KGS
OF
75-6

Page 15 is missing

RELATION OF BIOTIC ASSEMBLAGES TO LITHOFACIES
IN STANTON LIMESTONE (UPPER PENNSYLVANIAN),
SOUTHEASTERN KANSAS

by

Michael A. Senich

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of
Science in the Department of Geology
in the Graduate College of
The University of Iowa

May, 1975

Thesis supervisor: Associate Professor Philip H. Heckel

Graduate College
The University of Iowa
Iowa City, Iowa

CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's thesis of

Michael A. Senich

has been approved by the Examining Committee for the thesis requirement for the Master of Science degree in the Department of Geology at the May, 1975 graduation.

Thesis committee: Philip H. Heckel
Thesis supervisor

Gilbert Klapper
Member

Brian F. Glenister
Member

ACKNOWLEDGMENTS

Completion of this thesis has been aided through the assistance of many people to whom I can barely begin to express my gratitude. Dr. Philip H. Heckel suggested this problem, and in serving as thesis supervisor, has given invaluable counsel and criticism throughout all phases of the work. His patience and enthusiasm are greatly appreciated. Drs. Gilbert Klapper and Brian F. Glenister served on the thesis committee and provided helpful comments during final preparation.

Several other people have given freely of their time and assisted immeasurably in the identification of paleontological specimens. Dr. Norman D. Newell at the American Museum of Natural History identified bivalves and provided much encouragement through several communications. Dr. Roger L. Batten, also at the American Museum, confirmed or corrected gastropod identifications, and was helpful in providing information concerning similar Upper Paleozoic gastropod faunas. Dr. J. M. Cocke of Central Missouri State University accompanied the author in the field on one occasion, and assisted in collection and identification of corals. Mr. Harrell Strimple, Research Associate and Curator at the University of Iowa, identified most crinoid specimens. Mr. Ronald Lewis (M.S. Iowa, 1974) also aided in crinoid identification and discussed many problems concerning their taxonomy and ecological significance. Finally, Mr. Al Kamb, Curator of Invertebrate Paleontology at the University of Kansas, provided the author with access to many type specimens and extensive collections from the Stanton Formation. To all these people, I offer sincerest thanks and appreciation.

The Kansas Geological Survey partially defrayed the cost of field expenses, and provided sampling equipment, maps and many publications. A University of Iowa Teaching/Research Fellowship summer stipend covered all remaining expenses.

Special thanks are given to all the ranchers of Wilson County who cooperated fully in permitting the author to visit localities on their property. Mr. Mel Carlson of Chanute, Kansas was particularly helpful in granting access to his quarry and locating several additional exposures.

To all those who I have inadvertently omitted and who in any way helped with the completion of this thesis, I can only offer my apologies and thanks to one and all!

ABSTRACT

Localized thickenings attributable to phylloid algal-mound complexes characterize Upper Pennsylvanian limestone sequences in southeastern Kansas. Particularly well-developed algal mounds and associated limestone channels and a fringing rim facies occur in the lower Stanton Formation (Missourian) in Wilson County. Each facies is characterized by a recognizable biotic assemblage and a range of lithologies. Few previous efforts have been made to relate the nature of these biotic assemblages to the variety of lithologies in the lower Stanton.

The mound facies is least taxonomically diverse, but is readily recognized by abundant phylloid algae and diagnostic brachiopod genera *Enteletes* and *Hystriculina*. Lithologies are dominantly sparry algal calcilutites with minor algal sparites and algal calcarenites. Channel and rim facies are easily distinguished from algal mounds on the basis of greater taxonomic diversity and different major lithologies, but are less readily distinguished from one another. The channel is characterized by the diagnostic brachiopod *Schizophoria* cf. *S*. *texana*, the bryozoan *Meekoporella* *dehiscens* and the bivalve genus *Edmondia*. Massive, well-washed skeletal calcarenite dominates central channel regions, and grades laterally into muddy skeletal calcarenites and skeletal calcilutites on the channel margins. The rim facies contains thirteen genera and three species unknown in either the mound or channel, but only the brachiopod *Derbyia deercreekensis* occurs with sufficient frequency to be considered diagnostic. Rim lithologies display greatest variability of all major facies, but are predominantly muddy skeletal calcarenites with minor skeletal calcilutite, abraded calcarenite and skeletal oolite.

Detailed examination of biotic assemblages demonstrates that mound, channel and rim biotas are not mutually exclusive. Considerable overlap occurs in major and minor elements. Subjectively defined micro-biofacies represent only recognizable end-members of variable biotic composition. Additional petrographically defined microfacies characterize lithologic variation in each major facies, but few are useful in field terminology due to rapid lateral lithologic gradation.

Biotic and sedimentologic observations show that abundant macrobiotic elements are not always responsible for producing major sand-size lithologic constituents. If these relationships are not recognized, gross misinterpretations of facies characteristics are possible from field or petrographic observations made independently.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

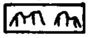
LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

Localized thickening of limestone units characterize the Upper Pennsylvanian sequence in Kansas. Many of these thickenings are attributed to phylloid algal mound complexes (Heckel & Cocke, 1969). Of particular interest are algal mound developments in the Stanton Limestone (Lansing Group, Missourian Stage) of southeastern Kansas, which display measurable topographic relief (Figure 1 and Plate 1). The algal carbonate buildups extend up to tens of kilometers along outcrop, fringe a basin, and are transected by contemporaneous limestone channels. Contemporaneous deposits of the basin and channels may lie as much as 30 meters lower topographically than the buildups. Empirical data from outcrop and corehole samples enabled Heckel (1972) to distinguish three major limestone facies in the Stanton mound complex related to depositional topography: 1) buildup calcilutite, 2) channel and basin-rim calcarenite, and 3) basinal calcilutite.

Each facies is characterized by a distinct biota. Buildup calcilutite is generally dominated by phylloid algal blades, with local encrusting red algae and occasional stromatolitic laminations. Invertebrates are

Figure 1--Generalized stratigraphic column of part of the Upper Pennyslvanian section in eastern Kansas (modified after Heckel & Cocke, 1969). All lithologic symbols standard except , which indicates phylloid algal-mound complexes.

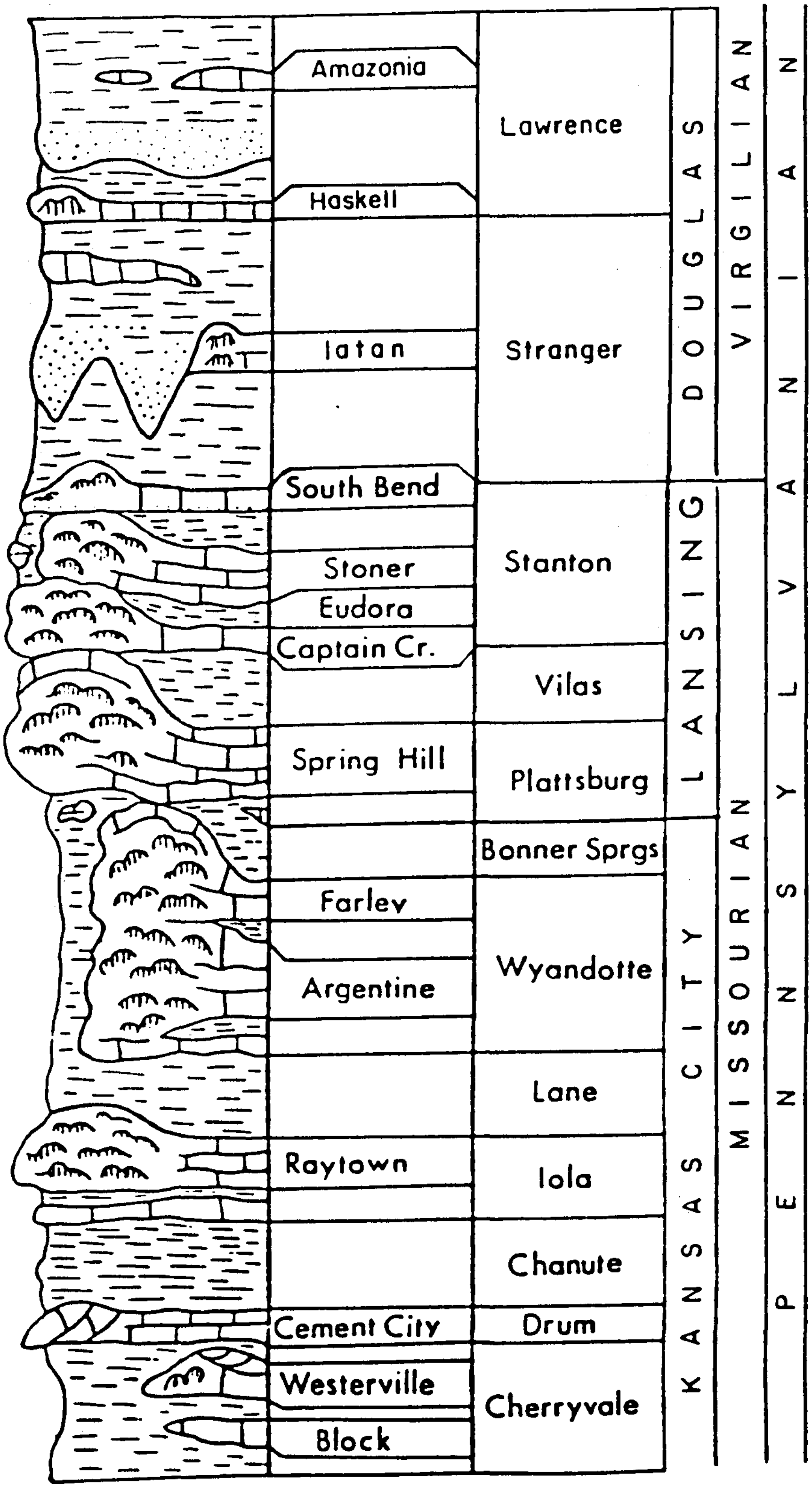

Amazonia
Lawrence
Haskell
Iatan
Stranger
South Bend
Stanton
Stoner
Eudora
Captain Cr.
Vilas
Spring Hill
Plattsburg
Bonner Sprgs
Farley
Wyandotte
Argentine
Lane
Raytown
Iola
Chanute
Cement City
Drum
Westerville
Cherryvale
Block
DOUGLAS
LANSING
KANSAS CITY
VIRGILIAN
MISSOURIAN
PENNSYLVANIAN

Figure 1

scattered and consist of rare gastropods, ostracods, bryozoans, brachiopods and echinoderms. Channel and rim calcarenites are composed chiefly of fragments of pelmatozoan echinoderms, algae, bivalves, gastropods, bryozoans and foraminifers. Certain brachiopods, bryozoans, bivalves and corals occur as whole fossils in parts of this facies, whereas phylloid algae occur only as broken and abraded fragments. Basinal calcilutite is dominated by whole fenestellid fronds, other bryozoans, brachiopods, calcisponges and unabraded pelmatozoan pieces. Phylloid algae are rare.

Previous Work

Previous work on the Stanton Limestone has generated an extensive bibliography, much of which involves Missourian stratigraphic paleontology (Girty, 1903; Beede, 1909; Moore, 1935, 1941, 1949; Moore, Frye & Jewett, 1944; Johnson, 1946, 1947, 1963; Mudge & Yochelson, 1962; Cridland, Morris & Baxter, 1963; and Wagner, 1964). Most major taxonomic groups have been previously studied, and several attempts have been made to establish detailed faunal and floral zonations. Only those studies concerning recognition of biotic assemblages in the lower three members of the Stanton will be mentioned specifically. References pertinent to the discussion of discrete taxonomic units will be reviewed in Appendix B.

Newell (1933) described faunal assemblages that characterize individual formations and members in the Missourian Stage (then Series) across eastern Kansas. His work focused primarily on Stanton exposures along the Kansas River in northeastern Kansas, but in one locality in southeastern Kansas (the Fredonia Cement Plant Quarry) he discovered an "exotic" fauna in the upper part of the formation. It was termed "exotic" because many genera and species had not been reported previously from the Mid-Continent region. The significance of this fauna remained an enigma until mapping by Heckel in 1966-1970 (partly published, 1972) demonstrated that the original locality of this exotic fauna occurs in the channel calcarenite facies. Fossils collected by Heckel at other localities in the channel have been identified by Newell (written commun., 1967) as members of his "exotic" fauna.

Wilson (1962) interpreted Stanton mound complexes in southeastern Kansas as barrier reefs with reef-associated deposits formed under organic (probably algal) influence. He noted algal stromatolite development associated with a "lagoonal fauna" in the basal Stanton north and east of Fredonia, but did not cite distinctive biotic elements. Moore (1964) summarized the paleoecology of several marine assemblages within Pennsylvanian and Permian cyclothems of Kansas. He briefly described a Captain Creek-type (Enteletes) assemblage from the lower member of the Stanton in northeastern Kansas, but mentioned only the occurrence of Enteletes, Hystriculina and associated fusulinids. Extensive faunal lists were presented for units above and below the Stanton, but detailed descriptions of Stanton faunas were not included.

Purpose and Scope

Subsequent to Newell's original faunal descriptions (Newell, 1933, 1934, 1935, 1937, 1942), preliminary delineation of major biotic elements by Heckel (1972) suggests a possible association between distinctive biotas and major lithofacies. Detailed documentation of the nature of the biotic assemblages and their relationship with lithofacies, however, was not established. Primary objectives of this study are delineation of biotas in the algal-mound calcilutite and channel and basin-rim calcarenite facies where exposed in the lower limestone members of the Stanton Limestone. Additional objectives involve quantitative evaluation of the differences, similarities and relations between identifiable macrobiotic elements and major sediment constituents determined by petrographic analysis.

Methods

Field investigations were completed during an eight-week period in the summer of 1973. A three-fold approach was established for: 1) collection of lithologic samples, 2) recovery of paleontological specimens, and 3) counting density and distribution of organisms on certain well exposed surfaces. Representative lithologic samples were selected in the mound and calcarenite facies for laboratory thin-section preparation. Wherever possible, at least two or three samples were taken at each locality, and in places with several lithologies, enough samples were collected to effectively cover the range of variation in the exposure. Paleontological specimens weathering free from bedding plane surfaces were collected for preparation and identification. Collecting bias towards exceptionally well preserved or unusual specimens was reduced by taking quadrat counts on selected bedding plane surfaces. A one m^2 grid with decimeter divisions was utilized. Smaller 100 cm^2 units assured systematic coverage of each area and also served as memory location aids when counting high organism densities. Large proportions of small specimens and discernible fragments were counted within randomly selected 100 cm^2 units for extrapolation to the m^2 area. Multiple quadrats were taken at extensive exposures, and a paint spray was used to mark area corners in order to avoid overlap. Care was also taken in choosing surfaces to avoid counting obvious non-representative concentrations that would unduly bias the numbers and proportions of skeletal components at a particular locality.

Laboratory investigations were completed during the academic year 1973-1974. Identification of prepared specimens was attempted to generic or specific levels for well preserved whole specimens, to generic or familial levels for large broken fragments and to class or ordinal levels for highly fragmented and abraded bioclasts. Approximately 150 thin-sections were analyzed for petrographic characteristics indicative of sediment type. A standard 250 counts per slide of all grain types served to determine relative proportions of major components. An additional 100 to 200 skeletal grain counts enabled an estimate of the relative abundance of each type of organic constituent in the sediment. Petrographic data were partially evaluated and displayed using an IBM 360 series, model 65 computer and a Statistical Analysis System program designed by Barr and Goodnight (1972).

Area of Study: Geographic and Stratigraphic

The Stanton Limestone in eastern Kansas crops out in a roughly linear belt from Leavenworth County to southwesternmost Montgomery County (Figure 2), with best known development of mound and mound-associated facies occurring in Woodson, Wilson and northern Montgomery Counties (Heckel & Cocke, 1969). Presence of good fossil-rich exposures in mound calcilutites and mound-associated calcarenites in the two lower limestone members of the Stanton Limestone (Figure 1) make Wilson County a particularly attractive area in which to investigate different limestone facies and their associated biotas. Thus, this study will be restricted to biotic occurrences in the Captain Creek and Stoner limestone members in Wilson County, Kansas.

Figure 2--Outcrop belt of Missourian strata in eastern Kansas and adjacent states. Horizontally lined area represents distribution of the Lansing Group, including the Plattsburg Formation, Vilas Shale and Stanton Formation (modified after Cocke, 1970). For detail of the Stanton in Wilson County, see Plate 1.

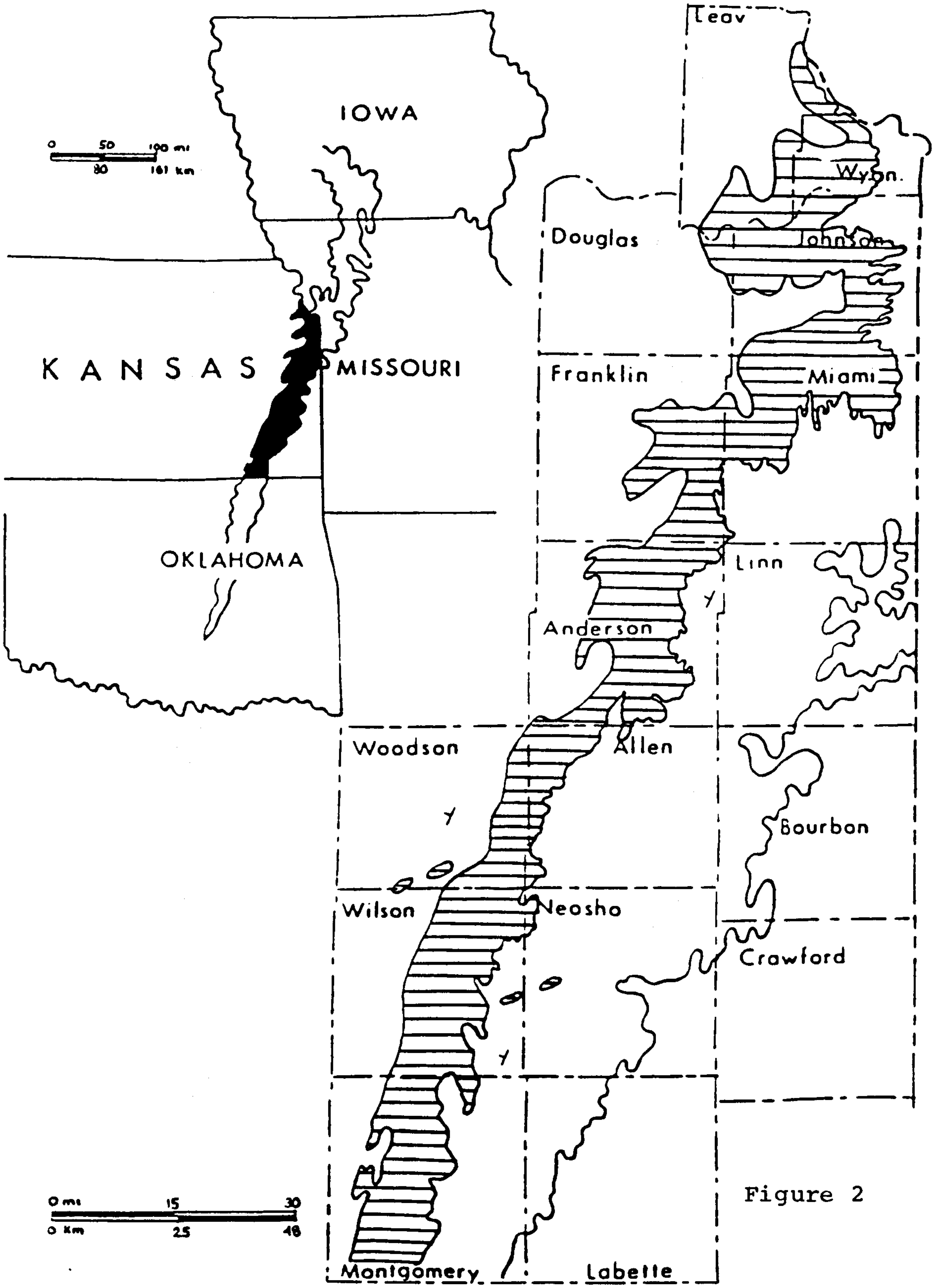

IOWA
0 50 100 mi
80 161 km
KANSAS
MISSOURI
OKLAHOMA
Leav
Wyan.
Douglas
Johnson
Franklin
Miami
Linn
Anderson
Woodson
Allen
Bourbon
Wilson
Neosho
Crawford
Montgomery
Labette
0 mi 15 30
0 Km 25 48

Figure 2

STRATIGRAPHY

Thickness of the Stanton Limestone along outcrop in eastern Kansas ranges from about seven meters in the northeast to 36 meters in the thickest known exposure in Montgomery County (Heckel, 1975). Gradual westward regional dip produces outcrop widths of up to 15 kilometers normal to depositional strike. The Stanton has been traced into northwestern Missouri, and equivalent strata have been recognized in the Wann Formation of northeastern Oklahoma (Cocke, 1970; Heckel, 1975). Condra (1930) also recognized members of the Stanton in an isolated inlier in the Platte Valley region of southeastern Nebraska.

In northeastern Kansas the Stanton persists as a fairly uniform sequence of open-marine limestones and shales. Individual members can be easily delineated and maintain their character laterally for many kilometers with only minor variation (Heckel & Cocke, 1969). South of Anderson County in east-central Kansas, poorly known lateral relations between open-marine and algal-mound facies make identification of members less easy. Great local variations and abrupt lateral facies changes characterize limestones where algal-mound complexes are transected by contemporaneous channels. Mound thicknesses increase locally to 10 meters or more and are several times thicker than normal non-mound equivalents (Heckel & Cocke, 1969). South of the mound complex, limestones in the Stanton thin and grade abruptly into a thick sequence of shale, siltstone, sandstone and thin limestones in southern Montgomery County and northeastern Oklahoma (Heckel, 1975).

A detailed stratigraphic framework has been established for mound and mound associated facies in the Stanton algal-mound complex. Heckel (1972, p. 587) describes algal buildups in the lower Stanton as " . . . broad, platformlike stratigraphic reefs up to several kilometers wide, separated by contemporaneous limestone channels one to two kilometers wide and up to 36 kilometers long." A fringe of skeletal calcarenite rims the mound and dips westward up to 15° into a marginal basin where it is overlain by shale. Good exposures of facies changes between the mound, channel and rim are rare, making exact relationships between facies difficult to establish. However, several exposures located by Heckel (pers. communs., 1973-74) show intertonguing relations that demonstrate contemporaneity between facies.

Captain Creek Limestone Member

Description

The Captain Creek Limestone is the most easily recognizable unit of the Lansing Group in northeastern Kansas (Newell, 1935). In Leavenworth County, the Captain Creek is typically one meter of even, thin-bedded, dense, blue-gray calcilutite which thickens southward, reaching three meters or more in Anderson, Allen and Woodson Counties. The uniformity of the member in northeastern Kansas, along with a diverse biota characterized by *Enteletes* and *Hystriculina* suggests normal open-marine shelf deposition in northeastern Kansas.

Abrupt thickening characterizes the Captain Creek in Wilson and Montgomery Counties. It appears as an irregular thick-bedded to massive, light to dark gray, often mottled and vuggy algal calcilutite approaching 15 meters in thickness at the southern extremity. Lithologies are variable and grade from non-algal to algal and sparry algal calcilutites and algal calcarenites. *Enteletes* and *Hystriculina* are more sporadic in occurrence whereas blades and fragments of phylloid algae dominate the easily visible biota.

Kansas Geological Survey

Open File Report 1975-06

Missing Page 15

visible organic remains are less frequently found in northern exposures (Moore, 1935). South of the mounds, the Eudora thickens abruptly to 20 meters of gray to brown shale (Heckel & Cocke, 1969).

Recognition of the Eudora in Wilson County is often paramount in establishing proper stratigraphic assignment of major limestone lithofacies to either the Captain Creek or Stoner Member. In the absence of Eudora shale, closer examination of rock type is necessary to separate Captain Creek from Stoner. Such assignment however, is questionable in relatively few cases.

Stoner Limestone Member

Description

The Stoner is typically thin to wavy-bedded, light gray fine grained skeletal calcarenite to calcilutite in northeastern Kansas. Thin shaly partings separate individual beds which normally range from five to 20 centimeters thick (Moore, 1935). Thickness of three to four meters characterizes the Stoner throughout much of east-central Kansas.

Extreme lithologic variability and increased thickness characterizes the Stoner in southeastern Kansas. In Anderson County the upper three to four meters of the

7.5-meter unit consists of a small mound complex of algal calcilutites and laminar algal sparite (Heckel & Cocke, 1969). Southward, the Stoner ranges between three to seven meters of locally cross-bedded skeletal and algal calcarenite before attaining a maximum thickness of 12 meters of algal calcilutite in northern Montgomery County.

Wilson County exposures of the Stoner display prominent physical and lithologic variability and provide best development of channel and basin-rim facies. Good mound facies exposures are common but are not as widespread as in the underlying Captain Creek. Stoner mound facies is normally thick-bedded and lacks the massive vuggy fabric of the Captain Creek. Color mottling characteristic of the upper Captain Creek is generally absent in the Stoner mound facies. Lithologically, Stoner mound facies is dominantly sparry algal calcilutite, but it may also occur as an algal-poor skeletal calcilutite, with thin zones of algal sparite and dense poorly fossiliferous calcilutite.

Distribution in Major Facies

The channel calcarenite facies is best exposed in a linear series of outcrops extending east-northeastward from south of Fredonia to west of Altoona (Plate 1).

Fresh whitish-gray to gray color is most common on medium to thick-bedded exposures, whereas grayish-brown or brownish-orange is more characteristic of medium or thinly-bedded weathered surfaces. Local cross-stratification is accentuated in differentially weathered exposures along the channel axis. The central portion of the channel is dominated by a well-winnowed and sorted coarse skeletal calcarenite rich in pelmatozoan, bryozoan and other debris. Away from the channel axis, channel margins have variable rock types that incorporate more mud. Lithologies range from muddy skeletal calcarenite to skeletal calcilutite which may contain chips of phylloid algae.

The rim calcarenite is probably the most lithologically variable facies in the Stoner. Although wavy medium or thin beds are characteristic along the line of outcrop from Fredonia to Buffalo (Plate 1), whitish-gray weathered skeletal calcarenite are equally as prevalent as brownish-orange mottled sparry algal calcilutites. Additional calcilutitic and calcarenitic lithologies further suggest that no single rock type can characterize the range of variation. Heckel (pers. commun., 1974) has suggested that discrete micro-environments existing along the rim probably influenced development of the several lithofacies. This is supported by examination of biotic elements which appear to be somewhat lithologically controlled.

PALEONTOLOGY

In 1933 Newell noted that dissimilar biotas characterize different lithofacies in the Kansas Pennsylvanian. Biotic differences in southeastern Kansas may be even more dramatic with local changes appearing in the same overall lithology. Lack of uniformity can be found from layer to layer and frequently at various places within a single layer. As with modern marine invertebrates, Missourian biotas were likely influenced strongly by the nature of the substrate. Some species may have preferred muddy bottoms, others may have sought a firmer substrate. Coupled with other limiting factors such as light, depth, temperature, salinity and circulation, the possibilities of creating local environments and associated facies faunas greatly increase. In many instances, the relation between lithologic and biotic change is close. Lateral lithofacies changes are accompanied by abrupt biofacies changes. Subtle variations in lithology within a given bed may also be reflected in the biota.

Elements present may not differ significantly in these cases, but slight proportional differences between these elements may contribute to detectable micro-biofacies.

In the present study three generalized major biofacies are recognized, each corresponding to one of the primary lithofacies. Gross biotic differences are readily evident between the mound biofacies and the rim and channel biofacies, but rim and channel biotas are not as readily differentiated. Within the major biofacies, eight micro-biofacies are subjectively segregated. The rim exhibits most variability and correspondingly displays the greatest number (four) of micro-biofacies. The mound and channel facies show least variability, each containing two microfacies. These microfacies are not wholly distinguishable during the course of normal field activities. Present understanding can only allude to rough approximations concerning distribution and relationships. However, a more complete picture of the complexities within the major biofacies cannot be appreciated without some knowledge of microfacies development.

Newell (1933) clearly recognized the significance of facies faunas, but considered them only as geographically isolated communities within a given lithologic unit. He firmly believed that limiting environmental parameters influenced development of faunas, and that along depositional strike faunas would vary in response to these factors. His faunal lists distinguish northeastern and southeastern facies for most units studied in Kansas. Although a northeastern facies fauna could have species in common with southeastern faunas, each facies overall would appear distinct. Recognition and thorough understanding of these facies faunas are essential for proper correlation of Mid-Continent Pennsylvanian units.

The "exotic" fauna discovered near Fredonia remained enigmatic because Newell did not recognize abrupt local facies changes. The exotic fauna was originally reported only from the Fredonia Cement Plant within the presently defined channel calcarenite facies, because no other exposures of this facies were readily accessible at the time. Newell referred to this Stoner fauna as the "Fredonia facies" to distinguish it from more widespread "normal" marine faunas in northeastern and southeastern Kansas. With respect to the idea of geographically isolated facies faunas, the Fredonia facies essentially characterized southern faunas in the Stoner. However, present understanding shows this facies fauna to be only one of several biofacies in southeastern Kansas.

The exotic nature of this assemblage is further enhanced by the presence of several genera and species that were previously unknown in the Mid-Continent Pennsylvanian. Newell (1933) speculated that this fauna may represent an assemblage that developed in West Texas or the Cordilleran region, and except for a temporary and local invasion, was prevented from reaching the northern Mid-continent by some sort of barrier.

