

Lisa Bailey Corbitt. THE PETROLOGY AND STRATIGRAPHY OF THE REYNOLDS LIMESTONE MEMBER OF THE BLUEFIELD FORMATION (MISSISSIPPIAN) IN SOUTHEASTERN WEST VIRGINIA. (Under the direction of Dr. Donald W. Neal) Department of Geology, November 25, 1986.

The Reynolds Limestone Member of the Bluefield Formation is a thin (4 to 22 meters thick), extensive carbonate unit found throughout West Virginia. It is correlative, at least in part, with the driller's "Little Lime" and is a useful subsurface stratigraphic marker.

Petrographic analysis indicates that the Reynolds Limestone Member is composed of three shoaling upward sequences. The lithologies in each sequence include, in ascending order, biomicroparites (packstones) and biomicroparrudites (packstones) rich in echinoderms, bivalves, brachiopods, and bryozoans; micrites (mudstones), argillaceous biomicroparites (wackestones) and calcareous shales rich in peloids, brachiopods, bivalves, and gastropods; and dolostones or biolithites.

The shoaling upward sequences developed on a broad, shallow shelf dominated by terrigenous clastic sediments. A rise in sea level resulted in the initiation of carbonate sedimentation. The subsequent development of shallowing upward sequences in any given area was dependent upon variations in water depth, subsidence, rate of terrigenous sediment influx and the change in topographic relief.

Subsurface stratigraphy demonstrates a topographic high perpendicular to the outcrop pattern in Fayette and Greenbrier Counties. This feature subdivides the study area into 2 sub-basins, affecting sedimentation and the development of the sequence in each

area. Surface stratigraphy indicates that transitional sedimentation (dolostones or algal lithites) was restricted to the Clayton and Raines Corner sections, suggesting that the topographic high extended through Summers and Monroe Counties.

THE PETROLOGY AND STRATIGRAPHY
OF THE REYNOLDS LIMESTONE MEMBER
OF THE BLUEFIELD FORMATION
(MISSISSIPPIAN) IN SOUTHEASTERN WEST VIRGINIA

A Thesis
Presented to
the Faculty of the Department of Geology
East Carolina University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Geology

by
Lisa Bailey Corbitt

December 1986

15

THE PETROLOGY AND STRATIGRAPHY
OF THE REYNOLDS LIMESTONE MEMBER
(MISSISSIPPIAN) IN SOUTHEASTERN WEST VIRGINIA

by

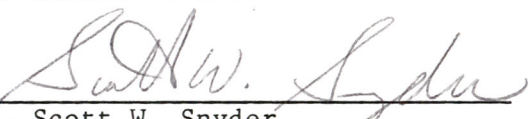
Lisa Bailey Corbitt

APPROVED BY:

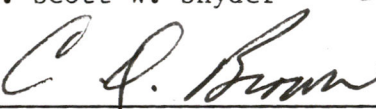
THESIS DIRECTOR


Dr. Donald W. Neal

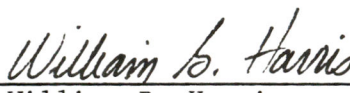
COMMITTEE MEMBER


Dr. Scott W. Snyder

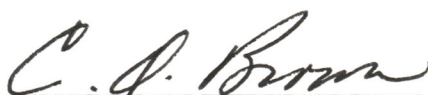
COMMITTEE MEMBER


Dr. Charles Q. Brown

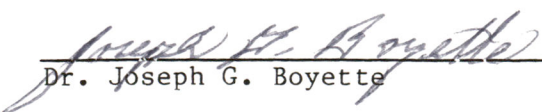
COMMITTEE MEMBER


Dr. William B. Harris

CHAIRMAN OF THE DEPARTMENT OF GEOLOGY


Dr. Charles Q. Brown

DEAN OF THE GRADUATE SCHOOL


Dr. Joseph G. Boyette

ACKNOWLEDGEMENT

Partial funding for this study was provided by the Alumni of East Carolina University through a graduate research grant.

My sincere appreciation to my friend and advisor, Donald W. Neal for sharing with me his knowledge and experience of Mississippian age carbonates, for his red chair, his willingness to listen and his almost neverending patience through all the aspects of this research project.

To Dr. Scott W. Snyder, and Dr. C. Q. Brown of the Geology Department, East Carolina University, and Dr. William B. Harris of the Department of Earth Sciences, University of North Carolina at Wilmington, who consented to serve on my thesis committee, I would like to express my gratitude for their comments and assistance.

My love and appreciation go to my husband and fellow geologist, Chris Corbitt, for his continuous encouragement, love and support without which this project would have never been completed.

Finally, to my mother Mildred C. Bailey and my father D. Edwin Bailey, I express sincere gratitude for their encouragement and understanding which made the completion of my thesis possible.

TABLE OF CONTENTS

	PAGE
ABSTRACT.....	i
ACKNOWLEDGEMENTS.....	iii
INTRODUCTION.....	1
PREVIOUS WORKS.....	6
PURPOSE.....	7
PROCEDURES.....	7
Thin Sections.....	8
Insoluble Residues.....	8
X-ray Diffraction.....	9
PETROLOGY.....	10
DEPOSITIONAL COMPONENTS.....	10
Allochems.....	10
Echinoderms.....	10
Brachiopods.....	10
Foraminifers.....	11
Bivalves.....	11
Bryozoans.....	12
Gastropods.....	12
Ostrocodes.....	13
Other Fossils.....	13
Ooids.....	13
Peloid.....	14
Intraclasts.....	15
NON-CARBONATE COMPONENTS.....	15
Trilobites.....	15
Other Non-Carbonate Components.....	15
Matrix.....	16
Micrite.....	16
Other Matrix.....	17
POST DEPOSITIONAL COMPONENTS AND PROCESSES.....	17
Cements.....	17
Microspar.....	19
Micritization.....	20
Pyrite.....	21
Silica.....	22
Gypsum.....	23
Dolomite.....	23
Compaction.....	24
Summary.....	26
MICROFACIES.....	28
INTRODUCTION.....	28
Microfacies I.....	33
Microfacies II.....	33
Microfacies III.....	36
Microfacies IV.....	36
Microfacies V.....	39
SUBSURFACE STRATIGRAPHY.....	41

SURFACE STRATIGRAPHY.....	52
VERTICAL RELATIONSHIPS.....	52
LATERAL RRELATIONSHIPS.....	69
DEPOSITIONAL ENVIRONMENT.....	72
DEPOSITONAL MODEL.....	72
GEOLOGIC HISTORY.....	75
CONCLUSIONS.....	78
REFERENCES CITED.....	80
APPENDIX A.....	86
APPENDIX B.....	95
APPENDIX C.....	102
APPENDIX D.....	104

LIST OF FIGURES, TABLES AND PLATES

FIGURE		PAGE
1.	General stratigraphic section of the lower Bluefield Formation.....	2
2.	Location map of field area.....	5
3.	Sequence of diagenetic events.....	27
4.	A denrogram of the modal data from the Reynolds Limestone Member.....	30
5.	The mean percent abundance of constituents in each microfacies.....	31
6.	Gamma-ray and bulk density log of the lower Bluefield Formation.....	42
7.	Location of stratigraphic cross sections.....	44
8.	Gamma-ray cross section A.....	45
9.	Gamma-ray cross section B.....	46
10.	Gamma-ray cross section C.....	47
11.	Gamma-ray cross section D.....	48
12.	Gamma-ray cross section E.....	49
13.	Isopach map of the Reynolds Limestone Member.....	50
14.	Outcrop locations.....	53
15.	Lithology and allochem abundance at Edray.....	54
16.	Lithology and allochem abundance at Droop.....	57
17.	Lithology and allochem abundance at Briery Knob.....	59
18.	A fence diagram of the lower Bluefield Formation.....	62
19.	Lithology and allochem abundance at Raines Corner.....	63
20.	Lithology and allochem abundance at Clayton and Muddy Creek Mountain.....	65
21.	Lithology and allochem abundance at Nemours.....	67
22.	An idealized shallowing upward sequence.....	73
23.	Development of a typical cycle.....	76

TABLE

1.	Brachiopods of the Reynolds Limestone Member.....	11
2.	Mean percent abundance of constituents in each microfacies..	32
3.	The relative percent abundance of each microfacies in a given section.....	68

PLATES

1.	Outcrop of the Reynolds Limestone Member.....	4
2.	Photomicrograph of an argillaceous micrite.....	34
3.	Photomicrograph of an algal biolithite.....	35
4.	Photomicrograph of a biomicrosparite.....	37
5.	Photomicrograph of a biomicrosparite.....	38
6.	Photomicrograph of a biomicrosparrudite.....	40

INTRODUCTION

In southeastern West Virginia, the Mississippian stratigraphic section is divided into two series (Englund and others, 1976). The Lower Mississippian Series, composed predominantly of shallow marine sandstones and shales (Arkle and others, 1979), correlates with the Price Formation and Maccrady Shale (Englund and others, 1976). The Upper Mississippian Series is transitional from marine limestone to shale and sandstone (Colten, 1970; Craig and Varnes, 1979; Englund and others 1976; Englund, 1979) and correlates with the Greenbrier and Mauch Chunk Groups (Weller and others, 1948; Sprouse, 1954; Dyar, 1957). The Mauch Chunk Group in West Virginia comprise a thick sequence of interbedded sandstones and shales representing nearshore to deltaic environments (Reger, 1926). The group is divided into four formations: the Bluefield Formation, Hinton Formation, Princeton Sandstone and Bluestone Formation (Fig. 1) (Dyer, 1957; Kanes, 1958). The Bluefield Formation is transitional between the underlying marine carbonates of the Greenbrier Group and overlying, predominantly terrigenous Hinton, Princeton, and Bluestone Formations. The lower part of the Bluefield Formation (Fig. 1), is composed of calcareous mudstone, argillaceous limestone, and lenses of sandstone. The upper Bluefield section consists of interbedded sandstone, siltstone and laminated claystone. The Bluefield Formation reaches a maximum thickness of approximately 400 m in Mercer, Monroe and Summers Counties (Reger, 1926). Thickness decreases to the northwest. In Pocahontas County the minimum thickness is about 10 meters (Thomas, 1959). Marine

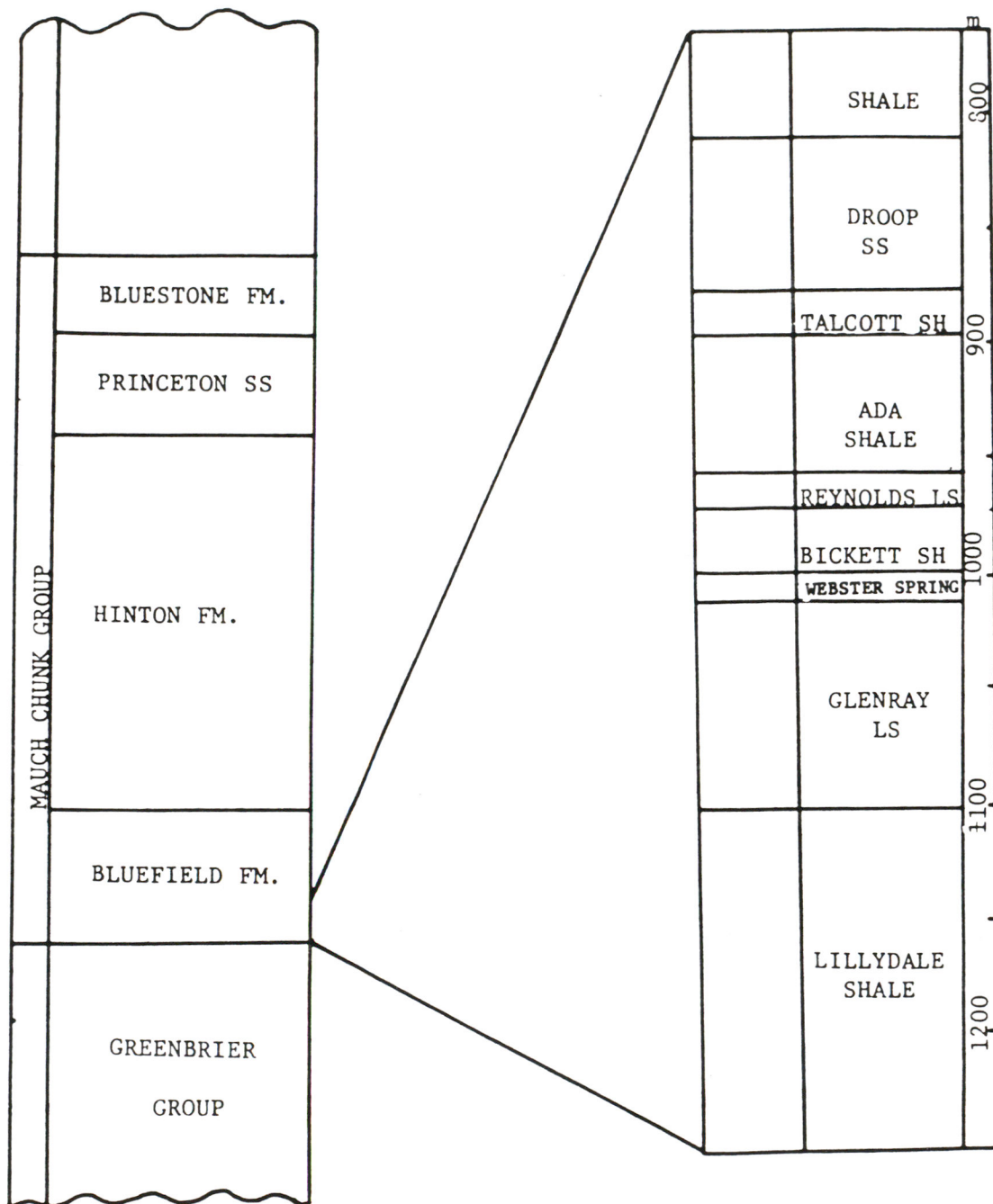


Figure 1. General Stratigraphic Section of the lower portion of the Bluefield Formation (after Manspeizer, 1958).

deposition generally characterized the Bluefield Formation. According to Humphreville (1981), the Bluefield Formation represents episodes where nearshore mud, sand and freshwater marshes encroach on a marine carbonate environment.

Among the numerous thin limestones within the Bluefield, the most conspicuous and continuous is the Reynolds Limestone Member. According to Reger (1926), the Reynolds Limestone at the type locality is "...a gray shaly bed usually 10 to 15 feet thick, coming under the Ada Shale and being rich in marine fauna". It represents the last major marine transgression in the Bluefield Formation. In Pocahontas County, north of the type locality, the Reynolds Limestone Member is a more resistant carbonate unit with less interbedded shale. Characteristically, the member features a diverse fauna, is geographically extensive and represents the last major marine transgression in the Bluefield Formation (Plate 1).

The study area is located in southeastern West Virginia in McDowell, Wyoming, Raleigh, Fayette, Mercer, Summers, Nicholas, Monroe, Greenbrier and Pocahontas Counties (Fig. 2). The Reynolds Limestone Member crops out in Mercer, Summers, Monroe, Greenbrier and Pocahontas Counties (Fig. 2). It occurs only in the subsurface in the western part of the study area. The Reynolds Limestone is used as the key horizon for correlation of the Greenbrier and lower Bluefield in the subsurface (Youse, 1964)



Plate 1. Outcrop of the Reynolds Limestone Member at Droop Mountain, Pocahontas County, West Virginia.

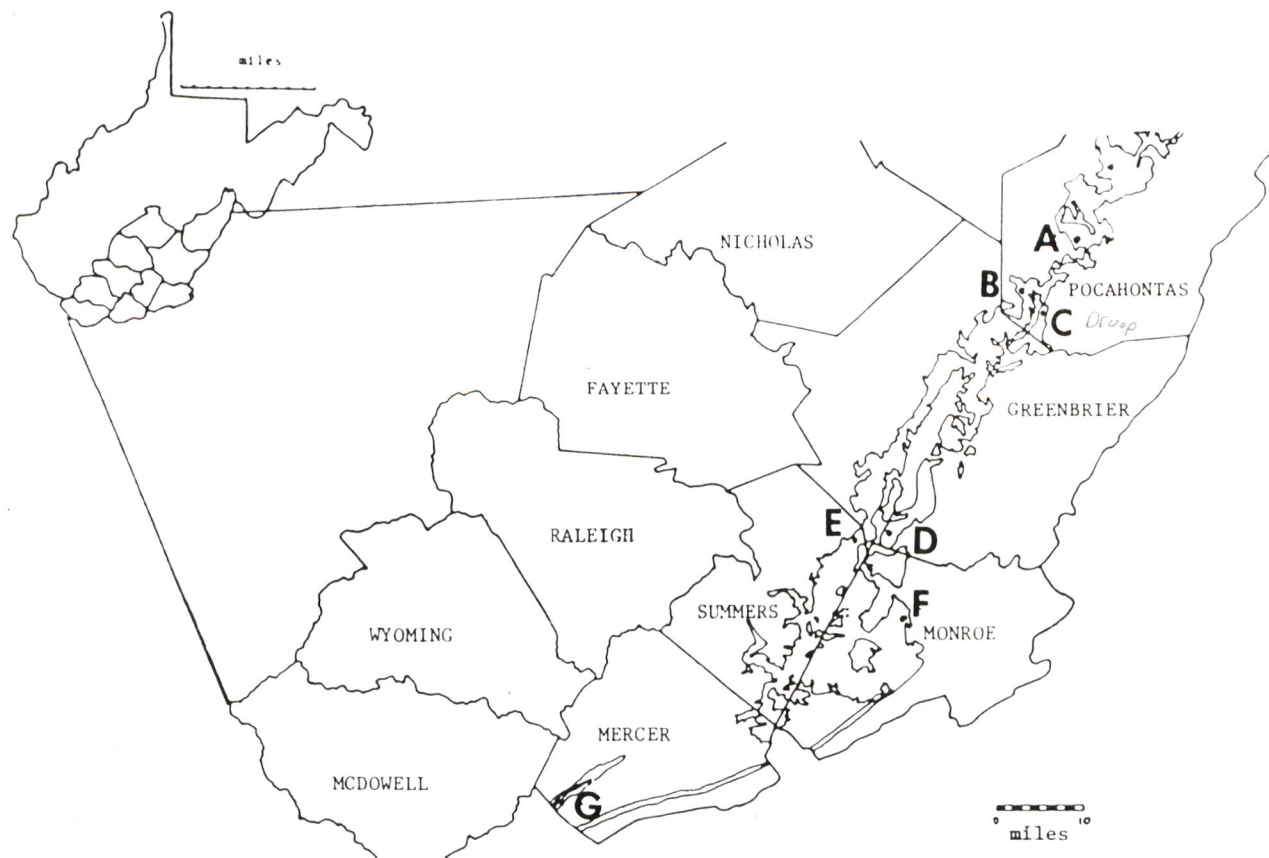


Figure 2. Index map of West Virginia showing the area of investigation and the outcrop pattern of the Bluefield Formation.

PREVIOUS WORKS

The Mauch Chunk Group overlies the Greenbrier Group and is overlain by the Pennsylvanian Pottsville Group. It was originally defined in Mauch Chunk, Pennsylvania as the "Mauch Chunk Red Shale" (Ashburner 1877). It was also referred to as "No. XI" by the Geological Survey of Pennsylvania (Reger, 1926). At the type locality in northeastern Pennsylvania, it is a shale with some sandstone, no coal and only rare occurrences of limestone (Reger, 1926). To the south, in West Virginia, the Mauch Chunk loses its monotonous character and becomes a sequence of sandstone, limestone, occasional coal and a variety of shales. Hennen (1913) recognized the complex nature of the Mauch Chunk in West Virginia and described it as the "Mauch Chunk Series". Campbell (1896) divided the Mauch Chunk Series into the four formations that are used today (Fig. 1). Reger (1926) and Wilpolt and Marden (1959) described the Mauch Chunk Group and determined its general stratigraphic framework.

Arkle and others (1979) provided a general overview of the Mississippian System including lithology, paleontology and structural controls in West Virginia. Presley (1979) discussed the depositional systems, based on recent facies studies, of the Upper Mississippian strata in northern West Virginia. The stratigraphy and paleontology of the Bluefield Formation were described in greater detail by Manspeizer (1958) and Humphreville (1981).

PURPOSE

The purpose of this research is to: 1) provide a detailed description of the mineralogy and petrology of the Reynolds Limestone Member; 2) characterize the diagenetic alteration of the unit; 3) interpret the depositional environment(s); and 4) delineation of the vertical and lateral relationships of the unit in outcrop and in the subsurface.

PROCEDURES

Seven outcrops of the Reynolds Limestone Member were measured, described and sampled from the Bluefield Formation outcrop belt in southeastern West Virginia (Fig. 2). The Bluefield crops out from western Mercer County northward through central Pocahontas County. Outcrops were selected to provide 1) the most complete exposures of the Reynolds Limestone Member and 2) the broadest possible geographic coverage.

Sampling of the outcrops involved two techniques. Initially, the outcrop was sampled every 0.8 m. Because of the interbedding of shale and limestone, a sampling scheme based on lithologic change was adopted. The top and bottom of each lithologic unit was sampled and, depending on the thickness, one, two or three samples were taken within the unit. A total of 93 samples were collected for study. Measured and described sections are included in Appendix A.

THIN SECTIONS

Eighty one thin sections were prepared, examined and described. Other samples were analyzed using a standard binocular microscope. Each thin section was stained with a solution of Alizarin Red S and potassium ferricyanide in dilute hydrochloric acid. By this method, calcite stains red, iron-poor calcite stains mauve, ferroan calcite stains purple, ferroan dolomite stains light blue and ankerite stains dark blue (Evamy, 1963; Friedman, 1971). Thin sections were point counted (300 points per slide) and each point was identified by mineralogy or allochem type. Dunham's (1962) grain volume percent method was used in this study. According to this method, voids, cement and matrix within the allochems are counted as part of the allochem (Appendix B). The data were analyzed with the help of SAS (Statistical Analysis System). Rock types were named based on Folk's carbonate classification (1959). Dunham's classification (1962) is shown in parenthesis.

INSOLUBLE RESIDUES

Fifty-two samples were treated with concentrated (industrial grade) hydrochloric acid to obtain percentages of carbonate and non-carbonate components. Samples weighing from 17.5 to 24.0 g were crushed to sand-sized aggregates and placed in an acid bath for approximately 24 hours. Excess acid was decanted, the sample washed, filtered, dried in an oven at 65 C for approximately 24 hours and weighed.

Using the original sample weight and the weight of the insoluble residue, percent carbonate and non-carbonate material was calculated. Samples were analyzed by binocular and petrographic microscopes to determine mineralogy. Selected samples were also analyzed by x-ray diffraction in order to determine insoluble component mineralogy (Appendix C).

X-RAY DIFFRACTION

Four interbedded shale samples from the Reynolds Limestone Member and nine insoluble residue samples were analyzed for bulk mineral composition by x-ray diffraction analysis. Samples were powdered, packed into plastic sample holders and scanned between 3 to 45 degrees two-theta at 2 degrees per minute. The source of radiation was Cu k-alpha.

PETROLOGY

The Reynolds Limestone Member consists of allochems, matrix, non-carbonate components and diagenetic cements, evaporites, iron minerals, and dolomite.

