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RELATION OF BIOFACIES TO LITHOFACIES IN INTERPRETING DEPOSITIONAL ENVIRONMENTS IN THE PITKIN LIMESTONE (MISSISSIPPIAN) IN NORTHEASTERN OKLAHOMA

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RELATION OF BIOFACIES TO LITHOFACIES IN INTERPRETING DEPOSITIONAL ENVIRONMENTS IN THE PITKIN LIMESTONE (MISSISSIPPIAN) IN NORTHEASTERN OKLAHOMA

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APPROVED FOR THE SCHOOL OF GEOLOGY AND GEOPHYSICS

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ABSTRACT

This thesis provides a detailed community analysis of the Pitkin Limestone (Chesterian) in northeastern Oklahoma. Three communities were identified and distinguished from each other based on faunal rank abundances and composition. Paleoenvironmental interpretations were made from the community and lithofacies information.

The _Ovatia_-_Sphenotus_ Community is composed primarily of brachiopods and pelecypods. This community is associated with the mudstones and wackestones of the Pitkin. The community was located in the quiet waters and muddy substrate of the open marine shelf below normal wave base. Distribution of the community is widespread across the study area. The _Ovatia_-_Sphenotus_ Community represents the initial stabilization and colonization stage in the total community's succession.

The _Pentremites_-_Composita_ Community is composed of bryozoans, echinoderms and brachiopods. This community is associated with the bryozoan crinoidal packstones and grainstones of the Pitkin. The abundance of the stalked echinoderms and the bryozoan _Archimedes_ indicates the community was located in shallow, open marine waters near normal wave base. The community is widely distributed across the study area and the thick accumulations indicate a long period

of community stability. The Pentremites-Composita Community represents the diversification stage in the total community succession.

The third community is the Ovatia-Diaphragmus Community and is composed primarily of brachiopods, crinoids, and pelecypods. The community is associated with the mixed skeletal bioclastic lithofacies and the oolitic packstones. The disappearance of the corals, blastoids, and the reduced numbers of bryozoans indicate this was a more stressful environment than those of the previous community. This community lived in a moderately turbulent environment near normal wave base and in close proximity to the abundant ooid shoals. The community is also widely distributed across the study area and developed thick accumulations. The Ovatia-Diaphragmus Community represents a regressive stage in the total community's succession due to the greater effects of the physical environment on the fauna.

It is proposed that topographic highs in western Adair County (Clupper, 1978) and southern Cherokee County (Nageotte, (1981) affected the development and distribution of the communities during the Pitkin. The higher energy communities, the Pentremites-Composita and Ovatia-Diaphragmus Communities, developed earlier in the Pitkin in the areas associated with these highs. The initial development of these two communities on the basinward, southern and western, sides of the highs suggests that the major ocean current patterns were from the south and west.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

Plate | Page

RELATION OF BIOFACIES TO LITHOFACIES IN INTERPRETING DEPOSITIONAL ENVIRONMENTS IN THE PITKIN LIMESTONE (MISSISSIPPIAN) IN NORTHEASTERN OKLAHOMA

CHAPTER 1

INTRODUCTION

Nature of the Problem

Northeastern Oklahoma is a geologically important area in which the Mississippian-Pennsylvanian unconformity and the strata immediately above and below are well exposed at the surface. The Pitkin Limestone (Chesterian) represents the uppermost Mississippian in this area and crops out in an arc along the southern and southwestern flanks of the Ozark Uplift in northeast Oklahoma (Sutherland and Manger, 1979). In recent years extensive study has been carried out on the Pitkin in both Oklahoma and Arkansas. There have been three previous theses done at the University of Oklahoma on the lithostratigraphy and depositional environments of the Pitkin Limestone in northeastern Oklahoma. This research has resulted in the characterization of the limestones of the Pitkin as dominantly bioclastic and oolitic grainstones along with discussions of the depositional environments based on interpretations of lithofacies (Clupper, 1978; Orgren, 1979, Nageotte, 1981). However, little has been done with faunal and paleoecological aspects of the Pitkin Limestone and their relationships to these lithofacies.

The purposes of this thesis are to extend the previous studies by relating megafaunal distributions to the previously designated lithofacies, to determine their paleoecologies and thus to provide a more broadly based evaluation of the depositional environments in the Pitkin Limestone.

Location of the Study Area

The study area is situated in northeastern Oklahoma along the flanks of the Ozark Uplift. It covers most of Cherokee County plus southern Adair, northern Sequoyah, northeastern Muskogee and northeastern Wagoner Counties (Fig. 1). Included in the study area are townships 14 to 18 North and ranges 19 to 12 East. The area is approximately 760 square miles (1960 square kilometers) in size.

In general, rocks dip away from the axis of the uplift which runs from Tahlequah northeast to the St. Francis Mountains. The Pitkin Limestone is discontinuously exposed at the surface in the area due primarily to northeast trending faulting and folding of the strata. The Pitkin Limestone thins to the north and northeast due to regional truncation during early Pennsylvanian time and tends to thicken to the south and southwest towards what was a basin at the time of deposition.

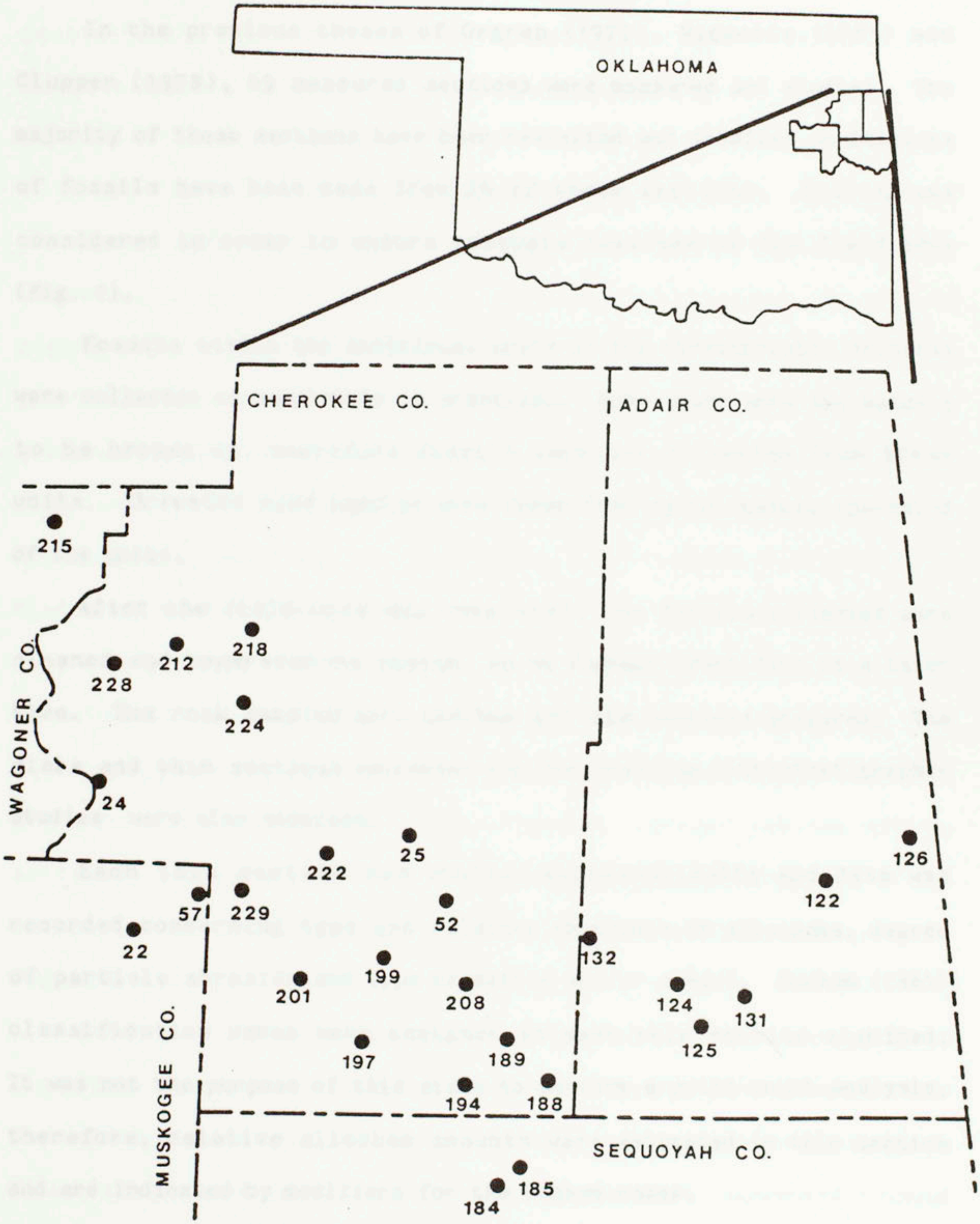


Figure 1. Location of the study area and location of the measured sections within the study area.

Methods of Investigation

In the previous theses of Orgren (1979), Nageotte (1981) and Clupper (1978), 69 measured sections were measured and studied. The majority of these sections have been revisited and detailed collections of fossils have been made from 26 of these sections. Spacing was considered in order to ensure adequate coverage of the field area (Fig. 1).

Fossils within the individual units of the stratigraphic sections were collected as completely as practical. Some units were too massive to be broken up, therefore fossils were not collected from these units. Oriented hand samples were taken from approximately one-third of the units.

After the field work was completed, the fossils collected were cleaned and separated by phylum, to be further identified at a later time. The rock samples were slabbed and thin sections prepared. The slabs and thin sections collected for the previous lithostratigraphic studies were also examined.

Each thin section was studied microscopically and data was recorded concerning type and relative abundance of allochems, degree of particle abrasion and type of matrix and/or cement. Dunham (1961) classification names were assigned to each thin section examined. It was not the purpose of this study to perform a point count analysis, therefore, relative allochem amounts were estimated in thin section and are indicated by modifiers for the Dunham names.

The fossils collected were further identified by the use of photographs and detailed generic descriptions provided in various publications. It was decided that for the purposes of this study, identification of fossils to the genus level with notation of more than one species, if present, would be adequate.

Previous Investigations

Adams and Ulrich (1904) were the first to use the term Pitkin Limestone in place of the older "Archimedes Limestone" in order to comply with the rules of stratigraphic nomenclature. The formation was named for the town of Pitkin, in Washington County, Arkansas, near presumed exposures of the formation. It was determined at a later time that the exposures at the town of Pitkin were actually of Pennsylvanian age; the name, however, was retained for the highest Mississippian limestones in the area.

Snider (1915) worked with the Pitkin Limestone of northeastern Oklahoma. He discussed the generalized lithologies of the Mississippian strata as well as the trends associated with the Mississippian-Pennsylvanian unconformity. Snider was one of the earliest investigators to do detailed paleontological studies of the Chesterian Series. This included numerous plates, faunal lists and descriptions.

Buchanan (1927) discussed the distribution and correlation of the Pitkin Limestone in Oklahoma. Regional relationships of the Pitkin were established by Roth (1929) when he correlated the Mississippian faunas of Oklahoma and Arkansas. L. R. Laudon (1941) described crinoid species found in the Pitkin and Hale Formations in northeastern Oklahoma.

Easton (1941, 1943) extensively studied the fauna and stratigraphy of the Pitkin in Arkansas. Lengthy faunal lists and descriptions were given and he noted the variable lithic characteristics. Easton reconstructed the paleoecology of the late Chesterian seas and proposed ecologic barriers causing a difference in coral faunas of the Pitkin from the Mississippian Valley type section.

Detailed mapping of all Paleozoic formations in northeastern Oklahoma was done in the early 1950s in preparation for the publication of a new state geological map by a number of Master's students at the University of Oklahoma. Their maps and stratigraphic interpretations were summarized by Huffman (1958). R. B. Laudon (1958), using primarily subsurface information, interpreted the Carboniferous stratigraphy at the shelf to basin transition in the Arkoma Basin of eastern Oklahoma.

Lane (1967) and Lane and Straka (1974) made a study of the conodont faunas of the Chesterian and Morrowan strata in Arkansas and Oklahoma. These investigations have resulted in conodont zonations of the Upper Mississippian and Lower Pennsylvanian sequence in the area. Sutherland and Manger (1977) edited a guidebook that contains summary articles concerning paleontology, biostratigraphy and lithostratigraphy of the Upper Mississippian and Lower Pennsylvanian in Oklahoma and Arkansas.

Three Master's theses have been completed at the University of Oklahoma specifically on the Pitkin Limestone. The studies by Clupper (1978), Orgren (1979) and Nageotte (1981) deal with the lithostratigraphy and depositional environments of the formation primarily in Adair, Cherokee and Muskogee Counties of Oklahoma.

Stratigraphy of the Chester Series

The stratigraphic succession found in the Chester Series include the Meramecian-Lower Chesterian Moorefield Formation, the Chesterian Hindsville, Fayetteville, and Pitkin Formations (Fig. 2). The southwest flank of the Ozark Uplift, where the study area was located, was a shallow shelf where carbonate deposition dominated during the Chester. There does not appear to have been any severe tectonic movement in the region to affect deposition during this time.

The Moorefield Formation, where present in Oklahoma, is partly Meramecian and Chesterian. The middle and upper portions of the Moorefield contain ammonoid assemblages which are of the lowest Chesterian and equivalent to the upper Visean P_{1c} Subzone and lower P_2 Zone of the western European Carboniferous section (Saunders and others, 1977). Huffman (1958) divided the Moorefield Formation into four members; the Tahlequah, a glauconitic limestone, the Bayou Manard, an argillaceous limestone, the Lindsey Bridge, a cherty calcarenite, and the Ordance Plant, a siltstone.

Turmelle (1982), in a study of the lower Chester in Adair County, was unable to find any physical evidence of an unconformity between the Moorefield and Hindsville formations. Biostratigraphic studies of this interval have not helped clarify the nature of the boundary. Turmelle (1982) concluded that Huffman's (1958) Moorefield members are laterally intertonguing facies controlled by pre-Moorefield topography and therefore the contact between the Moorefield and

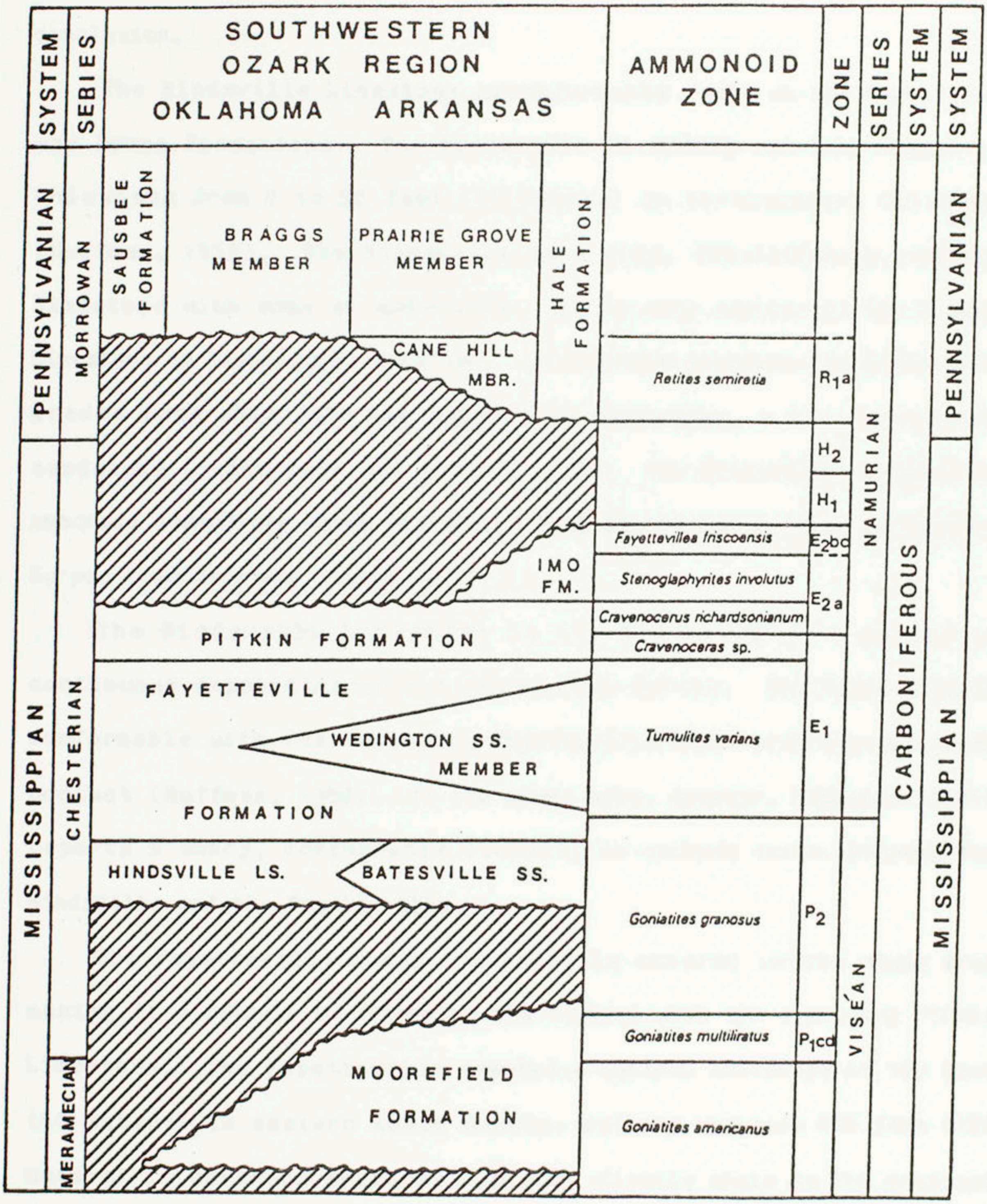


Figure 2. Stratigraphic column of northeastern Oklahoma and northwestern Arkansas. Modified from Sutherland and Manger (1979).

Hindsville is conformable. Further studies are needed to confirm this conclusion.

The Hindsville Limestone unconformably rests on the Moorefield and Boone Formations. The Hindsville is widespread and ranges in thickness from 0 to 50 feet (15 meters) in northeastern Oklahoma (Huffman, 1958). The Hindsville is a gray, fossiliferous, oolitic limestone with some crossbedding. It is very similar to the Pitkin Limestone in lithologic character. In northern Arkansas the Hindsville grades laterally into the Batesville Sandstone, a tan, quartzose sandstone (Sutherland and others, 1979). The Hindsville contains an ammonoid assemblage which correlates with the Visean P_2 Zone of western Eurpoe (Saunders and others, 1977).

The Hindsville Limestone is the beginning of a period of continuous deposition in the Chesterian Series. The Hindsville is conformable with the overlying Fayetteville Shale with a gradational contact (Huffman, 1958). In the study area, however, Nagoette (1981) reports a sharp, conformable contact, in certain areas, between the Hindsville and the Fayetteville.

The Fayetteville Shale typically is covered in the study area making it difficult to determine its contact with the overlying Pitkin Limestone. The Fayetteville reaches a maximum thickness of 165 feet (50 meters) in eastern Adair County, but may approach 400 feet (120 meters) in northern Arkansas. Black, fissile shale is the dominant lithology with thin beds of blue-black, carbonate mudstone at the base and top of the formation. The limestones of the Fayetteville are typically only a few inches thick and consist of fine grained mudstones and wackestones. The deltaic Wedington Sandstone Member occurs in the upper-middle portion of the Fayetteville in Washington County, Arkansas, where it has a maximum thickness of 80 feet (24 meters). The westernmost limit of the Wedington extends into easternmost Adair County, Oklahoma as a thin wedge (Huffman, 1958).

Overall, the Fayetteville Shale is not very fossiliferous, but is correlated with the lower portion of the Namurian E_1 Zone of western Europe (Saunders and others, 1977). Where the contact of the Fayetteville with the overlying Pitkin is not covered, the contact is believed to be gradational. The Fayetteville-Pitkin boundary is somewhat arbitrary, but in this study was taken to be that point where the shale partings between the limestone beds were not more than several inches thick.

The Pitkin Limestone ranges in thickness from 0 to over 60 feet (18 meters) in surface exposures in northeastern Oklahoma. North of Wagoner and Cherokee Counties the Pitkin is absent due to truncation below Lower Pennsylvanian strata. The formation thickens significantly to the southeast, in the subsurface of northwestern Arkansas (Fig. 3). The Pitkin is dominantly a dark gray, bioclastic and oolitic limestone with lesser amounts of mudstone and wackestone.

In the study area the Pitkin Limestone represents the uppermost Mississippian and is unconformably overlain by Lower Pennsylvanian Morrowan Series. The Pitkin has been correlated with the upper Namurian E_1 Zone and the lower Namurian E_{2a} Zone of western Europe based on both conodonts (Lane, 1977) and ammonoids (Saunders and others, 1977).

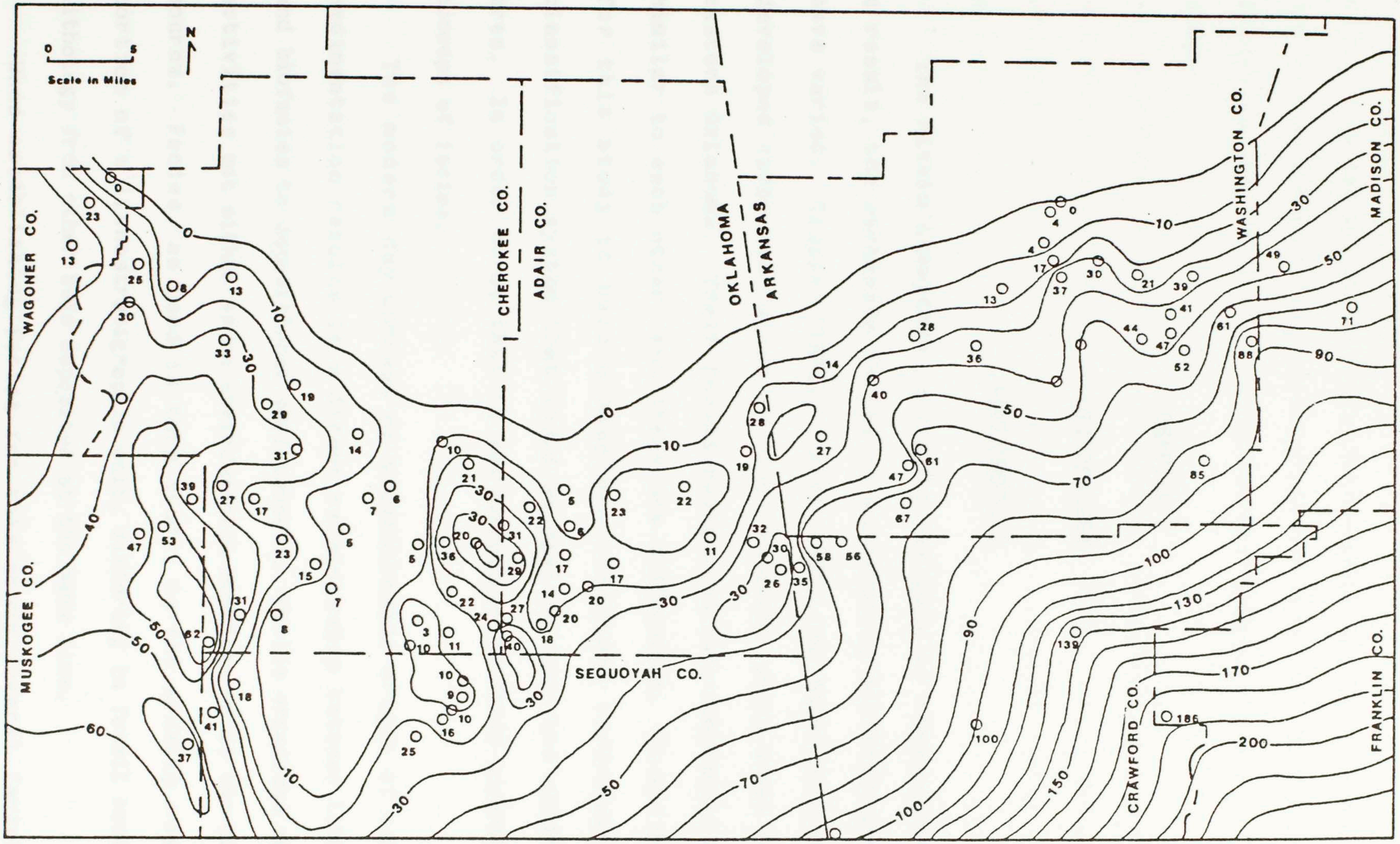


Figure 3. Regional isopach map of the Pitkin Limestone. Modified from Nageotte (1981), Plate 13.