The biotic lists presented in this paper contain taxa identified by the present author and appropriately marked taxa identified by previous authors. These marked taxa represent rare elements of the biota identified during more intensive study of specific taxonomic groups. Present collections of representative biotas may have inadvertently omitted many rare elements. Although these rare elements have little consequence on the gross characteristics of the biota, they may enable a fuller understanding of the range of diversity in a given facies. No attempt will be made to discuss the significance of an individual taxon unless specifically identified by the present author. Brief notes concerning specific taxa described in previous reports are found in Appendix B. Plate 2 accompanying Appendix B lists the distribution of all biotic constituents.

Mound Biofacies

Fossil assemblages apparent in the mound biofacies are noticeably poor in invertebrates compared to assemblages in the calcarenite biofacies. Table 1 lists all elements recovered from the mound, but may be somewhat misleading. Many genera and species are rare occurrences in one or two exposures, and several are known only as single specimens. The list in no way represents a biota recoverable at every locality. Mound biotas are generally characterized by predominance of phylloid algae and occurrences of the brachiopod *Enteletes*.

Algae

Large blades of phylloid algae dominate mound assemblages, occasionally to the exclusion of all other elements. Pray and Wray (1963) first applied the term "phylloid" to leaflike green and red algae in which diagenetic alteration has obliterated all internal structure. Mound algae are typically strongly recrystallized, and only in rare instances does any trace of the hypothallus appear. Recrystallization also frequently destroys the outer perithallus leaving peculiar undulatory thin lines of carbonate spar in the calcilutite (Figure 3). Small fragments from moundrock near Neodesha, display weak organic structure indicative of

Table 1--Biotic elements recognized in the mound biofacies. Species marked with an asterisk denote elements described from the lower Stanton in previous investigations, but not identified in the current study. Major groups are listed in order of importance in the mound, and individual species are listed in approximate order of importance within each group.

Table 1

- _Algae_
  - Rhodophyta
    - _Archaeolithophyllum_
  - Chlorophyta
    - *?_Anchicodium_
    - codiaceans undifferentiated
- _Echinoderms_
  - indeterminate ossicles
  - _Erisocrinus_ cf. _E._ _typus_
  - cf. _Graffhamicrinus_
  - ?_Archaeocidaris_ sp.
- _Brachiopods_
  - _Composita_ "_subtilita_"
  - _Phricodothyris_ _perplexa_
  - _Punctospirifer_ _kentuckyensis_
  - _Dielasma_ _bovidens_
  - _Enteletes_ "_pugnoides_"
  - _Hystriculina_ _wabashensis_
  - _Antiquatonia_ _crassicostata_
  - _Reticulatia_ _americana_
  - _Echinaria_ _semipunctata_
  - _Pulchratia_ cf. _P._ _symmetrica_
  - *_Teguliferina_ _armata_
  - *_Cancrinella_ _boonensis_
- _Bryozoans_
  - indeterminate fenestellids
  - indeterminate rhomboporids
  - indeterminate encrusting trepostomes
- _Coelenterates_
  - _Dibunophyllum_ _valeriae_
  - _Dibunophyllum_ sp.
  - _Neokoninckophyllum_ cf. _N._ _heckeli_
  - _Lophamplexus_ sp.
  - _Stereostylus_ sp.
  - _Geyerophyllum_ cf. _G._ _cylindricum_
  - _Lophophyllidium_ sp.
  - _Sutherlandia_ sp.
  - _Syringopora_ _multattenuata_
  - *_Caninia_ _torquia_
  - *_Lophophyllum_ _westi_

Table 1 (cont'd.)

Bivalves	
	indeterminate myalinids
	Cypricardella sp.
	Astartella sp.
Gastropods	
	Euconospira turbiniformis
	Gosseletina cf. *G. spironema*
	**Trachydoma whitei*
Cephalopods	
	indeterminate orthoconic nautiloids
	*?*Titanoceras*
Sponges	
	**Heliospongia ramosa*

Figure 3--Photomicrographs of phylloid algal blades. A) Curved blade, sheltering a spar-filled void; upper surface marked by dark continuous rind; lower surface marked by discontinuous dark line (arrow). B) Former algal blade marked by broad, sweeping undulatory upper surface. Both examples from the Wilson County State Lake Spillway (WCSLS). Bar for scale, both X26.

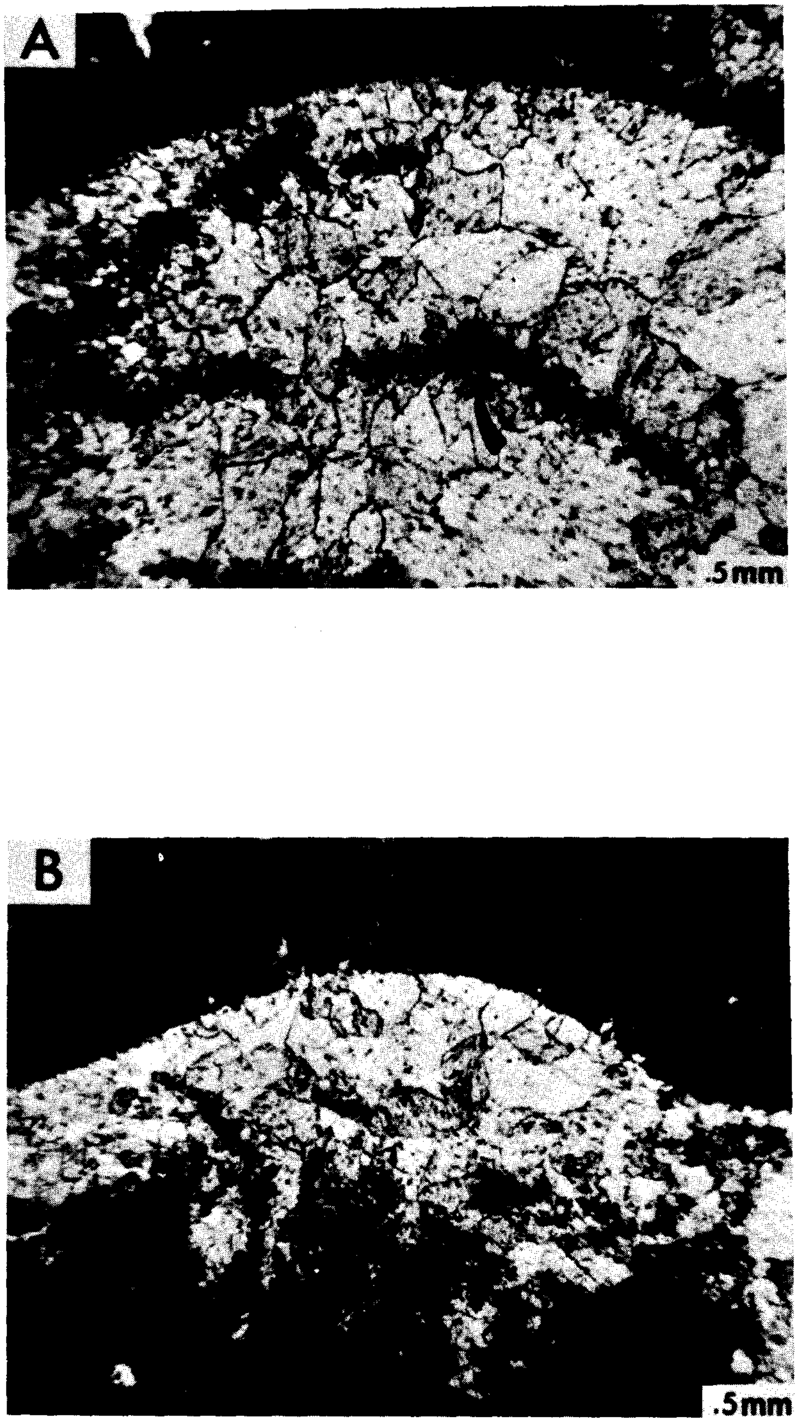


Figure 3

the coralline red alga *Archaeolithophyllum* (Figure 4). Wray (1965) has also identified the calcareous green alga~~e~~ *Anchicodium* from the Captain Creek mound in Wilson County; *Eugonophyllum* has been reported from Stoner mound in Montgomery County, but no definite green algae have been encountered in the present study.

Echinoderms

Echinoderm debris is chiefly pelmatozoan, but rare echinoid plates and spines, possibly of the genus *Archaeocidaris*, also were found. Pelmatozoan debris is primarily disarticulated column ossicles and small brachial plates, but larger primibrachs and dissociated dorsal cup ossicles occur with some regularity.

The most complete specimens recovered are two small dorsal cups both belonging to the genus *Erisocrinus*. Echinoderm remains generally show few signs of abrasion. Ossicles maintain sharp margins and frequently display well preserved finely sculptured external morphology. Four to five centimeter long column segments are common at some localities.

Brachiopods

Brachiopods are the only invertebrates appearing in appreciable numbers that can be readily identified. The ubiquitous orthid *Enteletes* "*pugnoides*" (See Appendix

Figure 4--Archaeolithophyllum sp. A) Exceptionally large, well-preserved fragment (a) and less well-preserved blade. B) Several fragments displaying well-preserved characteristic internal structure. Both examples from roadcut exposure west of Neodesha (CSL 21 30 15). Bar for scale, both X26.

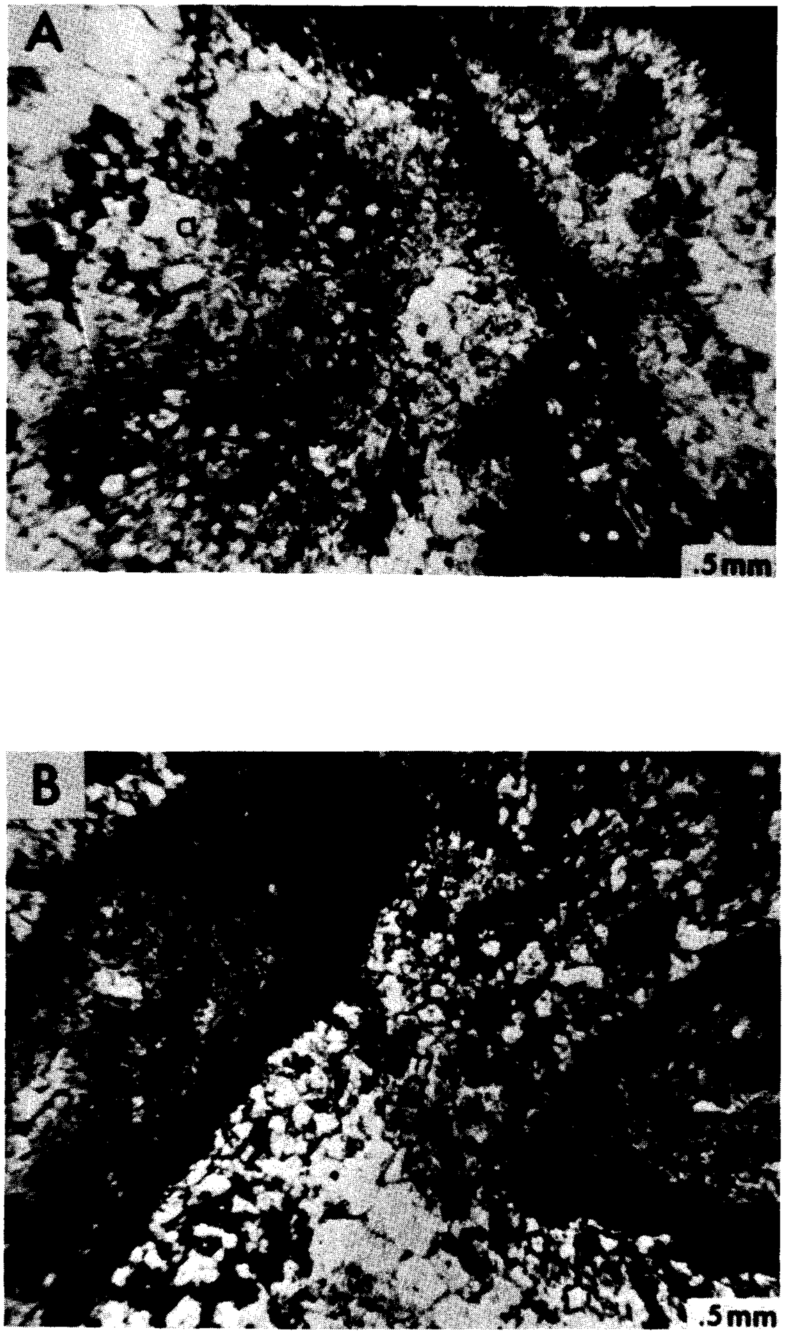


Figure 4

B) is perhaps the most diagnostic species. This distinctive strongly plicate form is almost exclusively restricted to the mound facies, with only a few specimens occurring in more calcilutitic marginal portions of the rim and channel facies. The thin, fragile shell is often well-preserved, displaying concentric growth lines and fine radiating costellae. Highly inflated brachial valves are most common, but whole specimens are not infrequent. Two spiriferid species are also common, but not restricted to the mound. *Composita* "*subtilita*" (See Appendix B) and *Phricodothyris perplexa* usually occur as small .5 to one centimeter long ovate forms, with occasional larger *Composita* specimens attaining 2.5 to 3 centimeters in length. Unlike *Enteletes*, these species occur typically as whole articulated shells. Fine surface ornamentation, particularly growth lines and larger spine bases on *Phricodothyris*, are generally well preserved.

Other brachiopods occur sporadically throughout the mound. *Punctospirifer* and the small terebratulid *Dielasma* attain local significance in non-algal calcilutites or sub-mound calcarenites such as the Benedict bed, but are less frequent constituents in algal-dominated lithologies. Productids occur in all mound lithologies, but are generally rare. An exception is *Hystriculina* wabashensis, which is frequently as common as Enteletes. Various stages of crushing and distortion are apparent on most brachiopod specimens, but severe fragmentation and abrasion are minimal.

Bryozoans

Bryozoan debris is ubiquitous within the mound, but large identifiable pieces are rare. Most common are small fragments of fenestellid fronds. Differences in size and shape of fenestrulae and arrangement of zooecia on fenestellid pieces suggest that several species may have lived in the mound environment. Small indeterminate encrusting trepostomes and cylindrical rhomboporids have been noted from only two localities. The severity of fragmentation of fenestellid fronds makes it difficult to determine which part of the mound was favored by these bryozoans. General observations note a tendency for bryozoan debris concentrations to occur in non-algal or slightly algal calcilutites having little spar content.

Coelenterates

Despite the diversity of types, corals are infrequent elements in mound biotas. Most genera or species occur only as isolated specimens. A rare occurrence of numerous specimens of one species, Dibunophyllum valeriae, is known only from the Wilson County State Lake spillway (Plate 2). Dibunophyllids and neokoninckophyllids are generally the most common types.

Coral preservation is exceptionally good in virtually all cases. Many specimens weather completely free from the matrix, and display fine details of the calice and other external morphology. Broken fragments of individual corallites show few signs of abrasion or decomposition, and usually display fine septal and dissepimental details. Overall scarcity of corals and apparent random occurrence makes it difficult to determine which area in the mound they may have favored.

Sutherlandia and Syringopora multattenuata are the only tabulate corals known, and have been found only as single occurrences at Erickson's Quarry, ENE of Buffalo (Loc. EQ; see Appendix A) and the road ditch north of Buffalo (Loc. RDNB; see Appendix A) respectively.

Bivalves

In comparison to other major facies, mound biotas are characterized by a paucity of bivalves. Only four specimens were found, one of which is an indeterminate myalinid near the channel margin. The remaining specimens are Cypricardella and Astartella, both of which are small, 10 mm or less, siphonate heterodonts. All of the heterodonts are well-preserved single subquadrate valves marked with prominent concentric banding. Both are similar in overall appearance, except for distinct papillation along the anterior margin of Astartella.

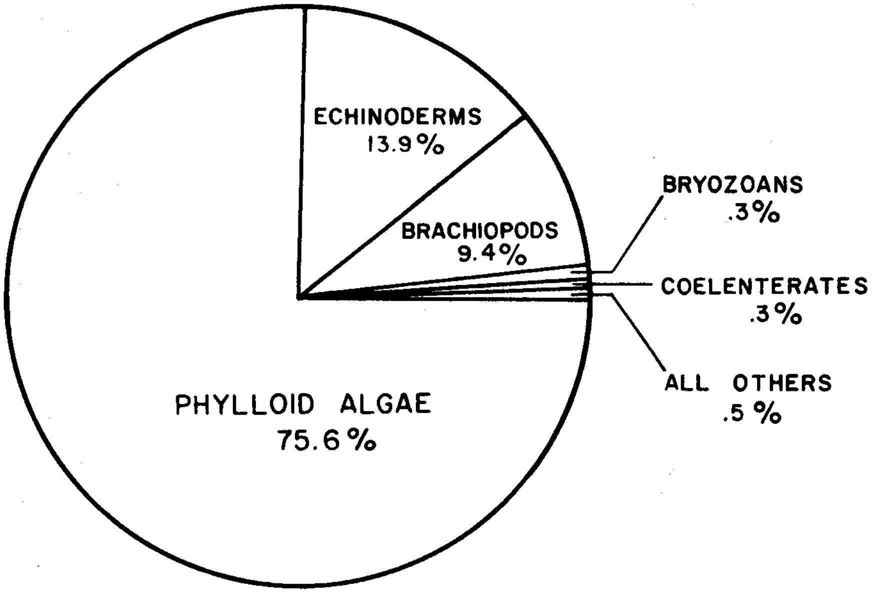
Minor Elements

Gastropods and cephalopods are rare enough elements in mound biotas that extensive collecting within the mound has produced only four rather poor specimens. A single indeterminate orthoconic nautiloid is known from only one locality. Several poorly preserved septa appear in the three to four centimeter longitudinal section, but no evidence of a siphuncle is visible. Attempts to remove the specimen from a dense sparry algal calcilutite proved futile. Three slightly crushed gastropod specimens broke cleanly from a muddy algal calcarenite matrix. All three specimens are small low-spired turbinate forms 5 mm to one centimeter in height.

Biotic Abundance and Distribution

Occurrence of major taxa takes on greater significance when considered in relation to the total biota. Quadrat counts on eleven bedding plane surfaces (Figure 5) provide enough basic data to gain an understanding of the abundance and distribution of macrobiotic constituents within the mound facies.

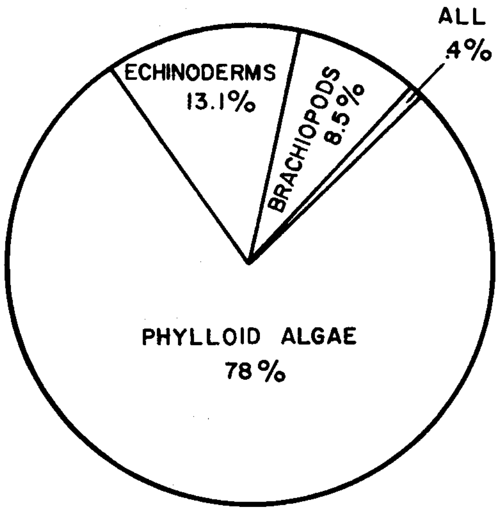
Figure 5--Diagrams illustrating average biotic composition of mound lithologies. A) Composite diagram of all quadrated mound facies localities. B) Mound-edge localities within 2 km of rim and channel calcarenite facies. C) Mound-interior localities greater than 2 km from major calcarenite facies. All percentages based on N quadrats. Quadrated localities marked on Plate 1.



Average Mound

(N = 11)

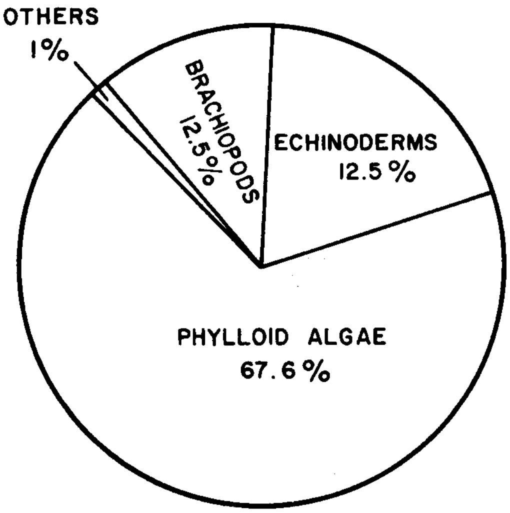
Figure 5A



Mound--Edge

(N = 7)

Figure 5B



Mound--Interior

(N = 4)

Figure 5C

Thin, dark, irregular blades and stringers of phylloid algae clearly dominate the mound biota, and as expected, are the most readily noticeable components at every locality. Echinoderm ossicles and brachiopod valves and whole shells constitute the bulk of the remaining biotic composition, and together with algae constitute nearly 99 percent of the total biota.

Although minor lithologic variation is noticeable at any locality in the mound facies, there are no readily visible overall trends. Correspondingly, variation in biotic composition can be expected, but again trends are not readily apparent. In an attempt to resolve the mound facies, an artificial subdivision is made based on proximity to major influencing calcarenite facies. Two grossly defined regions are considered: 1) mound-edge localities within two kilometers of the rim and channel facies, and 2) mound-interior localities greater than two kilometers away from major calcarenite facies. Separation of quadrated localities according to this scheme yields compositional differences illustrated in Figures 5 and 6 and summarized in Table 2. Readily apparent are changes in percentages of the three major components. Both algal and echinoderm percentages increase appreciably from the mound-interior to the

Figure 6--Graphic display of average number of elements/m^2 for the mound-edge and mound-interior micro-biofacies.

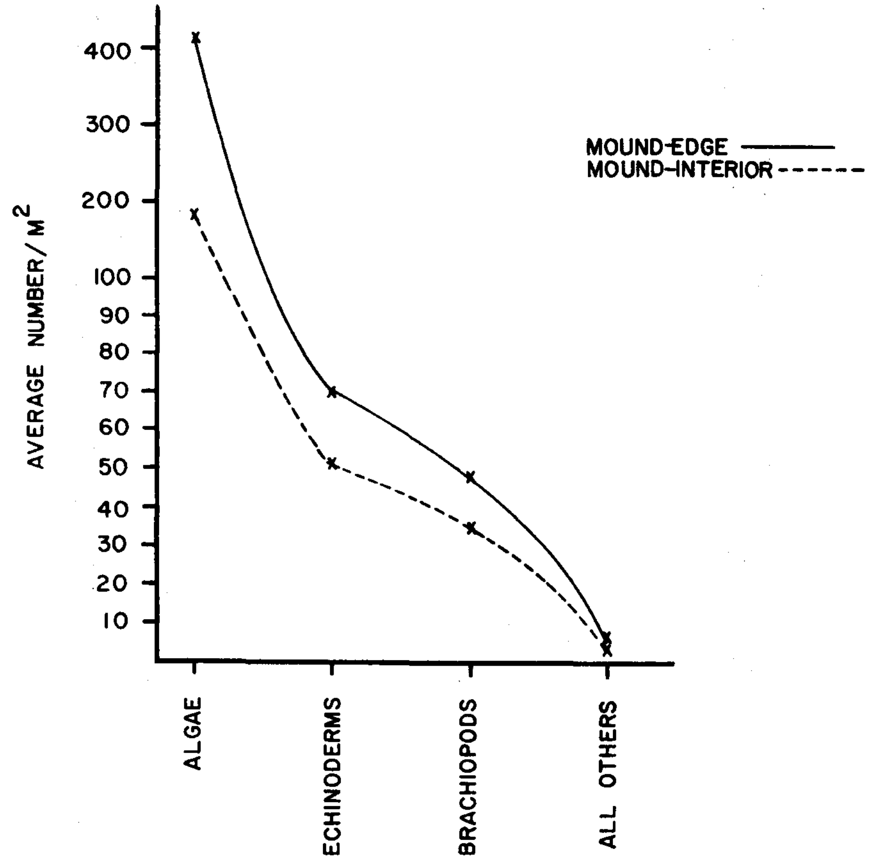

AVERAGE NUMBER/ M^2
400
300
200
100
90
80
70
60
50
40
30
20
10
ALGAE
ECHINODERMS
BRACHIOPODS
ALL OTHERS
MOUND-EDGE
MOUND-INTERIOR

Figure 6

Table 2--Data summary of N quadrat counts in the mound-edge and mound-interior micro-biofacies.

Table 2

Mound-edge
N=7

	tot. cts.	%	ave./m^2
Algae	2831	78	404.4
Echinoderms	477	13.1	68.1
Brachiopods	308	8.5	44.0
Bryozoans	7	.2	1.0
Coelenterates	9	.2	1.3
Bivalves	-	-	-
Gastropods	-	-	-
Cephalopods	-	-	-

Mound-interior
N=4

	tot. cts.	%	ave./m^2
Algae	707	67.6	176.8
Echinoderms	198	18.9	49.5
Brachiopods	131	12.5	32.8
Bryozoans	5	.5	1.3
Coelenterates	3	.3	.8
Bivalves	1	.1	.3
Gastropods	1	.1	.3
Cephalopods	-	-	-

mound-edge, but neither percentage reflects marked density increases toward the mound-edge. Algal density increases more than two-fold, despite a proportional increase of only ten percent of the total biota. Echinoderm density also increases markedly toward the mound-edge, but represents only a small proportional increase of the total biota. Brachiopods similarly display marked density increase, but unlike algae or echinoderms, their proportion of the total biota decreases noticeably toward the mound-edge. The net effect of smaller density increases of echinoderms and brachiopods compared to algae reflects an apparent proportional decrease of these constituents in the total biota.

Channel Biofacies

An abundant and diverse invertebrate fauna characterizes the channel biofacies. All major phyla are represented, and include many additional species that do not occur in the mound facies (Table 3 and Plate 2). Nine genera and five species that are common in mound lithologies are noticeably rare, if not absent, in the channel facies.

Newell (1933) characterized the fauna of the channel facies (then termed Fredonia facies) as an

Table 3--Biotic elements recognized in the channel biofacies. Species marked with an asterisk are described from previous investigations, but not identified in the current study. Major groups are listed in order of importance, and individual species ranked in order of importance within each group.

Table 3

Echinoderms

- *Erisocrinus* cf. *E. typus*
- *Stellarocrinus* sp.
- *Cibolocrinus conicus*
- *Endelocrinus tumidus*
- *Parerisocrinus obovatus*
- *Cibolocrinus* sp.
- *Parulocrinus* sp.
- *Ulocrinus* sp.
- *Schistocrinus* sp.
- cf. *Plaxocrinus*
- *Apographiocrinus typicalis*
- indeterminate cromeocrinidae
- *Archaeocidaris* sp.

Brachiopods

- *Composita* "*subtilita*"
- *Phricodothyris perplexa*
- *Punctospirifer kentuckyensis*
- *Hustedia mormoni*
- *Schizophoria* cf. *S. texana*
- *Dielasma bovidens*
- *Neospirifer* "*dunbari*"
- *Echinaria semipunctata*
- *Linoproductus* cf. *L. platyumbonus*
- *Linoproductus* cf. *L. prattenianus*
- *Enteletes* "*pugnoides*"
- *Derbyia* sp.
- *Meekella* cf. *M. striatocostata*
- *Orbiculoidea* sp.
- **Composita trilobata*
- **Teguliferina* sp.
- **Parenteletes cooperi*
- **Juresania nebrascensis*

Bryozoans

- *Meekoporella dehiscens*
- indeterminate fenestellids
- indeterminate cyclostome
- *Fenestella* sp.
- indeterminate encrusting trepostome

Coelenterates

- *Neokoninckophyllum* cf. *N. heckeli*
- indeterminate lophophyllids
- ?*Stereostylus*

Table 3 (cont'd.)

- ?Lophamplexus
- indeterminate geyerophyllids
- Michelinia sp.
- Caninia torquia
- indeterminate dibunophyllids
- Lophophyllidium sp.

Bivalves
- Septimyalina sp.
- Edmondia sp.
- Septimyalina burmai
- indeterminate myalinids
- ?Limipecten sp.
- ?Pseudomonotis sp.
- *Aviculopecten interlineatus
- *Acanthopecten sp.
- *Pteria sp.
- *Conocardium sp.
- *Myalina kansasensis
- *Myalina cuneiformis

Algae
- Rhodophyta
  - Archaeolithophyllum sp.
- Chlorophyta
  - Dasycladaceae
    - ?Epimastopora sp.

Gastropods
- indeterminate bellerophontids
- Euconospira turbiniformis
- Straparollus (Euomphalus) reedsi
- Lepetopsis peregrina
- *Helictostylus girtyi
- *Straparollus (Euomphalus) plummeri
- *Naticopsis scintilla
- *Macrochilina cf. M. paludinaeformis
- *Ptychomphalus cf. P. persimplex
- *Pithodea broadheadi

Cephalopods
- Tainoceras sp.
- Eoasianites hyattianum
- *Kionoceras sp.
- *Metacoceras sp.
- *Coloceras sp.

---

assemblage of exotic orthoids and peculiar gastropods. In this study, a slightly different assemblage distinguishes the channel facies. The most diagnostic species are the orthid Schizophoria cf. S. texana, the cyclostome bryozoan Meekoporella dehiscens and the bivalve Edmondia. None have been found in mound biotas and only a few specimens of Schizophoria and Meekoporella have been recovered from the rim calcarenite. Echinoderm debris, particularly columnals and other assorted ossicles, is unusually abundant but not restricted to the channel.

Echinoderms

Pelmatozoan debris is the most conspicuous invertebrate material in well-washed granular calcarenites. Channel-margin mud-rich calcarenites contain slightly lower concentrations. In most lithologies, ossicles generally appear fresh, unabraded and frequently display fine details on articular surfaces. Identifiable cups and plates are exceedingly rare, except for an unusual occurrence of Erisocrinus in the Fredonia Cement Plant quarry. A coarse encrinite is exposed in the inactive northeast wall (about one kilometer east of Newell's original locality). Numerous cups (25 to $30/m^2$) and assorted ossicles litter bedding plane surfaces.