DEPOSITIONAL COMPONENTS

Allochems

Echinoderms

Echinoderms are the most abundant allochem in the Reynolds Limestone Member (up to 42% of rock volume). In outcrop, they occur as whole samples, broken crinoid stems, plates and spines. In thin section, they occur as fragmented, single calcite crystals showing unit extinction. As the mud fraction increases, there is a decrease in echinoderms. Subphyla in the Reynolds Limestone Member include Blastozoa, Crinozoa and Echinozoa. According to Price and Heck (1939), Blastozoa are represented by Pentremites sp. and Crinozoa are represented by numerous indeterminate columnals. Echinozoa are represented by echinoid spines and fragments. According to Tucker (1981), echinoderms are a major constituent of bioclastic platform deposits.

Brachiopods

Brachiopods are common in the Reynolds Limestone Member (up to 23% of rock volume, average of 9.75% rock volume). In outcrop, they are present as well preserved articulated whole shells and fragments. Species are representative of the articulated Spiriferid and Strophomenid

Orders (Table 1; Price and Heck, 1939). In thin section, brachiopods occur as fragments, spines and occasionally as whole specimens. Identification (thin section) was based on shell morphology and microstructure.

TABLE 1

<u>Orthotetes keokuk</u>	Strophomenida
<u>Orthotetes kaskaskiensis</u>	Strophomenida
<u>Diaphragmus elegans</u>	Strophomenida
<u>Productus ovatus</u>	Strophomenida
<u>Productus inflatus</u>	Strophomenida
<u>Spirifer pellaensis</u>	Spiriferid
<u>Spiriferina spinosa</u>	Spiriferid
<u>Composita trinuclea</u>	Spiriferid
<u>Composita subquadrata</u>	Spiriferid
<u>Eumetria verneuilliana</u>	Spiriferid

Brachiopods of the Reynolds Limestone Member (Price and Heck, 1939).

Foraminifers

Foraminifers are locally common in the Reynolds Limestone Member (average 4% of rock volume). The most common genus is Endothyra (Wells, 1950; Wray, 1951, 1952; Leonard, 1968; Slagel 1978).

Preservation of the foraminifers is generally good, but in some sections they have been totally micritized.

Bivalves

Pelecypods are a common component of the fauna of the Reynolds Limestone Member (average 17% of rock volume ; up to 23% of rock volume). In outcrop, they may be articulated, or occur as

disarticulated and broken fragments. Generally, pelecypods are diagenetically altered and the original microstructure is destroyed. Price and Heck (1939) identified Leda bellistriata, Allorisma clavata and indeterminate pelecypod fragments. In thin section, bivalves occur most often as disarticulated valves, and occasionally as whole specimens.

Bryozoans

Bryozoans are a relatively common component of the Reynolds Limestone Member (average 12.5% of rock volume; up to 31.7% of rock volume). In outcrop, bryozoans occur as broken fronds and an occasional screw-like axis of Archimedes. According to Price and Heck (1929), Septopora sp. is also present. In thin section, bryozoans are usually fenestrate forms showing separation of individual zooecia. Less commonly, but still prominent, are occurrences of large fronds and fragments. Preservation of bryozoans varies from well preserved (showing internal structure, zooecia and fibrous walls) to partially or completely micritized (obliterating microstructure).

Gastropods

Gastropods are uncommon in the Reynolds Limestone Member (average 5% of rock volume). They were observed only in thin section where they appear as diagenetically altered shells with no previous structure or morphology preserved. Geopetal structures are commonly associated with gastropods. Price and Heck (1939) identified Straparollus planidorsatus in the Reynolds Limestone Member.

Ostracodes

Ostracodes are rare in the Reynolds Limestone Member. Where found, they constitute only up to 2% of the rock volume. They appear to have had a smooth outer surface and have undergone diagenetic alteration. Specimens occur as articulated and disarticulated valves less than 1mm in length.

Other Fossils

Algae are rare in the Reynolds Limestone Member, but they do occur as isolated algal laminations. At the Raines Corner section, blue-green algae occur as laminites, forming stromatolites. The algae provides a semiresistant open network in which lime mud and sand grains are trapped. The algal laminations are slightly undulose and some contain rip up clasts and fractures. Sponges are also present in small amounts.

Ooids

Calcareous ooids are spherical or ellipsoidal carbonate particles with uniform concentric laminae coating a nucleus (Flügel, 1982). Several types of ooids can be differentiated based on the number of laminae, size, shape and whether they are complete or incomplete. Ooids are uncommon in the Reynolds Limestone Member, but are represented by normal ooids, superficial ooids and cracked or broken ooids.

Normal ooids measure less than 2mm and have several laminae around a nucleus. The size and shape of the ooid is determined by the nucleus, generally a fossil fragment or quartz grain. In the Reynolds Limestone size ranges from 0.5mm to 1.0mm and averages 0.7mm. Superficial ooids, the most common type of ooid in the Reynolds Limestone Member, are grains surrounded by one or two laminae (Flügel, 1982). Friedman (1964) and Land (1979) suggested that superficial ooids are associated with quiet water environments. Sizes range from 0.5mm to 1.0mm and average 0.7mm. Cracked or broken ooids are a result of transportation or compaction. Most cracked or broken ooids are normal ooids.

Peloids

Peloids are cryptocrystalline carbonate aggregates of unknown origin. They are spherical to elliptical particles of varying size with no internal structure. They may include micritized carbonate particles, pseudo-ooids (cryptocrystalline carbonate particles with no concentric layers) or fecal pellets. Flügel (1982) recommended the term peloid be used instead of pseudo-ooid. Pellets and peloids are differentiated because peloids have no specific origin, whereas the term pellet implies a fecal origin. Peloids, common in the Reynolds Limestone Member, range in size from 0.03 to 0.2mm.

Intraclasts

Intraclasts represent pieces of indurated carbonate sediment that have been ripped up and redeposited by currents (Folk, 1974).

Intraclasts are not generally common but are locally abundant. They are composed of calcium carbonate, quartz, gypsum, pyrite, peloids, fossil fragments, phyllosilicates and dolomite. The intraclasts are rounded to irregular in shape and average 0.9mm in size.

NON-CARBONATE COMPONENTS

Trilobites

Trilobites have a segmented exoskeleton that is generally less than 1mm thick and consists of chitin heavily impregnated with calcite and calcium phosphate (Flügel, 1982). Trilobites are locally common in the Reynolds Limestone Member. At the Edray section they are found in outcrop. At other localities they are not observed in outcrop but are present in thin sections. Identification is based on microstructure, the sweeping effect of the fine prismatic lamellar structure and morphology. In thin section, a trilobite often appears as a "shepherd's crook". One genus Griffithides has been identified from the Reynolds Limestone Member, (Price and Heck, 1939).

Other Non-Carbonate Components

Several phosphatic bone fragments (collophane) are seen in the Reynolds Limestone Member. They probably represent skeletal fragments of fish. Plant fragments appear locally but are generally rare in the

Reynolds Limestone Member. They are present in samples with a high micrite fraction.

Quartz is the most abundant terrigenous component. It is present as silt and sand-sized particles. Silt is associated with abundant micrite or peloids. Sand-sized particles are associated with abundant fossils and a minor mud fraction. Sand-sized grains range in size from 0.2mm to 0.6mm. In both silt and sand-sized grains the extinction is parallel to slightly undulose, and grains are angular to subrounded and contain few inclusions. This evidence suggests a metamorphic origin.

Feldspar was observed in trace amounts in thin section. The grains show albite twinning, suggesting it is plagioclase. There were not enough grains present to distinguish the variety. Feldspar was also identified in x-ray analysis but the variety was indistinguishable.

Matrix

Micrite

Friedman (1978) defined micrite as lithified, mechanically deposited lime mud which occurs either as matrix among sand-sized particles in a limestone or as the only particles in a fine-grained limestone. Micrite ranges in grain size from one to four microns (Folk, 1974).

In outcrop, micrite is opaque and dull gray in color; in thin section it is translucent with a faint brownish cast. Micrite is common in the Reynolds Limestone Member where it occurs as homogeneous layers

or mixed with siliciclastic material.

There are several modes of origin for micrite, including direct precipitation from seawater (Milliman and others, 1969; Cloud, 1962; Neumann and Land, 1975), decomposition of the hard parts of invertebrates (Chave, 1962; Folk and Robles, 1964; Flugel, 1982) and biological abrasion of algae, fungi and invertebrates (Chave, 1962; Folk and Robles, 1964). The samples studied do not indicate the origin of the micrite within the Reynolds Limestone Member.

Other Matrix

Mica is a common siliciclastic component of the Reynolds Limestone Member. It occurs as silt-sized bladed crystals in thin section. X-ray studies of insoluble material and shales indicate the presence of muscovite. The mica crystals are subparallel to the bedding surface.

X-ray analysis of clay minerals indicates illite is the only clay mineral in the limestone and shale of the Reynolds Limestone Member. Other clays may be present in small amounts beyond the resolution of x-ray analysis.

POST-DEPOSITIONAL COMPONENTS AND PROCESSES

Cements

Varieties of cement found in the Reynolds Limestone Member include syntaxial, fibrous, bladed, blocky spar, drusy and meniscus. Syntaxial cement refers to the overgrowth of a skeletal grain such that the original grain and the overgrowth are optically continuous (Folk,

1965). Overgrowths are most commonly associated with echinoderms but they also occur on trilobites, ostracodes and brachiopods (Longman, 1980). In the Reynolds Limestone Member only echinoderms are associated with syntaxial overgrowths. Growth of the cement begins in the pores of an echinoderm skeleton. As pores are filled, the volume of syntaxial cement increases, forming many serrated edges. As the volume continues to increase, the number of edges decrease and the growth of the cement becomes more rapid. As a result, the cement is progressively elongated in the C direction (Bathurst, 1971; Longman, 1980). Lucia (1962) suggested that overgrowths may be prevented or at least inhibited where the echinoderm (or other fossil) is coated with micrite. If there is a break in the micrite coating, the overgrowth will continue to grow around the micrite. Syntaxial overgrowths are present in the Reynolds Limestone Member when a) there is a high percentage of echinoid fragments and b) there is a low percentage of mud fraction.

Fibrous to bladed calcite cement forms as an early diagenetic cement (Longman, 1980). The long axes of crystals are perpendicular to the host-particle surface and grow into pore spaces. They are normally a brownish color due to inclusions. In the Reynolds Limestone Member this type of cement occurs in interparticle and intraparticle pores. It is most often associated with brachiopods, mollusks, trilobites and echinoderms. Fibrous cement commonly occurs in shallow marine environments, but may also form in beach rocks and in deeper marine environments with restricted sedimentation (Flügel, 1982).

Blocky spar is a secondary cement almost always associated with a

subhedral crystals of calcite. It occurs in both interparticle and intraparticle pores. Equant anhedral crystals normally form within intraparticle pores of bivalves, crinoid stems, brachiopods, gastropods and fenestrate bryozoans.

Drusy cement also occurs as a secondary cement. It occurs as subhedral to anhedral crystals with crystal size increasing from the pore wall to the center of the cavity (Flugel, 1982). Drusy cement forms in the Reynolds Limestone Member in intraparticle pores of the larger allochems or as interparticle cement in samples with a low micrite fraction.

Meniscus cement implies precipitation in the vadose zone from water localized around the points of grain contact (Bathurst, 1971). If pore water occurs between grains in a meniscus fashion, the cement assumes a meniscus texture (Dunham, 1971). The cement is brown due to microscopic inclusions. Meniscus cement in the Reynolds Limestone Member is associated with brachiopods, pelecypods, echinoderms and gastropod fragments.

Microspar

According to Folk's (1965) original definition, microspar is a neomorphic crystal mosaic with crystal diameters commonly from 4 to 10 μm but ranging up to 50 μm . The origin of microspar is highly debated and it probably originates by several means.

Historically, microspar is used to describe "recrystallized micrite" (Flugel, 1982). Folk (1974) states that microspar originates

from the recrystallization of micrite. Carbonate mud generally consists of either high-Mg calcite or aragonite. During diagenesis, aragonite inverts to calcite and high-Mg calcite loses some magnesium. Micrite forms relatively equant blocks of low-Mg calcite, about 2 μm in diameter. Excess Mg ions form a "cage" around each calcite grain. In order for microspar to form, the excess magnesium ions have to be removed (Folk, 1973, 1974; Longman, 1977). Magnesium ions can be removed by brackish water, fresh water input, absorption of Mg onto clay minerals (Longman, 1977), rain water and surficial weathering (Flügel, 1982; Longman, 1977). Others suggest that micrite and microspar coexist and result from the calcitization of an aragonite-dominated mud (Lasemi and Sandberg, 1984).

Microspar in the Reynolds Limestone Member occurs as matrix and as isolated patches within allochems or highly fossiliferous samples. The "matrix" microspar is the most common. Its origin is best explained by removal of the Mg ion cage from low-Mg calcite. Longman (1977) illustrated the method in his study of the Bromide Formation. He suggested that clays in interbedded shales attract Mg ions. The less common isolated patches of microspar possibly resulted from neomorphic alteration by meteoric water input.

Micritization

Blue-green algae in the photic zone commonly bore holes (6-10 μm in diameter) in carbonate particles (Bathurst, 1966; Purdy, 1963). After death and decay of the algae, bore holes are sites for

precipitation of fine grained aragonite or Mg-calcite. Continuous boring and filling leads to centripetal replacement of grains (Fuchtbauer, 1974). The crystals are so small that under a light microscope they resemble micrite, thus this process is called micritization (Parker 1981). Partial alteration forms a micritic envelope. Through prolonged micritization, skeletons and grains, may be transformed into structureless intraclasts. Micritic envelopes can also be formed by the intergrowth of calcareous algae on the surface of carbonate particles (Kobluk and Risk, 1977; Flugel, 1982). This envelope protects the carbonate particles from further micritization. Unless the algal laminations are preserved, it is difficult to distinguish this "constructive" envelope from the destructive envelopes described by Bathurst (1966) and Flugel (1982). Regardless of the type of micritization, Bathurst (1958, 1966), Wilson (1968) and Purdy (1963) found that micritization is usually concentrated in slowly agitated lagoonal environments.

Micritization is common in the Reynolds Limestone Member as micritic envelopes and as totally micritized particles. Total micritization is more common in samples that have a moderate to high mud fraction. Micritic envelopes predominate in samples with a high allochem percentage.

Pyrite

Pyrite is common in the Reynolds Limestone Member (average of 1.5%, up to 11% of the rock volume). It is stable in conditions where sulfur activity is high (negative Eh and a moderate pH). Pyrite

commonly occurs as framboids but is also present as irregular masses. There are two varieties of framboidal pyrite: a) "fine pyrite" composed of spheres less than 0.03mm in diameter which aggregate into globules measuring 0.15 to 0.2mm, and b) singular spheres less than 0.12mm in size (Fuchtbauer, 1974). Both forms result from decomposition of organic matter coupled with an abundance of dissolved sulfate. Bacterial reduction of sulfate releases sulfide into the water producing H_2S . The H_2S then reacts with Fe^{2+} in solution to form pyrite (Berner, 1971). The concentration of sulfate in seawater and the necessity of organic material suggests an environment of organic-rich marine muds (Tucker, 1981). In the Reynolds Limestone Member pyrite occurs as type "b" framboids, ranging in size from 0.01mm to 0.1mm with an average size of 0.03mm.

Silica

Silicification is rare in the Reynolds Limestone Member. Silica in the form of chalcedony replaces bryozoan, echinoderm and other fossil fragments. Silica also occurs as small spherical patches of chert (approximately 0.15mm in diameter) or irregular patches of chert in microspar. Chert is composed of microcrystalline and chalcedonic quartz (Folk, 1974). Possible sources for silica include skeletons of siliceous organisms (sponges, diatoms, etc.), terrigenous sediments, and SiO_2 -rich water. Neither the source nor the mechanism of silica enrichment is known; however, the close association of terrigenous sediments would favor them as a possible source.

Gypsum

Gypsum occurs only in one sample of the Reynolds Limestone Member. It occurs as large anhedral to subhedral crystals filling in the void space of a fragmented bivalve. It is associated with blocky calcite cement and is partially replaced by dolomite and calcite.

Dolomite

Dolomite is locally abundant in the Reynolds Limestone Member. It usually occurs at the lower or upper boundaries of the member, but occasionally appears in the center, associated with shale partings. The amount of dolomite is also variable, anywhere from 0% to 95% of a sample. The Raines Corner and Clayton sections have the highest concentrations of dolomite (Raines Corner averages 19%; Clayton averages 47%).

Based on Gregg and Sibley's (1984) textural classification of dolomites, three basic types of dolomite can be recognized; idiotopic-E, idiotopic-P and idiotopic-S. All three varieties are found in the Reynolds Limestone Member. Idiotopic-E dolomite is crystal supported, loosely packed, well formed dolomite rhombs (Gregg and Sibley, 1984). In the Reynolds Limestone Member such rhombs average 0.02mm in size. The crystals often have parallel extinction in cross-polarized light. The intercrystalline areas consist of microspar or micrite.

Idiotopic-P (porphyrotopic) dolomite is euhedral dolomite with crystals that float in a limestone matrix (Gregg and Sibley, 1984). In the Reynolds Limestone Member the rhombs average 0.02mm in size, but range up to 0.1mm and are associated with the replacement of allochems.

Idiotopic-S dolomite is composed of subhedral to anhedral crystals with little or no intercrystalline matrix. Straight boundaries are common and many of the crystals have preserved crystal face junctions (Gregg and Sibley, 1984). In the Reynolds Limestone Member the rhombs average 0.02mm but occur as small as 0.005mm.

Ferroan dolomite, identified by staining, is locally abundant. It occurs as idiotopic-S dolomite. The rhombs average 0.02mm with a range extending from 0.005mm to 0.1mm. It occurs at the lower and upper contacts of the Clayton section.

Compaction

Compaction includes any process that decreases the bulk volume of rocks. The Reynolds Limestone Member has undergone mechanical compaction, pressure solution and fracturing. The degree of compaction is influenced by the type of early cementation (lime muds opposed to blocky calcite), overburden and tectonics. Mechanical compaction is recorded in the Reynolds Limestone Member by cracked ooids and fragmented fossils. Cracked ooids occasionally have splayed cortices which later were healed with calcite. Most ooids show no signs of mechanical compaction. Flugel (1982) stated that the presence of deformed and undeformed ooids in a sediment package indicates overburden compaction of unlithified sediments (early compaction).

Compaction and fracturing are more prevalent in fossils.

Bryozoans, brachiopods and echinoderms are most affected. The timing of compaction is unknown but calcite and clay healing of the fractures

indicates early compaction.

Pressure solution is the process of preferential dissolution of mineral material at points of stress. There are two types of pressure solution in the Reynolds Limestone Member: a) grain-to-grain pressure solution and b) stylolitization.

Grain-to-grain pressure solution is common in samples with a minor mud fraction. When pressure solution takes place, transformation of point contacts between grains to surface contacts is easily recognizable in thin section. Grain-to-grain contacts occur between practically every kind of fossil present in the member. Pressure solution contacts also occur along the quartz-carbonate boundaries.

Stylolitization varies from grain-to-grain pressure solution in that it transects the whole rock rather than occurring between isolated grains (Bathurst, 1971). In the Reynolds Limestone Member, stylolites and microstylolites cut across micrite, cements and allochems. The controlling factor in stylolitization is orientation of the axis of linear stress (Bathurst, 1971). In the Reynolds Limestone Member the axis is approximately perpendicular to bedding, indicating it was caused by overburden pressures. The undulating surface is due to differences in solubility of material (cement, mineral or allochem) across the interface. The time of stylolitization in the Reynolds Limestone Member is unknown, but it must have occurred after cementation because stylolites transect cements, micrite and allochems.

Fractures healed with calcite, quartz, pyrite and clays occur occasionally in the Reynolds Limestone Member. The time and method of formation is unknown, but this process occurred after cementation.

Summary

Diagenesis within the Reynolds Limestone Member can be ascribed to 3 different phases (Fig. 3). During the first phase (early diagenesis) destruction of the original allochem structure began through micritization. Dolomitization occurred penecontemporaneously with deposition or shortly after burial. Cementation by meniscus, fibrous and bladed calcite as well as compaction began during this time. The second phase of diagenesis (middle diagenesis) began shortly after burial with the formation of syntaxial overgrowths and further compaction. The final phase of diagenesis (late diagenesis) occurred with continual burial. Blocky and drusy pore filling cements formed and compaction continued. Timing of the formation of microspar, pyrite, gypsum and silica is unknown.

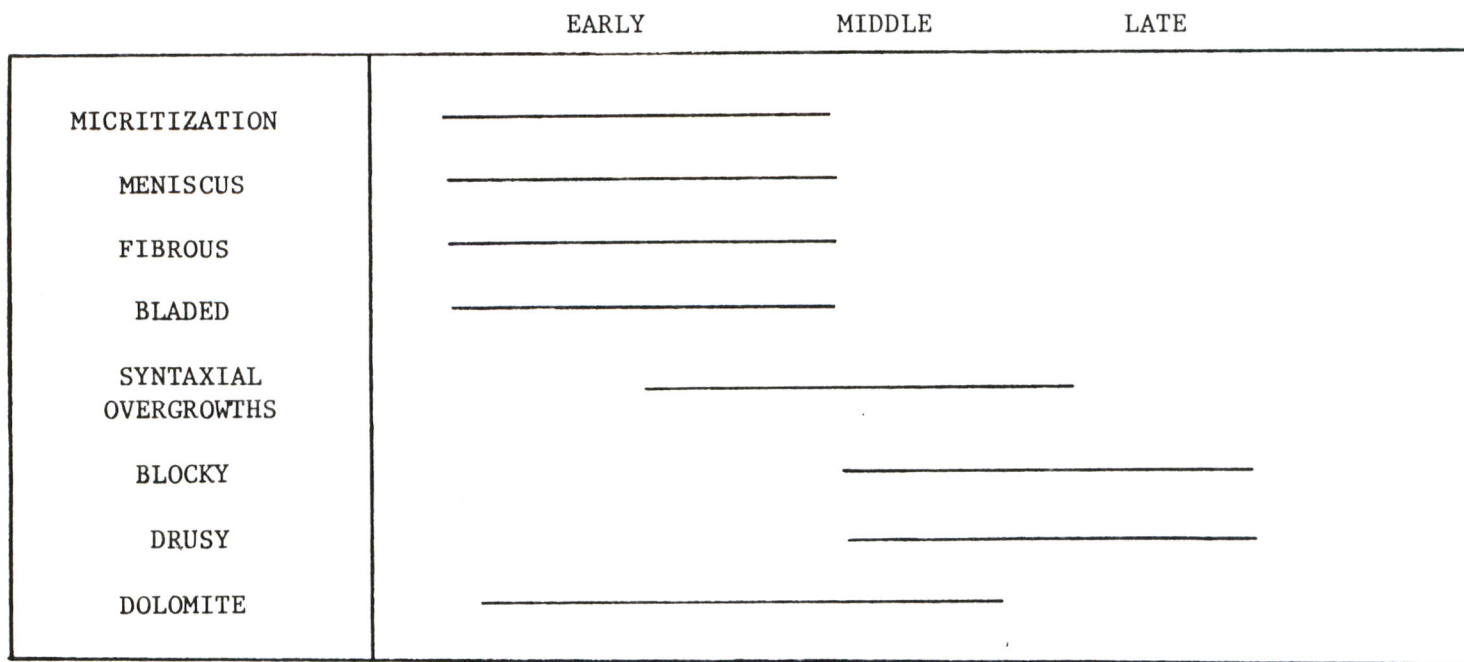


Figure 3. Generalized sequence of diagenetic events.