CHAPTER 2

LITHOFACIES

Introduction

The Pitkin Limestone is highly variable in composition and as a result, the carbonate facies as decribed by different geologists have varied. Clupper (1978), Orgren (1979), and Nageotte (1981) each developed carbonate facies in their adjacent study areas in northeastern Oklahoma. Their facies categories have components that are similar to each other, but there are differences. It was desirable for this study to have a single, consistent carbonate facies classification system that could be applied over the entire study area. In order to do this it was necessary to first understand the concept of facies.

The modern day concept of autochthonous origin of carbonate sedimentation results in a direct relationship between lithofacies and biofacies to depositional environments. Marine organisms and their activities act either as an environmental modifier or as the carbonate source. Facies, as used in this study, is the areally restricted portion of a lithostratigraphic unit, differing in fossil content and lithology from other beds deposited at the same time.

When establishing facies for this study several factors were used: the texture of the rock, allochemical analysis of thin sections and slabs, both as to allochem type and quantity, and comparison of facies as described in previous theses on the Pitkin in the area of study.

Allochems were carefully observed for quantity and associations with other allochems and matrix. There are a number of references available to aid in the identification of fossils, ooids, pellets, and other allochems in thin section. The quantity of a particular allochem is expressed as a percentage of the total amount of allochems and it has been visually estimated. While this method is not as accurate as point counting, it is nevertheless adequate for the purposes of this study.

It should be noted, however, that care must be taken when comparing relative abundances of the various allochems. Bathurst (1975) noted that the dominant sediment producer is selectively preserved, whether it is delicate or robust. In modern reefs the algae Halimeda is a dominant carbonate producer, but it composes less than 15 percent of reef biota. In spite of this, it is still possible to make useful interpretations of lithofacies and biofacies from relative abundances.

The textural analysis of limestones centers around Dunham's (1961) classification which compares the presence or absence of mud to the hydraulic environment. Calm water allows mud to settle to the bottom and accumulate there. Dunham further subdivides the textural classification by abundance of grains and whether they are mud or grain supported. Caution should be used when applying these concepts as the amount of mud preserved is not invariable related to hydrologic environment at the time of deposition. Attention must also be paid to sorting, abrasion and coating of associated grains. Possible diagenesis of micrite to microsparite should also be noted as this is not obvious in Dunham's classification.

Nine facies are recognized in the Pitkin Limestone in this study area. These are: 1) Oolite Facies, 2) Oolitic Facies, 3) Bioclastic: mixed Facies, 4) Bioclastic:oncolitic Facies, 5) Bioclastic:bryozoan-crinoidal Facies, 6) Pelletal Facies, 7) Wackestone Facies, 8) Mudstone Facies, and 9) Shale Facies (Table 1).

Oolite Facies

The oolite facies is a grainstone with greater than 80% ooids and less than 20% skeletal grains or pellets (Table 1). This facies is not very abundant in the Pitkin, but it is important in interpreting depositional environments. This facies corresponds to the oolite facies of Clupper (1978) and Nageotte (1981), and the crinoidal-oolitic grainstone facies of Orgren (1979).

The oolite facies is typically well sorted, with concentric ooids dominating (Pl. 4, Fig. 6). Nuclei of ooids are dominantly skeletal grains with peloids the second most common. The observed diameter of ooids averages 0.5 to 0.6 mm.

Study of recent oolites, particularly in the Bahamas, indicate that the formation of ooids is related to current agitation and super-saturation of the sea water with calcium carbonate (Bathurst, 1975). The scarcity of skeletal grains tends to indicate that the sea water

FACIES \ ALLOCHEMS	Ooliths	Skeletal	Oncolites	Pellets	Bryozoa-Crinoids
Oolite	>80%	<20%	<20%	<20%	--
Oolitic	>30% <80%	>20% <80%	--	30%	--
Bioclastic:					
Mixed	<30%	>70%	<30%	<30%	<40%
Oncolitic	<30%	>70%	>30%	<30%	<40%
Bryozoan-Crinoidal	<30%	>70%	<30%	<30%	>40%
Pelletal	<30%	<30%	<30%	>70%	<30%
Wackestone	>10% allochems				
Mudstone	<10% allochems				

TABLE 1. Pitkin Lithofacies.

is supersaturated with calcium carbonate and ooid formation indicates turbulent waters perhaps as shallow as 6 to 7 feet (Purdy, 1963).

This facies is interpreted as representing shoals composed of ooids that were buffeted by strong tidal or open ocean currents. These currents over the shoals would have caused the substrate to be in a state of mobility that was not suitable to most forms of marine life. Much of the skeletal material found in these oolites were most likely transported from nearby areas. Cross-bedding is a characteristic feature.

Oolitic Facies

The oolitic facies are grainstones or packstones with ooids comprising greater than 30% but less than 80% of the allochem composition. Other allochems found may be pellets, oncolites or algal coated grains, or a variety of skeletal grains (Pl. 3, Fig. 13). Allochems, other than ooids, are found in amounts greater than 20% but less than 70% of the total allochem content (Table 1). This facies is very common in the Pitkin and corresponds to the oolitic facies of Nageotte (1981), the mixed skeletal-oolitic facies of Clupper (1978), and the crinoidal-oolitic grainstone and oncolitic pelloidal-oolitic grainstone facies of Orgren (1979).

The greater amounts of skeletal grains in the oolitic facies implies a greater stability of the substrate than that found in the oolite facies and consequently the occurrence of a larger, more diverse fauna (Purdy, 1964). The oolitic facies includes both grainstones and packstones with packstones indicating a somewhat quieter, less turbulent marine environment than that represented by oolitic grainstones.

Oolitic grainstones commonly exhibit cross-bedding, as well as a high ooid content, and is interpreted as representing a shoal or near shoal environment similar to that of the oolite facies. The ooid content of these grainstones typically falls in the 70 to 80 percent range with a general absence of carbonate mud.

Oolitic packstones seem to represent the most stable substrate of this facies, with the diversity and abundance of fauna greater than that found in the oolitic grainstones. Algae is common in the Pitkin and it could be that algae helped bind the sediments, increasing their stability. The oolitic packstones generally do not exhibit cross-bedding and typically have an ooid content of 50 to 60 percent, with a correspondingly higher skeletal content. Crinoids, bryozoans, brachiopods, and pelecypods are the most commonly observed fossils. The oolitic packstones are interpreted as representing an environment that was located a greater distance from the oolite shoals than that represented by the oolitic grainstones. This muddy oolitic facies could represent the platform side of the shoal since the carbonate mud matrix content is greater and the ooid content is less than that found on the lagoon side of the shoal in modern carbonate sediments (Purdy, 1964). The ooids were probably transported into the muddier environment by storms or flood tides.

Bioclastic:mixed Facies

The bioclastic:mixed facies includes those packstones and grainstones that have an allochem content dominated by skeletal grains (Table 1). The allochem content is composed of greater than 70% skeletal grains with less than 30% ooids, oncolites, pellets, and less than 40% bryozoan and crinoid grains (Pl. 3, Fig. 14). This facies corresponds to the bioclastic and encrinite facies of Nageotte (1981), the linoproductid-spiculiferous subfacies of Clupper (1978), and the spiculite, mixed skeletal packstone and grainstone facies of Orgren (1979).

Brachiopods, pelecypods, and foraminifers are the most abundant skeletal component of this facies. The presence or absence of micrite and the dominant skeletal grains are important in interpretng the several depositional environments that may be represented by this facies. The presence of coated or abraded grains suggests turbulent water and possible transportation of the grains.

The bioclastic:mixed facies is interpreted as representing both a shelf facies deposited seaward of oolite shoals and a shelf lagoon facies deposited landward of such shoals. Environments of the first type are found near normal wave base with good current circulation (Wilson, 1975). Lithologic textures are variable, but in the Pitkin the bioclastic:mixed facies consist predominantly of packstones. The fauna of this environment would be diverse and locally abundant, with the presence of brachiopods, corals, and echinoderms indicating normal marine salinities. In the second case, that of the shelf lagoon facies, water would have been shallow, open with moderate circulation and normal to slightly above normal salinity (Wilson, 1975). Lithologic textures are variable. The fauna of this environment is diverse and locally abundant, but organisms requiring normal marine salinities, such as brachiopods, echinoderms, and cephalopods, would be rarer than in the shelf facies (Wilson, 1975).

Bioclastic:oncolitic Facies

The bioclastic:oncolitic facies includes packstones and grainstones that have an allochem content with greater than 70% skeletal grains and more than 30% of the grains have an algal or micritic coating (Table 1). This facies corresponds to the oncolitic facies of Nageotte (1981), gastropodal-oncolitic facies of Clupper (1978), and the oncolitic pelloidal-oolitic grainstone facies of Orgren (1979).

Coated grains in the Pitkin are either oolitic, oncolitic, or micritic. Oncolitic coats originate from a grain encrusted by algae or a combination of algae and foraminifera (Pl. 4, Figs. 1-4). Many of the oncolitic coats are of the form-genus Osagea seen as ellipsoidal or biscuit shaped colonies (Groves, 1983). Abundant algal tubes of the blue-green algae Girvanella are seen both encrusting skeletal grains and isolated in micrite. The alga helped trap mud as it encrusted a grain and this caused the microlaminations that follow the curvature of the grain.

Grains with micritic coats are included in the oncolitic facies. The formation of the micritic coats is probably due to the boring activity of blue-green, green, and red algae (Klement and Toomey, 1964). Mud fills the tubes after the algae dies giving the micritic rind appearance of these grains. While these micritic coats are not algal encrustations they do result from the activity of algae, which justifies including them in this facies.

The allochems most frequently found encrusted are bryozoan fragments and to a much lesser extent crinoid ossicles or shell fragments. The presence of Girvanella and Osagia oncolites are suggestive of open marine platform (Flugel, 1977), in areas that are subtidal or low intertidal.

Oncolites require frequent movement, usually by currents or waves, to form their laminated appearance. Water depths were probably very shallow at the time of deposition. How frequently the oncolites are agitated will determine whether the laminations are inverted, random, or concentric (Logan and others, 1962). Oncolites probably develop in less turbulent water than do ooids, as oncolites may be found in wackestone and packstones, as well as grainstones (Flugel, 1977).

Bioclastic:bryozoan-crinoidal Facies

The bioclastic:bryozoan-crinoidal facies includes packstones and grainstones that have an allochem content with greater than 70% skeletal grains of which greater than 40% are bryozoans and/or crinoids (Table 1). Other allochem grain types are less than 30% of total allochem content. The bioclastic:bryozoan-crinoidal facies corresponds to the bryozoan-crinozoan subfacies of Clupper (1979), the bioclastic facies of Nageotte (1981), and the bryozoan-crinoidal packstone facies of Orgren (1978).

This facies is distinctive and easily recognizable based on the common occurrence of bryozoans and crinoids (Pl. 2, Fig. 13). Bryozoans and crinoids may occur separately as the dominant allochem or in combination with the other. This facies is either a grainstone or more commonly a packstone. Fragments of the bryozoan Archimedes are abundant and perhaps the most distinctive faunal components in the Pitkin. Both bryozoans and crinoids were tall, flexible, suspension feeders that possessed similar holdfast systems and inhabited similar environments.

In the Pitkin fenestrate forms of bryozoans are common while ramose and branching forms are less common. In recent carbonate environments major environmental factors such as substrate, currents, turbulence, and rates of sedimentation are reflected in the growth forms of bryozoans (Schopf, 1969). Bryozoans and crinoids could attach to hard or soft substrates and required moderate currents (Ausich, 1980; Dodd and Stratton, 1981).

The bioclastic:bryozoan-crinoidal facies is interpreted as representing a shelf facies. Water is shallow with normal marine circulation and salinity (Wilson, 1975). The fauna of the facies is diverse and abundant.

Pelletal Facies

The pelletal facies are packstones and grainstones that contain greater than 70% pellets and less than 30% of all other types of allochems (Table 1). The term pellet refers to any cryptocrystalline carbonate grain that is less than 0.2 mm long and lacks an internal structure (Scholle, 1978). Included in this facies are peloids whose origin is not discernable. The pelletal facies corresponds to the peloidal facies of Nageotte (1981), the peloidal facies of Clupper (1978), and the oolith-intraclast pelloidal packstone facies of Orgren (1979).

Pellets are commonly fecal in origin, but some represent micritized grains (Pl. 4, Fig. 5). Textures of the pelletal facies are dominantly packstones with a few grainstones. Careful examination of the pellets' abundance, external features, and associations with other allochems may be helpful in determining whether they are micritized grains or of fecal origin. Fecal pellets would suggest a different depositional environment from micritized grains.

Modern depositional environments where pellets are found are quite varied. Pellets are common to abundant in supratidal, intertidal, and subtidal environments (Laporte, 1967). They are found primarily in restricted marine shoals and shelf lagoons (Wilson, 1975). A relatively calm hydrologic condition is indicated by the abundance of pellets and mud. Grasses and algae may be common, serving to help trap mud with various burrowing organisms inhabiting the substrate.

Wackestone Facies

The wackestone facies is any unit with greater than 10% allochem content, but is mud supported (Dunham, 1961). The allochems may be ooids, pellets, and/or skeletal grains (Table 1). The wackestone facies corresponds to the wackestone facies of Nageotte (1981), and the nodular wackestone facies of Orgren (1979). Clupper (1978) did not have a specific wackestone facies, but rather incorporated wackestones into other facies.

Rocks of the wackestone facies are variably bedded with the shale partings between the beds. There are local abundances of productid brachiopods and pelecypods with no abrasion or other signs of transportation indicating probable life positions. Spicules, bryozoans, and crinoids are common with the skeletal fragments commonly large to very large, which suggests little or no transportation of particles (Pl. 1, Fig. 16). Wackestones in the Pitkin may have the fossils homogenized due to bioturbation or in distinct laminations due possibly to infrequent strong currents.

The very nature of wackestone facies, few fossils with abundant mud, would indicate quiet hydrologic conditions. Wackestones may be found in shelf lagoons or deep shelf environments (Wilson, 1975). Wackestone facies in the Pitkin commonly occurs at the base or near the base of the formation. This close vertical stratigraphic proximity to the deep water environment of the Fayetteville would suggest that the wackestone facies is primarily a deeper shelf facies. The few wackestone facies found stratigraphically higher in the Pitkin may represent shelf lagoon environments (Wilson, 1975).

Mudstone Facies

The mudstone facies is any unit with less than 10% allochem content (Table 1). This facies corresponds to the mudstone facies of Nageotte (1981) and Clupper (1978), and the interbedded shale and carbonate mudstone facies of Orgren (1979). Allochems are sparse and may be of any type, but are typically skeletal grains (Pl. 1, Fig. 15).

Mudstones of the Pitkin are commonly wavy or thick bedded with less common layers of wackestones and packstones. Mudstones are deposited in areas of restricted marine circulation, generally below normal wave base. Other mudstones may represent quiet periods when mud is trapped and bound by shallow water grasses and algae alternating with more turbulent periods (Walker, 1974). Carbonate muds, due to their fluidity, are not suitable for many organisms, but deposit feeders may be attracted to them because of their organic content (Craig and Jones, 1966).

Mudstone facies undoubtedly represented a quiet water environment. It is important to determine deep shelf from shelf lagoon mudstones. Examination of the position of the mudstone facies in the vertical stratigraphic sequence, such as was described in the preceding wackestone facies section, is helpful in this determination.

Shale Facies

The shale facies of the Pitkin is relatively uncommon and is limited to thin beds of a few inches in thickness. They are lighter in color and are less fissile than those of the Fayetteville shales. The shales are found predominantly at or near the base of the Pitkin. Bryozoans, brachiopods and rugose corals are found locally in these shales.

The shale facies could possibly represent periods of brief increased clastic influx in quiet waters of open shelf or open shelf lagoon (Wilson, 1975). These shale facies could also represent periods of cessation of carbonate deposition while the normal slow influx of clastic material and faunal activity continued (Heckel, 1972). Climatic fluctuations or water depth variations may have been contributing factors.

CHAPTER 3

BIOFACIES AND PALEOECOLOGY

Introduction

This chapter will be concerned with the composition and distribution of the biofacies and communities of the Pitkin Limestone and paleoenvironmental interpretations. The major unit used is the biofacies, which is defined as the rock unit containing a community (Dodd and Stanton, 1981). Biofacies may be composed of one or more communities.

There are several types of communities dependent on pre- and post-burial factors affecting the fossils. These include a fossil community, residual fossil community, transported fossil assemblage and mixed fossil assemblage. For a detailed discussion of these communities see Fagerstrom (1964). Fossil communities and residual communities are the most useful in yielding information about paleoecology, community composition and community dispersion. A fossil community is an assemblage of fossils that belonged to the same ecological community in approximately the same relative percentages as when they were alive. A residual community is similar to the fossil community, but has experienced some winnowing of the smaller taxa. Transported and mixed fossil assemblages are of limited use, but may give information about energy conditions and sedimentary source areas at the time of deposition (Fagerstrom, 1964).

Present day marine benthic communities are dominated by soft body organisms that are not preserved after death (MacDonald, 1976). Little is known about comparable soft bodied organisms in the Carboniferous, but there is no reason to assume that they were not equally abundant. This lack of soft bodied organisms does not prevent the use of shelly organisms in community or paleoecological analyses (Boucot, 1981).

Determination of the composition of a community may be accomplished by a variety of methods. Cluster analysis of the presence and absence of the taxa (Mello and Buzas, 1968) and determination of relative and rank abundances of the taxa (Walker and Bambach, 1974) were the methods used in this study. Rank abundances, which of the taxa is most abundant, second, third, and fourth, and relative abundances of the taxa at each locality proved to be the most useful method for determining communities. The mean rank abundance is useful as a gauge of the regularity of dominance of the communities members (Walker and Bambach, 1974). After communities have been established it is then desirable to look at the paleoenvironment, community interaction, and community succession.

The Pitkin Limestone is composed of three biofacies, with each biofacies consisting of one community. These biofacies include:

the Brachiopod-Pelecypod Biofacies that is composed of the Ovatia-Sphenotus Community, the Crinoid-Bryozoan-Brachiopod Biofacies that is composed of the Pentremites-Composita Community, and the Brachiopod-Crinoid-Pelecypod Biofacies that is made up of the Ovatia-Diaphragmus Community. The Pitkin also consists of several lithofacies that were unfossiliferous or contained few identifiable fossils. These lithofacies include: oolite, oolitic grainstone, pelletal, shale, and some of the mudstones.

Brachiopod-Pelecypod Biofacies

Plate 1

The Brachiopod-Pelecypod Biofacies is made up of the Ovatia-Sphenotus Community (Table 2). Brachiopods and pelecypods characterize this biofacies with minor occurrences of gastropods, blastoids, corals, and bryozoans. The fauna was predominantly epifaunal, low level suspension feeders.

The Ovatia-Sphenotus Community is characterized by the productids Ovatia (Pl. 1, Fig. 5), Diaphragmus (Pl. 1, Fig. 4), and Buxtonia (Pl. 1, Fig. 9), the spiriferds Anthracospirifer (Pl. 1, Fig. 8), Composita (Pl. 1, Fig. 7), and Eumetria (Pl. 1, Fig. 2), and pelecypods (Pl. 1, Figs. 1, 10, 12) such as Edmondia, Sphenotus, Schizodus, and Aviculopecten. These six brachiopods and pelecypods consistently occur together and are widespread. The spirifid Torynifer (Pl. 1, Fig. 13), Camorphoria (Pl. 1, Fig. 3), and Dielasma (Pl. 1, Fig. 11), the davidsoneacean Orthotetes (Pl. 1, Fig. 14), and gastropods are not as widespread, but are locally

Table 2. Rank abundance and trophic position of Ovatia-Sphenotus Community, Pitkin Limestone.

Genus	Rank[1]	Trophic Position[2]
Ovatia genera	1	A
Diaphragmus elegans	2	A
Composita genera	3	B
Pelecypoda	4	B,C
Edmondia genera		
Sphenotus genera		
Schizodus genera		
Aviculopecten genera		
Torynifer setigera	5	B
Camorphoria genera	6	B
Orthotetes genera	6	B
Anthracospirifer genera	7	B
Dielasma genera	8	B
Buxtonia arkansana	9	A
Eumetria genera	10	B
Rugosochonetes genera	11	B
Eolissochonetes tumescens	11	B

[1] Rank is based on mean rank abundance.

[2] A - Semi-infaunal low level suspension feeders, B - Epifaunal low level suspension feeders, C - Infaunal low level suspension feeders.