Elsewhere in the channel, a few specimens of Erisocrinus, Parerisocrinus and ?Ulocrinus have been recovered. Most pelmatozoan debris consists of ossicles of various sizes and smaller disarticulated brachials. Column ossicles are usually disarticulated, but occurrences of articulated segments up to 10 centimeters long are common. These larger segments are known from both the coarse, well-washed and marginal mud-rich calcarenites.

Brachiopods

Schizophoria cf. S. texana is the only brachiopod characteristic of the channel. In its adult form, the subelliptical shell possesses a broad, shallow, ventral sinus which imparts a slightly bilobed appearance at the anterior margin (Newell, 1931). Additional secondary ornament of fine indistinct radial lirae and prominent concentric growth markings make Schizophoria easily recognized. However, juvenile specimens lacking ornamentation or ventral sinus may be difficult to separate from juveniles of the closely related genus Enteletes. Most Schizophoria recovered were found near the center of the channel in well-washed, locally cross-bedded coarse, granular, spar-cemented calcarenite. Disarticulated shells and fragments predominate over complete articulated specimens.

High abundance and diversity of brachiopods is the most striking aspect of channel faunas. Most abundant are the ubiquitous species of *Composita*, *Punctospirifer* and *Phricodothyris* which often concentrate gregariously in marginal areas of the channel. In all instances, these species occur as whole specimens, often displaying fine details of ornamentation and lacking effects of extended transport. Of the remaining brachiopods, only *Dielasma* and *Hustedia* occur with any frequency, and their distribution is sporadic. No preferred lithologic association could be detected for these, as small clusters and isolated individuals occur equally within calcilutitic and calcarenitic rock types of the channel. Although rare, *Neospirifer* "*dunbari*" (See Appendix B) apparently has a distinct distribution in that it is found only in channel margin calcilutites. Individual specimens are rarely complete, but fine details of fasicles are normally well preserved. Productids have only a scattered occurrence near the central portion of the channel. Small hystriculinids, linoproductids and *Echinaria* are normally broken or disarticulated and heavily abraded. Although no specimens of these genera were recovered from channel margin muddy calcarenites, mound exposures near the channel margin did yield a few *Hystriculina* and *Antiquatonia*.

Bryozoans

With the exception of the distinctive cyclostome *Meekoporella*, little other bryozoan debris is amenable to immediate generic identification. Fenestellid fragments are common in channel margin calcarenites, and particularly abundant as small 5-10 mm pieces in clean calcarenites near the center of the channel. Well-preserved fragments are more common than impressions. Trepostomes and cyclostomes are unusually rare elements in the channel.

Meekoporella dehiscens is as characteristic of the channel biofacies as *Schizophoria*. Only one occurrence is presently known in Wilson County outside the channel (Benedict Bridge, see Appendix A). When originally described, *M. dehiscens* was known only from the Fredonia Cement Plant quarry. Since then, excellent specimens have been found in several more recent exposures. As first described, *M. dehiscens* is ". . . a zoarium of thin bifoliate sheets joined at angles of approximately 120 degrees. The sheets form a deep inverted subpyramidal chamber which is typically six-sided and narrows to a point within 30-60 mm" (Moore and Dudley, 1944). Recovered specimens are usually broken in section parallel to the plane of the chamber openings, lending the impression of a large web-like growth. Specimens freed from the matrix break along the chamber sides, exposing a characteristic finely pitted, chalky-white surface marked by irregular growth increments.

Coelenterates

Large three to four centimeter long lophophyllids are unusually common in muddy calcarenite east of Erickson's Quarry (Loc. EEQ; see Appendix A). In other channel exposures, corals are generally infrequent elements. Neokoninckophyllum is the most frequently recovered type, with ?Stereostylus, ?Lophamplexus and small, one to two centimeter indeterminate lophophyllids occasionally as common as Neokoninckophyllum. The rare but distinctive Michelinia is the only tabulate coral known in the channel facies.

Coral preservation is excellent throughout the channel, particularly in coarse granular calcarenite of the central region. Fine morphologic details are easily recognizable on most forms breaking cleanly from the granular calcarenite. Specimens weathering from other channel lithologies tend to have badly abraded external surfaces, but well-preserved internal morphology.

Bivalves

With the exception of a channel margin occurrence at Hoff's Farm (Loc. FQWA; see Appendix A), bivalves are generally infrequent channel elements. Only three clearly recognizable forms of more than fifteen described by Newell (1933) from the Fredonia facies have been recognized in the study. Edmondia is most readily identified, although it has been found only as poorly preserved internal molds. All specimens of Edmondia were found in the well-washed skeletal calcarenite near the center of the channel. Pectinids are represented by two badly battered pieces: an internal mold of ?Limipecten and a partial right valve of Pseudomonotis, both of which were recovered from the central portion of the channel. Remaining specimens are myalinids, and most of these are the gregarious Septimyalina. They are limited primarily to "clam beds" (FQWA) in muddy channel margin calcarenites, although some occur in coarse skeletal calcarenites. Internal molds and a few well-preserved valves characterize the channel margins, whereas fragments are more prevalent in the central region.

Minor Elements

Although recognizable algal fragments are present in the channel, many non-descript abraded sparry grains may be derived from phylloid algae. Only one locality west of Altoona (NLE 13-29-15; see Appendix A), contains much recognizable algae. Most partially preserved remains are the red alga *Archaeolithophyllum*, and a single fragment may be the green dasyclad algae *Epimastopora*. All algae detected in unquestionable channel lithologies are fragmented and abraded with frequent thin muddy coatings that may suggest transport from mound environments near the channel margin.

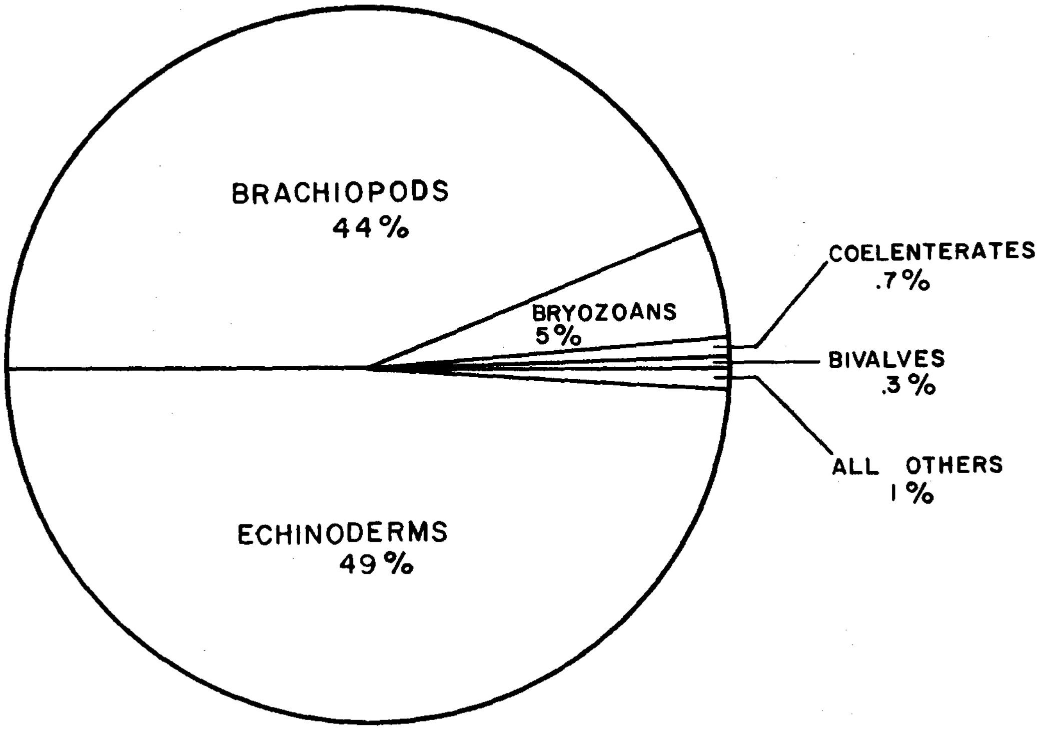
Only three battered, incomplete cephalopods are known to the author from channel calcarenites. A large *Tainoceras* fragment and a second indeterminate nautiloid have been recovered from the center of the channel. Both specimens show signs of extended abrasion, particularly *Tainoceras* in which characteristic nodes have been virtually worn smooth. The only ammonoid known from Wilson County is a small portion of *Eoasianites hyattianum*. The piece is deeply eroded and no single suture can be traced completely. Unlike the nautiloids, this specimen was found in a thin-bedded muddy calcarenite apparently associated with another major channel extending through Woodson County (Heckel, pers. commun., 1974).

Of particular interest is the apparent absence of many peculiar gastropods Newell cited. Several species described by him from Fredonia were found at his original locality at the Fredonia Cement Plant, but extensive collecting at other channel exposures produced only eight fragmentary specimens representing only four of ten reported species. All specimens lack shell or ornamentation, except the easily recognized turbinate form Euconospira turbiniformis, which is characteristically marked by a sweeping cross-hatched pattern on each whorl and a small, distinctive selenizone at the whorl periphery. All gastropod specimens were recovered from the coarse granular calcarenite in the center of the channel.

Biotic Abundance and Distribution

Quadrat countings were suitable only on three large bedding planes, but these surfaces provide enough data consistent with outcrop observation to adequately represent abundances and proportions of macrobiotic constituents within the channel center (Figure 7). These counts represent the coarse, well-washed skeletal calcarenite near the axis of the channel. Channel margins consist of a more calcilutitic lithology and modified biota, but only two localities provided surfaces of minimum size and neither displayed a well-defined quantifiable biota. Because further attempts to obtain consistent and reproducible data from these surfaces proved futile, only scattered qualitative field observations can presently suggest micro-biofacies subdivision within the channel.

Figure 7--Composite diagram illustrating average biotic composition of a channel center lithology. Diagram is based on quadrat counts of three surfaces. Quadrated localities designated on Plate 1.



Average Channel Center

(N = 3)

Figure 7

Echinoderm (pelmatozoan) debris and brachiopods overwhelmingly dominate the biota, with bryozoan debris subordinate but significant. Collectively, these three elements constitute 98 percent of the total biota. Several brachiopod types are common, but Composita and Punctospirifer seem to be the most frequent. Meekoporella is the most characteristic bryozoan, but fragments are primarily an assortment of several fenestellid and cyclostome types. The remaining one to two percent of the biota is a variety of battered skeletal types. Only the bivalve Edmondia has been recognized with any frequency. In general, whole skeletal elements increase in diversity and numbers away from the channel center, with pockets of myalinids appearing near the channel-mound transition.

Rim Biofacies

A biota equally as abundant and diverse as the channel biota characterizes the rim biofacies (Table 4 and Plate 2). All major phyla are represented, including 13 genera and three species that have not been reported from the other major facies. In addition, several major elements common in the mound or channel are diminished or lacking in the rim. Most characteristic of the rim biota is the great variation from place to place with

Table 4--Biotic elements recognized in the rim biofacies. Species marked with an asterisk denote elements described from the lower Stanton in previous investigations, but not identified in the current study. Major groups are listed in order of importance in the mound, and individual species are listed in approximate order of importance within each group.

Table 4

Echinoderms

Erisocrinus cf. _E. typus_
Archaeocidaris sp.
Sciadiocrinus angustus
Stellarocrinus sp.
cf. _Graffhamicrinus_
Cibolocrinus conicus
cf. _Aesiocrinus_
indeterminate cymbiocrinidae
Anobasocrinus sp.
indeterminate cromeocrinidae
cf. _Plaxocrinus_
Schistocrinus sp.
indeterminate pirassocrinidae

Brachiopods

Composita "_subtilita_"
Punctospirifer kentuckyensis
Hustedia mormoni
Neospirifer "_dunbari_"
Phricodothyris perplexa
Derbyia cf. _D. deercreekensis_
Derbyia sp.
Dielasma bovidens
Schizophoria cf. _S. texana_
Hystriculina wabashensis
Echinaria semipunctata
Antiquatonia crassicostata
Reticulatia americana
Linoproductus cf. _L. prattenianus_
Linoproductus cf. _L. platyumbonus_
Pulchratia symmetrica
Neochonetes transversalis
Enteletes "_pugnoides_"
*_Teguliferina_ sp.
*_Juresania nebrascensis_

Bryozoans

indeterminate fenestellids
indeterminate trepostomes
Fenestella sp.
Polypora sp.
Rhombopora sp.
Meekoporella dehiscens

Table 4 (cont'd.)

- *Bivalves*
  - indeterminate myalinids
  - *Septimyalina* sp.
  - *Septimyalina burmai*
  - indeterminate pectinid

- *Gastropods*
  - indeterminate bellerophontids
  - *Gosseletina* sp.
  - *Glabrocingulum* sp.
  - *Euconospira turbiniformis*
  - *Meekospira* sp.
  - *Pseudozygopleura* sp.
  - *Pharkidonotus* sp.
  - *Retispira* sp.

- *Coelenterates*
  - *Caninia torquia*
  - *Dibunophyllum* sp.
  - *Dibunophyllum* cf. *D. valeriae*
  - ?*Stereostylus*
  - ?*Lophamplexus*
  - *Michelinia* sp.
  - ?*Neokoninckophyllum*
  - *Geyerophyllum* sp.
  - *Syringopora multattenuata*

- *Algae*
  - red and green phylloid
  - Rhodophyta
    - *Archaeolithophyllum* sp.
    - Solenoporaceae
      - *Parachaetetes* sp.

- *Cephalopods*
  - indeterminate orthoconic nautiloids
  - **Kionoceras* sp.
  - **Metacoceras* sp.
  - **Coloceras* sp.

strong associations between particular organism assemblages and specific lithologies.

An abundance of pelmatozoan and bryozoan debris along with the common brachiopods *Composita*, *Punctospirifer* and *Hustedia* dominate skeletal constituents in the rim. Numbers and proportions of these elements differ little from that in the channel biofacies. Few species, with the exception of the distinctive orthotetid brachiopod *Derbyia deercreekensis*, seem to be indigenous to the rim facies. Other brachiopods, particularly productids, that are rare in the mound and channel are locally common in certain microfacies of the rim. Myalinid bivalves are locally important in "clam" beds. Frequently, bivalve density increases to the apparent exclusion of other skeletal elements.

Echinoderms

As in the channel, echinoderm remains are primarily assorted ossicles and brachials of pelmatozoans. However, unlike the other major facies, local concentrations of echinoid spines and plates (?*Archaeocidaris*) frequently litter bedding plane surfaces. Pelmatozoan ossicles are normally disarticulated and frequently display fine details on articular surfaces. Large articulated segments up to several centimeters long are rare, but can be found in coarse, granular calcarenites as well as skeletal calcilutites. Badly abraded and broken ossicles are particularly abundant in a cross-bedded pelmatozoan calcarenite exposed along U.S. Highway 75 north of Buffalo (Locs. NBRC and RDNB; see Appendix A).

Dorsal cups and identifiable plates are generally rare in the rim except for an abundant crinoid fauna at Doyle's Quarry (Loc. DQSR; see Appendix A). Most of the taxa are single occurrences and have not been found elsewhere in the rim (Plate 2).

Brachiopods

Although rare indeterminate derbyiids occur in the channel, the infrequent *Derbyia* cf. *D. deercreekensis* most closely approximates a rim-restricted brachiopod. Dunbar and Condra (1932) first described this distinctive species noting that

> . . . the ventral cardinal area is high with a broad prominent deltidium and usually disposed at almost right angles to the valves. The ventral valve has the form of a low, unsymmetrical pyramid with apex at the beak and gradual slopes to the anterior and anterolateral margins.

The dorsal valve has not been found articulated, but is described as strongly convex with a moderately inflated umbo. Specimens of *Derbyia* are not restricted to a particular area or lithology. Badly abraded and fragmented shells occur in coarsest skeletal calcarenite, and finely detailed individuals were recovered from muddier lithologies.

The small strophomenid *Neochonetes transversalis* is confined to two occurrences in skeletal calcilutite. The thin, alate ventral valves are marked by fine radial lirae, and display finely mucronate cardinal extremities. (A small indeterminate fragment recovered from the channel displays features similar to *Neochonetes*, but the shell is too badly broken to be positively identified.)

The abundant brachiopods *Composita*, *Punctospirifer*, *Hustedia*, *Dielasma* and *Phricodothyris*, remain the most ubiquitous, and differ little in numbers and preservation from those in the channel. All occur as whole skeletal elements, and show no distributional trends within the rim. Well preserved specimens have been collected from thin to medium-bedded skeletal calcilutites as well as coarse, locally cross-bedded, skeletal calcarenites.

Although not restricted to the rim facies, *Neospirifer* "*dunbari*" occurs in gregarious numbers of large specimens showing marked morphological variation. Exceptionally large specimens (up to 8 cm) displaying a range of variation from gibbous to alate features are particularly concentrated in medium-bedded muddy calcarenite at locality DQSR. These specimens are normally whole and display excellent preservation of rib fasiculation. Neospirifer occurring in coarser rim calcarenites are frequently as large and variable, but rarely well preserved. Abraded fragments commonly lack ribbing and possess little detail of cardinal extremities.

Productids are more common and diverse than in either the mound or channel facies, but are unevenly distributed and infrequent elements of the biota. Local concentrations found in skeletal calcilutites yield the greatest diversity, with coarse abraded skeletal calcarenites containing only a few isolated specimens. In areas of greatest productid development, small hystriculinids and linoproductids commonly occur in subequal proportions with Antiquatonia and Reticulatia. Large echinarids occur infrequently. Productids rarely display good preservation, and few specimens have both valves clearly observable. Most spines are broken off. Two specimens show fine details of external morphology, but both are completely crushed.

Bryozoans

Virtually all bryozoan material in the rim consists of fragments seldom exceeding 15 mm in greatest dimension. It includes a wide variety of fenestellid cryptostomes, trepostomes and rhomboporids. Larger fenestellid fronds up to 10 centimeters across occur in both coarse and fine abraded skeletal calcarenite. Bryozoan debris is so highly fragmented and badly abraded that further identification is beyond the scope of this project. Thus, unlike the channel, no species characterize the rim biofacies.

Bivalves

The genus Septimyalina dominates all bivalve occurrences in the rim. Scattered specimens may be expected at all exposures, except the cross-bedded pelmatozoan calcarenite at localities NBRC and RDNB. The most spectacular bivalve development in any facies is the "clam" bed north of Roper (Loc. NW SW 24·27·15; see Appendix A), where great numbers of Septimyalina cover the exposure, virtually to the exclusion of other macrofauna. Preservation throughout the rim is exceptionally good, although whole specimens are difficult to recover. In contrast to the channel, original and replaced shell material is more common than external or internal molds. Fine details of concentric banding and other secondary morphology are generally lacking in the rim except in the "clam" bed where individual growth increments may be observed on many specimens.

Gastropods

Large, readily observable gastropods are generally rare in the rim facies. Outside of the Benedict Bed (Loc. BRC; see Appendix A), only two indeterminate bellerophontids and one *Euconospira* have been collected, and all are badly deteriorated. All specimens are known from muddly skeletal calcarenites. At locality BRC, however, a rich, diverse gastropod fauna occurs in the dense skeletal oolite of the Benedict Bed. Bellerophontids and spired pleurotomarians dominate, with a few loxonematids and subulitids completing the assemblage. Specimens are small, seldom greater than 10 mm in greatest dimension and commonly lack details of shell ornamentation.

Despite the apparent dearth of gastropods in hand specimen, most rim lithologies include good numbers of small gastropods observable only in thin-section. All types are less than two millimeters in greatest dimension, and vary considerably in shape. The most common form appears to be a spired pleurotomarian possessing several small whorls. Other low spired, trochoid and planispiral types lack immediately recognizable details, prohibiting further identification.

Coelenterates

Corals are infrequent elements in most rim exposures, but are fairly common in a few places. Unusual concentrations of Caninia torquia are particularly common north of Benedict (Loc. RDWC 2·28·15; see Appendix A), and large five-centimeter-long specimens of the lophophyllids ?Stereostylus and ?Lophamplexus are abundant nearby (Loc. RDSDF; see Appendix A). Remaining corals readily identifiable in the rim include scattered dibunophyllids, neokoninckophyllids, and geyerophyllids. Michelinia and a single occurrence of Syringopora multattenuata (locality NBRC) represent the only tabulate corals known from the rim.

With the exception of the two localities mentioned, corals are such infrequent elements that distinct lithologic preference is not obvious. Well-preserved examples of all major types have been recovered from various calcilutitic and calcarenitic lithologies throughout the rim.

Minor Elements

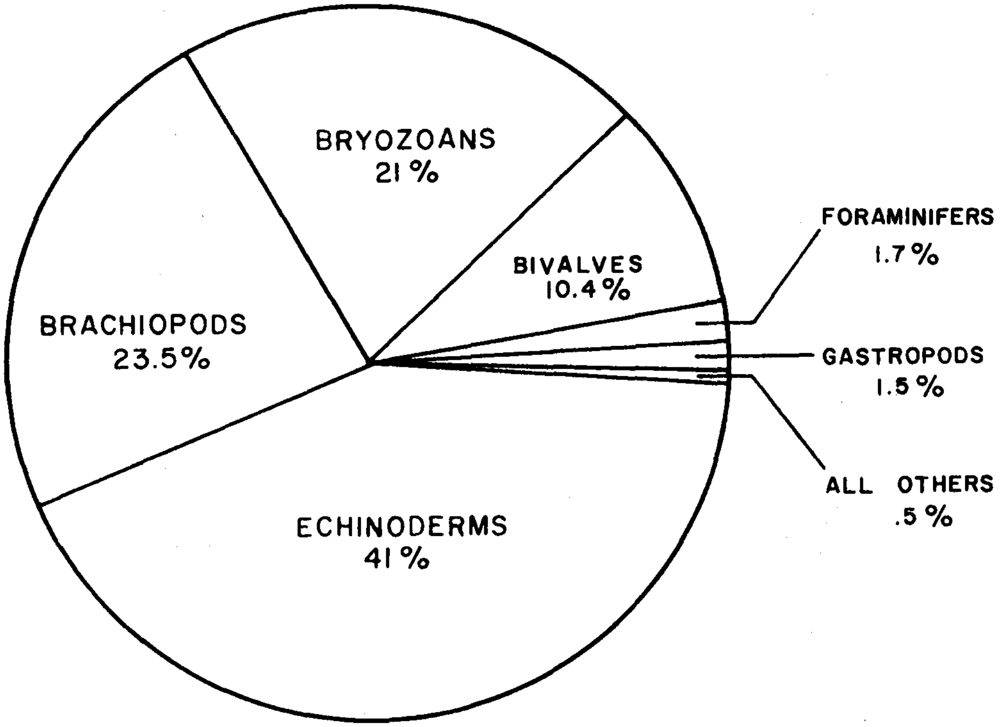
Although not identifiable with the naked eye, thin-sections reveal many blades and fragments of algae in various stages of preservation in both calcarenitic and calcilutitic lithologies. Typically, coarse, abraded, pelmatozoan-rich calcarenites include many irregularly shaped sparry fragments in which little or no internal structure is preserved. But enough of these grains reveal faint cellular arrangement of *Archaeolithophyllum* and the solenoporid red alga, *Parachaetetes*, to suggest that algal fragments may be more common than can be definitely proved. Rim calcilutites contain both small fragments and larger sinous blades that show internal structure of *Archaeolithophyllum*.

Although more common than in the channel or mound, cephalopods remain rare. Five, large (15-20 cm), incomplete nautiloids were found in abraded pelmatozoan calcarenite near Buffalo, Kansas. None proved identifiable because severe crushing and abrasion masked septal development and obscured the siphuncles. Newell (1933) reported species of *Kionoceras*, *Coloceras* and *Metacoceras* from the Stoner, but none were described from localities in the rim.

Biotic Abundance and Distribution

Suitably exposed surfaces are rare in the rim biofacies, but eight well-exposed bedding planes provide sufficient quadrat data to adequately characterize the biota (Figure 8). Echinoderm debris and brachiopods are again the most prevalent components, but they do not

Figure 8--Composite diagram illustrating average biotic composition of the rim facies, based on eight quadrated surfaces marked on Plate 1.



Average Rim

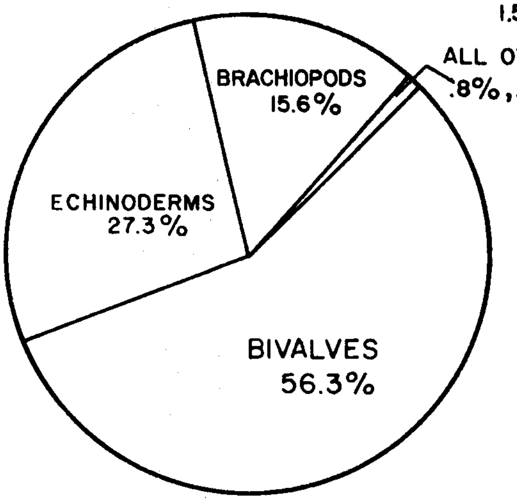
(N = 8)

Figure 8

dominate as strongly as in the channel. Bryozoan debris and the local concentrations of myalinid bivalves occupy a greater proportion of the total biota. Small local concentrations are responsible for the minor percentages of gastropods and foraminifers. Although outweighed numerically by major elements, several bellerophontid and pleurotomarian snails and numerous fusulinids represent the only significant surface exposure of these forms in any of the facies. Except for echinoderm and bryozoan material, all forms occur as whole or nearly complete skeletal elements.

The high degree of lithologic and biologic variability within the rim renders a single average biotic composition unlikely to accurately characterize the range of variation in the entire facies. Unlike the mound facies however, there are no general spatial criteria for segregating areas of the rim. Separation into northern and southern portions is of little value because quadrat data are limited in southern regions. Thus, the different lithic variants for which quadrat data are available were plotted separately (Figure 9 and Table 5) yielding microfacies patterns. A fourth lithology of abraded, cross-bedded pelmatozoan calcarenite was not amenable to quadrat analysis.

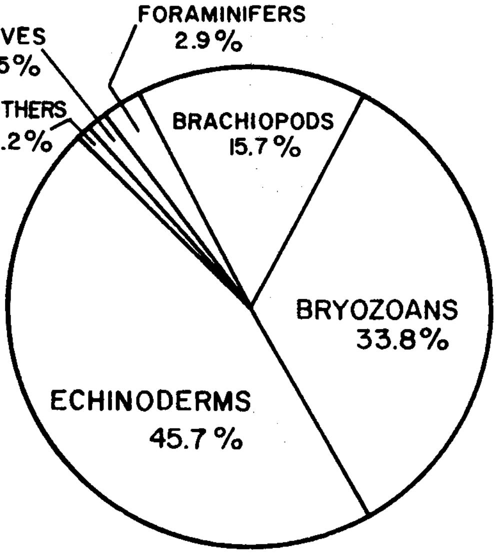
Figure 9--Average composition of rim micro-biofacies, based on N quadrats. A) "Clam" beds. B) Muddy skeletal calcarenite. C) Skeletal oolite.



"Clam" Beds

(N = 2)

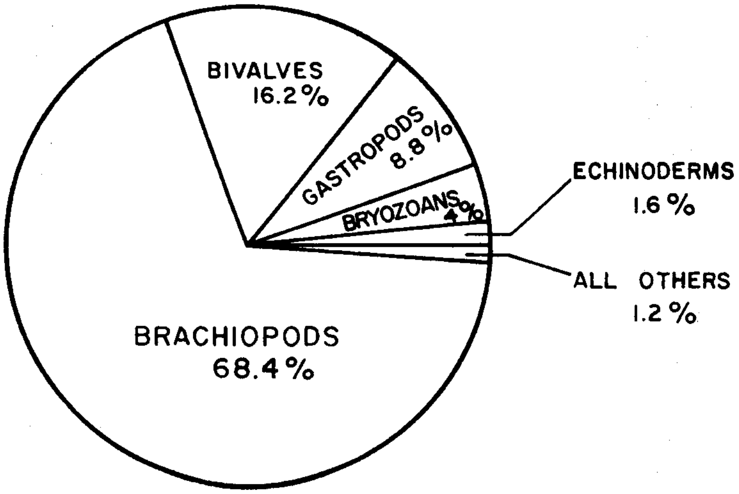
Figure 9A



Muddy Skeletal Calcarenite

(N = 5)

Figure 9B



Skeletal Oolite

(N = 1)

Figure 9C

Table 5--Data summary of N quadrat counts in the "clam" beds, muddy skeletal calcarenite and skeletal oolite micro-biofacies of the rim.

Table 5

"Clam bed"
N=2

	tot. cts.	%	avg./m^2
Bivalves	224	56.3	112
Echinoderms	109	27.3	54.5
Brachiopods	62	15.6	31
Coelenterates	2	.5	1
Bryozoans	1	.3	.5
Algae	-	-	-
Gastropods	-	-	-
Cephalopods	-	-	-

"Muddy skeletal calcarenite"
N=5

	tot. cts.	%	avg./m^2
Echinoderms	948	45.7	189.6
Bryozoans	702	33.8	140.4
Brachiopods	326	15.7	65.2
Foraminifers	61	2.9	12.2
Bivalves	33	1.5	6.6
Coelenterates	4	.2	.8
Gastropods	-	-	-
Cephalopods	-	-	-
Algae	-	-	-

"Skeletal oolite"
N=1

	tot. cts.	%	avg./m^2
Brachiopods	413	68.4	-
Bivalves	98	16.2	-
Gastropods	53	8.8	-
Bryozoans	23	3.8	-
Echinoderms	10	1.6	-
Coelenterates	7	1.2	-
Algae	-	-	-
Cephalopods	-	-	-

Differences among rim microfacies apparent on the diagrams are nearly as great as between major facies. Large proportions of Septimyalina in the "clam" beds microfacies greatly reduces all other skeletal types. Most notable is the severe reduction of bryozoan debris. In contrast, bryozoan and pelmatozoan percentage increases significantly at the expense of bivalves in the muddy skeletal calcarenite microfacies. Excluding local concentrations of fusulinids in the muddy skeletal calcarenite, brachiopods, corals and all other constituents remain fairly constant between the facies. Inversely proportional relations between major constituents are generally reflected in the average numbers of individuals per m^2 (Figure 10). The concentration of bivalves declines sharply in the muddly skeletal calcarenite, whereas echinoderms and bryozoans increase several-fold. With the loss of bivalves, however, brachiopods more than double in concentration, despite a lack of significant percentage change between the microfacies.