MICROFACIES

INTRODUCTION

"Microfacies" was first defined in petrologic terms as the features, composition or appearance of a rock or mineral as seen in thin section (Brown, 1943). It has also been used by Fairbridge (1954) as a textural term to refer to lithologic and paleontologic properties recognized in thin section. Microfacies may also indicate a "fine grained facies" or a facies on a small scale (Gary and others, 1973). In this study, microfacies were determined using petrologic characteristics and associations determined by cluster analysis.

Five microfacies were recognized from the analysis of 72 thin sections. A data matrix (72 samples x 22 variables) was established for multivariate analysis by counting 300 points per thin section. The twenty-two variables included, micrite, mica, quartz, pyrite, feldspar, organics, phosphate, ooids, peloids, intraclasts, echinoderms, trilobites bryozoans, brachiopods, ostracodes, foraminifers, gastropods, bivalves, sponges, algae, matrix, and unidentified fossil fragments. The matrix variable includes a mixed, very fine-grained siliciclastic and carbonate matrix. The siliciclastic portion includes micas, feldspars, quartz and clays.

Since the sampling scheme was not totally random and the variables are not normally distributed, the non-parametric technique of cluster analysis was applied. Cluster analysis was chosen because it can analyze large numbers of samples and variables. Secondly, it has been

used successfully in similar previous studies (Purdy, 1963; Behrens, 1965; Bonham-Carter, 1965; Smosna and Warshauer, 1978 and 1979; Gray, 1985). The point count data were analyzed using Ward's minimum variance hierarchical cluster analysis method (Q-mode) from SAS (Statistical Analysis System). Ward uses the sum of squares between individual clusters for hierarchical clustering. It is biased toward producing clusters with roughly the same number of observations because it tends to join clusters within a small number of observations (Fig.4; SAS Institute, 1984).

Five clusters were chosen using the cubic clustering criterion (CCC) to evaluate Ward's method. The CCC, an approximation of R^2 , is that portion of variability of the dependent variable "explained" by the independent variable when more than one independent variable is being compared (SAS, 1982). The CCC is used by plotting its value against the number of clusters, ranging from two clusters up to about one-tenth the number of observations (SAS, 1982). Peaks that plot greater than 2 or 3 indicate good clustering. Peaks with a CCC between 0 and 2 indicate possible clusters that should be interpreted cautiously (SAS, 1982). The peak for the Reynolds Limestone Member data fell at 1.9008, suggesting that the clusters are valid but the variability within the clusters is not totally explained by the independent variables (i.e., micrite, bryozoans, etc.). This result is expected because the variability is also influenced by outside factors (i.e., tectonics, sea-level changes, storms). The averages for the variables were computed and are presented in Figure 5 and Table II.

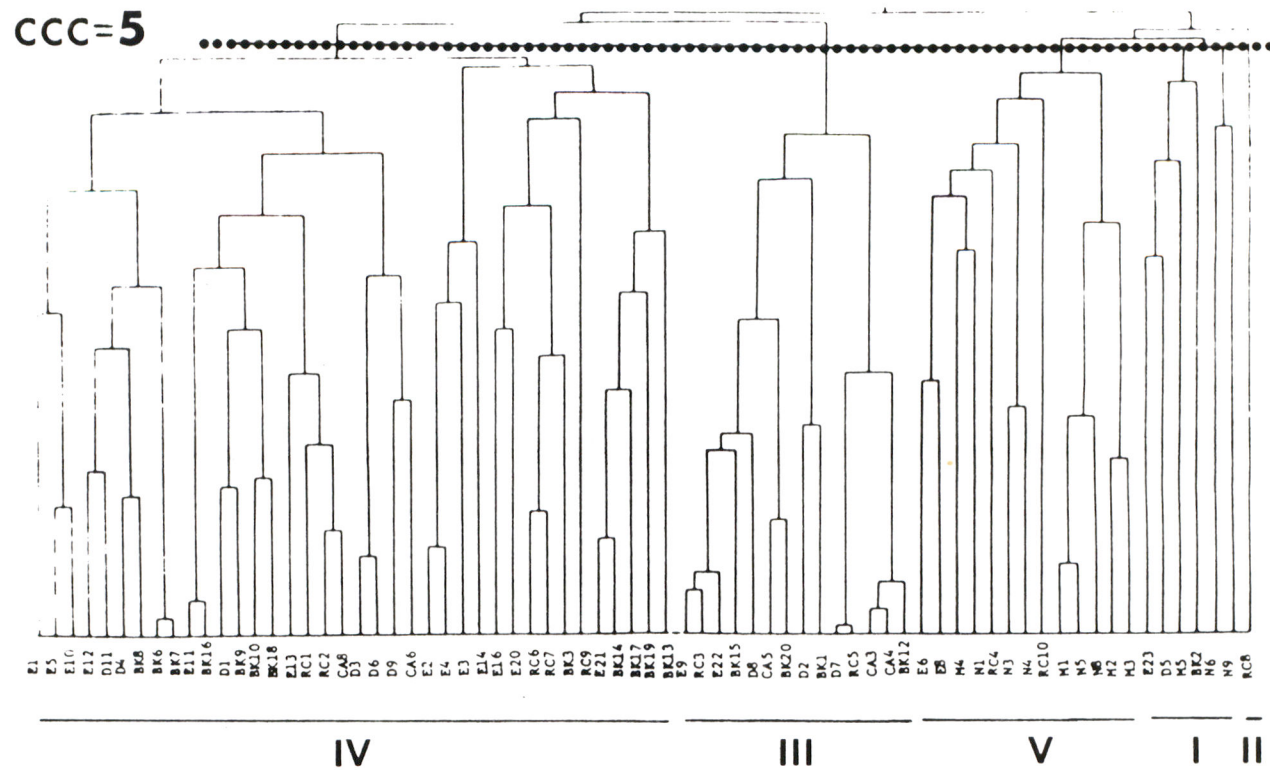


Figure 4. A dendrogram showing the clustering of modal data from the Reynolds Limestone Member. The cubic clustering criteria (CCC) is equal to 5.

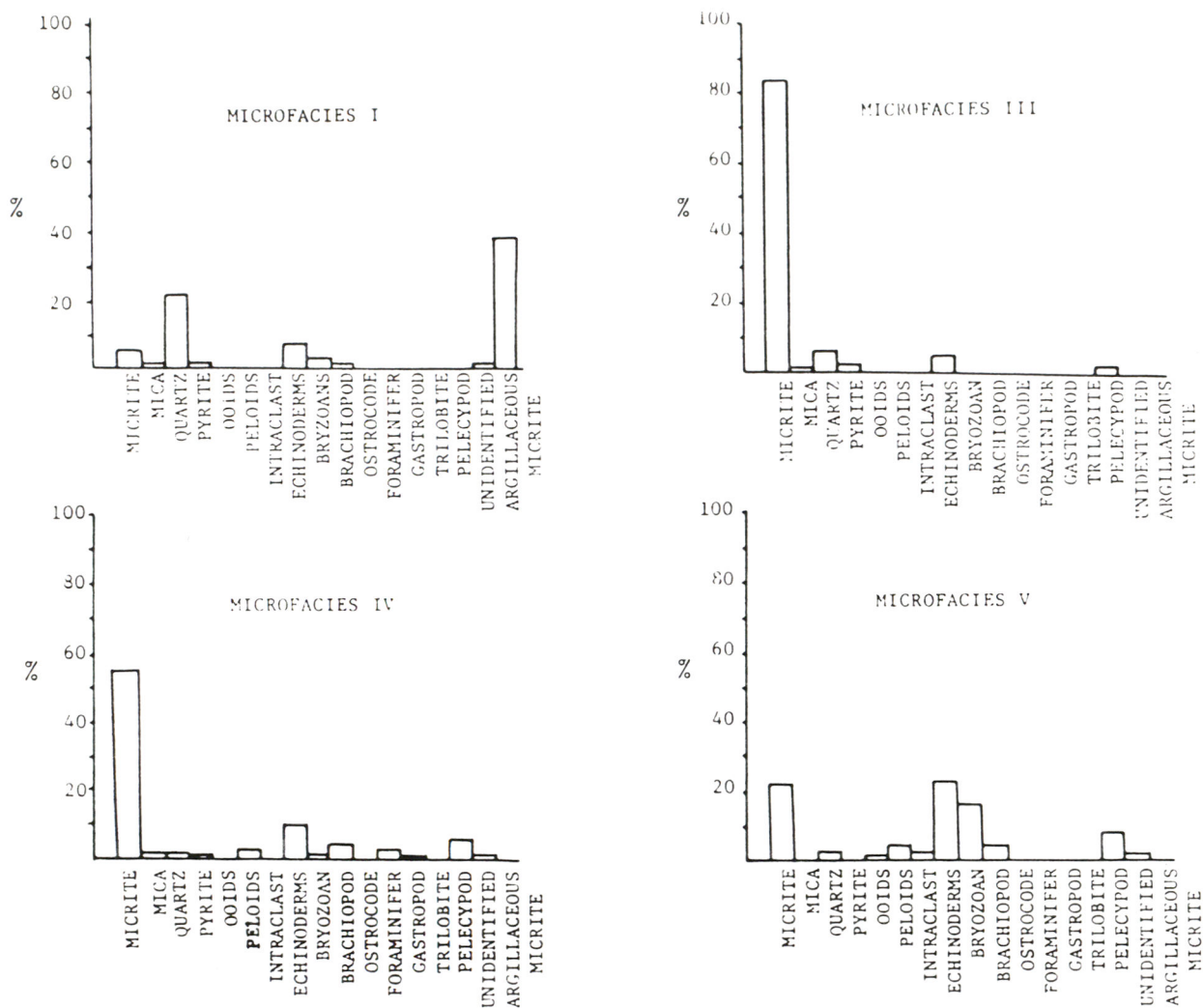


Figure 5. The $\bar{x}$ percent abundance of constituents in each microfacies (microfacies II is 100% algal).

* constituents less than 1% are not shown.

TABLE II

	Micrite	Mica	Quartz	Pyrite	Ooids	Peloids	Intraclasts
I	7.7	2.8	22.9	2.6	0.05	0.8	0.7
III	79.5	0.7	3.5	1.8	-	1.6	0.3
IV	56.0	3.0	2.8	1.7	0.2	3.7	0.4
V	22.9	-	1.7	0.5	2.0	5.8	3.8
	Echinoderms	Bryozoans	Brachiopods	Ostracodes	Foraminifers		
I	9.8	4.7	1.1	0.2	0.2		
III	5.5	0.9	1.8	0.1	1.2		
IV	11.5	2.3	4.9	0.6	2.5		
V	23.7	18.2	5.4	0.2	0.2		
	Gastropods	Trilobites	Pelecypods	Unidentified fossils			
I	0.2	0.05	8.7	1.0			
III	-	0.1	2.3	0.5			
IV	1.4	0.4	7.4	1.1			
V	0.3	1.0	10.7	1.9			
	Argillaceous micrite	Others					
I	36.5	-					
III	0.2	-					
IV	-	-					
V	-	1.7					

The mean percent abundance of constituents in each microfacies

(Microfacies II is 100% algal).

MICROFACIES I

Microfacies I represents a siliciclastic-rich carbonate microfacies (Plate 2). Argillaceous micrite (mudstone), averaging 35.4%, is the major constituent of this microfacies. The argillaceous component is a mixture of clay and very fine silt-sized material. Predominant minerals are illite (identified from x-ray diffractograms) and quartz. Other important constituents include echinoderms (averaging 9.7%) and micrite (averaging 7.7%). Most of the samples in this microfacies are categorized as biomicrites. Some samples are laminated, but subsequent bioturbation partially destroyed the original sedimentary features. In outcrop, microfacies I occurs as a thinly bedded limestone unit. The fauna of this microfacies includes ostracodes, gastropods, some bivalves and brachiopods. More abundant faunal elements, such as echinoderms and bryozoans, show signs of abrasion and fragmentation.

MICROFACIES II

Microfacies II consists of one sample, an algal biolithite (boundstone) (Plate 3). It is from the upper portion of the Raines Corner section. Both upper and lower contacts of the biolithite are with microfacies III. The biolithite has cryptalgal laminations with grain sizes ranging from mud to fine silt. Composition changes from a calcareous mud to a quartz sand, and color changes (light to dark) with respect to composition. Laminations are slightly undulose with some containing rip up clasts and ripple marks.

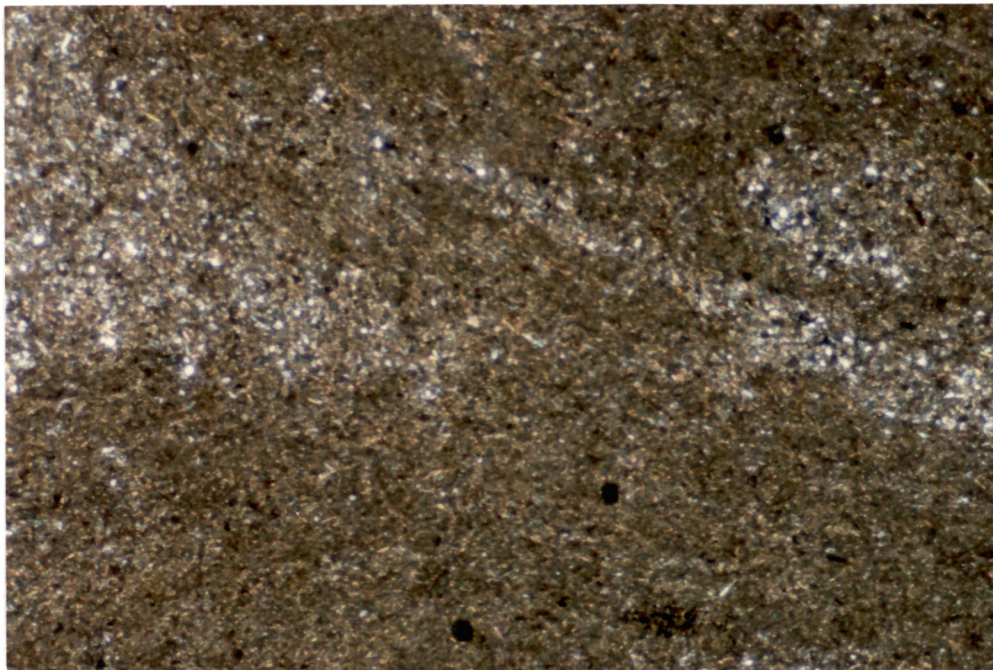


Plate 2. Photomicrograph (X 25) of an argillaceous micrite (mudstone) representative of microfacies I.



Plate 3. Photomicrograph (X 25) of an algal biolithite (boundstone) representative of microfacies II.

MICROFACIES III

Microfacies III is composed of biomicrosparites (wackestones) and argillaceous micrites, (mudstones) which collectively represent 19% of all samples (Plate 4). Micrite is the major constituent, averaging 79.5%. In outcrop microfacies III occurs as a thinly bedded limestone interbedded with calcareous shale. Faunal diversity in the biomicrosparite is low. Major faunal elements include echinoderms (averaging 3.5%) and pelecypods (averaging 1.7%) with minor amounts of brachiopods, bryozoans, and foraminifers (Fig.5). Other secondary constituents include quartz, pyrite and minor amounts of mica. The most prominent sedimentary feature is bioturbation. Less frequently, patches of sparry calcite occur as geopetal fabrics.

Argillaceous micrites represent two of the samples. They are laminated and contain no fossils. Micrite is the major component, but 12% of the sample consists of siliciclastic material (quartz, pyrite and mica). Grain size ranges from mud to fine silt.

MICROFACIES IV

Microfacies IV consists of biomicrosparites (wackestones), but the extent fossil predominance varies (Plate 5). It is the largest cluster, representing, 53% of the samples, and is distinguished by a high percentage of micrite (averaging 56%), diversity of the fauna and paucity of siliciclastic material. In outcrop, microfacies IV is a massive limestone interbedded with calcareous shales. Echinoderms are usually the predominant fossil type (averaging 11.6%), but bryozoans (averaging 2.3%), brachiopods (averaging 4.9%), foraminifers (averaging

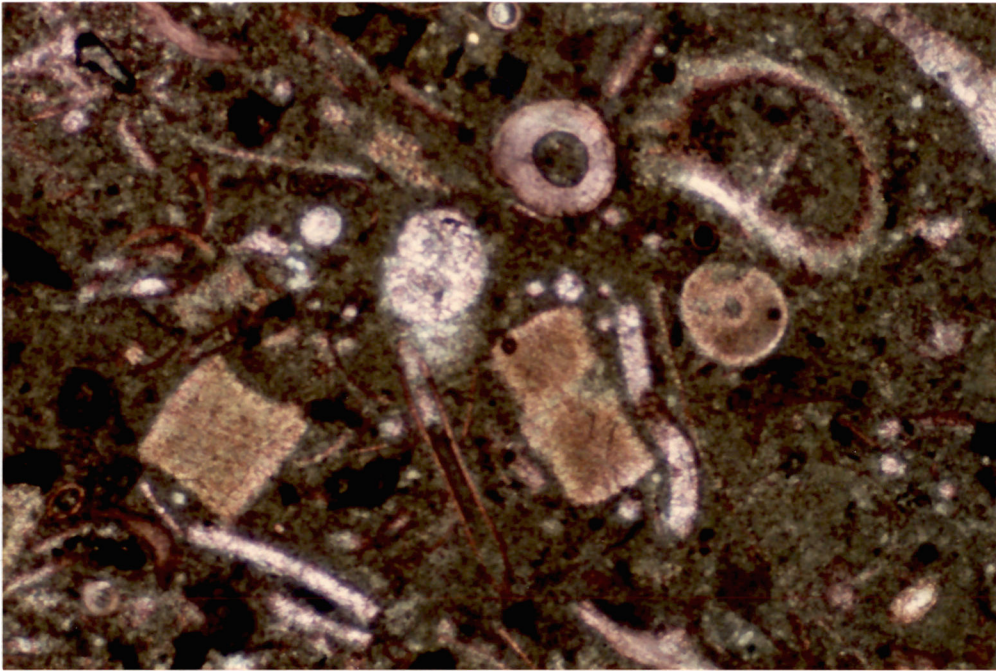


Plate 4. Photomicrograph (X 25) of a bioturbosparite (wackestone) representative of microfacies III.

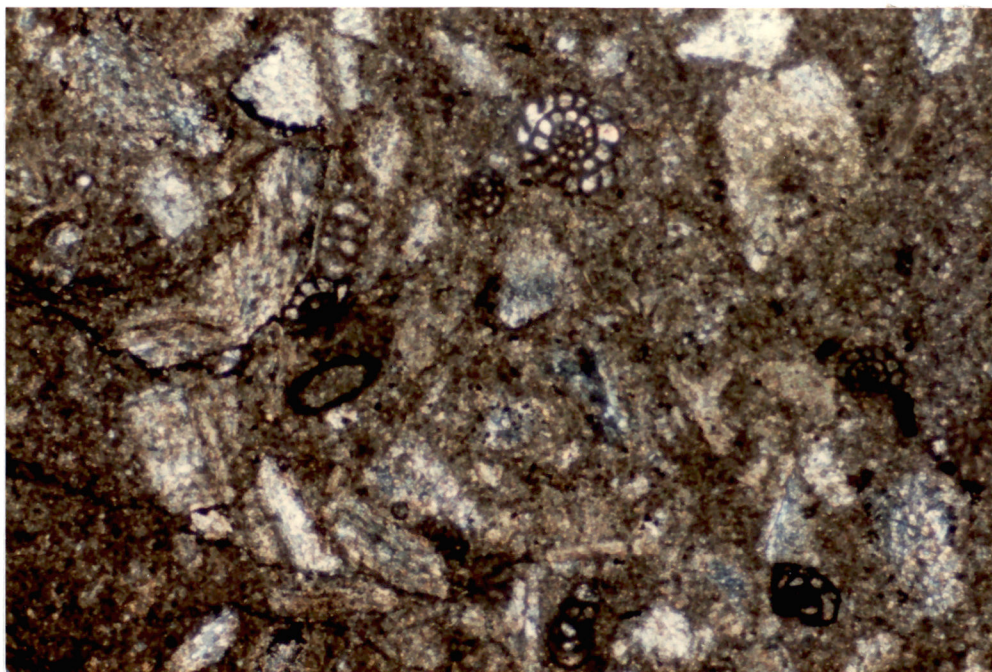


Plate 5. Photomicrograph (X 25) of a bioturbate (wackestone) representative of microfacies IV.

2.5%) and pelecypods (averaging 7.4%) are also abundant. Quartz averages 2.8%. Other constituents that are locally abundant include ostracodes, phosphate, organics and feldspar. Bioturbation is the predominant sedimentary feature. In addition, some samples have been partially dolomitized.

MICROFACIES V

Eighteen percent of the samples are represented by microfacies V. Biomicroparites and biomicroparrudites (wackestones and packstones) are the dominant rock types (Plate 6). In outcrop microfacies V occurs as a massive limestone. Faunal diversity is high; echinoderms average 23.7%, bryozoans 18.2%, pelecypods 10.7% and brachiopods 5.4%. Other allochems include ooids (averaging 2.0%) and peloids (averaging 5.8%). Minor constituents such as phosphate, sponges and algae are locally abundant. Bioturbation is the predominant sedimentary feature. The ooids are abraded and fragmented, suggesting they are not indigenous to this microfacies.

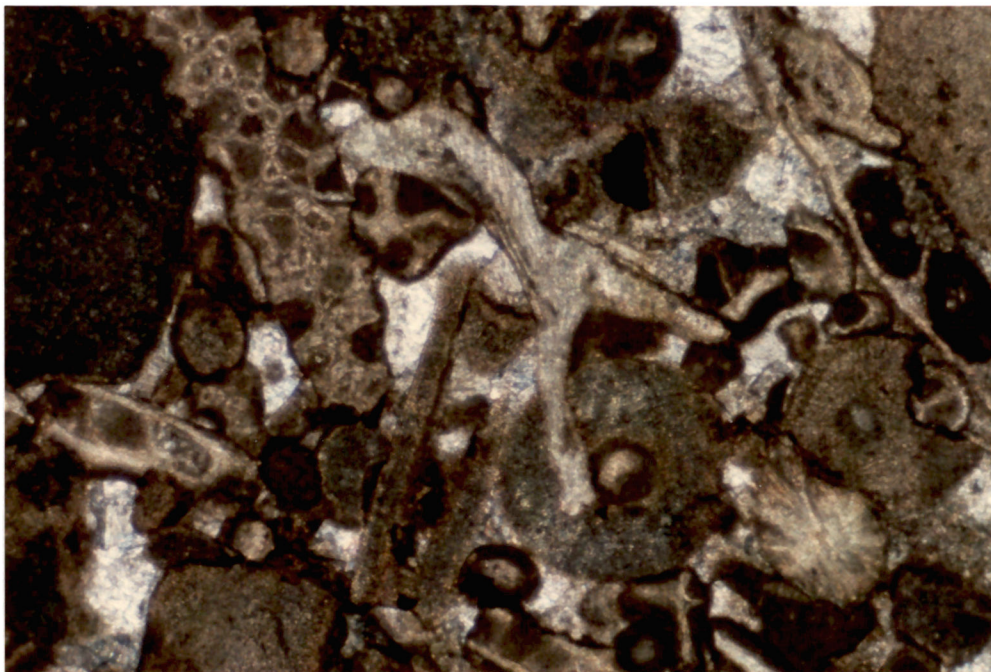


Plate 6. Photomicrograph (X 25) of a biomicrosparrudite (packstone)
representative of microfacies V.

