods. Shale partings 0.5 to 2 inches thick. Thin, nodular bedding. Shale weathers out. Forms a slight reentrant. Unit pinches out laterally. Basal contact gradational. (0.5 foot above base)	1.0
3	Packstone and grainstone. Dark blue gray to gray brown. Weathers medium gray. Very fine to coarse grained. Poorly sorted. Becomes coarse upward. Composed of skeletal debris. Abundant bryozoan fragments. Medium bedded. Forms a slight reentrant at base of cliff. Rough weathering. Basal contact covered. (3.0 feet above base)	3.5
FAYETTEVILLE SHALE		26.0
2	Covered interval.	26.0
HINDSVILLE FORMATION - partial thickness		3.5
1	Grainstone. Medium gray brown. Weathers medium gray. Ironstained. Medium to coarse grained. Poorly sorted. Coated skeletal debris. Thick bedded. Well exposed. Smooth weathering. Basal contact covered. (sampled at base)	3.5

Measured Section 206: South Terrapin Creek

Location: NW¼ SE¼ sec. 31, T. 14 N., R. 23 E., Cherokee County, Oklahoma.

From Cookson, drive south 2.1 miles on Route 82 to the entrance of the Sixshooter Camping Area. Permission to enter the land must be obtained from Mr. or Mrs. Stratton who live in the first house on the left as one drives 1.4 miles west into the camping area. Drive east 2.5 miles on the gravel road opposite the Sixshooter entrance to parking space #12. Park there and proceed on foot south, across Terrapin Creek, on an abandoned road for a distance of 1.0 mile. Walk west from the abandoned road 200 yards into a wooded ravine until a Pitkin bluff is encountered. Follow the bluff north approximately 50 yards to the painted unit numbers. The section begins in the uppermost units of the Hindsville Formation, located 20 yards downslope (east) from the Pitkin bluffs.

This section was measured on April 22, 1980. The units are laterally persistent within the Pitkin. The Fayetteville Shale is completely covered. The Pitkin is fairly well exposed forming a pronounced bench at its contact with the Sausbee.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
6	Grainstone. Medium gray to gray brown. Weathers dark gray brown. Ironstained. Fine to coarse grained. Poorly sorted. Conglomeratic with pebble inclusions. Minor quartz grains. Poorly exposed. Covered laterally. Thin bedded. Rough weathering. Basal contact undulating with a maximum relief on the unconformity of 1.0 foot. (sampled at base)	2.5
PITKIN LIMESTONE - partial thickness		10.0
5	Grainstone. Light to medium gray. Weathers light gray brown. Medium to coarse grained. Poorly sorted. Contains crinoid debris. Thick bedded. Laterally persistent. Rough weathering. Basal contact undulating. (2.5 feet above base)	3.0

Offset 10 feet south on top of unit 4.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
4	Packstone and shale. Medium gray. Weathers light gray. Fine to coarse grained. Poorly sorted. Composed of crinoidal and bryozoan skeletal debris. Medium bedded. Shale weathers out leaving loose fossils. Slightly slumped. Rough weathering. Basal contact undulating. (sampled at base)	4.0
3	Grainstone. Medium to dark gray. Weathers light gray to gray brown. Medium to coarse grained. Poorly sorted. Abundant bryozoan debris. Wackestone lenses. Minor cross-laminations. Supports moss. Covered laterally. Basal contact covered. (0.2 foot above base)	3.8
FAYETTEVILLE SHALE		21.0
2	Covered interval.	21.0
HINDSVILLE FORMATION - partial thickness		1.7
1	Grainstone. Medium to dark gray. Weathers light gray brown. Coarse grained. Well sorted. Contains skeletal debris with minor coated grains. Thick bedded. Well exposed. Smooth weathering. Jointed in part. Basal contact covered. (1.2 feet above base)	1.7

Measured Section 207: Sugar Mountain

Location: SW¼ SW¼ sec. 28, T. 16 N., R. 23 E., Cherokee County, Oklahoma.

From the intersection of Route 100 and Route 82 north of Cookson, drive east 2.5 miles on Route 100. Turn north (left) onto a paved county road and proceed north across Caney Creek 5.3 miles. Turn northeast (right) onto a private gravel road and drive 0.3 mile to a cluster of small houses on the east (right) side of the road. Obtain permission to enter the land from Mr. Pegion who lives in the first house. Walk east, up a small valley behind the last house on the right, until large cliffs of Pitkin and Sausbee are encountered. The Pitkin section is located approximately 150 feet north of the stream on the lower portion of the cliff face.

This section was measured on April 24, 1980. The Fayetteville is intermittently exposed below the cliff face. The sharp Hindsville-Fayetteville contact is exposed in the stream valley, 50 feet east of the Pitkin cliff face. The Pitkin is well exposed with only the basal units covered. The basal Sausbee is variable in lithologic character, ranging from a sandy limestone to a conglomeratic sandstone.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
10	Sandstone. Medium gray. Weathers light to rust brown. Fine to very coarse grained. Poorly sorted. Conglomeratic with pebble to cobble inclusions. Friable. Changes facies laterally. Basal contact undulating with low relief on the unconformity. (sampled at base)	1.8
PITKIN LIMESTONE - partial thickness		10.2
9	Wackestone. Dark gray. Weathers medium to light gray. Coarse grained. Poorly sorted. Thin bedded. Forms a deep reentrant. Covered laterally by slumping. Weathers rough and angular. Basal contact gradational. (sampled at base)	0.3
8	Grainstone. Medium to dark gray. Weathers light gray brown. Medium to coarse grained. Poorly sorted. Oolitic with skeletal grains. Thick bedded. Well exposed. Forms a laterally persistent bluff. Weathers rough and angular. Basal contact undulating. (1.0 foot above base)	2.0

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
Offset 40 feet south on top of unit 7.		
7	Grainstone. Medium gray brown. Weathers light gray brown. Very fine grained. Well sorted. Peloidal. Mudstone lenses. Thick bedded. Well exposed. Forms a laterally persistent bluff. Smooth weathering. Basal contact gradational. (1.8 feet above base)	2.2
6	Mudstone and shale. Medium gray brown. Weathers light gray. Minor brachiopods. Thin to medium nodular bedding. Shale partings weathered out. Forms a deep reentrant. Basal contact gradational. (not sampled)	0.4
5	Packstone. Light to medium gray. Weathers light gray. Coarse grained. Poorly sorted. Contains crinoidal debris. Thin to medium wavy bedding. Well exposed. Unit forms a small reentrant at its base. Basal contact gradational. (1.0 foot above base)	2.8
4	Grainstone. Light to medium gray brown. Weathers medium gray. Coarse grained. Poorly sorted. Crinoid, bryozoan, and brachiopod skeletal debris. Thick bedded. Weathers smooth and rounded. Partially moss covered. Covered laterally. Basal contact covered. (2.4 feet above base)	2.5
FAYETTEVILLE SHALE - estimated thickness		70.0
3	Covered interval.	67.4
2	Shale. Black. Weathers black. Ironstained in part. Fissile. Brittle. Poorly exposed. Minor mudstone nodules. Basal contact sharp.	2.2
HINDSVILLE FORMATION - partial thickness		
1	Grainstone. Dark gray. Weathers medium gray. Medium grained. Moderately well sorted. Oolitic with coated skeletal grains. Thick bedded. Poorly exposed. Smooth weathering. Jointed. Basal contact covered. (sampled at base)	0.2

Measured Section 208: North Elk Creek Road Cut

Location: NE¼ SE¼ sec. 31, T. 15 N., R. 23 E., Cherokee County, Oklahoma.

To reach this section, drive south 1.9 miles on Route 82 from the intersection of Route 82 and Route 100 north of Cookson. Thin Pitkin exposures can be seen on the east side of the road.

This section was measured on April 27, 1980, with the assistance of Dr. Patrick K. Sutherland. At this location, the Pitkin exposure is thin due to pre-Pennsylvanian erosion. However, the Nodular Limestone and Shale Facies of the basal Pitkin is well exposed, which is the exception rather than the rule. The exposure is located near a fault and is dipping northeast at 27°. The overlying Sausbee is covered with a coarse cobble conglomerate talus.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION - partial thickness		4.0
5	Covered interval. Conglomerate talus. (float sample)	3.0
4	Covered interval.	1.0
PITKIN LIMESTONE		5.2
3	Wackestone. Dark blue gray. Weathers rust brown. Coarse grained. Poorly sorted. Mudstone lenses. Minor corals. Forms a single thin bed. Poorly exposed. Weathers rough and friable. Basal contact gradational. (sampled at base)	0.2
2	Mudstone and wackestone. Dark blue gray. Weathers light gray to blue gray. Dense. Fossiliferous, containing corals, brachiopods, and crinoids. Medium to thick bedded. Poorly exposed in road cut. Basal contact covered. (B-4.5 feet above base) (A-3.0 feet above base)	5.0

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
FAYETTEVILLE SHALE - partial thickness		7.0
1	Covered interval. Abundant blocky mudstone talus.	7.0

Measured Section 209: West Caney Creek

Location: NW¼ NE¼ sec. 3, T. 15 N., R. 23 E., Cherokee County, Oklahoma.