The skeletal oolite microfacies is wholly unlike the previous facies and is difficult to compare. Brachiopod percentage is greater than four times the rim average, and gastropods, which are unusually insignificant, comprise nearly 10 percent of the biota. The oolite may have formed as a wind-row accumulation of

Figure 10--Graphic display of average number of elements/m^2 for the rim "clam" beds and muddy skeletal calcarenite micro-biofacies.

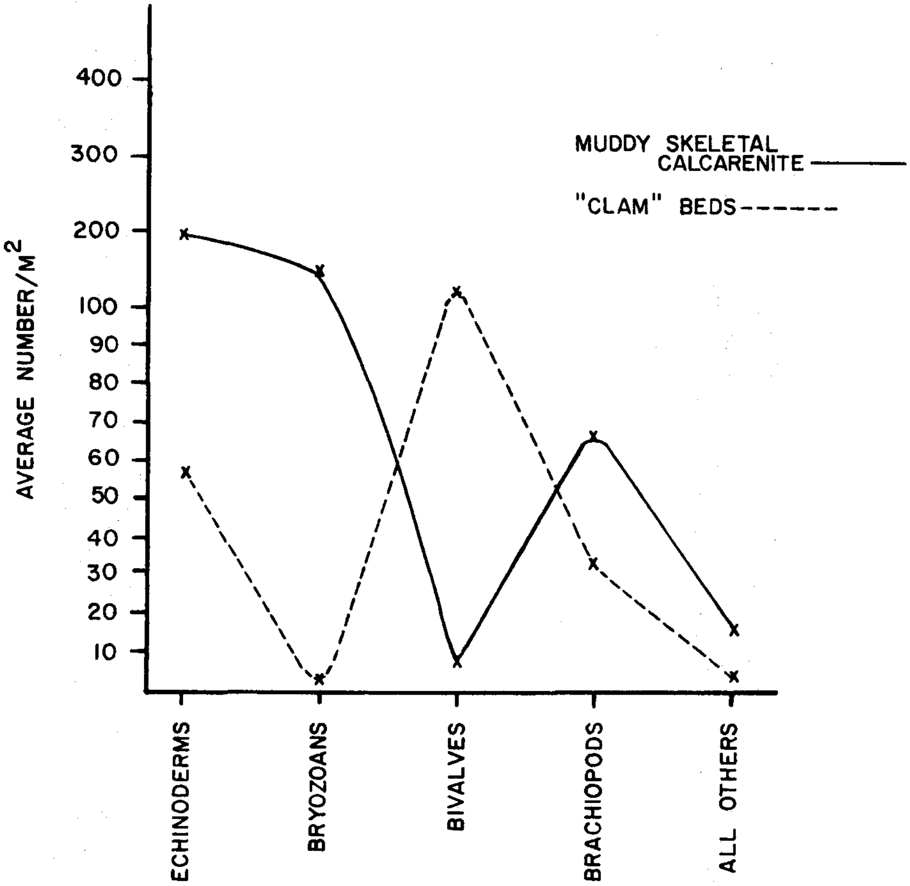

400
300
200
100
90
80
70
60
50
40
30
20
10
AVERAGE NUMBER/M²
MUDDY SKELETAL CALCARENITE
"CLAM" BEDS
ECHINODERMS
BRYOZOANS
BIVALVES
BRACHIOPODS
ALL OTHERS

Figure 10

skeletal material from many sources, and may not possess a significant indigenous biota (Heckel, pers. commun., 1975). The limited number of suitably exposed surfaces prevents extensive quadrating, and renders any further interpretation tenuous.

PETROGRAPHY

Constituent composition of various limestone types is essential in recognizing the relation between biotic assemblages and major lithofacies. All grain types, skeletal and non-skeletal, are critical in characterizing the major limestones, but particularly important is the abundance and vareity of skeletal constituents, and the relation of observable macrobiotic elements to the skeletal composition. Several authors have utilized constituent particles, grain size and fabric to describe modern carbonate facies (Vaughan, 1918; Bramlette, 1926; Thorp, 1936; and Illing, 1954). Ginsburg (1954) has been perhaps the most lucid in describing grain sizes and constituent particle compositions of south Florida carbonate sediments. He concludes that differences in environment produce sediments with different grain size and constituent composition, but where changes in the environment are small and gradual, sediments are less distinctive, and their differentiation requires recognition of gradual changes in relative abundances of the major constituent particles. Petrographic examination of impregnated sediments has demonstrated the usefulness of this approach in recent carbonates, and suggests the value of similar techniques in describing ancient limestone facies. Several attempts have been made which describe ancient facies petrographically (Henson, 1950; Sander, 1951; and Cuvillier, 1951), with two additional studies being particularly significant. Jaanusson (1952) used thin-section volumetric measures to define Ordovician limestone facies of Öland and the Siljan in Sweden. Similarly, Terriere (1960) determined relative abundances and proportions of major constituents in Pennsylvanian limestones of west Texas.

The mound, channel and rim lithofacies of the lower Stanton are divided petrographically into eight subjective microfacies. Five of these divisions correspond to the semi-quantitatively defined microbiofacies described previously. The remaining three divisions are established through thin-section observation of differences in dominant organisms and matrix composition. Limestones are named according to Dunham's (1962) classification, and are intended only as descriptive rather than genetic terms.

Method

Data on thirteen constituent grain types are derived from examination of approximately 150 thin-sections. Constituent grains observed include: 1) non-skeletal spar, mud and void spaces, and 2) skeletal grains representing ten major organism phyla. A standard 250 counts of all constituents reflect the bulk composition of all samples, whereas additional counts of skeletal grains provide a measure of the sediment contribution of major organism groups.

Non-Skeletal Constituents

Since detailed petrology is not a primary concern in this study, a simplified definition of non-skeletal constituents has been adopted. Folk (1959, 1965) considers mud as any non-visibly crystalline carbonate ooze, and defines spar as any mosaic of crystals greater than 4 microns formed as cement or through neomorphism. This definition necessarily includes microspar (5-10 microns) and pseudospar (15-30 microns). However, Folk (1965) recognizes neomorphism as the primary agent responsible for conversion of mud to micrite, and eventually micrite to microspar and pseudospar (grain aggradation). He does not refute the possibility of grain diminution, original microspar, or pseudospar, but more fully supports a mud→micrite→microspar→pseudospar neomorphic sequence.

Grains less than 5 microns (in this study) could not be identified as mud, recrystallized mud or fine allochemical debris. As a result, a simplified division of non-skeletal matrix and cement is used. "Mud" is used herein to include all non-visibly crystalline carbonate and crystalline carbonate up to 5 microns (carbonate ooze and micrite, *sensu* Folk, 1959, 1965). "Spar" encompasses all remaining size grades of visibly crystalline carbonate (microspar, pseudospar and spar). Furthermore, no distinction is made between original cement and secondary void-filling, or between calcite and dolomite. Therefore, in examining data for mud and spar portions, caution should be exercised to avoid the assumption that stated percentages fully reflect original sediment composition, with respect to both original texture and mineralogy.

Skeletal Constituents

In each major lithofacies, mean skeletal grain size is within the medium sand range (approx. 1.5ϕ). Preservation is generally exceptional, and in many instances small grains can be identified with little difficulty. Some organisms, however, are more susceptible to alteration than others, and occasionally recrystallization may obscure fine internal structural features. Extreme recrystallization completely obliterates all structural details, leaving only a blocky spar mosaic. Comprehensive petrographic descriptions and illustrations (Horowitz and Potter, 1971; and Majewske, 1969) have aided identification of all grains, including those affected by alteration. Of necessity finely comminuted organic debris (less than 5 microns) has been included with the mud portion of all samples.

Grain Interpretations

Several problems arise in recognition and interpretation of skeletal grains. Recrystallization of particular grains may be so intense that it is almost impossible to distinguish these grains from spar cement. Repeated misidentification would necessarily alter the true proportions of these constituents in any given sample. Particularly prone to misidentification are fragments of phylloid algae. Internal algal structure is frequently destroyed, leaving only a thin organic rind to recognize a former algal blade. Extreme diagenesis may also destroy external rinds, lending the appearance of an inorganic sparry filling in the rock. However, smoothly curved surfaces bounding these sparry regions may suggest the presence of a former algal blade. Bivalves, gastropods and other originally aragonitic organisms also recrystallize completely, but distinctive shapes enable fairly easy recognition of these grains. As a result, reported proportions of algae and inorganic spar may overlap by 3-4 percent where distinction between former algal blades and inorganic spar has been impossible.

An additional problem encountered is the relation of numerical (point-count) data to absolute numbers of individuals. Several factors strongly influence the presence or absence of specific skeletal grains. Obviously important is the actual abundance of an organism living in a given environment. Relatively high densities of an organism have the potential of contributing a volumetrically greater amount of sand or mud size sediment. However, skeletal structure, death and reproductive rates, and both physical and biological decomposition affect the amount of skeletal debris actually contributed by organisms.

Calcium carbonate is organized in skeletal frameworks according to some basic strategy (Majewske, 1969). The structure of a skeleton and its basic body design are necessarily functions of this organization. Organisms such as green algae with loosely organized bundles of $CaCO_3$ held together by organic material readily disintegrate after death and leave little trace in the sediment. Those with a stronger arrangement of

$CaCO_3$ do not disintegrate as rapidly after death and may be preserved in the sediment as whole skeletal material. Body design, also a function of $CaCO_3$ organization, can increase an organism's potential sediment contribution. Single shelled and bivalved organisms can only contribute one or two pieces, whereas a segmented or jointed organism such as a crinoid has the potential of contributing a myriad of skeletal pieces.

Death and reproductive rate can also be a prominent factor. For example, if given two organisms of similar skeletal structures and body designs, but different rates of death and reproduction, the organism with the greater reproductive rate will make a greater contribution to the sediment.

Finally, the ~~a~~effects of physical and biological decomposition strongly influence the presence and abundance of skeletal material. Biological destruction can easily weaken a relatively strong shell, making it more susceptible to further fragmentation. Physical forces, particularly waves and currents, can easily abrade calcareous skeletons and play an important role in sorting skeletal debris.

Any combination of these factors operating simultaneously can readily affect the skeletal composition of the sediment. Since point-counts are the only quantitative method for analyzing ancient sediments and are volumetric measures, it is important to realize that derived numerical data reflects only an organism's ability to contribute mud or sand size particles to the sediment, and may not represent the absolute number and diversity of organisms living in a given environment.

Mound Lithofacies

Mud-supported rocks dominate lithologies within the mound facies, and may be classified according to Dunham (1962) as either mudstones, skeletal mudstones (less than 10 percent allochems) or skeletal wackestones (greater than 10 percent allochems). Rare grain-supported lithologies described as skeletal packstones are found in areas transitional to major calcarenite facies (Figure 11). Allochems in all lithologies are almost exclusively skeletal grains, with only occasional inorganic clasts. Pellets are virtually absent in all lithologies, but minor burrowing or turbation may be responsible for small, infrequent (fine sand-sized) pelletoid grains. Sparry algal calcilutites of Heckel and Cocke (1969) (algal wackestones) are the most common rock type in the mound, and are readily recognized by areas of spar-filled sheltered voids. Algal calcilutites are locally

Figure 11--Mound facies lithologies. Bar in lower right hand corner for scale. All photomicrographs X25.

A. Mound-edge algal sparite exposed west of Neodesha (NWC 16 30 15).
B. Mound-interior sparry algal calcilutite exposed west of Neodesha (CSL 22 30 15).
C. Mound-edge skeletal calcilutite exposed at the mound at Altoona north--Pettit's Farm (MANPF).
D. Mound-interior algal calcilutite exposed west of Neodesha (SWC 21 30 15).
E. Mound-edge abraded skeletal calcarenite exposed west of Altoona (CSL 9 29 15).
F. Mound-interior algal calcilutite exposed at Erickson's quarry (EQ).

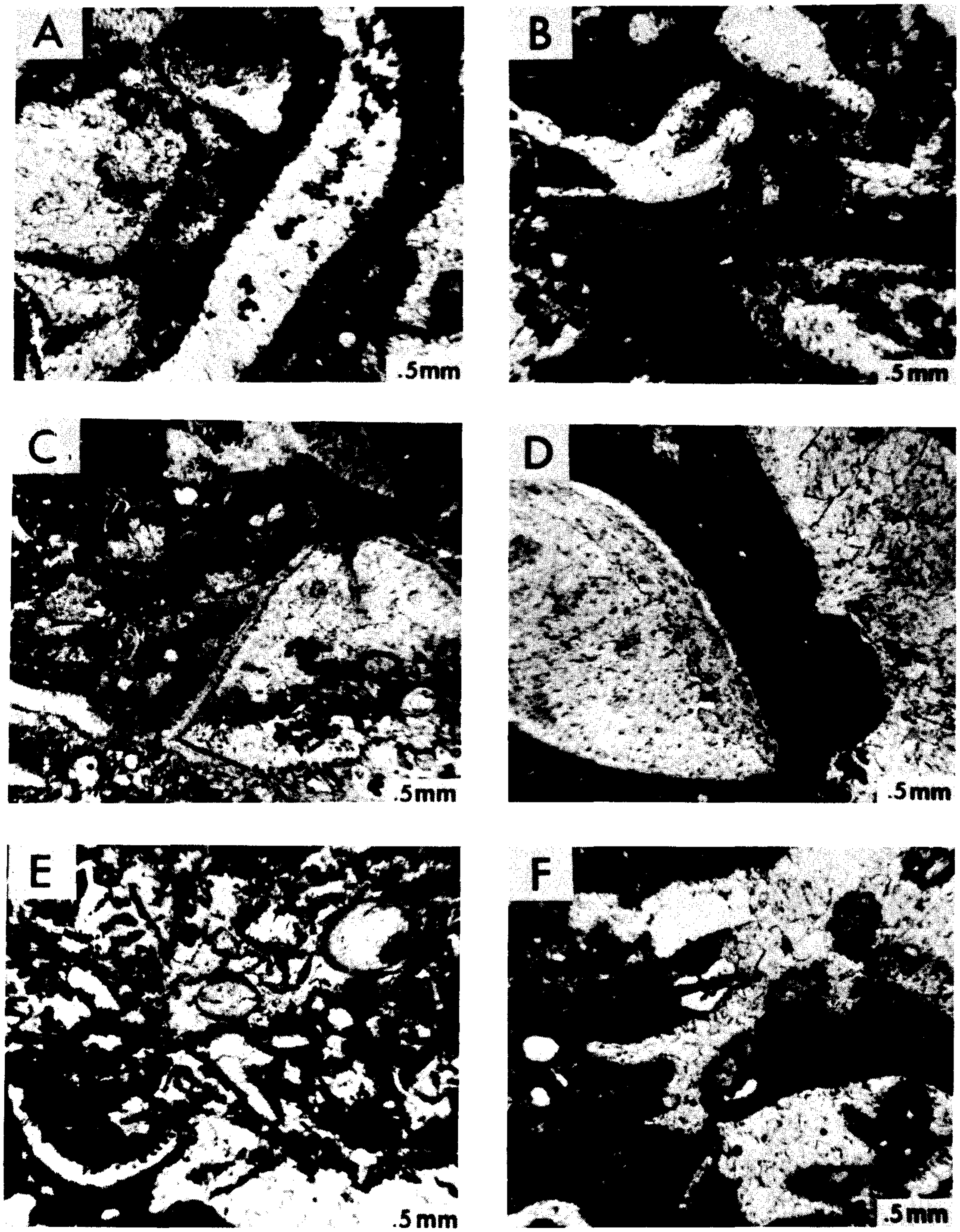


Figure 11

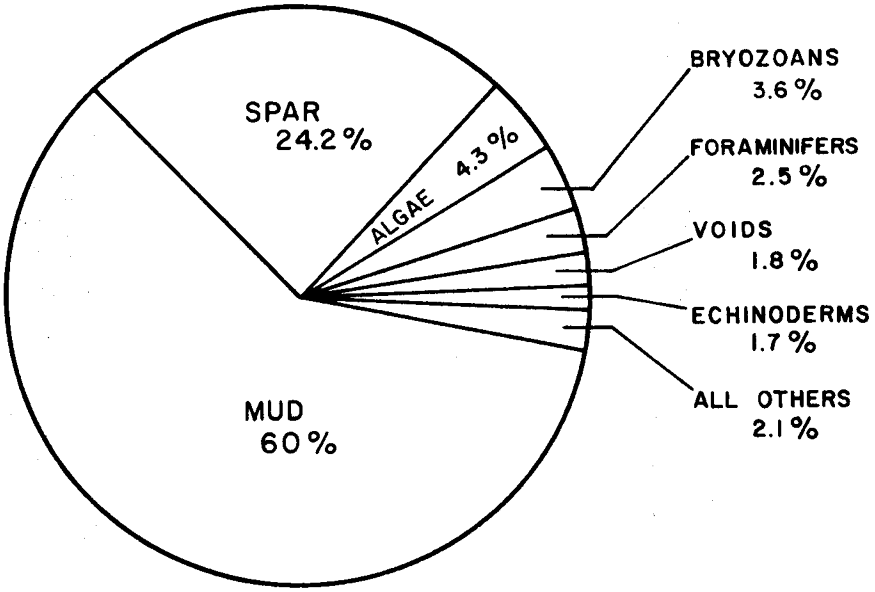
abundant; these have features similar to the sparry algal calcilutites, but lack spar-filled voids. Other varieties such as algal sparite and algal calcarenite occur less frequently.

Bulk Composition

Carbonate mud dominates the average mound lithology, comprising nearly 60 percent of the total composition (Figure 12A). Spar, including neospar and pseudospar, is the only other major component, averaging 24 percent and occasionally constituting as much as 45 percent in algal sparites. In contrast to more calcarenitic lithofacies mound lithologies are generally poor in skeletal components, averaging slightly more than 15 percent and never exceeding 25 percent by volume.

Lithologic variability observable at different localities in the mound warrants consideration of compositional trends within the mound. Distinct petrographic trends are, however, not immediately apparent. For comparative purposes, mound lithologies are again divided subjectively into the two geographic subdivisions: 1) mound-edge, and 2) mound-interior microfacies. This subdivision permits gross lithologic description of two regions in the mound, and also affords an opportunity to contrast finer skeletal components with macrobiotic

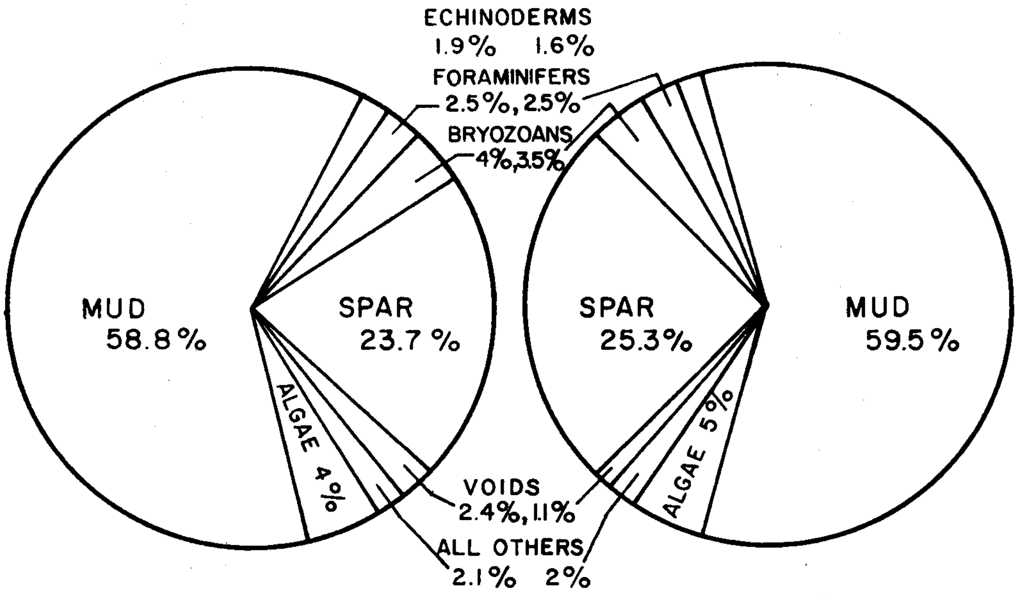
Figure 12--Diagrams illustrating bulk sedimentologic composition of average mound lithologies. A) Composite of all point-counted mound localities suggesting an average mound composition. B) Mound-edge microfacies. C) Mound-interior microfacies. All percentages based on point-counts of N thin-sections. Raw data is compiled in Table 13, Appendix C.



Mound Bulk Composition

(N = 57)

Figure 12A



Mound-Edge

(N = 20)

Figure 12B

Mound-Interior

(N = 37)

Figure 12C

components from the same regions. Separation according to this scheme unfortunately shows little regional trends. In fact, Figure 12B, 12C and Table 6 display remarkably consistent average compositions for these two regions. None of the major constituents vary much more than a single percent. Field demonstration of lithologic variability over a single outcrop suggests microfacies development, but further attempts to differentiate discrete microfacies provide no additional resolution.

Skeletal Composition

Additional counts of skeletal grains provide an indication of relative proportions and contribution of major organism groups. Although a minor portion of the total composition, skeletal fragments are highly diverse (Figure 13A). Small, irregular poorly-preserved fragments of phylloid algae are most abundant in the average mound lithology. Assorted types of bryozoan fragments, whole foraminifers and echinoderm pieces constitute the bulk of the remaining composition, and together with algae they constitute 85 percent of the total skeletal composition.

As with the data for bulk composition, little differentiation of mound-edge and mound-interior can be

Table 6--Data summary of point-counts on N thin-sections describing bulk sedimentologic composition in the mound-edge and mound-interior microfacies.

Table 6

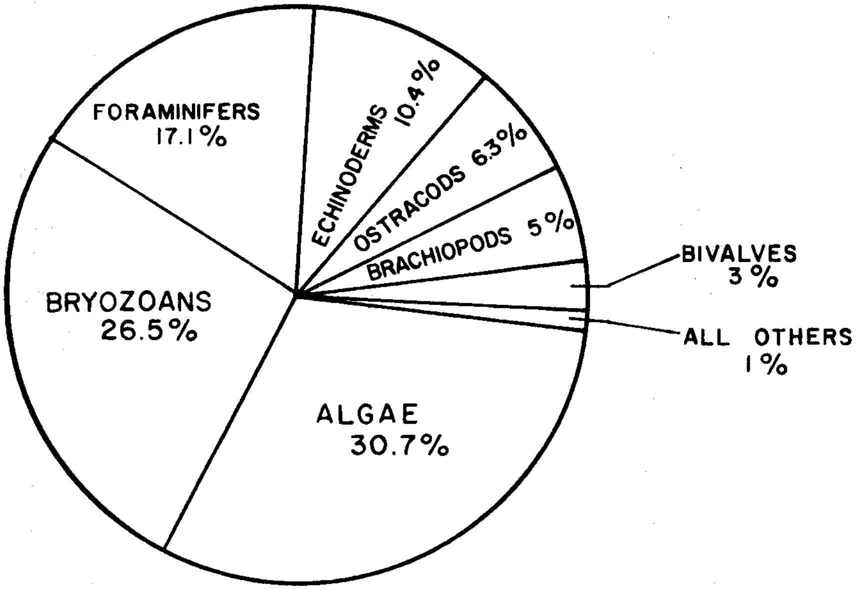
Mound-edge
N=20

	tot. cts.	%	avg./section
Spar	1186	23.7	59.3
Mud	2940	58.8	147.0
Void	120	2.4	6.0
Algae	250	5.0	12.5
Echinoderms	98	1.9	4.9
Bryozoans	189	3.8	9.5
Brachiopods	40	.8	2.0
Bivalves	30	.6	1.5
Gastropods	3	.1	.2
Ostracods	37	.7	1.9
Foraminifers	119	2.4	6.0
Coelenterates	-	-	-

Mound-interior
N=37

	tot. cts.	%	avg./section
Spar	2343	25.3	63.3
Mud	5507	59.5	148.8
Void	107	1.2	2.9
Algae	463	5.0	12.5
Echinoderms	150	1.6	4.1
Bryozoans	321	3.5	8.7
Brachiopods	50	.5	1.4
Bivalves	34	.4	.9
Gastropods	14	.2	.4
Ostracods	86	.9	2.3
Foraminifers	228	2.5	6.2
Coelenterates	-	-	-

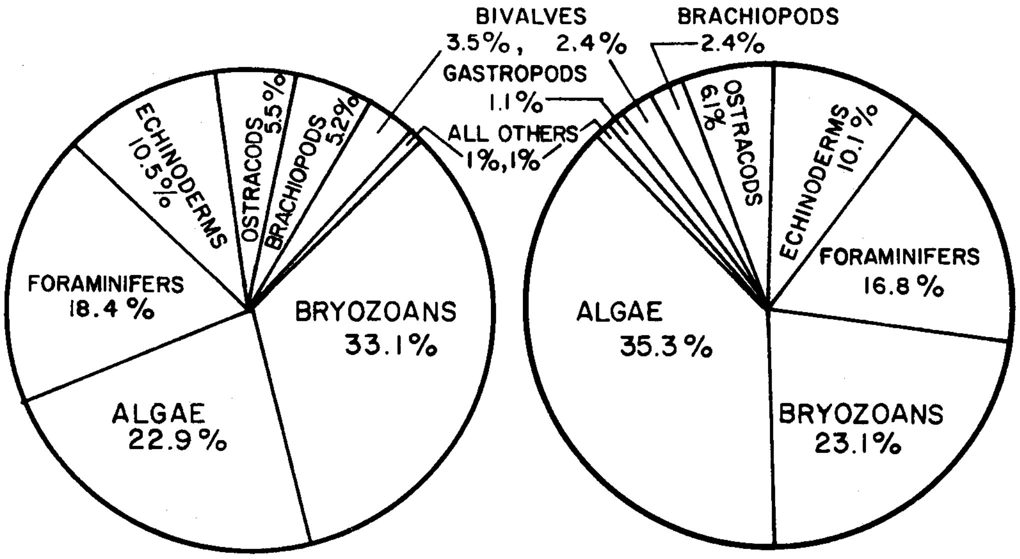
Figure 13--Diagrams illustrating skeletal composition of average mound lithologies. A) Composite of point-counted thin-sections suggesting an average mound skeletal composition. B) Mound-edge microfacies. C) Mound-interior microfacies. Percentages based on point-counts of N thin-sections. Raw data is compiled in Table 14, Appendix C.



Mound Skeletal Composition

(N = 57)

Figure 13A



Mound-Edge

(N = 20)

Figure 13B

Mound-Interior

(N = 37)

Figure 13C

made with skeletal composition (Figure 13B, 13C and Table 7). All constituent percentages, with the exception of algae and bryozoans, exhibit little appreciable differences in the two regions. Algae and bryozoans are inversely related; algal percentage of the total biota is greater in the mound-interior, whereas bryozoan percentage is greater near the mound-edge. The density of bryozoans per thin-section (Figure 14) further reflects their preference for the mound-edge, and also amplifies their inverse relationship with algae. The density of all remaining skeletal constituents shows no significant change toward the mound-edge or mound-interior.

Channel Lithofacies

Grain-supported and subordinate mud-supported channel lithologies would be classified as skeletal packstones and skeletal wackestones (Figure 15). Skeletal calcarenite (skeletal packstone) with occasional mud lenses is the most common rock type in the channel center, and is readily recognized by its coarse texture and abundant skeletal debris. Channel margin lithologies are significantly more mud-supported than channel center types, but none are low enough in grain percentage to be classified as true mudstones. Other less frequent

Table 7--Data summary describing average skeletal composition of the mound-edge and mound-interior microfacies. Note that the true percentage of algae may be 3-4 percent higher if present spar-filled voids were originally algal.

Table 7

Mound-edge
N=20

	tot. cts.	%	avg./section
Echinoderms	191	10.5	9.6
Bryozoans	601	33.1	30.1
Brachiopods	95	5.2	4.8
Bivalves	63	3.5	3.2
Gastropods	15	.8	.8
Ostracods	99	5.5	5.0
Foraminifers	334	18.4	16.7
Algae	415	22.9	20.8

Mound-interior
N=37

	tot. cts.	%	avg./section
Echinoderms	355	10.1	9.6
Bryozoans	811	23.1	21.9
Brachiopods	177	5.0	4.8
Bivalves	86	2.4	2.3
Gastropods	38	1.1	1.0
Ostracods	214	6.1	5.8
Foraminifers	591	16.8	15.9
Algae	1240	35.3	33.5

Figure 14--Graphic display of average number of counts/ thin-section for mound-edge and mound-interior microfacies.