Plate 1

Ovatia-Sphenotus Community

Figure 1: Pelecypod of Superfamily Trigoniacea, exterior right valve, X1.4. (MS 229, unit 7)

Figure 2: Eumetria costata, exterior of pedicle valve, X2. (MS 132, unit 3)

Figure 3: Camorphoria explanata, exterior of pedicle valve, X2. (MS 138, unit 2A)

Figure 4: Diaphragmus elegans, exterior of pedicle valve, X1. (MS 215, unit 5)

Figure 5: Ovatia ovatus, exterior of pedicle valve, X1. (MS 212, unit 3)

Figure 6: Rugosochonetes chesterensis, exterior of pedicle valve, X2. (MS 22, unit 6)

Figure 7: Composita subquadrata, exterior of pedicle valve, X2.2. (MS 189, unit 2)

Figure 8: Anthracospirifer pellansis exterior of pedicle valve, X1. (MS 22, unit 6)

Figure 9: Buxtonia arkansana, exterior of pedicle valve, X1. (MS 132, unit 3)

Figure 10: Pelecypod of Superfamily Pectinacea, exterior of left valve, X1.25. (MS 22, unit 8)

Figure 11: Dielasma illinoisensis, exterior of pedicle valve, X2. (MS 138, unit 2A)

Figure 12: Pelecypod of Superfamily Anatinocea, exterior of left valve, X1.2. (MS 215, unit 6)

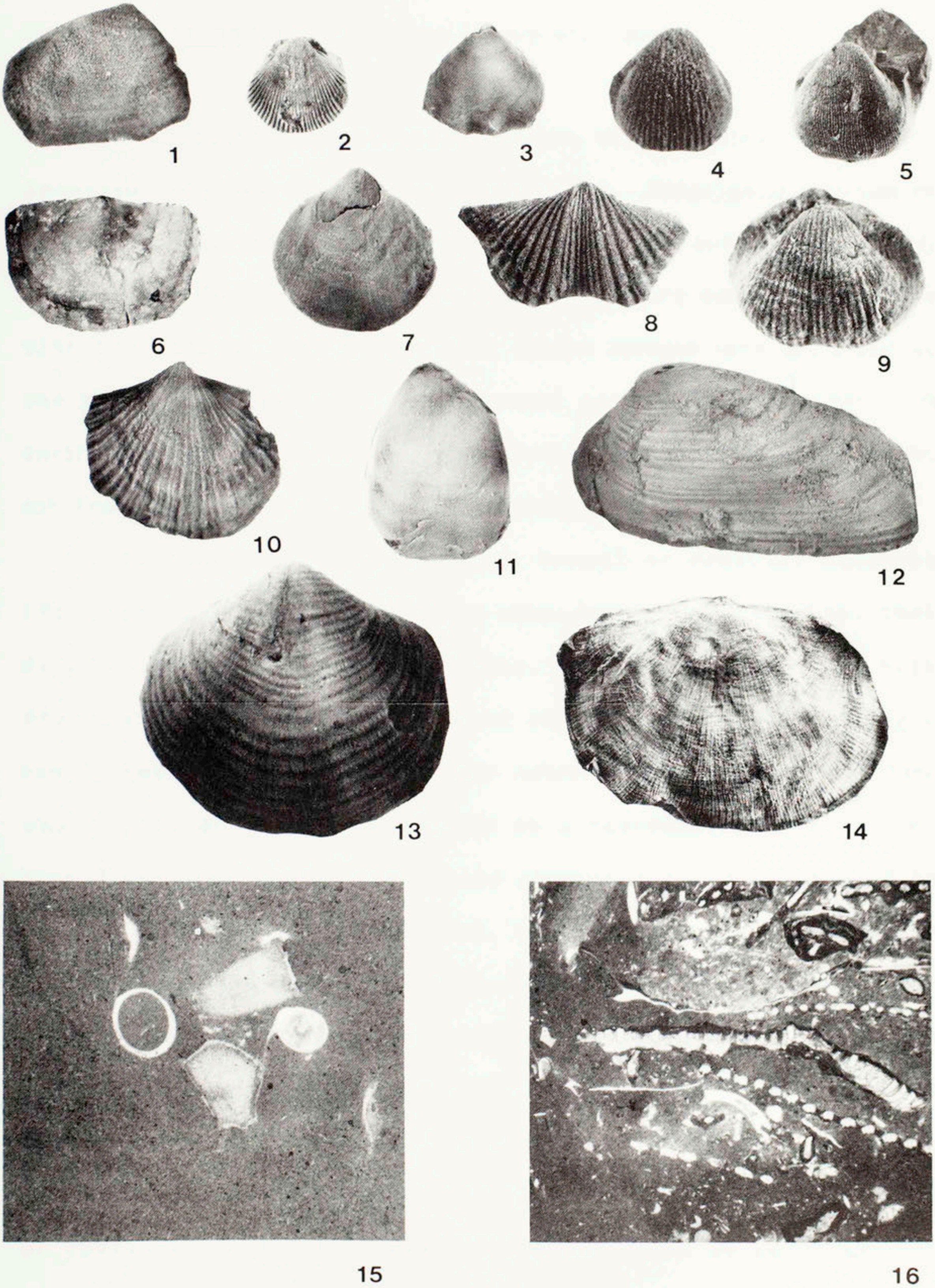
Figure 13: Torynifer setigera, exterior of pedicle valve, X2. (MS 212, unit 3)

Figure 14: Orthotetes subglobosus, exterior of pedicle valve, X1. (MS 22, unit 8)

Figure 15: Thin section of the Mudstone Facies. This specimen contains rare crinoid debris. Community fauna is limited to wackestone and packstone lenses within the mudstones, X6. (MS 22, unit 6)

Figure 16: Thin section of the Wackestone Facies. This specimen contains bryozoan, brachiopods, and carbonate mud, X6. (MS 224, unit 3)

PLATE 1



abundant and an integral part of the community. The chonetids Rugosochonetes (Pl. 1, Fig. 6) and Eolissochonetes, the rugose coral Barytichisma, trilobites, bryozoans, and blastoids are locally important.

The productid brachiopods dominate the community, representing approximately 64% of the taxa identified. Pelecypods comprise the largest group of fossils other than the brachiopods of this community. Sponge spicules are abundant and are commonly associated with the taxa of this community. Intact sponges were not found and the exact distribution of the sponges cannot be determined. The environment was of low energy, therefore sponge spicules were probably not transported from outside this community.

This community represents a fossil or residual community (Fagerstrom, 1964) based on a size-frequency histogram, shell disarticulation, faunal diversity, and lithofacies. The size-frequency histogram (Fig. 4-1) of the brachiopod Diaphragmus is nearly bell shaped and has a near symmetrical skewness (Folk, 1980) which indicates that this could be a residual community. In a significant portion of the shells it cannot be determined if the shells have been disarticulated, so this criteria is of limited value. Faunal diversity is high, with 34 brachiopod species, which is indicative of a fossil community (Fagerstrom, 1964). The lithofacies are mudstones and wackestones so currents were generally absent, weak or sporatic. The fossils showed little or no signs of abrasion indicating at most only a limited amount of transportation of fossils. With this assessment of the fauna it is thought that

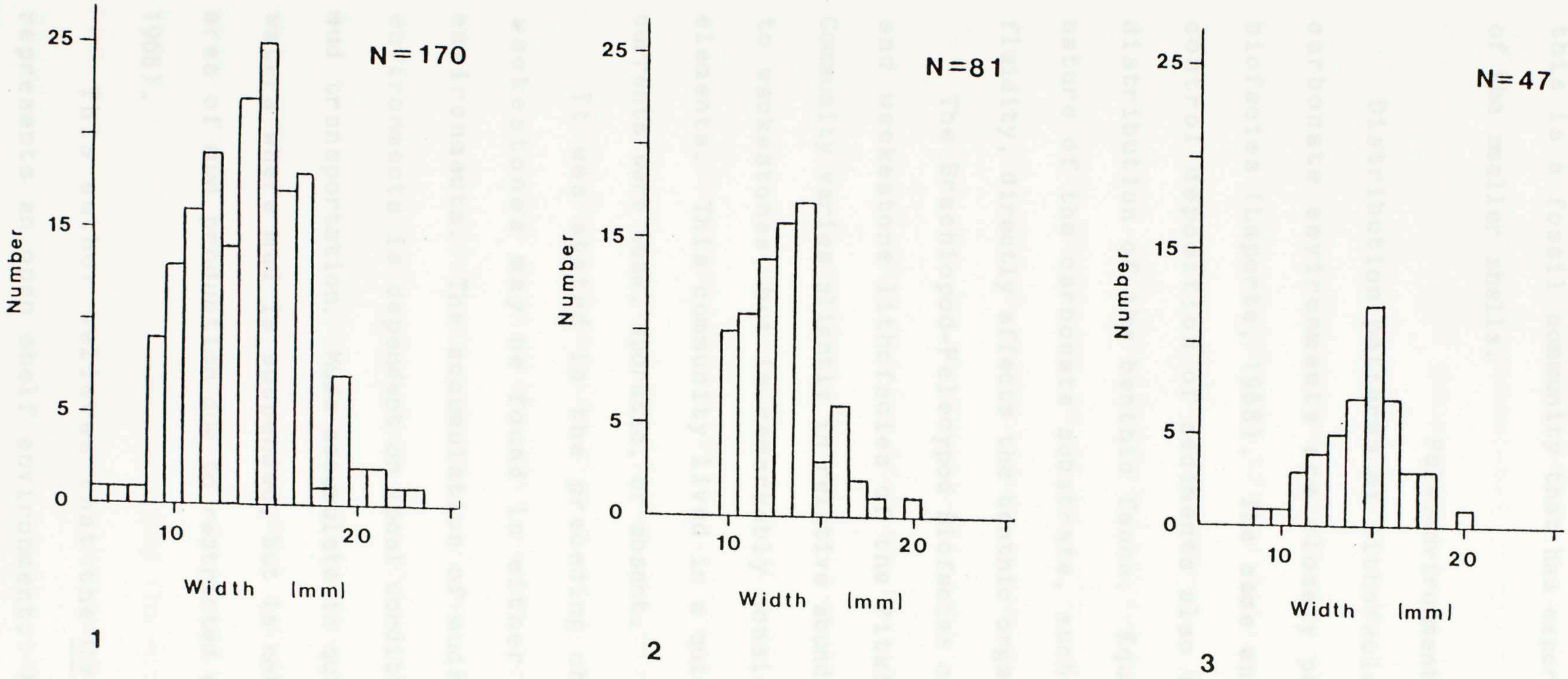


Figure 4. Size-frequency histogram of <u>Diaphragmus</u> <u>elegane</u>.
1 - <u>Ovatia</u>-<u>Sphenotus</u> community
2 - <u>Pentremites</u>-<u>Composita</u> community
3 - <u>Ovatia</u>-<u>Diaphragmus</u> community

this is a fossil community that has experienced only minor winnowing of the smaller shells.

Paleoenvironment

Distribution patterns of lithofacies in modern shallow water carbonate environments are closely paralleled by those of the biofacies (Laporte, 1968). The same environmental conditions that control deposition of sediments also affects the abundance and distribution of the benthic fauna. Equally important is that the nature of the carbonate substrate, such as the organic content and fluidity, directly affects the benthic organisms (Laporte, 1968).

The Brachiopod-Pelecypod Biofacies correlates with the mudstone and wackestone lithofacies of the Pitkin. The Ovatia-Sphenotus Community varies slightly in relative abundance of taxa from mudstones to wackestones, but is remarkably consistent in its major faunal elements. This community lived in a quiet, muddy environment where currents were weak, sporatic, or absent.

It was stated in the preceding chapter that mudstones and wackestones may be found in either open shelf or lagoonal environments. The accumulation of muds in modern shallow water environments is dependent on local conditions of water agitation and mud transportation. Muds accumulate in quiet waters and in turbulent waters where mud is suspended, but is not transported away from the area of mud production due to restricted water circulation (Laporte, 1968).

This author believes that the Ovatia-Sphenotus Community represents an open shelf environment. Modern day brachiopods are marine and live in normal marine salinities (Dodd and Stanton, 1981). The mudstones and wackestones of the Pitkin are stratigraphically close to the deeper water sediments of the Fayetteville. The faunal composition and stratigraphic position of the muds seem to support the open shelf environmental interpretation.

Within the mudstones of the Pitkin the fauna is found only in thin wackestone or packstone layers. The fossils show no signs of abrasion or of significant transportation, with some of the brachiopods appearing to be in life positions. This suggests that the fauna settled, established a community and then were covered by mud, either due to an occasional severe storm or because the rate of mud accumulation was too high for the community to survive.

In recent sediments the water content and therefore the fluidity of muds may be high, limiting the epifauna to those possessing special morphologic adaptations (Walker, 1974). The fauna associated with the muddy substrate of the Pitkin possessed a variety of morphologic adaptations to overcome the high fluidity of the muds (Fig. 5). These include small size, thin flat shape, spines, byssal or modified pedicle threads, and extended hinge. The productid brachiopods possessed spines and a deep cup shape which stabilized them (Fig. 5-2), inhibited their sinking into the mud and kept the anterior margin above the substrate (Muir-Wood and Cooper, 1960). The chonetid brachiopods have a thin, flat shape which allowed them to float on the mud (Fig. 5-1). Spines along the hinge helped anchor them into the mud and kept their anterior margin above the sediment. Anthracospirifer possessed an elongated hinge (Fig. 5-4) and

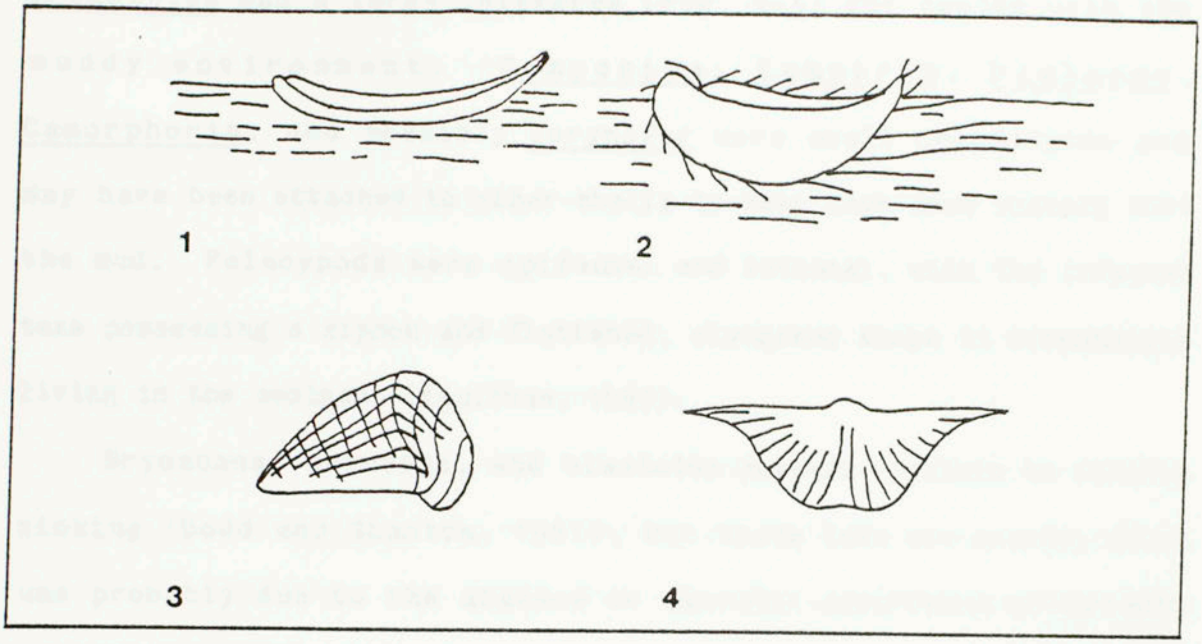


Figure 5. Morphological adaptations in brachiopods to prevent sinking into soft substrate. 1 - Thin, flat shape, 2 - spines, deep, cup-shaped lower valve, 3 - large, flat interarea, 4 - extended hinge. From Dodd and Stanton (1981, p. 70)

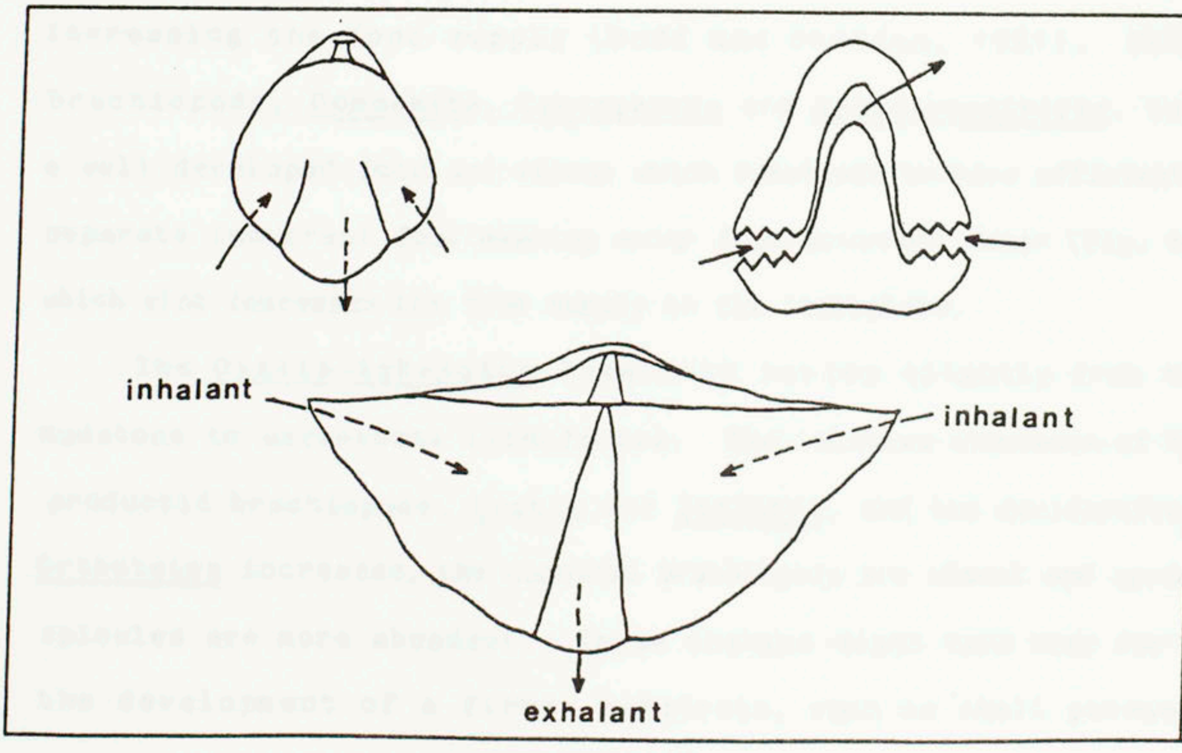


Figure 6. Current patterns produced by brachiopods in relation to the fold and sulcus. From Dodd and Stanton (1981, p. 73)

Orthotetes had a large interarea (Fig. 5-3) for coping with the muddy environment. Composita, Eumetria, Dielasma, Camorphoria, and possibly Torynifer were small brachiopods and may have been attached to other shells to keep them from sinking into the mud. Pelecypods were epifaunal and infaunal, with the infaunal taxa possessing a siphon and flattened, elongated shape to accommodate living in the sediment (Kauffman, 1969).

Bryozoans, crinoids, and blastoids possess rootlets to inhibit sinking (Dodd and Stanton, 1981), but these taxa are scarce, which was probably due to the absence or sporatic occurrence of currents needed to supply sufficient food. Brachiopods and pelecypods would have the same problem to some extent, however, many of the brachiopods possessed a highly developed lophophore which was able to increase current velocity of the water through the lophophore, effectively increasing the food supply (Dodd and Stanton, 1981). Other brachiopods, Composita, Camorphoria and Anthracospirifer, have a well developed fold and sulcus which functions to more efficiently separate incurrent food bearing water from excurrent water (Fig. 6), which also increases the food supply to the lophophore.

The Ovatia-Sphenotus Community varies slightly from the mudstone to wackestone lithofacies. The relative abundance of the productid brachiopods, Ovatia and Inflatia, and the davidsonicean Orthotetes increases, the chonetid brachiopods are absent and sponge spicules are more abundant. These changes might have been due to the development of a firmer substrate, such as shell pavement formation and reduced influx of mud allowing the community to become better established. This would have the effect of allowing the community to stabilize so that it persisted longer through time.

Crinoid-Bryozoan-Brachiopod Biofacies

Plate 2 and Plate 4, Figs. 1-4

The Crinoid-Bryozoan-Brachiopod Biofacies is made up of the Pentremites-Composita Community (Table 3). Echinoderms, bryozoans, and brachiopods characterize this biofacies with Girvanella and Osagia as important contributors to the community. Corals, trilobites, and pelecypods are less abundant, but are found throughout the biofacies. The fauna was predominantly epifaunal with high and low level suspension feeders. The abundance of the bryozoans, algae, and crinoids are difficult to quantify, therefore visual estimates were made of their relative abundances to determine their rank abundance within the community.

The Pentremites-Composita Community is characterized by an abundance of crinoids, bryozoans, and brachiopods that are widespread and consistently occur together. Bryozoans are dominated by the fenestellid Archimedes (Pl. 2, Fig. 14) with lesser abundances of treptosomes and cyclostomes. Crinoids are also very abundant, but due to their ease of disarticulation after death are very difficult to identify. The crinoid genera Agassizocrinus, Scytalocrinus and Bronaughocrinus are three of the more abundant of the genera reported by Laudon (1941), Easton (1943), and Strimple (1977) from the Pitkin Limestone.

Table 3. Rank abundance and trophic position of Pentrenites-Composita Community, Pitkin Limestone.

Genus	Rank[1]	Trophic Position[2]
Crinoids and Bryozoans[3]	1	D
Diaphragmus elegans	2	A
Composita genera	3	B
Ovatia genera	4	A
Pentremites genera	5	D
Buxtonia arkansana	6	A
Barytichisma species	7	B
Camorphoria genera	8	B
Torynifer setiagra	8	B
Dielasma genera	9	B
Echinoconchus alternatus	10	A
Reticulariina spinosa	10	B

[1] Rank is based on mean rank abundance.

[2] A - Semi-infaunal low level suspension feeders, B - Epifaunal low level suspension feeders, C - Infaunal low level suspension feeders, D - Epifaunal high level suspension feeders.

[3] Based on visual estimates.