SUBSURFACE STRATIGRAPHY

The lower Bluefield Formation was traced into the subsurface in McDowell, Wyoming, Raleigh, Fayette and Nicholas Counties using gamma-ray logs obtained from the West Virginia Geological and Economical Survey. Gamma-ray logs measure the natural radioactivity of the rocks. The logs normally reflect the shale content of the units because radioactive elements tend to concentrate in clays and shales (Schlumberger, 1972).

The Reynolds Limestone Member is referred to as the "Little Lime" by drillers and is recognized in the subsurface by its easily identified gamma-ray signature, as well as by its stratigraphic position in relation to the "Big Lime" (Greenbrier Limestone) (Fig. 6; Flowers, 1956). It is a continuous argillaceous limestone that thins to the northwest. The average thickness is 15 m. The lower portion of the "Little Lime" gamma-ray signature is equivalent to the Glenray Limestone (Youse, 1964). Because of its similar lithology and close proximity to the Reynolds, the Glenray has been referred to as part of the "Little Lime". The Glenray is continuous in the southeast, but pinches out to the northwest (Figs. 7-11). The shale between the Glenray Limestone and the Reynolds Limestone is correlative to the Bickett Shale in outcrop. The Bickett Shale is a discontinuous unit. The Lillydale Shale lies stratigraphically below the Glenray, separating the "Little Lime" from the Greenbrier Group. The Lillydale Shale (Pencil Cave of the driller) is continuous across the area but thins to the northwest. It often contains discontinuous sandstones.

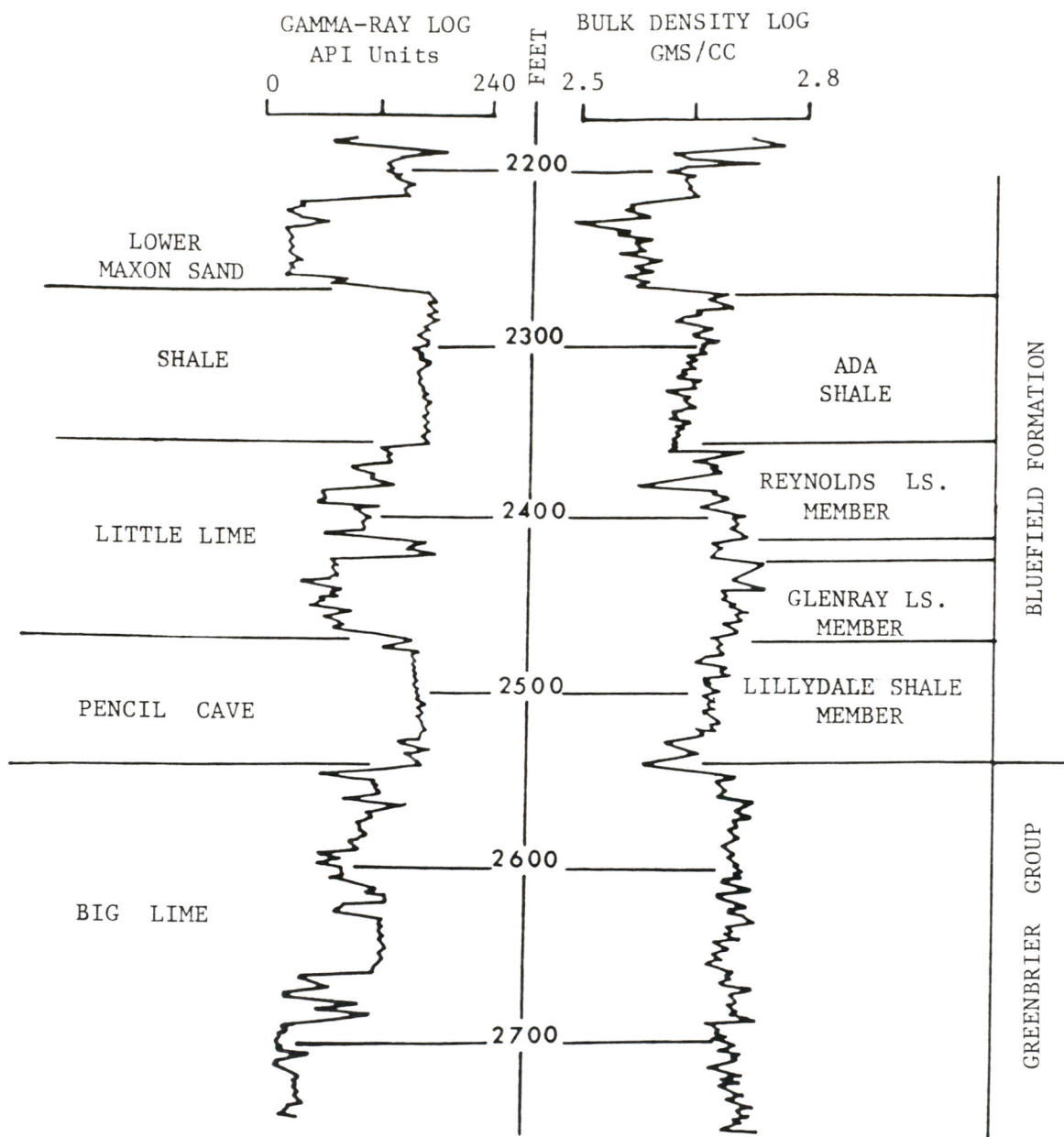


Figure 6. Gamma-ray and bulk density log (MCD 460) illustrating typical signatures of the Reynolds Limestone Member and related units in southeastern West Virginia.

Above the Reynolds Limestone Member is a continuous shale unit correlative with the Ada Shale in outcrop. It is variable in thickness, but gradually thins to the northwest. Stratigraphically above the shale is a discontinuous sandstone unit, referred to by drillers as the Lower Maxon Sand.

Figure 7 locates selected stratigraphic cross sections and identifies the wells involved in their construction. The base of the Reynolds Limestone Member was used as the datum because, by comparison, sands and shales of the lower Bluefield are discontinuous and the upper contact of the Greenbrier is questionable on gamma-ray logs. Section A strikes NE-SW, approximately parallel to the outcrop belt (Fig.8). In McDowell County, the Reynolds Limestone Member is approximately 20 meters thick. Excluding an area in southern Fayette County, the thickness varies only slightly from McDowell to Nicholas County.

Sections B through E strike perpendicular to the outcrop trend (Fig.7). The Reynolds Limestone Member is thickest along section B in McDowell County, averaging 18 meters (Fig. 9). It gradually thins to the northwest and is thinnest in western Wyoming County, averaging 11 meters. Along section C it gradually thins from 17 meters in the southeast to 12 meters in the northwest (Fig.10). Along section D it is thinnest in Greenbrier and Fayette Counties, averaging 13 meters in the east and 6 meters to the west (Fig.11). Section E, located in central Nicholas County, shows a slight change in thickness from 14 meters in the east to 13 meters in the west (Fig.12). Generally, the Reynolds Limestone Member thins to the northwest (Fig.13). The unit is thickest in the southern portions of the study area and thinnest across



FIGURE 7. The location of stratigraphic cross sections.
Well locations are identified by number.

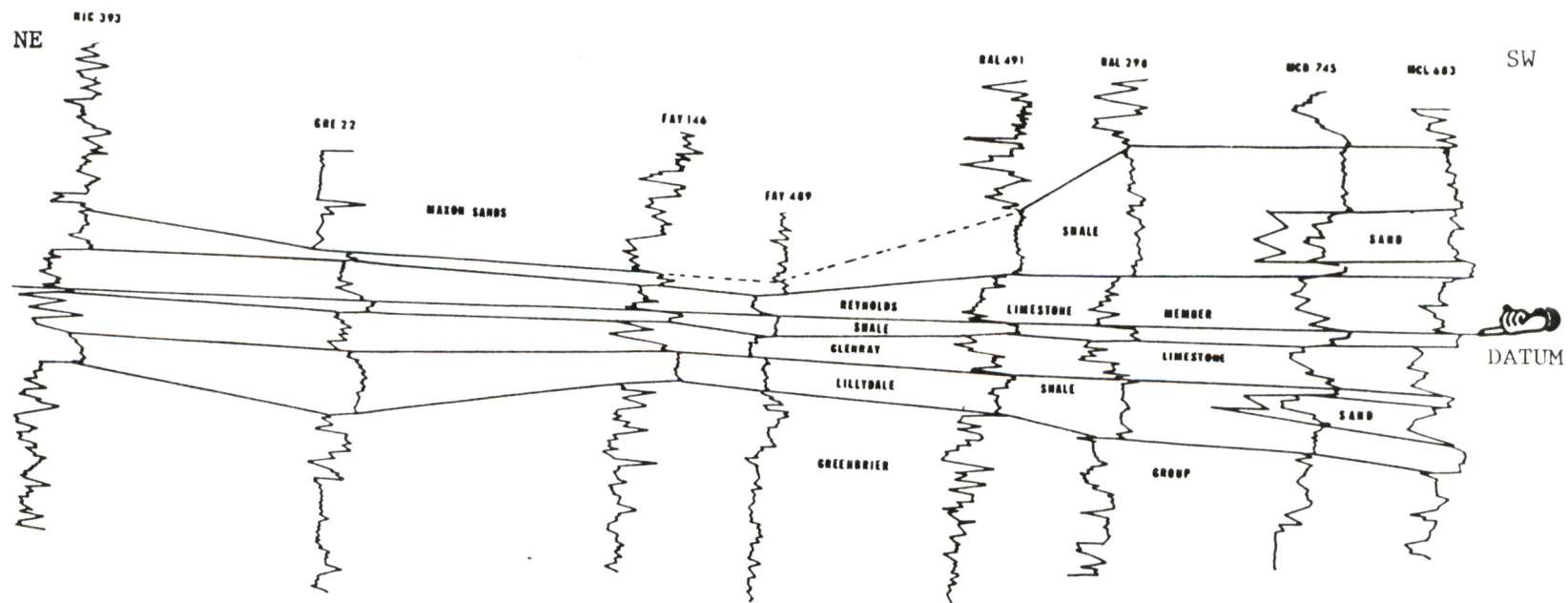


FIGURE 8. Gamma-ray cross-section A striking NE-SW across Nicholas, Greenbrier, Fayette, Raleigh and McDowell counties.
Vertical scale 1 inch = 100 feet

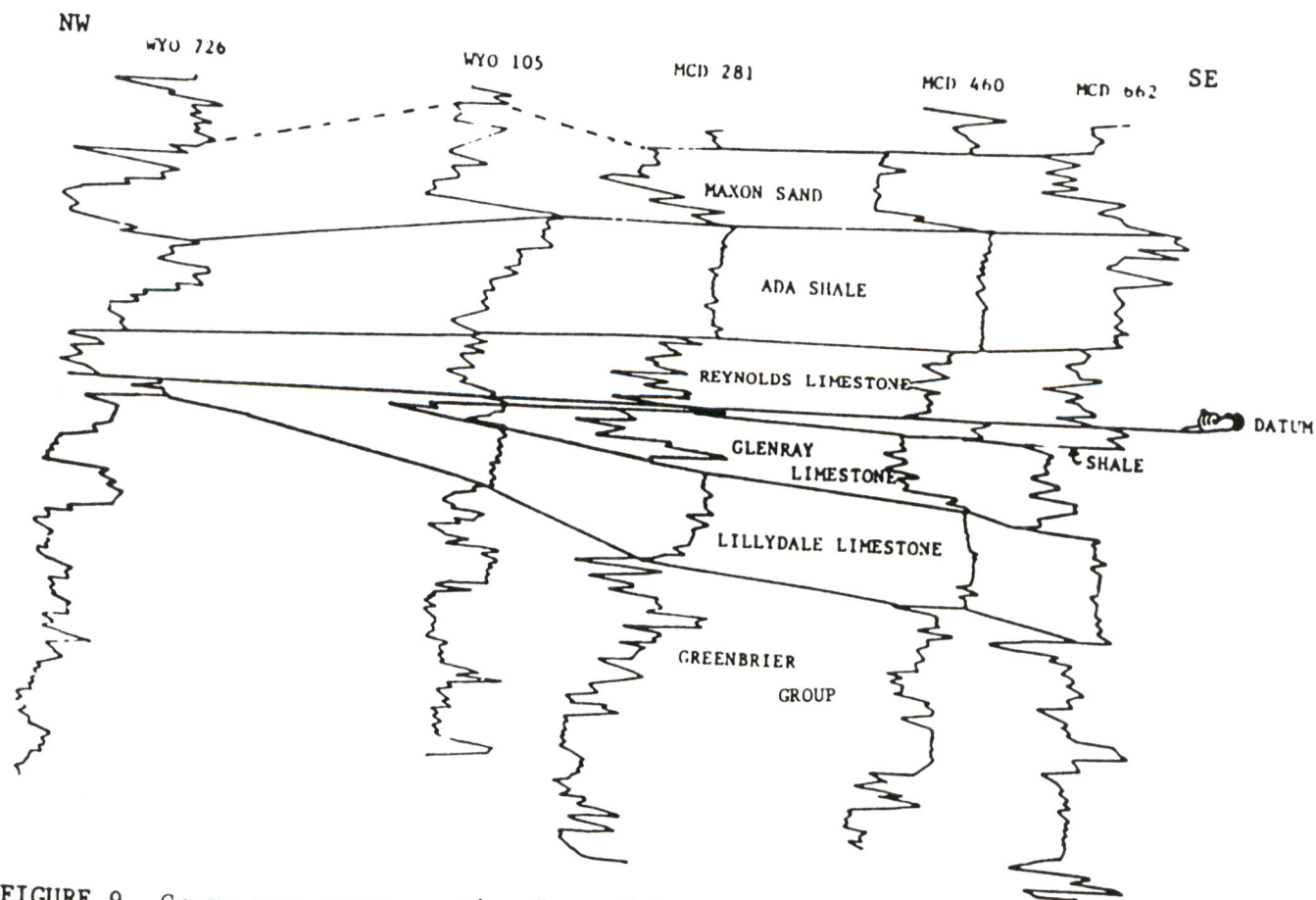


FIGURE 9. Gamma-ray cross-section B striking SE-NW across McDowell and Wyoming Counties.
Vertical scale 1 inch = 100 feet

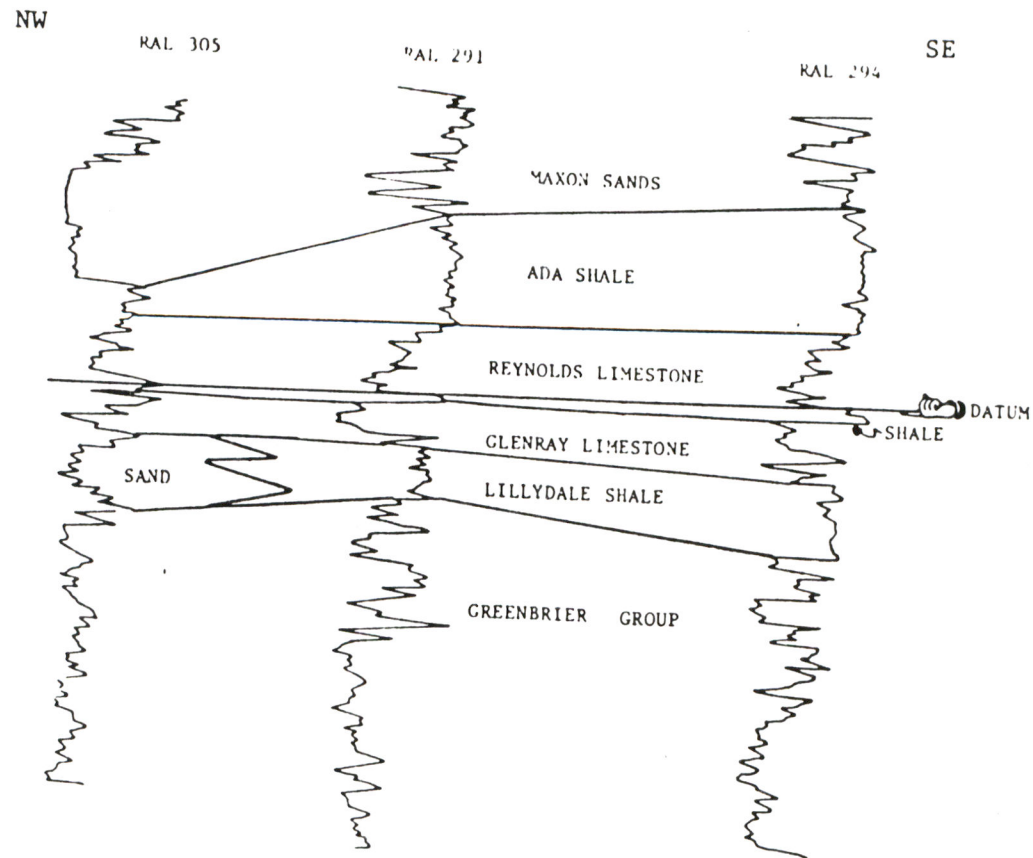


FIGURE 10. Gamma-ray cross-section C striking SE-NW across Raleigh County
 Raleigh County. Vertical scale 1 inch= 100 feet

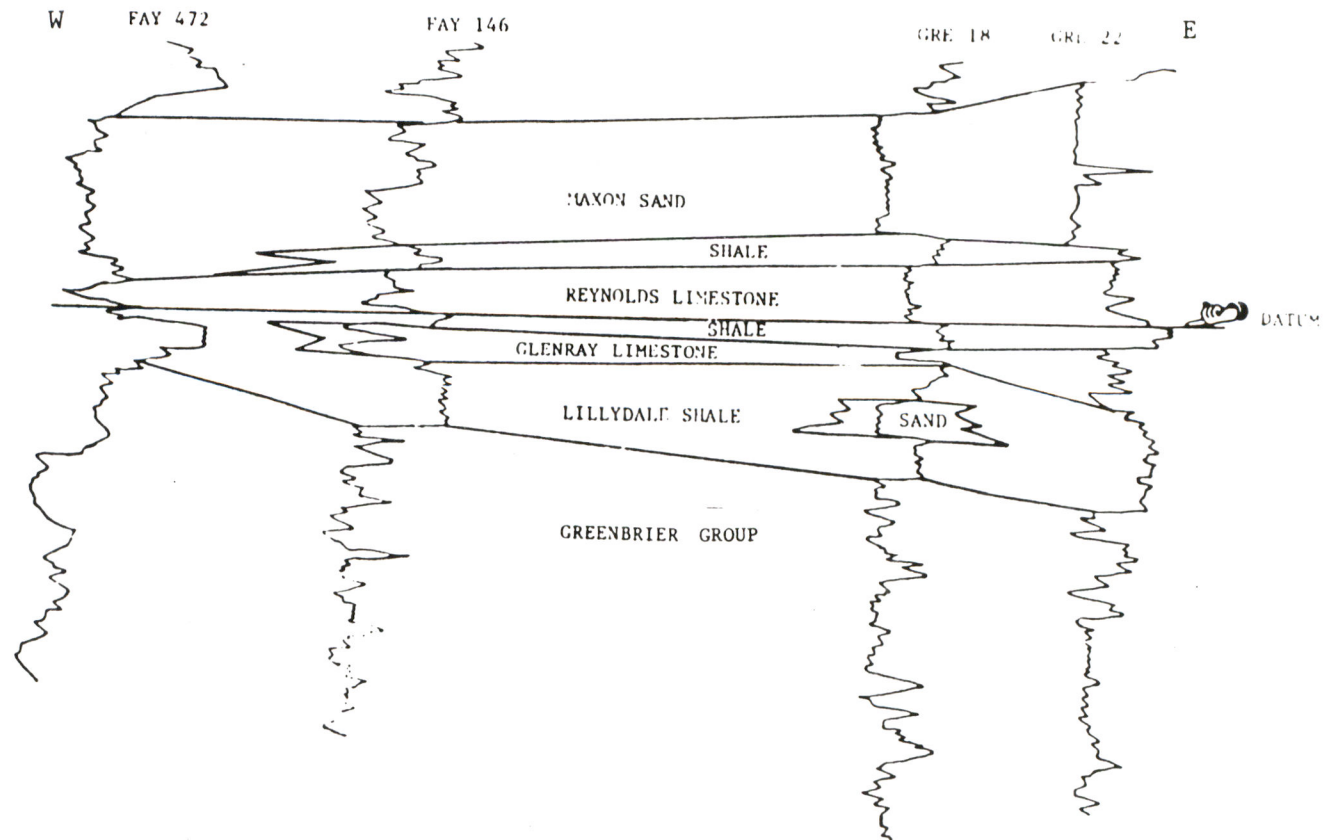


FIGURE 11. Gamma-ray cross-section D striking E-W across Greenbrier and Fayette Counties.
Vertical scale 1 inch = 100 feet

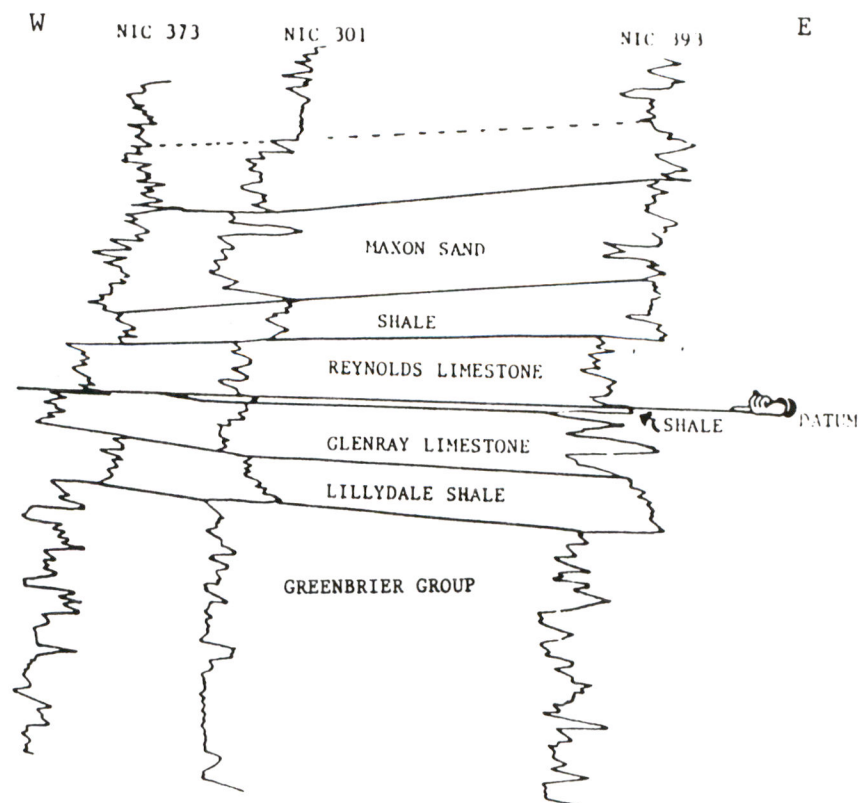


FIGURE 12. Gamma-ray cross-section E striking E-W across Nicholas County. Vertical scale 1 inch = 100 feet.