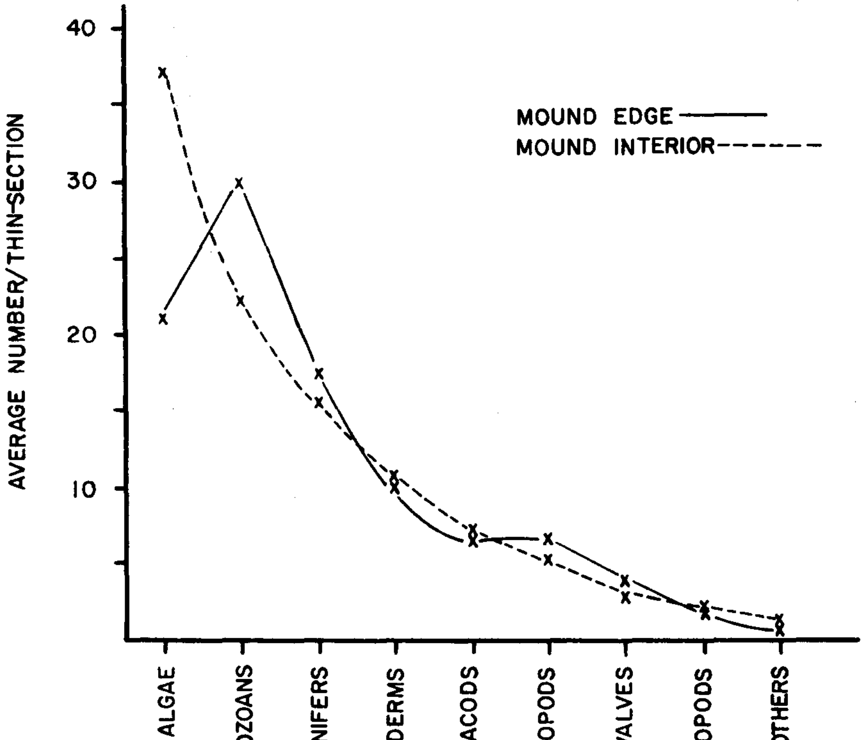

40
30
20
10
AVERAGE NUMBER/THIN-SECTION
MOUND EDGE
MOUND INTERIOR
ALGAE
BRYOZOANS
FORAMINIFERS
ECHINODERMS
OSTRACODS
BRACHIOPODS
BIVALVES
GASTROPODS
ALL OTHERS

Figure 14

Figure 15--Channel facies lithologies. Bar in lower right hand corner for scale. All photomicrographs X25.

A. Channel center well-washed skeletal calcarenite exposed at the Fredonia Cement Plant (FNW-2).
B. Channel center skeletal calcarenite exposed at the Quarry west of Altoona (QWA-1).
C. Channel center pelmatozoan-bryozoan calcarenite exposed at Orneilas' Farm (OF).
D. Channel center well-washed pelmatozoan calcarenite exposed at the Altoona roadcut (ACS).
E. Channel margin skeletal calcilutite exposed west of Altoona (NLE 13 29 15-w).
F. Channel margin muddy skeletal calcarenite exposed at Altoona north--Pettit's Farm (ANPF).

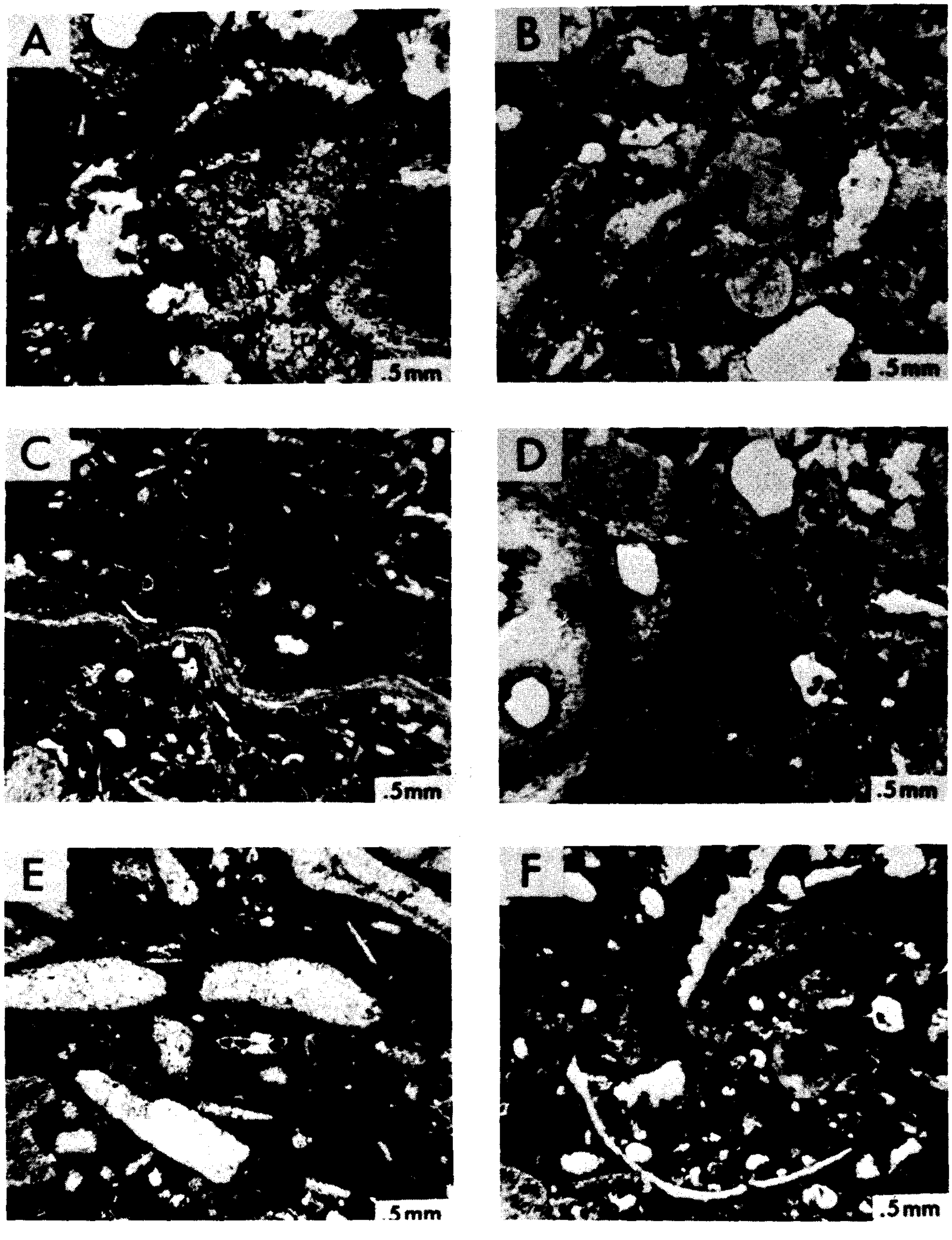


Figure 15

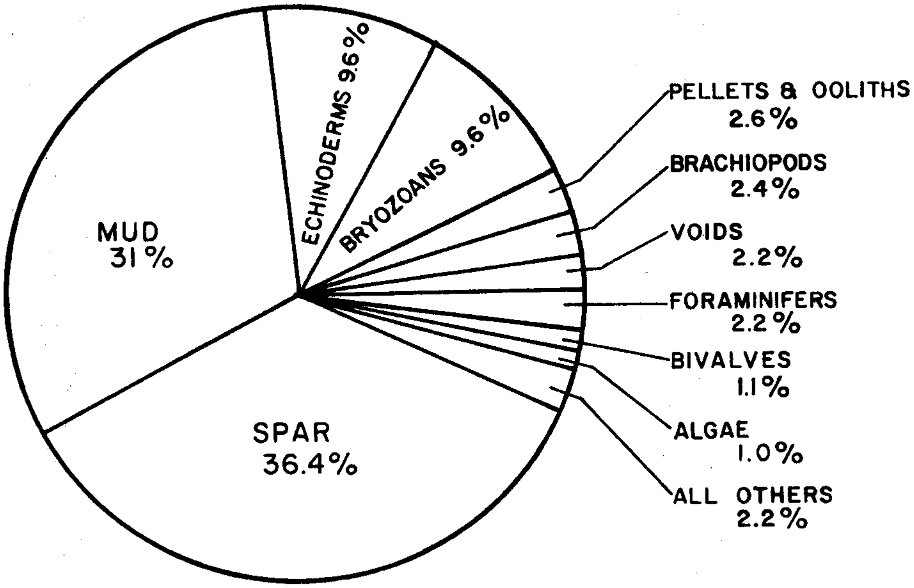
lithologies approach textures more characteristic of grainstones, but all have a small proportion of mud matrix.

Grains in all lithologies are dominated by a variety of skeletal types. Organic and/or inorganic mud pellets and oolitically coated grains are minor elements, primarily found near channel margins. Conspicuous mud rinds coat many skeletal grains, particularly in the channel center, but it is unknown whether these rinds may be micrite envelopes, thin, recrystallized oolitic coatings or simple mud rims created by grain agitation in a slightly muddy environment.

Bulk Composition

Spar and mud are the most prominent constituents in channel calcarenites, averaging greater than 67 percent of the total composition (Figure 16A). In some instances spar predominates over all other constituents, reaching as high as 76 percent. In contrast to this are occasional lithologies with mud content approaching 64 percent. In all instances skeletal constituents are subordinate to matrix and cement. Extremes for skeletal content range from 44

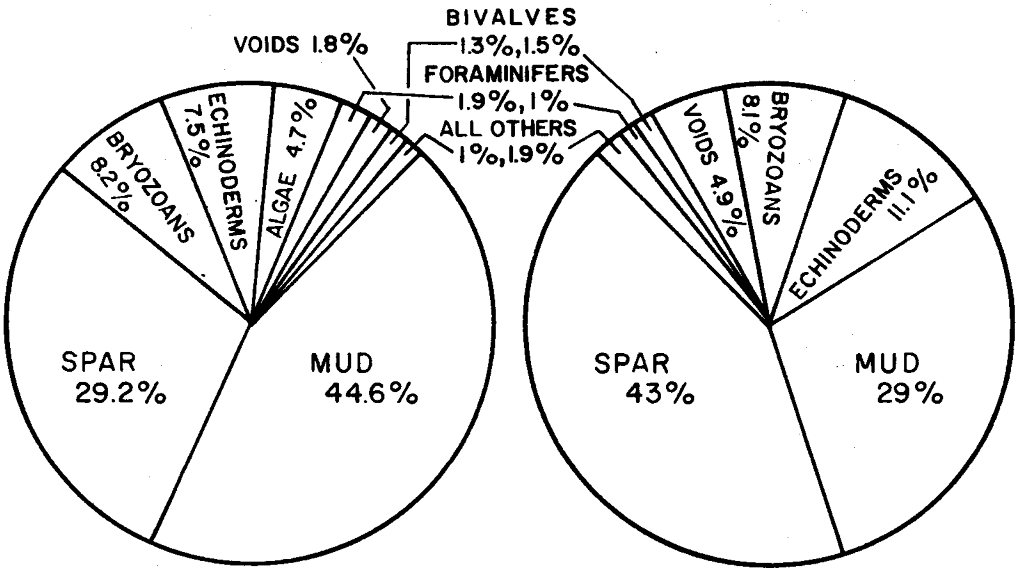
Figure 16--Diagrams illustrating bulk sedimentologic composition of average channel lithologies. A) Composite of all channel counts suggesting an average channel composition. B) Channel center microfacies. C) Channel margin microfacies. Percentages based on point-counts of N thin-sections. Raw data is displayed in Table 13, Appendix C.



Channel Bulk Composition

(N = 41)

Figure 16A



Channel Margin

(N = 11)

Figure 16B

Channel Center

(N = 30)

Figure 16C

percent to 15 percent; the average channel lithology is nearly 33 percent skeletal debris by volume.

The average composition for all channel lithologies does not reveal the variation in major and minor constituents between the channel center and channel margin. Figure 16B, 16C and Table 8 illustrate distinctly different compositions for these two regions. Immediately striking is the inverse relationships between mud and spar proportions. Mud content in the channel margin exceeds spar by an average of 15 percent, whereas spar exceeds mud in the center of the channel by a similar average of nearly 15 percent. Other relations are apparent between major skeletal contributors. In both channel regions, echinoderm and bryozoan debris are the primary skeletal constituents. Although the proportion of bryozoans does not change significantly, they are slightly more abundant than echinoderms in the channel margin. Echinoderms however, are significantly more abundant in the channel center. Algal fragments are the only other major skeletal constituent, and appear significant only in the channel margin.

Skeletal Composition

Additional grain counts amplify the proportions of skeletal constituents in the channel (Figure 17 and

Table 8--Data summary of point-counts on N thin-sections describing bulk sedimentologic composition in the channel center and channel margin microfacies.

Table 8

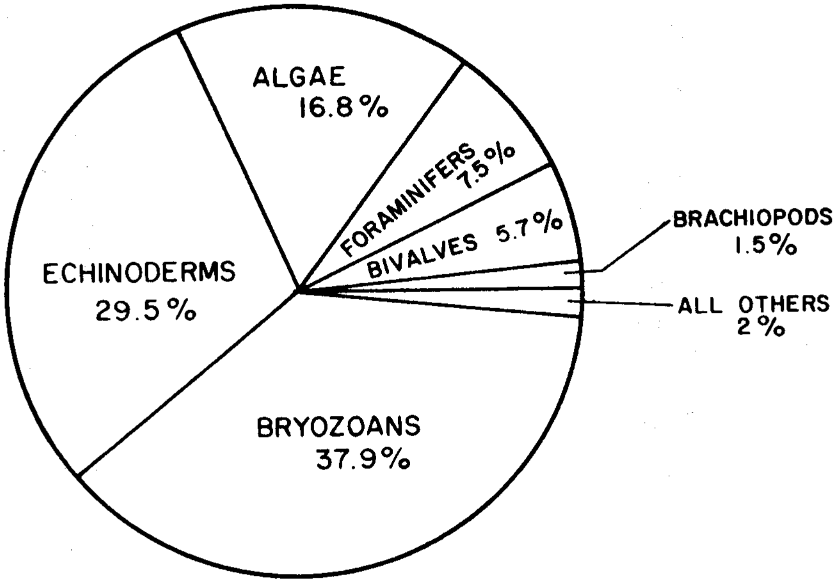
Channel-center
N=30

	tot. cts.	%	avg./section
Spar	3222	43.0	107.4
Mud	2178	29.0	72.6
Void	368	4.9	12.3
Algae	12	.2	.4
Echinoderms	831	11.1	27.7
Bryozoans	609	8.1	20.3
Brachiopods	69	.9	2.3
Bivalves	110	1.5	3.6
Gastropods	8	.1	.3
Ostracods	7	.1	.2
Foraminifers	73	1.0	2.4
Coelenterates	13	.2	.4

Channel-margin
N=11

	tot. cts.	%	avg./section
Spar	803	29.2	73.0
Mud	1226	44.6	111.5
Void	50	1.8	4.5
Algae	128	4.7	11.6
Echinoderms	206	7.5	18.7
Bryozoans	226	8.2	20.5
Brachiopods	14	.5	1.3
Bivalves	37	1.3	3.4
Gastropods	6	.2	.5
Ostracods	2	.1	.2
Foraminifers	51	1.9	4.6
Coelenterates	1	.1	.1

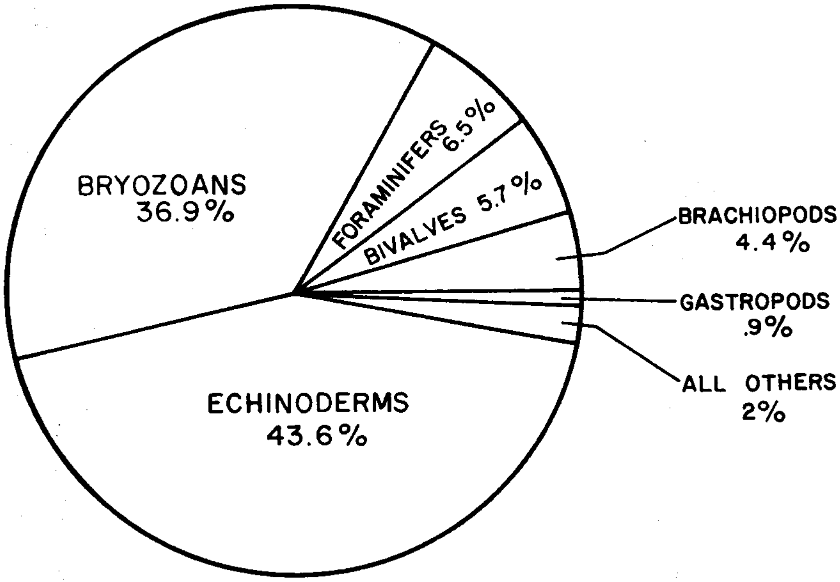
Figure 17--Average skeletal compositions of A) channel center microfacies, and B) channel margin microfacies. Point-count percentages based on N thin-sections. Raw data is compiled in Table 14, Appendix C.



Channel Margin Skeletal Composition

(N = 11)

Figure 17A



Channel Center

(N = 30)

Figure 17B

Table 9). Potentially significant is the overall trend of the three major skeletal contributors across the channel. Echinoderms tend to concentrate in the channel center, bryozoans are more significant in the channel margin, and algae become increasingly more abundant approaching the channel-mound transition. Despite being the major skeletal contributor in the channel margin, bryozoan proportion in the total skeletal composition remains fairly uniform across the channel. Bryozoan density increases only slightly toward the channel margin (Figure 18), but this increase is greatly enhanced by substantial reduction in the proportion and density of echinoderms from the channel center to the margin. This sharp echinoderm decrease is accompanied by an equally abrupt increase in total algal proportion and density. All remaining individual skeletal proportions and densities show little variance across the channel, except brachiopods, which tend to be more abundant in the channel center.

Rim Lithofacies

Although portions of the rim facies contain mud and whole or disarticulated skeletal material, much of the facies is characterized by highly abraded skeletal debris and spar cement (Heckel, 1972).

Table 9--Data summary describing average skeletal composition of the channel center and channel margin microfacies.

Table 9

Channel center
N=30

	tot. cts.	%	avg./section
Echinoderms	1585	43.6	52.8
Bryozoans	1341	36.9	44.7
Brachiopods	159	4.4	5.3
Bivalves	207	5.7	6.9
Gastropods	34	.9	1.1
Ostracods	18	.5	.6
Foraminifers	237	6.5	7.9
Algae	22	.6	.7
Coelenterates	30	.8	1.0

Channel margin
N=11

	tot. cts.	%	avg./section
Echinoderms	436	29.5	39.6
Bryozoans	561	37.9	51.0
Brachiopods	22	1.5	2.0
Bivalves	84	5.7	7.6
Gastropods	10	.7	.9
Ostracods	5	.3	.5
Foraminifers	111	7.5	10.1
Algae	249	16.8	22.6
Coelenterates	1	.1	.1

Figure 18--Graphic display of average number of counts/thin-section for channel center and channel margin microfacies.

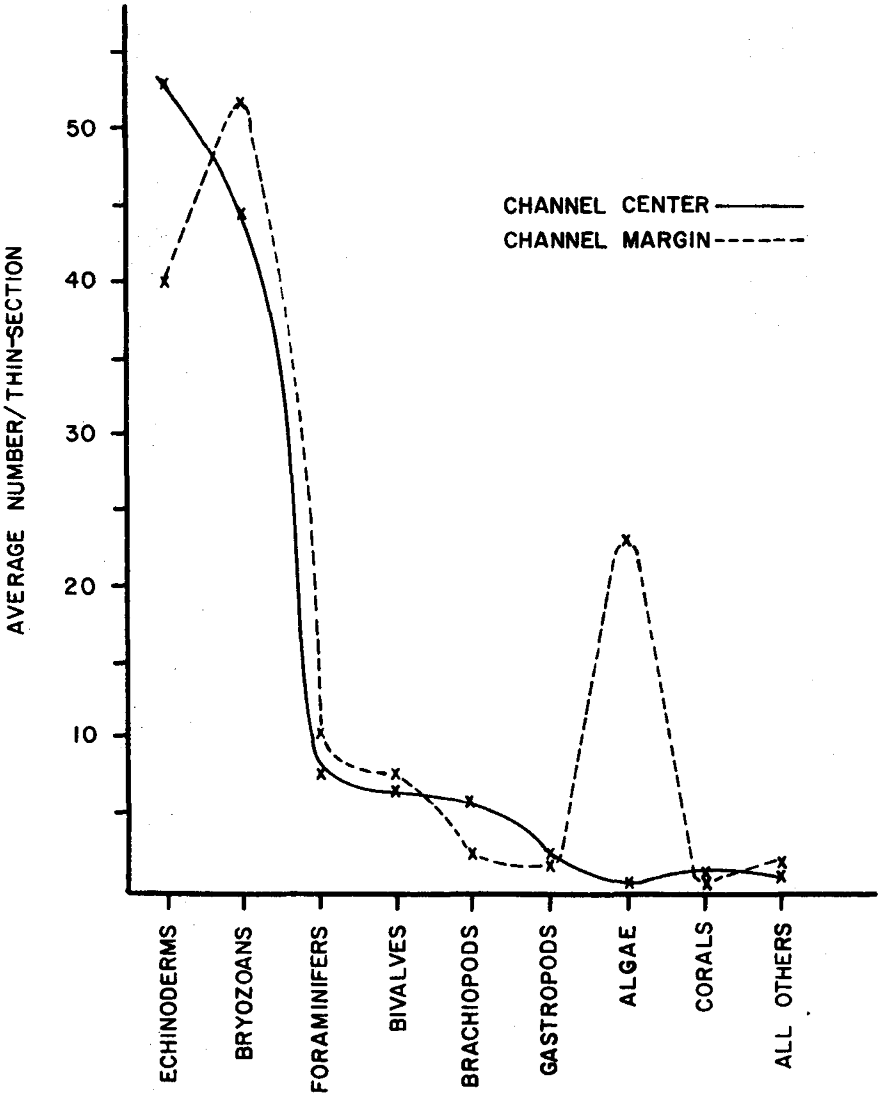

AVERAGE NUMBER/THIN-SECTION
50
40
30
20
10
CHANNEL CENTER
CHANNEL MARGIN
ECHINODERMS
BRYOZOANS
FORAMINIFERS
BIVALVES
BRACHIOPODS
GASTROPODS
ALGAE
CORALS
ALL OTHERS

Figure 18

Grain-supported muddy skeletal calcarenites (skeletal wackestones or packstones) dominate the facies, with minor mud-supported types interbedded or occurring in localized areas (Figure 19). A few rare lithologies lack substantial grain content and warrant classification as mudstones. Coarse, granular, mud-free rocks (grainstones) are infrequent, and it is not likely that the texture is primary, as evidence of neomorphic microspar is readily apparent. Muddy skeletal calcarenites grade laterally into skeletal calcilutites toward the mound. Near the mound-rim transition, rim calcilutites appear similar to mound lithologies, lacking only large algal fragments.

Grains are primarily an assortment of abraded and unabraded skeletal types. Ooids may be prominent in local areas, particularly at Locality BRC, but are generally of minor importance. Other small pelletoid grains are found in rare instances, probably as a result of bioturbation or inorganic clotting.

Bulk Composition

Spar and mud dominate rim lithologies, comprising more than 73 percent of the average composition (Figure

Figure 19--Rim facies lithologies. Bar in lower right hand corner for scale. All photomicrographs X25.

A. Skeletal oolite microfacies exposed at the Benedict roadcut (BRC).
B. "Clam" beds skeletal calcarenite exposed north of Roper (NCL NE 24 27 15).
C. Abraded skeletal calcarenite exposed at the North Buffalo roadcut (NBRC).
D. Abraded pelmatozoan calcarenite exposed at Benedict bridge (BB).
E. Muddy skeletal calcarenite microfacies exposed at Doyle's quarry south of Roper (DQSR).
F. Skeletal calcilutite found interbedded with lithologies typical of the muddy skeletal calcarenite microfacies exposed at the roadditch south of Doyle's Farm (RDSDF).

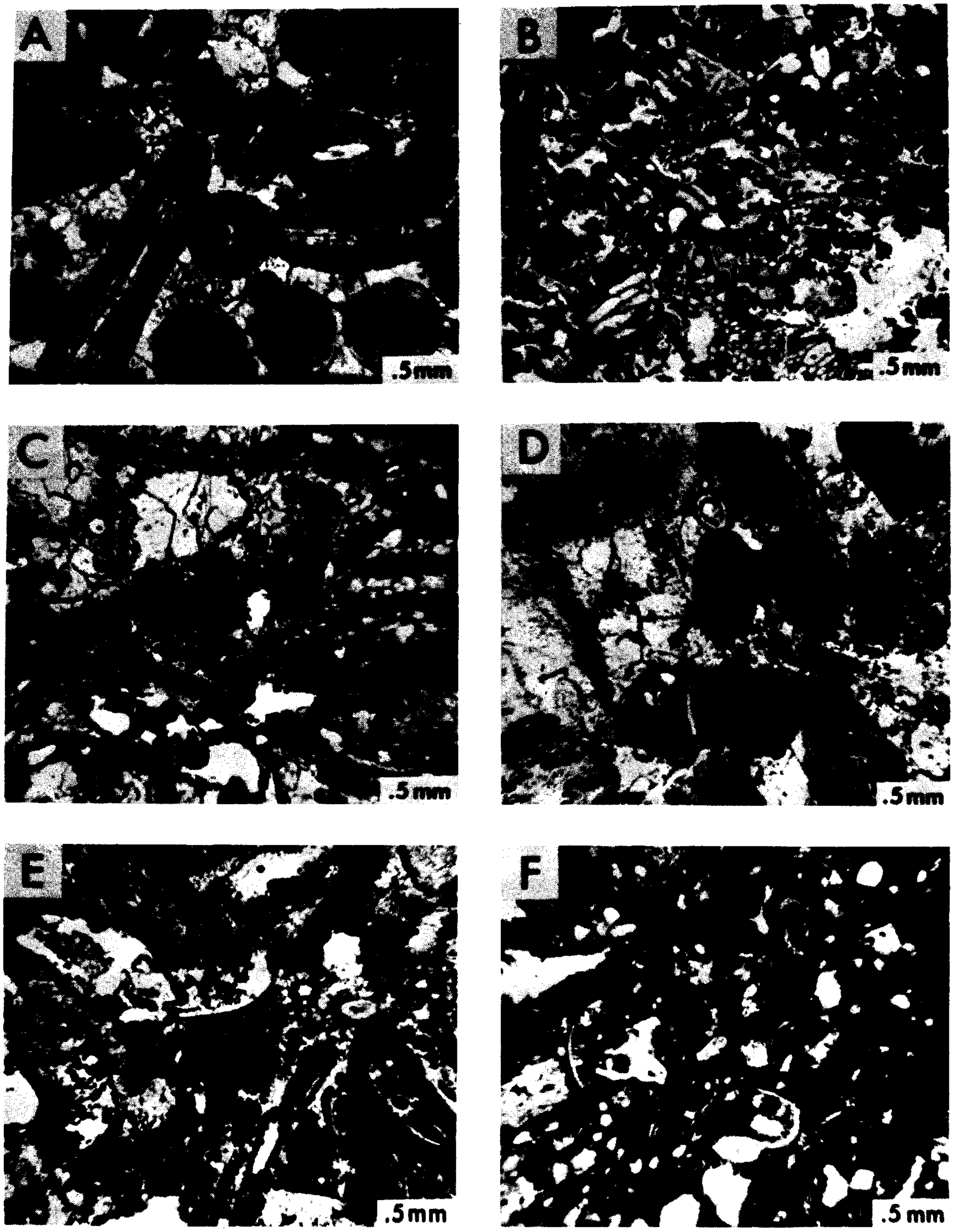
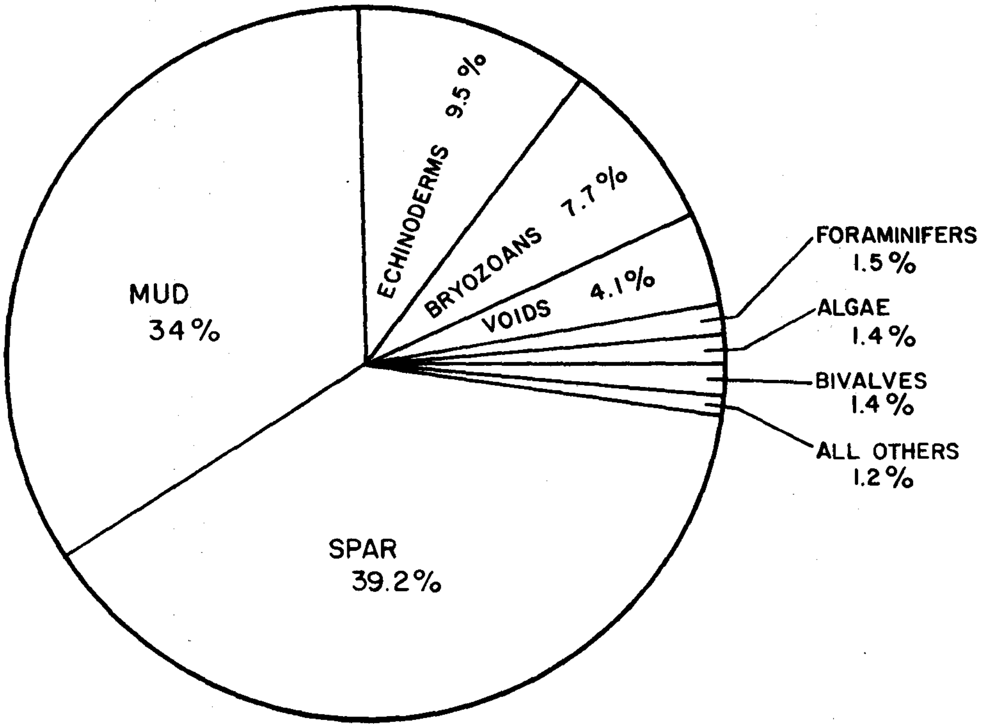


Figure 19

20). Extreme cases of spar development approach 64 percent by volume, but a substantial portion of this may be recrystallized mud or micrite. Spar proportions drop to a low of 6 percent in some instances. Mud content also shows similar proportional variation, from as low as 6 percent in coarse, abraded, skeletal calcarenites, to as much as 59 percent in skeletal calcilutites. Skeletal constituents are subordinate to matrix and cement in most instances, but range from 10-55 percent; an average rim lithology is nearly 28 percent skeletal debris by volume.