Plate 2

Pentremites-Composita Community

Figure 1: Diaphragmus elegans, exterior of pedicle valve, X1.5. (MS 215, unit 5)

Figure 2: Camorphoria explanata, exterior of pedicle valve, X2. (MS 138, unit 2A)

Figure 3: Anthracospirifer pellansis, exterior of pedicle valve, X1. (MS 22, unit 6)

Figure 4: Ovatia ovatus, exterior of pedicle valve, X1. (MS 212, unit 3)

Figure 5: Pentremites sp., ventral view of theca, X2.2. (MS 224, unit 3)

Figure 6: Composita subquadrata, exterior of pedicle valve, X2. (MS 189, unit 2)

Figure 7: Buxtonia arkansana, exterior of pedicle valve, X1. (MS 132, unit 3)

Figure 8: Dielasma illinoisensis, exterior of pedicle valve, X2. (MS 138, unit 2A)

Figure 9: Barytichisma sp. A, exterior view of corallite, X1. (MS 52, unit 2)

Figure 10: Thin section of the rugose coral Barytichisma sp. A, X2. (MS 52, unit 2)

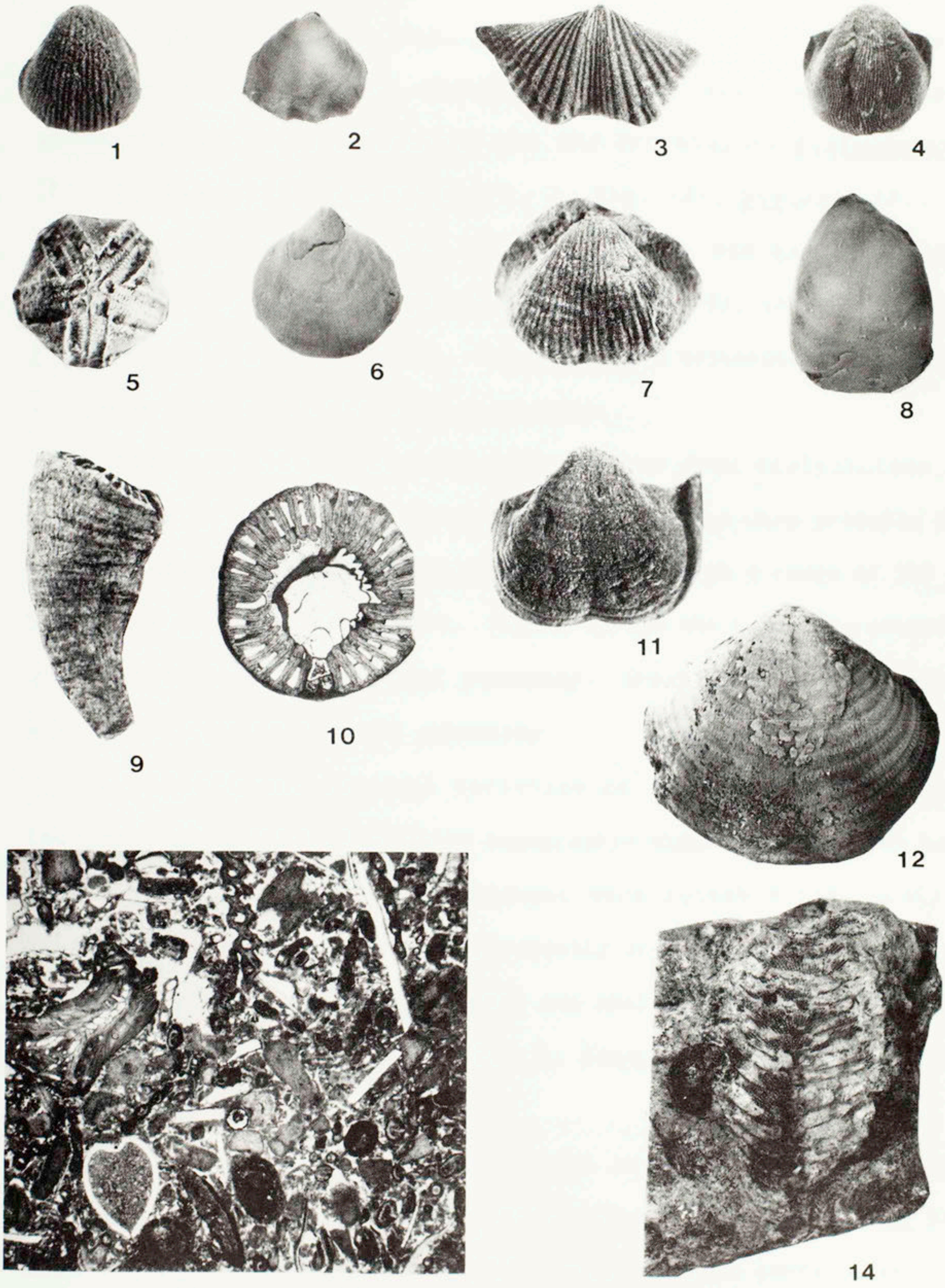
Figure 11: Echinoconchus alternatus, exterior of pedicle valve, X1. (MS 224, unit 2)

Figure 12: Torynifer setigera, exterior of pedicle valve, X2. (MS 138, unit 2A)

Figure 13: Thin section of the Bioclastic: bryozoan-crinoidal Facies. Bryozoan and crinoid skeletal debris is very abundant, X6. (MS 218, unit 2)

Figure 14: Bryozoan Archimedes. Note intact fronds and spiral of the axis embedded in carbonate mud, X1. (MS 24, unit 3)

PLATE 2



Brachiopods are widespread and include Composita (Plate 2, Fig. 6), Camorphoria (Pl. 2, Fig. 2), and the productids Diaphragmus (Pl. 2, Fig. 1), Ovatia (Pl. 2, Fig. 4), and Buxtonia (Pl. 2, Fig. 4), which consistently occur together. Less abundant, but still widespread are the brachiopods Echinoconchus (Pl. 2, Fig. 11), Torynifer (Pl. 2, Fig. 12), Dielasma (Pl. 2, Fig. 8), Anthracospirifer (Pl. 2, Fig. 3), and Reticulariina, the rugose coral Barytichisma (Pl. 2, Figs. 9, 10), and the blastoid Pentremites (Pl. 2, Fig. 5). Pelecypods and trilobites are present in sparse amounts at only a few localities.

This community is distinguished by the even distribution of abundances of the taxa. Crinoids and bryozoans were probably the most abundant taxa present in the community, with a range of 30% to 50% based on visual estimates. Rugose corals and blastoids comprise approximately 9% of the total community. Brachiopods and pelecypods make up the remainder of the community.

A significant lateral variation of this community was the increased abundance of algae on topographic highs and near wave base where conditions in the environment were suitable for oncolite development. Algae encrusted predominantly bryozoans (Pl. 4, Figs. 3, 4) and to a lesser extend crinoids and shell fragments. Girvanella (Pl. 4, Fig. 2) and Osagia (Pl. 4, Figs. 1, 3) consituted the dominant alga observed.

This community represents a fossil community based on a size-frequency histogram, shell disarticulation, faunal diversity, and lithofacies. There is little doubt however, that certain taxon of this community, primarily crinoids, have experienced at least some transportation. The size-frequency histogram (Fig. 4-2) has a right skewed curve (Folk, 1980) which suggests a fossil community that has not undergone significant transportation (Fagerstrom, 1964). There appears to have been very little disarticulation of the shells and limited evidence of abrasion of the shells suggesting little or no transportation of the fossils. Fenestrate bryozoans, such as Archimedes, were observed at various locations with their fronds still intact (Pl. 2, Fig. 14). The delicate nature of these fronds could not tolerate significant transportation and still remain intact. Faunal diversity is high with 26 brachiopod species. The substrate was predominantly sand sized grains and muddy matrix, so currents could not have been so strong as to transport fossils great distances.

Paleoenvironment

The Crinoid-Bryozoan-Brachiopod Biofacies correlates with the Bioclastic: oncolitic and the Bioclastic: byrozoan-crinoidal lithofacies. These lithofacies indicate an environment of low to moderate turbulence. That the energy conditions of this biofacies were greater than those found in the Brachiopod-Pelecypod Biofacies is evident not only in the variable substrate of this biofacies, but also in the differing trophic positions and taxa of the community. Unlike the previous community the Pentremites-Composita Community consists of several trophic levels (Fig. 7). Brachiopods were close to the substrate and were low level epifaunal suspension feeders.

Blastoids, bryozoans and crinoids were low and intermediate level epifaunal suspension feeders (Ausich, 1980). This seems to indicate that the water was agitated enough to bring in adequate food for such a variety of taxa. Ausich (1980) in his studies on Mississippian crinoid communities felt this variability in crinoid stalk length was due to a size selectivity for food within a feeding level. This size selectivity probably applies equally as well to the varying feeding levels of the other taxa in this community.

The higher energy of this environment is also indicated by the other taxa composing this community. In addition to the abundance of taxa mentioned above, rugose and tabulate corals are widespread and are generally associated with turbid agitated waters (Dodd and Stanton, 1981). Brachiopod abundances are also indicative of a more energetic environment. Biconvex brachiopods, such as Composita, Dielasma, Camorphoria, and Torynifer, and ribbed brachiopods, such as Anthracospirifer, Eumetria, and Reticulariina, seem to be more frequently associated with at least moderately turbulent water (Dodd and Stanton, 1981). This seems to be true for the Pitkin also. When comparing the Ovatia-Sphenotus Community to the Pentremites-Composita Community it was observed that the latter community contains twice the total relative abundance of biconvex and ribbed brachiopods as the former community.

Girvanella and Osagia oncolites are moderately abundant in this biofacies. They are typically encrusting bryozoan fragments and may have formed by encrusting living bryozoans as well as rolling freely on the ocean floor (J. R. Groves, 1984, personal

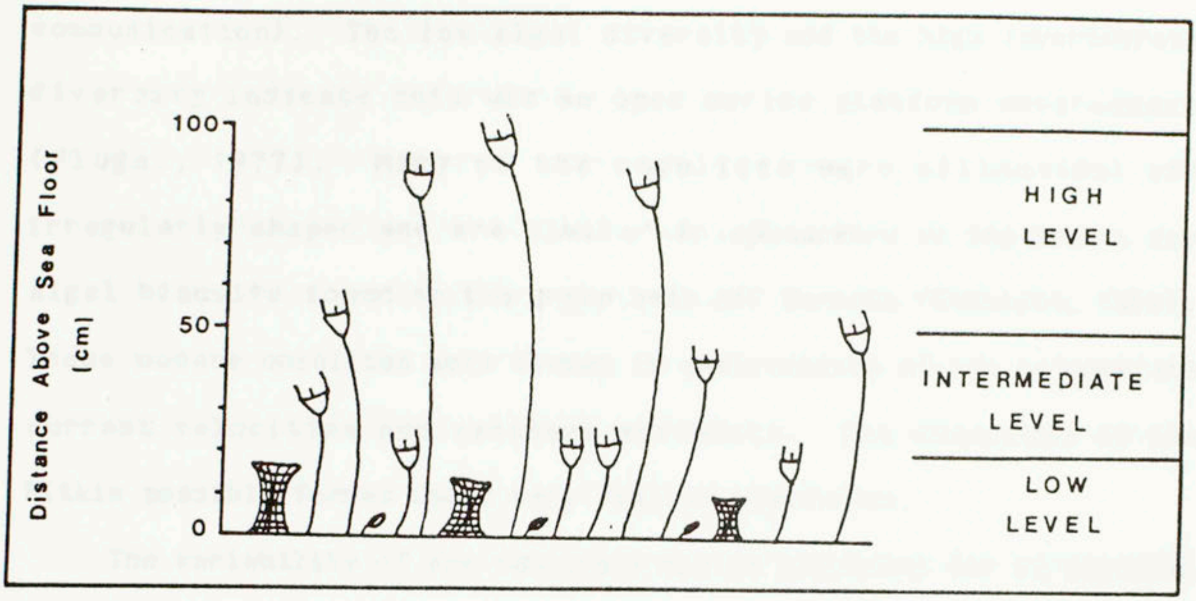


Figure 7. Above sea floor subdivisions of epifaunal suspension feeders. From Ausich (1980, p. 279, fig. 3).

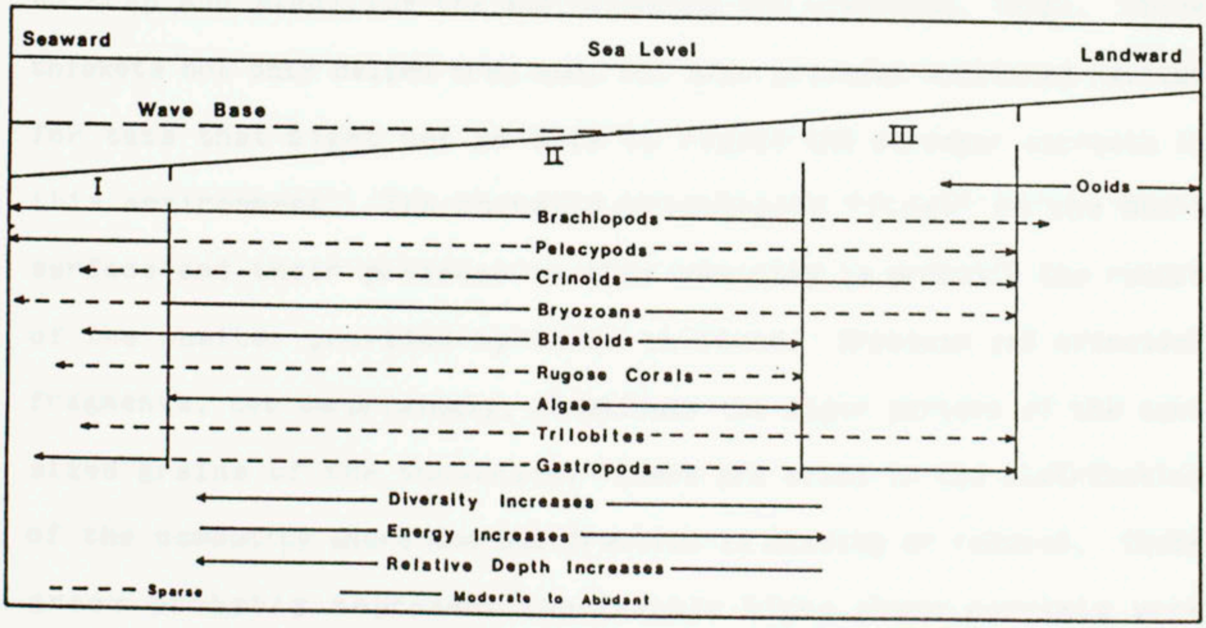


Figure 8. Inferred ecological conditions of the Pitkin Limestone. I - Ovatia-Sphenotus Community, II - Pentremites-Composita Community, III - Ovatia-Diaphragmus Community.

communication). The low algal diversity and the high invertebrate diversity indicate this was an open marine platform environment (Flugel, 1977). Many of the oncolites were ellipsoidal and irregularly shaped and are similar in appearance to the modern day algal biscuits found in the grass beds off Bermuda (Gebelein, 1969). These modern oncolites were formed in environments of low to moderate current velocities and sediment movements. The oncolites of the Pitkin possibly formed under very similar conditions.

The variability of the substrate may be accounted for by physical as well as biological factors, that in turn had an effect on the community. The community is associated with a muddy, sandy substrate. The abundant bryozoans, crinoids, and blastoids probably formed dense, patchy thickets that could baffle the currents helping to trap and stabilize the mud (Ginsburg and Lowenstam, 1958). These thickets not only helped trap mud, but also provided sheltered habitat for taxa that might not be able to resist the stronger currents in this environment. The chonetid brachiopods "float" on the mud's surface and their presence in this community is probably the result of the shelter provided by these thickets. Bryozoan and crinoidal fragments, not surprisingly, constitute the major portion of the sand sized grains of the substrate. There are areas in the distribution of the community where the mud fraction is missing or reduced. These areas probably represent topographic highs where currents were slightly stronger.

The <u>Pentremites-Composita</u> Community covers the area of the shallow carbonate shelf from below wave base to near wave base (Fig.

8). This area of the carbonate shelf may be divided into zones as determined by the composition of the Pentremites-Composita Community. The below wave base zone is characterized by abundant fenestrate bryozoans and sparse crinoids. The near wave base zone had nearly equal to slightly more abundant crinoids than bryozoans with the fenestrate bryozoans becoming replaced by ramose and encrusting bryozoan forms. Brachiopods, blastoids, algae, gastropods, and corals are found in both environmental zones.

The below wave base zone was an environment of low energy with turbid water and muddy substrate. Fenestrate bryozoans, particularly Archimedes, were abundant in this zone. Archimedes was tolerant of turbid water (Cowen and Rider, 1972) and in the Mississippian was adapted to areas of high rates of deposition, quiet waters with weak currents and soft substrates (McKinney, 1979). This type of environment may be found in areas near and below wave base and in protected areas within shifting shoals (McKinney, 1979).

The near wave base zone was a low to moderate energy environment with a muddy to carbonate sand substrate. Crinoids are more abundant than in the below wave base zone. While fenestrate bryozoans may not be as abundant, bryozoans in general are still plentiful. Crinoids are low energy rheophiles and it is believed that Mississippian crinoids were also rheophilic (Ausich, 1981). The greater abundance of crinoids supports the idea that this zone is near wave base.

Brachiopod-Crinoid-Pelecypod Biofacies

Plate 3, Figs. 1-12

The Brachiopod-Crinoid-Pelecypod Biofacies is made up of the Ovatia-Diaphragmus Community (Table 4). Moderately abundant brachiopods and crinoids, sparse pelecypods, bryozoans, and foraminifera, with minor occurrences of gastropods and trilobites characterize this biofacies. The fauna was primarily epifaunal, low and high level suspension feeders. Fossils were difficult to collect from this biofacies and while the community's composition is believed to be valid, the mean rank abundances of its taxa could vary with more collection of fossils.

The Ovatia-Diaphragmus Community is characterized by the brachiopods Ovatia (Pl. 3, Fig. 1), Diaphragmus (Pl. 3, Fig. 4), and Composita (Pl. 3, Fig. 7), and crinoids (Pl. 3, Fig. 12). These three brachiopods and crinoids are widespread and consistently occur together. The brachiopods Anthracospirifer (Pl. 3, Fig. 5), Torynifer (Pl. 3, Fig. 8), Buxtonia (Pl. 3, Fig. 10), and Echinoconchus (Pl. 3, Fig. 9), pelecypods (Pl. 3, Figs. 3, 6, 11), such as Schizodus, Sphenotus, and Edmondia, gastropods, bryozoans, and trilobites are less widespread and less abundant.

The productid brachiopods are the dominant taxa of this community, representing approximately 60% of the fauna identified. Crinoids and pelecypods comprise a significant portion of the community, representing a very approximate 15-20% of the fauna.

This community represents a residual and possibly a mixed fossil community (Fagerstrom, 1964) based on the size-frequency histogram,

Table 4. Rank abundance and trophic position of Ovatia-Diaphragmus Community, Pitkin Limestone.

Genus	Rank[1]	Trophic Position[2]
Ovatia genera	1	A
Diaphragmus elegans	2	A
Composita genera	3	B
Crinoids[3]	4	D
Anthracospirifer genera	5	B
Torynifer setigera	6	B
Buxtonia arkansana	7	A
Pelecypoda	8	B,C
Edmondia genera		
Sphenotus genera		
Schizodus genera		
Echinoconchus alternatus	9	A

[1]Rank is based on mean relative abundance.

[2]A - Semi-infaunal low level suspension feeders, B - Epifaunal low level suspension feeders, C - Infaunal low level suspension feeders, D - Epifaunal high level suspension feeders.

[3]Based on visual estimates.

Plate 3

Ovatia-Diaphragmus Community

Figure 1: Ovatia ovatus, exterior of pedicle valve, X1. (MS 212, unit 3)

Figure 2: Camorphoria explanata, exterior of pedicle valve, X2. MS 138, unit 2A)

Figure 3: Pelecypod of Superfamily Anatinocea, exterior of left valve, X1.5. (MS 229, unit 7)

Figure 4: Diaphragmus elegans, exterior of pedicle valve, X1.5. (MS 212, unit 3)

Figure 5: Anthracospirifer pellensis, exterior of pedicle valve, X1. (MS 22, unit 6)

Figure 6: Pelecypod of Superfamily Trigoniacea, exterior of right valve, X1.4. (MS 229, unit 7)

Figure 7: Composita subquadrata, exterior of pedicle valve, X2. (MS 189, unit 2)

Figure 8: Torynifer setigera, exterior of pedicle valve, X.75. (MS 212, unit 3)

Figure 9: Echinoconchus alternatus, exterior of pedicle valve, X1. (MS 224, unit 2)

Figure 10: Buxtonia arkansana, exterior of pedicle valve, X1. (MS 132, unit 3)

Figure 11: Pelecypod of Superfamily Anatinocea, exterior of left valve, X1. (MS 215, unit 6)

Figure 12: Crinoid, dorsal view of calyx and arms, X1.25. (MS 215, unit 5)

Figure 13: Thin section of a skeletal oolitic packstone. Abundant ooids and crinoids with some bryozoans, X6. (MS 124, unit 5)

Figure 14: Thin section of the Bioclastic: mixed Facies. Note variety of skeletal debris, pelecypods, brachiopods, crinoids, and gastropods in carbonate mud, X6. (MS 228, unit 4)

PLATE 3

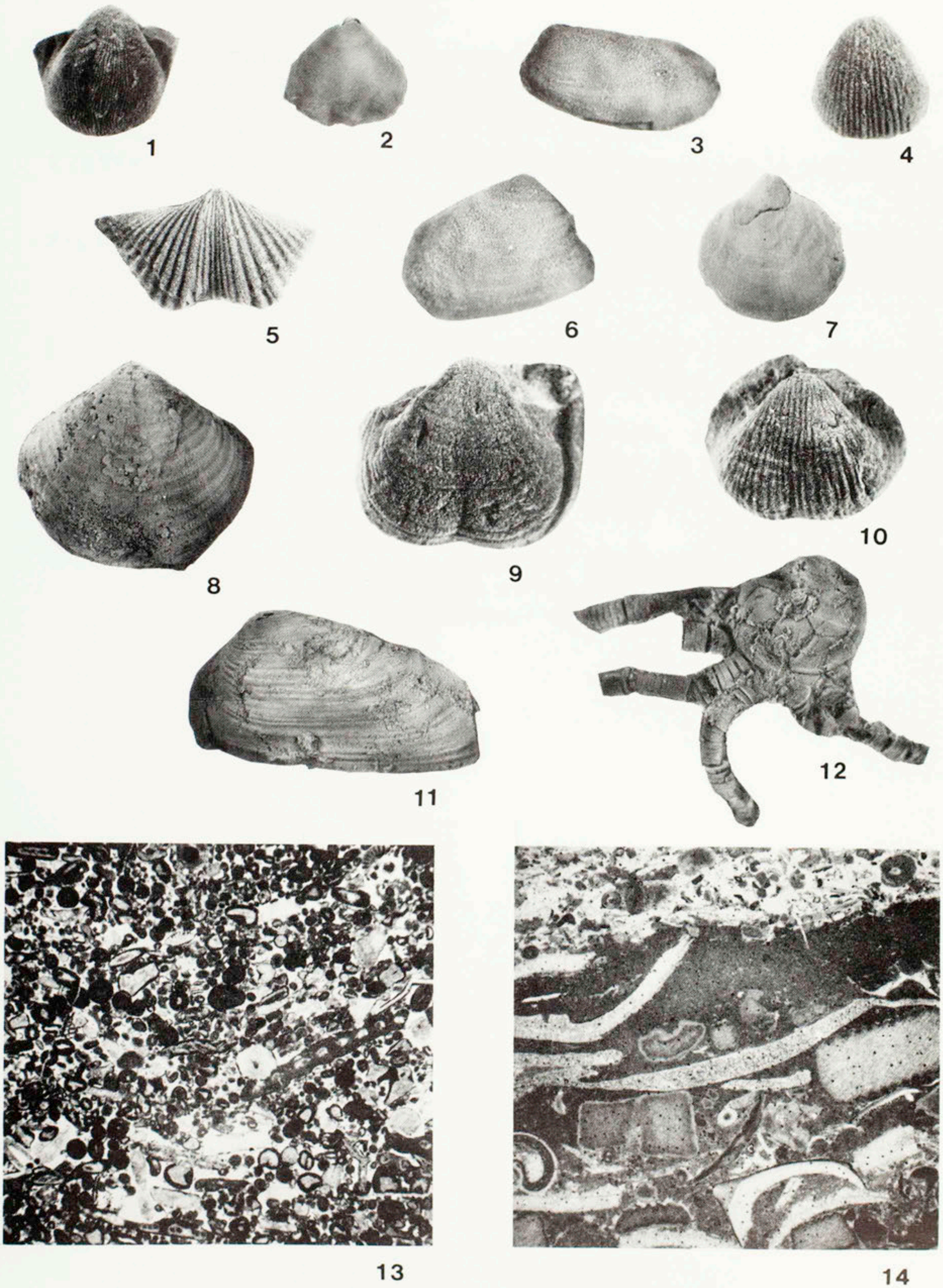


Plate 4

Bioclastic: oncolitic, Pelletal, and Oolite Facies

Figure 1: Thin section of Bioclastic: oncolitic Facies. Note several small oncolites, some encrusting bryozoan fragments. (MS 25, unit 2)