From the intersection of Route 100 and Route 82 north of Cookson, drive east 2.5 miles on Route 100. Turn north (left) onto a paved county road and proceed north across Caney Creek 2.2 miles. Turn east (right) onto a gravel road and drive an additional 1.9 miles to a cement bridge that crosses a tributary of Caney Creek. From the bridge, walk west along the edge of a pasture 0.25 mile to a wooded promentory that extends north into the pasture. Turn south and cross the stream. A poorly exposed Pitkin bluff should be seen on the south side of the stream. Follow the bluff east to the point where the lowest units are at stream level and look for the painted unit numbers.

This section was measured on April 28, 1980. It is moss covered, and for the most part, poorly exposed. It is easily accessible and provides a good data point in the northern part of the study area. There is as much as 1 foot of local relief on the unconformity that marks the Pitkin-Sausbee contact. The unconformity can be seen truncating unit 7 of the uppermost Pitkin.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
8	Grainstone. Medium gray. Weathers rust brown. Coarse grained. Poorly sorted. Minor pebble inclusions. Medium bedded. Forms a resistant, moss covered ledge. Basal contact undulating. Relief on the unconformity does not exceed 2.0 feet. (sampled at base)	2.2
PITKIN LIMESTONE - partial thickness		20.6
7	Grainstone. Medium gray. Weathers rust brown. Fine to coarse grained. Poorly sorted. Contains abundant coated skeletal grains. Medium bedded. Intermittently exposed. Locally truncated by the pre-Pennsylvanian unconformity. Basal contact undulating. (sampled at base)	0.5
6	Limestone. Dark gray. Weathers light gray. Very fine grained. Well sorted. Rare fossil inclusions. Thin grainstone lense is present 0.3 foot above base. Medium, wavy bedding. Laterally persistent. Smooth weathering. Basal contact covered. (2.4 feet above base)	3.4
5	Covered interval.	5.5
4	Grainstone. Dark gray. Weathers light gray. Fine grained. Well sorted. Oolitic with medium to coarse skeletal inclusions. Thick bedded. Laterally persistent. Becomes a pure skeletal grainstone upward. Smooth weathering. Basal contact welded. (0.2 foot above base)	2.6
3	Mudstone. Dark gray brown to buff. Weathers light gray. Sparsely fossiliferous containing brachiopods. Thick bedded. Moss covered. Basal contact undulating. (2.0 feet above base)	2.8

Offset 50 feet west on top of unit 2-B.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
2-B	Wackestone to packstone and shale. Medium to dark gray. Weathers light to medium brown. Coarse grained. Poorly sorted. Abundant brachiopods and bryozoans. Thin to medium bedded. Poorly exposed forming a reentrant. Shale weathers out. Petroliferous. Basal contact gradational. (1.0 foot above base)	1.8
2-A	Grainstone. Medium gray. Weathers medium gray brown. Coarse grained. Poorly sorted. Contains abundant crinoid debris. Thick bedded. Moss covered. Exposed by digging. Covered laterally. Basal contact covered. (not sampled)	3.0
1	Covered interval.	1.0

Measured Section 210-A: Irma's Place

Location: SW¼ SE¼ sec. 12, T. 15 N., R. 22 E., Cherokee County, Oklahoma.

From the intersection of Route 82 and Route 100 north of Cookson, drive north 2.85 miles on Route 82. The section is exposed on the east side of the road.

This section was measured on April 28, 1980 with the assistance of P. K. Sutherland. The exposure is thin, consisting mostly of the Nodular Limestone and Shale Facies. It is overlain by coarse, cobble conglomerate talus of assumed basal Sausbee Formation. The Sausbee blocks contain abundant Mississippian rugose corals (Sutherland, 1980, personal communication). Some of the cobbles in the conglomerate are as much as 4 inches in diameter and are predominantly composed of mudstone and wackestone carbonate textures. The Pitkin thickness at this location is questionable because of local faulting, slumping, and recent excavation.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
SAUSBEE FORMATION		
3	Covered interval. The grassy slope above the road cut is covered with large slump blocks of coarse, cobble conglomerate. The conglomerate contains rugose corals and large clasts of fine grained Pitkin lithologies. (float sample)	3.0
PITKIN LIMESTONE - estimated thickness		4.5
2	Packstone. Medium to dark gray brown. Weathers dark gray brown. Fine to medium grained. Poorly sorted. Skeletal grains are coated. Minor ooliths. Fossiliferous. Slightly slumped. Basal contact undulating to gradational. (sampled at base)	1.0
1	Mudstone and shale. Dark gray brown. Weathers blue gray. Abundant crinoids, bryozoans, gastropods, and brachiopods. Medium bedded. Poorly exposed. Wackestone and packstone lenses. Basal contact covered. (C-3.4 feet above base) (B-3.0 feet above base) (A-1.5 feet above base)	

<u>Measured Section 210-B: Carter's Cabins</u>

Location: NE¼ SW¼ SW¼ sec. 12, T. 15 N., R. 22 E., Cherokee County, Oklahoma.

This section is located 0.5 mile north of M.S. 210-A on the northeast side of Route 82, just beneath the driveway for Carter's Cabins.

This section was measured on April 28, 1980. It is similar to M.S. 210-A. The Sausbee Formation has been removed by Recent erosion, but sandy rubble can be seen lying on unit 4 which is inferred to be a remnant of Sausbee lithologies. The measured interval lies just north of a fault where a thick, well exposed interval of Fayetteville Shale abuts Pitkin Limestone as a result of vertical offset.

UNIT NO.	LITHOLOGY	THICKNESS (FEET)
PITKIN LIMESTONE - estimated thickness		6.2
4	Mudstone. Dark gray. Weathers light blue gray. Sparsely fossiliferous. Resistant to weathering. Jointed. Basal contact covered. (sampled at base)	1.2
3	Covered interval.	2.5
2	Mudstone and wackestone. Dark gray. Weathers light gray. Thin to medium bedded. Minor shale partings. Highly fossiliferous. Basal contact gradational. (2.0 feet above base)	2.5
FAYETTEVILLE SHALE - partial thickness		1.7
1	Shale and mudstone. Dark gray. Weathers light gray to rust brown. Sparsely fossiliferous. Thin bedded. Black shale is in thin beds 1 to 2 inches thick. Petroliferous. Basal contact covered. (1.0 foot above base)	1.7

APPENDIX B

POINT COUNT DATA

This appendix includes the point count data from both the Pitkin and basal Sausbee thin sections. The raw data, from the original counting, is converted into fraction percent. All percent values are given in the nearest whole number. These fraction percent values may be interpreted as being the same as volume percent composition (see Methods of Investigation, Chapter 1).

The counter used in this study had only 13 keys, hence, broad terms were used, rather than specific, in order to encompass the largest number of grains under each item as possible. For example, peloid, the general term, was used as an item rather than pellet, the specific term. Grain definitions and definitions of cement, matrix, spar, microspar, and carbonate mud were all taken from the Glossary of Geology, second edition (Bates and Jackson, eds., 1980).

Items most commonly included in the miscellaneous category were all unidentifiable grains, coral fragments, algal fragments, spicules, ostracodes, trilobites, and grapestones or compound grains (Bathurst, 1971).

The last two columns contain the modified Dunham classification for each Pitkin thin section. In the letter code for modifiers, the small letters c = crinoidal, b = bryozoan, s = skeletal, o = oolitic, and p = peloidal. For Dunham's (1962) modified classification, the capital letters M = mudstone, W = wackestone, P = packstone, G = grainstone, and X = crystalline carbonate.