Variable lithologic composition in rim calcarenites cannot be depicted by an average composition. Lithologic differences and microfacies patterns observed in field and hand specimen examination are amplified through petrographic observation (Figure 21 and Table 10). Immediately striking are both the large proportion of spar in all microfacies, and, with minor exception, its consistent proportion as 35-36 percent in each microfacies. Mud is generally the second most abundant constituent, but unlike spar, it varies appreciably in each of the microfacies. It is so low in the skeletal oolite microfacies that ooids are significantly more abundant; this is the only microfacies in which matrix is less than an individual

Figure 20--Composite diagram illustrating average bulk sedimentologic composition of the rim facies, based on point-counts of N thin-sections. Data is displayed in Table 13, Appendix C.

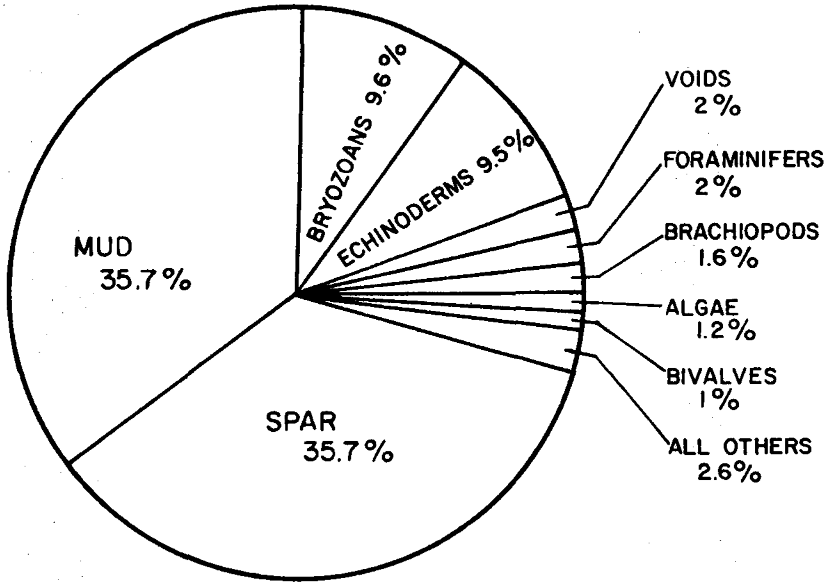


Rim Bulk Composition

(N = 44)

Figure 20

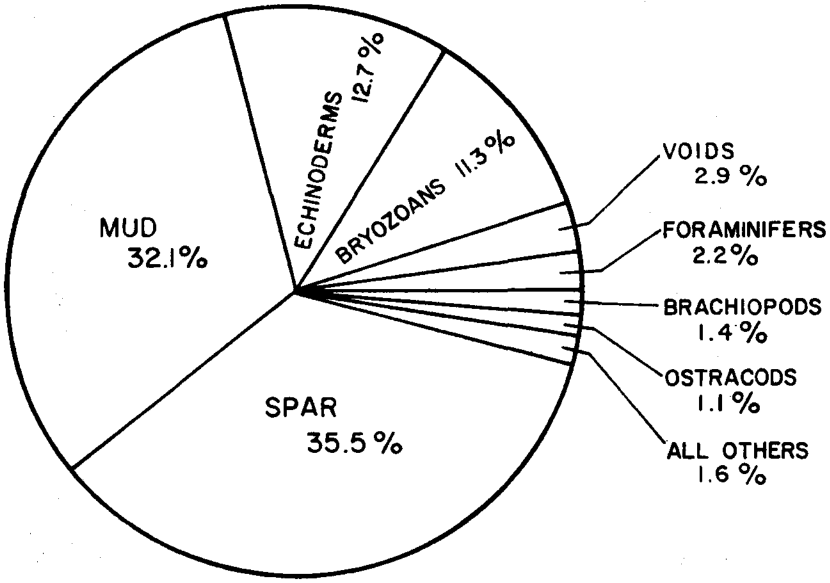
Figure 21--Diagrams illustrating bulk sedimentologic composition of rim microfacies. A) Abraded calcarenite. B) Muddy skeletal calcarenite. C) Skeletal oolite. D) "Clam" beds.



Abraded Calcarenite

(N = 24)

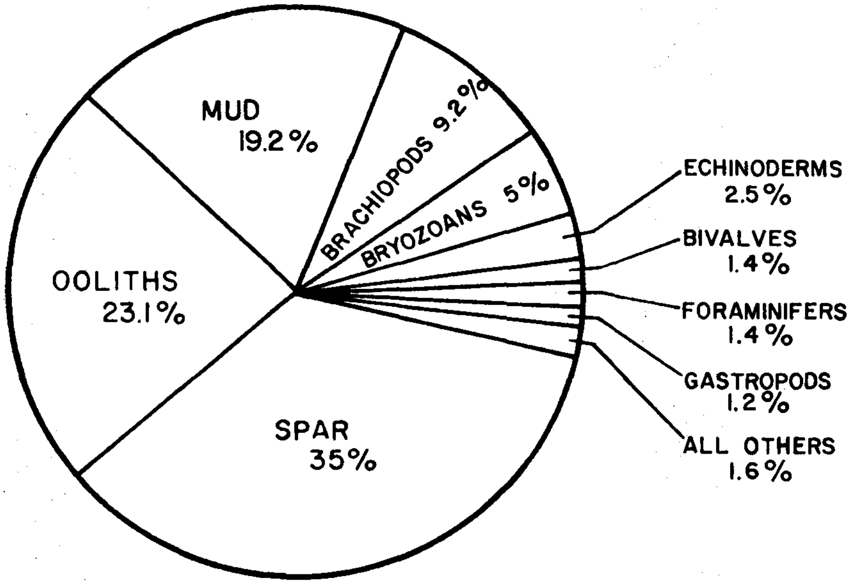
Figure 21A



Muddy Skeletal Calcarenite

(N = 12)

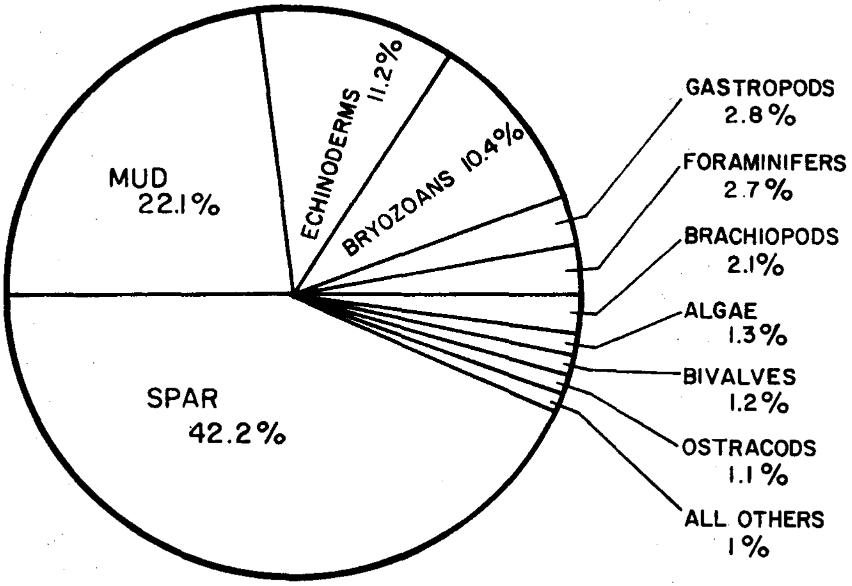
Figure 21B



Skeletal Oolite

(N = 5)

Figure 21C



"Clam" Beds

(N = 3)

Figure 21D

Table 10--Data summary of point-counts on N thin-sections describing bulk sedimentologic composition in the rim abraded calcarenite, muddy skeletal calcarenite, skeletal oolite and "clam" beds microfacies.

Table 10

Abraded calcarenite
N=24

	tot. cts.	%	avg./section
Spar	2180	35.7	90.8
Mud	2179	35.7	90.8
Void	124	2.0	5.2
Algae	74	1.2	3.1
Echinoderms	581	9.5	24.2
Bryozoans	589	9.6	24.5
Brachiopods	100	1.6	4.2
Bivalves	59	1.0	2.5
Gastropods	41	.7	1.7
Ostracods	53	.9	2.2
Foraminifers	122	2.0	5.1
Coelenterates	3	.1	.1

Muddy skeletal calcarenite
N=12

	tot. cts.	%	avg./section
Spar	1062	35.5	88.5
Mud	961	32.1	80.1
Void	89	2.9	7.4
Algae	20	.6	1.8
Echinoderms	367	12.7	30.6
Bryozoans	338	11.3	28.2
Brachiopods	43	1.4	3.6
Bivalves	7	.2	.8
Gastropods	3	.1	.3
Ostracods	34	1.1	2.8
Foraminifers	66	2.2	5.5
Coelenterates	-	-	-

Table 10 (cont'd.)

Skeletal oolite
N=5

	tot. cts.	%	avg./section
Spar	444	35.5	88.8
Mud	241	19.2	48.2
Void	2	.2	.4
Algae	5	.4	1.0
Echinoderms	32	2.5	6.4
Bryozoans	63	5.0	12.5
Brachiopods	115	9.2	23.0
Bivalves	18	1.4	3.6
Gastropods	15	1.2	3.0
Ostracods	8	.6	1.6
Foraminifers	18	1.4	3.6
Coelenterates	-	-	-
Ooliths	289	23.1	57.8

"Clam" beds
N=3

	tot. cts.	%	avg./section
Spar	315	42.2	105.0
Mud	165	22.1	55.0
Void	19	2.5	6.3
Algae	10	1.3	3.3
Echinoderms	84	11.2	28.0
Bryozoans	78	10.4	26.0
Brachiopods	16	2.1	5.3
Bivalves	9	1.2	3.0
Gastropods	21	2.8	7.0
Ostracods	8	1.1	2.7
Foraminifers	20	2.7	6.7
Coelenterates	-	-	-

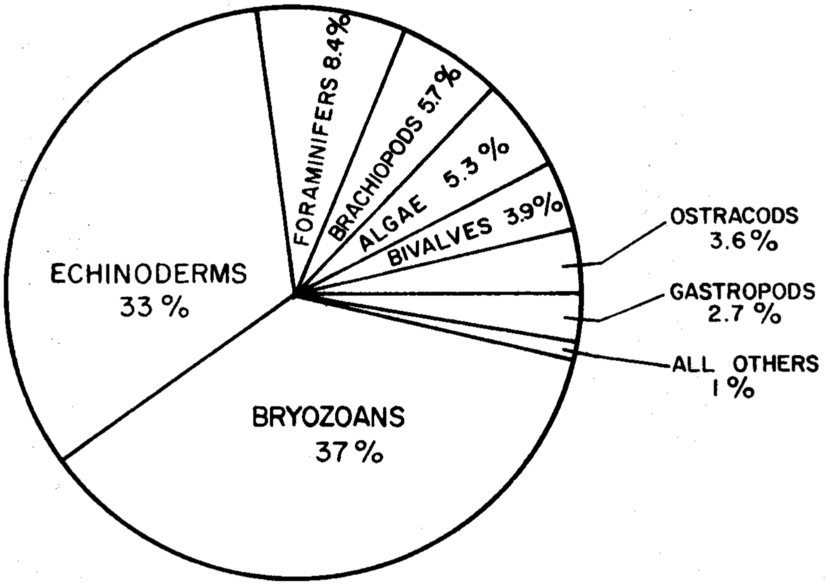
grain type. Skeletal grains constitute anywhere from slightly less than one-quarter to more than one-third of the total composition in any microfacies. In the abraded calcarenite, "clam" beds, and muddy skeletal calcarenite facies, echinoderm and bryozoan debris constitute the bulk of the skeletal material. Brachiopods are the most abundant skeletal grain in the skeletal oolite facies, but it is worth noting that many ooid nuclei are skeletal grains, particularly bryozoan and echinoderm fragments.

Skeletal Composition

Additional grain counts emphasize the contribution and proportions of major skeletal groups in the four microfacies of the rim (Figure 22 and Table 11). Unlike the channel facies, echinoderm content in the non-oolitic microfacies remains fairly constant, whereas bryozoan content appears to fluctuate. Bryozoan debris is reasonably abundant in the skeletal oolite microfacies but echinoderm material is notably reduced. Brachiopod contribution in this facies is higher than anywhere else.

The proportions of minor skeletal elements perhaps best differentiate the subjectively defined microfacies. The "clam" beds have the greatest proportion of minor elements, the most important of which are gastropods.

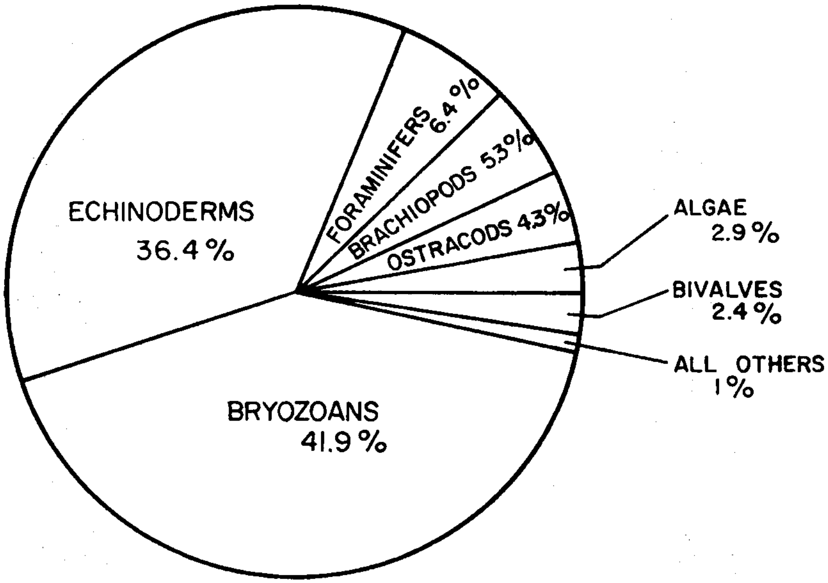
Figure 22--Average skeletal compositions of rim microfacies. A) Abraded calcarenite. B) Muddy skeletal calcarenite. C) Skeletal oolite. D) "Clam" beds. Percentages based on point-counts of N thin-sections. Raw data is compiled in Table 14, Appendix C.



Abraded Calcarenite
Skeletal Composition

(N = 24)

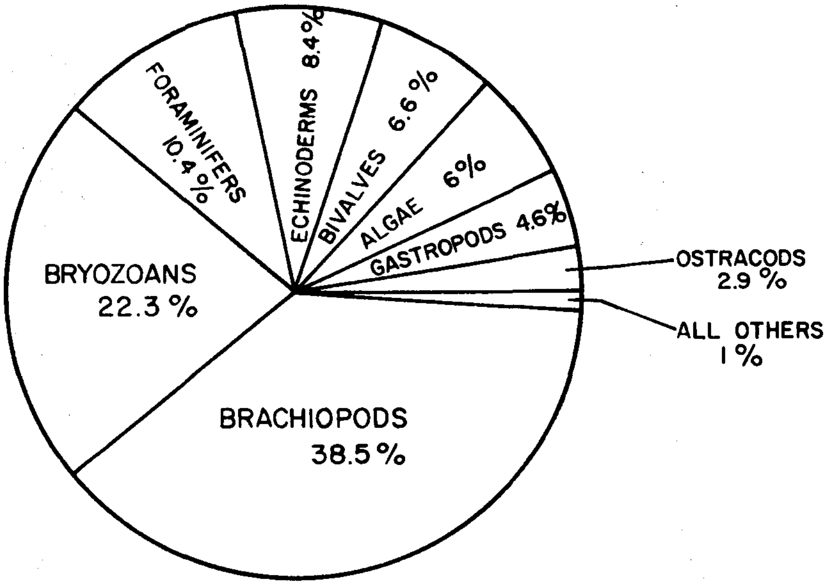
Figure 22A



Muddy Skeletal Calcarenite

(N = 12)

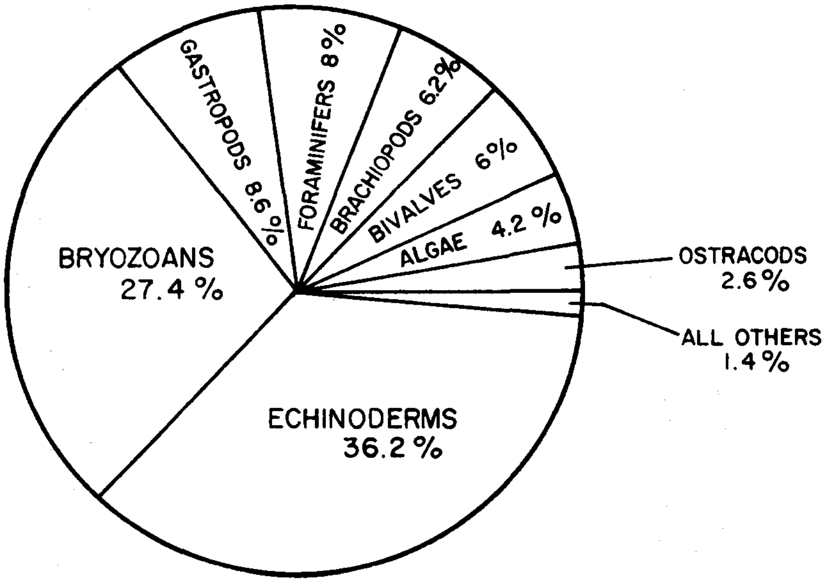
Figure 22B



Skeletal Oolite

(N = 5)

Figure 22C



"Clam" Beds

(N = 3)

Figure 22D

Table 11--Data summary describing average skeletal composition of the rim abraded calcarenite, muddy skeletal calcarenite, skeletal oolite and "clam" beds microfacies.

Table 11

Abraded calcarenite
N=24

	tot. cts.	%	avg./section
Echinoderms	1142	33.0	47.6
Bryozoans	1278	37.0	53.3
Brachiopods	205	5.9	8.5
Bivalves	134	3.9	5.6
Gastropods	95	2.7	4.0
Ostracods	125	3.6	5.2
Foraminifers	291	8.4	12.1
Algae	182	5.3	7.6
Coelenterates	4	.1	.2
Sponges	-	-	-

Muddy skeletal calcarenite
N=12

	tot. cts.	%	avg./section
Echinoderms	659	36.4	54.9
Bryozoans	758	41.9	63.2
Brachiopods	95	5.3	7.9
Bivalves	43	2.4	3.6
Gastropods	7	.4	.6
Ostracods	77	4.3	6.4
Foraminifers	116	6.4	9.7
Algae	53	2.9	4.4
Coelenterates	-	-	-
Sponges	-	-	-

Table 11 (cont'd.)

Skeletal oolite
N=5

	tot. cts.	%	avg./section
Echinoderms	52	8.4	10.4
Bryozoans	137	22.3	27.4
Brachiopods	237	38.5	47.4
Bivalves	41	6.6	8.2
Gastropods	28	4.6	5.6
Ostracods	18	2.9	3.6
Foraminifers	64	10.4	12.8
Algae	37	6.0	7.4
Coelenterates	-	-	-
Sponges	-	-	-

"Clam" beds
N=3

	tot. cts.	%	avg./section
Echinoderms	181	36.2	60.3
Bryozoans	137	27.4	45.6
Brachiopods	31	6.2	10.3
Bivalves	30	6.0	10.0
Gastropods	43	8.6	14.3
Ostracods	13	2.6	4.3
Foraminifers	40	8.0	13.3
Algae	21	4.2	7.0
Coelenterates	2	.4	.6
Sponges	1	.2	.3

The remaining microfacies cannot be as easily distinguished on the basis of the most important minor element alone. Each contain a proportion of foraminifers which is greater than any other individual minor skeletal type. Clear distinction of these microfacies may require consideration of third or fourth most frequent minor skeletal elements, or in extreme circumstances, consideration of the entire assemblage of minor elements.

Plots of the density of skeletal grains per thin-section (Figure 23) do not further differentiate the rim microfacies, except for the lithologically distinct skeletal oolite. Density plots do illustrate that, despite obvious hand specimen differences, the rim facies is remarkably consistent in terms of skeletal compostion. The abraded calcarenite, muddy skeletal calcarenite and "clam" beds microfacies are dominated by varying densities of echinoderms and bryozoans. Densities of all other skeletal constituents display minor variation, but are generally consistent throughout these microfacies. The only exception to these trends occurs in the skeletal oolite, where echinoderm and bryozoan density is unusually low and brachiopod density is dramatically higher.

Figure 23--Graphic display of average number of counts/ thin-section for all rim microfacies.

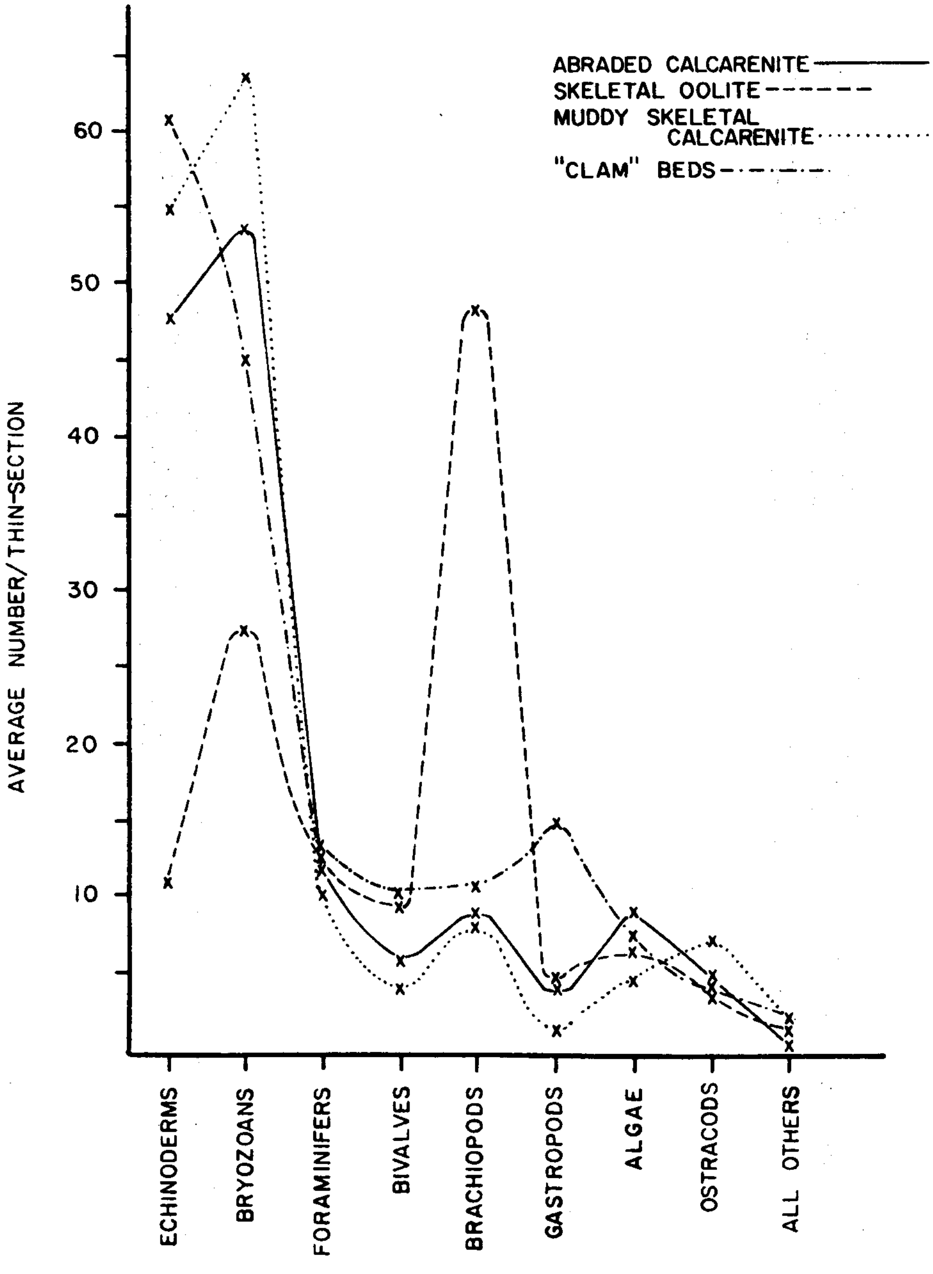

ABRADED CALCARENITE
SKELETAL OOLITE
MUDDY SKELETAL CALCARENITE
"CLAM" BEDS
AVERAGE NUMBER/THIN-SECTION
60
50
40
30
20
10
ECHINODERMS
BRYOZOANS
FORAMINIFERS
BIVALVES
BRACHIOPODS
GASTROPODS
ALGAE
OSTRACODS
ALL OTHERS

Figure 23

SUMMARY AND CONCLUSIONS

Summary

Previous investigations concerning the Stanton Limestone in eastern Kansas have focused on aspects of physical stratigraphy and Mid-Continent correlation or systematic and stratigraphic paleontology. With the exception of Newell (1933), little effort has been made to relate the nature of diverse Stanton biotas to the variety of marine lithologies throughout its outcrop. However, mapping by Heckel (1972, 1975) has delineated several major facies in the lower Stanton of southeast Kansas, and suggests the presence of biotic assemblages closely associated with these facies.

The Stanton Limestone in northeastern Kansas is a fairly uniform sequence of open-marine limestones and shales; individual members maintain character laterally for many kilometers with only minor variation. However, abrupt thickening of individual members and lateral facies changes associated with algal-mound complexes characterize Stanton units in southeastern Kansas. Algal-mound complexes are well-developed in the Captain Creek and Stoner limestone members in Wilson County (Heckel and Cocke, 1969), and consist of broad, algal buildups separated by contemporaneous channels and fringed by a westward dipping rim. Each of these facies are represented by major lithologies. The mound lithofacies is dominantly algal calcilutite and the channel and rim lithofacies are dominantly skeletal calcarenites.

Closely associated with these lithofacies are diverse and abundant invertebrate biotas. None of the biotas are mutually exclusive assemblages, but characteristic elements and proportions of all taxa serve to distinguish three grossly delineated biofacies and several micro-biofacies within the major facies. The mound, channel and rim facies are collectively dominated by varying proportions of three macrobiotic types: 1) phylloid algae, 2) echinoderm (pelmatozoan) debris, and 3) brachiopods. Concentrations of bryozoans and bivalves seem locally significant, but these and remaining major taxonomic groups are generally infrequent macrobiotic constituents. The mound is least taxonomically diverse, but is easily recognized by abundant phylloid algae and the brachiopods _Enteletes_ and _Hystriculina_. All other taxa are scattered, infrequent elements, except for the ubiquitous brachiopod _Composita_ which is abundant in all major facies. Channel and rim biotas are generally distinguished from mound biotas on the basis of greater taxonomic diversity and absence of appreciable algal content, but are less readily distinguished from one another. The channel is characterized by the brachiopod *Schizophoria* cf. *S. texana*, the bryozoan *Meekoporella dehiscens* and the bivalve *Edmondia*. Several other genera and species found only within the channel occur too infrequently to be considered fully diagnostic. Thirteen genera and three species unknown in either the mound or channel are present in the rim facies. Of these, only *Derbyia deercreekensis* occurs with any frequency to be regarded as fully diagnostic. Unusual assemblages of echinoderms, gastropods and bivalves are known from isolated localities, but none occur consistently throughout the rim.

Petrographic examination has demonstrated that single lithologies cannot adequately characterize each of the major facies. Varying proportions of mud, spar and skeletal constituents describe distinct lithologic types, which are indicative of several laterally gradational microfacies within the mound, channel and rim facies. Sparry algal calcilutites dominate interior portions of the mound, with algal sparites and algal calcarenites more abundant near major calcarenite facies. The channel is characterized by a central region of coarse, well-washed skeletal calcarenite which grades laterally into muddy skeletal calcarenites and skeletal calcilutites on the channel margins. The rim exhibits greatest inhomogeneity of all major facies, but is commonly represented by muddy skeletal calcarenites. These calcarenites also grade laterally into skeletal calcilutites approaching the mound. Several other calcarenitic types found in areally restricted exposures complete the range of variation in rim lithologies.

Echinoderm debris, bryozoan debris and foraminifers are the most important contributors of sand-size sediment in the major facies, with algal fragments replacing echinoderms as most important in the mound facies. All other skeletal constituents are generally of minor importance, except for rare concentrations of brachiopod and gastropod debris. Algal fragments are associated with mud-rich sediments, bryozoan debris dominates mixed mud-spar sediments, and echinoderm debris prevails in mud-free sediments. Petrographic observation of skeletal grain types illustrates that major macrobiotic elements are not always responsible for producing major sand-size skeletal constituents. Proportions of elements in observable macrobiotas may be considerably different from proportions of primary skeletal constituents in the sediment (Figure 24).

Figure 24--Composite diagram summarizing data for major macrobiotic elements and skeletal grain types in all major facies. The sequence of facies represents a compositional cross-section through a hypothetical portion of the channel, mound and rim. The question marks indicate non-quantified estimates of macrobiotic composition in the channel margin.