Figure 2: Thin section showing well preserved tubules of the blue-green algae Girvanella. (MS 24, unit 3)

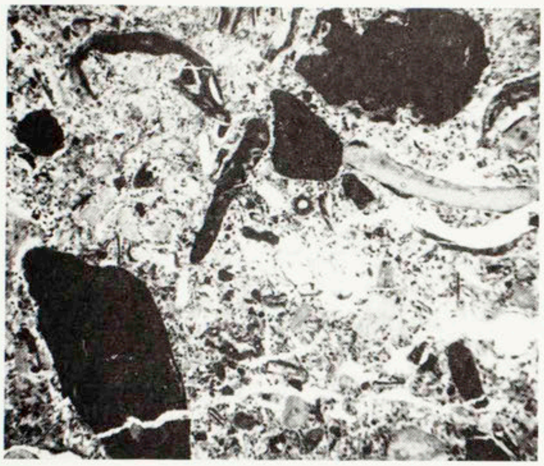
Figure 3: Thin section of algae encrusting a bryozoan fragment. Oncolite is of the form genus Osagia. (MS 126, unit 4B)

Figure 4: Thin section of an oncolite. Algae encrusting bryozoan fragments. (MS 189, unit 4)

Figure 5: Thin section of Pelletal Facies. Notice the uniformity of size and shape. This sample is exceptional for its almost total lack of other skeletal debris. (MS 124, unit 2)

Figure 6: Thin section of Oolite Facies. The oolitic coats surround a variety of skeletal grains. Cement is primarily sparry calcite. (MS 224, unit 4)

PLATE 4



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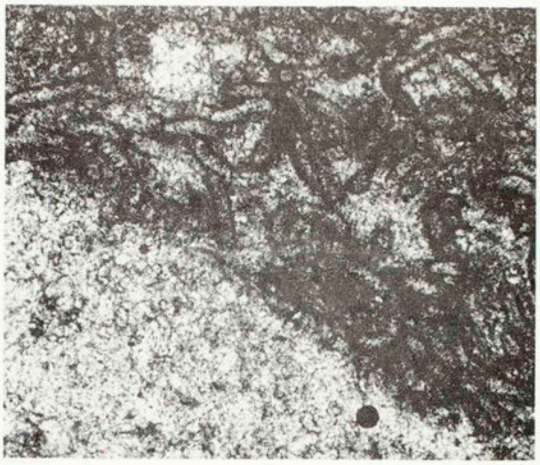

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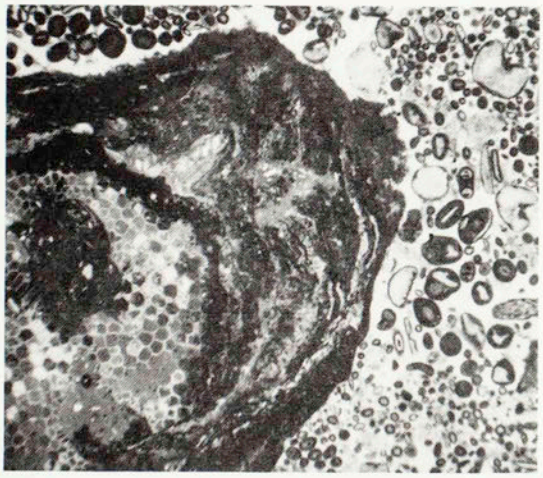

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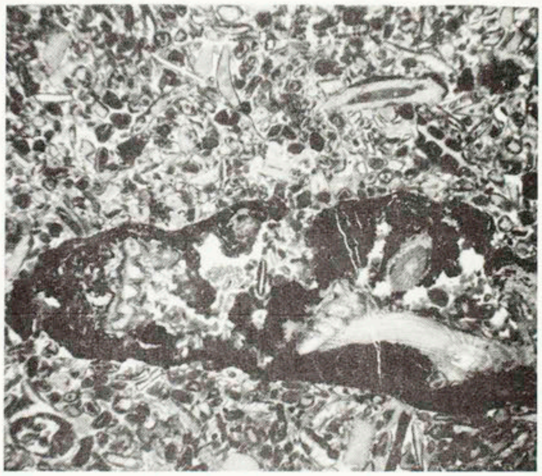

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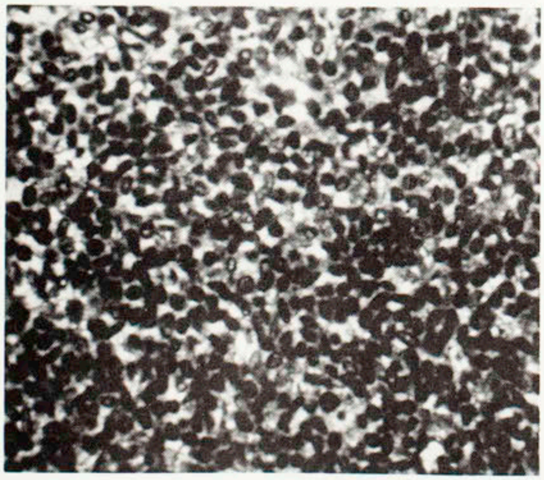

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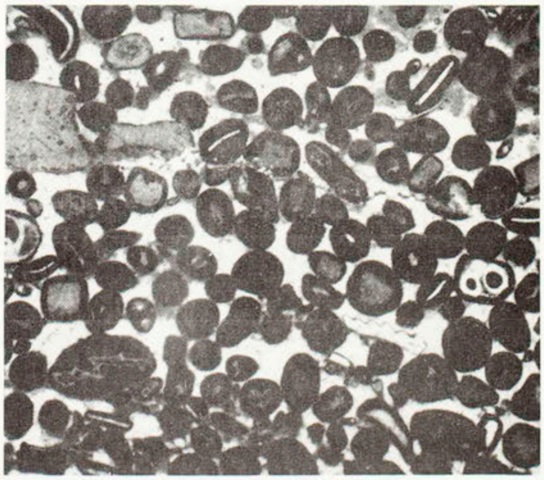

Figure 6 ⌴ 1mm

faunal diversity, shell abrasion and lithofacies. The size-frequency histogram (Fig. 4-3) is nearly bell shaped and has a near symmetrical skewness (Folk, 1980) which indicates this could be a residual community (Fagerstrom, 1964). Faunal diversity is high, with 23 brachiopod species, although it is lower than the previous communities. A few of the taxa show obvious signs of abrasion indicating transportation of the shells, probably from an adjacent, more onshore environment. Many of the shells, however, show little signs of transportation. The lithofacies is predominately a carbonate sand substrate that indicates a moderately turbulent environment capable of transporting the shells. This community probably more closely represents a residual community. A mixed fossil community would be expected to have a bimodal size-frequency histogram and ecologically incompatible taxa. Neither of these was found in this community. Some transportation of the fauna has occurred, but they have probably stayed within the same environment in which they lived. From previous studies on the pre-burial transportation of fossils it is generally believed that transportation is limited and does not commonly move the fossils beyond their life environments (Wilson, 1975; Boucot, 1981).

Paleoenvironment

The Brachiopod-Crinoid-Pelecypod Biofacies correlates with the Bioclastic: mixed lithofacies and Oolitic packstones of the Oolitic lithofacies. These lithofacies represent an environment of low to moderate turbulence and are adjacent to the oolite shoals (Fig. 8). The substrate was muddy to poorly washed with poor to moderate sorting of skeletal grains.

The Ovatia-Diaphragmus Community is composed of taxa consisting of low and intermediate suspension feeders. The presence of crinoids and bryozoans indicate that currents brought adequate suspended food for such a varied fauna. The moderate abundance of crinoids and sparse abundance of bryozoans would have helped stabilize the muddy substrate where they were present (Ginsburg and Lowenstom, 1958). Nearer the ooid shoals, where crinoids and bryozoans were sparse, the substrate was probably low to moderately mobile. This mobility is indicated by the preponderance of spiny, large, productid brachiopods, such as Ovatia, Echinoconchus, Buxtonia, and Diaphragmus. The deep cup shape of their pedicle valves and the stabilizing spines would allow them to survive more easily in this type of mobile substrate than other brachiopods. The pelecypods were primarily burrowers which indicates a soft substrate.

The community's composition, lithofacies and the stratigraphic position of the community indicate this environment was a prograding shoal margin. Anderson and Paydersky (1974) and Purdy (1964) describe this type of environment as having a community of high diversity, a muddy substrate with low to moderate mobility and some transportation of fossils from adjacent more onshore environments.

Community Succession

Community succession is generally an orderly change in a community in a particular area through time (Walker and Alberstadt, 1975). Succession may be physically controlled by the environment, allogenic succession, or community controlled, autogenic succession (Sanders, 1968; Walker and Alberstadt, 1975). Changes that occur during succession include: increased diversity, increased biomass, decreased population fluctuations and an overall gain in efficiency (Johnson, 1970). Johnson (1972) noted that succession is the result of a species-by-species replacement process which might develop over a long period of time and that different stages of succession are reached by different parts of the community at different times. When the succession is disturbed by an environmental event, such as a severe storm, it may lead to a regression of the community to an earlier stage (Walker and Alberstadt, 1974; Dodd and Stanton, 1981).

The initial barren substrate is colonized by a pioneer community which is characterized by low species diversity, while relative abundances of the species will vary greatly (Johnson, 1970; Dodd and Stanton, 1981). The pioneer community alters the local substrate creating new niches for other taxa. Modifications continue during the succession with each new community adapted to the new conditions and diversity increases (Dodd and Stanton, 1981). Under stable conditions, the community will increase in species diversity, while unstable conditions will result in the orderly reduction of species diversity (Johnson, 1970). Areas of regression by moderate progradation, such as the Pitkin Limestone, accentuate the onshore to offshore environmental stress gradients leading to well defined community boundaries (Rollins and others, 1979).

Communities in the study area consist of three types, the occurrence of which was associated with changing water depth. These include the deeper water Ovatia-Spnenotus Community, a shallower water Pentremites-Composita Community and the shallow water Ovatia-Diaphragmus Community. The succession of one community by another took place when physical changes in the environment ended long periods of stability (Fig. 9). Community succession in the Pitkin is comparable to the Devonian Haragen-Bois D'Arc sequence of Oklahoma (Walker and Alberstadt, 1975) and the Ordovician Chickamauga Group of Tennessee (Walker and Parker, 1976).

The Ovatia-Sphenotus Community, community I, represents the stabilization and colonization stages (Fig. 9) of Pitkin succession. The community may be divided into the sub-communities Ia and Ib (Fig. 10). Contained within sub-community Ia are the taxa which are most likely to represent the "pioneer sub-community" (Table 5).

Colonization is the second successional stage (Walker and Alberstadt, 1974; Bretsky and Bretsky, 1975) and is represented by the sub-communities Ia and Ib in the Pitkin. Sub-community Ia (Fig. 10) is more diverse (20 genera) than the pioneer sub-community. The sub-community is dominated by brachiopods, especially the productids which are adapted for the still soft substrate. Infaunal pelecypods and brachiopods attached to the shell pavement by a pedicle were also a part of the sub-community.

This sub-community is associated with the mudstones of the Pitkin. The sub-community was periodically buried by mud, either due to storm activity or a very high rate of deposition. Recolonization of the mud would occur after a period of time.

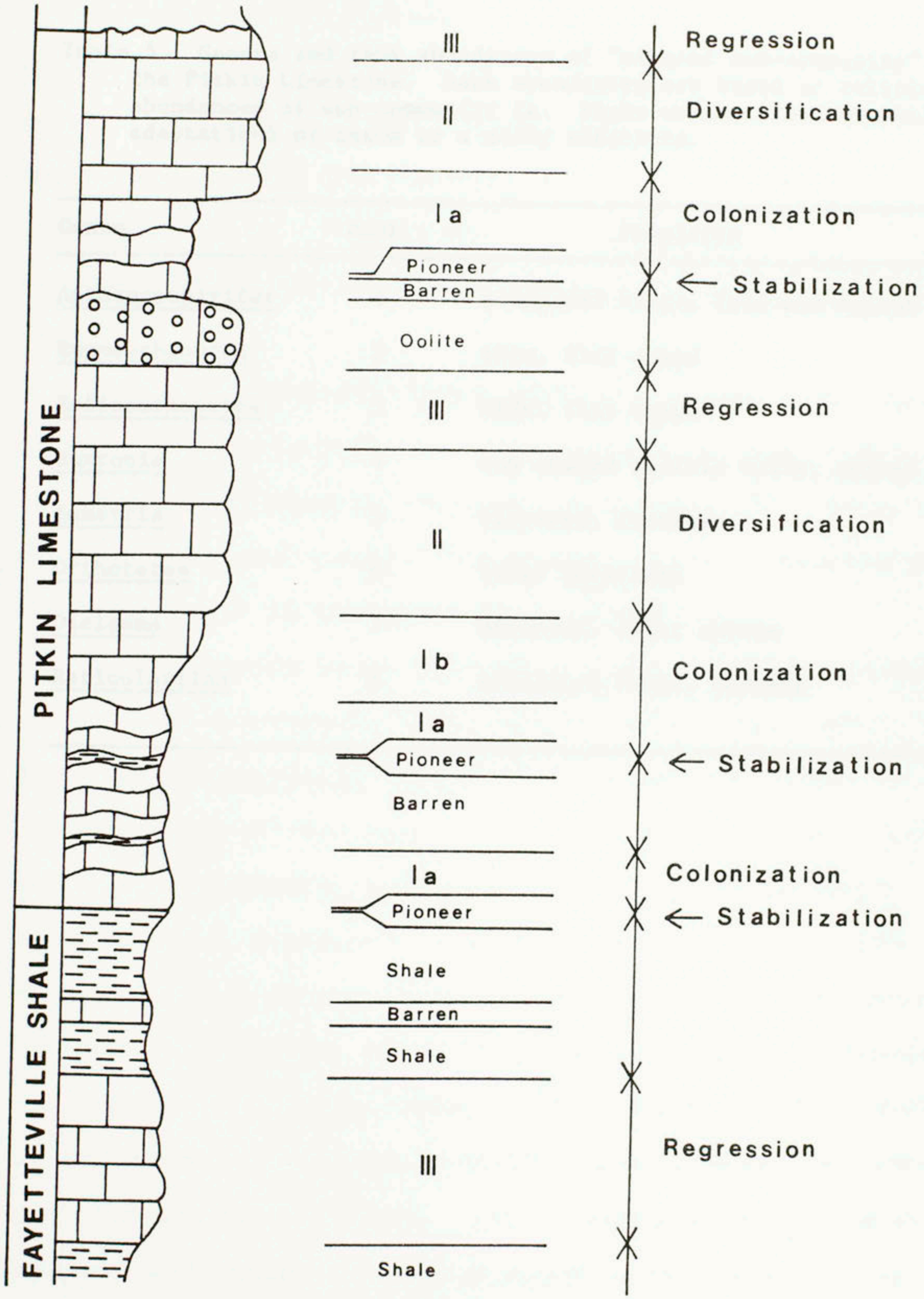

Figure 9. Idealized section of Pitkin Limestone showing community succession.

Table 5. Genera and rank abundances of "pioneer sub-community" for the Pitkin Limestone. Rank abundances are based on relative abundances of sub-community Ia. Right column lists morphological adaptations of taxon to a muddy substrate.

Genus	Rank	Phenotype
Anthracospirifer	1	elongated hinge, fold and sulcus
Rugosochonetes	2	thin, flat shape
Eolissochonetes	3	thin, flat shape
Buxtonia	4	cup shaped pedicle valve, spines
Eumetria	5	biconvex, costate
Orthotetes	6	large interarea
Dielasma	7	biconvex, faint sulcus
Reticulariina	8	elongated hinge, costate

Sub-community Ib represents a more mature stage of development of sub-community Ia. Diversity increases slightly to 24 genera and relative abundances of the taxa have changed (Fig. 10). The faunal composition of this sub-community has been changed when compared to sub-community Ia. This change is attributed to the maturing of sub-community Ib and reduction in the suitable niches for the pioneer taxa.

Community I developed rapidly, which is indicated by the thinness of the community in outcrop. The community is found primarily in the Upper Fayetteville and Lower Pitkin (Fig. 9). While this community has a short temporal distribution, it has a widespread areal distribution over the study area (Pl. 5 and Pl. 6).

Diversification is the third stage in the community's succession (Walker and Alberstadt, 1974; Bretsky and Bretsky, 1975). The _Pentremites_-_Composita_ Community, community II (Fig. 9), is representative of this stage and is associated with the oncolitic and bryozoan-crinoidal bioclastic lithofacies of the Pitkin. The diversity has increased to greater than 24 genera with the reappearance of several brachiopod genera and the appearance of bryozoan and crinoidal genera (Fig. 10). Bryozoans, particularly the bryozoan _Archimedes_, began to first appear in this community. As the community develops, crinoids begin to appear and then to dominate over the bryozoans. The blastoid _Pentremites_, rugose and tabulate corals become much more prominent in this community (Fig. 10) than in the preceding community. Pelecypods show a sharp decline in abundance, but this may be an artifact of sampling. The abundance

TAXA	COMMUNITIES			
	I a	I b	II	III
<u>Buxtonia</u>	3.4	1.6	6.5	4.9
<u>Diaphragmus</u>	18.4	17.9	15.7	18.5
<u>Echinoconchus</u>	0	0.2	1.3	1.5
<u>Inflatia</u>	0	1.4	0.8	0
<u>Ovatia</u>	25.8	44.3	14.5	35.8
<u>Orthotetes</u>	2.9	5.4	0	0.3
<u>Anthracospirifer</u>	6.7	1.7	2.7	8.0
<u>Reticulaiina</u>	0.4	0.2	2.9	1.4
<u>Eumetria</u>	3.0	1.4	4.6	2.4
<u>Torynifer</u>	1.3	2.1	5.6	7.1
<u>Athyrsis</u>	0	1.0	0.2	0
<u>Cleiothyridina</u>	0	0.2	1.2	1.3
<u>Girtyella</u>	0.2	0.4	0	0.7
<u>Rugosochonetes</u>	6.0	0	0.2	0
<u>Eolissochonetes</u>	3.6	0	3.6	1.3
<u>Dielasma</u>	2.4	0.2	3.1	0
<u>Camorphoria</u>	3.8	2.6	5.0	1.4
<u>Composita</u>	10.3	8.3	16.5	10.4
Pelecypods	9.0	10.9	0.8	3.9
Corals	0.2	>1.0	5.8	0
Blastoids	4.3	0.2	8.8	0
Crinoids	0	0	15.0	10.0
Bryozoans	0	0	15.0	3.0

Figure 10. Distibution and abundances of fauna, Pitkin Limestone.

of pelecypods, as indicated by slabs and thin sections, remained relatively constant from the preceding sub-communities.

Community II represents a mature, diverse community. The community is found in thick bioclastic beds indicating long periods of stability. The similar abundances of the taxa within the community and the increased diversity of trophic types indicates that this was a climax community (Walker and Alberstadt, 1975; Dodd and Stanton, 1981).

Community III, the Ovatia-Diaphragmus Community, represents the transition from a community predominately biologically influenced to one that is increasingly physically influenced by the environment. Diversity has decreased to approximately 20 genera. This change is due to the disappearance of several brachiopod genera as well as corals and the blastoid Pentremites. The brachiopods relative abundances are similar to those found in community I, while the abundances of crinoids and bryozoans are greatly reduced. These characteristics represent a community that has regressed due to physical environmental influences resulting from the shallowing water. Storms, increased turbulence of the shallowing seas and the close proximity of ooid shoals altered the substrate as well as causing the substrate to become unstable. This not only controlled the composition of community III, but also periodically resulted in migrating ooid shoals burying the community (Fig. 9) thus destroying it.

Following the burial of community III by the ooid shoal there was a rapid increase in water depth altering the nature of deposition. Mud was again deposited and the cycle of succession would start again. This rapid increase of water depth also occurred during development of communities II and III causing those communities to regress to an earlier stage of succession. It is also important to note that different stages of succession are reached by different parts of the community at different times. This is readily observed when studying the various community's distribution and succession through time across the study area (Pl. 5 and Pl. 6).

The order of succession of the communities in the Pitkin Limestone is readily observable in outcrop, however, there are variations to this succession sequence. It is desirable to determine if this sequence is as ordered as it appears or if it is a random or chance arrangement of communities. There are a number of statistical tests available to determine randomness or non-randomness of the sequence. A binomial probability computer program was utilized (Harper, 1984, personal communication) for its ease of use and interpretation. A facies relationship diagram (Walker, 1979) could then be constructed to illustrate the transitions from one community to the next.

Several matrices were constructed (see Appendix B) which include: (1) observed number of transitions between communities and lithofacies, (2) observed transition probabilities, and (3) transition probabilities for random sequence. These matrices were then utilized to compute the binomial probabilities of the transitions.