SAMPLE	NUMBER COUNTS	TOTAL PERCENT		FRACTION PERCENT														
		CEMENT-MATRIX	CONSTITUENTS	OOLITHS	SPAR	MUD + MICROSPAR	CRINOIDS	BRYOZOANS	BRACHIOPODS	GASTROPODS	FORAMS	COATED GRAINS	PELOIDS	INTRACLASTS	PELECYPODS	MISCELLANEOUS	Modifiers	Classification
183-2	305	41	59	-	16	25	10	1	-	-	-	41	-	3	-	4	s	P
183-3	343	24	76	-	19	5	30	39	-	-	1	-	-	1	-	5	bc	G
183-4	338	33	67	1	23	10	16	6	2	-	-	35	2	2	1	2	bc	G
183-5	332	21	79	6	13	8	9	3	-	-	-	53	2	4	-	2	bc	G
183-6	300	28	72	14	22	6	18	-	1	3	-	13	13	6	1	3	sp	G
184-1	323	63	37	-	25	38	8	14	3	-	-	-	2	5	1	4	s	W
184-2	340	49	51	-	37	11	11	2	4	-	1	25	4	3	-	2	s	P
184-3	340	51	49	-	17	34	10	11	4	-	-	11	5	3	-	5	s	P
184-4	316	49	51	6	19	30	5	6	4	-	-	19	1	7	1	2	cb	P
184-5	291	37	63	2	22	15	9	2	3	-	-	40	-	-	3	4	s	P
185-1	314	86	14	-	4	82	7	2	2	-	-	-	-	-	-	3		W
185-2	312	36	64	-	28	8	7	10	1	-	-	32	2	9	-	3	s	G
185-3	309	32	68	-	13	19	30	16	3	-	-	10	2	-	-	7	cb	P
185-4	286	25	75	8	14	11	44	6	-	-	-	10	1	2	2	2	c	P
185-5	312	32	68	40	29	3	5	1	-	-	-	16	3	1	-	2	os	G
186-1	353	33	67	39	30	4	6	2	1	-	-	12	5	1	-	-	os	G

SAMPLE	NUMBER COUNTS	TOTAL PERCENT CEMENT-MATRIX	TOTAL PERCENT CONSTITUENTS	FRACTION PERCENT OOLITHS	SPAR	MUD + MICROSPAR	CRINOIDS	BRYOZOANS	BRACHIOPODS	GASTROPODS	FORAMS	COATED GRAINS	PELOIDS	INTRACLASTS	PELECYPODS	MISCELLANEOUS	Modifiers	Classification
186-2	327	34	66	7	15	19	32	6	1	-	-	12	3	5	-	-	c	P
186-4	299	68	32	-	4	64	5	10	3	-	-	-	4	1	-	9	s	P
186-5	302	28	72	-	7	21	19	17	-	-	-	16	3	16	-	1	cb	P
186-6	338	33	67	32	32	1	9	-	-	-	1	17	6	2	-	-	oc	G
187-9	316	88	12	-	3	85	3	7	2	-	-	-	-	-	-	-		W
187-10	315	32	68	-	28	4	40	8	1	-	-	14	2	3	-	-	c	G
187-11	327	23	77	-	15	8	27	8	-	-	-	33	-	6	-	3	s	G
187-13	316	46	54	32	42	4	6	-	-	-	-	13	2	-	-	1	o	G
187-15	333	92	8	-	4	88	-	-	2	-	-	-	-	-	-	6		M
187-16	331	70	30	-	8	62	21	1	1	-	-	-	6	1	-	-	c	W
187-17	337	32	68	9	18	14	23	1	1	5	-	20	4	4	-	1	c	P
187-18	307	32	68	-	16	16	35	6	4	2	-	13	2	-	-	6	c	P
187-19	325	19	81	41	15	4	21	2	1	-	-	4	7	3	-	2	oc	G
188-2	307	81	19	-	2	79	4	7	5	-	-	-	-	-	-	3		W
188-3	314	40	60	12	21	19	19	10	4	-	-	4	3	3	1	4	s	P
188-5	314	34	66	25	29	5	8	5	2	-	2	10	8	1	-	5	os	G
188-6	387	37	63	12	24	13	7	15	-	2	-	22	1	3	-	1	s	P

		TOTAL PERCENT		FRACTION PERCENT														
SAMPLE	NUMBER COUNTS	CEMENT-MATRIX	CONSTITUENTS	OOLITHS	SPAR	MUD + MICROSPAR	CRINOIDS	BRYOZOANS	BRACHIOPODS	GASTROPODS	FORAMS	COATED GRAINS	PELOIDS	INTRACLASTS	PELECYPODS	MISCELLANEOUS	Modifiers	Classification
188-7	326	33	67	38	30	3	3	-	-	-	-	15	8	1	-	2	o	G
188-9	308	38	62	41	37	1	3	1	1	-	-	9	4	1	-	2	o	G
188-11	388	35	65	18	34	1	24	3	1	-	-	11	3	4	-	1	c	G
189-2	322	92	8	-	3	89	4	2	1	-	-	-	1	-	-	-		M
189-3A	307	69	31	-	1	68	10	15	4	-	-	-	-	-	-	2		W
189-3B	302	100	-	-	100	-	-	-	-	-	-	-	-	-	-	-		M
189-4	293	38	62	15	23	15	10	3	3	-	-	24	2	-	-	5	s	P
189-5	301	47	53	3	15	31	11	3	5	1	6	11	8	2	-	4	s	P
189-6	317	41	59	4	27	13	4	3	2	2	-	40	2	1	-	2	s	P
189-7	325	37	63	28	23	14	12	12	-	-	-	5	-	-	-	6	o	P
190-1	322	95	5	-	6	89	4	-	-	-	-	-	-	-	-	1		M
190-2	314	53	47	-	29	24	26	3	3	2	-	5	-	-	1	7	c	P
190-3	323	25	75	32	24	-	21	-	-	1	-	8	2	10	-	1	o	G
190-4	315	47	53	2	40	7	24	11	4	-	-	2	1	-	2	7	s	G
190-5	338	78	22	-	6	72	11	1	9	-	-	-	-	-	-	1		W
190-6	305	44	56	12	38	6	-	-	-	-	-	9	29	-	-	6	p	G
190-7	316	32	68	13	23	9	18	2	1	-	-	19	7	6	-	2	s	G

SAMPLE	NUMBER COUNTS	TOTAL PERCENT		FRACTION PERCENT														
		CEMENT-MATRIX	CONSTITUENTS	OOLITHS	SPAR	MUD + MICROSPAR	CRINOIDS	BRYOZOANS	BRACHIOPODS	GASTROPODS	FORAMS	COATED GRAINS	PELOIDS	INTRACLASTS	PELECYPODS	MISCELLANEOUS	Modifiers	Classification
190-8	307	32	68	43	31	1	4	-	-	-	-	12	6	2	-	1	o	G
191-1	310	98	2	-	2	97	-	-	-	-	-	-	-	-	-	1		M
191-2	313	35	65	48	35	-	2	-	4	-	1	4	5	-	-	1	o	G
191-3	301	68	32	-	68	-	-	-	-	-	4	-	2	-	6	20		X
191-4	317	39	61	5	39	-	19	5	5	-	-	18	1	2	-	6	s	G
191-5	307	34	66	17	33	1	13	3	1	-	-	22	1	1	3	5	s	G
191-6	348	30	70	28	25	5	11	2	-	-	1	17	4	4	1	2	o	G
191-7A	314	73	27	2	24	49	-	1	8	-	1	3	8	-	1	3	c	P
191-7B	311	33	67	44	32	1	2	-	-	-	-	12	6	-	-	3	o	G
191-8	340	40	60	-	19	·22	31	14	1	-	-	4	2	1	-	1		P
192-2	309	36	64	8	34	2	20	20	1	1	-	8	-	5	-	1	s	G
192-3	358	42	58	8	39	3	14	4	1	-	-	25	-	-	3	3	s	G
192-4	305	24	76	21	20	4	11	9	6	-	-	21	3	-	-	5	s	G
192-6	307	26	74	29	19	7	12	4	-	-	1	16	5	3	-	4	o	G
192-7	315	43	57	20	24	19	3	2	2	-	3	5	14	-	3	5	p	P
192-8	317	31	69	19	29	2	15	5	3	2	-	15	8	2	-	-	s	G
192-9	310	41	59	4	40	1	12	5	-	-	-	22	9	3	3	1	s	G
192-10	324	97	3	-	1	96	1	-	1	-	-	-	-	-	-	1		M

SAMPLE	NUMBER COUNTS	TOTAL PERCENT		FRACTION PERCENT														
		CEMENT-MATRIX	CONSTITUENTS	OOLITHS	SPAR	MUD + MICROSPAR	CRINOIDS	BRYOZOANS	BRACHIOPODS	GASTROPODS	FORAMS	COATED GRAINS	PELOIDS	INTRACLASTS	PELECYPODS	MISCELLANEOUS	Modifiers	Classification
192-11	309	22	78	25	20	2	13	1	-	-	12	13	11	3	-	-	o	G
192-12	314	38	62	4	10	28	27	4	1	-	-	16	5	2	-	3	s	P
192-13	320	100	-	-	1	99	-	-	-	-	-	-	-	-	-	-		M
193-1	328	83	17	-	6	77	6	7	1	-	-	-	1	-	1	1		W
193-2	328	30	70	16	15	15	14	2	-	-	-	25	6	2	2	3	s	P
193-3	313	56	44	-	53	3	30	10	3	-	-	-	-	-	-	1	s	G
193-4	401	21	79	40	20	2	10	1	2	-	-	10	8	4	-	3	o	G
193-5	301	44	56	-	7	40	22	8	4	-	-	8	2	1	2	6	cb	P
193-5(M)	308	89	11	-	2	87	6	1	2	-	-	-	-	-	1	1		W
193-6	319	38	62	14	38	-	13	5	2	-	-	19	2	3	2	2	b	G
193-7	300	23	77	44	23	-	5	-	-	-	1	17	5	1	-	4	o	G
193-8	320	34	66	11	34	-	16	3	1	1	-	21	2	10	-	1	s	G
193-9	312	32	68	39	32	-	2	-	-	-	1	18	7	1	-	-	o	G
194-3	326	63	37	-	12	51	7	14	3	-	1	1	4	2	-	3		W
194-4	381	80	20	-	38	32	3	11	-	-	4	10	2	-	-	-		W
194-5	330	64	36	-	8	56	17	4	2	-	-	2	3	7	-	1		W