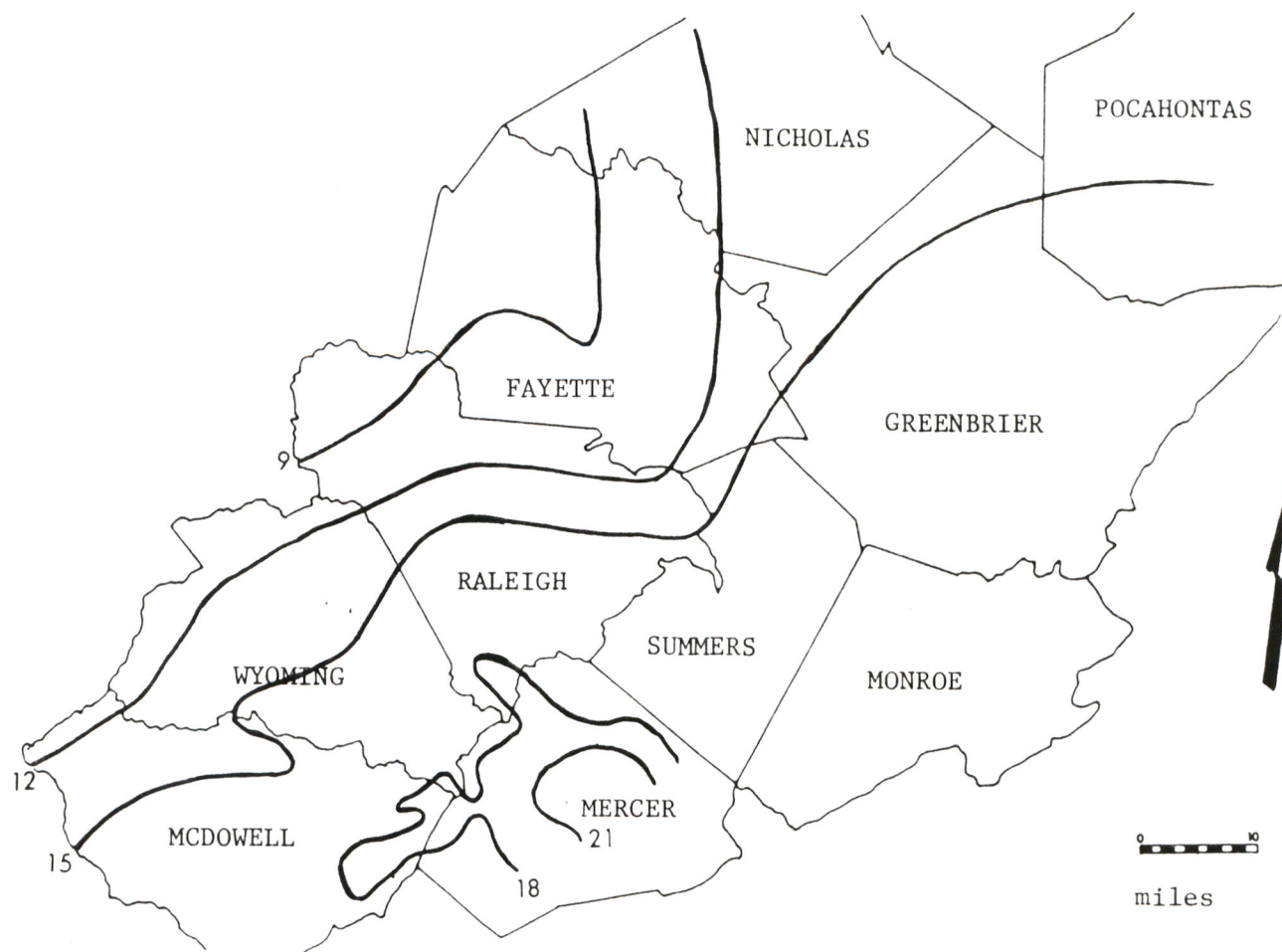


FIGURE 13. AN ISOPACH MAP OF THE REYNOLDS LIMESTONE MEMBER IN
SOUTHEASTERN WEST VIRGINIA.
CI= 3 meters

Fayette County.

Based on the subsurface data, it can be concluded that the Reynolds Limestone Member is easily identified by its gamma-ray signature and lithology. Secondly it is one of the few continuous units in this portion of the stratigraphic section. Because of its easy recognition and lateral continuity, it is a good indicator to drillers of stratigraphic location within the lower Bluefield Formation. Finally, the Reynolds Limestone Member is a good datum for the lower Mauch Chunk and the upper Greenbrier Groups.

SURFACE STRATIGRAPHY

The Reynolds Limestone Member was traced in outcrop in Mercer, Monroe, Summers, Greenbrier and Pocahontas Counties (Fig. 14). It is recognized by its lithology and stratigraphic position within the lower Bluefield Formation. The unit is a massive to thinly bedded blue-gray argillaceous limestone interbedded with calcareous shales. Stratigraphically, it occurs between the Bickett Shale and the Ada Shale in outcrop. Stratigraphic relationships of lithologies in each section are summarized below.

Vertical Relationships

The Edray Section is located in the northern portion of the study area in southern Pocahontas County. The section consists of biomicrosparites (wackestones) interbedded with calcareous shales (Fig. 15). The abundance of allochems is directly related to lithology. Echinoderms, bryozoans and foraminifers are more abundant in biomicrosparites containing small amounts of terrigenous material. Peloids, brachiopods, gastropods and pelecypod fragments are more abundant in argillaceous biomicrosparites and calcareous shales.

Three shallowing upward sequences are represented in the Edray section. The lowest sequence consists of argillaceous biomicrosparites (wackestones) interbedded with calcareous shales. The upper contact is at a partially dolomitized laminated argillaceous biomicrosparite (wackestone), indicative of microfacies IV. Echinoderms and



Figure 14. The index map of West Virginia showing the outcrop pattern and section locations.
 A- Edray; B- Briary Knob; C- Droop; D- Muddy Creek Mountain; E- Clayton;
 F- Raines Corner; G- Nemours.

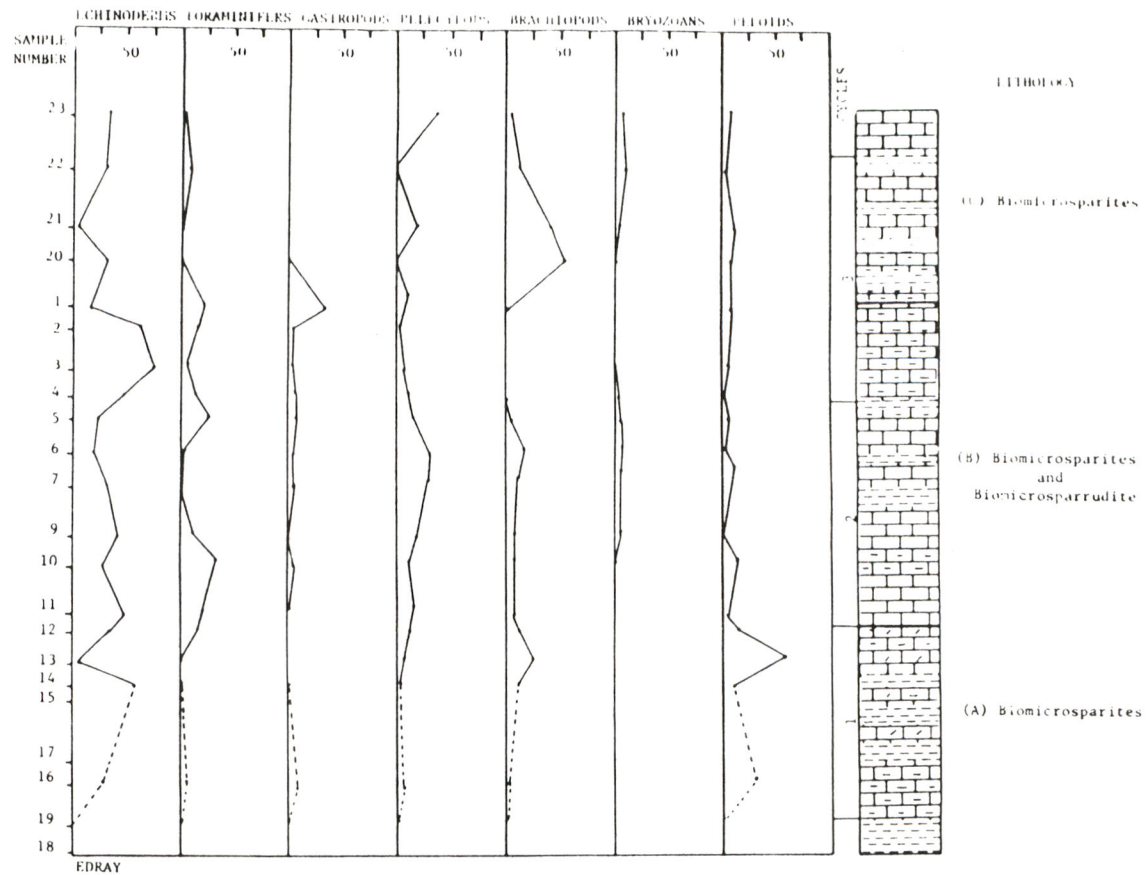


Fig. 15. Cyclic sedimentation demonstrated by lithology and percent abundance of allochems in the Edray Section.
Vertical Scale 1 inch= 10 feet.

foraminifers decrease in abundance whereas peloids and brachiopods increase in abundance at this boundary. An intertidal environment is indicated by the abundance of peloids, the presence of partially dolomitized laminated sediments and the low percentage of fauna. The interbeds of calcareous shale indicate episodic influxes of terrigenous material.

The lower half of cycle 2 is dominated by biomicrosparites and biomicrosparrudites (packstones) rich in echinoderms, foraminifers and pelecypods (microspar V). This portion of the cycle represents a subtidal environment with open circulation and very little terrigenous influx. Argillaceous biomicrosparites (wackestones) interbedded with calcareous shale (microfacies IV) becomes prevalent in the upper portion of cycle 2. Foraminifers generally decrease in abundance in the upper half of the cycle, whereas the abundance of pelecypods, echinoderms and brachiopods remains constant. The upper half represents an intertidal environment with restricted water circulation and periodic influx of terrigenous material.

Cycle 3 consists of biomicrosparites, argillaceous biomicrosparites and calcareous shales representing microfacies III and microfacies V. Bioturbated biomicrosparites (packstones) rich in echinoderms and foraminifers are abundant in the basal portion of the cycle (microfacies V). Argillaceous biomicrosparites (wackestones) rich in gastropods are most abundant in the central portion and terrigenous material, brachiopods and pelecypods increase in abundance in the upper portion of the cycle (microfacies III). The number of calcareous shale interbeds increases upward through cycle 3, recording a shallowing

episode from a subtidal environment with small to moderate amounts of terrigenous material to an intertidal environment with large amounts of terrigenous influx.

The Droop and Briery Knob sections are located in southern Pocahontas County. These sections consist of biomicrosparite, biomicrites, micrites (wackestones and mudstones) and calcareous shales. In both sections allochems are diverse but occur in low abundance. The abundance of allochems is directly related to the amount of terrigenous material. At Droop the lower unit (A) is a biomicrosparite (wackestone) rich in echinoderms, brachiopods, and bryozoans and peloids (Fig. 16). Unit B is interbedded micrites (mudstones), biomicrites (wackestones), and biomicrosparites (wackestones). The allochems in unit B are diverse but sparse. Unit C is a biomicrosparite (wackestone) rich in echinoderms, bryozoans, brachiopods, pelecypod fragments and peloids.

The Droop section records three shallowing upward sequences. The base of cycle 1, represented by a biomicrosparite (wackestone) with small amounts of terrigenous material is rich in echinoderms, pelecypods, brachiopods, bryozoans and peloids microfacies IV. At the upper contact echinoderms, pelecypods, brachiopods and bryozoans diminish in number while peloids and terrigenous sediments increase in abundance. Cycle 1 indicates an intertidal environment with a gradual change occurring up section from microfacies IV to microfacies III. The contact between cycle 1 and cycle 2 is marked by the change from an argillaceous biomicrosparite (wackestone) with fauna representative of

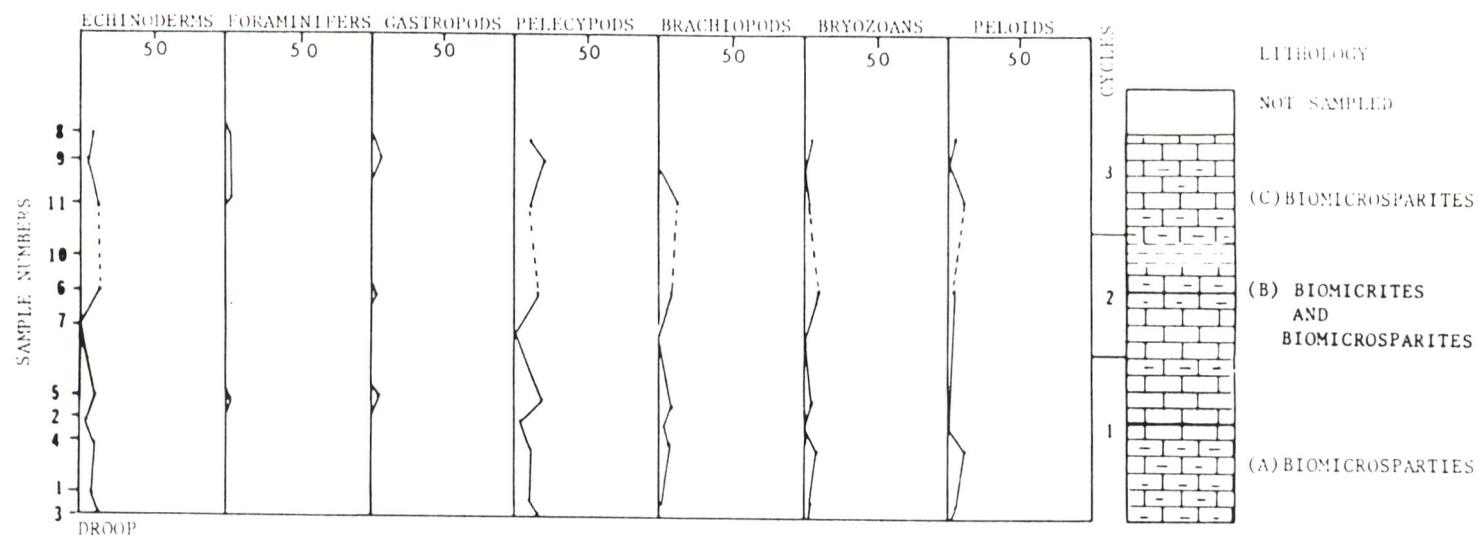


Fig. 16. Cyclic sedimentation demonstrated by lithology and percent abundance of allochems in the Droop Section.
Vertical scale 1 inch = 10 feet.

a restricted environment (microfacies III) to a biomicrosparite (wackestone) with little to no terrigenous material and fauna indicative of an open marine environment (microfacies IV).

Cycle 2 grades from a basal biomicrosparite (wackestone) with echinoderms, pelecypods, brachiopods, bryozoans and peloids (microfacies IV) into a calcareous shale. Excluding brachiopods and peloids, allochems are less abundant in the upper portion of the cycle. Cycle 2 suggests an intertidal environment at the base with an increase in terrigenous sediment moving up section.

Cycle 3 is only partially represented. The lower portion consists of a bioturbated biomicrosparite (packstone) with a high diversity of organisms such as echinoderms, bryozoans, foraminifers, gastropods and pelecypods (microfacies V). This suggests a subtidal environment with open marine circulation. Cycle three is distinguished from the upper portion of cycle two by a change from a sediment and faunal package indicative of an intertidal environment (microfacies IV) to one indicative of a subtidal environment (microfacies V).

The lower unit (A) at Briery Knob is a thinly bedded argillaceous biomicrosparite (mudstone) interbedded with shale (Fig.17). Unit B is a biomicrosparite (mudstone) with echinoderms, pelecypods, brachiopods, bryozoans and peloids. A thinly bedded biomicrosparite (mudstone) interbedded with calcareous shales records Unit C. The uppermost unit (D) consists of biomicrosparites (packstones) interbedded with calcareous shales. The biomicrosparites are rich in echinoderms, foraminifera, brachiopods, bryozoans, pelecypod fragments and peloids. The thinly bedded limestones and calcareous shales of units A and C

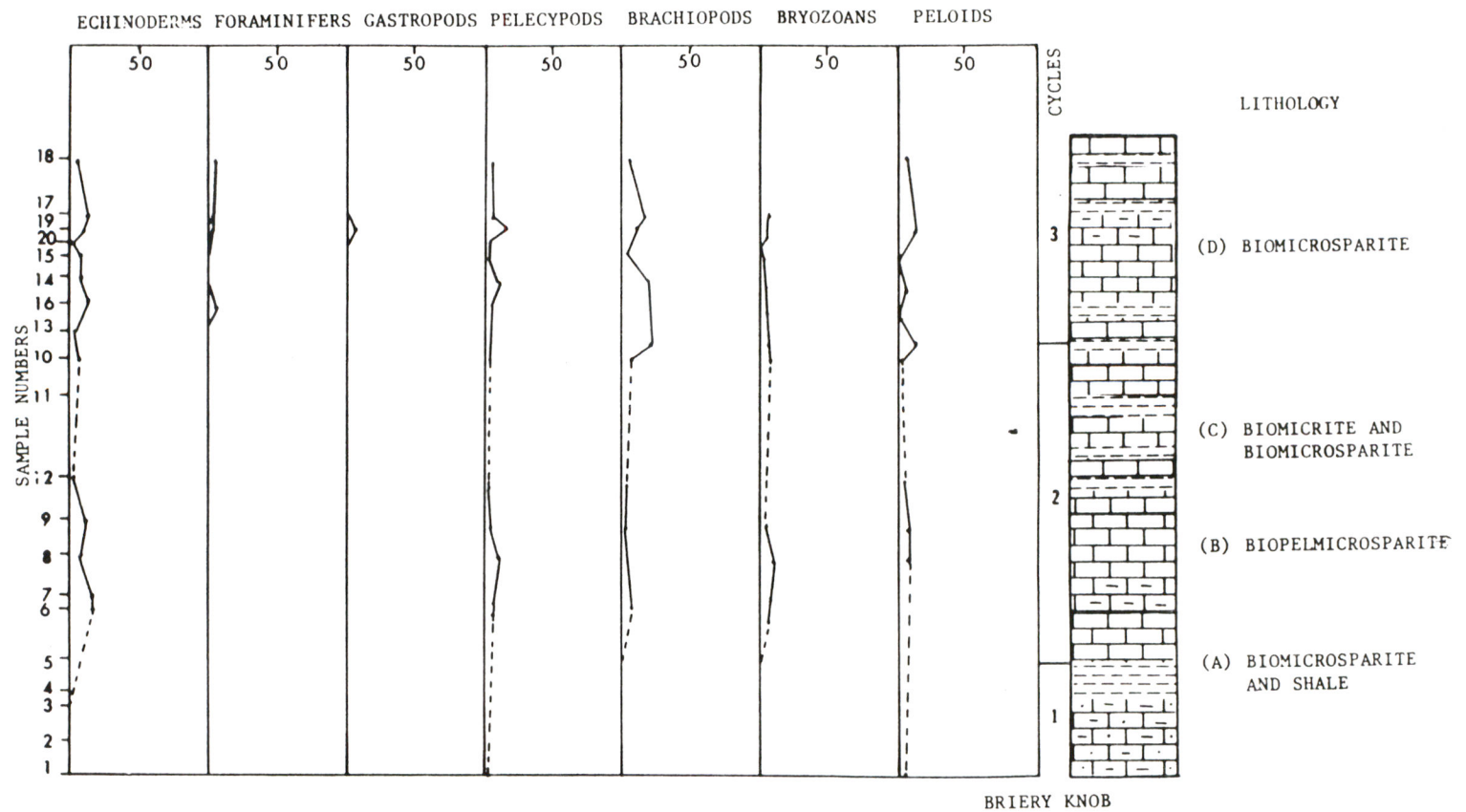


Fig. 17. Cyclic sedimentation demonstrated by lithology and percent abundance of allochems in the Briery Knob Section.
Vertical scale 1 inch = 10 feet

suggest a shallow marine environment with restricted water circulation and an influx of terrigenous material. The allochems in B and D record a shallow marine environment with moderate circulation. Briery Knob records 3 shallowing upward sequences. Cycle 1 represents the upper most portion of a sequence, a sandy argillaceous biomicrosparticle (microfacies I) grading into a calcareous shale. Pelecypods and peloids are the only allochems present. The lack of fauna, the abundance of terrigenous sediment and thinly bedded limestone suggests a shallow marine environment with restricted water circulation. The calcareous shales indicate an influx of terrigenous material.

The biopelmicrosparticles and biomicrites (mudstones) in cycle 2 record an intertidal environment as evidenced by the paucity and low diversity of fauna, laminated sediments and the abundance of peloids. Calcareous shales increase in abundance in the upper portion of the cycle recording episodic influxes of terrigenous material.

A subtidal environment is recorded at the base of cycle 3 as indicated by massive biomicrosparticles (packstone) with a diverse fauna such as echinoderms, foraminifers, bryozoans brachiopods and pelecypods (microfacies V). Moving up section, the fauna abundance decreases and biomicrosparticles becomes thinly bedded and are burrowed (microfacies III). This correlates with an increase in abundance of calcareous shales. Cycle 3 represents a gradual change from a subtidal environment to an intertidal environment with a simultaneous increase in terrigenous sediments.

Subsurface stratigraphy indicates that the Reynolds Limestone Member is thinnest across Greenbrier and Fayette Counties, averaging 13 m (Fig. 11). Other units of the lower Bluefield are also affected. The Glenray Limestone and Ada Shale are missing at Fayette 472 (Fig. 18). This suggests that there was a topographic high perpendicular to the outcrop pattern as shown in Fayette and Greenbrier Counties. The Raines Corner and Clayton sections are the only sections to record transitional sedimentation (microfacies II, dolostones or an algal lithite). Based on the transitional sedimentation in these sections, it is probable that the topographic high extends through Greenbrier and Monroe Counties.