The facies relationship diagram (Fig. 11) was constructed from the binomial probability data and represents the transitions with

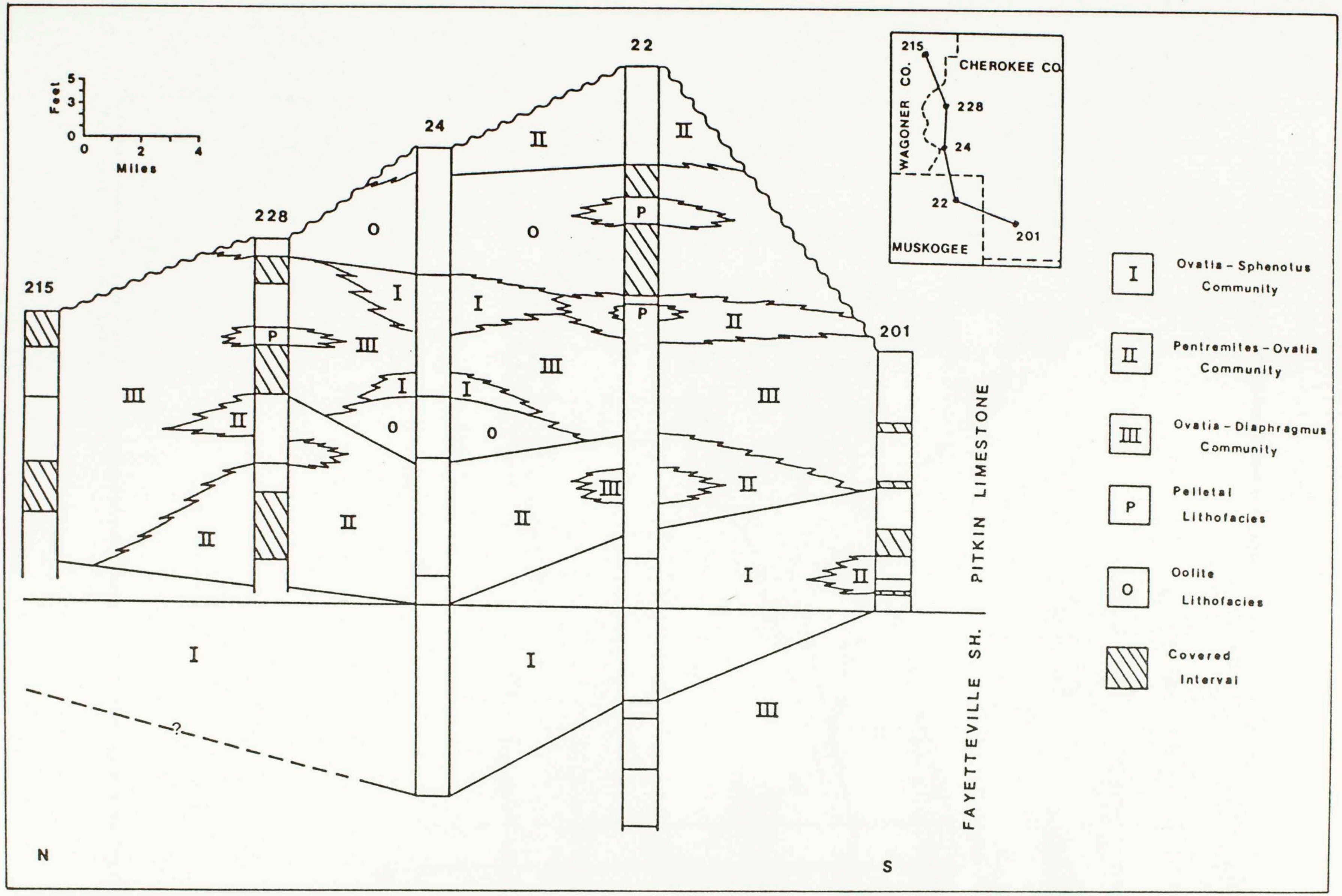
215
228
24
22
201
Feet
0
3
5
0
2
4
Miles
CHEROKEE CO.
WAGONER CO.
MUSKOGEE
PITKIN LIMESTONE
FAYETTEVILLE SH.
N
S
I
Ovatia - Sphenotus Community
II
Pentremites - Ovatia Community
III
Ovatia - Diaphragmus Community
P
Pelletal Lithofacies
O
Oolite Lithofacies
Covered Interval

PLATE 5

the highest probability of being non-random. Starting with the shale lithofacies in Figure 11, the transitions progress to sub-community Ia then to Sub-community Ib, with these transitions being reversable. The next transition is to community II, then to community III. Sub-community Ib may also progress into the pelletal lithofacies, then to community III. Community III may progress to a shale lithofacies, to community II or to oolitic lithofacies. The oolitic lithofacies transition is to community II.

Use of an interative proportional fitting method for estimating expected transition counts under a null hypothesis of random transition (Powers and Esterling, 1982) gave virtually identical results. In applying the Powers and Esterling approach, residuals, the observed value minus the expected value which is divided by the square root of the expected value, were calculated and assumed to be distributed as unit normal. Those residuals significant at the 0.10 level were considered as non-random.

The Pitkin's community succession sequence, therefore, is not a random sequence of events, but is an orderly succession of communities through time. It should be noted that the transitions illustrated in Figure 11 are not the only transitions that occur in the Pitkin, such as the transition from Sub-community Ia to the oolitic lithofacies. However, these other transitions could well be random and do not seem to indicate any trends. The facies relationship diagram also illustrates this series of transitions is a closed loop, indicating a cyclical nature for the community's transitions. This turns out to be exactly what has been observed in the Pitkin, with the communities, and therefore the biofacies, repeating themselves through time.

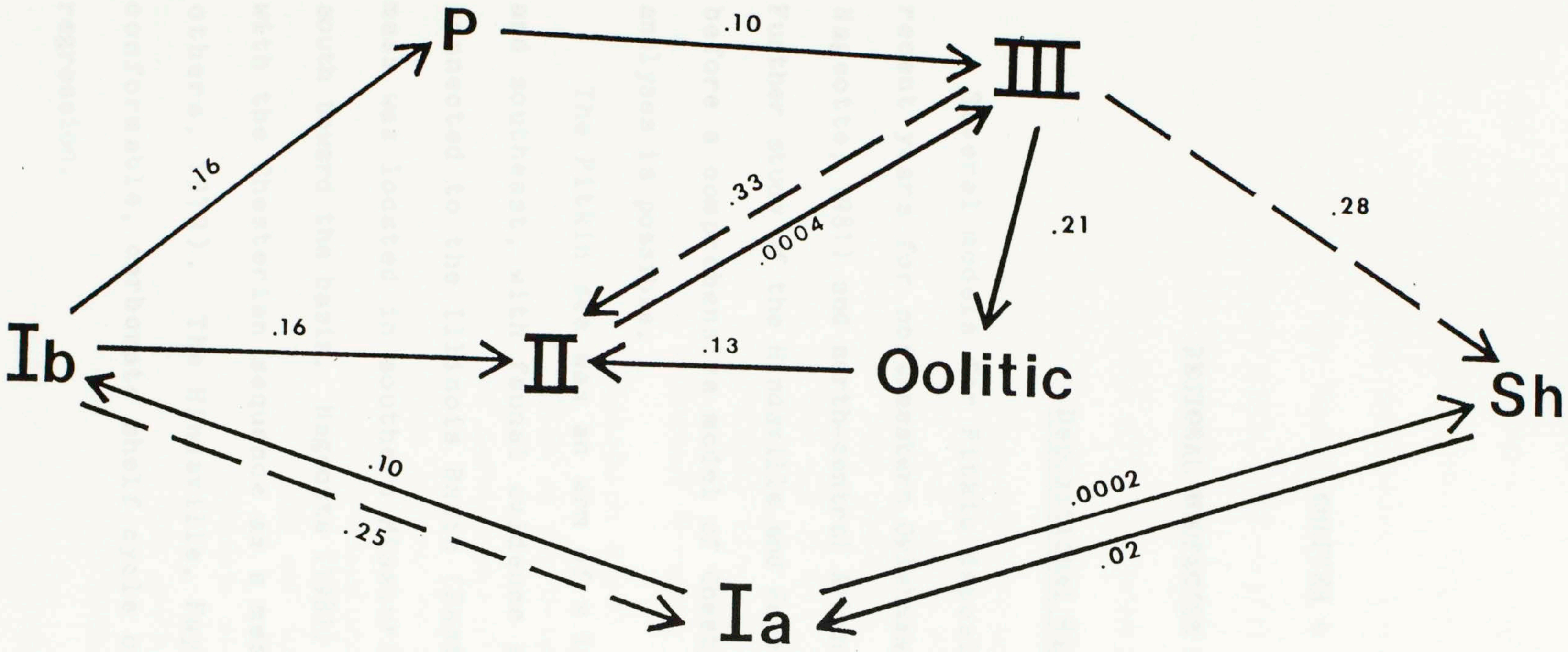

Figure 12. Facies transitions in Pitkin Limestone, Oklahoma, significant at 21% level. Arrows represent direction and probability of transitions that occur more commonly than random (solid arrows - high probability, dashed arrows - intermediate probability). Ia and Ib - sub-communities of Ovatia-Sphenotus Community, II - Pentremites-Composita Community, III - Ovatia-Diaphragmus Community, P - pelletal lithofacies, Sh - shale lithofacies, O - oolite and oolitic grainstone lithofacies.

CHAPTER 4

REGIONAL BIOFACIES ANALYSIS

Depositional History

Several models for Pitkin deposition have been developed in recent years for northeastern Oklahoma (Clupper, 1978; Orgren, 1979; Nageotte, 1981) and north-central Arkansas (Downs, 1983; Webb, 1984). Further study of the Hindsville and Fayetteville Formations are needed before a comprehensive model of Chesterian deposition and biofacies analyses is possible.

The Pitkin sea was an arm of a larger sea located to the south and southeast, with faunal evidence suggesting it was circuitously connected to the Illinois Basin (Easton, 1942). The presumed land mass was located in southern Missouri and the shelf sloped gently south toward the basin. Nageotte (1981) proposed a depositional model with the Chesterian sequence as a mesothemic cycle (Saunders and others, 1979). The Hindsville, Fayetteville and Pitkin form a conformable, carbonate shelf cycle of transgression followed by regression.

The Hindsville, a fossiliferous, oolitic limestone, in Oklahoma and the Batesville Sandstone in Arkansas were deposited in a shallow shelf environment during the beginning stages of a transgression. As the transgression continued water depths increased with the open marine shales of the Fayetteville deposited on the shelf. During middle Fayetteville time, the deltaic sands of the Wedington were deposited in northwestern Arkansas. These sands apparently formed a barrier and possibly affected patterns of deposition in Oklahoma by altering ocean currents (Glick, 1979). The end of Fayetteville time marks the period of maximum transgression, along with subsidence of the Wedington barrier and apparent inundation of the clastics source (Glick, 1979). Thin carbonate muds and bioclastics developed on topographic highs at the end of the upper Fayetteville.

Early Pitkin time marks the beginning of a regression of the seas. Water depths decreased bringing the sea bottom into the photic zone and carbonate deposition developed over the shelf. Along the southern and western limits of the study area the Fayetteville shales grade into mudstones and wackestones of the Pitkin, while bioclastics and ooid shoals developed inland of these muds. The mudstones and wackestones are interpreted as relatively deeper water deposits based on their proximity to the basin and the quiet water fauna associated with them. With continued carbonate deposition, bioclastics and ooid shoals dominate, prograding to the south and southeast.

Pitkin deposition beyond that point in time is unknown in northeastern Oklahoma due to post-Mississippian erosion across the region. However, in north-central Arkansas where upper units of the Pitkin are preserved Downs (1983) has recorded a second transgression followed by another shoaling sequence over much of northern Arkansas. Therefore, it is not unreasonable to suppose a similar sequence also had been deposited in northeastern Oklahoma.

Biofacies Distribution

The distribution and trends of the biofacies across the study area apparently were partially determined by the topographic features of the sea floor during the Pitkin. The varying water depths, the food supply, sediment, and current energies around the highs would have a controlling effect on the community patterns.

Nageotte's (1981) Figure 8 shows an isopach map of the Fayetteville Shale across the study area and he postulates that the areas where the Fayetteville was thinnest occurred over the topographic highs of the Boone Formation. Therefore, it would be expected to have these highs expressed on the surface of the Fayetteville at the beginning of carbonate deposition across the area.

The deeper waters of the outer shelf were located to the south and possibly west of the shallower water deposits of the Pitkin in the study area. The general pattern of energy dispersal, from open ocean currents, waves, and tides, would be onto the southern and western flanks of the topographic highs. Figure 12 shows the biofacies distribution at the base of the Pitkin and their relation to the postulated topographic highs in the study area. This horizon is not necessarily a time line, but rather, is meant to represent a reference plane for comparison of biofacies distribution.

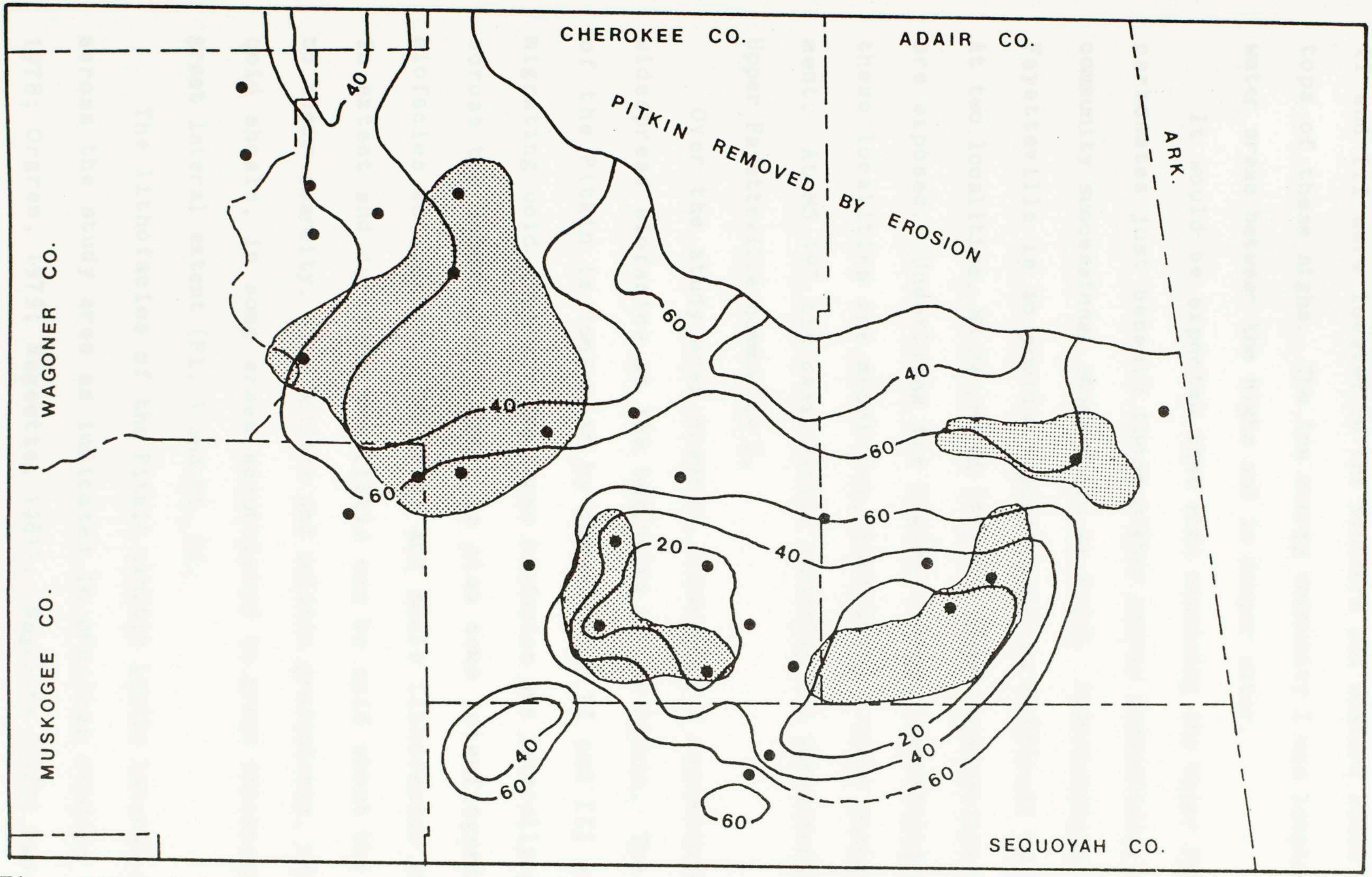

Figure 12. Relationship of community distribution to Fayetteville topographic highs at the base of the Pitkin Limestone. Contour lines are thicknesses of Fayetteville Shale. Shaded areas represents distribution of Communities II and III. Other points represents Community I.

It is apparent from Figure 12, the higher energy communities II and III were located on the southern and western sides and on the tops of these highs. The low energy community I was located in quiet water areas between the highs and in deeper water.

It would be expected that when examining the Upper Fayetteville carbonates just beneath these higher energy communities, an earlier community successional stage would be found. Unfortunately, the Upper Fayetteville is so poorly exposed this is difficult to determine. At two localities, MS 24 and MS 197, the Upper Fayetteville limestones are exposed. Underlying the higher energy communities at each of these localities are mudstones, indicating a lower energy environment. At MS 197 the basal Pitkin community III was underlain by the Upper Fayetteville community I.

Over the study area however, community I represents the most widespread biofacies at the beginning of the Pitkin. The remainder of the Pitkin is dominated by communities II and III and broad, migrating ooid shoals. The three biofacies are laterally persistent across the study area. There is also some interfingering of one biofacies to another. Pelletal and shale lithofacies are limited in extent and duration and little can be said about the fauna due to their scarcity. The oolites and oolitic grainstones, representing ooid shoals, in some areas accumulated to great thicknesses and of great lateral extent (Pl. 5 and Pl. 6).

The lithofacies of the Pitkin exhibit little lateral continuity across the study area as indicated in previous studies (Clupper, 1978; Orgren, 1979; Nageotte, 1981). Nageotte (1981) has described this irregular facies distribution as a facies mosaic. Irregular facies patterns along platform margins are not easily correlatible and bedding may be interrupted by shoals or organic buildups (Wilson, 1975).

The depositional strike on the western edge of the study area appears to have been northwest to southeast, while along the southern edge of the study area, depositional strike appears to have been northeast to southwest (Nageotte, 1981). Grainstone lithologies are more prevalent in north-central and the southern parts of Cherokee County (Orgren, 1978; Nageotte, 1981). In Adair County grainstone lithologies are dominant in the southern portion of the county. Mudstones and wackestones are more prevalent in central Cherokee and northern Adair Counties (Clupper, 1978).

Initial ooid shoal development was probably associated with the topographic highs in the study area (Fig. 12). The ooid accumulations developed rapidly and in some portions of the study area were very extensive. The fauna of the ooid shoals were very limited. Shoals represent intertidal and shallow subtidal environments with a mobile, unstable substrate that was not suitable for most organisms (Purdy, 1964).

As previously mentioned, the biofacies are laterally extensive over the study area. This can be directly attributable to the communities broad substrate tolerance. If the various lithofacies were grouped together as they relate to the fossil communities, mudstones and wackestones, bryozoan-crinoidal bioclastics, and mixed skeletal bioclastics with oolitic packstones, then these pockets of strata would be correlatible over the study area. This is in effect what results when the biofacies of the Pitkin were developed.

Regional Relationships

The completion of this study on the communities and their distribution in the Pitkin Limestone starts a new chapter in the study of the Pitkin. Previous studies have centered upon the lithofacies, carbonate mud mounds and paleontology of the Ozark region. However, little has been done with community or biofacies analysis. This study has demonstrated the usefulness of biofacies analysis in the Pitkin by providing a means of environmental interpretation and of determining widespread distribution patterns of the biofacies. Biofacies analysis offers the means to correlate the faunal facies of the Pitkin across the entire carbonate shelf of northern Arkansas with that of northeastern Oklahoma.

A detailed study of the Moorefield, Hindsville and Fayetteville and their relationships to the underlying Boone topographic highs is needed to fully understand the Chesterian environment and deposition.

While it is not yet possible to make regional correlations of communities, it is possible to compare similarities of fauna. The fauna of the Ozark region in northeastern Oklahoma and northern Arkansas is essentially identical and has been described by Snider (1915) and Easton (1942, 1943). There are a number of faunal similarities between the Ozark region and the type Mississippian of the Mississippi Valley region of Illinois. The Pitkin is contained in the Spirifer brazerianus Assemblage Zone (Dutro and others, 1979) and is characterized by the following species: Orthotetes subglobosus, Anthracospirifer pellansis, Cleiothyridina sublamellosa, Torynifer setigera, Rugosochonetes oklahomensis, and Rugosochonetes chesterensis.

The Pitkin has been correlated to the Manard, Clore, and Kincaid formations in Illinois and a number of taxa common to both areas have been noted (Easton, 1943). These include Composita subquadrata, Eumetria costata, and Buxtonia arkansana, as well as those of the Spirifer brazerianus Assemblage Zone. The brachiopod zonation and the faunal similarities are important in the positioning of the Pitkin in time and geographically with the Mississippi Valley region of Illinois. The age of the Pitkin, based on various zonation schemes, was discussed in Chapter 1. The importance of the faunal similarities is the implication that the two regions must have had a common connection during the Chesterian. Swann (1963) concluded that the Chester seas extended primarily from the Illinois region to the Black Warrier region into the Arkansas Valley region.

CHAPTER 5

CONCLUSIONS

The fauna of the Pitkin Limestone is abundant and diverse throughout the study area. This fauna can be grouped into communities based on the relative and rank abundances at the various localities. The composition and distribution of these communities reflect the energy, substrate type, and distribution of available food within the environment.

The Ovatia-Sphenotus Community, community I, was a community inhabiting a quiet water, muddy substrate environment. The absence of algae and the diverse brachiopod fauna indicate this was a marine somewhat deeper open shelf environment. The depth of the water of this environment is unknown, however the water was "deep" relative to the other communities. This community inhabited the substrate below normal wave base. This is indicated by the lack of evidence of transport of the fossils and the scarcity of corals, bryozoan, blastoids, and crinoids that require currents to carry food to them. Community I represents the stabilization and colonization stage in the succession of the community through time.

The Pentremites-Composita Community, community II, inhabited an environment with muddy to sandy substrate and of low to moderate energy. The fauna is very diverse with abundant corals, bryozoans, crinoids, blastoids, and brachiopods. The abundance of intermediate level epifaunal suspension feeders and the muddy, sandy substrate indicate shallow water below and near normal wave base. Algae was locally abundant indicating this community was well into the photic zone. The algae normally took the form of oncolites that were composed of Girvanella and Osagia. Lateral variations of the taxa were related to the energy of the environment. The bryozoan Archimedes dominates in the lower energy environment and as the energy increases the crinoids became much more abundant. This community represents the diversification stage in the total community's succession. The biofacies is extensively distributed throughout the study area with thick accumulations of the biofacies indicating long periods of stability.

The Ovatia-Diaphragmus Community, community III, inhabited a muddy, sandy environment of moderate energy. The fauna of this community is less diverse than the previous communities. The community lacks the corals, blastoids, and bryozoans of community II. This suggests a more stressful environment and unstable substrate with the presence of ooids indicating this community was adjacent to ooid shoals. Community III represents a regressional stage in the succession of the total community as a result of the increased physical stress of the environment. This community persisted over long periods of time and was distributed over much of the study area.

The transitions of community I, to II, to III are non-random and so represent a true community succession. The determination of this non-randomness was accomplished by using Walker's (1979) method of determining transition probabilities. These transitions are illustrated in a facies relationship diagram (Fig. 11) that shows the transitions between communities and the unfossiliferous lithofacies.

The communities are correlatable across the entire study area with some interfingering of the communities as a result of variable local environmental conditions. Unfortunately, the correlation of the communities across the entire carbonate shelf of northeastern Oklahoma and northern Arkansas is not possible at present. However, with community analysis applied to the fauna of northern Arkansas this should be possible due to the similarity of the faunas and environments of the Pitkin.

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APPENDIX A

MEASURED SECTIONS

This appendix contains locations and descriptions of faunal collections of the 25 measured sections in this study. These measured sections were originally described by Clupper (1978), Orgren (1979), and Nageotte (1981), and their descriptions were used to develop the lithofacies for the units.

Each of the measured sections were divided into lithofacies and the units within these lithofacies were listed. Each unit contains the following: (1) Dunham's (1961) classification, (2) relative abundance and types of macrofossils, (3) relative abundance and genus name of fossils identified, and (4) thickness of unit expressed in feet.

Measured Section 22: Braggs Mountain

Location: SW¼, SW¼, Sec. 21, T. 15 N., R. 20 E. Located on a west facing road cut along OK 10 approximately 4 miles southeast of Fort Gibson (Fort Gibson Dam Quadrangle).