SAMPLE	NUMBER COUNTS	TOTAL PERCENT CEMENT-MATRIX	CONSTITUENTS	FRACTION PERCENT OOLITHS	SPAR	MUD + MICROSPAR	CRINOIDS	BRYOZOANS	BRACHIOPODS	GASTROPODS	FORAMS	COATED GRAINS	PELOIDS	INTRACLASTS	PELECYPODS	MISCELLANEOUS	Modifiers	Classification
195-2	300	100	-	-	-	100	-	-	-	-	-	-	-	-	-	-		M
195-3	300	90	10	-	7	83	-	3	1	-	-	-	2	-	-	4		M
196-14	319	59	41	-	9	50	8	9	1	-	-	13	2	2	-	6	b	P
196-15	365	46	54	-	32	15	17	10	3	-	1	7	8	7	-	-	cb	P
196-17	300	28	72	29	27	1	13	5	-	-	-	12	3	8	-	2	o	G
196-18	313	37	63	6	28	9	7	7	4	-	1	25	3	9	1	-	s	G
196-19	306	47	53	3	37	10	14	11	4	1	1	14	2	2	-	-	cb	G
196-20	303	29	71	32	26	3	13	-	-	-	-	7	13	1	-	2	op	G
197-8	304	51	49	-	46	6	15	2	10	-	5	8	3	2	1	2	s	G
197-9	313	62	38	-	2	61	11	8	5	3	1	5	2	-	-	2		W
197-10	300	25	75	-	20	5	50	9	4	-	-	5	1	3	-	3	c	P
197-11	358	71	29	-	9	61	9	5	11	-	-	2	-	1	2	-		W
197-12	317	89	11	-	2	87	-	-	3	-	-	-	7	-	-	1		W
198-3	302	42	58	12	40	2	13	15	4	-	1	6	3	-	2	2	s	G
198-5	326	40	60	4	21	19	12	11	3	3	-	21	2	-	3	1	s	P
198-6	345	37	63	3	23	14	44	2	1	1	1	4	3	-	4	-	c	P

SAMPLE	NUMBER COUNTS	TOTAL PERCENT CEMENT-MATRIX	TOTAL PERCENT CONSTITUENTS	FRACTION PERCENT OOLITHS	SPAR	MUD + MICROSPAR	CRINOIDS	BRYOZOANS	BRACHIOPODS	GASTROPODS	FORAMS	COATED GRAINS	PELOIDS	INTRACLASTS	PELECYPODS	MISCELLANEOUS	Modifiers	Classification
199-5	304	56	44	-	14	42	6	5	3	-	2	12	10	3	-	-	ps	P
199-6	308	84	16	-	8	77	1	9	2	-	-	-	1	-	-	2	b	W
199-7	308	52	48	-	25	27	15	5	3	-	-	7	2	15	-	1	cb	P
200-2	321	44	56	10	15	29	17	5	2	-	1	11	1	5	2	2	s	P
200-4	302	32	68	39	31	1	4	-	1	-	-	11	10	-	1	2	po	G
200-5	307	29	71	15	17	12	34	3	1	-	-	9	5	4	-	-	c	P
200-6	308	73	27	-	17	56	3	6	-	-	-	12	2	3	-	-		W
200-8	309	39	61	-	34	5	12	2	1	-	-	21	1	24	-	-	s	G
201-2	312	70	30	-	6	64	1	17	9	-	-	-	1	-	-	2	b	W
201-4	314	46	54	-	12	34	23	22	2	-	-	4	-	1	2	-	cb	P
201-5	309	21	79	55	17	4	3	-	-	-	-	15	4	1	-	1	o	G
201-7	312	93	7	-	4	89	4	1	2	-	-	-	-	-	-	-		M
201-9	308	30	70	47	28	2	5	1	-	-	-	12	2	2	1	-	o	G
201-11	326	33	67	47	32	2	4	1	-	-	-	7	3	2	2	-	o	G
202-2	331	84	16	-	12	72	1	-	3	-	-	-	7	-	-	5		W
202-4	313	40	60	1	36	4	13	5	2	1	-	32	1	1	2	2	b	G

SAMPLE	NUMBER COUNTS	TOTAL PERCENT		FRACTION PERCENT														
		CEMENT-MATRIX	CONSTITUENTS	OOLITHS	SPAR	MUD + MICROSPAR	CRINOIDS	BRYOZOANS	BRACHIOPODS	GASTROPODS	FORAMS	COATED GRAINS	PELOIDS	INTRACLASTS	PELECYPODS	MISCELLANEOUS	Modifiers	Classification
202-6	311	27	73	3	26	1	20	3	-	-	-	33	2	11	-	1	s	G
202-7	319	56	44	-	4	52	8	1	-	1	-	15	7	9	1	2	s	P
202-8	303	29	71	23	29	-	3	1	-	1	-	32	4	4	-	3	s	G
202-9	363	23	77	69	23	-	-	-	-	-	-	5	2	1	-	-	o	G
202-11	310	37	63	6	36	1	3	-	-	-	-	20	28	4	-	2	p	G
203-6	310	91	9	-	5	86	2	-	-	-	-	-	3	-	-	4		M
203-7	316	93	7	-	2	91	1	1	-	-	-	-	4	-	-	1		M
203-8	316	28	72	23	14	14	15	3	1	-	-	26	3	-	1	-		P
203-10	323	65	35	1	8	57	1	4	4	-	1	16	3	1	2	3	b	W
203-11	300	23	77	-	23	1	8	1	-	-	-	43	1	13	2	8	s	G
203-12	305	67	33	-	21	46	3	-	2	4	-	17	1	2	-	4		P
203-13	300	25	75	16	23	2	-	1	-	-	1	28	25	1	-	3	p	G
204-4	323	65	35	-	31	34	11	14	2	3	-	-	3	-	-	3	b	W
204-5	306	51	49	-	-	51	16	19	4	-	-	2	-	-	1	7	bc	P
204-7	300	100	-	-	-	100	-	-	-	-	-	-	-	-	-	-		M
205-3	303	48	52	11	17	31	6	5	-	-	-	24	5	1	-	-	s	P

SAMPLE	NUMBER COUNTS	TOTAL PERCENT CEMENT-MATRIX	TOTAL PERCENT CONSTITUENTS	FRACTION PERCENT OOLITHS	SPAR	MUD + MICROSPAR	CRINOIDS	BRYOZOANS	BRACHIOPODS	GASTROPODS	FORAMS	COATED GRAINS	PELOIDS	INTRACLASTS	PELECYPODS	MISCELLANEOUS	Modifiers	Classification
205-4	307	61	39	-	15	46	10	4	1	-	4	6	6	2	3	3	s	P
205-5	300	24	76	-	22	2	19	2	2	-	-	50	-	2	-	1	bc	G
205-6	313	26	74	-	22	4	6	5	2	-	-	58	-	-	-	3	s	G
206-3	300	36	64	-	13	23	5	1	1	-	-	52	1	4	-	-	b	P
206-4	301	35	64	-	16	19	4	3	-	1	1	51	-	2	-	3	bc	P
206-5	304	33	67	3	31	2	17	4	1	-	-	39	-	-	-	2	cb	P
207-4	311	46	54	-	18	28	14	8	-	-	-	31	-	-	-	1	cb	P
207-5	300	41	59	-	19	22	38	5	1	-	-	4	-	1	10	-	c	P
207-7	300	31	69	48	19	12	7	1	1	-	-	6	3	2	-	1	o	P
207-8	300	26	74	19	23	3	8	-	1	1	-	28	12	4	-	1	p	G
207-9	302	77	23	-	26	51	11	-	2	-	-	1	-	-	5	4	c	W
208-2	300	64	36	8	5	59	11	1	2	-	-	2	3	-	3	6		W
208-3	308	81	19	4	3	78	5	1	1	-	-	2	3	-	-	3		W
209-2	300	43	57	-	20	23	25	-	3	-	-	26	-	-	1	2	c	P
209-3	300	63	37	-	5	58	1	-	-	-	-	-	31	-	2	3	p	W