The Raines Corner section consists of biomicrosparites, dolomitized argillaceous microsparites, algal lithites and calcareous shales and sandstones (Fig. 19). The basal unit (A) is a partially dolomitized massive biomicrosparite (packstone) rich in echinoderms, pelecypod fragments, brachiopods and bryozoans (microfacies V). Unit B is a dolomitized argillaceous microsparite (mudstone) devoid of allochems (microfacies III). Unit C is an algal lithite (boundstone) representative of microfacies II. The laminae are undulose and contain rip-up clasts and indicates a shallow environment with variable currents. Units A through C represent one complete shallowing upward cycle from a subtidal environment (unit A) to an intertidal environment (unit C). Unit D is an argillaceous biomicrosparite (wackestone) rich in echinoderms, pelecypod fragments, brachiopods and bryozoans (microfacies III). The upper portion is partially dolomitized. The change in lithology and faunal diversity suggests an intertidal

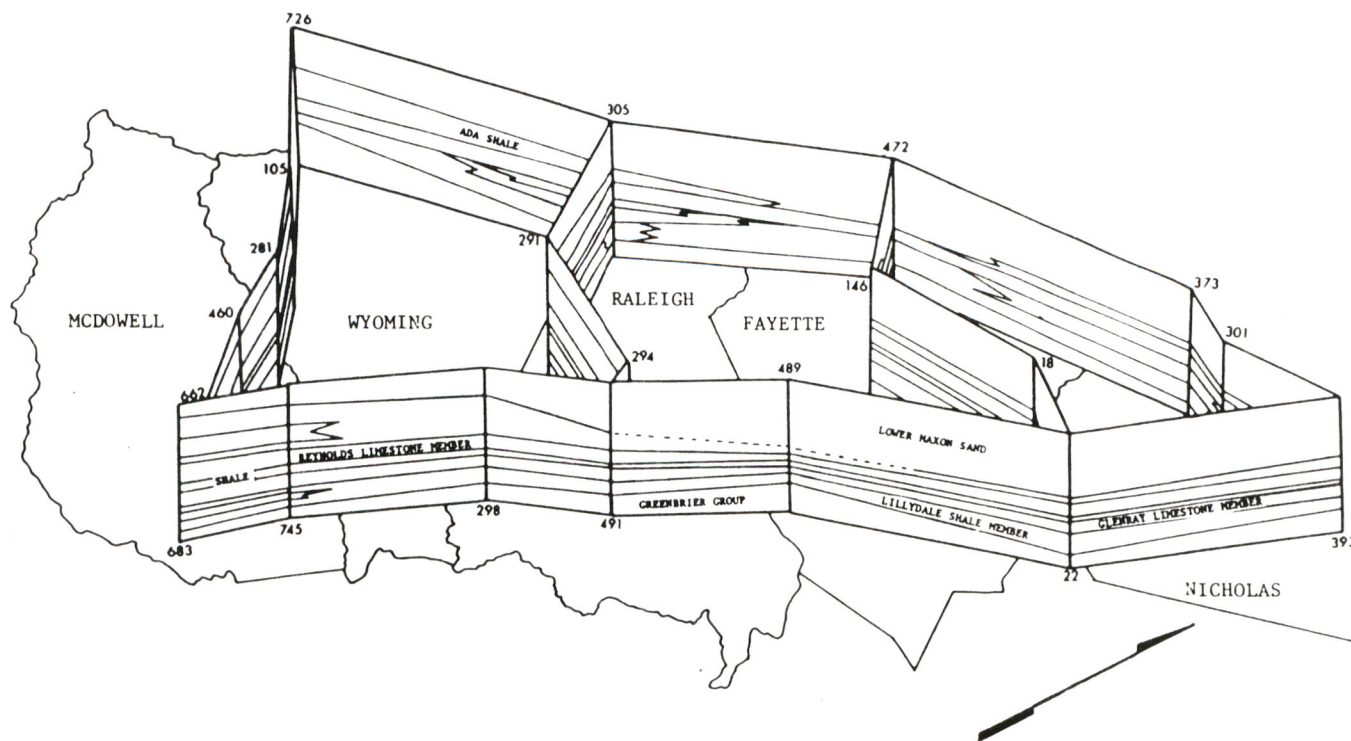


Figure 18. A fence diagram of the subsurface stratigraphy of the lower Bluefield in McDowell, Wyoming, Raleigh, Fayette and Nicholas Counties.

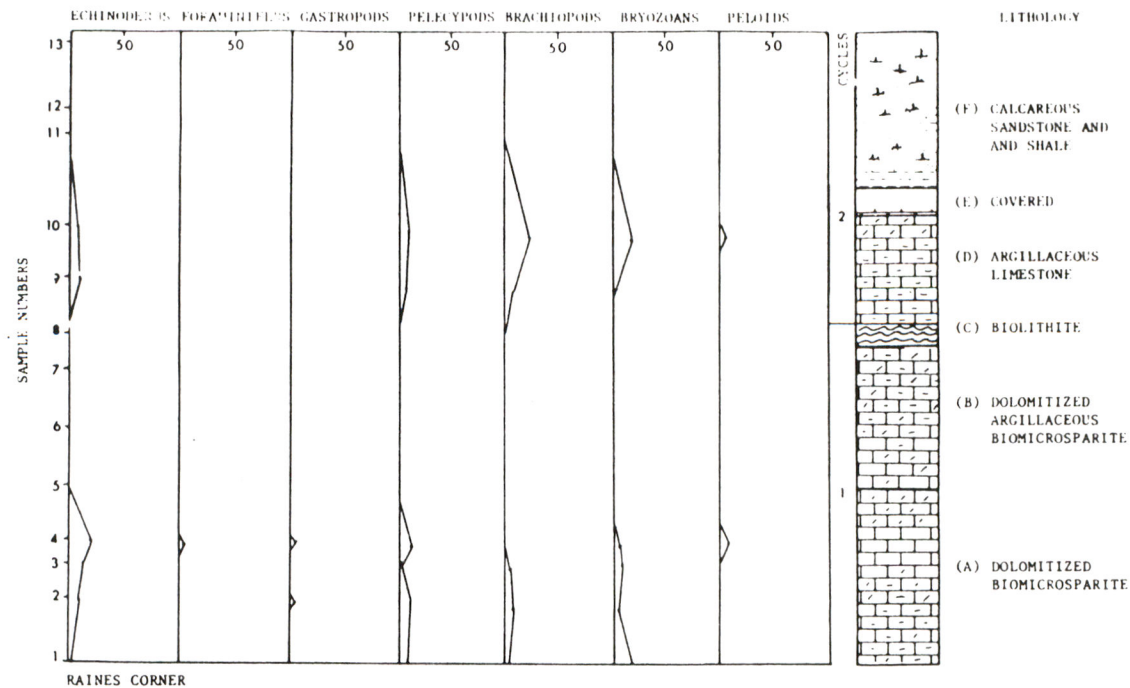


Figure 19. Cyclic sedimentation demonstrated by lithology and percent abundance of allochems in the Raines Corner Section.
Vertical scale 1 inch = 10 feet

environment. Unit E is covered. The upper most unit (F) consists of interbedded calcareous shale and sandstone (microfacies I). Allochems are only present in the lower portion of unit F where brachiopods and pelecypods are dominant. The abundance of sand and the influx of terrigenous material in unit F suggests the top of a second shoaling upward sequence.

The basal portion of the Clayton section fluctuates from a dolostone to a shale back to a dolostone and then to a dolomitized biomicrosparite (microfacies III)(Fig.20). This represents a shallow tidal flat environment that is being periodically inundated by the sea. Unit D a biomicrosparite (wackestone) with a diverse fauna such as pelecypod fragments, bryzoans (Archimedes), and brachiopods represents an intertidal environment (microfacies IV). Unit E is a microsparite (mudstone) with peloids occurring at the base and a calcareous shale at the top (microfacies III). The paucity of fauna and the increase in peloid abundance indicates a shift from microfacies IV to microfacies III accompanied by an influx of terrigenous material. Unit F is a dolostone, denoting an intertidal to supratidal environment. The Clayton Section records one complete shallowing upward sequence.

The basal section (A) at Muddy Creek Mountain is a partially dolomitized biomicrosparite (packstone) rich in echinoderms, pelecypod fragments and Archimedes (microfacies V) (Fig.20). The massive biomicrosparites and abundant allochems suggests a subtidal environment with open marine circulation. The two other units were not statistically analyzed but unit B is a calcareous shale interbedded

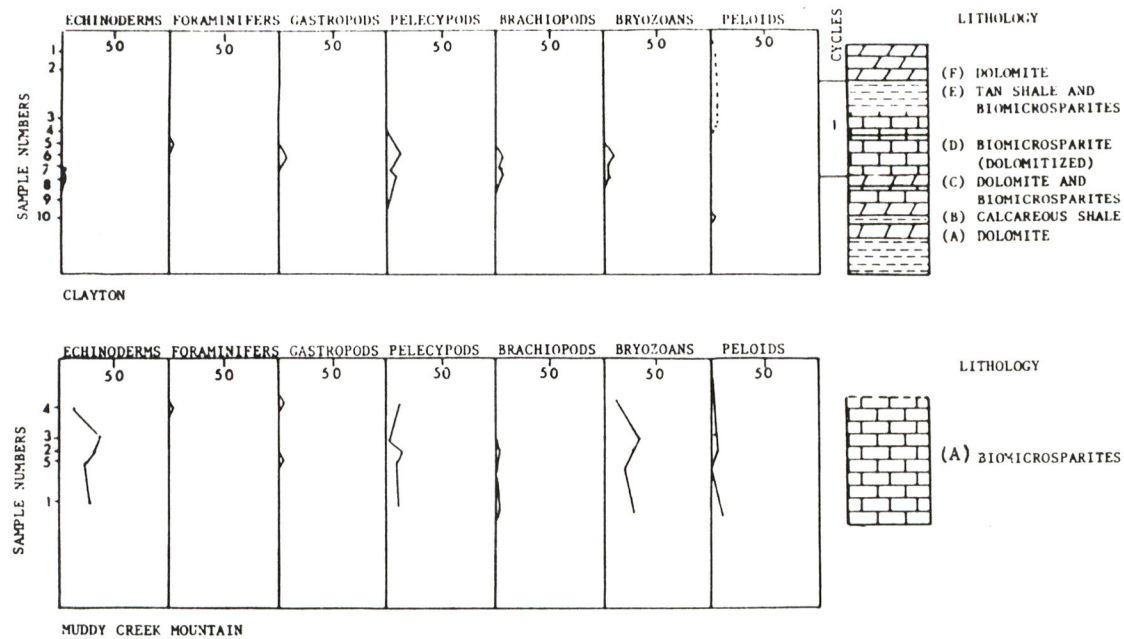


Figure 20. Cyclic sedimentation demonstrated by lithology and percent abundance of allochems in the Clayton and Muddy Creek Mountain Sections. Vertical scale 1 inch = 10 feet

with a thinly bedded mudstone indicating an influx of terrigenous material. Unit C is a massive packstone rich in echinoderms, brachiopods and pelecypod fragments. The lack of supratidal sediments suggests that Muddy Creek Mountain was located to the north of the topographic high that effected the Clayton and the Raines Corner sections.

The southern most area sampled was the Nemours Section (Fig.21). The basal unit (A) consists of biosparites and biomicrosparites (packstones) with abundant echinoderms, bryozoans, and brachiopods interbedded with calcareous shales (microfacies V). Unit B is covered. Unit C consists of biopelmicrosparites and biopelsparites (packstones) rich in echinoderms, bryozoans and pelecypod fragments (microfacies V). Unit D represents an increase in terrigenous sediment. It consists of calcareous shales interbedded with sandy argillaceous biomicrosparites (microfacies I). The Nemours Section represents one shallowing upward sequence from a subtidal to an intertidal environment with episodic influx of terrigenous material. Part of this section is missing due to local syndepositional deformation (Thomas, 1960;1966).

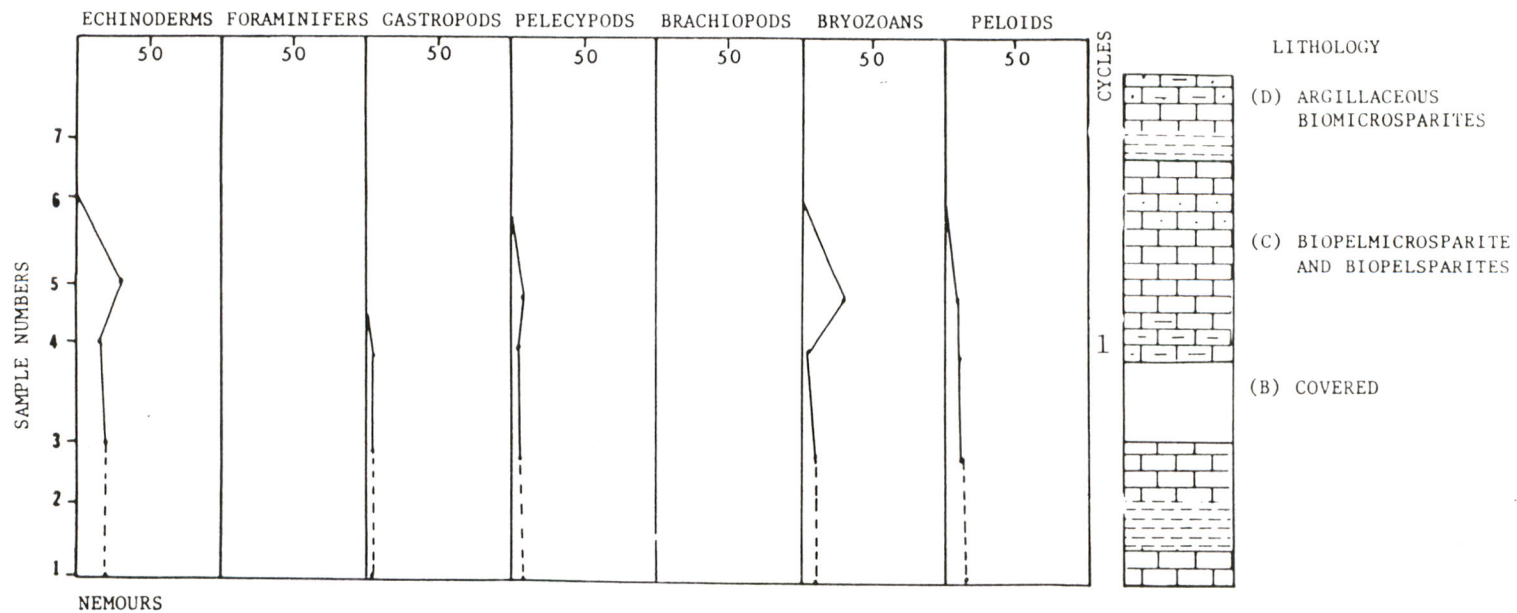


Figure 21 . Cyclic sedimentation demonstrated by lithology and percent abundance of allochems in the Nemours Section.
Vertical scale 1 inch = 10 feet

TABLE III

Microfacies	Nemours	Raines Corner	Clayton	Muddy Creek Mountain
-------------	---------	---------------	---------	----------------------

I	22.2	--	--	33.3
II	--	9.0	--	--
III	--	18.2	30.0	--
IV	11.2	45.4	20.0	--
V	44.4	18.2	--	66.7
Shale	22.2	9.1	10.0	--
Dolostone	--	--	40.0	--

Microfacies	Droop	Briery Knob	Edray
-------------	-------	-------------	-------

I	9.1	5.0	4.3
II	--	--	--
III	36.4	40.0	17.4
IV	45.5	40.0	47.8
V	--	--	8.7
Shale	9.0	15.0	21.8

The relative percent abundance of each microfacies, shale and dolostone in a given section.

Lateral Relationships

Microfacies I is represented by argillaceous biomicrites and is most abundant in the southern portion of the study area (Table III). It usually occurs at the upper and lower contacts of the Reynolds Limestone Member, representing a transition from predominantly carbonate sedimentation to terrigenous sedimentation or vice versa. When it occurs in the central portion of the section, it is in association with microfacies IV, V or a calcareous shale, indicating a period of terrigenous influx.

Microfacies II is an algal biolithite and only occurs at the Raines Corner Section (Table III). Stratigraphically, it occurs between microfacies I and microfacies III.

Dolostones occur at the upper and lower contacts of the Clayton section (Table III), representing the upper unit of a shoaling upward sequence. Because of the transitional nature of microfacies I, II, and the dolostones, they are combined for lateral interpretations and will be referred to as transitional sediments. Generally, there is a decrease in the percent abundance of transitional sedimentation to the southeast and northeast. Transitional sedimentation is highest in northeastern Summers County, southeastern Greenbrier County and northwestern Monroe County. This suggests that there was an intrabasinal control on sedimentation within this portion of the study area.

Microfacies III is represented by biomicrosparites and argillaceous micrites. Vertically, it occurs throughout the section, indicating a fluctuation from a deeper water environment to a shallow

restricted marine environment. The frequency of microfacies III increases to the northeast and decreases to the southwest (Table III). Table III indicates on an average 31 % of the Reynolds Limestone Member in Pocahontas County was deposited in a restricted shallow marine environment whereas only a nominal percentage of the Nemours section in Mercer County was deposited in this type of an environment.

Microfacies IV is represented by biomicrosparites. It is present throughout the vertical section, suggesting an oscillation from a subtidal environment to an intertidal environment. The frequency of microfacies IV within the vertical section is highest in Pocahontas County, indicating that approximately 40% of the Reynolds Limestone in Pocahontas County was deposited in an intertidal environment (Table III).

Microfacies V is represented by biosparites and biomicrosparrudites. It occurs vertically throughout the section, suggesting a fluctuation from an intertidal environment to a subtidal environment. Laterally, microfacies V increases in abundance to the southeast. Sections in Summers and Monroe Counties contain low percentages of microfacies V.

The lateral distribution of sediments suggests that the Mississippian sea encroached on the study area from the southeast. Predominance of transitional sedimentation in Summers and Monroe Counties suggest that there was a topographic high controlling the sedimentation within this area. The abundance of microfacies III in Pocahontas County and the paucity of it in Mercer County suggest that the terrigenous material was coming from the northeast. The abundance

of microfacies IV in Pocahontas County further suggest that the source of terrigenous material was close by.

DEPOSITIONAL ENVIRONMENT

Depositional Model

The Reynolds Limestone Member is a thin (4 to 22 meters), extensive carbonate unit found throughout most of West Virginia. Petrographic and stratigraphic analysis indicates that it is composed of at least three upward shoaling sequences. An ideal sequence comprises three units represented in ascending order, by biomicroparites (packstones) indicative of the deepest marine environment; calcareous shales, micrites (mudstones) and argillaceous biomicroparites (wackestones) indicating a shallowing of water depths and an influx of terrigenous material; and supratidal dolomites and biolithites. Biomicroparites (packstones) and biomicroparrudites (packstones) of the basal sequence are rich in echinoderms, bivalves, brachiopods and bryozoans. This sequence records the initial rise in sea level and represents the greatest water depth of the Mississippian sea during the deposition of the Reynolds Limestone Member. The basal sequence is interpreted to represent deposition in the subtidal zone based on the massive, bioturbated biomicroparites (packstones) (Fig. 22). The presence of bryozoans, crinoid stems and other echinoderms indicates that there was at least moderate water circulation which would be required for the fauna to obtain food (Humphreville, 1981). The absence of a micrite cement and the abundance of spar cement further suggest moderate water circulation, thus winnowing away the muds. Deposition is similar to that on the wide platform of the Bahama Banks (James, 1979).

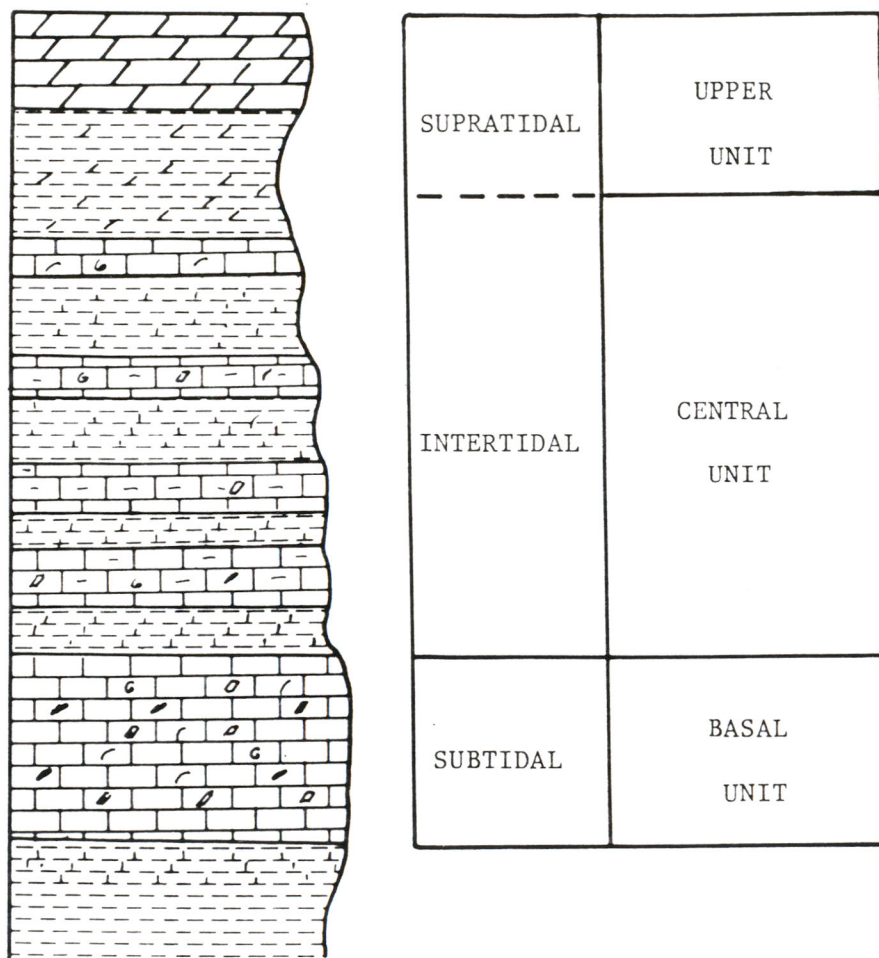


Figure 22. The correlation of the three units of the idealized shallowing upward sequence with depositional environments.

Thinly bedded micrites (mudstones), argillaceous biomicrosparites (wackestones) and calcareous shales of the middle sequence are rich in peloids, brachiopods, bivalves and gastropods. Thinly bedded sediments and the abundance of micrite cements suggest an intertidal environment with restricted water circulation. The brachiopods also suggest that there was a muddy substrate and restricted water circulation (Humphreville, 1981). The other allochems also indicate that the sea was shallow. The shallowing of the sea is probably a result of the influx of terrigenous sediments into the basin. This unit is representative of an intertidal zone with moderate energy similar to the intertidal zone of the Bahama Banks (James, 1979; Fig. 22).

Upper sequence dolostones and biolithites (boundstones) are present in only two sections, Raines Corner (microfacies II) and Clayton, along the topographic high extending through Monroe and Summers Counties. The sequence represents a supratidal or supratidal-intertidal transitional environment (Fig. 22).

The Reynolds Limestone Member extends throughout West Virginia and into Pennsylvania. The distribution suggests that the overall development of the unit is dependent on a synchronous basin-wide process, most likely a fluctuation of eustatic sea level. The cause of this sea level change during the Late Mississippian is unknown. Local variations in sea level within the basin are dependent upon autocyclic mechanisms. Effects on the deposition caused by the relative change in water depth may be attributed to differences in local subsidence, the rate of influx of terrigenous sediment and the relief of the topographic high in Monroe, Summers and Fayette Counties. The distance

from the shoreline is not a major factor on local water depth because the study area was located within the central portion of the shelf.

Geologic History

The Reynolds Limestone Member represents cyclic carbonate deposition during relative changes in sea level. Each cycle began as the Mississippian sea inundated the broad, terrigenous-clastic-dominated, shallow shelf from the southeast. The rise in sea level initiated carbonate sedimentation. Massive biomicrosparites (packstones) and biomicrosparrudites (packstones) rich in echinoderms and bryozoans indicated the study area had an open marine shelf environment (T1 and T2; Fig. 23).