The directions to this measured section are as found in Orgren (1979) and is easily accessible, well exposed, and easily collectable.

M.S. 22	DESCRIPTION	THICKNESS (Feet)
CHESTERIAN SERIES - partial thickness		84.2
PITKIN LIMESTONE.		46.9
<u>Bioclastic:bryozoan-crinoidal Facies</u>		
13	Crinoidal-bryozoan pelloidal grainstone.	8.5
12	Covered.	3.0
<u>Pelletal Facies</u>		
11	Pelloidal grainstone. Poorly to moderately exposed. Rare brachiopods collected. Abundant bryozoans and crinoids observed. Rare <u>Ovatia</u>.	2.3
10	Covered.	6.2
<u>Bioclastic:oncolitic Facies</u>		
9	Oncolitic pelloidal grainstone.	0.7
<u>Oolitic Facies alternating with Bioclastic:bryozoan-crinoidal Facies</u>		
8	Crinoidal oolitic grainstone. Well exposed, massive cliff forming unit. Lower 2 to 3 ft wackestone containing abundant whole brachiopods, pelecypods, and sparse gastropods; easily collected. Abundant <u>Ovatia</u> and <u>Diaphragmus</u>. Moderate <u>Orthotetes</u>. Rare to sparse <u>Buxtonia</u>, <u>Anthracospirifer</u>, <u>Eumetria</u>, <u>Composita</u>, <u>Camorphoria</u>, <u>Aviculopecten</u>, <u>Edmondia</u>, <u>Sphenotus</u>, and <u>Schizodus</u>.	22.0

M.S. 22	DESCRIPTION	THICKNESS (Feet)
Mudstone Facies		
7	Mudstone to brachiopodal wackestones. Well exposed, covered laterally. Wackestones contain abundant, easily collected whole brachiopods, pelecypods, gastropods with few cephalopods. Moderate Ovatia and Schizodus. Sparse Buxtonia, Diaphragmus, Orthotetes, Anthracospirifer, Eumetria, Rugosochonetes, Eolissochonetes, Camorphoria, Myalina, and Edmondia.	4.3
FAYETTEVILLE FORMATION - partial thickness		37.0
Shale and Mudstone Facies		
6	Interbedded shale and limestone. Moderately well exposed. Limestones are mudstone to packstone. Uppr limestones contain moderate pelecypods and brachiopods with sparse gastropods. Shales contain rare brachiopods. Moderate Camorphoria, Ovatia, and Anthracospirifer. Sparse Buxtonia, Diaphragmus, Reticulariina Rugosochonetes, Eolissochonetes, Leda, Myalina, Edmondia, and Schizodus.	7.9
Bioclastic:mixed Facies		
5	Foraminiferal spiculiferous grainstone to packstone. Poorly to moderately exposed. Few fossils collected. Sparse Ovatia.	1.6
4	Interbedded shale and limestone.	4.6
Oolitic Facies		
3	Bryozoan-crinoidal oolitic grainstone to packstone. Few brachiopods and pelecypods collected. Sparse Buxtonia, Ovatia, Anthracospirifer, Torynifer, Cleiothyrdine, Eolissochonetes, Schizodus, and Sphenotus.	4.9
Shale and Interbedded Mudstone Facies		
2	Shale with interbedded mudstone.	7.3
1	Covered.	10.6

Measured Section 24: Ft. Gibson Dam (East)

Location: NW¼, NE¼, Sec. 18, T. 16 N., R. 20 E. Located on the west facing cliff adjacent to the east side of the Ft. Gibson Dam (Fort Gibson Dam Quadrangle).

The directions to this measured section are as found in Orgren (1979) and is easily accessible and well exposed.

M.S. 24	DESCRIPTION	THICKNESS (Feet)
CHESTERIAN SERIES		59.0
PITKIN LIMESTONE		39.4
Oolite Facies		
6	Crinoidal oolitic grainstone. Moderately well exposed. Abundant bryozoan and brachiopods. Rare gastropods and cephlapods. Moderate Ovatia. Rare Buxtonia, Diaphragmus, Anthracospirifer, Torynifer, and Composita.	10.5
Bioclastic: mixed Facies overlain by Mudstone Facies		
5	Wackestone to mudstone. Poorly exposed.	9.8
Oolite Facies		
4	Crinoidal oolitic grainstone.	5.2
Bioclastic: bryozoan-crinoidal Facies with Oolitic Facies at top		
3	Crinoidal bryozoan packstone. Well exposed. Abundant bryozoans, crinoids, and brachiopods. Rare blastoids and pelecypods. Abundant Ovatia and Archimedes. Rare Buxtonia, Diaphragmus, Torynifer, Composita, and Schizodus.	11.2
2	Bryozoan packstone. Well exposed. Abundant brachiopods and bryozoans. Rare blastoids and gastropods. Moderate to abundant Archimedes. Sparse Diaphragmus and Ovatia. Rare Buxtonia, Composita, Camorphoria, and Pentremites.	2.6

Measured Section 25: Park Hill Mountain

Location: SW¼, NW¼, Sec. 27, T. 16 N., R. 22 E. (Park Hill Quadrangle).

The directions to this measured section are as found in Orgren (1979) with the exception that the store has been replaced by houses. The measured section is easily accessible and well exposed.

M.S. 25	DESCRIPTION	THICKNESS (Feet)
CHESTERIAN SERIES - partial thickness		20.5
PITKIN LIMESTONE		13.9
<u>Mudstone Facies</u>		
6	Shale overlain by mudstone.	0.7
<u>Oolitic Facies</u>		
5	Mixed skeletal oolitic grainstone. Abundant, recrystallized, abraded brachiopods. Moderate *Torynifer* and *Composita*.	2.3
4	Covered.	1.3
3	Oolitic peloidal grainstone to packstone. Well exposed with abundant bryozoans and crinoids. Sparse to moderate brachiopods and pelecypods. Sparse *Archimedes*, *Torynifer*, *Composita*, and *Sphenotus*.	4.9
<u>Pelletal Facies</u>		
2	Peloidal packstone to grainstone. Well exposed. Moderate crinoids. Rare brachiopods, trilobites, and blastoids. Rare *Pentremites*, *Eumetria*, and *Composita*.	2.3
<u>Mudstone Facies</u>		
1	Mudstone. Well exposed. Moderate crinoids. Rare brachiopods, blastoids, and trilobites. Rare *Pentremites*, *Torynifer*, and *Composita*.	2.3

M.S. 25	DESCRIPTION	THICKNESS (Feet)
FAYETTEVILLE SHALE - partial thickness		6.6
0	Interbedded shale and mudstone.	6.6

Measured Section 52: Carter's Cabins

Location: NE¼, SW¼, SW¼, Sec. 12, T. 15 N., R. 22 E. (Park Hill Quadrangle)

This section was originally designated as measured section 210-B (Nageotte, 1981), and is located 2.8 miles north of the intersection of Route 82 and Route 100 north of Cookson on the northeast side of Route 82, just beneath the driveway for Carter's Cabins.

M.S. 52	DESCRIPTION	THICKNESS (Feet)
CHESTERIAN SERIES - partial thickness		7.9
PITKIN LIMESTONE		6.2
Mudstone Facies		
4	Mudstone.	1.2
3	Covered.	2.5
Wackestone Facies		
2	Wackestone and mudstone. Poorly to moderately exposed. Moderate to abundant brachiopods, rugose corals, crinoids, and bryozoans. Few gastropods and cephalopods. Moderate Camorphoria and Barytichisma. Sparse Buxtonia, Diaphragmus, Ovatia, Tetracamera, Cleiothyridina, Composita, and Archimedes.	2.5

M.S. 52	DESCRIPTION	THICKNESS (Feet)
FAYETTEVILLE SHALE - partial thickness		1.7
Shale Facies		
1	Shale with mudstone. Poorly exposed. Abundant brachiopods with few pelecypods. Abundant Eolissochonetes and Rugosochonetes. Sparse Ovatia, Composita, Camorphoria, and Sphenotus.	1.7

Measured Section 57: West Red Berry Mountain

Location: SE¼, SW¼, SW¼, Sec. 12, T. 15 N., R. 20 E. (Ft. Gibson Dam Quadrangle).

The directions to the measured section as as found in Orgren (1979).

M.S. 57	DESCRIPTION	THICKNESS (Feet)
CHESTERIAN SERIES - partial thickness		38.6
PITKIN LIMESTONE - partial thickness		38.6
Oolitic Facies		
10	Covered.	3.6
9	Crinoidal-oolitic grainstone.	3.6
8	Covered.	4.9
Bioclastic: bryozoan-crinoidal Facies overlain by Oolitic Facies		
7	Peloidal-crinoidal grainstone grading into oolitic grainstone. Moderately well exposed. Abundant crinoids and bryozoans with few gastropods and brachiopods. Moderate Composita. Rare Camorphoria and Anthracospirifer.	6.2
6	Covered.	1.6

M.S. 57	DESCRIPTION	THICKNESS (Feet)

Pelletal Facies

5	Pelletal grainstone to packstone. Moderately well exposed. Abundant crinoids and bryozoans with few brachiopods. Rare Anthracospirifer, Eumetria, and Rugosochonetes.	1.0

Bioclastic: mixed Facies overlain by thin Pelletal Facies

4	Brachiopod-crinoidal packstone grading into pelletal packstone.	4.3

Oolite Facies

3	Oolitic grainstone.	1.6

Oolitic Facies

2	Crinoidal oolitic grainstone.	10.5

Bioclastic: bryozoan-crinoidal Facies

1	Bryozoan crinoidal packstone.	1.0

Measured Section 122: East Stilwell Mountain

Location: S½, Sec. 1, T. 15 N., R. 25 E. (Stilwell East Quadrangle).

The directions to this measured section are as found in Clupper (1978). Mr. Tom Carson is owner of this land and should be contacted at Carson Insurance in Stilwell before entering his land.

M.S. 122	DESCRIPTION	THICKNESS (Feet)

CHESTERIAN SERIES - partial thickness 22.5

PITKIN LIMESTONE - partial thickness. 22.5

Pelletal Facies

13	Crinoidal peloidal packstone.	1.0

M.S. 122	DESCRIPTION	THICKNESS (Feet)
Bioclastic: oncolitic Facies		
12	Crinoidal oncolitic packstone. Moderately exposed, not laterally extensive. Few rugose corals. Rare Caninostrotion.	1.4
Bioclastic: mixed Facies		
11	Oncolitic skeletal packstone.	1.5
Bioclastic: bryozoan-crinoidal Facies		
10	Skeletal packstone with interbedded calcareous shales. Poorly exposed. Few rugose and colonial corals and rare brachiopods. Sparse Barytichisma and Michelinia. Rare Tetracomera and Composita.	2.0
Wackestone Facies		
9	Brachiopodal, crinoidal, foraminiferal wackestone and mudstone.	3.0
Bioclastic: bryozoan-crinoidal Facies		
8B	Intraclast-bearing crinoidal, bryozoan grainstone.	2.0
Oolitic Facies		
8A	Crinoidal oolitic packstone.	1.0
7	Oolitic grainstone.	2.5
6	Mixed skeletal, oolitic grainstone.	2.5
Bioclastic: mixed Facies		
5	Skeletal grainstone.	2.0
Oolitic Facies		
4	Crinoidal oolitic grainstone.	2.0
Bioclastic: bryozoan-crinoidal Facies		
3	Bryozoan crinoidal packstone.	1.0
2	Bryozoan crinoidal packstone.	0.5

Measured Section 124: Lyons Mountain

Location: W½, Sec. 35, T. 15 N., R. 24 E. (Greasy Quadrangle).

The directions to this measured section are as found in Clupper (1978). Mr. Charlie Gardner is owner of this land and permission to enter land should be obtained. Mr. Gardner lives in a trailer house approximately 0.5 mile further up the road from this measured section.

M.S. 124	DESCRIPTION	THICKNESS (Feet)
CHESTERIAN SERIES - partial thickness		17.0
PITKIN LIMESTONE - partial thickness		17.0
<u>Oolitic Facies</u>		
5	Oolitic grainstone.	10.0
<u>Wackestone Facies</u>		
4	Skeletal wackestone. Moderately exposed, laterally discontinuous. Abundant gastropods, rare brachiopods, pelecypods, and bryozoans. Rare <u>Reticulariina</u>, <u>Girtyella</u>, <u>Archimedes</u>, and <u>Sphenotus</u>.	0-1.0
<u>Pelletal Facies</u>		
3	Skeletal packstone.	4.3
<u>Mudstone Facies</u>		
2	Mudstone and skeletal wackestones with interbedded shales. Moderately well exposed. Few brachiopods. Rare <u>Rugosochonetes</u>.	1.7
1	Covered.	

Measured Section 126: South Bugger Mountain

Location: N½, Sec. 27, T. 16 N., R. 26 E. (Stilwell East Quadrangle).

The directions to this measured section are as found in Clupper (1978). Permission from landowner, Mr. Bigby, is needed to enter land. Owner lives in white house on north side of highway approximately 0.25 mile west of turn-off to gravel road.

M.S. 126	DESCRIPTION	THICKNESS (Feet)
CHESTERIAN SERIES - partial thickness		18.6
PITKIN LIMESTONE - partial thickness		18.6
<u>Bioclastic: oncolitic Facies overlain by Bioclastic: bryozoan-crinoidal Facies</u>		
9	Crinoidal packstone. Well exposed. Abundant crinoids with some pelecypods and brachiopods. Rare *Diaphragmus*.	3.3
<u>Pelletal Facies</u>		
8	Peloidal grainstone.	2.3
<u>Wackestone Facies</u>		
7	Brachiopodal wackestone. Well exposed. Abundant crinoids and brachiopods. Abundant *Diaphragmus* and *Ovatia*. Rare *Torynifer* and *Composita*.	1.5
<u>Bioclastic: mixed Facies</u>		
6	Skeletal grainstone. Well exposed. Moderate crinoids, and brachiopods. Rare *Echinoconchus*.	1.5
5	Covered.	0.5
<u>Oolitic Facies</u>		
4D	Oolitic packstone. Moderately well exposed. Moderate crinoids and brachiopods with few pelecypods. Rare to sparse *Composita*, *Girtyella*, *Torynifer*, and *Eumetria*.	2.8
4C	Oolitic grainstone. Moderately exposed. Moderate crinoids and brachiopods with few pelecypods. Rare *Allorisma*.	0.2-0.5
4B	Oolitic packstone.	2.5
4A	Skeletal oolitic grainstone.	1.2

M.S. 126	DESCRIPTION	THICKNESS (Feet)
Pelletal Facies		
3	Pelletal packstone.	1.0
Wackestone Facies		
2	Crinoidal wackestone. Poorly exposed laterally. Moderate crinoids with few brachiopods. Rare *Diaphragmus* and *Echinoconchus*.	1.5
1	Covered.	

Measured Section 131: Northwest Dahlonegah Mountain

Location: NW¼, Sec. 5, T. 14 N., R. 25 E. (Greasy Quadrangle).

The directions to this measured section are as found in Clupper (1978).

M.S. 131	DESCRIPTION	THICKNESS (Feet)
CHESTERIAN SERIES - partial thickness	. . . .	17.0
PITKIN LIMESTONE - partial thickness	. . . .	17.0
Wackestone Facies		
6	Skeletal wackestone with interbedded shales.	3.0
Bioclastic: mixed Facies		
5	Skeletal packstone to wackestone with interbedded shales.	4.0
4	Brachiopodal wackestone. Moderately exposed. Few to moderate crinoids and brachiopods. Rare *Anthracospirifer*, *Composita*, and *Dielasma*.	3.0
Oolitic Facies		
3	Oolitic grainstone.	1.0

M.S. 131	DESCRIPTION	THICKNESS (Feet)

Pelletal Facies

2	Peloidal grainstone. Poorly exposed. Few brachiopods, pelecypods, crinoids, and bryozoans. Rare Composita and Edmondia.	6.0

Measured Section 132: Adair-Cherokee Line

Location: W½, Sec. 19, T. 15 N., R. 24 E. (Tailholt Quadrangle).

The directions to this measured section are as found in Clupper (1978).

M.S. 132	DESCRIPTION	THICKNESS (Feet)

CHESTERIAN SERIES - partial thickness 31.3

PITKIN LIMESTONE - partial thickness 31.3

Mudstone Facies

10	Mudstone.	1.5

Shale Facies

9	Shale.	1.0

Oolitic Facies

8	Oolitic grainstone.	4.5

Oolitic Facies overlain by Mudstone Facies

7	Oolitic grainstone. Moderately well exposed. Abundant brachiopods with few pelecypods. Moderate Ovatia. Rare Diaphragmus, Anthracospirifer, Sphenotus, and Schizodus.	6.0

Shale Facies

6	Shale.	0.5

M.S. 132 DESCRIPTION THICKNESS (Feet)

Bioclastic: mixed Facies

5 Pelecypodal packstone. Well exposed. Abundant crinoids and pelecypods, with some brachiopods. Rare Punctospirifer, Reticulariina, Girtyella, and Composita. 1.0

Oolitic Facies overlain by Pelletal Facies

4 Brachiopodal oolitic packstones. Well exposed. Abundant crinoids, bryozoans and brachiopods with moderate pelecypods and gastropods. Upper 2 ft of this unit is very fossiliferous. Rare Aviculopecten and Edmondia. 6.3

Bioclastic: bryozoan-crinoidal Facies

3 Bryozoan crinoidal packstone. Well exposed. Very fossiliferous. Abundant brachiopods, blastoids, bryozoans, and crinoids. Sparse to moderate gastropods, trilobites, and pelecypods. Rare cephalopods. Abundant Buxtonia, Diaphragmus, Eumetria, Ovatia, and Composita. Moderate Reticulariina, Torynifer, Eolissochonetes, and Camorphoria. Rare to sparse Michelinia, Barytichisma, Inflatia, Orthotetes, Cleiothyridina, Rugosochonetes Dielasma, and Archimedes. 5.5

Mudstone Facies

2 Mudstone with interbedded shales. Well exposed. Fossils are in lenses and thin beds of wackestones and packstones. Abundant brachiopods with moderate gastropods and sparse trilobites. Abundant Ovatia. Moderate Buxtonia. Rare to sparse Diaphragmus, Reticulariina, Eumetria, Torynifer, Rugosochonetes, and Composita. 5.0

FAYETTEVILLE SHALE . . . . ?

1 Shale. ?

Measured Section 184: Smith Hollow

Location: SE¼, NE¼, Sec. 21, T. 13 N., R. 23 E. (Marble City Quadrangle).

The directions to this measured section are as found in Nageotte (1981), with the exception that from the railroad tracks in Marble City to the turn-off at Pettit Methodist Church is 0.6 mile rather than 1.5 miles.

M.S. 184	DESCRIPTION	THICKNESS (Feet)
CHESTERIAN SERIES		75.0
PITKIN LIMESTONE		10.0
Bioclastic: oncolitic Facies		
5	Bryozoan packstone.	2.0
Bioclastic: bryozoan-crinoidal Facies overlain by Bioclastic: oncolitic Facies		
4	Bryozoan packstone. Well exposed. Fossils were collected predominantly from lower half of unit. Abundant crinoids, brachiopods, and bryozoans. Rare blastoids and trilobites. Sparse Diaphragmus, Composita, and Camorphoria. Rare Pentremites, Echinoconchus, Ovatia, Reticulariina, Torynifer, Athyris, Dielasma, and Edmondia.	4.5
Bioclastic: mixed Facies		
3	Foraminiferal packstone with interbedded shales. Well exposed. Sparse to moderate brachiopods. Rare Ovatia, Hustedia, Torynifer and Composita.	0.5
2	Foraminiferal packstone. Well exposed. Moderate crinoids with few brachiopods and pelecypods. Rare cephalopod. Rare Diaphragmus, Echinoconchus, and Schizodus.	2.5
Wackestone Facies		
1B	Wackestone with interbedded shales.	0.15
FAYETTEVILLE SHALE - partial thickness		65.0

M.S. 184	DESCRIPTION	THICKNESS (Feet)
1A	Covered.	?

Measured Section 188: South Beaver Mountain.

Location: C, Sec. 25, T. 14 N., R. 23 E. (Bunch Quadrangle).

The directions to this measured section are as found in Nageotte (1981).

M.S. 188	DESCRIPTION	THICKNESS (Feet)
CHESTERIAN SERIES		45.7
PITKIN LIMESTONE		23.7
Oolitic Facies		
11	Oolitic grainstone.	1.5
10	Covered.	1.3
9	Oolitic grainstone.	3.2
8	Covered.	2.0
Oolite Facies		
7	Oolitic packstone.	4.0
Bioclastic: bryozoan-crinoidal Facies		
6	Gastropodal bryozoan packstone to grainstone. Well exposed. Moderate brachiopods, gastropods, crinoids, and bryozoans. Sparse Anthracospirifer.	1.7
Oolitic Facies		
5	Oolitic packstone. Well exposed. Few to moderate brachiopods with some bryozoans. Moderate Anthracospirifer, Eumetria, and Torynifer.	2.2

M.S. 188	DESCRIPTION	THICKNESS (FEET)
4	Covered.	5.5
3	Oolitic packstone. Well exposed. Moderate brachiopods, bryozoans, and crinoids. Rare rugose coral at base of unit. Rare _Ovatia_, _Eolissochonetes_, and _Barytichisma_.	0.5
Mudstone Facies		
2	Mudstone to wackestone. Well exposed. Abundant brachiopods and crinoids with some bryozoans. Abundant _Ovatia_. Rare to sparse _Diaphragmus_, _Composita_, and _Dielasma_.	1.8
FAYETTEVILLE SHALE		22.0
1	Covered.	?

Measured Section 189: Ford's Corner

Location: NW¼, NE¼, Sec. 16, T. 14 N., R. 23 E. (Bunch Quadrangle).

The directions to this measured sections are as found in Nageotte (1981).

M.S. 189	DESCRIPTION	THICKNESS (Feet)
CHESTERIAN SERIES		46.7
PITKIN LIMESTONE		21.7
Oolitic Facies		
7	Oolitic packstone.	2.5
Bioclastic: oncolitic Facies		
6	Algal brachiopodal packstone.	2.2
5	Brachiopodal pelecypodal packstone.	0.5

M.S. 189	DESCRIPTION	THICKNESS (Feet)
4	Algal bryozoan packstone.	2.0

<u>Mudstone Facies</u>

3	Mudstone with thin wackestone at base.	11.0
2	Mudstone with wackestone lenses. Poorly to moderately exposed. Abundant brachiopods. Moderate crinoids with some gastropods. Moderate <u>Composita</u> and <u>Ovatia</u>. Rare to sparse <u>Buxtonia</u>, <u>Diaphragmus</u>, <u>Eumetria</u>, and <u>Dielasma</u>.	3.5

FAYETTEVILLE SHALE 25.0

1	Mudstone and shale.	25.0

Measured Section 194: Stratton Hollow

Location: C, NE¼, Sec. 30, T. 14 N., R. 23 E. (Cookson Quadrangle).

The directions to this measured section are as found in Nageotte (1981).