SAMPLE	NUMBER COUNTS	TOTAL PERCENT		FRACTION PERCENT														
		CEMENT-MATRIX	CONSTITUENTS	OOLITHS	SPAR	MUD + MICROSPAR	CRINOIDS	BRYOZOANS	BRACHIOPODS	GASTROPODS	FORAMS	COATED GRAINS	PELOIDS	INTRACLASTS	PELECYPODS	MISCELLANEOUS	Modifiers	Classification
209-4	300	34	66	60	30	4	1	-	1	-	-	-	3	-	-	1	o	G
209-6	300	51	49	5	41	10	-	-	-	-	-	6	35	-	-	3	p	G
209-7	300	37	63	22	35	2	2	-	3	-	-	29	3	1	-	3		G
210A-1A	300	81	19	-	20	61	9	-	2	-	-	1	-	-	2	5		W
210A-1B	300	49	51	-	30	19	11	12	3	1	1	23	3	2	1	2	bc	P
210A-2	300	39	61	9	25	14	20	2	1	-	-	24	1	-	1	3	bc	P
210B-2	300	76	24	-	12	64	9	4	4	-	-	1	-	-	3	3		W
210B-4	300	64	36	-	2	62	1	3	7	1	-	-	23	-	1	2	p	W

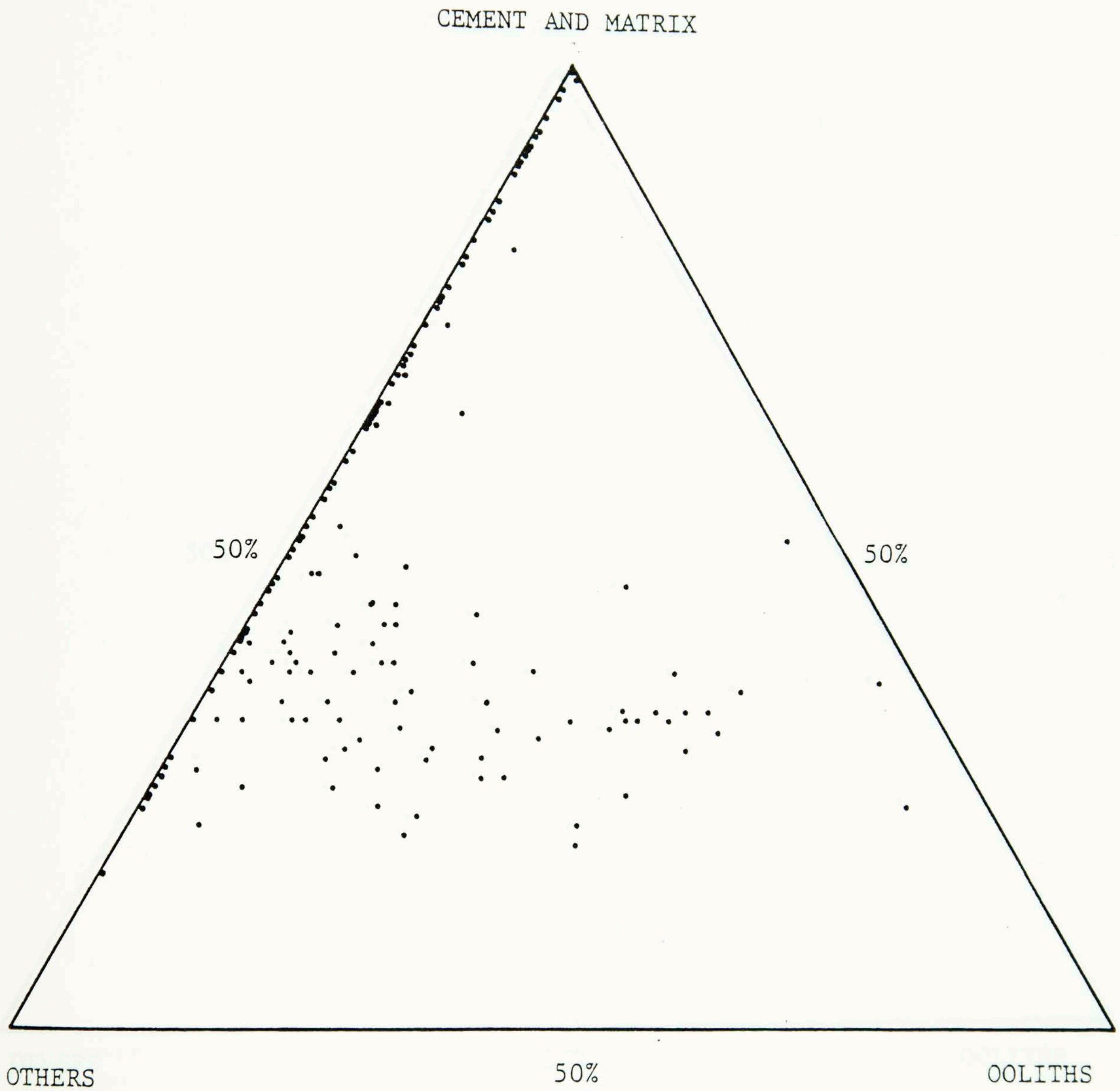
SAMPLE	NUMBER COUNTS	TOTAL PERCENT CEMENT-MATRIX	CONSTITUENTS
183-7	300	23	77
184-6	310	31	69
185-6	304	40	60
186-7	317	26	74
187-20	300	32	68
188-12	314	39	61
189-8	302	30	70
190-9	301	41	59
191-8	316	60	40
192-14	294	24	76
193-10	323	41	59
194-6	310	33	67
195-4	300	46	54
196-21	313	46	54
197-13	302	43	57
199-8	300	41	59
200-9	331	30	70
201-12	306	43	57
202-12	305	32	68

FRACTION PERCENT BASAL SAUSBEE FORMATION														
QUARTZ GRAINS	CEMENT-MATRIX	CARBONATE GRAINS	Conglomerate											
50	23	27	C											
65	31	4												
60	40	-	C											
17	26	57												
17	32	51	C											
58	39	3												
4	30	66	?											
9	41	50												
-	60	40												
18	24	58												
6	41	53												
30	33	37	C											
2	46	52	C											
6	46	48	C											
-	43	57	C											
-	41	59	C											
11	30	59												
24	43	33	C											
66	32	2	C											

SAMPLE	NUMBER COUNTS	TOTAL PERCENT		FRACTION PERCENT BASAL SAUSBEE FORMATION			
		CEMENT MATRIX	CONSTITUENTS	QUARTZ GRAINS	CEMENT-MATRIX	CARBONATE GRAINS	Conglomerate
203-14	312	38	62	62	38	-	
204-8	300	30	70	70	30	-	
205-7	303	37	63	30	37	33	C
206-6	320	20	80	57	20	23	C
207-10	304	46	54	3	46	51	C
208-5	313	62	38	-	62	38	C
209-8	300	26	74	18	26	56	C
210-3	303	21	79	37	21	42	C