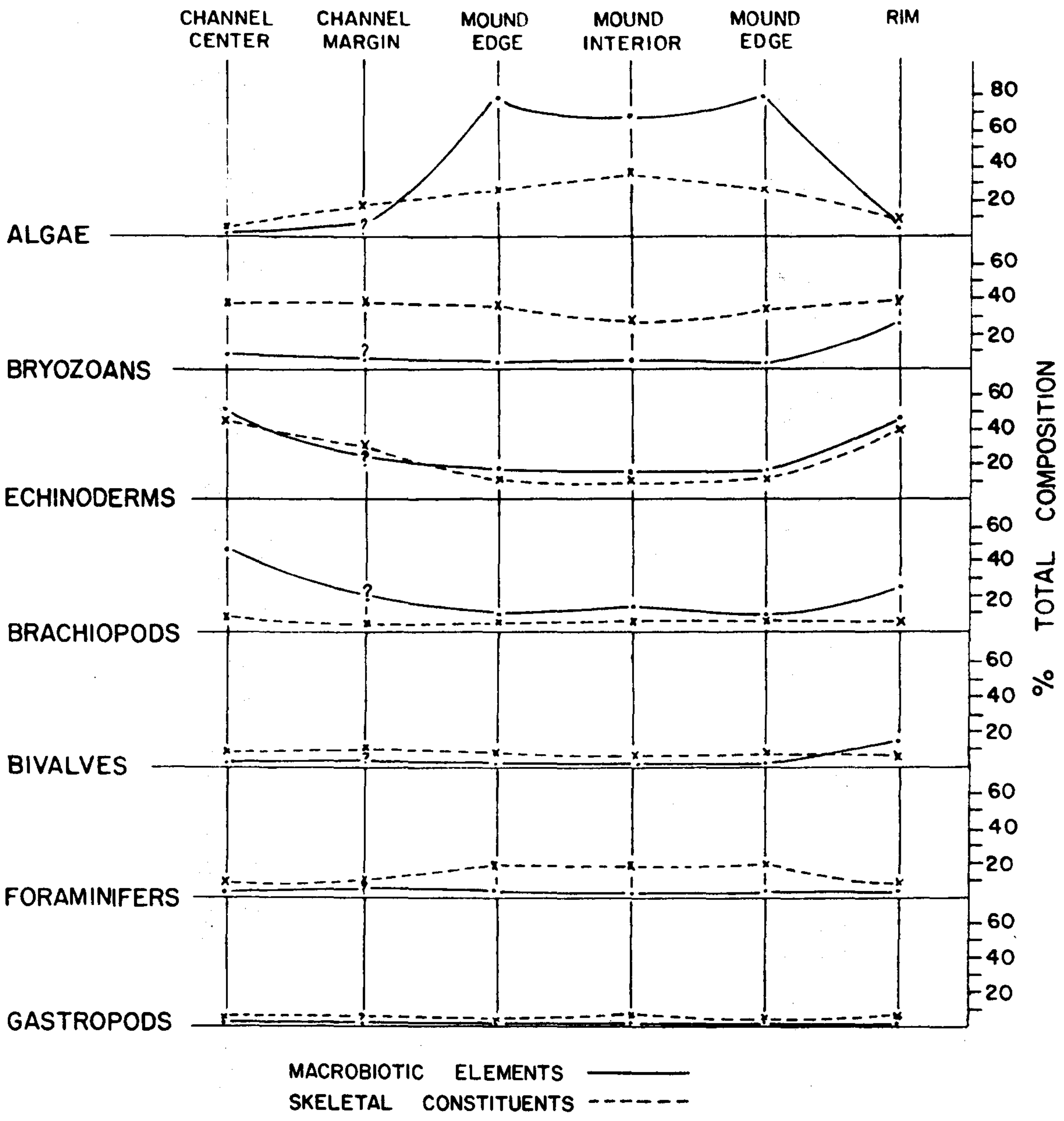

CHANNEL CENTER
CHANNEL MARGIN
MOUND EDGE
MOUND INTERIOR
MOUND EDGE
RIM
ALGAE
BRYOZOANS
ECHINODERMS
BRACHIOPODS
BIVALVES
FORAMINIFERS
GASTROPODS
80
60
40
20
% TOTAL COMPOSITION
?
MACROBIOTIC ELEMENTS
SKELETAL CONSTITUENTS

Figure 24

Conclusions

The data presented in this paper allow general conclusions to be drawn in two major areas: 1) significance of macrobiotic elements and skeletal constituents in Pennsylvanian limestones of southeastern Kansas, and 2) environmental interpretations derived from numbers and diversity of biotic elements.

Descriptions of fossiliferous limestone units are frequently made either in terms of whole-shell macrofauna or skeletal composition. Either approach necessarily affects what is perceived to be the actual biotic composition, and what is ultimately interpreted to be the depositional significance of a particular unit. Both skeletal and macrobiotic content have been used in relatively few instances to interpret limestone units. Contemporaneous limestone facies in the lower Stanton clearly demonstrate the need for interpretations based on both aspects of biotic composition. Frequently observed macrobiotic elements often have little correlation with sand-size skeletal grains that constitute the bulk of the rock. This is particularly true of those major organism groups other than echinoderms. Algae and brachiopods are commonly more abundant as macrobiotic elements than as skeletal grains, although algal fragments tend to be increasingly more prominent toward the mound-interior (Figure 24). Remaining major contributors are more abundant as sand-size skeletal material, yet seem relatively insignificant as macrobiotic elements. Particularly striking is the general paucity of bryozoans in macrobiota, despite the major sediment contribution they make in all facies. Overall, it should be noted that only a few organism groups characterize the macrobiota of each facies, whereas the sediment is characterized by great diversity of skeletal grain types.

The numbers and diversity of organisms present in each major facies suggest generalized environmental conditions. Interpretations must remain conjectural, however, because of the lack of sufficient quantitative measures of organism abundance and diversity in certain microfacies. Particularly critical in describing environmental features is the recognition of indigenous versus alien elements in each facies. Interpretations based on mixed assemblages, which include transported elements may distort the true picture. In each of the major facies, only those species which have been described as diagnostic or characteristic can be considered indigenous to their respective facies. Essentially restricted distribution, well-preserved external ornamentation and frequency of occurrence all suggest in place appearance of these diagnostic species. Remaining elements in each biotic substrate. Despite the amount of mud, high algal content suggests relatively shallow, clear water for optimum utilization of sunlight. Clear, relatively non-turbid water is also suggested by the number of suspension-feeding crinoids and bryozoans present. Low species diversity of those groups identified in conjunction with the quiet water also suggests poor circulation over the mound. Low nutrient levels due to infrequent replenishment would result from poor circulation, and may be at least partially responsible for decreasing organism diversity and abundance toward the mound-interior. Slightly increased circulation resulting in higher nutrient levels at the mound-edge supported a somewhat more abundant and diverse biota.

Unlike the mound, the channel facies supported a richer and more varied biota consisting principally of echinoderms, bryozoans and brachiopods. Within the generally clean, well-washed skeletal sand of the channel center, local firm areas provided a suitable substrate for a variety of rooted or attached pelmatozoans, bryozoans, corals and some brachiopods. Some bryozoans encrusting local surfaces and long, articulated pelmatozoan columns suggest minimal transport. Channel margins were distinctly muddier, and, as evidenced by high percentages of bryozoans, these substrates may also have been firm at least locally. It is suspected that high bryozoan percentage may be partially derived from quantities of debris washed in from the channel center. Currents in the channel center winnowed mud, resuspended organic detritus, and continually replenished nutrient levels required by the diverse filter- and suspension-feeding brachiopods, echinoderms, bryozoans and corals. The amount of mud in the channel margins suggests that current activity and agitation were not as intense as in the center, but any increased turbidity in the margin was tolerated by suspension-feeding organisms such as the numerous bivalves.

The rim exhibits greatest environmental variation and correspondingly has the greatest biotic diversity of all the major facies. The muddy skeletal calcarenite and "clam" beds microfacies both possessed a mixed mud-skeletal sand substrate, which was soft enough for bivalves and certain brachiopods to partially sink in and rest on the bottom, yet still firm enough in places for stalked or attached organisms to gain an anchorage. Turbidity in the muddy skeletal calcarenite microfacies was probably low, and good circulation was necessarily maintained to replenish relatively rich nutrient levels required by the numerous filter-feeding groups. The "clam" beds may have experienced slightly turbid conditions similar to the channel margins. Deposit-feeding bivalves, gastropods and filtering organisms with mechanisms for keeping feeding apparatuses clear were the dominant biotic elements in this microfacies. In contrast to the muddy environs were the relatively mud-free abraded calcarenite and skeletal oolite microfacies. Grain abrasion and oolitic coatings indicate fairly intense water agitation capable of destroying fragile organisms such as echinoderms and bryozoans. Highly tolerant organisms, particularly certain brachiopods, small bivalves and gastropods, seem to represent the only indigenous organisms. All other skeletal debris was likely washed in from other sources. The general lack of attached or rooted organisms may also indicate that these microfacies had a fairly soft, possibly shifting, skeletal or oolitic sand substrate.

The general picture in southeastern Kansas during lower Stanton deposition involves a complex association of shallow, normal marine environments. Broad mud mounds rich in algae and relatively poor in all other major invertebrate groups dominated most of the region, and reflect very shallow water with strong sunlight penetration, but relatively poor circulation and nutrient replenishment, particularly in the interior. Contemporaneous with the mounds was a long, linear, skeletal sand-filled channel, noticeably algal-poor, but relatively rich in several suspension-feeding invertebrate groups, particularly echinoderms, brachiopods and bryozoans. These organisms all suggest increased circulation and nutrient replenishment in deeper water. Trending parallel to the depositional strike of the mounds was a wide, rimming drape of skeletal sands, small muddy banks and local oolite shoals. Major invertebrate groups were extremely abundant and diverse, especially brachiopods, echinoderms, bryozoans and local pockets of bivalves. Varying densities of these organisms reflect several microenvironments with different degrees of water agitation, and generally good overall circulation and nutrient replenishment along the edge of the regional mound.

BIBLIOGRAPHY

BIBLIOGRAPHY

Barr, A. J. and Goodnight, J. H., 1972, The statistical analysis system, Students Supply Stores, N. Carolina St. Univ., Raleigh, N. C.

Beede, J. W., 1909, Carboniferous invertebrates, Kansas Univ. Geol. Survey, 6(1).

Bramlette, M. N., 1926, Some marine bottom samples from Pago Pago harbor, Samoa, Carnegie Inst. Wash. Pub. 344, Pap. Tortugas Lab., 23:1-36.

Bridwell, A., 1939, The brachiopod genus Enteletes with a description of a new species, Kansas Acad. Sci. Trans., 42:329-335.

Chayes, F., 1956, Petrographic modal analysis; an elementary statistical appraisal, Wiley Pub., New York, 113p.

Cocke, J. M., 1970, Dissepimental rugose corals of Upper Pennsylvanian (Missourian) rocks of Kansas, Kansas Univ. Paleont. Contrib. Art. 54 (Coelenterate 4), 67p.

Condra, G. E., 1930, Correlation of the Pennsylvanian beds in the Platte and Jones Point sections of Nebraska, Nebraska Geol. Survey, 3:57p.

Cridland, A. A., Morris, J. E. and Baxter, R. W., 1963, The Pennsylvanian plants of Kansas and their significance, Palaeontographica, 112(B):58-92.

Cuvillier, J., 1951, Correlations stratigraphiques par microfacies en aquitane occidentale, E. J. Brill and Co., Leiden.

Dunbar, C. O. and Condra, G. E., 1932, Brachiopoda of the Pennsylvanian System in Nebraska, Nebraska Geol. Survey, 5(2):377p.

Dunham, R. J., 1962, Classification of carbonate rocks according to depositional texture, AAPG Memoir #1, pp. 108-121.

Folk, R. E., 1959, Practical petrographic classification of limestones, AAPG Bull., 43(1):1-38.

________, 1965, Some aspects of recrystallization in ancient limestones, IN: Dolomitization and limestone diagenesis--A symposium, SEPM Spec. Pub. 13:14-48.

Ginsburg, R. N., 1956, Environmental relationships of grain size and constituent particles in some south Florida carbonate sediments, AAPG Bull., 40(10): 2384-2427.

Girty, G. H., 1903, Tabulated list of invertebrate fossils from the Carboniferous section in Kansas, USGS Bull., 211:73-83.

Grinnell, R. S. and Andrews, G. W., 1964, Morphologic studies of the brachiopod genus Composita, Jour. of Paleo., 38(2):227-248.

Haglund, W. M., 1967, Brachiopod genus Enteletes in Pennsylvanian deposits of Kansas, Kansas Univ. Paleo. Contrib. Paper 23, 30p.

Henson, F. R. S., 1950, Cretaceous and Tertiary reef formations and associated sediments in Middle East, AAPG Bull., 34:215-238.

Heckel, P. H., 1972, Pennsylvanian stratigraphic reefs in Kansas, some modern comparisons and implications, Geol. Rundschau, 61(2):584-598.

________, 1975, Stratigraphic and depositional framework of the Stanton Formation in southeastern Kansas, Kansas Geol. Survey Bull., 210.

________ and Cocke, J. M., 1969, Phylloid algal-mound complexes in outcropping Upper Pennsylvanian rocks of Mid-Continent, AAPG Bull., 53(5):1058-1074.

Horowitz, A. S. and Potter, P. E., 1971, Introductory petrography of fossils, Springer-Verlag, New York, 302p.

Illing, L. V., 1954, Bahaman calcareous sands, AAPG Bull., 38:1-95.

Jaanusson, V., 1952, Untersuchungen uber die Korngrosse der Ordovizischen kalksteine, Geol. Foren. Forhandl., 74(2):124.

Johnson, J. H., 1946, Lime-secreting algao from the Pennsylvanian and Permian of Kansas, GSA Bull., 57:1087-1120.

________, 1947, *Nubercularia* from the Pennsylvanian and Permian of Kansas, Jour. of Paleo., 21:41-45.

________, 1963, Pennsylvanian and Permian algae, Colorado School of Mines Quart., 58(3):211p.

King, R. H., 1933, *Neosprifer dunbari* Ralph H. King *nom. nov.*, Jour. of Paleo., 7:441.

Lutz-Garihan, A., 1974, The brachiopod genus Composita from the Wreford megacyclothem (Lower Permian) in Nebraska, Kansas and Oklahoma, GSA abs. with Progs., North-Central Section, 6(6):527.

Majewske, O. P., 1969, Recognition of invertebrate fossil fragments in rocks and thin sections, Leiden, Brill, 210p.

Moore, R. C., 1935, Stratigraphic classification of Pennsylvanian rocks of Kansas, Kansas Geol. Survey Bull., 22:124-137.

________, 1941, Upper Pennsylvanian gastropods from Kansas, Kansas Geol. Survey Bull., 38(4):121-163.

________, 1949, Divisions of the Pennsylvanian System in Kansas, Kansas Geol. Survey Bull., 83:203.

________, 1964, Paleoecological aspects of Kansas Pennsylvanian and Permian cyclothems, Kansas Geol. Survey Bull., 169(1):287-381.

________ and Dudley, R. M., 1944, Cheilotrypid bryozoans from Pennsylvanian and Permian rocks of the mid-continent region, Kansas Geol. Survey Bull., 52 (6):229-408.

________, Frye, J. C. and Jewett, J. M., 1944, Tabular description of outcropping rocks in Kansas, Kansas Geol. Survey Bull., 52(4):186.

Mudge, M. R. and Yochelson, E. L., 1962, Stratigraphy and paleontology of the uppermost Pennsylvanian and lowermost Permian rocks in Kansas, USGS Prof. Paper 323, 213p.

Newell, N. D., 1931, New Schizophoriidae and a trilobite from the Kansas Pennsylvanian, Jour. of Paleo., 5:260-269.

_________, 1933, The stratigraphy and paleontology of the upper part of the Missouri Series in eastern Kansas, unpub. Ph.D. dissert., Yale Univ., 247p.

_________, 1934, Some Mid-Pennsylvanian invertebrates from Kansas and Oklahoma: 1 Fuslinidae, Brachiopoda, Jour. of Paleo., 8:422-432.

_________, 1935, The geology of Johnson and Miami Counties, Kansas, Kansas Geol. Survey Bull., 21(1)77-78.

_________, 1937, Late Paleozoic pelecypods; Pectinacea, Kansas Geol. Survey Bull., 10(1):123p.

_________, 1942, Late Paleozoic pelecypods; Mytilacea, Kansas Geol. Survey Bull., 10(2):115p.

Pray, L. C. and Wray, J. L., 1963, Porous algal facies (Pennsylvanian), Honaker Trail, San Juan Canyon, Utah, IN: Shelf carbonates of the Paradox basin, Four Corners Geol. Soc. 4th Field Conf., p. 204-234.

Sander, B., 1951, Contributions to the study of depositional fabrics--rhythmically deposited Triassic limestones and dolomites, AAPG Bull., translated from original German by E. B. Knopf.

Spencer, R. S., 1967, Pennsylvanian Spiriferacea and Spiriferinacea of Kansas, Univ. of Kansas Paleo. Contribs., Paper 14, 35p.

Sutherland, P. K. and Harlow, F. H., 1967, Late Pennsylvanian brachiopods from north-central New Mexico, Jour. of Paleo., 5:1065-1089.

Terriere, R. T., 1960, Geology of the Grosvenor Quadrangle, Brown and Coleman Counties, Texas, USGS Bull., 1096-A:1-35.

Thorp, E. M., 1936, Calcareous shallow-water marine deposits of Florida and the Bahamas, Carnegie Inst. Wash. Pub. 452, Pap. Tortugas Lab., 29:37-119.

Vaughan, T. W., 1918, Some shoal-water bottom samples from Murray Island, Australia, and comparison of them with samples from Florida and the Bahamas, Carnegie Inst. Wash. Pub. 213, Pap. Tortugas Lab., 9:285-288.

Wagner, H. C., 1964, Pennsylvanian megacyclothems of Wilson County, Kansas, and speculations concerning their depositional environments, Kansas Geol. Survey Bull., 169(2):565-591.

Wilson, F. W., 1962, A discussion of the origin of the reeflike limestone lenses of the Lansing Group (Upper Pennsylvanian) of southeast Kansas, Kansas Geol. Soc. 27th Field Conference, pp. 101-105.

Wray, J. L., 1964, Archaeolithophyllum, an abundant calcareous alga in limestones of the Lansing Group (Pennsylvanian), southeastern Kansas, Kansas Geol. Survey Bull., 170(1):1-13.

________, 1965, Calcareous algae in limestones of the Lansing Group, IN: Pennsylvanian marine banks in southeastern Kansas, Geol. Soc. American Ann. Mtg., Kansas City, Field Conf. Guidebook, p. 47-54.

APPENDICES

APPENDIX A

LOCALITY REGISTER

APPENDIX A

LOCALITY REGISTER

Mound Localities

Locality CSL 8 29 15 Stoner member

SW¼, SE¼, sec. 8, T29S, R15E; roadcut along north side of Kansas highway 47; locality code: center of south line of section 8.

Locality SAW Stoner member

Southeast corner, sec. 8, T29S, R15E; small roadcut on the north side of K-47; locality code: Schneider's Auto Wrecking.

Locality CSL 9 29 15 Stoner member

Center of south line of section 9, T29S, R15E; roaduct exposure on south side of K-47.

Locality MANPF Captain Creek and ?Stoner members

NW¼, SW¼, sec. 7, T29S, R15E; large exposure on section line road, ½ km north of K-47; locality code: mound north of Altoona at Pettit's Farm.

Locality ESL 12 29 15 Stoner member

SE¼, SE¼, sec. 12, T29S, R15E; small roadditch exposure on the north side of K-47.

Locality QNWC 23 29 15 Captain Creek member

NW¼, NW¼, sec. 23, T29S, R15E; inoperative water-filled quarry in the extreme northwest corner of section 23.

Locality CSL 22 30 15 Captain Creek and ?Stoner members

Center of south line section 21, T30S, R15E; long roadcut exposure on north and south sides of Kansas highway 96, 5.5 km west of Neodesha.

Locality CSL 21 30 15 Captain Creek member

Center of south line, section 21, T30S, R15E; small roadcut exposure on south side of K-96.

Locality SWC 21 30 15 Captain Creek member

SW¼, SW¼, sec. 21, T30S, R15E; small exposure in the extreme southwest corner of section 21.

Locality SWC 22 30 15 Captain Creek member

SW¼, SW¼, sec. 22, T30S, R15E; roadditch exposures on north and south side of K-96; extreme southwest corner of section 22.

Locality CSL 22 29 15 Captain Creek member

SE¼, SW¼, sec. 22, T29S, R15E; poor roadditch exposure near the center of the south line of section 22.

Locality NWC 16 30 15 Captain Creek member

NW¼, NW¼, sec. 16, T30S, R15E; small roadditch exposure in the extreme northwest corner of section 16.

Locality PFQ Captain Creek member

SE¼, NE¼, sec. 26, T29S, R14E; large inoperative quarry at Pryor's Farm, approximately 4 km south of Fredonia.

Locality Jct 75-39 Captain Creek member

NE¼, SW¼, sec. 17, T27S, R16E; field and roadcut exposures on the north side of the junction of U. S. highway 75 and Kansas highway 39.

Locality NQEB Captain Creek and Stoner members

NE¼, NE¼, sec. 22, T27S, R16E; large inoperative water-filled quarry; excellent exposures along quarry ramp; locality code: New Quarry East of Buffalo.

Locality RRSENQEB Captain Creek and Stoner members

NW¼, SW¼, sec. 36, T27S, R16E; exposure along north and south side of Atchison, Topeka and Santa Fe Railway; locality code: Railroad Southeast of the New Quarry East of Buffalo.

Locality WCSLS Captain Creek member

SE¼, SW¼, sec. 17, T27S, R16E; large exposure in the Wilson County State Lake Spillway, north and south of U.S. 75.

Locality WCSLOQ Captain Creek and Stoner members

SE¼, SE¼, sec. 17, T27S, R16E; inoperative quarry on south side of U.S. 75, less than 1 km east of WCSLS; locality code: Wilson County State Lake Old Quarry.

Locality QSEC 25 30 14 Stoner member

SE¼, SE¼, sec. 25, T30S, R14E; small inoperative quarry in field in the southeast corner of section 25.

Locality EQ Captain Creek member

SW¼, SW¼, sec. 5, T27S, R17E; inoperative quarry on south side of Wilson-Woodson County line road; locality code: Erickson's Quarry (presently Nelson's quarry).

Locality QCSL 7 30 15 Captain Creek and ?Stoner members

SE¼, SW¼, sec. 7, T30S, R15E; inoperative quarry in pasture near south center of section 7; also known as Graff's Quarry.

Locality CSL 10 29 15 Captain Creek member

Center of south line section 10, T29S, R15E; roadcut exposure of lowermost Stanton and underlying Vilas Shale on the north side of K-47.

Locality WSL 6 28 17 Captain Creek member

SE¼, SW¼, sec. 6, T28S, R17E; small roadcut exposure of lowermost Stanton near west end of the south line of section 6.

Locality CWL 6 28 17 Captain Creek member

NE¼, SE¼, sec. 1, T28S, R16E; small roaduct exposure on west side of road and outcrop in field approximately 100 meters west of roadcut; locality code: center of west line section 6.

Locality QSWC 36 27 16 Captain Creek member

SE¼, SW¼, sec. 36, T27S, R16E; abandoned and partially water-filled quarry in pasture approximately ½ km northeast of the southwest corner of section 36.

Channel Localities

Locality NEC 14 29 15 Stoner member

SE¼, NE¼, sec. 14, T29S, R15E; small, rubbly exposure on hillside in pasture; south side of K-47.

Locality ANPF ?Captain Creek and Stoner members

NW¼, SW¼, sec. 7, T29S, R16E; excellent exposure of channel-margin beds dipping south toward channel-center; locality code: Altoona cut North at Pettit's Farm.

Locality ELNC 18 29 15 Stoner member

SW¼, NW¼, sec. 18, T29S, R15E; small exposure of channel-margin beds dipping toward channel center.

Localities ACS and ACN Stoner member

R16E

Center of north line section 18, T29S, R15E; excellent roadcut exposure of channel-center lithology on north and south sides of K-47; locality code: Altoona Cut North and South.

Localities QWA-l and QWA-u Stoner member

R16E

NE¼, NW¼, sec. 18, T29S, R15E; active aggregate quarry west of Altoona; locality code: Quarry West of Altoona lower and upper portions.

Locality FQWA Stoner member

R16E

NE¼, NW¼, SW¼, sec. 18, T29S, R15E; small exposure of channel-margin beds in pasture immediately behind barn; locality code: Farm behind the Quarry West of Altoona; also known as Hoff's Farm.

Locality EEQ Stoner member

NE¼, NW¼, sec. 3, T27S, R17E; small, rubbly road-ditch exposure on the north side of the Wilson-Woodson County line road; exposure is of calcarenite associated with the major Woodson County channel; locality code: East of Erickson's Quarry.

Locality EQ-ch Captain Creek member

NW¼, NE¼, sec. 5, T27S, R17E; small, calcarenite channel exposure in the southeast corner of Erickson's Quarry; locality code: Erickson's Quarry-channel.

Locality QEWW Stoner member

SE¼, SE¼, sec. 14, T29S, R14E; abandoned quarry south of Fredonia presently being used as a sanitary landfill; locality code: Quarry East of the Water Works.

Locality ESL 12 29 15 Stoner member

SE¼, SE¼, sec. 12, T29S, R15E; small roadcut exposure of channel-margin beds on north and south sides of K-47; locality code: East on South line of section 12.

Locality OF Captain Creek and Stoner members

SE¼, SE¼, SE¼, sec. 29, T28S, R17E; outlier of channel-center beds exposed on hill immediately northwest of farmhouse; locality code: Orneilas' Farm.

Locality FNW Stoner member

NE¼, SW¼, NE¼, sec. 24, T29S, R14E; inactive northwest wall of the Fredonia Cement Plant Quarry; type section of Newell's (1933) "Fredonia facies"; locality code: Fredonia Northwest.

Locality FNC Captain Creek and Stoner members

SW¼, NW¼, sec. $\overset{19}{9}$, T29S, R15E; inactive north-central wall of the Fredonia Cement Plant Quarry; located east of FNW; locality code: Fredonia North-central.

Locality FNE Captain Creek and Stoner members

19

SE¼, NW¼, sec. 9, T29S, R15E; inactive east end of the north wall of the Fredonia Cement Plant Quarry; located adjacent to FNC; locality code: Fredonia Northeast.

Rim Localities

Locality CNL 5 27 16 Stoner member

Center of the north line of section 5, T27S, R15E; small roadditch exposure on south side of Wilson-Woodson County line road.

Locality WNL 5 27 16 Stoner member

West on north line of section 5, T27S, R16E; poor, rubbly roadditch exposure approximately 70 meters west of CNL 5 27 16 on south side of Wilson-Woodson County line road.

Locality NBRC Stoner member

SE¼, SE¼, sec. 6, T27S, R16E; long roadcut exposure on the east side of U.S. highway 75 north of Buffalo; locality code: North Buffalo Road Cut.

Locality RDNB Stoner member

NE¼, SE¼, sec. 6, T27S, R16E; roadditch exposure on east side of U.S. 75 north of Buffalo; locality code: Road Ditch North of Buffalo.

Locality RDSWB Stoner member

NE¼, SE¼, sec. 13, T27S, R15E; roadditch exposure on south side of section line road approximately ½ km east of the Missouri Pacific Railroad crossing; locality code: Roadditch Southwest of Buffalo.

Locality SE SW 18 27 16 Stoner member

SW¼, SE¼, sec. 18, T27S, R16E; small roadcut exposed on the west side of highway 39 less than 1 km south of the junction of highways 39 and 75.

Locality CSL 13 27 15 Stoner member

Center of the south line of section 13, T27S, R15E; small roadcut exposure on the east side of K-39.

Locality NW SW 24 27 15 Stoner member

NW¼, SW¼, sec. 24, T27S, R15E; myalinid "clam" beds exposed in roadditch along east side of K-39.

Locality SWL 24 27 15 Stoner member

SW¼, SW¼, sec. 24, T27S, R15E; small, rubbly exposure in roadditch along the west side of K-39; locality code: West on South line of section 24.

Locality CNE 26 27 15 Stoner member

NE¼, NE¼, sec. 26, T27S, R15E; small roadcut exposure along east side of K-39; locality code: Center of the northeast quarter of section 26.

Locality CNE 26 27 15-2 Stoner member

SE¼, NE¼, sec. 26, T27S, R15E; continuation of previous locality, approximately 200 meters south, along the east side of K-39.

Locality CNE 26 27 15-w Stoner member

NW¼, NE¼, sec. 26, T27S, R15E; same units exposed as in previous two localities; exposure along the west side of K-39.

Locality SW NE 26 27 15 Stoner member

SW¼, NE¼, sec. 26, T27S, R15E; final exposure in series of small roadcuts in section 26; exposed on the east side of K-39.

Locality DQSR Stoner member

SW¼, SE¼, sec. 35, T27S, R15E; inoperative water-filled quarry approximately 100 meters east of K-39 in pasture; locality code: Doyle's Quarry South of Roper.

Locality RDSDF Stoner member

NE¼ through SE¼, NW¼, sec. 2, T28S, R15E; continuous exposures in roadditch along east and west sides of K-39; locality code: Road Ditch South of Doyle's Farm.

Locality RDWC 2 28 15 Stoner member

NW¼, NW¼, sec. 2, T28S, R15E; small, rubbly exposure in roadditch; locality code: Roadditch--West corner of section 2.

Locality BB Stoner member

NE¼, NE¼, sec. 16, T28S, R15E; excellent exposures along banks of the Verdigris River at the Benedict Bridge (low-water ford southwest of the town of Benedict).

Locality BRC Captain Creek member

NE¼, NE¼, sec. 10, T28S, R15E; type section of the Benedict bed (dense skeletal oolite); exposed in a roadcut north of Benedict and approximately 200 meters south of the town dump.

Locality EC 22 29 14 Stoner member

SW¼, NE¼, sec. 22, T29S, R14E; excellent bedding plane exposures in pasture behind farmhouse.

Locality NCL NE 24 27 15 Stoner member

SW¼, NE¼, sec. 24, T27S, R15E; poor exposure in roadditch along the west line of section 24.

Locality PR Stoner member

Center of the NW¼, sec. 21, T28S, R15E; poor exposure (dredged blocks and slabs) along small creek near western edge of ranch; locality code: Pfeiffer's Ranch.

Locality PRP Stoner member

NW¼, sec. 21, T28S, R15E; approximately 2/3 km south and 400 meters of Pfeiffer's Ranch farmhouse in abandoned pasture; dredged blocks and slabs brought up in drainage ditches in pasture; locality code: Pfeiffer's Ranch Pond.

Locality EB Stoner member

NW¼, NW¼, sec. 2, T28S, R15E; exposure on stream bank slope of the Elders Branch of the Verdigris River.