Shortly after sea level became stable, carbonate sedimentation began to dominate the study area. During this period of time, biomicrosparites (wackestones and packstones) and argillaceous biomicrosparites (wackestones) rich in echinoderms and brachiopods became more prominent. The increase in argillaceous material suggests that terrigenous sediments had started prograding into the system (T2; Fig. 23). As time progressed, sea level remained constant but the water depth progressively shallowed. This was due to continuous deposition of carbonate and terrigenous sediments (T3; Fig. 23) including argillaceous biomicrites (mudstones) and argillaceous biomicrosparites (wackestones) rich in brachiopods, pelecypod fragments and gastropods. In topographically high areas, calcareous sands and dolomites were

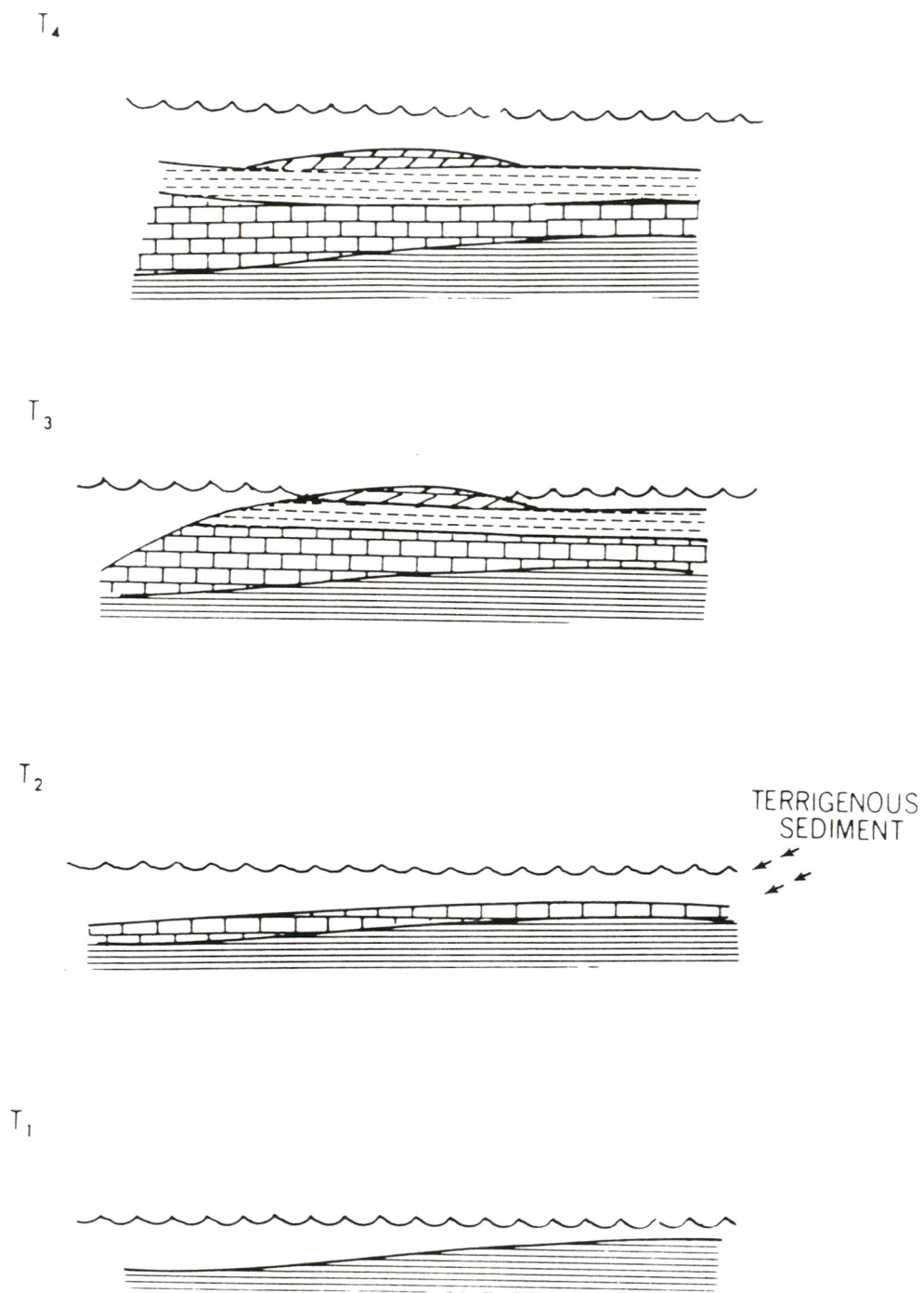


Figure 23. The development of a typical cycle.

deposited. As time passed, the Mississippian sea deepened again (T4; Fig.23). This cycle occurred at least two other times as represented by the three sequences.

Conclusions

1. The Reynolds Limestone Member is a gray to black, massive to thinly bedded, argillaceous limestone interbedded with black calcareous shales. Sediments were grouped into five microfacies by statistical methods.

- A. Microfacies I is a siliciclastic-rich argillaceous micrite. It is interpreted to represent an intertidal to supratidal environment.
- B. Microfacies II is an algal lithite that indicates an intertidal environment.
- C. Microfacies III contains biomicrosparites and argillaceous micrites interbedded with calcareous shales. It is interpreted to represent an intertidal environment.
- D. Microfacies IV is a massive biomicrosparite indicative of an intertidal environment.
- E. Microfacies V consists of massive biomicrosparites and biomicrosparrudites representing a subtidal environment.

2. The Reynolds Limestone Member represents subtidal to supratidal sediments deposited in three shallowing upward sequences. Carbonate sedimentation began penecontemporaneously with the deepening of the Mississippian sea. Shortly after sea level became stable, terrigenous sediments entered the basin from the northeast. Sea level remained constant, but the sediments indicate a shallowing of environments because of continuous carbonate and terrigenous

deposition. Along topographically high areas dolomite formed, representing a supratidal environment. As time passed, the Mississippian sea deepened. This sequence occurred at least two other times.

3. Various types of diagenetic alteration occurred in the Reynolds Limestone Member and were controlled, to some degree, by the type of allochems and the depth of burial. Micritization, meniscus, fibrous and bladed cements began forming shortly after deposition. With further burial, syntaxial overgrowths formed. Pore-filling cements such as blocky and drusy cements occurred with the continuation of burial. Timing of the introduction of microspar, pyrite, gypsum and silica is unknown. Dolomite occurred penecontemporaneously with deposition or shortly after burial.

4. The Reynolds Limestone Member is a valid stratigraphic unit in southeastern West Virginia, mappable in outcrop and traceable into the subsurface. It extends westward in the subsurface through McDowell, Wyoming, Raleigh, Fayette and Nicholas Counties, thinning to the northwest from 22 meters in Mercer County to 8 meters in Fayette County.

5. A topographic high divided the area into two sub-basins. It is recognized in outcrop in Monroe and Summers Counties. The high is traceable in the subsurface in Fayette and Greenbrier Counties.

CITED REFERENCE

- Ager, D.K., 1981, Nature of the stratigraphical record (second edition): New York, Wiley Interscience, 122p.
- Anderson, E.J., and Goodwin, P.W., 1980, Application of the PAC hypothesis to limestones of the Helderberg Group: Soc. of Econ. Paleo. and Miner., Eastern section Guidebook, 32p.
- Arkle, T., Beissel, D.R., Larese, R.F., Nuhfer, E.B., Patchen, D.G., Smosna, R.A., Gillespie, W.H., Lund, R., Norton, C.W., Pfefferkorn, H.W., 1979. The Mississippian and Pennsylvanian (Carboniferous) systems in the United States - West Virginia and Maryland: United States Geological Survey Professional Paper 1110-D, 35p.
- Ashburner, C.A., 1877, A measured section of Paleozoic rocks of central Pennsylvania: Am. Phil. Soc. Proc., vol. 16.
- Bambach, R.K., 1976, The restricted distribution of abundant bivalve mollusks in the lower and middle Paleozoic: Geol. Soc. American Abstracts with programs, v. 8, no. 6, p. 765.
- Bathurst, R.G.C., 1958, Diagenetic fabrics in some British Dinantian limestones Liverpool Manchester: Geol. Jour., 2: 11-36.
- _____, 1966, Boring algae, micrite envelopes and lithification of molluscan biosparites: Geol. Jour., 5: 15-32.
- _____, 1971, Carbonate sediments and their diagenesis: Elsevier Scientific publishing Co., New York, 658pp.
- Behrens, E.W., 1965, Environment reconstruction of part of the Glen Rose Limestone, Central Texas: Sedimentology, 4: 65-111.
- Berner, R.A., 1971, Bacterial processes effecting the precipitation of calcium carbonate cements, In Bricker, O. ed., Carbonate cements: John Hopkins University, Studies in Geology, no. 19, p. 247-251.
- Bonham-Carter, G.F., 1965, A numerical method of classification using qualitative and semi-quantitative data, as applied to the facies analysis of limestone: Bull. Canadian petrol. Geol., 13: 482-502.
- Brown, John S., 1943, Suggested use of the word microfacies: Economic Geology, v. 38, p. 235.
- Busch, R.M., and Rollins, H.B., 1984, Correlation of carboniferous strata using a hierarchy of transgressive- regressive units: Geology, v. 12, pp. 471-474.
- Campbell, M.R., Mendenhall, W.C., 1896, U.S. Geological Survey, Pocahontas Folio no. 26.

- Chave, K.F., 1962, Factors influencing the mineralogy of carbonate sediments: *Limm. Oceanography*, 7: 218-233.
- Cloud, P.E., 1962, Environment of calcium carbonate deposition west of Andros Island, Bahamas U.S. Geological Survey Prof. Pap. 35, 138pp.
- Colten, C.W., 1970, The Appalachian Basin - its depositional sequences and their geologic relationships, in Fisher, G.W. (ed), Studies in Appalachian Geology: central and southern: John Wiley and sons, inc., p.5-47.
- Craig, L.C., Varnes, K.L., 1979, History of the Mississippian System - an interpretive summary: U.S. Geological Survey Prof. Paper 1010-R (part II).
- Duncan, H., 1957, Bryozoans: *Geol. Soc. America memoir* 67, v.2, p. 783-800.
- Dunham, R., 1962, Classification of carbonate rocks according to depositional texture: in *Amer. Assoc. Petrol. Geol. Memoir* 1: p. 108-121.
- Dyar, R.F., 1957, The Bluestone Group, Princeton Conglomerate, and Hinton Group - Mauch Chunk Series in Southeastern West Virginia, masters thesis West Virginia University.
- Englund, K., 1976, Guidebook to carboniferous stratigraphy of southwestern Virginia and southeastern West Virginia: *Geol. Soc. of America NE-SE sectional meeting, field trip guidebook* No.3, 40p.
- _____, 1979, The Mississippian and Pennsylvanian (Carboniferous) systems in the United States - Virginia: U.S. Geological Survey Prof. paper 1110-c 21p.
- Evamy, B.D., 1963, The application of a chemical staining technique to a study of dedolomitization: *Sedimentology*, 2: 164-170.
- Fairbridge, Rhodes W., 1954, stratigraphic correlation by microfacies: *American Journal of Science*, v.252, p.683-694.
- Flowers, Russell, 1956, A subsurface study of the Greenbrier limestone in West Virginia: *West Virginia Geological Econ. Survey, Investigation no. 15*, 17pp.
- Flügel, E., 1982, Microfacies analysis of limestone: Springer - Verlag, New York, 633pp.
- Folk, R.L., 1959, Practical petrographic classification of limestones: *Amer. Assoc. Petrol. Geol. Bull.*, 43: p. 1-38.

- _____, 1965, Some aspects of recrystallization in ancient limestones
In Pray, L.C. and Murray, R.C., eds. Dolomitization and Limestone
diagenesis: a symposium: Soc. Econ. Paleontologist and
Mineralogists, Spec. Pub. 13: p. 14-48.
- _____, 1973, Carbonate Petrology in the post- Sorbian age. In
Ginsburg, R.N., ed. Evolving concepts in sedimentology:
Johns Hopkins Univ. Press, Baltimore: p.118-158.
- _____, 1974a, The natural history and crystalline calcium carbonate
effect of magnesium content and salinity: Jour. Sed. Petrology,
v.44: p.40-53.
- _____, 1974b, petrology of sedimntary rocks: hemphill Publishing
co., Austin Texas, 182 pp.
- _____, and Land, L.S., 1975, Mg/Ca ratio and salinity: two controls
over crystallization of dolomite: Amer. Assoc. petrol. Geol.
Bull., 59: p 60-68.
- _____, and Robles, R., 1964, Carbonate sands of Isla Perez, Alacran
reef complex, Yucatan: Jour.sed.Petrology, 72: 255-292.
- Freidman, G.M., 1964, Early diagenesis and lithification in Carbonate
sediments: Journal of Sed.Petrol. Vol. 34, no.4, pp. 777-813.
- _____, 1971, Staining. In Carver, R.E., ed. Proceedures in
sedimmentary petrology: John Wiley and Sons, Inc., New York, 653pp.
- _____, Gebelein, C.D., and Sanders, J.E., 1971, Micrite envelopes of
carbonate grains are not exclusively of photosynthetic algal
origin: Sedimentology, 16: 89-96.
- _____, Amiel, A.J., Braun, M., and Miller, D.S., 1973, Generation of
carbonate particles and laminites in algal mats, examples from
sea-marginal hypersaline pools, Gulf of Aqaba, Red Sea: Amer.
Assoc. Petrol. Geol. Bull., 57: 541-558.
- _____, Sanders, J.E., 1978, Principles of sedimentology: John Wiley
and Sons, New york, 792p.
- Fuchtbauer, Hans, 1974, Sediments and Sedimentary rocks I, part II:
John Wiley and sons, Inc., New York p.190-381.
- Gary, Margret, McAfee, Robert, Wolf, Carol, 1973, Glossary of Geology:
American Geological Institute, Washington D.C., 805pp.
- Goodwin, P.W., and Anderson, E.J., 1985, Punctated aggradational
cycles; a general hypothesis of episodic stratigraphic
accumulation: Geology, vol. 93, p. 515-533.

- Gray, B.E., 1985, Petrology of the Alderson Formation (Mississippian) in Southeastern West Virginia. Unpublished masters thesis, ECU, 166pp.
- Gregg, J.M. and Sibley, D.F., 1984, Epigenetic dolomitization and the origin of xenotopic dolomite textures. *Jour. Sed. Petrology*, 54: 908-931.
- Hines, R.A., 1983, Petrology of the Stoney Gap Sandstone (Upper Mississippian) Mercer County, West Virginia: unpublished Masters Thesis, ECU, 90pp.
- Humphreville, R.G., 1981, Stratigraphy and paleoecology of the Upper Mississippian Bluefield Formation, unpublished masters thesis West Virginia University, 230pp.
- James, N.P., 1979, Reefs. In Walker, R.G., ed., Facies Models 2nd ed., Geoscience Canada Reprint series 1, 229-244.
- Kanes, W.H., 1957, A study of the upper middle Mississippian of southeastern West Virginia, unpublished masters thesis, West Virginia University.
- Kobluk, D.R., and Risk, M.J., 1977, Calcification of exposed filaments of endolithic algae micrite envelope formation and sediment production: *Jour. Sed. Petrology*, 47: pp. 517-528.
- Land, L.S., Behrens, E.W., and Frishman, S.A., 1979, The ooids of Baffin bay, Texas: *Jour. Sed. Petrology*, 49: pp. 1269-1278.
- Lasemi, Z., and Sandberg, P.A., 1984, Transformation of aragonite-dolomitized lime muds to microcrystalline limestones: *Geology*, 12: pp. 420-423.
- Leonard, A.D., 1986, The petrology and stratigraphy of upper Mississippian Greenbrier Limestones of eastern West Virginia: Unpublished Ph.D. dissertation, West Virginia University, Morgantown, West Virginia, 219pp.
- Longman, M.W., 1977, Factors controlling the formation of microspar in the Bromide Formation: *Jour. Sed. Petrology*, 47: 347-350.
- _____, 1980, Carbonate diagenetic textures from near surface environments: *Amer. Assoc. Petrol. Geol. Bull.*, 64: 461-487.
- _____, 1982, Carbonate diagenesis as a control on stratigraphic traps (with examples from the Williston Basin): *Amer. Assoc. Petrol. Geol. Education Course Notes Series*, no. 21.
- Lucia, F.J., 1962, Diagenesis of a crinoidal sediment: *Jour. Sed. Petrology*, 32: pp. 848-865.

- Manspeizer, Warren, 1958, The Bluefield Group- Mauch Chunk Series in southeastern West Virginia: unpublished masters thesis, West Virginia University. pp.96.
- Millman, J.D., Ross, D.A., and Ku, T.H., 1969, Precipitation and lithification of deep-sea carbonates in the Red sea: Jour. Sed. Petrology, 39: pp 724-736.
- Moore, Editor, 1965, Treatise on Invertebrate Paleontology (H), Brachiopoda. Univ. of Kansas Press. Vol I and II.
- Neuman, A.C., and Land, L.S., 1975, Lime mud deposition and calcareous algae in the Bight of Abaco, Bahamas: a budget. Jour. Sed. Petrology, 45: pp.763-786.
- Parker A. and Sellwood B.W., 1981, Sediment Diagenesis, D. Reidel Publishing Company, Boston, p.289-384.
- Price, P.H., 1929, Pocahontas County, West Virginia Geol. Econ. Survey, County Reports, 531pp.
- _____, and Heck, E.T., 1939, Greenbrier County. West Virginia Geol. Econ. Survey, County Reports, 846 pp.
- Purdy, E.G., 1963, Recent carbonate facies of the Great Bahama Bank: Jour. Geol., 71: 472-497pp.
- Reger, D.B., 1926, Mercer, Monroe, and Summers Counties, West Virginia Geol. Econ. Survey, County Reports, 963p.
- Rudwick, M.J.S., 1970, Living and Fossil Brachiopods, Hutchinson and Co., Ltd., London, 199pp.
- S.A.S. Institute, 1982, SAS User's Guide: Statistics Statistical Analysis System Institute, Cary, N.C., 584pp.
- Schlumberger, 1972, Log Interpretation Volume I Principles, Schlumberger Limited, New York, 112pp.
- Slagel, E.S., 1978, The Paleontology and paleoecology of the Hillsdale Limestone (Mississippian, Meramecian), Washington County, Virginia: Unpublished masters thesis, East Carolina University, 175 pp.
- Smosma, R., and Warshauer, S.M., 1978, The evolution of a carbonate shelf, Silurian McKenzie Formation, West Virginia: a cluster analytic approach: Jour. Sed. Petrology, 48: 127-142pp.
- Smosna, R., and Warshauer S.M., 1979, A scheme for multivariate analysis in carbonate petrology with an example from the Silurian Tonoloway Limestone: Jour. Sed. Petrology, 49: 257-272 pp.

- Sprouse, D.W., 1954, Subsurface Upper Mississippian rocks of West Virginia: unpublished masters thesis, University of Illinois, 48p.
- Thomas, W.A., 1959, Upper Mississippian stratigraphy of southwestern Virginia, southern West Virginia and eastern Kentucky: unpublished Ph.D. dissertation, Virginia Polytechnical Institute, Blacksburg, Virginia, 322 p.
- Tucker, M.E., 1981, Sedimentary Petrology an Introduction: John Wiley and Sons, New York. 252 pp.
- Ulrich, E.O., 1911, Bearing of the paleozoic bryozoan on paleogeography: Geol. Soc. of America Bull., V.22, p.252-257.
- Weller, J.M., et. al., 1948, Correlation of the Mississippian formations of North America: Geol. Soc. America Bull., V.59, p.91-196.
- Wells, D., 1950, Lower-middle Mississippian of southeastern West Virginia: Amer. Assoc. Petrol. Geol. Bull., 34: 882-922 pp.
- Wilpolt, R.H., and Marden, D.W., 1959, Geology and oil and gas possibilities of the upper Mississippian rocks of southwestern Virginia, southern West Virginia and eastern Kentucky: United States Geological Survey Bull., 1072-K, p.587-656.
- Wray, J.L., 1951, The Greenbrier series in northern West Virginia and its correlates in southwestern Pennsylvania: unpublished masters thesis, West Virginia University, 64pp.
- Wray, J.L., 1952, Endothyrid foraminifera from the Greenbrier Series (Mississippian) of northern West Virginia: Jour. Paleo., 26: pp. 946-952.
- Youse, Arthur C., 1964, Gas producing zones of Greenbrier (Mississippian) Limestone, southern West Virginia and eastern Kentucky: Amer. Assoc. Petrol. Geol. Bull., Vol. 48, No.4, pp. 465-486.

APPENDIX A

EDRAY SECTION (POCAHONTAS COUNTY)

This section was measured along U.S. Route 219, approximately 1.8 miles north of Edray, West Virginia. The lower contact of the Reynolds Limestone Member is approximately 61 meters south (towards Edray) from the picnic and overlook area.

UNIT	LITHOLOGY	THICKNESS	TOTAL
F	Biomicrosparites, rich in echinoderms and brachiopods. Thinly bedded, weathering yellowish tan to gray interbedded with shale that weathers black to dark gray. Limestone beds are more numerous towards the top.	4.37m	19.17m
E	Biomicrosparites, rich in echinoderms, foraminifera and gastropods. Massively bedded, blue-gray limestone; weathering from tan to gray brown, very fossiliferous.	1.85m	14.8m
D	Biomicrosparites and biomicrosparrudites rich in echinoderms, foraminifera and bivalves. Black irregularly bedded, blocky limestone interbedded with shale (less than 15.24 cm thick). Both the shale and limestones are very fossiliferous.	4.04m	12.95m
C	Biomicrosparite, rich in echinoderms and foraminifera. A massively bedded white to gray limestone; very resistant and weathers purple. Not as fossiliferous as units B and D.	2.84m	8.91m
B	Biomicrosparites rich in echinoderms and partially dolomitized interbedded with shale. Very fossiliferous blue-gray limestone thinly laminated, weathering tannish gray. Shale increases toward the base of the bed.	3.81m	6.07m
A	Biomicrosparite rich in echinoderms. Initially has a massive appearance but closer observation indicates a very weathered, tannish gray, "dirty" (approx. 38% insolubles) limestone; very fossiliferous.	2.26m	2.26m

CLAYTON SECTION (SUMMERS COUNTY)

The Clayton Section is measured in the vicinity of Clayton, West Virginia, along West Va. 7 (Clayton Road). The Reynolds Limestone Member is located 0.7 of a mile from the intersection of West Virginia 7 and West Virginia 3 towards Clayton. The section is located on the right hand side of the road in Griffith Creek.

UNIT	LITHOLOGY	THICKNESS	TOTAL
F	Massive gray crystalline dolomite weathering tan to buff, shale present at the upper contact.	0.9m	5.27m
E	Tan shale (covered)	1.5m	4.37m
D	Biomicrosparite, partially dolomitized rich in quartz, pyrite and bivalves. The lower contact is a crystalline biogenic dolomite. A massive limestone with planer laminations at the upper and lower boundaries. The central portion has wavey laminations; weathers yellow to dark brown.	1.4m	2.87m
C	The upper contact is a bryzoan rich dolomitized biomicrosparite. The lower contact is a Ferroan dolomite. This unit has a massive blocky, nodular appearance and weathers white.	0.84m	1.47m
B	A green to red terrigenous limey shale	0.23m	0.63m
A	Ferroan dolomite weathering tan to white	0.4m	0.4m

BRIERY KNOB SECTION (Pocahontas County)

The Briery Konb Section was measured along West Virginia Route 29 approximately 2.5 miles south of Lobelia, in Little Levels District. The top of the Reynolds Limestone Member is located at the intersection of W. Va. Routes 29 and 29/4, moving down section the Reynolds Limestone Member continues south for approximately 30 meters. The lower contact is with the Bickett Shale, the upper contact is not present at this section.