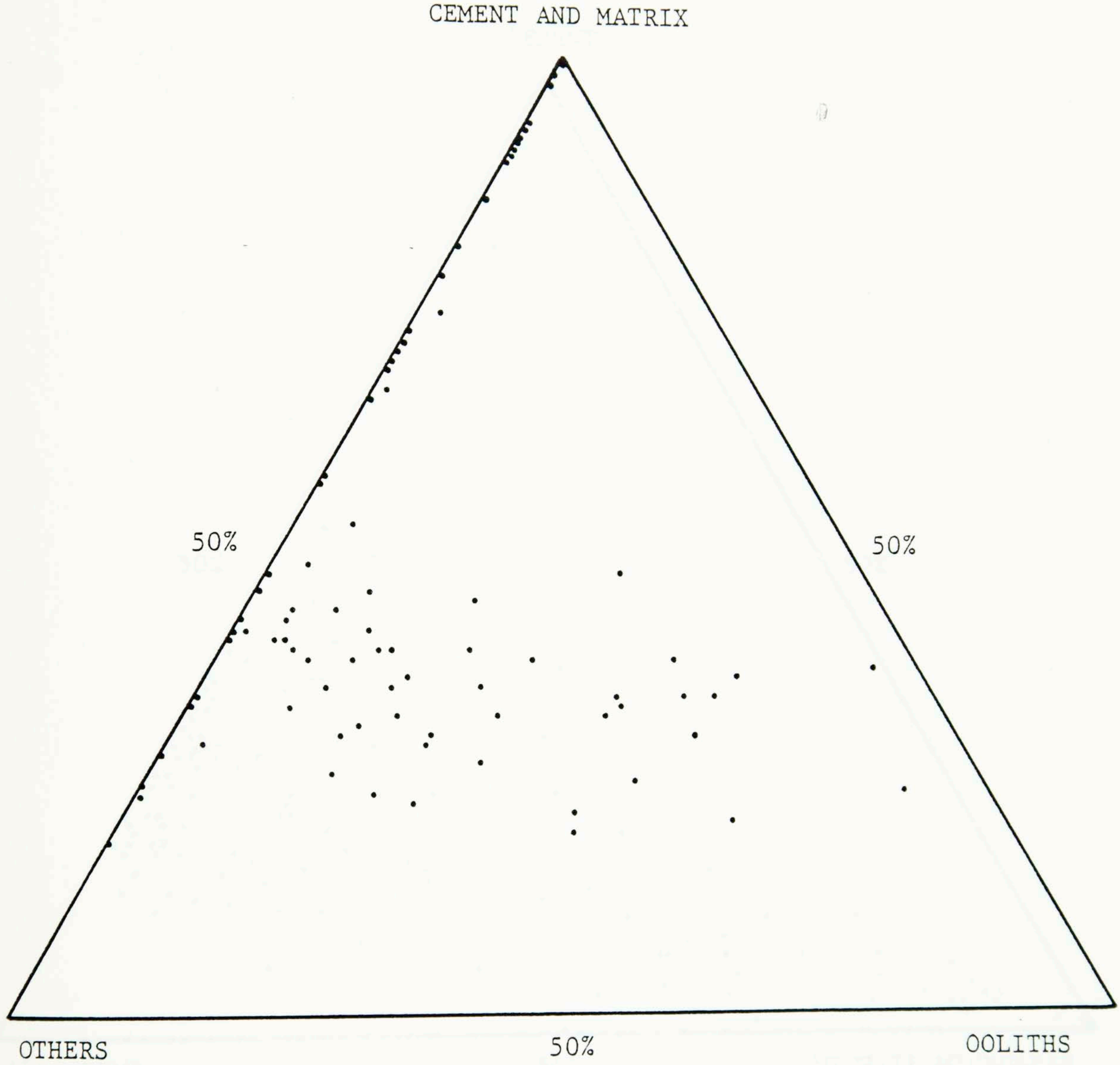
APPENDIX C

MODAL ANALYSIS



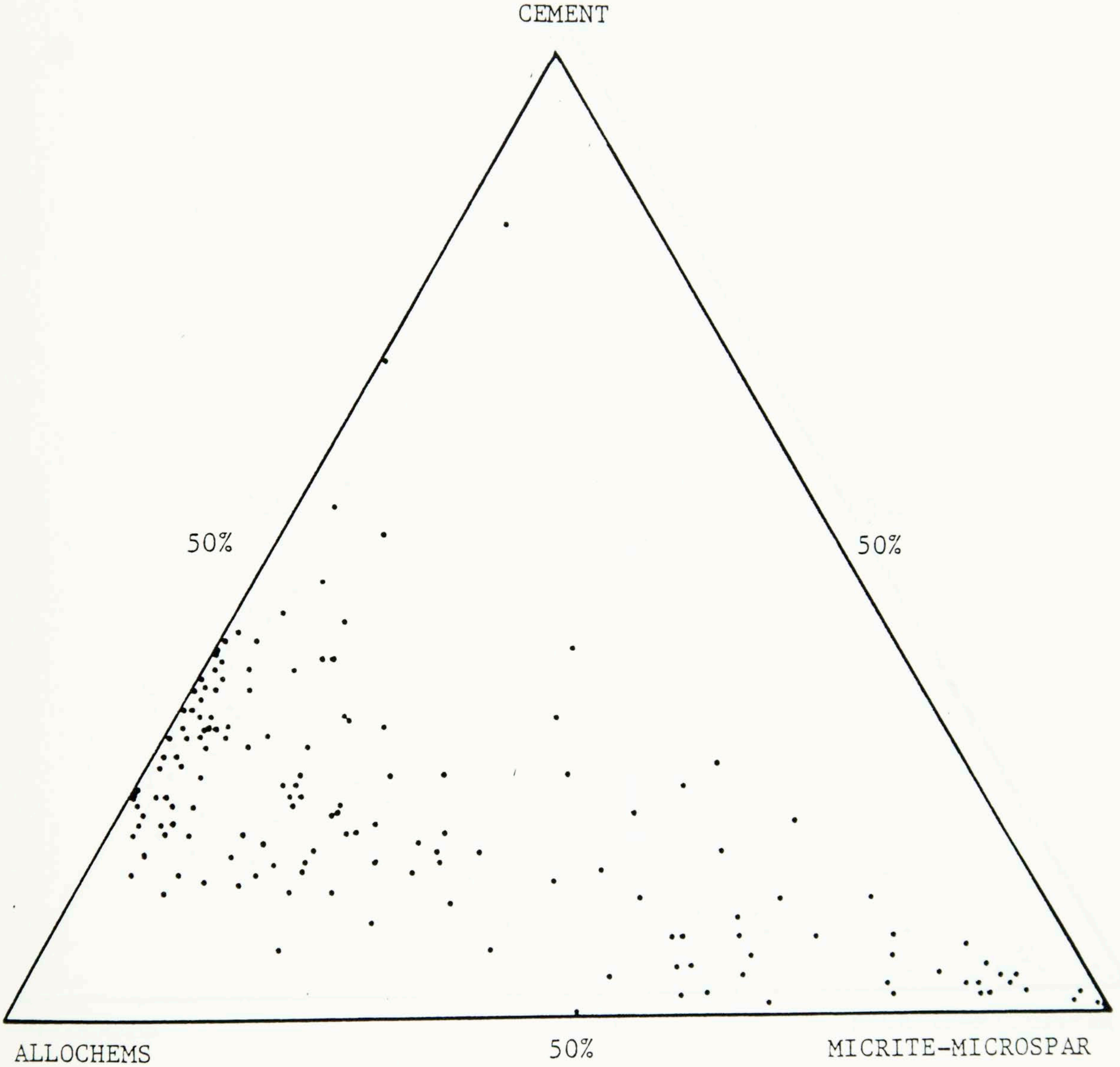
I

Contribution of ooliths to the volume of the various Pitkin lithologies within the study area. About half of the units have 0% of their volume ooliths, the other half is comprised of at least 1% ooliths indicating a proximity to oolite shoals at the time of deposition.



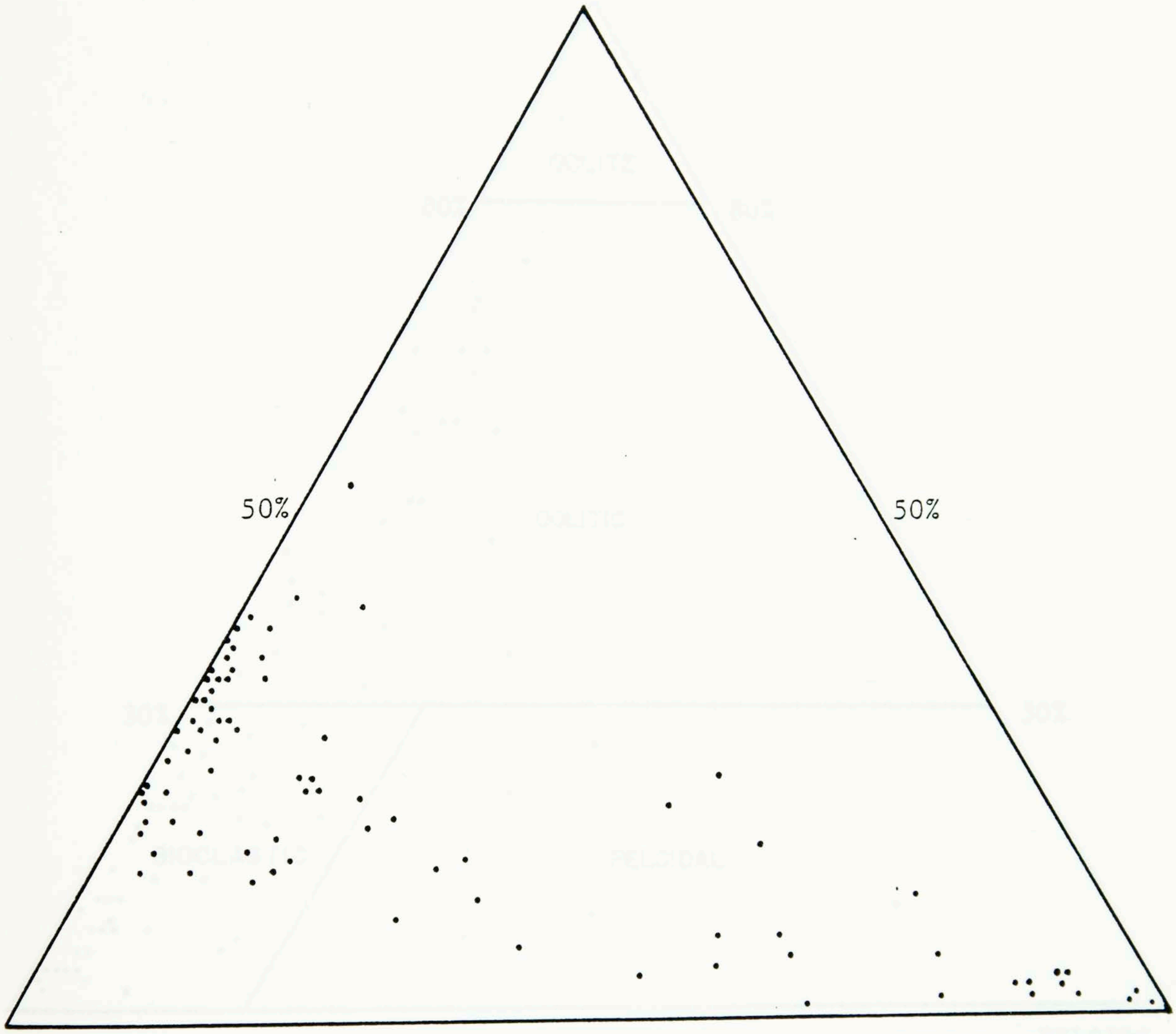
II

Same as C-I except that only the thickest measured sections are plotted. There are fewer nonoolitic units in this plot because the effects of the pre-Pennsylvanian unconformity have been removed.