M.S. 194	DESCRIPTION	THICKNESS (Feet)

CHESTERIAN SERIES 21.0

PITKIN LIMESTONE 3.3

<u>Wackestone Facies</u>

5	Wackestone.	1.5

<u>Bioclastic: bryozoan-crinoidal Facies</u>

4	Bryozoan packstone. Well exposed. Abundant crinoids. Moderate brachiopods, blastoids, and bryozoans. Rare trilobites and rugose corals. Rare to sparse <u>Pentremites</u>, <u>Anthracospirifer</u>, <u>Torynifer</u>, <u>Cleiothyridina</u>, and <u>Composita</u>.	1.0

M.S. 194	DESCRIPTION	THICKNESS (Feet)
3	Bryozoan packstone with interbedded shale. Moderate bryozoans, with few crinoids, brachiopods, and pelecypods. Sparse _Archimedes_ and _Torynifer_.	0.8
FAYETTEVILLE SHALE		17.7
2	Covered.	?

Measured Section 197: Pine Hollow

Location: NW¼, NE¼, Sec. 17, T. 14 N., R. 22 E. (Cookson Quadrangle).

The directions to this measured section are as found in Nageotte (1981).

M.S. 197	DESCRIPTION	THICKNESS (Feet)
CHESTERIAN SERIES		17.3
PITKIN LIMESTONE		6.8
Bioclastic: mixed Facies		
12	Covered.	1.8
11	Brachiopodal packstone. Poorly exposed. Moderate brachiopods with some crinoids and bryozoans. Moderate _Buxtonia_. Rare _Ovatia_.	0.5
Bioclastic: bryozoan-crinoidal Facies		
10	Crinoidal bryozoan grainstone. Well exposed. Abundant crinoids and bryozoans with few brachiopods. Rare _Diaphragmus_, _Girtyella_, _Ovatia_, _Composita_, and _Dielasma_.	1.4
Wackestone Facies		
9	Wackestone and interbedded shale.	0.7

M.S. 197	DESCRIPTION	THICKNESS (Feet)

Bioclastic: mixed Facies

8	Brachiopodal packstone to grainstone. Moderately exposed. Fossils were collected from the upper half of unit. Moderate brachiopods. Moderate Diaphragmus. Sparse Ovatia.	2.4

FAYETTEVILLE SHALE 10.5

Mudstone Facies

7	Mudstone.	0.5
6	Covered.	2.3

Wackestone Facies

5	Wackestone. Well exposed. Abundant brachiopods. Sparse Inflatia, Ovatia, Anthracospirifer, Punctospirifer, Reticulariina, Tetracamera, Eumetria, Athyris, and Composita.	1.7

Shale Facies

4	Shale and mudstone.	5.0
3	Covered.	1.0

Measured Section 199: North Gum Creek

Location: W½, SE¼, Sec. 28, T. 15 N., R. 22 E. (Park Hill Quadrangle).

The directions to this measured section are as found in Nageotte (1981).

M.S. 199	DESCRIPTION	THICKNESS (Feet)

CHESTERIAN SERIES - partial thickness 40.6

PITKIN LIMESTONE - partial thickness 4.9

M.S. 199	DESCRIPTION	THICKNESS (Feet)
Bioclastic: bryozoan-crinoidal Facies		
7	Bryozoan grainstone. Poorly exposed. Abundant crinoids with some brachiopods and pelecypods. Rare Anthracospirifer.	2.5
Bioclastic: oncolitic Facies		
6	Oncolitic packstone with interbedded shale.	1.0
Bioclastic: bryozoan-crinoidal Facies		
5	Bryozoan packstone. Moderately to poorly exposed. Abundant bryozoans and crinoids. Few brachiopods and pelecypods with rare cephalopods. Rare Rugosochonetes.	1.4
FAYETTEVILLE SHALE		35.7
4	Covered.	?

Measured Section 201: Northwest Qualls

Location: W½, NE¼, Sec. 35, T. 15 N., R. 21 E. (Qualls Quadrangle).

The directions to this measured section are as found in Nageotte (1981).

M.S. 201	DESCRIPTION	THICKNESS (Feet)
CHESTERIAN SERIES - partial thickness		37.8
PITKIN LIMESTONE		22.8
Oolitic Facies		
11	Pelletal oolitic grainstone.	6.5
10	Covered.	

M.S. 201	DESCRIPTION	THICKNESS (Feet)
9	Oolitic grainstone. Well exposed. Few brachiopods, crinoids, and bryozoans. Rare trilobites. Sparse Composita.	4.2
8	Covered.	0.5
Mudstone Facies		
7	Mudstone with wackestone lenses. Well exposed. Fossils were collected from upper 10 ft of unit. Abundant brachiopods and pelecypods. Few bryozoans, crinoids, trilobites, and gastropods. Abundant Ovatia. Rare to sparse Orthotetes, Anthracospirifer, Eumetria, Hustedia, Aviculopecten, Edmondia, and Sphenotus.	3.6
6	Covered.	2.5
Oolitic Facies		
5	Oolitic packstone. Well exposed. Abundant crinoids with few to moderate pelecypods. Difficult to obtain fossils intact. Rare Edmondia and Archimedes.	2.0
Bioclastic: mixed Facies		
4	Pelecypodal packstone. Moderately well exposed. Moderate crinoids, brachiopods, and pelecypods. Rare Diaphragmus, Ovatia, Orthotetes, Camorphoria, Composita, Sphenotus, and Schizodus.	1.0
3	Covered.	0.3
Mudstone Facies		
2	Mudstone.	1.4
FAYETTEVILLE SHALE - partial thickness		15.0
1	Covered.	15.0

Measured Section 208: North Elk Creek Road Cut

Location: NE¼, SE¼, Sec. 31, T. 15 N., R. 23 E. (Cookson Quadrangle).

The directions to this measured section are as found in Nageotte (1981).

M.S. 208	DESCRIPTION	THICKNESS (Feet)
CHESTERIAN SERIES - partial thickness		12.2
PITKIN LIMESTONE		5.2
Wackestone Facies		
3	Wackestone. Poorly exposed. Few crinoids and brachiopods. Few rugose corals. Sparse *Barytichisma*.	0.2
2	Wackestone and mudstone. Poorly exposed. Moderate crinoids and brachiopods. Rare *Dielasma* and *Composita*.	5.0
FAYETTEVILLE SHALE		7.0
1	Covered.	?

Measured Section 212: North of Wolf Hollow

Location: SW¼, NW¼, Sec. 10, T. 17 N., R. 20 E. (Hulbert Quadrangle).

The directions to this measured section are as found in Orgren (1979).

M.S. 212	DESCRIPTION	THICKNESS (Feet)
CHESTERIAN SERIES - partial thickness		55.8
PITKIN LIMESTONE - partial thickness		8.2

M.S. 212	DESCRIPTION	THICKNESS (Feet)

Oolitic Facies

6	Covered.	1.3
5	Oolitic crinoidal packstone to grainstone.	1.3

Bioclastic: bryozoan-crinoidal Facies

4	Peloidal crinoidal packstone.	1.0

Wackestone Facies

3	Pelletal brachiopodal wackestone. Well exposed. Lower portion contains the most easily obtainable fossils. Abundant brachiopods with few crinoids and pelecypods. Abundant _Diaphragmus_ and _Ovatia_. Moderate _Composita_. Rare to sparse _Eumetria_, _Torynifer_, _Sphenotus_, and _Schizodus_.	4.6

FAYETTEVILLE SHALE - partial thickness 47.5

2	Covered.	33.0

Measured Section 215: Yonkers

Location: SE¼, SE¼, Sec. 10, T. 18 N., R. 19 E. (Rocky Point Quadrangle).

The directions to this measured section are as found in Orgren (1979).

M.S. 215	DESCRIPTION	THICKNESS (Feet)

CHESTERIAN SERIES - partial thickness 43.6

PITKIN LIMESTONE - partial thickness 23.0

Oolitic Facies

7	Covered.	3.0

M.S. 215	DESCRIPTION	THICKNESS (Feet)
6	Brachiopodal oolitic packstone. Well exposed. Moderate brachiopods. Sparse _Diaphragmus_, _Ovatia_, _Eumetria_, _Torynifer_, _Composita_, _Camorphoria_, and _Sphenotus_.	4.3
Bioclastic: mixed Facies		
5	Brachiopodal bryozoan-crinoidal packstone. Well exposed. Abundant crinoids, bryozoans, and brachiopods. Few pelecypods and trilobites. Abundant _Diaphragmus_ and _Ovatia_. Sparse _Buxtonia_, _Composita_, and _Camorphoria_.	5.6
4	Covered.	4.3
Oolitic Facies overlying thin Mudstone Facies		
3	Crinoidal oolitic grainstone with a basal spiculiferous mudstone.	5.6
FAYETTEVILLE SHALE - partial thickness		20.8
2	Covered.	?

Measured Section 218: NW of Ogles Mountain

Location: Road cut between Sec. 5 and Sec. 6, T. 17 N., R. 21 E. (Thompson Corner Quadrangle).

The directions to this measured section are as found in Orgren (1979).

M.S. 218	DESCRIPTION	THICKNESS (Feet)
CHESTERIAN SERIES - partial thickness		16.2
PITKIN LIMESTONE - partial thickness		13.2
Oolitic Facies		
7	Covered.	0.7

M.S. 218	DESCRIPTION	THICKNESS (Feet)
6	Crinoidal oolitic grainstone.	5.2
5	Covered.	1.6

<u>Bioclastic: bryozoan-crinoidal Facies</u>

4	Crinoidal-bryozoan packstone. Poorly exposed. Moderate crinoids, bryozoans, and brachiopods. Rare *Dielasma*.	3.3
3	Covered.	1.6
2	Bryozoan crinoidal packstone to wackestone.	0.7

FAYETTEVILLE SHALE - partial thickness	3.0
1 Shale and covered.	3.0

Measured Section 224: Brown Mountain

Location: S½, SW¼, Sec. 30, T. 17 N., R. 21 E. (Thompson Corner Quadrangle).

The directions to this measured section are as found in Orgren (1979).

M.S. 224	DESCRIPTION	THICKNESS (Feet)
	CHESTERIAN SERIES - partial thickness	33.3
	PITKIN LIMESTONE - partial thickness	33.3

<u>Oolite Facies</u>

4	Oolitic grainstone.	6.6

<u>Mudstone Facies</u>

3	Mudstone with bryozoan wackestone lenses. Well exposed. Abundant bryozoans, brachiopods, blastoids, crinoids, and pelecypods. Abundant *Pentremites*	

M.S. 224	DESCRIPTION	THICKNESS (Feet)
	and Diaphragmus. Moderate Composita. Rare to sparse Buxtonia, Anthracospirifer, Eumetria, Girtyella, Camorphoria, Dielasma, Archimedes and Edmondia.	14.1

Bioclastic: bryozoan-crinoidal Facies overlain by thin Oolitic Facies

2	Bryozoan-crinoidal packstone. Upper 1/3 of unit is an oolitic packstone. Fossils were collected primarily from lower portion of unit. Abundant bryozoans, crinoids, and brachiopods. Few pelecypods and rugose corals. Sparse Composita, Eumetria, Torynifer, Buxtonia, Diaphragmus, Echinoconchus, Ovatia, Orbiculoidea, Camorphoria, Dielasma, and Archimedes.	8.9
1	Bryozoan crinoidal packstone. Well exposed. Abundant crinoids. Moderate bryozoans. Few brachiopods, pelecypods, and trilobites. Moderate Archimedes. Rare Composita, Diaphragmus, Ovatia, and Edmondia.	3.6

FAYETTEVILLE SHALE . . . . ?

Measured Section 228: Bald Knob

Location: NE¼, NW¼, Sec. 18, T. 17 N., R. 20 E. (Hulbert Quadrangle).

The directions to this measured section are as found in Orgren (1979).

M.S. 228	DESCRIPTION	THICKNESS (Feet)
CHESTERIAN SERIES - partial thickness		30.4
PITKIN LIMESTONE - partial thickness		30.4
Oolite Facies		
9	Oolitic grainstone.	1.6

M.S. 228	DESCRIPTION	THICKNESS (Feet)
8	Covered.	2.3
Oolitic Facies		
7	Crinoidal oolitic grainstone to packstone.	3.6
Pelletal Facies		
6	Peloidal packstone.	1.6
5	Covered.	4.3
Oolitic Facies overlain by Bioclastic: bryozoan-crinoidal Facies		
4	Crinoidal oolitic grainstone grading to bryozoan packstone. Moderately well exposed. Moderate bryozoans, crinoids, and brachiopods. Rare Buxtonia, Diaphragmus, Ovatia, Reticulariina, Eumetria, and Torynifer.	5.9
Bioclastic: bryozoan-crinoidal Facies		
3	Crinoidal pelletal packstone.	2.3
2	Covered.	5.9
1	Bryozoan crinoidal packstone. Poorly exposed. Abundant bryozoans and crinoids with few brachiopods and rugose corals. Rare to sparse Archimedes and Barytichisma.	2.6
0	Mudstone nodules in dirt.	?

Measured Section 229: Red Berry Mountain

Location: NW¼, NW¼, Sec. 8, T. 15 N., R. 21 E. (Zeb Quadrangle).

The directions to this measured section are as found in Orgren (1979).

M.S. 229	DESCRIPTION	THICKNESS (Feet)
CHESTERIAN SERIES - partial thickness		52.8
PITKIN LIMESTONE - partial thickness		51.3
<u>Bioclastic: bryozoan-crinoidal Facies</u>		
10	Oolitic crinoidal grainstone.	3.9
9	Covered.	2.0
<u>Oolitic Facies</u>		
8	Oolitic grainstone.	0.7
<u>Mudstone Facies to Wackestone Facies</u>		
7	Mudstone to brachiopodal wackestone. Well exposed. Abundant brachiopods, pelecypods, and gastropods. Abundant <u>Ovatia</u>. Sparse <u>Buxtonia</u>, <u>Diaphragmus</u>, <u>Orthotetes</u>, <u>Anthracospirifer</u>, <u>Eumetria</u>, <u>Aviculopecten</u>, <u>Pteronites</u>, <u>Edmondia</u>, <u>Sphenotus</u>, and <u>Schizodus</u>.	3.0
<u>Oolite Facies</u>		
6	Oolitic grainstone.	3.6
<u>Oolitic Facies</u>		
5	Crinoidal-oolitic grainstone.	5.3
4	Bryozoan oolitic grainstone grading into crinoidal oolitic grainstone. Well exposed. Massive unit. Abundant crinoids. Few to moderate brachiopods, pelecypods, and bryozoans. Rare trilobites and cephalopods. Moderate <u>Archimedes</u>. Rare <u>Echinoconchus</u>, <u>Ovatia</u>, and <u>Composita</u>.	3.6
<u>Bioclastic: bryozoan-crinoidal Facies</u>		
3	Bryozoan packstone. Well exposed. Massive unit. Abundant crinoids and bryozoans. Moderate brachiopods. Few blastoids and pelecypods. Rare <u>Diaphragmus</u>, <u>Echinoconchus</u>, <u>Cleiothyridina</u>, <u>Girtyella</u>, <u>Composita</u>, <u>Aviculopecten</u>, and <u>Archimedes</u>.	4.3

M.S. 229	DESCRIPTION	THICKNESS (Feet)
2	Covered.	24.9
FAYETTEVILLE SHALE		?
Mudstone Facies		
1	Mudstone.	1.3

APPENDIX B

COMMUNITY SUCCESSIONAL ANALYSIS

This appendix consists of the data and results of the community successional analysis. Walker's (1979) statistical analyses of community transitions were used to construct the matrices. The results of these matrices were then entered into a computer program (Harper, 1984, personal communication) that analyzed the data and calculated the binomial probabilities for each transition. A facies relationship diagram was then constructed from these results. The level of significance that is chosen will determine which transitions are at high, intermediate, and low probabilities of being non-random.

The first matrix is composed of the observed transitions.

The second matrix is composed of the probabilities of the observed transitions. These values are calculated by the formula:

$$p_{ij} = \frac{n_{obs}}{n_j}$$

where n_{obs} is the number of observed transitions and n_j is the total transitions of the row.

The third matrix is composed of the transition probabilities if those transitions were random. These values are calculated by:

$$r_{ij} = \frac{n_j}{N - n_i}$$

where r_{ij} is the random probability of transition from facies i to facies j, n_i is the number of occurrences of facies i, n_j is the number of occurrences of facies j, and N is the total number of occurrences of all facies.

Rather than determining whether these transitions are significant or not only by subjective conjecture, it is better to determine statistically the significance. This is accomplished by computing the binomial probability of at least n transitions occurring. This is given by:

$$PRMORE = \sum_{M}^{N} C\ (N,M)\ p^{M}\ q^{N-M}$$

where $C\ (N,M) = \frac{N!}{M!\ (N-M)!}$ = the number of possible combinations of N objects taken M at a time, $N = n_j$ is the number of occurrences of facies j, $M = n_{obs}$ = is the number of observed transitions, p = r_{ij} = is the probability of success on a single trial, and q = 1 - p = is the probability of failure in a single trial. The results of these calculations are listed in a table following the matrices. A 0.21 level of significance is decided on and those probabilities less than or equal to the level of significance are accepted.

n_i \ n_j	O	III	II	Ib	Ia	P	SH
O		4	4	0	3	0	1
III	6		7	3	4	2	7
II	3	15		2	1	1	0
Ib	2	1	4		4	2	0
Ia	3	5	4	7		2	12
P	1	4	1	1	0		0
SH	0	7	1	0	13	0	

Observed number of transitions between facies.

n_i \ n_j	O	III	II	Ib	Ia	P	SH
O		.333	.333	0	.250	0	.084
III	.207		.241	.103	.138	.069	.241
II	.136	.682		.091	.045	.045	0
Ib	.154	.077	.308		.308	.154	0
Ia	.091	.152	.121	.212		.061	.364
P	.143	.571	.143	.143	0		0
SH	0	.333	.048	0	.619	0	

Observed transition probabilities.

n_i \ n_j	O	III	II	Ib	Ia	P	SH
O		.288	.168	.104	.200	.056	.160
III	.139		.194	.120	.231	.065	.185
II	.130	.313		.113	.217	061	.174
Ib	.121	.290	.169		.202	.056	.161
Ia	.144	.346	.202	.125		.067	.192
P	.115	.277	.162	.100	.192		.154
SH	.129	.310	.181	.112	.216	.060	

Transition probabilities for random sequence.

FACIES ABBREVIATIONS

O - Oolitic grainstone and oolite lithofacies,

Sh - Shale lithofacies,

P - Pelletal lithofacies,

Ia - Sub-community of Ovatia-Sphenotus Community associated with the mudstone lithofacies,

Ib - Sub-community of Ovatia-Sphenotus Community associated with the wackestone lithofacies,

II - Pentremites-Composita Community,

III - Ovatia-Diaphragmus Community.

Binomial Probability of M or More Successes in N Trials

Obs	Facies	P	N	M	PRMORE
1	O-III	0.288	12	4	0.47023
2	O-II	0.168	12	4	0.12804
3	O-IB	0.104	12	0	1.00000
4	O-IA	0.200	12	3	0.44165
5	O-P	0.056	12	0	1.00000
6	O-SH	0.160	12	1	0.87659
7	III-O	0.139	29	6	0.20758
8	III-II	0.194	29	7	0.32645
9	III-IB	0.120	29	3	0.69306
10	III-IA	0.231	29	4	0.92848
11	III-P	0.065	29	2	0.57049
12	III-SH	0.185	29	7	0.28171
13	II-III	0.130	22	3	0.55881
14	II-III	0.313	22	15	0.00041
15	II-IB	0.113	22	2	0.72810
16	II-IA	0.217	22	1	0.99540
17	II-IA	0.061	22	1	0.74959
18	II-SH	0.174	22	0	1.00000
19	IB-O	0.121	13	2	0.47834
20	IB-III	0.290	13	1	0.98835
21	IB-II	0.169	13	4	0.16411
22	IB-IA	0.202	13	4	0.25884
23	IB-P	0.056	13	2	0.16266
24	IB-SH	0.161	13	0	1.00000
25	IA-O	0.144	33	3	0.87296
26	IA-III	0.346	33	5	0.99657
27	IA-II	0.202	33	4	0.92315
28	IA-IB	0.125	33	7	0.10990
29	IA-P	0.067	33	2	0.65826
30	IA-SH	0.192	33	12	0.01586
31	P-O	0.115	7	1	0.57479
32	P-III	0.277	7	4	0.09819
33	P-II	0.162	7	1	0.70979
34	P-IB	0.100	7	1	0.52170
35	P-IA	0.192	7	0	1.00000
36	P-SH	0.154	7	0	1.00000
37	SH-O	0.129	21	0	1.00000
38	SH-III	0.310	21	7	0.48966
39	SH-II	0.181	21	1	0.98490
40	SH-IB	0.112	21	0	1.00000
41	SH-IA	0.216	21	13	0.00008
42	SH-P	0.060	21	0	1.00000

APPENDIX C

This appendix contains the faunal list of the taxa collected and identified from the Pitkin Limestone, Oklahoma. Certain taxa were collected, but were not identified, such as gastropods, cephalopods, trilobites, crinoids, and many of the bryozoans. The pelecypods, blastoids, and bryozoan Archimedes were only tentatively identified to genus due to poor preservation and the difficulty in identification of these taxa.

Brachiopods

Athyris aff. *cestriansis* (Snider)

Buxtonia arkansana (Girty)

Rugosochonetes aff. *oklahomensis* (Snider)

R. aff. *sericeus* (Girty)

R. aff. *chesterensis* (Walker)

Eolissochonetes tumescens (Easton)

Camorphoria aff. *cestriensis* Snider

C. aff. *explanata* (McChesney)

Clieothyridina cf. *sublamellosa* (Hall)

Composita aff. *trinuclea* Hall

C. aff. *subquadrata* (Hall)

C. cf. *acinus* Girty

Diaphragmus elegans (Norwood and Pratten)

Dielasma cf. *shumardana* (Miller)

D. cf. *arkansonum* Walker

D. cf. *formosum* (Hall)

D. cf. *illinoisense* Weller

Echinoconchus alternatus (Norwood and Pratten)

Eumatria cf. *vera* Hall

E. aff. *costata* Hall

E. cf. *pitkinensis*

Girtyella cf. *indianensis* (Girty)

Hustedia cf. *multicostata* Girty

Inflatia aff. *inflatia* (McChesney)

Ovatia ovatus Muir-Wood and Cooper

Orthotetes aff. *subglobosus* Girty

O. cf. *batesvillensis*

Reticulariina aff. *spinosa* (Norwood and Pratten)

Anthracospirifer *pellansis* (Weller)

A. cf. *laidyi* (Norwood and Pratten)

Syringothyris aff. *aequalis*

Torynifer *setigera* (Hall)

Tetracamera cf. *neogenes* Girty

Punctospirifer sp. A

Obiculoidea cf. *newberryi* (Girty)

Corals

Barytichisma sp. A

Caninostrotion sp. A

Michelinia sp. A

Pelecypods

Allorisma sp.

Aviculopecten sp.

Myaline sp.

Pteronites sp.

Sphenotus sp.

Schizodus sp.

Echinoderms

Archimedes sp.

Pentremites sp.