UNIT	LITHOLOGY	THICKNESS	TOTAL
F	Biomicrosparites, rich in peloids, brachiopods, bivalves and quartz. Thinly bedded limestone (2-5 cm, irreg. bedded), interbedded with shale (less than 15 cm thick); weathering a tannish yellow to gray, black when fresh.	3.05m	14.45
E	Biomicrosparite, rich in peloids, brachiopods and echinoderms. Thinly bedded limestone (5-10 cm thick) interbedded with shale. Weathers white to tan, black when fresh. The lower portion of the section is partially covered.	2.26m	11.4m
D	Biomicrosparite and biomicrite, is rich in brachiopods and quartz, respectively. Thinly bedded (.5 to 2.5cm thick), fossiliferous limestone partially covered, interbedded with shales at the bottom; more massive towards the top.	3.35m	9.14
C	Biopelmicrosparite rich in echinoderms massive fossiliferous limestone with the upper four feet bedded. It weathers black to yellow and is very resistant.	2.18m	5.79m

B	Biomicrosparite, rich in echinoderms interbedded with shale. Blocky irregularly bedded crystalline limestone (.5-2 cm thick) weathers yellow to black	1.93m	3.61m
A	Biomicrosparite, rich in quartz and laminated argillaceous micrites. Thinly bedded gray crystalline limestone, weathers tan to black.	1.68m	1.68m

DROOP MOUNTAIN SECTION (POCAHONTAS COUNTY)

The Droop Mountain Section is located approximately 4 miles southwest of Hillsboro and approximately 1.5 miles north of Droop Mountain State park. The Reynolds Limestone Member crops out on a sharp curve near the top of Droop Mountain, an abandoned garage existed on the curve at the time of sampling.

UNIT	LITHOLOGY	THICKNESS	TOTAL
D	The upper unit was not sampled but according to Manspeizer (1958). It is a massively bedded limestone (averaging 1.25'), flutted well defined, blue gray and nonresistant.	2.04m	10.24m
C	Biomicrosparite rich in bivalves and echinoderms. A massive blue gray limestone weathering yellow, contains resistant beds of brachiopods and shell hash.	3.35m	8.20m
B	Argillaceous biomicrites, micrites and biomicrosparites rich in echinoderms and bivalves. A blocky to irregular thinly bedded limestone, weathering grayish blue (sampling difficult due to thin bedding).	2.79m	4.85m
A	Biomicrosparite rich in quartz, bivalves and echinoderms. A massive, resistant blue black laminated, slightly sandy crystalline limestone with beds averaging 15cm to 30cm thick, weathering yellow to black.	2.06m	2.06m

MUDDY CREEK MOUNTAIN SECTION (GREENBRIER COUNTY)

The Muddy Creek Mountain Section is located on West Virginia Route 46, northeast of Alderson West Virginia. Traveling northwest from West Virginia 63 along West Virginia Route 46 the Reynolds Limestone Member outcrops 0.5km west of Davis Hollow.

UNIT	LITHOLOGY	THICKNESS	TOTAL
C	Massive limestone, no bedding; light gray, weathers a light tan; sparse fossils upper contact is covered.	0.6m	10.1m
B	Thinly bedded limestone(1-3cm thick); weathers light tan to gray; very fossiliferous. 50% of this unit is covered (thickness is estimated).	5.8m	9.5m
A	Massive crystalline gray limestone, biomicrosparrudites and biomicrosparites rich in echinoderms, bryozoans and peloids; weathers tan.	3.7m	3.7m

RAINES CORNER SECTION (MONROE COUNTY)

The Raines Corner Section is located in the vicinity of Raines Corner, West Virginia, on the west side of Indian Creek. It is located approximately 2.5 miles north of Raines Corner along U.S. Route 219, approximately 300 feet south of the "covered bridge" park.

UNIT	LITHOLOGY	THICKNESS	TOTAL
F	A covered area with calcareous gray sandstone occasionally out-cropping (weathers brown)	1.8m+	17.2m+
E	A calcareous shale with a decrease in shale upward; a calcareous sandstone is present at the upper contact.	1.5m	15.4m
D	Argillaceous limestone at the base, The upper contact is a calcareous shale. The central portion is covered	1.5m	13.9m
C	The upper contact is a massive gray crystalline dolomite rich in brachiopods and bryozoans. The remainder of the unit is a gray slightly laminated argillaceous biomicrosparite. The unit is partially covered.	3.0m	12.4m
B	The upper portion of unit B is an algal biolithite, the rest of the unit is a dolomitized argillaceous microsparite; massive gray, wavy laminations and some crossbeds; weathering a yellow to dark brown.	2.0m	9.4m
A	A dolomitized biomicrosparite rich in bryozoans, bivalves and echinoderms. Fossiliferous content decreases up section. The rock is a dark gray.	7.4m	7.4m

NEMOURS SECTION (MERCER COUNTY)

The Nemours section is located on the east limb of the Abbs Valley Anticline on West Virginia 102 west of Nemours, West Virginia. The Reynolds Limestone Member is located approximately 30 meters east of West Virginia Route 82/2.

UNIT	LITHOLOGY	THICKNESS	TOTAL
D	Biomicrosparites rich in echinoderms An argillaceous thinly bedded fossiliferous limestone weathering tan to brown. Shales increases upward.	1.5m	10.5
C	Biopelmicrosparites and biopelsparites rich in echinoderms, bryozoans and quartz. The upper portion contains lenses of calcareous sandstones. The unit weathers brown to gray.	4.3m	9.0m
B	Covered	1.7m	4.7m
A	Biosparites and biomicrosparites rich in echinoderms and peloids; shale is present in the central portion of the unit; weathers brown to gray.	3.0m	3.0m

APPENDIX B

SAMPLE QUARTZ PELOID MICROSPAR MICRITE MATRIX SPAR OPAQUE FELDSPAR DOLOMITE MICA PHOSPHATE GYPSUM INTRACLAST OOLDS

E1	0.3	3.0	49.3	6.3	--	--	1.0	1.0	--	--	--	--	--	--
E2	--	--	46.7	0.7	--	--	--	--	--	--	--	--	--	--
E3	--	2.7	44.0	--	--	--	--	--	--	--	--	--	--	--
E4	--	0.7	43.0	--	--	--	--	--	--	--	--	--	--	--
E5	--	2.3	52.0	--	--	--	2.0	--	--	--	--	--	--	--
E6	--	1.0	34.0	18.3	--	--	2.3	--	--	--	--	--	--	--
E8	--	11.0	30.0	12.3	--	--	--	--	--	--	--	--	--	--
E9	--	--	78.3	--	--	--	--	--	--	--	--	--	--	--
E10	--	7.3	47.7	53.3	--	--	--	--	--	--	--	--	--	--
E11	--	0.3	68.0	--	--	--	--	--	--	--	--	--	--	--
E12	--	7.3	55.0	0.7	--	--	--	--	--	--	--	--	--	--
E13	--	9.3	60.7	--	--	--	0.7	--	21.7	--	--	--	--	--
E14	--	4.0	46.3	--	--	3.0	1.3	--	10.3	--	--	--	--	--
E16	--	9.3	37.7	--	--	4.3	2.0	--	24.3	--	--	--	--	3.0
E20	2.0	0.3	45.7	--	--	--	1.3	--	--	--	--	--	--	--
E21	--	8.3	46.7	1.7	--	--	2.7	--	--	--	--	--	--	--
E22	3.3	0.3	76.3	--	--	--	1.0	--	--	--	--	--	--	--
E23	0.7	4.0	43.3	--	36.3	--	--	--	--	--	--	--	--	--
MC1	--	7.7	21.0	--	--	2.3	0.3	--	--	--	--	--	--	2.0
MC2	--	3.7	12.0	--	--	2.3	--	--	--	--	--	--	1.7	0.7
MC3	--	3.7	14.3	--	--	6.0	0.3	--	--	--	--	--	--	0.7
MC4	--	1.3	20.7	--	--	--	1.3	--	21.7	--	--	--	12.3	--
MC5	--	0.3	7.3	--	30.0	0.7	0.7	--	--	--	--	2.0	3.7	0.3
D1	7.3	4.7	68.0	--	--	--	2.7	--	--	--	--	--	--	--
D2	1.9	--	71.0	--	--	--	1.7	--	--	--	--	--	--	--
D3	1.7	2.0	61.0	--	--	1.3	0.3	--	--	--	--	--	0.3	--
D4	2.0	9.3	54.0	--	--	--	2.0	--	--	--	--	--	3.0	--
D5	--	0.3	2.0	--	--	--	1.0	--	50.0	--	--	--	0.3	--
D6	0.7	0.3	58.0	--	--	--	1.3	--	--	--	--	--	2.0	--
D7	--	--	97.0	--	--	--	1.7	--	--	--	--	--	--	--
D8	1.3	0.7	79.0	--	--	--	1.0	--	--	--	--	--	--	--
D9	--	--	66.0	--	--	--	0.3	--	--	--	--	--	--	--
D11	0.3	8.0	56.7	0.7	--	--	1.3	--	--	--	--	--	--	--

SAMPLE ECHINODERMS BRACHIOPODS BRYOZOANS OSTROCODES FORAMINIFERS TRILOBITE GASTROPOD PELECYPOD ALGAL SPONGE

E1	8.0	--	--	--	9.4	0.3	13.7	6.7	--	--
E2	30.3	--	--	1.0	10.0	0.7	2.3	2.3	--	--
E3	42.0	--	--	0.3	5.0	--	0.3	4.7	--	--
E4	26.7	--	0.3	1.3	10.0	0.7	1.7	7.7	--	--
E5	11.7	2.0	2.0	0.7	11.7	2.3	2.0	8.3	--	--
E6	10.7	9.3	2.7	--	1.0	3.7	0.7	15.3	--	--
E8	16.7	5.0	0.7	0.7	--	3.3	0.7	18.3	--	--
E9	9.3	1.0	0.7	0.3	3.7	1.0	--	4.7	--	--
E10	13.3	2.3	--	0.3	14.0	--	0.3	6.0	--	--
E11	15.7	1.7	--	--	6.7	--	--	5.7	--	--
E12	12.7	6.3	--	0.3	8.7	0.7	--	7.0	--	--
E13	1.7	4.3	--	--	--	--	--	1.7	--	--
E14	26.3	5.0	--	--	--	--	--	2.3	--	--
E16	9.3	2.3	--	--	2.3	--	3.3	3.3	--	--
E20	1.3	1.7	--	--	--	--	--	--	--	--
E21	4.7	21.0	2.0	0.3	--	--	--	11.3	--	--
E22	6.7	3.3	3.0	0.7	3.0	--	--	--	--	--
E23	21.0	0.3	6.0	--	0.7	0.3	--	22.0	--	--
MC1	28.0	2.0	25.7	1.0	--	--	--	8.7	--	--
MC2	38.3	2.0	25.3	--	--	--	--	11.0	--	--
MC3	36.6	--	31.7	--	--	0.3	--	4.3	--	--
MC4	10.3	--	13.3	--	0.3	--	0.3	13.0	2.3	1.7
MC5	25.7	0.3	20.3	--	--	--	0.7	7.0	--	--
D1	6.0	0.7	2.0	--	--	--	--	9.0	--	--
D2	3.7	1.7	--	0.3	--	--	--	2.3	--	--
D3	13.0	--	1.7	--	--	0.3	0.3	17.7	--	--
D4	10.0	3.0	4.0	0.3	--	--	--	10.7	--	--
D5	11.3	6.0	1.3	1.0	0.3	--	2.7	23.0	--	--
D6	13.7	6.3	3.0	--	--	--	0.3	13.7	--	--
D7	--	--	--	--	--	--	--	--	--	--
D8	7.3	--	0.3	--	0.3	--	--	10.0	--	--
D9	5.0	--	--	--	0.3	--	5.0	22.0	--	--
D11	13.3	8.7	0.7	0.3	0.3	--	--	9.3	--	--

SAMPLE QUARTZ PELOID MICROSPAR MICRITE MATRIX SPAR OPAQUE FELDSPAR DOLOMITE MICA PHOSPHATE GYPSUM INTRACLAST OIDS

BK1	14.7	0.7	71.7	--	--	--	2.7	--	--	10.0	--	--	--	--
BK2	4.0	--	--	--	73.3	1.3	1.7	--	--	15.7	--	--	--	--
BK3	14.7	--	40.7	--	--	--	2.3	--	34.7	7.7	--	--	--	--
BK6	1.0	--	53.3	--	--	--	2.0	--	--	--	0.3	--	0.3	--
BK7	0.7	7.3	53.3	--	--	--	0.3	2.0	--	--	--	--	--	--
BK8	3.7	7.0	53.0	--	--	--	0.7	1.0	--	--	--	--	--	--
BK9	5.3	7.7	69.7	--	--	--	2.3	--	--	--	--	--	--	--
BK10	0.7	1.0	72.7	--	--	--	1.3	--	--	--	--	--	1.0	--
BK12	5.3	1.7	85.3	--	--	--	2.0	--	--	--	--	--	--	--
BK13	7.0	14.3	41.0	--	--	--	2.7	--	--	--	--	--	1.3	--
BK14	--	3.7	42.7	--	--	7.0	3.0	--	--	--	--	--	--	--
BK15	1.7	--	85.3	--	--	--	0.3	--	--	--	--	--	--	--
BK16	0.3	--	69.3	--	--	--	0.3	--	--	--	--	--	--	--
BK17	--	9.7	45.0	--	--	0.3	1.7	--	--	--	--	--	--	--
BK18	--	3.7	69.7	--	--	2.7	1.3	--	--	--	--	--	--	--
BK19	--	0.7	47.0	--	--	0.7	0.7	--	--	--	--	--	--	--
BK20	8.6	--	78.3	--	--	--	3.3	--	--	3.7	--	--	--	--
CLA1	4.7	0.3	--	--	--	--	2.3	--	92.3	--	--	--	--	--
CLA3	3.3	1.0	--	89.3	--	0.3	1.3	--	4.0	0.7	--	--	--	--
CLA4	--	--	--	89.3	--	--	5.0	--	4.7	0.7	--	--	--	--
CLA5	3.0	--	--	75.3	--	--	2.7	--	12.0	--	--	--	--	--
CLA6	--	--	--	60.0	--	--	4.3	--	10.0	--	--	--	--	--
CLA7	--	--	--	--	--	0.7	3.7	--	93.7	0.3	--	--	--	--
CLA8	0.7	--	59.3	--	--	--	2.3	--	17.7	--	--	--	2.7	--
CLA9	--	1.3	--	3.3	--	2.0	1.0	--	90.7	--	--	--	--	--
CLA10	--	--	--	--	--	0.3	4.7	--	94.7	--	--	--	0.3	--
N1	0.3	14.7	--	--	--	27.7	0.3	--	--	--	0.3	1.0	5.0	--
N3	14.0	7.0	25.7	3.7	--	--	--	--	--	--	--	--	2.3	3.7
N4	23.7	8.3	--	1.3	--	33.0	--	--	--	--	--	--	1.0	2.3
N5	2.7	6.7	7.3	--	--	19.3	--	--	--	--	--	--	1.3	0.3
N6	66.7	--	32.3	--	--	--	1.0	--	--	--	--	--	--	--
N8	3.7	1.3	14.4	--	--	15.3	0.7	--	--	--	--	--	--	--
N9	64.3	--	--	--	22.7	--	11.0	--	--	--	--	--	--	--

SAMPLE ECHINODERMS BRACHIOPODS BRYOZOANS OSTROCODES FORAMINIFERS TRILOBITE GASTROPOD PELECYPOD ALGAL SPONGE

BK1	--	--	--	--	--	--	--	0.3	--	--
BK2	--	--	--	--	--	--	--	--	--	--
BK3	--	--	--	--	--	--	--	--	--	--
BK6	18.0	5.3	5.7	2.0	--	3.7	--	5.7	--	--
BK7	17.0	7.3	6.0	--	--	2.7	--	6.0	--	--
BK8	7.3	5.3	8.7	--	0.3	0.3	--	11.3	--	--
BK9	11.0	1.0	2.3	--	0.3	1.0	--	2.7	--	--
BK10	7.3	8.3	5.3	--	--	--	--	1.7	--	--
BK12	2.0	0.3	--	--	--	--	--	0.3	--	--
BK13	5.0	23.3	3.7	--	--	--	--	0.3	--	--
BK14	8.0	19.7	2.3	--	--	1.0	0.7	10.3	--	--
BK15	8.3	--	0.7	--	--	--	--	0.7	--	--
BK16	16.3	--	0.7	0.7	4.7	--	--	2.3	--	--
BK17	14.0	16.0	2.7	--	2.7	--	--	4.7	--	--
BK18	6.7	7.0	--	--	6.0	0.3	--	1.3	--	--
BK19	9.3	12.0	1.3	0.3	2.0	1.0	5.7	17.7	--	--
BK20	0.7	3.7	--	--	--	0.3	--	0.3	--	--
CLA1	--	--	--	--	--	--	--	--	--	--
CLA3	--	--	--	--	--	--	--	--	--	--
CLA4	--	--	--	--	--	--	--	0.3	--	--
CLA5	--	0.7	2.0	--	0.3	--	--	3.0	--	--
CLA6	--	5.3	1.7	--	--	--	5.7	13.7	--	--
CLA7	--	0.7	--	--	--	--	--	1.0	--	--
CLA8	1.3	1.3	6.7	--	--	0.3	--	5.7	--	--
CLA9	--	--	--	--	--	--	--	1.7	--	--
CLA10	--	--	--	--	--	--	--	--	--	--
N1	20.7	--	12.7	--	--	0.3	0.7	12.7	--	--
N3	20.7	--	13.3	0.7	--	--	0.7	7.3	--	--
N4	15.7	--	9.3	--	--	--	0.7	4.0	--	--
N5	26.0	--	28.0	--	--	0.3	--	7.0	--	--
N6	--	--	--	--	--	--	--	--	--	--
N8	32.0	--	25.0	0.3	--	--	--	5.7	--	--
N9	--	--	--	--	--	--	--	--	--	--

SAMPLE	QUARTZ	PELOID	MICROSPAR	MICRITE	MATRIX	SPAR	OPAQUE	FELDSPAR	DOLOMITE	MICA	PHOSPHATE	GYPSUM	INTRACLAST	OOIDS
RC1	--	--	67.3	--	--	--	2.0	--	13.3	--	--	--	--	--
RC2	--	--	59.7	--	--	--	2.7	--	14.7	--	--	--	1.3	--
RC3	--	--	77.7	--	--	--	1.7	--	0.7	--	--	--	3.0	--
RC4	--	6.7	13.7	--	--	--	--	--	19.9	--	--	--	15.0	13.3
RC5	--	--	95.7	--	--	--	2.3	--	1.7	--	--	--	--	--
RC6	4.0	--	36.0	--	--	--	2.0	--	45.3	12.7	--	--	--	--
RC7	7.3	--	28.0	--	--	--	1.3	--	51.7	11.7	--	--	--	--
RC8	1.7	--	--	--	--	--	0.3	--	--	5.0	--	--	--	--
RC9	--	--	52.0	--	--	--	0.3	--	--	3.6	--	--	--	--
RC10	--	0.3	--	--	--	0.3	--	--	44.7	--	--	--	--	--

SAMPLE	ECHINODERMS	BRACHIOPODS	BRYOZOANS	OSTROCODES	FORAMINIFERS	TRILOBITE	GASTROPOD	PELECYPOD	ALGAL	SPONGE
--------	-------------	-------------	-----------	------------	--------------	-----------	-----------	-----------	-------	--------

RC1	3.7	1.0	18.0	--	--	--	--	4.0	--	--
RC2	7.0	3.3	1.7	--	--	--	0.3	9.0	--	--
RC3	10.0	1.3	3.0	0.3	--	--	--	1.3	--	--
RC4	21.0	--	2.0	0.3	0.3	--	0.7	7.0	--	--
RC5	0.3	--	--	--	--	--	--	--	--	--
RC6	--	--	--	--	--	--	--	--	--	--
RC7	--	--	--	--	--	--	--	--	--	--
RC8	--	--	--	--	--	--	--	--	93.0	--
RC9	6.0	3.3	0.7	--	--	--	--	1.3	--	--
RC10	4.7	23.3	18.0	--	--	1.7	--	4.7	--	0.7

APPENDIX C

APPENDIX C

NUMBER OF CLUSTERS	R-SQUARED	CUBIC CLUSTER CRITERION
10	0.838902	8.4299
9	0.821080	7.9354
8	0.798162	7.2269
7	0.772186	6.5944
6	0.736984	5.6459
5	0.650937	1.9008
4	0.556632	-0.8555
3	0.458580	-2.0920
2	0.357764	-1.5666
1	0.000000	0.0000

APPENDIX D

APPENDIX D

SAMPLE NUMBER	WEIGHT OF SAMPLE	WEIGHT OF INSOLUBLE	PERCENT INSOLUBLE
RC2	21.45	6.31	29.45
RC3	17.54	5.39	30.68
RC5	22.03	7.34	33.31
RC6	18.63	7.84	42.08
RC7	19.14	10.63	55.54
RC8	17.99	7.87	43.75
RC9	19.69	8.65	43.93
D1	23.94	12.94	54.05
D2	19.89	10.12	50.88
D3	21.64	5.46	25.23
D4	23.26	8.52	36.63
D5	21.47	5.73	26.69
D6	21.99	8.96	40.75
D7	18.49	5.41	29.26
D8	20.74	9.47	45.67
D9	21.04	5.99	28.47
D10	19.86	5.24	26.38
D11	20.95	7.00	33.41
BK1	19.12	12.53	65.53
BK2	19.26	14.47	75.13
BK3	18.91	10.44	55.21
BK4	19.91	13.52	67.91
BK6	20.03	5.32	26.56
BK7	19.07	5.66	29.68
BK8	19.12	9.29	48.59
BK9	17.89	9.15	51.15
BK12	18.67	11.38	60.95
BK13	19.71	5.65	28.67
BK14	21.06	4.72	22.41
BK15	19.61	7.32	37.33
BK16	19.35	4.18	21.60
BK17	18.29	4.58	25.04
BK18	20.27	6.09	30.04
BK19	20.10	5.99	29.80
BK20	20.09	11.05	55.00
CLA3	20.90	5.70	27.27
CLA4	21.50	4.99	23.21
CLA5	20.80	5.38	25.87
CLA6	20.15	4.26	21.14
CLA7	20.65	7.64	37.00
CLA8	21.34	7.69	36.04
E9	20.02	6.43	32.12
E10	18.00	5.02	27.89

SAMPLE NUMBER	WEIGHT OF SAMPLE	WEIGHT OF INSOLUBLE	PERCENT INSOLUBLE
E11	23.46	6.92	29.50
E12	20.36	5.21	25.59
E13	22.95	9.18	40.00
E14	20.86	7.05	33.80
E20	20.38	12.96	63.59
E21	22.41	4.31	19.41
E22	20.90	7.34	35.12
E23	19.67	4.71	23.95