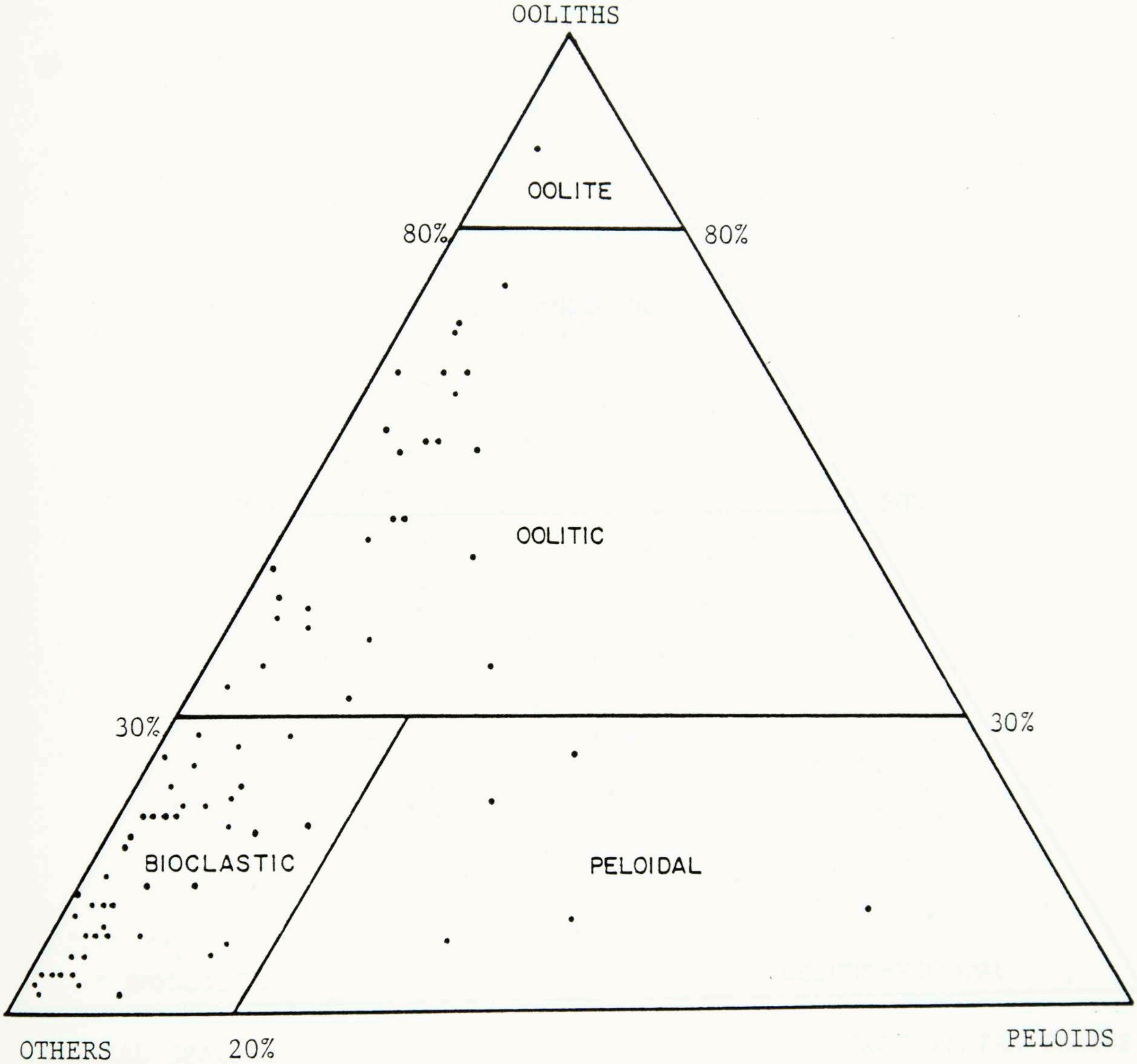
III

Textural analysis of the Pitkin Limestone. All of the units of the measured sections of this study are plotted. There are two clusters of points, one represents grainstones and packstones, while the other represents wackestones and mudstones.



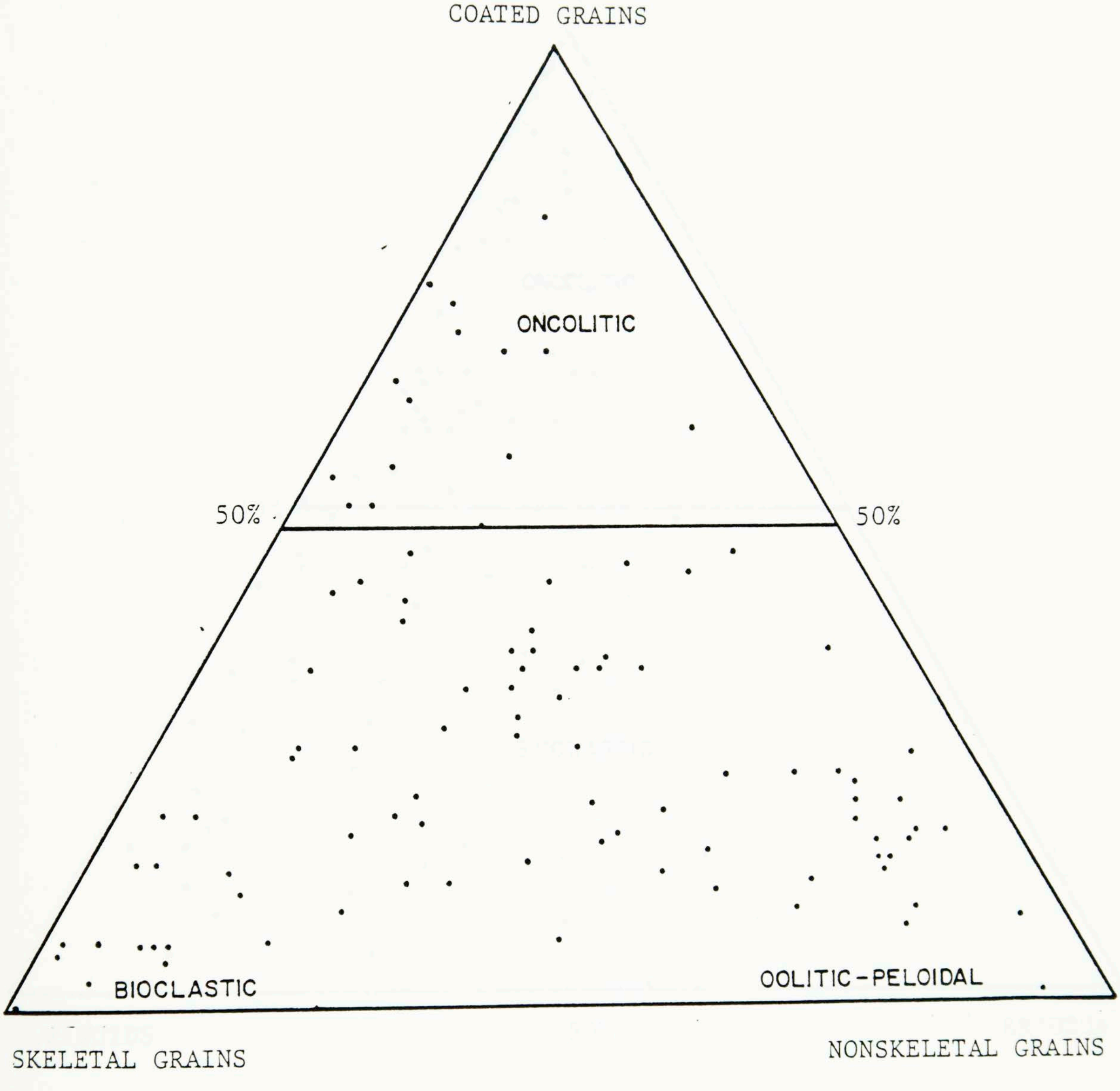
IV

Same as C-III except that only the thickest sections are plotted. There are fewer mud dominated units in this plot because the effects of the pre-Pennsylvanian unconformity has been removed.