Locality PFQ Captain Creek and Stoner members

SE¼, NE¼, sec. 26, T29S, R14E; exposure of rim calcarenite overlying Captain Creek mound in inoperative quarry; locality code: Pryor's Farm Quarry.

Locality NWL 22 28 15 Stoner member

NW¼, SW¼, sec. 22, T28S, R15E; poor exposure of dredged blocks in roadditch along abandoned section line road; locality code: North on the west line of section 22.

APPENDIX B

TAXONOMIC PROBLEMS

APPENDIX B

TAXONOMIC PROBLEMS

Composita Problem

Examination of *Composita* specimens from Stanton Limestone outcrops yields two similar species and a third species which displays characteristics that are somewhat similar to the other two. Dunbar and Condra (1932) reviewed *Composita* specimens from several Stanton localities and described three similar species: *Composita subtilita* (Hall), *C. ovata* Mather and *C. elongata* Dunbar and Condra. However, their discussions note that ". . . Compositas of the Pennsylvanian System are so varied in form as to invite subdivision into several species and at the same time to make that subdivision difficult (p. 365)." Despite this difficulty in separation they maintained these forms as separate species, describing greatly different juvenile shapes: *C. ovata* is shaped like a thin circular lens, whereas *C. subtilita* is much longer than wide and much thicker than *C. ovata* (p. 371). *C. elongata* is described as being much smaller and elongate and more easily mistaken for *Dielasma* than the other *Composita* species (p. 372).

Specimens considered in this report can be separated with moderate success, but they do show some variation. Large samples from individual localities frequently contain distinct *C. subtilita* and *C. ovata* types, but also contain dozens of specimens intermediate in shape. *C. elongata* is a rare element, and not always distinct, resembling *C. subtilita* in many features. The variation in these species and their common occurrence suggests that they may not be discrete species, but actually end members illustrating extremes of intra-populational variation.

Detailed morphologic studies on *Composita* show similar problems of variation between species. Sutherland and Harlow (1967) note that specimens of *C. subtilita* and *C. ovata* from north-central New Mexico show marked variation in shape and character. Grinnell and Andrews (1964) contend that intergradation between typical specimens exists to a varying extent, and that this is particularly prevalent in large collections. A more recent investigation of the problem utilizes biometric analysis on a sample of more than 700 *Composita* specimens (Lutz-Garihan, 1974). The study concludes that the sample consists of an intergradational population of individuals which cannot be separated into groups clearly interpretable as separate species, and that *C. subtilita* and *C. ovata* should be regarded as end members in the population. She further concludes that these end members do not differ significantly in distribution, abundance or stratigraphic horizons, and that they must therefore be recognized not as subspecies but as intraspecific morphotypes.

Lack of sufficient material precludes conclusive illustration of intergradation in the Stanton. However, observed variation in specimens collected seems to sustain morphotypic designations in this study. *Composita elongata* and *C. ovata* appear to represent extremes of variation in what will be referred to herein as *Composita* "*subtilita*."

Enteletes Problem

Specimens of *Enteletes* from the lower Stanton show marked similarity in all morphological features except the fold, which may be clearly unicrested, bicrested, tricrested or transitional in nature. Newell (1931) was the first to recognize variation in Upper Pennsylvanian and Permian enteletids and attempted a refinement of the species *Enteletes hemiplicatus* (Hall), which embraced all Mid-continent forms until that time. Analysis of morphologic features and stratigraphic ranges prompted Newell to establish three new species and a new variety. Of particular interest are bicrested *E. pugnoides* Newell and unicrested *E. hemiplicatus* var. *plattsburgensis* Newell, each described from cotypes from the Lansing Group (Newell, 1931). Stratigraphic ranges for these species established first occurrences in the Farley and Argentine Limestones (Kansas City Group), and final appearances in the Meadow (now Captain Creek) Limestone.

Dunbar and Condra (1932) reviewed extensive *Enteletes* collections and accepted Newell's species as valid. *Enteletes hemiplicatus* var. *plattsburgensis* closely resembles unicrested *E. hemiplicatus*, but may be distinguished by its smaller size, earlier development of lateral plications, and somewhat lower stratigraphic range (*E. h.* var. *plattsburgensis*, Argentine and Farley to lower Stanton; *E. hemiplicatus*, Plattsmouth limestone, Shawnee group, to the . . . upper part of the Wabaunsee group, Virgilian). *Enteletes pugnoides* approaches *E. hemiplicatus* var. *plattsburgensis* in size, proportion, and stratigraphic range, differing only in a bicrested fold. Dunbar and Condra (1932) note that juvenile forms of Newell's species are indistinguishable and that crests in both appear to arise independently in contrast to bifurcation of a single crest. The mature crests however appear distinct morphologically and apparently separate valid populations.

Two specimens from the Captain Creek near Eudora and Garnett, Kansas having the general shape and proportions as *E. hemiplicatus* and *E. pugnoides*, but possessing a tricrested fold, prompted Bridwell (1939) to establish a third species, *Enteletes costidorsitriplicatus*. Close comparison is made with *Meekella striatocostata*, but possession of fine radial lirae, the origin of lateral plications and other surficial markings clearly established this new species as an enteletid. It is interesting to note that Bridwell concluded his article with the statement; " . . . when closely associated (stratigraphically), specimens should be considered belonging to the same species if the parts which are comparable are practically identical."

Haglund (1967) again opened the *Enteletes* problem by reexamining earlier collections and re-collecting key localities. Biometric analyses of external features and serial observation of often poorly preserved internal morphology revealed no substantial differences between single and multi-crested species. Haglund also observed a continuous sequence of crest variation between uni- and multi-crested forms suggesting randomness in development. He concluded that the number of fold crests has little systematic importance, and effectively synonymized *E. pugnoides*, *E. hemiplicatus* var. *plattsburgensis* and *E. costidorsitriplicatus*, choosing *Enteletes pugnoides* Newell as name bearer for the species. Stratigraphically, *E. pugnoides* (*sensu* Haglund) has been reported throughout the Upper Missourian to as high as the Plattsmouth Limestone (lower Virgilian).

All three crest types have been identified from several localities in the current study. Bicrested forms appear to be more abundant and are normally associated with sub-equal numbers of uni- and tri-crested forms. A few localities yield only one form, but this may be attributable to low numbers of recovered specimens. Intermediate crest variation can be seen on several specimens, especially as abnormally sub-equal crest heights in multi-crested forms.

The *Enteletes* problem in the lower Stanton is clearly pivotal upon original typological definition of species and character weighting of fold crests. Newell (1931) and Dunbar & Condra (1932) admit the rare occurrence of transitional crests, lending some credibility to the single variable species proposal. However, Haglund (1967) leaves room for doubt by noting that the occurrences of *E. pugnoides* as high as the Plattsmouth are only single crested forms. Despite these unexplained unicrested occurrences, Haglund's proposal seems most reasonable. Therefore, use of *Enteletes* "*pugnoides*" Newell in this paper will include all Stanton variations of *E. pugnoides* and *E. hemiplicatus* var. *plattsburgensis sensu* Newell (1931) and *E. costidorsitriplicatus sensu* Bridwell (1939).

Neospirifer Problem

In 1852, Hall described *Spirifer triplicata* which Morton later regarded as synonymous with his *Spirifer cameratus*. Morton's evaluation was considered valid until Girty found *S. triplicata* Hall to be distinct from *S. cameratus*, and re-established Hall's species (King, 1933). In their synthesis of Mid-Continent Pennsylvanian brachiopods, Dunbar & Condra (1932) referred Hall's species to the genus *Neospirifer*, hence *N. triplicatus* (Hall). However, unknown at this time was Kutorga's 1842 species of *Spirifer triplicata* which pre-occupied the name. Realizing the homonymy, King (1933) renamed *N. triplicata* as *Neospirifer dunbari*.

Dunbar & Condra (1932) recognized two varieties of *N. dunbari* (=*triplicatus*), *N. dunbari* var. *alatus* and *N. dunbari* var. *gibbosus*. The former appears to have arisen from the *dunbari* stock by developing unusually transverse proportions. Shell plications maintain the subangular shape and strong fasiculation characteristic of *N. dunbari*, but also develop simple plications on the extended wing-like projections. In contrast to the alate form, the gibbous variety is strongly convex and the ventral cardinal area is shortened from the elongate rectangular shape characteristic of *N. dunbari* to an exceptionally high triangular shape in *N. d.* var. *gibbosus*.

The concept of *Neospirifer dunbari* in the Upper Pennsylvanian becomes somewhat clouded with the comments of several authors. Sturgeon & Hoare (1968) note that within *N. dunbari* there is ". . . a considerable amount of variation in the number and arrangement of bifurcations of costae and costellae," and that the ". . . amount of variation appears to be as great within a population as between populations." Dunbar and Condra allude to shell variations particularly between *dunbari* and the alate variety. The two forms seem to more or less intergrade, but the alate variety remains distinct partially due to a more limited stratigraphic range. Spencer (1967) describes the ranges of all three forms, listing *N. dunbari dunbari* as the most conservative and ranging throughout the entire Pennsylvanian. The alate and gibbous varieties interestingly enough have virtually identical ranges first appearing in the Dennis Limestone (lower Kansas City

Group) and expiring in the Howard Limestone (Wabaunsee Group, middle Virgilian).

Several dozen specimens have been collected and identified from the Stanton during the current study. Few specimens are well preserved in all details, but enough remains to identify most as *N. dunbari*, and to observe variants approaching dimensions and proportions of the gibbous and alate varieties. Definite identification of these varieties could not be made from available material.

From the previous discussions of *Composita* and *Enteletes*, it is reasonable to consider the possibility of a complete range of variation from alate through gibbous forms within the Upper Pennsylvanian *Neospirifer dunbari* lineage. The factors which could induce such a diversification of form during this particular time remain unknown.

The concept of three distinct *dunbari* varieties is maintained in this study. Usage of *Neospirifer* "*dunbari*" in this paper is collective for all forms similar to the three varieties, but not clearly separable as *N. d. dunbari*, *N. d. alatus* and *N. d. gibbosus*.

APPENDIX C

RAW DATA--TABLES

Table 12--Raw data counts for all quadrated surfaces in the mound, channel and rim facies.

Table 12

Quadrat Counts

Locality	Area (cm^2)	Echino	Bryoz	Algae	Brach	Clams	Gasts	Corals	Forams
				Mound Quadrats					
QNWC 23•29•15	5600	9		421	63			1	
QNWC 23•29•15	2100			168	26			3	
QNWC 23•29•15	6600	18		450	44			2	
ESL 12•29•15	6200	14		464	32				
JCT 75-39	10000	31		500	35			1	
EQ	3300	96	5	449	52			1	
EQ	3300	309	2	379	56			1	
RRSENQEB	1000	92	5	271	20			3	
CSL 22•30•15	2100	14		35	19		1		
CSL 22•30•15	2500	66		34	15				
WSL 6•28•17	2700	26		367	77				
				Channel Quadrats					
EQ	4100	105	1		162	1			
OF	1000	136	22		42	1		8	
OF	10000	9	3		24			1	

Table 12 (cont'd.)

Locality	Area (cm^2)	Echino	Bryoz	Algae	Brach	Clams	Gasts	Corals	Forams
Rim Quadrats									
NW SW 24·27·15	7300	42	1		37	109		1	
NW SW 24·27·15	3500	67			25	115		1	
BRC	3900	10	23		413	98	53	7	
BRC	10000	172	212		75	23		2	
DQSR	5400	38	20		50	2		2	
DQSR	1000	208	81		16	1		1	61
BB	10000	213	168		92	2		1	
BB	9000	317	221		93	5			
QEWW	2000	351	1		8	4		4	

Table 13--Point-count data for mound, channel and rim facies thin-sections examined for bulk sedimentologic composition. Symbols represent: SP=spar; M=mud; V=void; E=echinoderms; BY=bryozoans; A=algae; F=foraminifers; BA=brachiopods; CL=bivalves; O=ostracods; G=gastropods; CO=coelenterates (corals); OL=ooliths.

Table 13

Bulk Composition Counts

			Rim Facies										
Locality	SP	M	V	E	BY	A	F	BA	CL	O	G	CO	OL
RDWC 2·28·15	133	76		15	24		2	3	2		2	1	
NCL NE 24·27·15	81	71		48	38		6	7	2		2		
CNE 26·27·15-W	38	134		13	24		9	2	24	6			
CNE 26·27·15-W	45	65	3	44	42		4	16	25		4	2	
CNE 26·27·15-W	51	128		13	26	9	5	11	4	2	1		
CNE 26·27·15-W	14	98	7	48	75	1	1	5		1			
CNE 26·27·15-W	66	110	5	21	42	7		2	6	2			
CNE 26·27·15-2	93	111	1	16	22	4		1	7		1		
CNE 26·27·15-W	86	89		20	44	1	5	3	2				
PR	63	124		15	16	4	15	7		6			
PR	65	120		11	20	5	10	12	3	2	2		
PRP	119	107		5	6	2	4	2		6			
PRP	88	107		11	16	8	11	6		4			
EB	40	87		42	71	1	3	3	2	1			
EB	63	66		52	60		2	2		4	1		
RDSDF	86	54	30	35	41		4						
RDSDF	50	148		3	16	6	10	7					
RDSDF	81	65	14	23	50	2	5	1		9			
RDSDF	129	51	23	4	13			18		12			
RDSDF	97	62	4	27	48	1		5	1	5			
PFQ	111	56	7	71	5								
PFQ	133	34	4	63	7			4		5			
PFQ	159	34	21	34	2								
PFQ	89	83	1	19	14	2	35		1	5			
BRC	93	46	2	6	9		2	22	7				63

Table 13 (cont'd.)

Locality	SP	M	V	E	BY	A	F	BA	CL	O	G	CC	CL
BRC	85	40		5	10	3		34	5	2	6		60
BRC	120	35		8	2			14	6	2	2		57
BRC	75	91		12	31		15	2	1	2	1		17
BRC	71	29		1	3	2	1	43		1	6		92
WCL NE 24•27•15	125	41	11	31	17	1	3	3	2	6	9		
WCL NE 24•27•15	109	53	8	5	23	9	11	6	5	2	10		
BB	101	75	12	37	15	3	3	1	2		1		
BB	109	22		98	17		3	1					
BB	77	97	1	27	36		9			2	1		
BB	51	81		64	47		6	1					
NWL 22•28•15	102	122	5	6	7		8						
NWL 22•28•15	77	134	4	4	18		8		4	1			
NBRC-nb	156	20	29	14	11		8	4		2	6		
NBRC-nm	152	16	26	17	15		4	4	3	4	9		
DQSR-3	110	108		5	18		8			1			
DQSR-2	84	128	2	2	11	7	12			3	1		
CNL 5•27•16-2	145	30	5	5	2	34	4	1	2	2	20		
DQSR-1	87	70	3	42	26	1	6	9	4	2			
RDNB-2	92	92	13	16	20		2	12	2		1		
Mound Facies													
BRC-t	44	146	2	3	25	1	26	1		2			
CSL 22•30•15	92	151	1	3				1		1	1		
CSL 22•30•15	61	160	1	10	6	1	7		4				
CSL 22•30•15	60	176			1	13							
CSL 22•30•15	69	160			4	16		1		1			
CSL 22•30•15	59	166				20	2	1	2				

Table 13 (cont'd.)

Locality	SP	M	V	E	BY	A	F	BA	CL	O	G	CO	OL
CSL 22·30·15	60	170		2	5	1	5		5	1	1		
CSL 22·30·15	67	166		4	7		5	1					
WCSLS-2	84	140	1	3	6	13	1	2					
WCSLS	43	174	3	24		1	2		3	1			
WCSLS-A	72	160	8		1	4	5	3					
WCSLS-B	120	118		8	1		1			2			
WCSLS-D	105	99		2	2	30	12						
WCSLS	10	162	43	9	7	15	4			4			
WCSLS	56	173	6	3	1	8	2	3	1	1			
WCSLS	68	147	18	2	3	10	2						
QCSL 7·30·15	50	156	7	5	15	9	8						
QCSL 7·30·15	39	140	11	4	25	14	14			3			
QCSL 7·30·15	54	154	7	1	8	17	7	1	1				
QCSL 7·30·15	43	158	3	8	13	11	1	9	4				
QCSL 7·30·15	42	172			11	12	6			6	1		
QCSL 7·30·15	46	152		4	16	7	15	3		4	3		
QCSL 7·30·15	68	139	3	6	8	14	8	1		3			
QCSL 7·30·15	41	158	1	5	14	13	10	3		2	3		
CSL 9·29·15	60	155	6	2	10	3	6	3	2	3			
CSL 9·29·15	45	168		6	14	1	5	5	1	4	1		
CSL 9·29·15	59	166		1	7		9	1		7			
SWC 21·30·15	42	133	3	1	3	42	13	4	3	6			
SWC 21·30·15	21	169	2	1	19	19	8	1	2	8			
CSL 22·29·15	28	183		13	9	11	5			1			
CSL 22·29·15	18	181	7	3	27		3	1	5	5			

Table 13 (cont'd.)

Locality	SP	M	V	E	BY	A	F	BA	CL	O	G	CO	OL
SWC 22•30•15	74	137		2	14	7	8	1	1	6			
CSL 21•30•15	42	156			7	14	23			8			
CSL 21•30•15	68	69	5		1	94	8						
NE 15•30•15	103	114	10	4	7	3	5	1	2				
EQ	74	146	16	3	3	7				1			
EQ	45	155	3	4	9	18	2	10	3		1		
QSWC 36•27•16	75	143	2	2		26	1	1		1			
QSWC 36•27•16	109	132	5				3		1				
QSWC 36•27•16	38	167		4	16	1	13	1	3	7			
WSL 6•28•17	58	171	2			11	4	1		3			
WSL 6•28•17	50	196	4										
WSL 6•28•17	65	155	4		6	14	1		3	1			
WSL 6•28•17	112	100	4	5	3	8	13	4	1				
RRSENQEB	34	150		17	26	6	9	5	1	2			
RRSENQEB	58	140		11	4	22	7	3	2	3			
RRSENQEB	87	141		6	4	8	2			2			
RRSENQEB	79	116		15	28	4	2	1		3	1		
CSL 8•29•15-2	56	160	6	1	4	7	10	3	1	2			
CSL 21•30•15	44	155		4	6	16	15	3		7			
EEQ	13	174		3	29	21	6		3	1			
NQEB	48	185			1	1	10		5				
NQEB	6	165		5	40		12	6	11	5			
MANPF	63	132	1	15	18	11	4	2		3	1		
MANPF	115	114	7	4	8			1		1			

Channel Facies

Locality	SP	M	V	E	BY	A	F	BA	CL	O	G	CO	OL
FNW-2B	173	16	25	35							2		

Table 13 (cont'd.)

Locality	SP	M	V	E	BY	A	F	BA	CL	O	G	CO	OL
FNW-2B	185	10	20	33	1				1				
FNW-2C	170	35	23	17			2		3				
FNW-2D	170	16	30	21				9	4				
FNW-2E	97	54	17	43	28		1	4	6				
FNW-1A	163	38	19	29			1						
FNW-1A	182	14	38	15									1
FNW-1B	51	133		30	33		2		1				
FNW-1E	96	92	5	15	32		8		2				
FNW-1F	80	93		13	51		5	2	6	1			
QWA-11	75	92		43	31			2	7				
QWA-12	86	110	2	30	11		3		8				
QWA-13	189	23	2	16	2		1	1	3		1	13	
QWA-14	72	92	18	29	25	2	6		7				
QWA-15	100	96		18	23	5	2		5	1			
QWA-16	85	103	4	21	24		4		9				
QWA-17	133	28	11	49	16	1		1	11				
QWA-18	127	54	9	27	23		5		4		1		
QWA-19	67	113	10	23	29	1	6		3				
ACS-1	87	112		33	25		12	1	3	2			
ACS-2	116	29	55	43	2		2		3		1		
ACS-2	123	28	56	42				2					
ACS-3	72	105	1	4	59		1	4	4				
ACS-4	50	125		28	31		5	4	5	1	1		
ACS-5	88	81	1	26	38		11		5				
ACS-5	55	113	8	30	30		9	2	3				

Table 13 (cont'd.)

Locality	SP	M	V	E	BY	A	F	BA	CL	O	G	CO	OL
ACS-9	65	120		12	43		2	4	2	1	1		
ANPF-4	52	150	9	10	23		2	1	3				
ANPF-6	81	108	5	20	20		10	4	1		1		
ELNC 13•29•15	94	95	5	20	27		3	1	5				
ELNC 13•29.15	82	110		25	19		4	1	8		1		
ELNC 13•29•15	88	108	3	13	26		6	1	4		1		
ELNC 13•29•15	112	97	2	23	6		5		3	1	1		
NLE 13•29•15	84	71	1	56	34			3				1	
NLE 13•29•15	63	108	10	6	5	42	10		5				
NLE 13•29•15	24	159		5	15	36	6	1	3		1		
NLE 13•29•15	64	112	9	3	7	50	3	1	1				
NLE 13•29•15	59	108	6	25	44		2	1	4	1	1		
EQ-NWch	134	30		63	19		2	2					
CWL 6•28•17	164	32	2	15	7	9	5	5	5	2	4		
CWL 6•28•17	95	126	24		1	2		1		1			
OF	83	88	14	36	2	2	9	16	1				
OF	48	135		7	27	1	12	15	1	1	3		

Table 14--Point-count data for mound, channel and rim facies thin-sections examined for skeletal composition. Symbols represent: ECH=echinoderms; BRY=bryozoans; ALG=algae; BRA=brachiopods; CLA=bivalves; OST=ostracods; COR=coelenterates (corals); MIS=miscellaneous (all others).

Table 14

Skeletal Grain Counts

Locality	ECH	BRY	ALG	FOR	BRA	CLA	OST	GAS	COR	MIS
				Rim Facies						
RDWC 2·28·15	42	67		7	10	4		4	1	1
NCL NE 24·27·15	78	77		11	15	13		3	2	1
CNE 26·27·15-W	16	39		9	3	26	7			
CNE 26·27·15-W	73	59		7	20	34		4	3	
CNE 26·27·15-W	19	44	10	8	11	4	3	1		
CNE 26·27·15-W	57	80	1	1	5		1			
CNE 26·27·15-W	25	55	8		2	8	2			
CNE 26·27·15-2	34	50	5		3	7		1		
CNE 26·27·15-W	52	133	1	14	6	5				
PR	25	29	4	23	9	1	9			
PR	31	47	9	22	23	6	6	4		
PRP	15	43	7	11	14		10			
PRP	31	41	20	23	16		9			
EB	68	111	4	5	4	2	6			
EB	82	168	1	25	8	2	12	3		
RDSDF	81	105	2	6	6					
RDSDF	6	36	10	15	14		19			
RDSDF	53	115	3	8	1	1	19			
RDSDF	13	29			33		12	1		
RDSDF	57	121	1		12	1	7	1		
PFQ	129	13	2		5		1			
PFQ	141	36		3	9	1	10			
PFQ	66	13								
PFQ	38	42	11	44		4	11			
BRC	7	16		14	49	11		3		

Table 14 (cont'd.)

Locality	ECH	BRY	ALG	FOR	BRA	CLA	OST	GAS	COR	MIS
BRC	7	12	8		54	5	3	11		
BRC	12	6	1	2	34	12	4	4		1
BRC	24	91	7	44	11	4	5	1		
BRC	2	12	21	4	89	9	6	9		
WCL NE 24·27·15	93	33	9	10	9	8	11	26		1
WCL NE 24·27·15	10	27	12	19	7	9	2	14		
BB	54	19	3	9	1	12		2		
BB	118	26		4	2					
BB	50	71		13	2	9	2	3		
BB	102	88		9	1					
NWL 22·28·15	31	36		23	1	6	3			
NWL 22·28·15	4	18		8		4	1			
NBRC-nb	65	55		31	14	2	7	19		
NBRC-nm	56	54	7	16	15	12	13	27		
DQSR-3	18	59		16	2		5			
DQSR-2	23	61	20	20	5	12	9			
CNL 5·27·16-2	8	9	80	9	5	4	4	31		
DQSR-1	84	58	14	16	16	8	4			
RDNB-2	34	36		2	25	2		1		

Mound Facies

Locality	ECH	BRY	ALG	FOR	BRA	CLA	OST	GAS	COR	MIS
BRC-t	7	42	1	43	3		3	1		
CSL 22·30·15	4	7	13	2	2		1	1		
CSL 22·30·15	14	14	8	11		12				
CSL 22·30·15		1	34							
CSL 22·30·15		7	37	3	1		1			
CSL 22·30·15	3		36	5	2	3	1			

Table 14 (cont'd.)

Locality	ECH	BRY	ALG	FOR	BRA	CLA	OST	GAS	COR	MIS
CSL 22•30•15	2	27	1	9	1	7	2	1		
CSL 22•30•15	6	18	12	17	1	2				
WCSLS-2	1	3								
WCSLS	43	8	2	3	1	3	1	1		
WCSLS-A	2	24	12	19	4					
WCSLS-B	17	5		7	1	5	4			
WCSLS-D	3	22	44	16	1		1			
WCSLS	11	10	33	10			4	1		
WCSLS	3	4	19	5	3	1	1			
WCSLS			5							
QCSL 7•30•15	9	45	22	21						3
QCSL 7•30•15	7	4	3	2			6			
QCSL 7•30•15	9	34	32	14	1		6	1		3
QCSL 7•30•15	14	33	23	4	20	4	2			
QCSL 7•30•15	1	31	36	17	1		12	2		
QCSL 7•30•15	9	41	37	40	7		11	5		
QCSL 7•30•15	12	24	36	16	3		8	1		
QCSL 7•30•15	7	32	35	14	5		2	5		
CSL 9•29•15	4	45	9	18	9	6	9			
CSL 9•29•15	13	63	16	28	12	2	13	3		
CSL 9•29•15	10	25	7	24	5	2	16			
SWC 21•30•15	2	9	123	35	17	4	10			
SWC 21•30•15	3	26	29	21	4	4	13			
CSL 22•29•15	20	25	26	14	5		9	1		
CSL 22•29•15	6	36	5	6	2	5	13			

Table 14 (cont'd.)

Locality	ECH	BRY	ALG	FOR	BRA	CLA	OST	GAS	COR	MIS
SWC 22·30·15	6	37	19	16	2	1	9			
CSL 21·30·15		11	21	36	1		14			
CSL 21·30·15	1	25	201	17	2		4			
NE 15·30·15	10	17	41	19	5	4	3	2		
EQ	6	13	22				3			
EQ	16	20	35	3	20	3	1	2		
QSWC 36·27·16	2	13	65	10	1	1	7	1		
QSWC 36·27·16	3	4	12	6		3	1			
QSWC 36·27·16	14	30	5	29	3	4	16			
WSL 6·28·17	3	3	31	7	2		8	2		
WSL 6·28·17										
WSL 6·28·17	2	16	37	2	13	8	7			
WSL 6·28·17	38	6	27	56	13	6	2	2		
RRSENQEB	24	48	7	23	9	1	6			
RRSENQEB	12	8	24	8	5	2	7			
RRSENQEB	7	19	20	12	7		10			
RRSENQEB	40	78	39	14	20	2	5	2		
CSL 8·29·15-2	3	32	31	19	10	2	3			
CSL 21·30·15	10	22	55	33	11		19			
EEQ	3	102	79	10		17	3	4		
NQEB		6	12	39	3	6	13			
NQEB	7	65	2	25	6	12	11	1		
MANPF	21	37	18	10	4	1	7	2		
MANPF	8	40	9	12	11		3			
Channel Facies										
FNW-2B	91			2		4		3		

Table 14 (cont'd.)

Locality	ECH	BRY	ALG	FOR	BRA	CLA	OST	GAS	COR	MIS
FNW-2B	76	3		1		3				
FNW-2C	41			2		4		3		
FNW-2D	66				19	9	2	4		
FNW-2E	79	55		3	4	7	1		1	
FNW-1A	72			3						
FNW-1A	49	1								
FNW-1B	43	51		4		1		1		
FNW-1E	21	64		13		2				
FNW-1F	20	61		7	3	8	1			
QWA-11	58	65		1	3	23				
QWA-12	55	54		6	12	10	1			
QWA-13	27	18		4	1	6		2	26	
QWA-14	4	7		2						
QWA-15	42	75	8	5	6	11	1	2		
QWA-16	36	44		8		12				
QWA-17	88	34	2		3	23				
QWA-18	54	32		6	1	6		1		
QWA-19	67	88	3	19		20	1	2		
ACS-1	49	55		18	1	6	2			
ACS-2	83	3		2	2	9		1		
ACS-2	93				3			4		
ACS-3	4	64		1	4	4				
ACS-4	54	67		8	10	7	2	2		
ACS-5	53	71		14	7	5				
ACS-5	53	75		14	2	6				

Table 14 (cont'd.)

Locality	ECH	BRY	ALG	FOR	BRA	CLA	OST	GAS	COR	MIS
ACS-9	38	137		11	8	4	1	1		
ANPF-4	19	71		5	1	4				
ANPF-6	46	60		28	7	6	1	2		
ELNC 13•29•15	47	68	1	8	1	25				
ELNC 13•29•15	49	56		7	3	16		1		
ELNC 13•29•15	31	50		9	2	6		2		
ELNC 13•29•15	55	27		11		5	1	1		
NLE 13•29•15	74	61	1	2	6	2	1	2	1	
NLE 13•29•15	11	15	94	18		11	1			
NLE 13•29•15	14	37	76	17	1	4		1		
NLE 13•29•15	4	14	77	3	1	1				
NLE 13•29•15	86	102		3	3	4	1	1		
EQ-NWch	99	42		4	4	1				
CWL 6•28•17	19	15	52	30	6	13	2	13		
CWL 6•28•17		5	7	2	3		4			
OF	63	27	6	19	31	1		3		
OF	20	85	1	45	36	3	6	4		