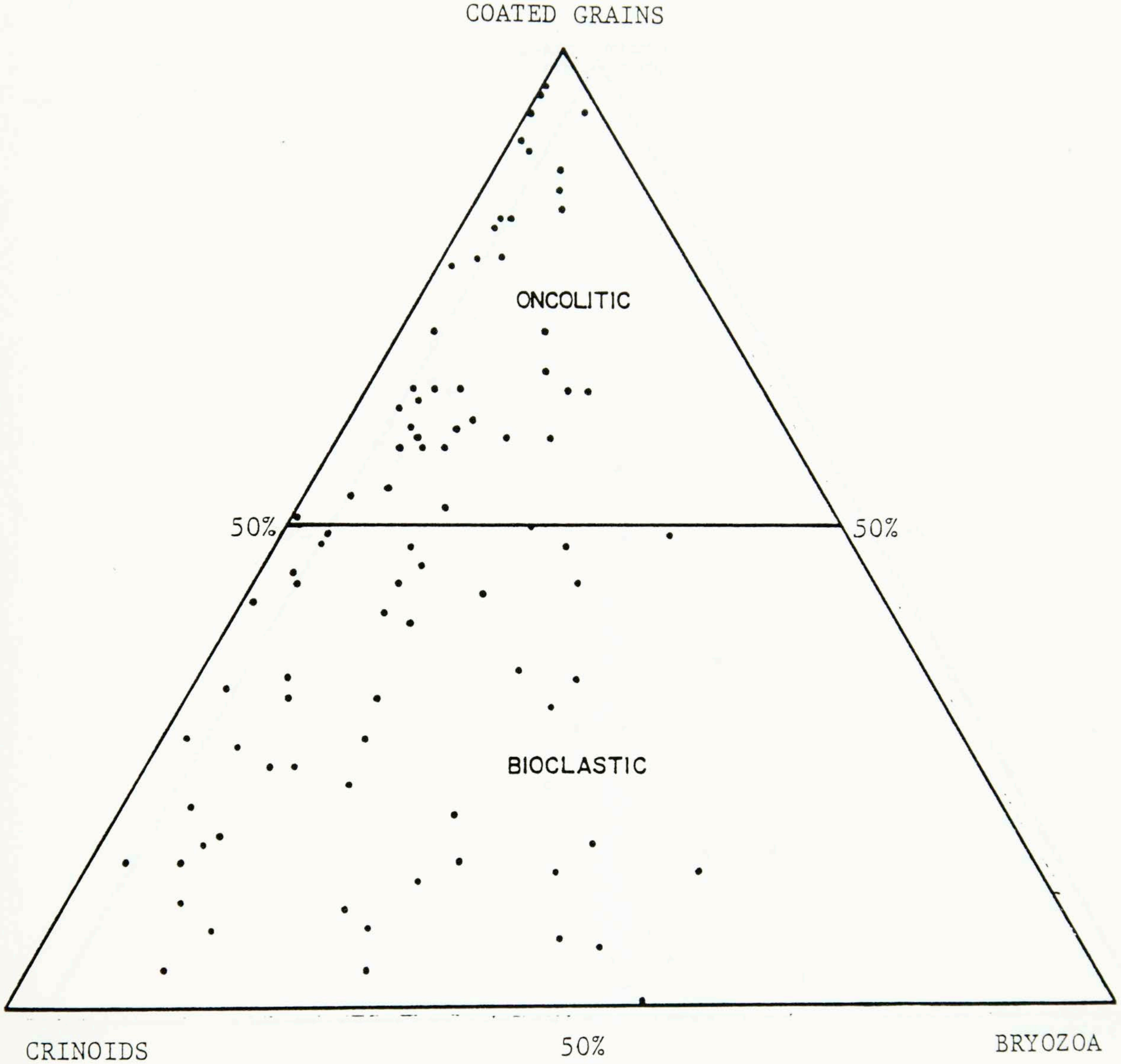
V

Allochem analysis of the Pitkin Limestone. Only grain dominated lithologies are plotted. This particular plot is used to define the Oolite, Oolitic, Bioclastic, and Peloidal Facies of Chapter III quantitatively. All but one of the units contain some peloids indicating that they are probably diagenetic rather than fecal in origin.



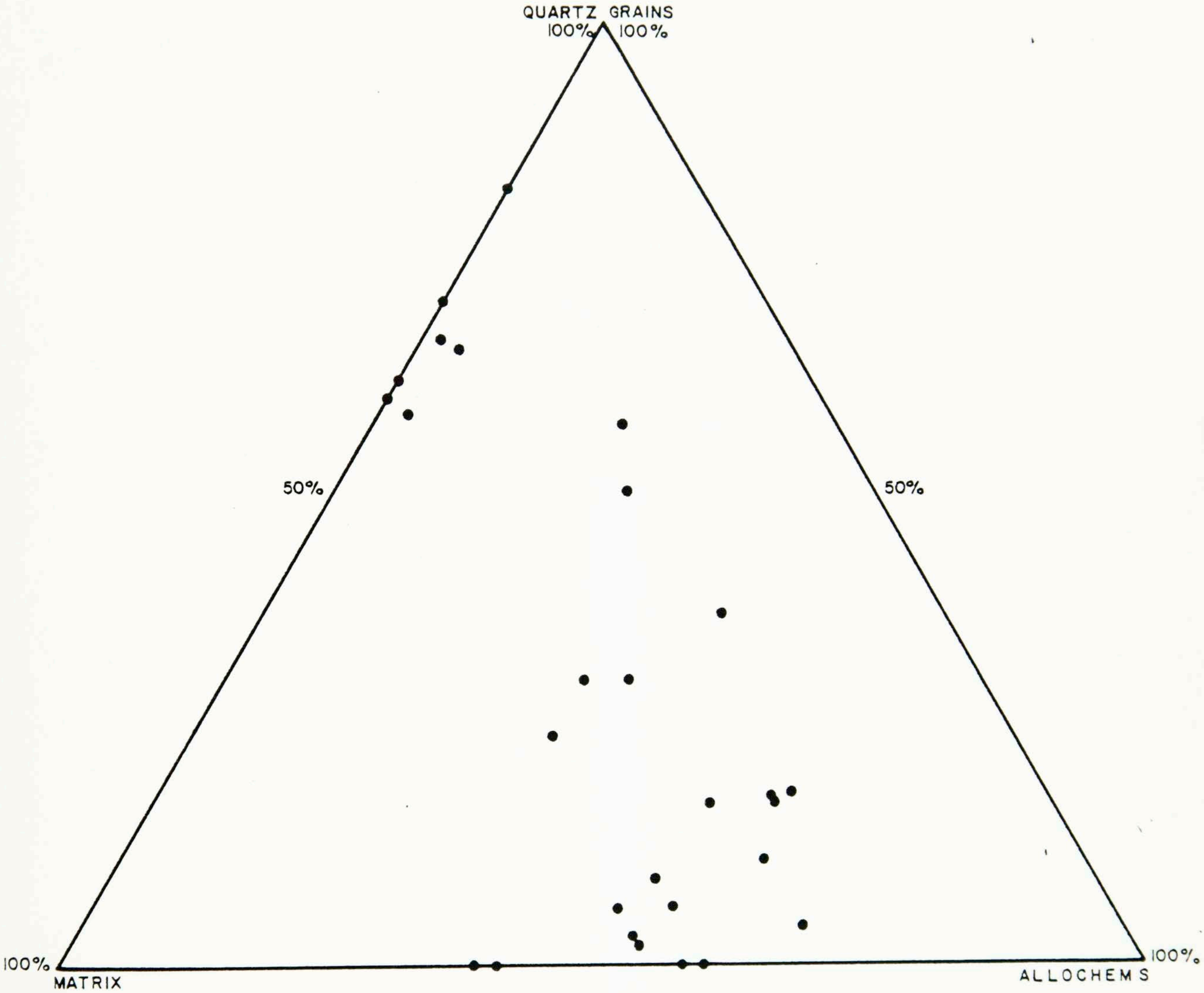
VI

Allochem analysis of the Pitkin Limestone. Note how the points are evenly distributed within the triangle. This plot is used to define the Oncolitic Facies quantitatively.



VII

Allochem analysis of the Pitkin Limestone. Coated grains, crinoids, and bryozoans are the most abundant grains in the Pitkin of this study area. Bryozoans are selectively encrusted by Girvanella therefore they are lacking in this plot. The points plotted in the portion of the diagram labeled "oncolitic" are mostly algal encrusted bryozoans.



VIII

Modal analysis of the basal Sausbee Formation lithologies. Each point is from one of the measured sections. The lithologies range from pure quartz sandstone to pure limestone. See Chapter V for a detailed explanation.

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